NIGERIAN INSTITUTION OF
AGRICULTURAL ENGINEERS
(A DIVISION OF NIGERIAN SOCIETY OF ENGINEERS)

eko 2018

19th International Conference & 39th Annual General Meeting

AGROPRENEURSHIP FOR SUSTAINABILITY IN A DIVERSIFIED ECONOMY

CONFERENCE PROCEEDINGS

EDITED BY
ENGR. PROF. J.A.V. FAMUREWA

EKO 2018

NIGERIAN INSTITUTION OF AGRICULTURAL ENGINEERS
(A DIVISION OF THE NIGERIA SOCIETY OF ENGINEERS)

PROCEEDINGS OF THE 19TH INTERNATIONAL CONFERENCE AND THE 39TH ANNUAL GENERAL MEETING OF THE NIGERIAN INSTITUTION OF AGRICULTURAL ENGINEERS (NIAE)

AGROPRENURSHIP FOR SUSTAINABILITY IN A DIVERSIFIED ECONOMY

HELD AT THE

FEDERAL INSTITUTE OF INDUSTRIAL RESEARCH OSHODI (FIIRO) LAGOS STATE

EDITED BY
ENGR. (PROF.) J.A.V FAMUREWA

PREFACE

EKO 2018 collection of articles contained herein represents the papers presented at the 19th International; Conference of the Nigerian Institution of Agricultural Engineers (NIAE) held at the Federal Institute of Industrial Research, Oshodi Lagos Nigeria between 10-14th September. 2018. The theme of the conference is ‘Agropreneurship for sustainability in a diversified economy’

The authors are appreciated for meticulously incorporating the comments and corrections pointed out by the reviewers. The group of anonymous reviewers are also appreciated for their efforts. We hope that the various recommendations made in the papers will go a long way in stimulating further intellectual debate as well as influencing policies formulation at various levels of governance. The papers are recommended for the reading of our students especially the post graduate students, researchers, policy makers, analyst and the general public.

However, the institution is not responsible for the views expressed in these papers, thus the contributors are responsible for the contents of their articles.

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PART ONE

INVITED PAPERS

ENGINEERING CREATIVITIES:

FOR GOOD GOVERNANCE & SOCIAL TRANSFORMATION

A KEYNOTE SPEECH AT THE 19TH INTERNATIONAL CONFERENCE & THE 39TH AGM OF THE NIAE

@ FIIRO, OSHODI, LAGOS

Engr Umar B. Bindir PhD (Cranfield)

FAEng, FNSE, FSESN, FNIAE, CEng, COREN®

SECRETARY TO THE GOVERNMENT OF ADAMAWA STATE

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TRADITIONAL RELEVANCE OF THE ENGINEER

"GLOBAL PHENOMENON!!!"

TODAY…

KEY TARGETS GLOBALLY?

- PROSPERITY
- COMPETENCES/JOBS
- WEALTH CREATION
- GOOD RECREATION
- GLOBAL INSTITUTIONS
- UNITY
- PEACE
- SECURITY
- DEVELOPMENT

PERSPECTIVE FOR DEVELOPMENT

1. To totally eradicate Absolute/extreme Poverty

- **FOOD SECURITY**
- **BASIC EDUCATION**
- **BASIC HEALTHCARE**
- **POTABLE WATER**
- **DECENT SHELTER**
- **DECENT CLOTHING**
- **etc**

PERSPECTIVE FOR DEVELOPMENT

1. To totally eradicate Absolute/extreme Poverty
2. So that every man, woman, and child in the Society have access, not just to basic minimum needs, but to all the opportunities to lead a prosperous, happy, safe and fulfilling life
   - SKILLS & COMPETENCES
   - JOBS
   - ETHICS
   - PLAY
   - SAFETY & SECURITY
   - etc

PERSPECTIVE FOR DEVELOPMENT

1. **To totally eradicate Absolute/extreme Poverty**
2. So that every man, woman, and child in the Society **have access, not just to basic minimum needs, but to all the opportunities** to lead a happy, safe and fulfilling life
3. The Society **emerges** as a **knowledge and a learning society** built on great values ***(hard work, honesty, sincerity, discipline, productivity, collective sense of purpose)***
   - ***WORLD CLASS INSTITUTIONS***
   - ***GLOBAL COMPANIES, PRODUCTS & KNOWHOW***
   - ***INNOVATIONS & COMPETITIVENESS***

<u>SUCCESS INDICATORS</u>

- **LOW EXTREME/ABSOLUTE POVERTY**
- **ECONOMIC VISIBILITY/PROSPERITY**
- **VIABLE BUSINESSES, AND ENTERPRISES**
- **COMPETITIVE ENTREPRENEURS**
- **HIGH COMPETENCES, KNOW-HOW & SKILLS**
- **<u>DYNAMIC/SUSTAINABLE DEVELOPMENT</u>**
- **etc…**

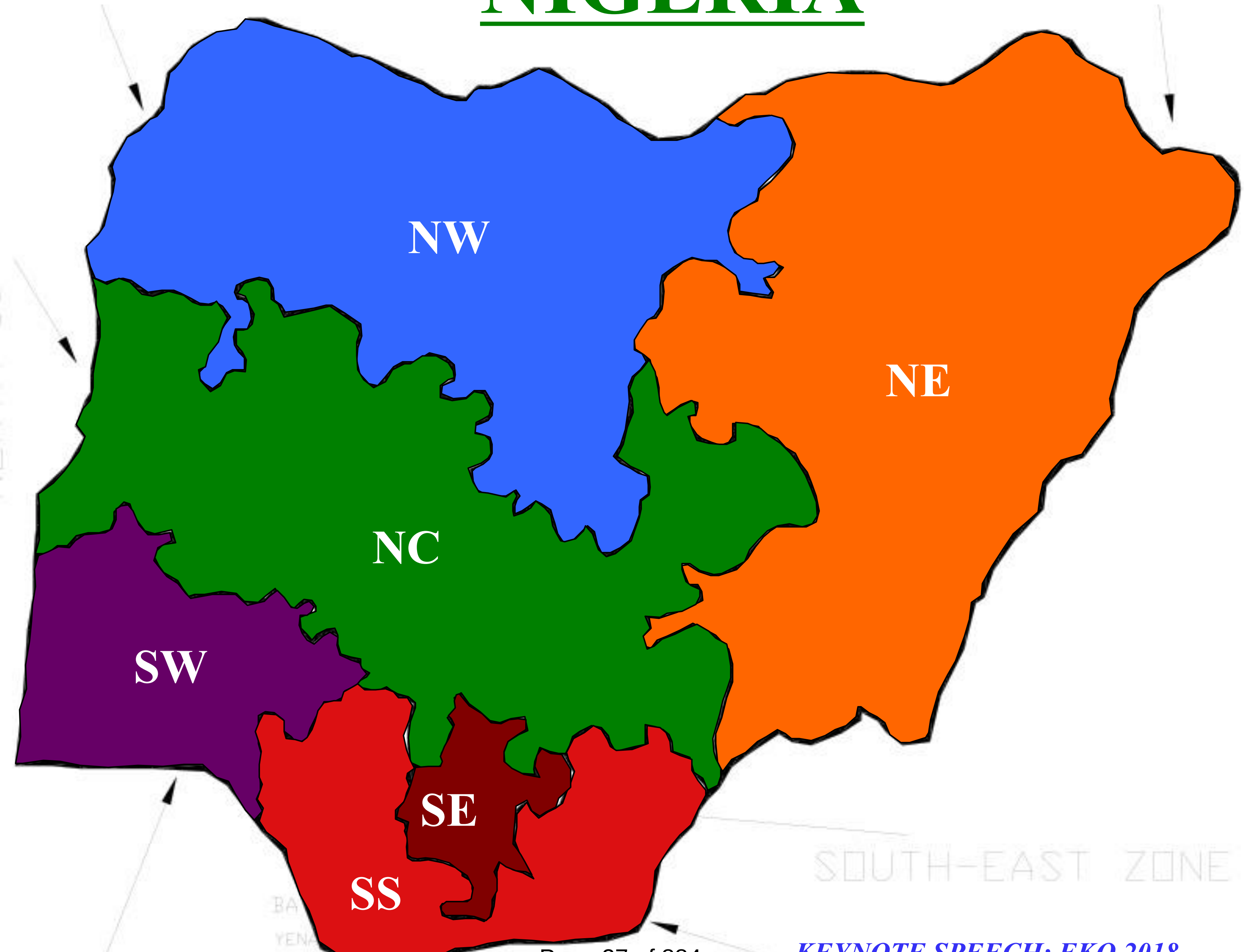
THE “SYLLABUS” ?

KEY ATTRIBUTES

- National STI Policy (practical and implementable) on moving ALL SECTORS)
- Vibrant Science, Technology and Innovation (STI) system
- Institutional Systems of Innovation (NSI)
- Sustained Research and Development (R&D) Investment
- Raw Material Endowments and downstream value addition
- Prioritised Technology Acquisition Focus and Mentor
- Strong Intellectual Property (IP) Management System
- Intense Deployment of ICT
- Viable Research - Industry Linkage models
  - Hi-Tech companies, Efficient Technology Incubation, Science and Technology Parks, Research Parks, Innopolis, Technopolis etc
- Economic Diversification

LECTURE RELEVANCE

NIGERIA



BRIEF FACTS *(SWOT)??*

- POPULATION (Nearly 200 Million)
  - Young, English Speaking, Traditionally Entrepreneurial, etc etc
- RESOURCE BASE (Agro/Minerals/Water, Oil/Gas etc)
- HIGH POVERTY (60/70%)
  - **Dominance of weak "primitive" Rural Life**
- WEAK INFRASTRUCTURE (Physical, Social)
- WEAK "LOCAL" **INDUSTRIES**
- **CORRUPTION** CHALLENGES
- **INSECURITY**
- EMERGING CHALLENGES OF **ENVIRONMENT**
- "**MATURING**" DEMOCRACIES, etc etc

FACTS & REALITIES…

- **FEW OR NO GLOBAL PRODUCTS**
- **FEW OR NO GLOBAL COMPANIES**
- **FEW OR NO GLOBAL KNOW-HOW, SKILLS AND CAPABILITY SERVICES**
- **FEW "GLOBAL" TECHNOLOGIES**
- **Etc etc etc**

AN INDICATION OF SERIOUS WEAKNESS

LOW UNDERSTANDING OF THE "SYLLABUS"

A CLEAR AGENDA FOR ENGINEERS

THE REALITY IS THAT

ACHIEVING ALL THESE

FIRMLY DEPENDS ON THE VIBRANCE CONNECTIVITY AND EFFICIENCY OF A GOOD KNOWLEDGE SYSTEMS HINGED ON:

AN EFFECTIVE SCIENCE, ENGINEERING, TECHNOLOGY & INNOVATION

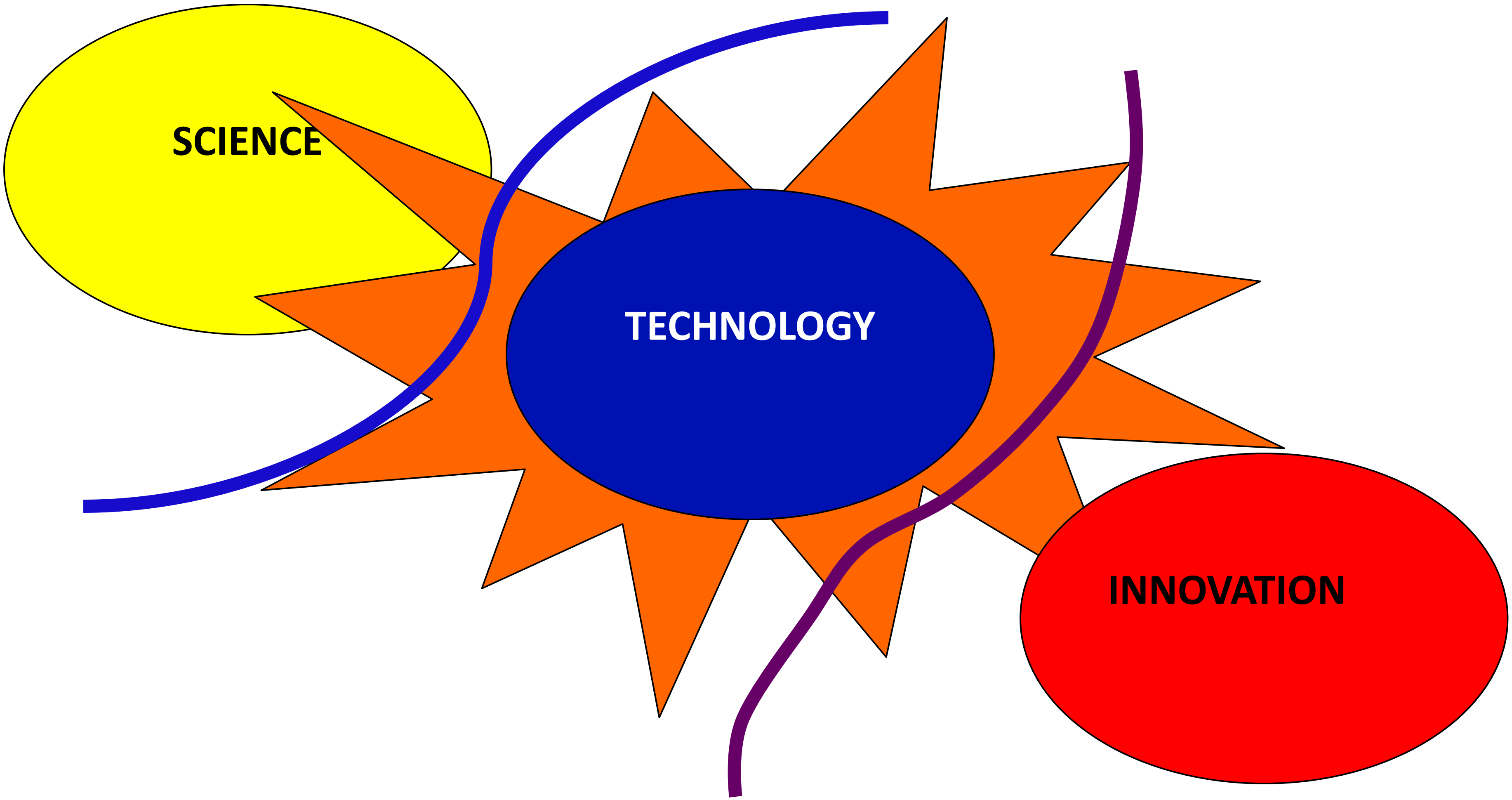
"THIS IS THE MASTER KEY"

(AND THERE IS NO CUTTING CORNERS)

UNDERSTANDING THE SETI VALUE CHAIN!!

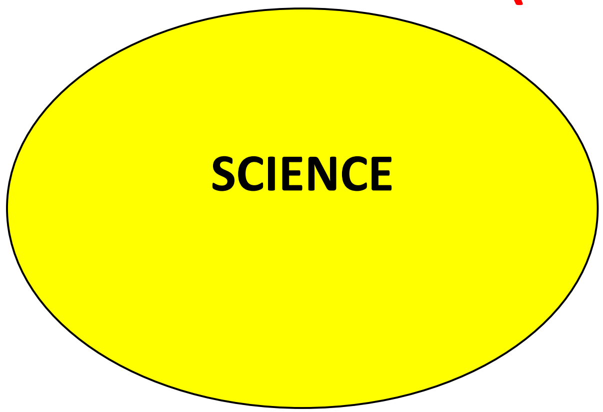
(PARTNERSHIP PLATFORM)

KEY "ELEMENTS"



KNOWLEDGE CAPACITY

FACTS AND FIGURES (Research)



Ability to study, generate knowledge, discover, conceive possibilities, document, present, communicate, publish…

RESEARCH (S)

- RESEARCH INFRASTRUCTURE (Labs & Equipment)
- WORLD CLASS PUBLICATIONS/PhDs/PROFESSORS)
- HIGH IMPACT/CITATION/ACADEMIC PARTNERSHIPS…
- RELEVANCE?

HIGH LEVEL, QUALITY KNOWLEDGE (S)

KNOWLEDGE, EXPERTISE, SPECIALISTS

INDUSTRIAL CAPABILITY

POSSIBILITIES AND APPLICATIONS (Development)

ENGINEERING & TECHNOLOGY

Ability to transform knowledge (S) into socio-economic solutions and assets)

TECHNOLOGY (IP)…

HIGH LEVEL, QUALITY KNOWLEDGE (S)

↓

KNOWLEDGE, PUBLICATIONS AND PhDs

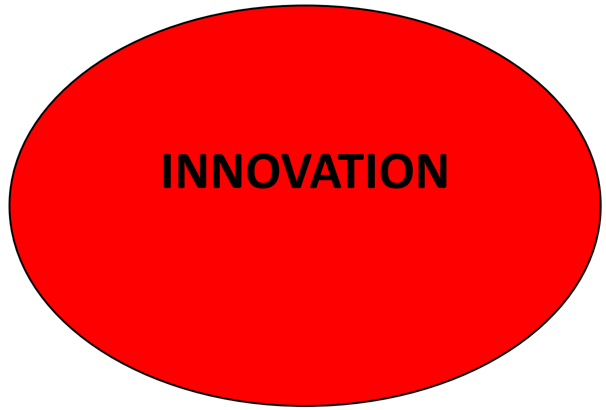
↓

INTELLECTUAL PROPERTY-IP (T)

???...

SUSTAINABLE DEVELOPMENT

SOLUTIONS AND PRODUCTS



"DYNAMIC" DEPLOYMENT OF SOLUTIONS TO COMPETITIVELY MEET & SUSTAIN SOCIO-ECONOMIC SOLUTIONS

ENTREPRENEURSHIP & INNOVATION (I)

- EVERYBODY…..
- FEASIBILITY, FINANCING, TRAINING
- BUSINESS PLANNING/MANAGEMENT
- IP MANAGEMENT & LICENSING
- PRODUCTION
- MANUFACTURING
- MARKETING, BRANDING
- etc….

ENTREPRENEURSHIP & INNOVATION (I)

- **PRODUCTS**
- **PROCESSES**
- **KNOW-HOW SERVICES (Consultancy etc)**
- **INDUSTRIAL SKILLS**
- **MANAGERIAL SKILLS**

A SHOWCASE

21ST CENTURY SUSTAINABLE COMMUNITY DEVELOPMENT

(PRACTICAL STUFF)

CASE I

AGRICULTURE & AGRO-ALLIED EFFORTS

<u>FOOD IS EVERYTHING!!</u>

TYPICAL OPPORTUNITY FOR NIGERIA and INDEED AFRICA TO REEL OUT:

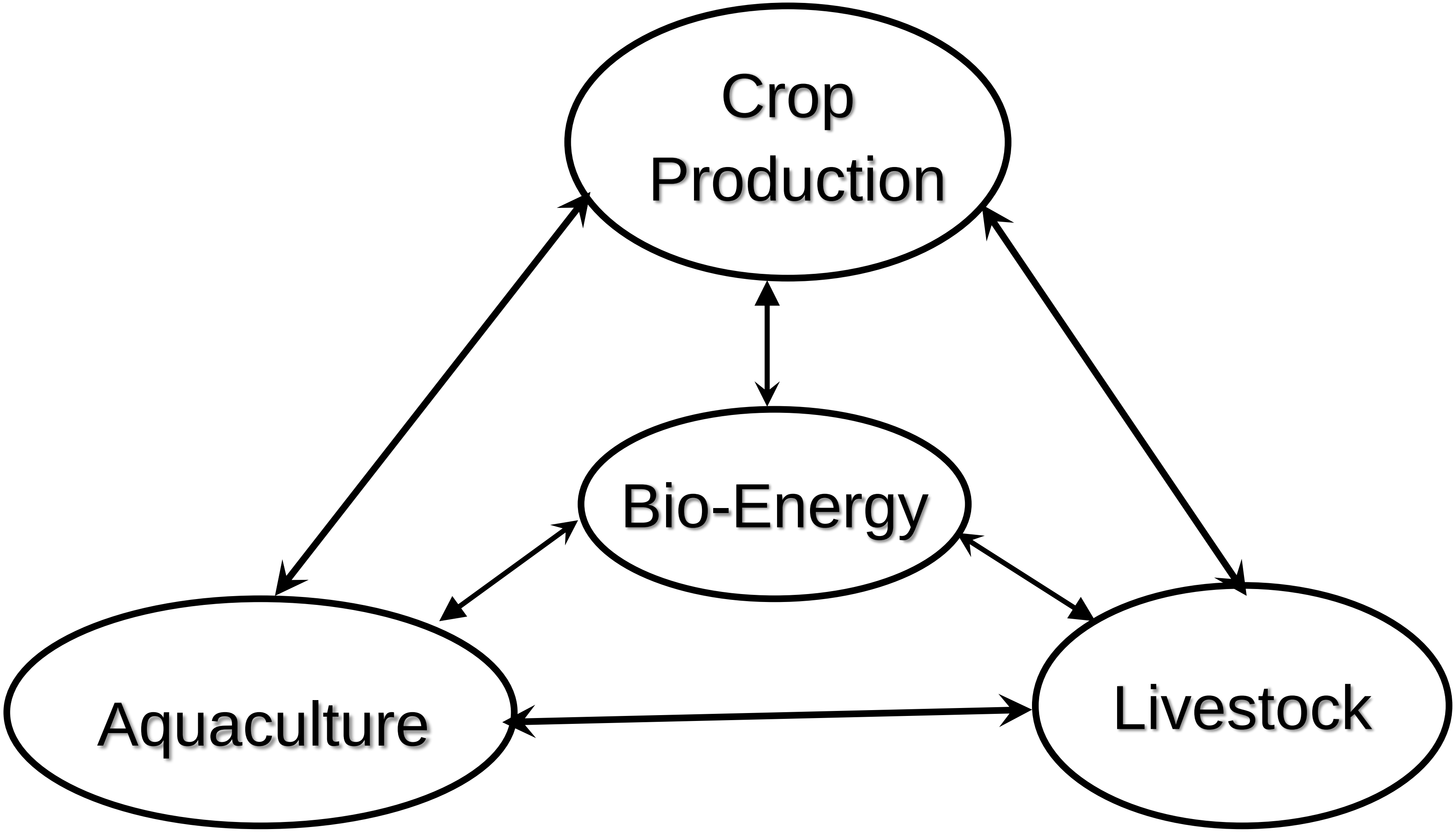
<u>A THIRD INDUSTRIAL REVOLUTION</u>

"AGRICULTURE AND AGRO-ALLIED INDUSTRIAL DEVELOPMENT: **<u>A COMPARATIVE ADVANTAGE</u>*****"***

HARNESSING THE OPPORTUNITY SETS OF INCREDIBLE ENVIRONMENTAL CAPITAL TO CREATE NEW POSSIBILITY SETS TO TACKLE IT'S TRIPLE CHALLENGES

- POVERTY/FOOD SECURITY
- UNEMPLOYMENT AND
- ENVIRONMENTAL DEGRADATION

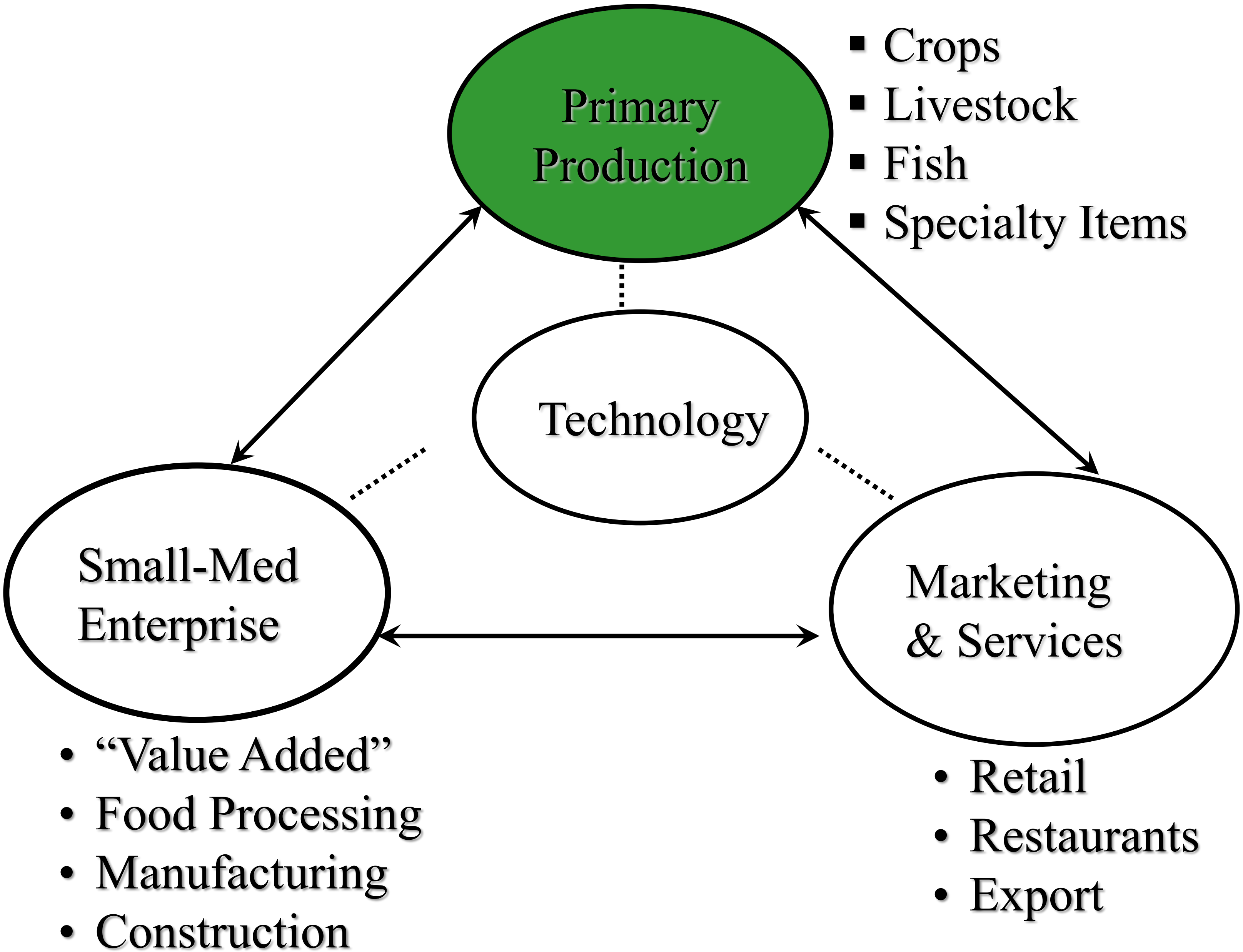
AN INTEGRATED PRODUCTION SYSTEM APPROACH



POTENTIAL KPIs

Parameter	Conventional Farming	Traditional Farming	Integrated Natural Farming
Yield	Medium - High	Low - medium	Medium – High
Quality	Low - medium	Medium - High	Medium – High
Cost	High	Low	Low
Toxicity	High	None	None
Environment	Damaged	Protected	Protected + Improved
Sustainability	Not sustainable	Sustainable	Sustainable

AN INTEGRATED PRODUCTION SYSTEM APPROACH



Songhaï

L'AFRIQUE RELÈVE LA TÊTE ! AFRICA STANDS UP !

songhai@songhai.org

THE MODEL

SONGHAI CENTRE

- **UNIVERSITY**
- **SCIENCE AND TECHNOLOGY PARK**
- **SMALL/LARGE FARM**
- **INDUSTRY**
- **SKILL ACQUISITION CENTRE**
- **RURAL COMMUNITY**
- **MUSEUM**
- **etc**

DESIGNED & DEVELOPED BY A NIGERIAN

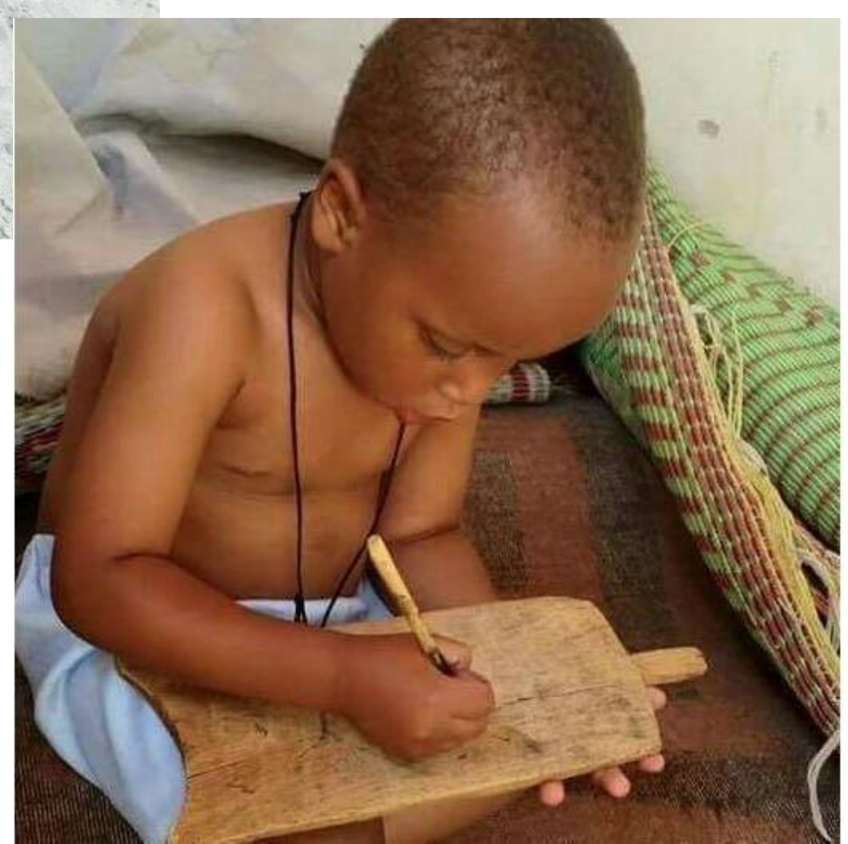
- **FR. PROF GODFREY NZAMUJO**
- **A REVEREND FATHER**
- **PROFESSOR OF ENGINEERING**
- **HAS 3 PhDs**
  - ***MECHANICAL ENGINEERING***
  - ***MECHATRONICS***
  - ***MICRO-BIOLOGY***
- **CHAIRMAN BOARD OF DIRECTORS**
- ***CHAIR THINK-TANK & MEMBER BOD***


SONGHAI INTEGRATED SYSTEM
CROP PRODUCTION
BIOENERGY
AQUACULTURE

CASE II

INNOVATIVE BASIC EDUCATION TOOLS FOR OUT OF SCHOOL CHILDREN

ALMAJIRI EDUCATION: UNIQUE…



DAVID SILVA
21

SOME ATTENTION…


PIAGGIO

CERT. No. 001452

FEDERAL REPUBLIC OF NIGERIA

Patents and Designs Act,

(CAP 344 Laws of the Federation of Nigeria 1990)

RP: NG/P/2013/744

ENT NO:

Date of Patent: 20-11-2013

Date of Sealing: 11-02-2014

ident of the Federal Republic of Nigeria and Commander-in-Chief of the Armed Forces

GOODLUCK EBELE JONATHAN

EAS a request for the grant of a patent has been made by: ENGR. UMAR BUBA BINDIR, PhD

BINDIR KNOWLEDGE DEVELOPMENT CENTRE INTERNATIONAL, NO. 11 MALLAM HAMID STREET, YOBE TOWN. C/O NOTAP, 4, BLANTYRE STREET, WUSE II, ABUJA

e sole use and advantage of an Invention for:

AN IMPROVED ELECTRO-DIGITAL TEACHING TABLET

HEREAS the Federal Government being willing to encourage all invention which may be for lic good, is please to accede to the request:

E, THEREFORE, that I do by this instrument give and grant unto the person(s) above named successor(s), executor(s), administrator(s) and assign(s) (each and any of whom are ter referred to as the patentee) by special licence, full power, sole privilege and authority, patentee or any agent or licensee of the patentee may subject to the conditions and provisions ed by any statute or order for the time being force at all times hereafter during the term of ein mentioned make, use, exercise, and vend the said invention throughout the Federal Republic a, and that the patentee shall have and enjoy the whole profit and advantage from time to time by reason of the said invention during the term of twenty years from the date first above this instrument: AND to the end that the patentee may have and enjoy the sole use and nd full benefit of the said invention, I do by this instrument strictly command all citizens of l Republic of Nigeria that they do not at any time during the continuance of the said term ctly or indirectly make use of or put in practise the said invention, nor in anywise imitate without the written consent, licence or agreement of the patentee, on pain of incurring such s may be justly inflicted on such offenders, and of being answerable to the patentee o law for damages thereby occasioned:

PR ALWAYS that this patent shall be revocable on any of the grounds from time to time by the law ed as grounds for revoking patents by me, and the same may be revoked and made void Acc :

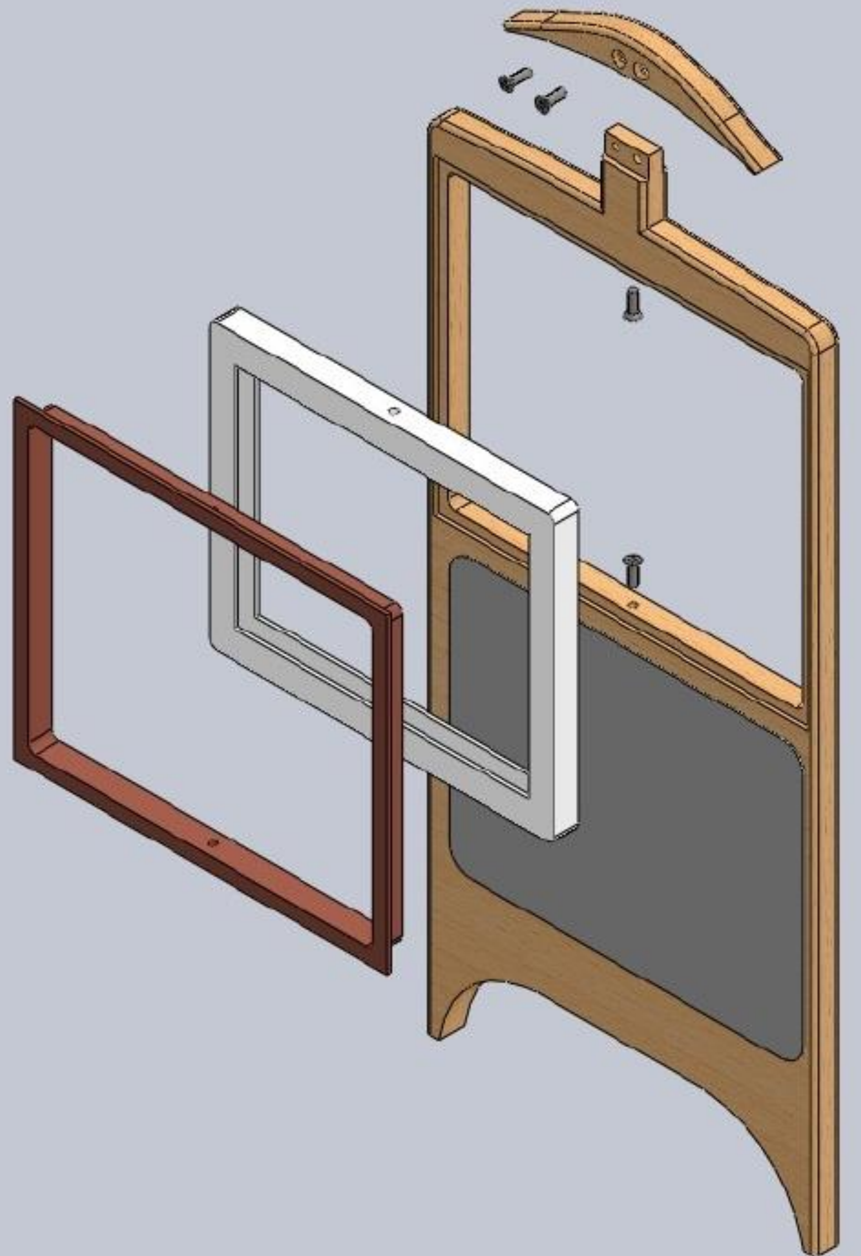
PR LSO that nothing herein contained shall prevent the granting of licences in such manner and considerations as they may by law granted.

MADE this 25th *day of* Feb

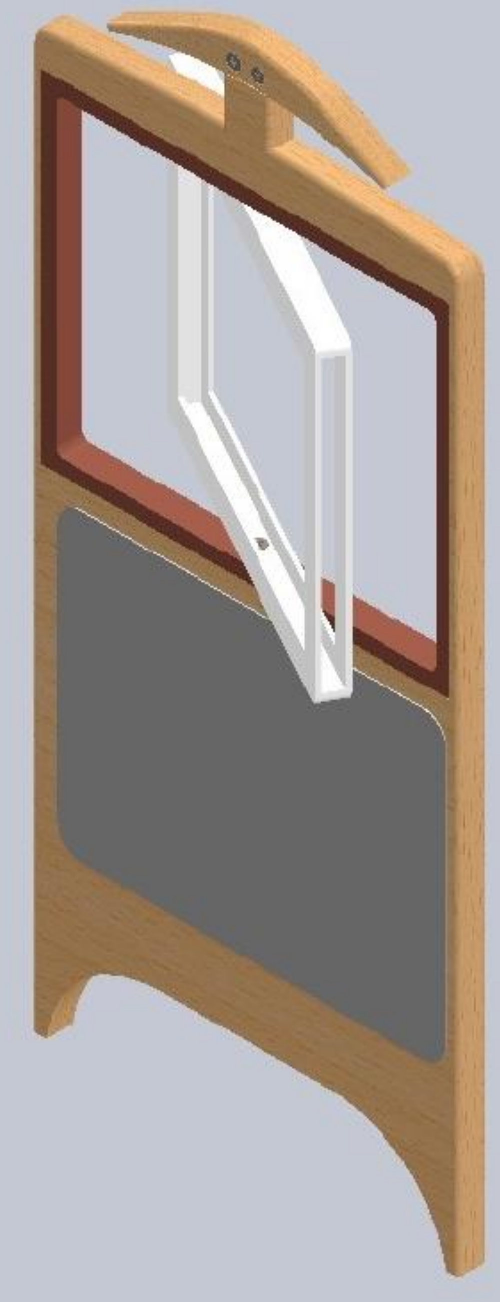
20 14

Registrar of Patents & Designs

- **THIS IS “SMART” TECHNOLOGY**
- **HARDWARE DEVELOPMENT**
- **SOFTWARE DEVELOPMENT**
- **etc**



SIMPLE EXPLODED VIEW OF THE SLATE



ISOMETRIC VIEW OF THE COMPLETE ASSEMBLY

CASE III

REGIONAL EMPOWERMENT INNOVATION

(THE NORTH EAST CORRIDOR)

SOKOTO
ZAMFARA
KATSINA
KANO
JIGAWA
YOBE
BORNO
KEBBI
NIGER
KADUNA
BAUCHI
GOMBE
ADAMAWA
PLATEAU
TARABA
NASSARAWA
ABUJA
KWARA
OYO
OSHUN
OGUN
EKITI
ONDO
KOGI
BENUE
EDO
ENUGU
ANAMBRA
EBONYI
DELTA
IMO
ABIA
CROSS RIVER
RIVERS
AKWA IBOM
BAYELSA
LAGOS
Lagos
Ibadan
Ogbomosho
Ilorin
Kano
Kaduna
Zaria
Maiduguri
Zinder
Maradi
Lake Chad
Garoua
Bamenda
Bafoussam
CAMEROON
Slave Coast
Bight of Benin
Guinea

OPPORTUNITIES

- LIVESTOCK AND POULTRY
  - BEEF
  - MILK
  - LEATHER
  - EGGS
  - POULTRY MEAT
- GRAINS
- OIL SEEDS
- MINERAL RESOURCES
- OIL and GAS
- LARGE MARKET
- CHEAP LABOUR
- INTERNATIONAL PASSENGER & CARGO AIRPORTS
- NATIONAL & GLOBAL SYMPATHY

TARGET

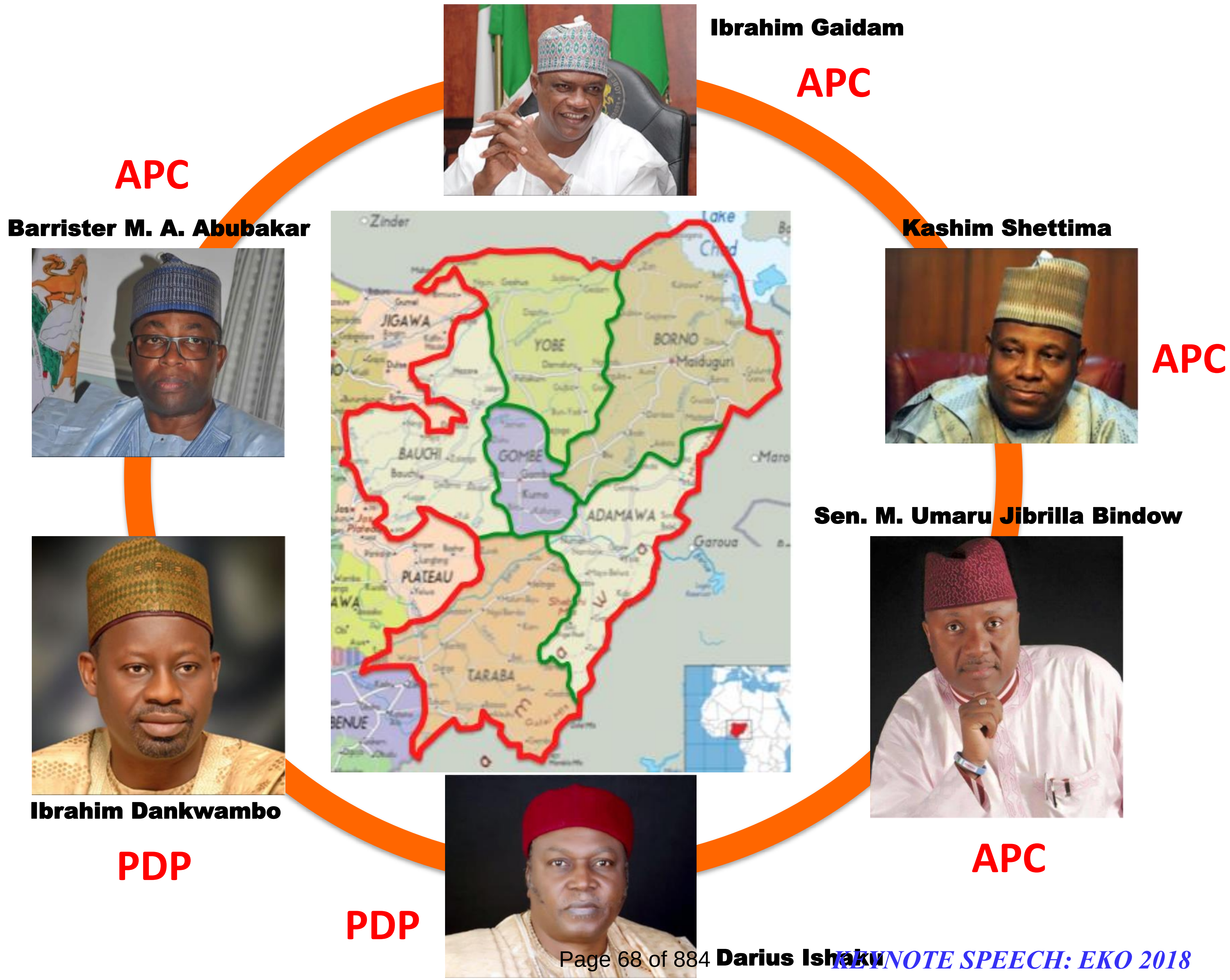
- PEACE
- UNITY
- STABILITY
- DEVELOPMENT
- MODERNISATION
- INDUSTRIALISATION

THE N.E. MEGA ECONOMIC CORRIDOR:

BAUCHI TO BAUCHI BACKBONE (UNIQUE)

- DUAL CARRIAGE HIGHWAY
- HIGH SPEED RAILWAY INFRASTRUCTURE
- POWER TRANSMISSION BACKBONE
- OPEN CANAL IRRIGATION INFRASTRUCTURE
- HIGH CAPACITY POTABLE WATER PIPE
- HIGH SPEED FIBRE OPTIC INFRASTRUCTURE

THE WAY FORWARD


Ibrahim Gaidam
APC
APC
Barrister M. A. Abubakar
Kashim Shettima
APC
Sen. M. Umaru Jibrilla Bindow
APC
Ibrahim Dankwambo
PDP
PDP
Darius Ishaku
Zinder
JIGAWA
YOBE
BORNO
Maiduguri
BAUCHI
GOMBE
ADAMAWA
PLATEAU
TARABA
BENUE
Garoua


NIGER
CHAD
Lake Chad
Sokoto
Katsina
Kano
Maiduguri
Damaturu
Potiskum
Bauchi
Gombe
Yola
Jalingo
Wukari
Kaduna
Zaria
Jos
Minna
Abuja
Lafia
Makurdi
Lokaja
Ilorin
Ogbomosho
Oshogbo
Ibadan
Abeokuta
Ikeja
Lagos
Benin City
Asaba
Onitsha
Enugu
Awka
Abakaliki
Owerri
Umuahia
Port Harcourt
Calabar
Ogoja
Ikom
Bight of Benin
Gulf of Guinea
Bight of Biafra
CAMEROON
Douala
7
8
NIGERIA
National capital
State capital
Town, village
Major airport
International boundary
State boundary
Highway
Main road
Secondary road
Railroad
© Nations Online Project

APC

PDP

OUTCOMES

(CONSTRUCT, OPERATE, MAINTAIN)

- **JOBS**
- **WEALTH**
- **PROSPERITY**
- **QUICK RECOVERY**
- **SUSTAINABLE DEVELOPMENT**
- **INDUSTRIALISATION**
- **NATIONAL COHESION**

CASE IV

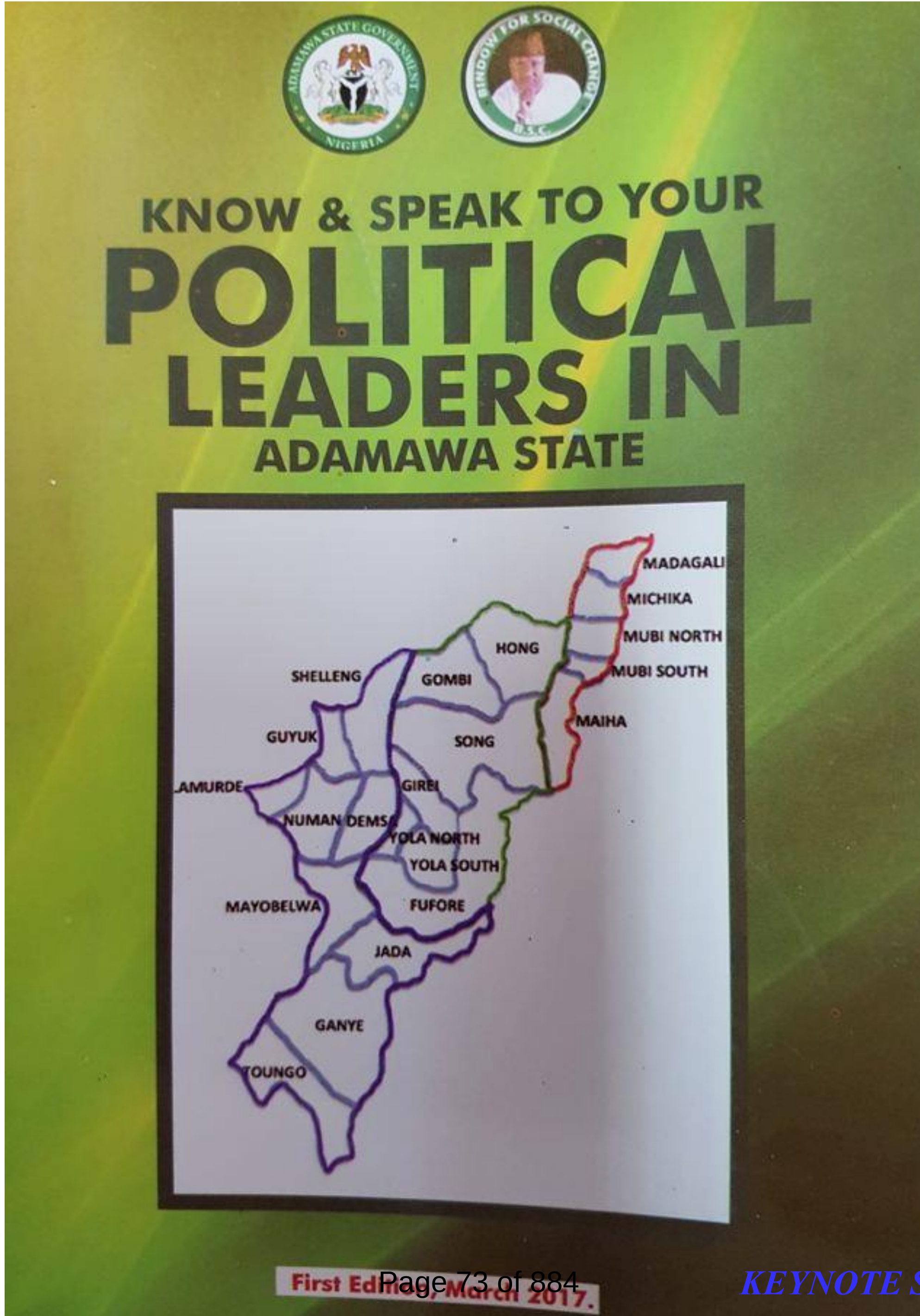
INNOVATIVE SYNERGY

PUBLIC TRADITIONAL PARTNERSHIP (PTP)

-THE ADAMAWA STATE MODEL-

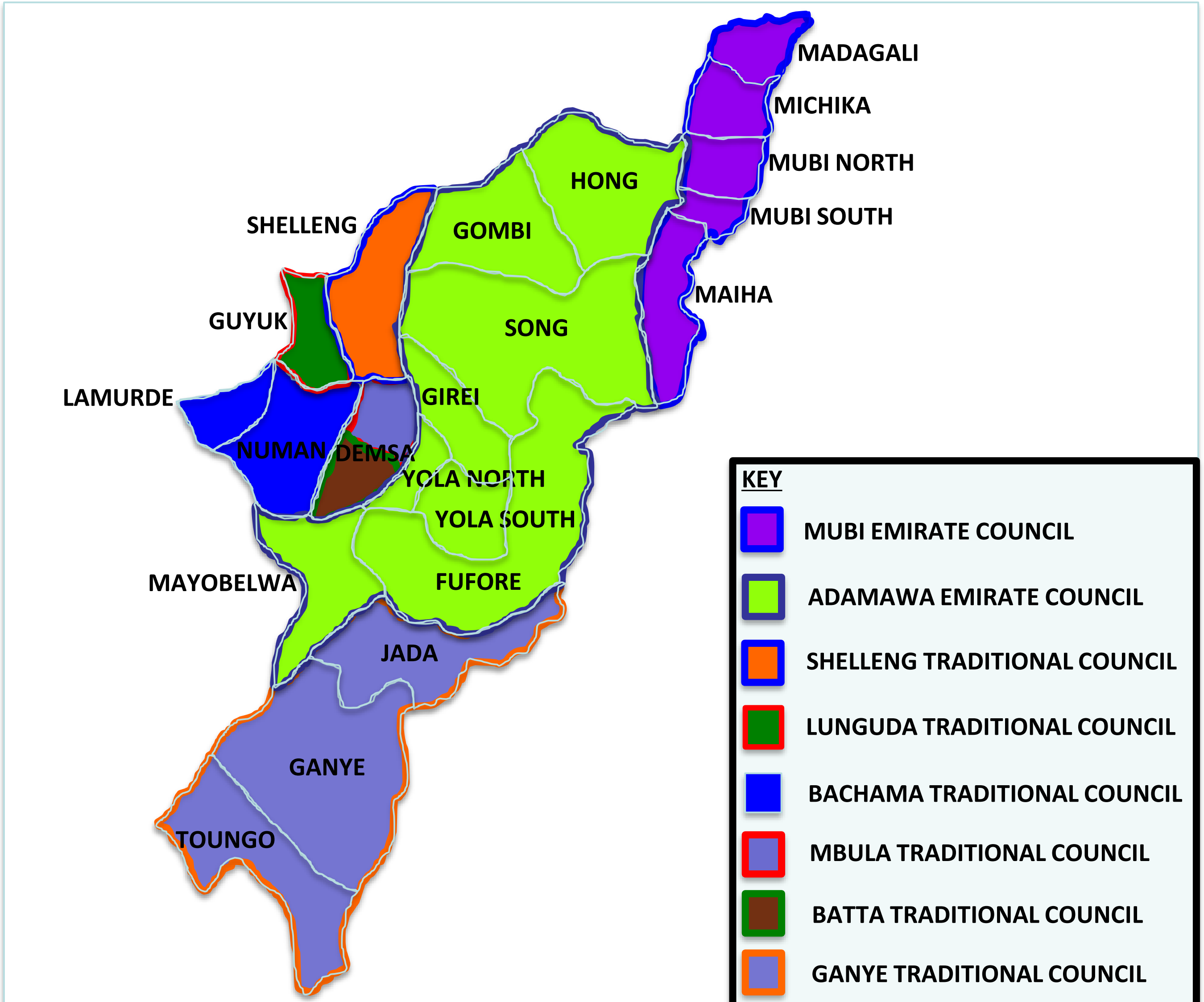
PUBLIC/POLITICAL LEADERSHIP...

- **GOVERNOR**
- **DEPUTY GOVERNOR**
- **3 DISTINGUISHED SENATORS**
- **8 HOUSE OF REPRESENTATIVES**
- **25 ASSEMBLY MEMBERS**
- **21 LG CHAIRMEN & 21 VICE CHAIRMEN**
- **226 WARD COUNCILLORS**


ADAMAWA STATE GOVERNMENT
NIGERIA
BINDOW FOR SOCIAL CHANGE
B.S.C.
KNOW & SPEAK TO YOUR
POLITICAL
LEADERS IN
ADAMAWA STATE
MADAGALI
MICHIKA
MUBI NORTH
MUBI SOUTH
HONG
GOMBI
SHELLENG
MAIHA
GUYUK
SONG
LAMURDE
GIREI
NUMAN
DEMSA
YOLA NORTH
YOLA SOUTH
MAYOBELWA
FUFORE
JADA
GANYE
TOUNGO

(2) TRADITIONAL LEADERSHIP

8 TRADITIONAL COUNCILS



ADAMAWA STATE TRADITIONAL LEADERSHIP STATISTICS

S/N	EMIRATE/CHIEFDOM	DH	VH	WH	LGA	PW
1	Adamawa Emirate Council	33	295	3248	8	88
2	Mubi Emirate Council	25	117	1703	5	57
3	Ganye Chiefdom	18	96	1082	3	31
4	Bachamma Kingdom	9	62	554	2	20
5	Batta Chiefdom	4	26	268	0.5	5
6	Mbula Chiefdom	3	16	87	0.5	5
7	Lunguda Chiefdom	7	50	425	1	10
8	Shelleng Chiefdom	5	56	443	1	10
	Total	104	718	7810	21	226

PTP INNOVATION

- STRUCTURED DOCUMENTATION
  - NAMES
  - LOCATION & TITLE DETAILSS
  - PHONE NUMBERS
  - ACCOUNT NUMBERS, BVN
- DYNAMIC DATABASE/DETAILS

PTP PROJECTS

- **SOCIAL INTELLIGENCE FOR SECURITY**

PTP PROJECTS...

- SOCIAL INTELLIGENCE FOR SECURITY
- **COMMUNITY PROJECTS MONITORING**

PTP INNOVATION

- **SOCIAL INTELLIGENCE FOR SECURITY**
- **COMMUNITY PROJECTS MONITORING**
- **TOOLS AND METHODS**

EVENTS MONITORING INSTRUMENT (TRADITIONAL)

S/N	ISSUE	MON	TUE	WED	THU	FRI	SAT	SUN	REMARKS
	ROBBER (SATA)								
	CHILD BIRTH (HAIHUWA)								
	DEATH (MUTUWA)								
	FIGHT (FADA)								
	KILLER (KISA)								
	CROWD (TAROO)								
	SHOOTING (HARBI)								
	KIDNAPPING (YIN GARKUWA)								

NAME OF WARD HEAD________________________ NAME OF WARD________________________ WEEK DATES______________

EVENTS MONITORING INSTRUMENT (TRADITIONAL)

S/N	ISSUE	MON	TUE	WED	THU	FRI	SAT	SUN	REMARKS
	VISITOR (BAKO)								
	WIFE BEATER (DUKAN MATA)								
	SPORTS (WASA)								
	FIRE (GOBARA)								
	ACCIDENT (HATSARI)								
	FLOOD (AMBALIYA)								
	DIVORCE (SAKIN AURE)								
	MISSING (BATA)								

NAME OF WARD HEAD____________________ NAME OF WARD____________________ WEEK DATES____________

CASE VI

INDUSTRY/GRASSROOTS INNOVATION:
PARTNERSHIPS FOR COMMUNITY DEVELOPMENT

GRADUALLY DEVELOP

VIABLE AND VISIBLE STI PARTNERSHIPS WITH INDUSTRY FOR GRASSROOTS DEVELOPMENT

FRIESLAND CAMPINA WAMCO Nig Plc

COMMITTMENT

PULLO KOSAM – "MILK"

CURRENT STATUS

TRANSFORMATION

THE DEAL


FrieslandCampina
FrieslandCampina WAMCO Nigeria PLC
F.OYO 027
F.OYO


F.OYO


FrieslandCampina
WAMCO Nigeria
collecting milk for

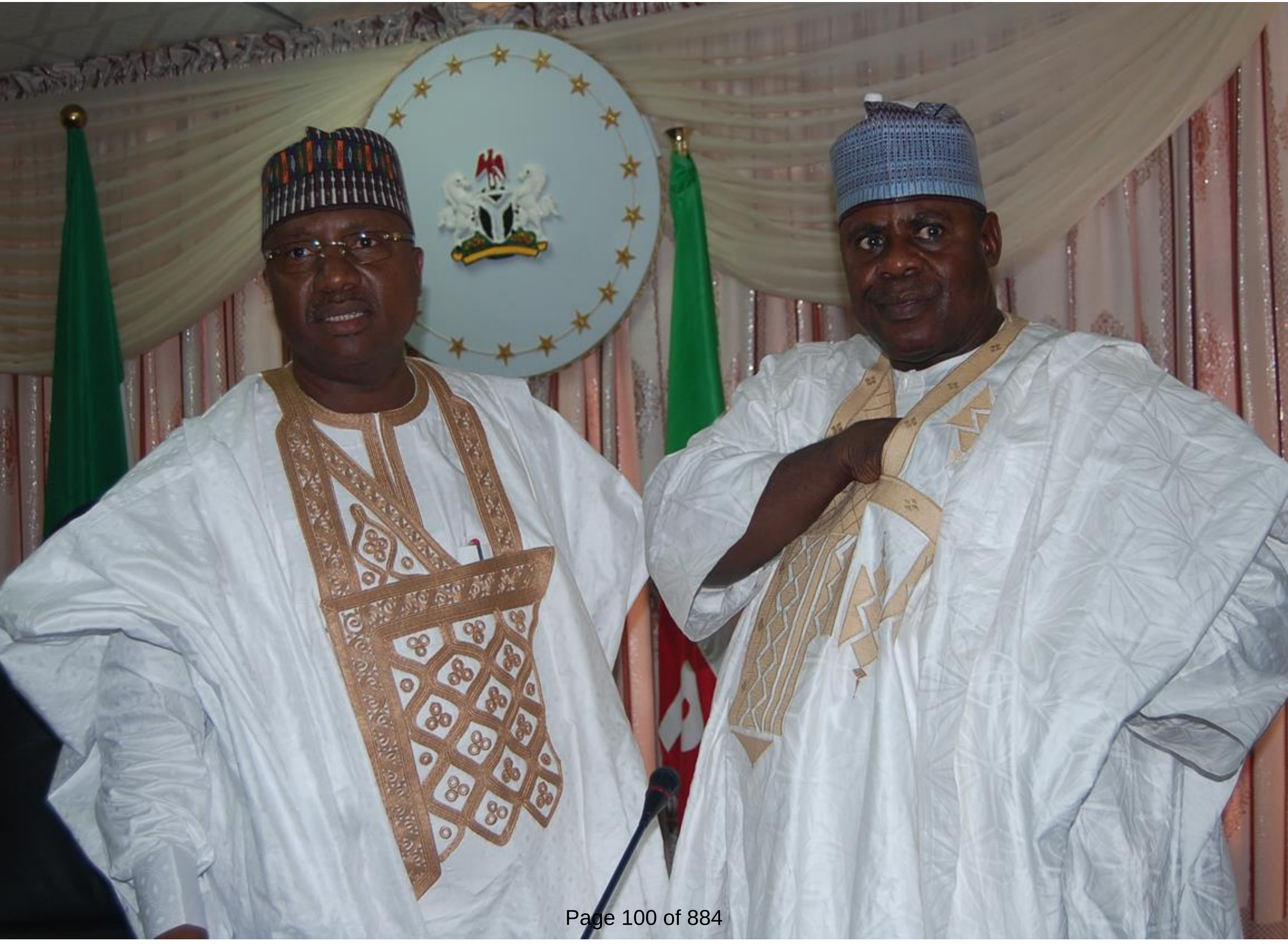

Peak
Peak
Peak
Peak
Peak
Evaporated Milk
Milk

NEXT LEVEL?

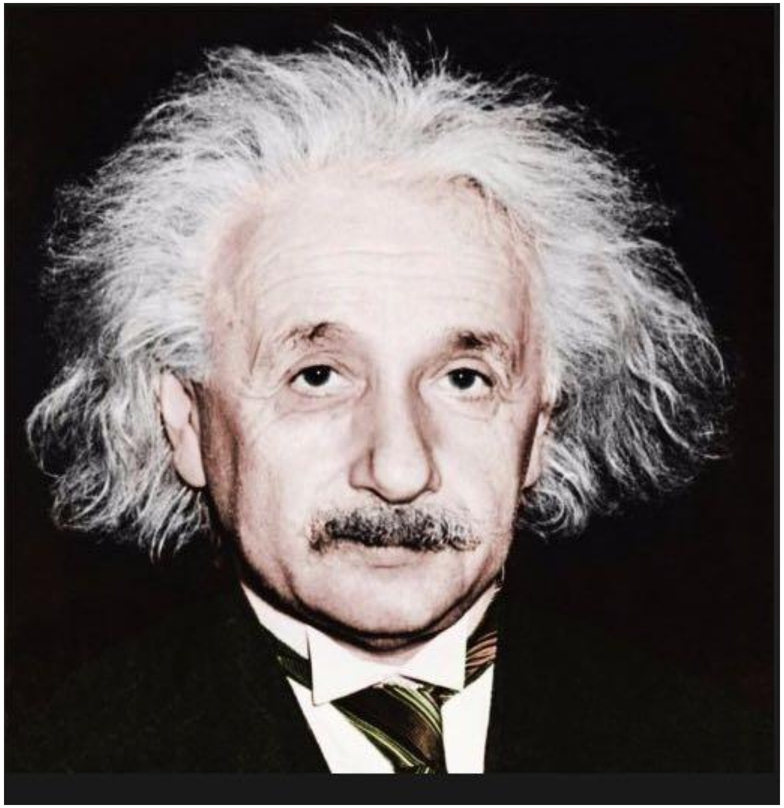
CASE VII

PUTTING ALL TOGETHER:

EMERGING LEADERS FOR GOOD GOVERNANCE



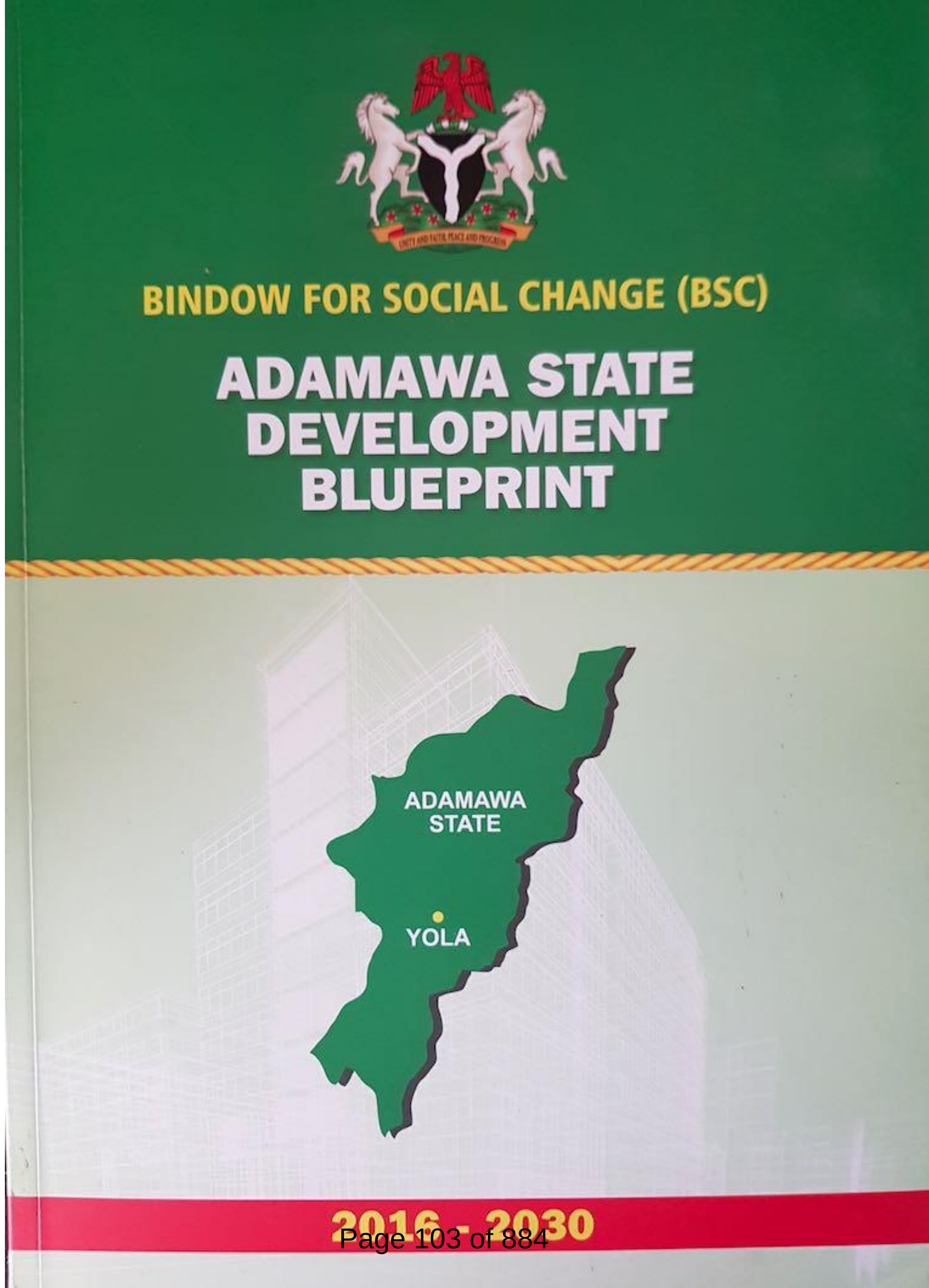
SIR ALBERT EINSTEIN



IT IS ONLY A FOOL WHO WILL CONTINUE TO DO THE SAME THING AND EXPECT A DIFFERENT OUTCOME

EVOLVED A

STATE DEVELOPMENT BLUEPRINT


BINDOW FOR SOCIAL CHANGE (BSC)
ADAMAWA STATE
DEVELOPMENT
BLUEPRINT
ADAMAWA
STATE
YOLA
2016 - 2030

LOGICAL & SYSTEMATIC IMPLEMENTATION

PHYSICAL INFRASTRUCTURE

RE-EVALUATED ROAD CONTRACT AND DELIVERY WITH HIGH COST SAVING

LOGICAL & SYSTEMATIC IMPLEMENTATION

EDUCATION

(DECLARED IN A STATE OF EMERGENCY)

LOGICAL & SYSTEMATIC IMPLEMENTATION

HEALTHCARE

(DECLARED IN A STATE OF EMERGENCY)

LOGICAL & SYSTEMATIC IMPLEMENTATION

AGRICULTURE

LOGICAL & SYSTEMATIC IMPLEMENTATION

TECHNICAL SKILLS TRAINING

LOGICAL & SYSTEMATIC IMPLEMENTATION

DEVELOPING THE INFORMAL SECTOR

LOGICAL & SYSTEMATIC IMPLEMENTATION

INTERNAL REVENUE IMPROVEMENT

LOGICAL & SYSTEMATIC IMPLEMENTATION

CLOSE MONITORING AND SOCIAL IMPACTS

RETURN OF PEACE & PROSPERITY

(THANK YOU MR. PRESIDENT)

OTHERS

- 4 FLIGHTS TO YOLA DAILY INCLUDING WEEKENDS
- BEST QUALITY PRIVATE UNIVERSITY IN NIGERIA
- YOLA – CITY OF DEVELOPMENT CONFERENCES & MEETINGS
- OVER 100 NEW AFFORDABLE HOTELS IN YOLA
- EXECUTED AN ANTI-CORRUPTION SUMMIT
- etc

ADAMAWA STATE HOUSE OF ASSEMBLY

House of Assembly Complex

Gibson Jalo Way, P. M. B. 2080, Yola

E-mail: theclerkadamawaassembly@yahoo.com

Mobile: 08038879005, 08054034157

Our Ref: ADHA/GEN/S/3 Your Ref: ______ Date: 8th/3/2017

The Executive Governor,
Adamawa State,
Yola.

HOUSE RESOLUTION ON VOTE OF CONFIDENCE ON HIS EXCELLENCY, GOVERNOR UMARU MOHAMMED JIBIRILLA BINDOW

The Hon. House during plenary of Wednesday 8th March, 2017, deliberated extensively and resolved to pass a vote of confidence on His Excellency the Executive Governor for his laudable achievements that made it possible for you to be nominated as the **LEADERSHIP GOVERNOR OF THE YEAR 2016,** by the Prestigious Leadership Newspaper.

The award is also in recognition of your resolved to transform Adamawa State especially on the delivery of a large number of high quality roads in the state.

Once again, **CONGRATULATIONS.**

Francis R. Gbansenso
Clerk of the H...

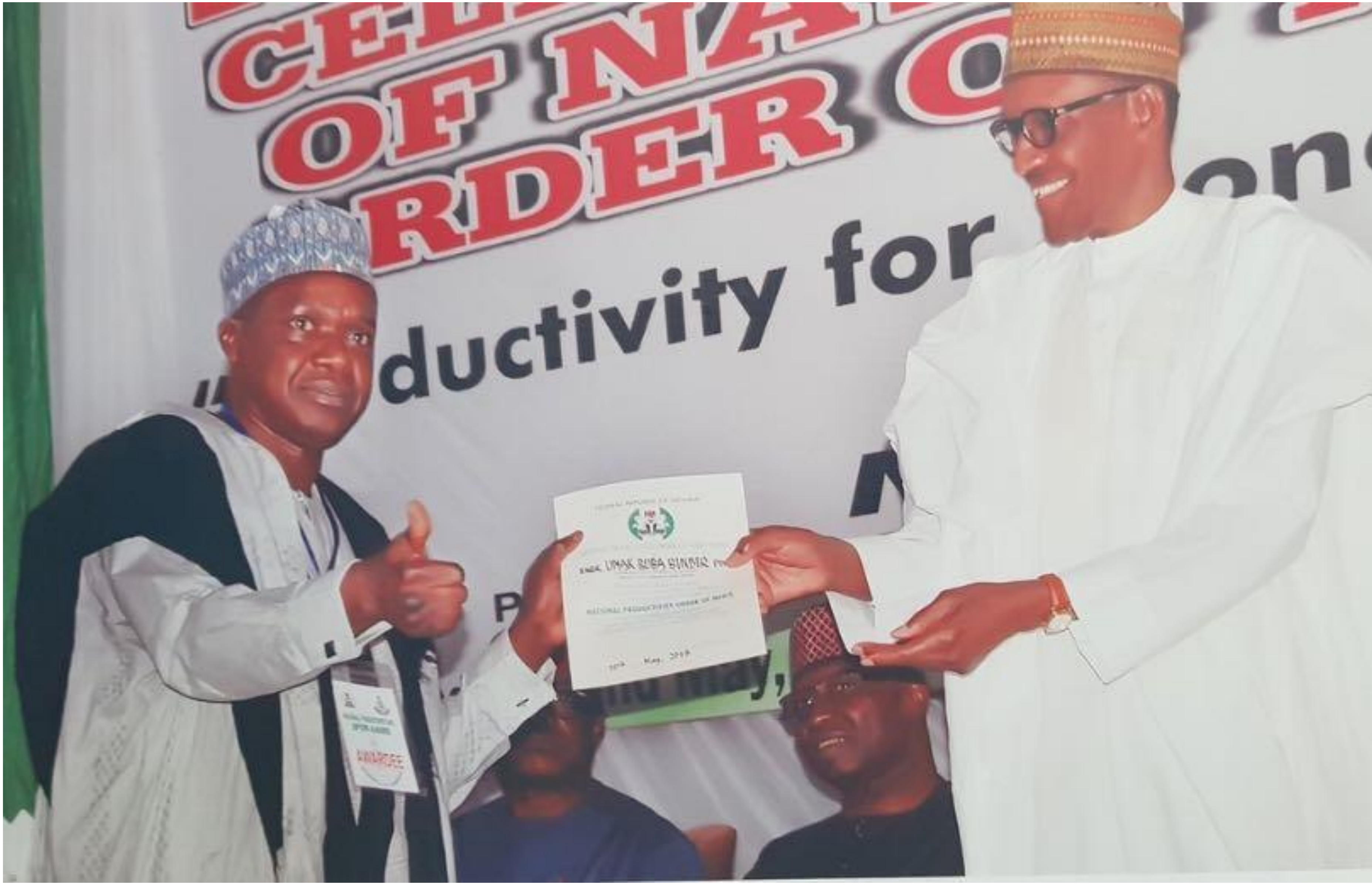

LEADERSHIP
GOVERNOR OF THE YEAR 2016
Your Excellency
Sen. Muhammad Umaru Jibrilla
Bindow
Executive Governor, Adamawa State
Congratulations Sir,
This is indeed a
Worthy award to a Worthy
Mentor/Leader/Father on a Worthy
Development.
Thank you for making us proud.
May you Grow from Strength to
Strength for continued
services to the
State and
Humanity.
COURTESY: Nana Asmau Gwadabe

#CONSENSUS

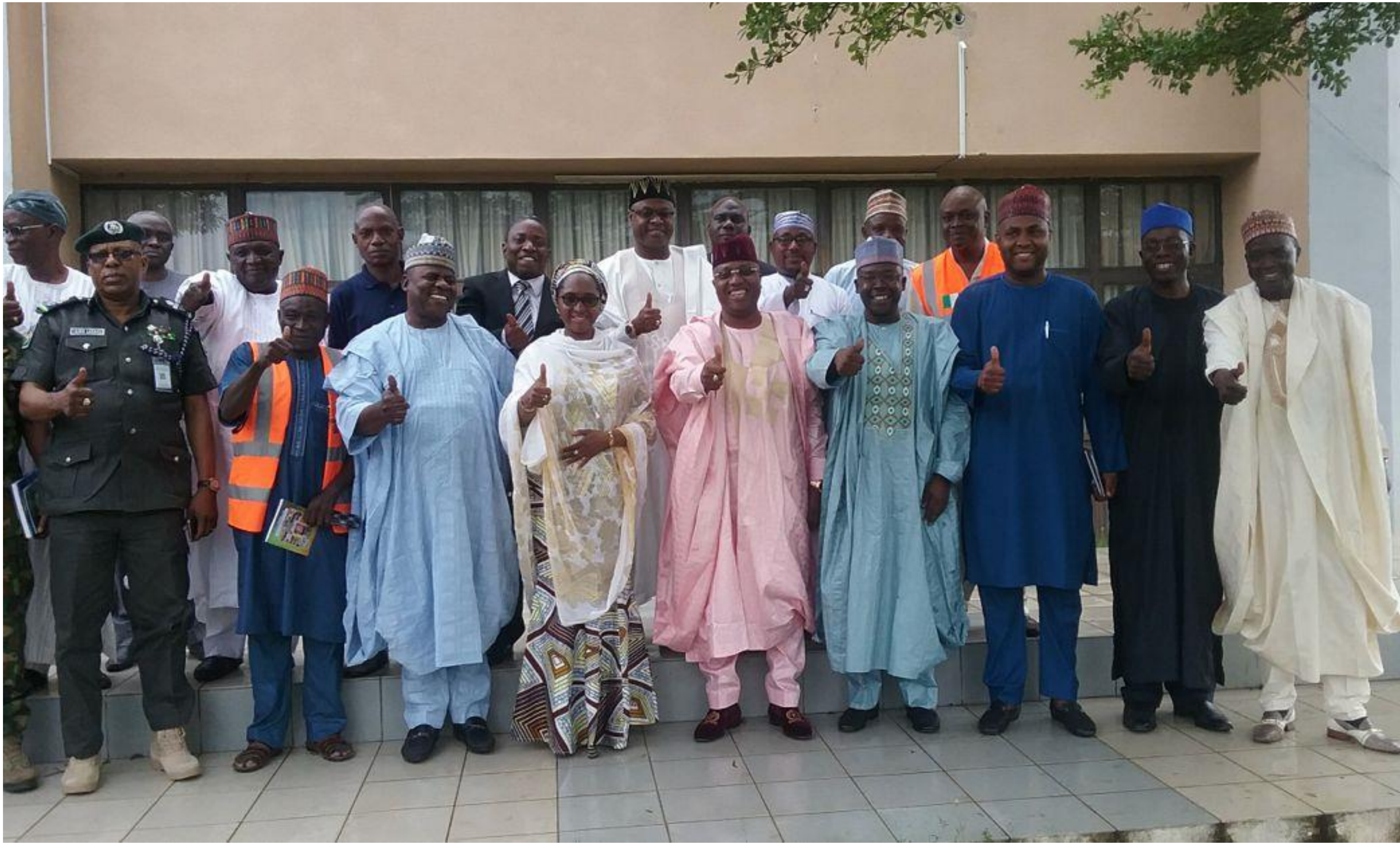
-2019-

BUHARI/BINDOW

FOR SOCIAL CHANGE (BSC)




we say
Congrats




"The more we
sweat in peace,
the less we
bleed in war."

FINAL STATEMENTS

ENGINEERING CREATIVITIES:

FOR GOOD GOVERNANCE & SOCIAL TRANSFORMATION

ADAMAWA TRANSFORMATION

- **IS THE RWANDA OF NIGERIA**
- **BINDOW IS THE LEE KUAN YEW OF ADAMAWA**
- **BINDOW IS THE BUHARI OF ADAMAWA**
- **SIMPLY PUT, A STATE IN NIGERIA WHERE ENGINEERING IS AT WORK**
- ***SEEING IS BELIEVING – ALL ARE INVITED TO YOLA***


THANK YOU

Agropreneurship for sustainability in a diversified economy: increasing yam value chain investments and creating opportunities for Nigerian agricultural engineers

Keynote Speaker at the 19th International Conference and 39th Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE), "EKO" 2018 Conference @ Akinrele Auditorium, Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos holding from 10-14 September, 2018 on the theme "Agropreneurship for Sustainability in a Diversified Economy".

By

Engr. Prof. Simon V. Irtwange, FNSE

Chairman, Technical Committee on Nigeria Yam Export Programme & Ag. National President, National Association of Yam Farmers, Processors and Marketers

Professor of Agricultural Processing & Storage, Department of Agricultural and Environmental Engineering, University of Agriculture, Makurdi ***Formerly:*** *Visiting Scholar, Agricultural Engineering Department, University of Ghana, P. O. Box LG 25, Legon, Accra, Ghana*

B.Tech (Akure), M.Eng (Nsukka), PhD (Ibadan), MBA, PGDE (BSU Makurdi), ***Cert, Seed Technology (India)****, Cert, Postharvest Bio.& Tech (Israel), MNIAE, MNSE, MASABE, MCSBE, MNIM, MNIFST, MTRCN, FCE+, pfd, F.AES, FCAI*

svirtwange@yahoo.com; +2348035885567

Proceedings of the 2018 International Conference of The Nigerian Institution of Agricultural Engineers Held at The Federal Institute of Industrial Research, Oshodi, Lagos, Nigeria, 10th - 14th, September, 2018.

MARKET OVERVIEW

ds in Yam Production &

AFRICA

- 54 million tons of yams are produced on 4.6 million ha.
- The value of **$13.7 billion** exceeds all other African staple crops equivalent to the combine value of cassava, maize, millet, sorghum and rice.

MARKET OVERVIEW

Nigeria:Yam Has a Higher Production Value Than Cassava, Maize, Millet, and Sorghum Combined

Comparison of production value for five food commodities in Nigeria

Crops	Area x1000 (ha)	Yield (T/ha)	Prod x 1000 Tons	Price US$/Ton	Prod. Value Million US$	Percentage to Yam
Yam	**3328**	**9949**	**31898**	**398**	**12694**	**100%**
Cassava	4100	10339	41086	157	6462	51%
Maize	4425	1572	6918	334	2311	18%
Millet	4050	1163	4976	297	1480	12%
Sorghum	6303	1174	7401	301	2226	18%
Rice	2387	1651	3976	364	1448	11%

Source FAOSTAT 2018: (Average data from 1995 to 2016)

MARKET OVERVIEW

n Yam Production & Trade

WEST AFRICA

- Over 95% of Africa’s yam production is the yam belt of West Africa **(Nigeria, Benin, Togo, Ghana, Côte d’Ivoire).**
- Yam is the preferred staple food in West Africa.
- It is consumed by a combined population of about 300 million.
- It has huge socio-cultural importance in West Africa such as marriages, thanksgiving and festivals.
- Demand exceeds supply
- Relatively expensive with very low affordability

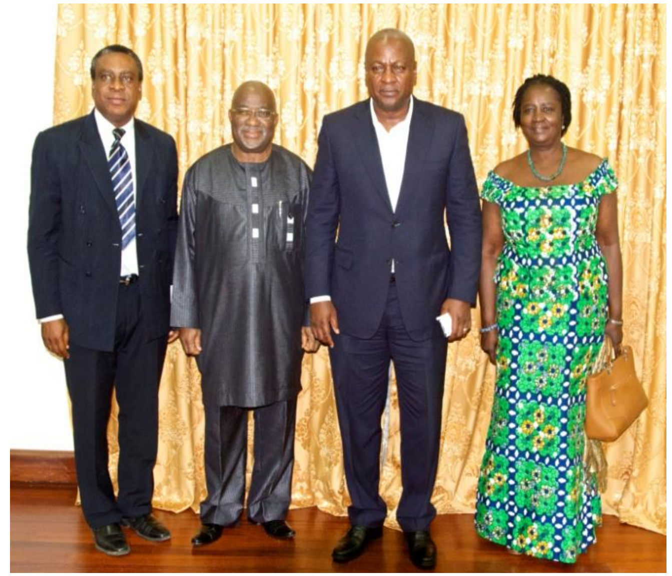
Ceremonial yam tubers at a market in Nigeria

MARKET OVERVIEW

in Yam Production & Trade

GHANA

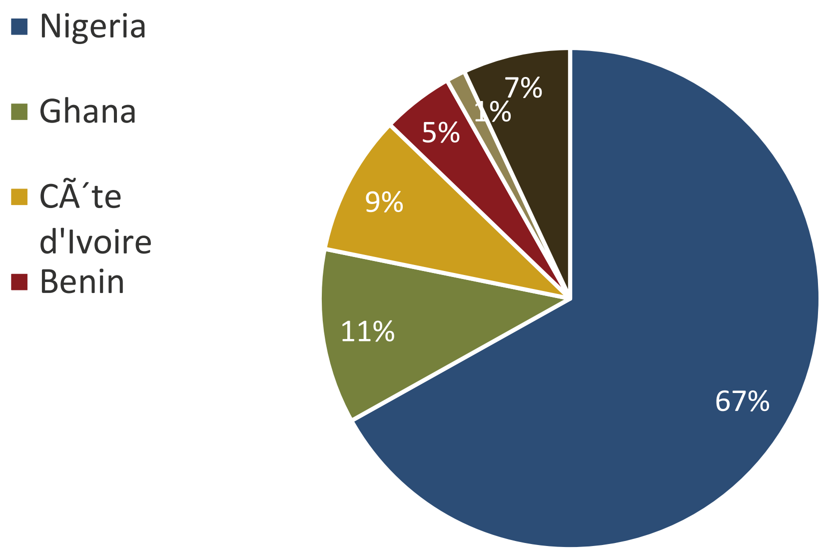
- **The yam export trade employs over one million work force.**
- **The country account for 94 percent of total yam exports in West Africa (US, Canada, UK and Europe).**
- **Yam production in the country contributed about 16 percent to the country's agricultural Gross Domestic Product (GDP)** between **2005** and **2010**
- The Government of Ghana has developed the National Yam Development Strategy and Yam Export Strategy (2013) aimed at increasing export volumes from current **35,000 tonnes** to as high as **400,000 metric tonnes and with expected revenue of about US$5billion by the next five (5) years.**



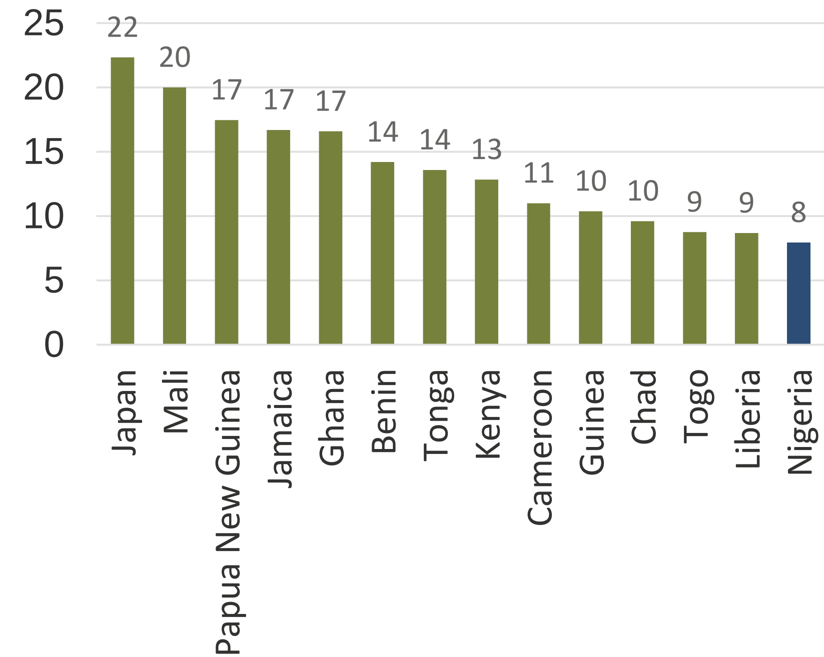
MARKET OVERVIEW

Nigeria is the Largest Yam Producer in the World In Spite of the Country’s Low Relative Agricultural Efficiency

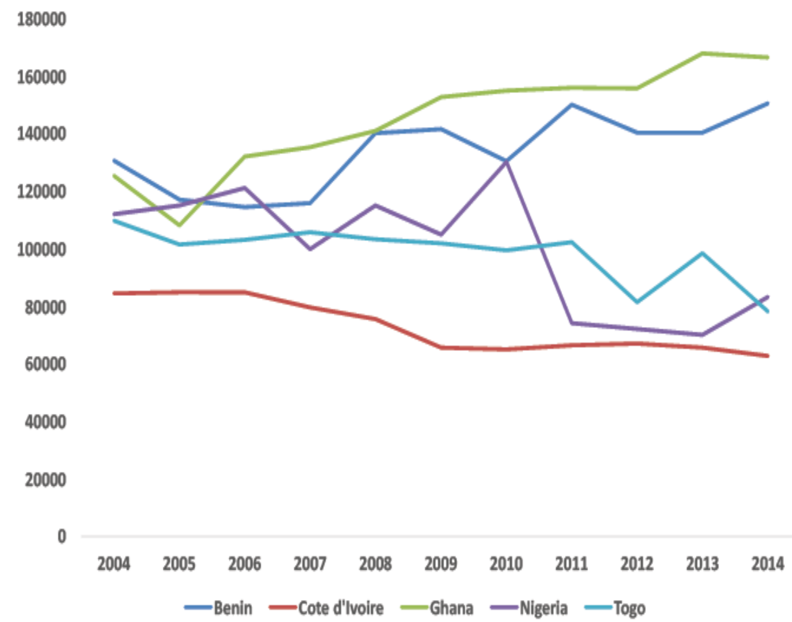
Country Share of Global Yam Production in 2015 (FAOStat)



2012 to 2016 Avg. Yam Yield (t/ha)



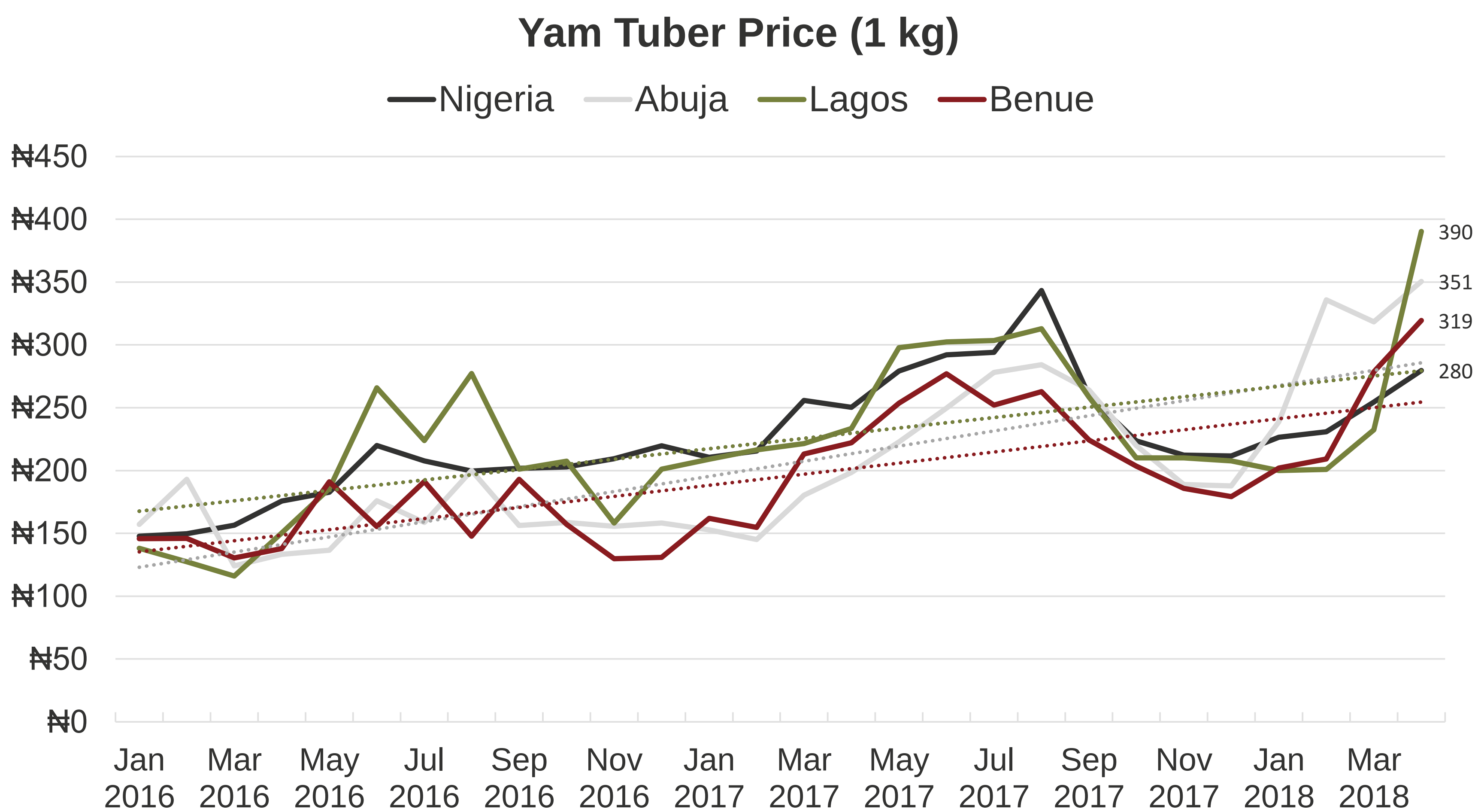
Average yield of Yam in West Africa (kg/ha)
Source: FAOSTAT, 2017



- ❑Nigeria remains one of the world’s largest producers of yam, which accounts for 61.7 percent of the global production of the root crop while there are over **60 varieties of yam**.
- ❑Nigeria is not among the major yam exporting countries as previous efforts **by Nasarawa and Oyo States and one-off trial at the NEPC Yam Conditioning Centre** were not sustainable.
- ❑Ghana controls’ Africa’s yam export market despite their low production.

MARKET OVERVIEW

YoY Tuber Prices Have Escalated Since 2016 – Price Per KG in Lagos Has Increased 160% (Apr 16' –Apr 18')



FURTHER PRICE PRESSURE

Inflation Risk→Herdsman Conflict in Benue State – Significant Yam Producing and Trading State→Nascent Yam Export Initiative, Assuming That A Commensurate Rise in Production Does Not Follow

Target commodity value chains for investments by zones in Nigeria & AfDB (Yam Missing)

A Stakeholders Inception Workshop for Technologies for African Agricultural Transformation (TAAT) – Capacity Development & Technology Outreach (CDTO) component was hosted at FARA HQ, Accra on 9-13 July, 2018.

TAAT project aims to scale up proven technologies across key value chains to promote productivity and profitability of African agriculture. It is funded by AfDB, implemented by FARA and other regional partners

The value chain commodities under consideration are: Maize, Wheat, Fish, Sorghum, Millet, Cassava, Rice, Orange-fleshed Sweetpotato (OFSP) & Cowpea (beans)

One Crop that is very important to income, food security and livelihoods - **YAM** - is missing.

NATIONAL YAM VALUE CHAIN ASSOCIATION

corporation:

Association of Yam Farmers, Processors and Marketers (CAC/IT/No. 94958) was first incorporated by the Corporate Affairs Commission on **22nd day of February, 2017** with the following as Board of Trustees:

1. Ambassador Ayuba J. Ngbako - Chairman
2. Prince Yandev Amaabai - Secretary
3. Engr. Prof. Simon V. Irtwange - Member/Technical Adviser
4. Chief Bernard Obi - Member
5. Hon. Isa Adams - Member
6. Chief Matthew Dangwam - Member
7. Hon. Mrs. Margaret Funke Adewale - Member
8. Hon. Misan Damoeroem - Member

CAC/IT/NO 94958

CORPORATE AFFAIRS COMMISSION
FEDERAL REPUBLIC OF NIGERIA

Certificate of Incorporation

of the Incorporated Trustees of

ASSOCIATION OF YAM FARMERS, PROCESSORS AND MARKETERS

I hereby certify that

AMBASSADOR AYUBA NGBAKO , PRINCE YANDEV AMAABAI , ENGR. PROF. SIMON IRTWANGE , CHIEF BERNARD OBI , HON. ISA ADAMS , CHIEF MATTHEW DANGWAN , HON. MRS. MARGARET FUNKE ADEWALE, HON. MISAN DAMOEROEM

the duly appointed trustees of ASSOCIATION OF YAM FARMERS, PROCESSORS AND MARKETERS *have this day been registered as a corporate body, subject to the below mentioned conditions and directions.*

Given under my hand and the Common Seal of the Corporate Affairs Commission at Abuja this 22nd day of February, 2017

CONDITIONS AND DIRECTIONS

This certificate is liable to cancellation should the objects or the rules of the body be changed without the previous consent in writing of the Registrar General or should the body at any time permit or condone any divergence from or breach of such objects and rules.

Note:
This cerificate does not bestow upon the Organization the right to establish any institution, engage in any business and the like without permission from the appropriate authority

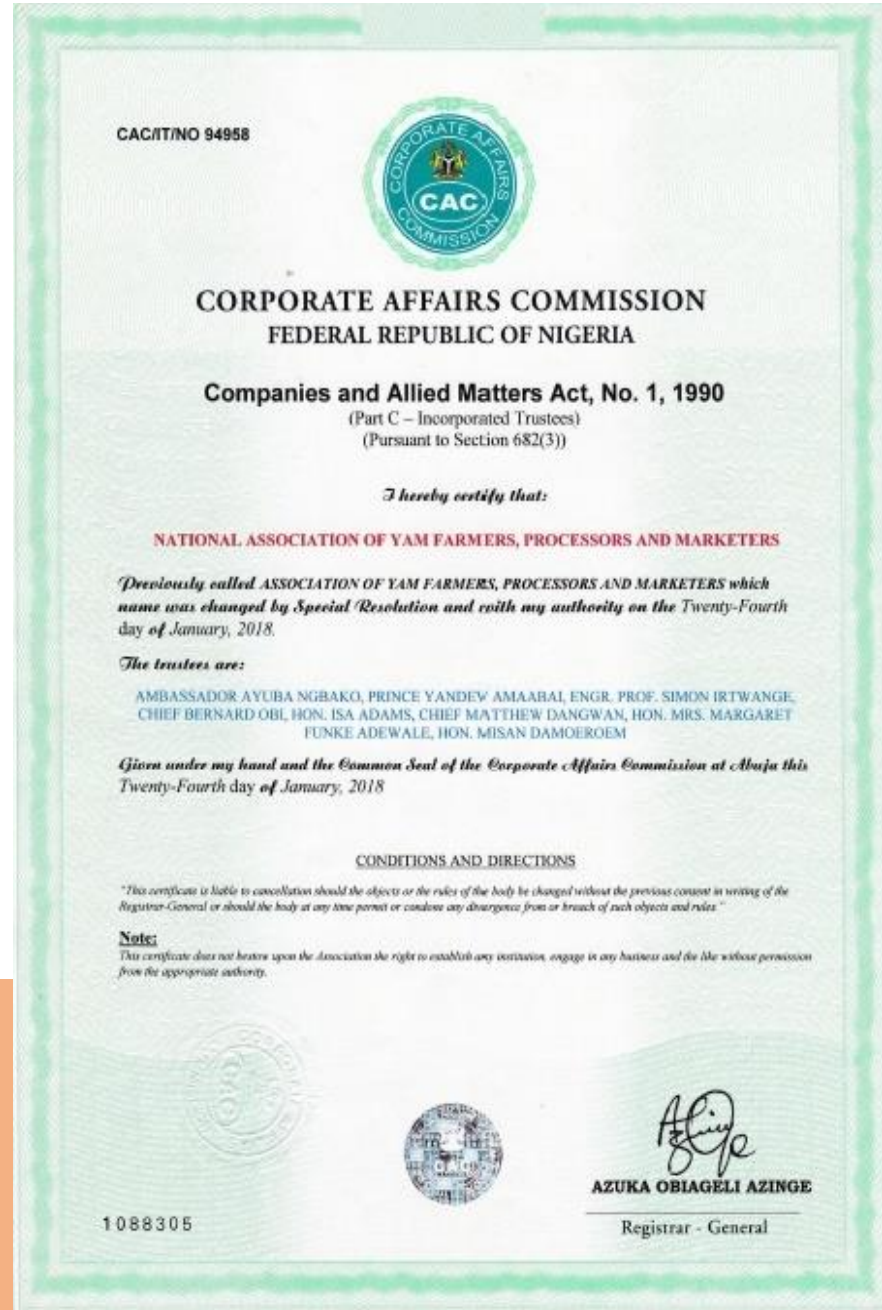
0976639

BELLO MAHMUD
Registrar - General

Change of Name of the Association

NATIONAL YAM VALUE CHAIN ASSOCIATION

- Following the meeting of yam stakeholders which took place on Thursday, 20th July, 2017 at the Block C Conference Hall of the Federal Ministry of Industry, Trade and Investment (FMITI) with the Director (Commodities and Products Inspectorate), a decision was taken to change the name of the Association to reflect a national umbrella body.
- The FMITI's letter to the Corporate Affairs Commission (CAC) to this effect dated 10th August, 2017 facilitated their incorporation of our association as "**National Association of Yam Farmers, Processors and Marketers**" on **24th January, 2018.**



CAC/IT/NO 94958

CORPORATE AFFAIRS COMMISSION
FEDERAL REPUBLIC OF NIGERIA

Companies and Allied Matters Act, No. 1, 1990
(Part C – Incorporated Trustees)
(Pursuant to Section 682(3))

I hereby certify that:

NATIONAL ASSOCIATION OF YAM FARMERS, PROCESSORS AND MARKETERS

Previously called ASSOCIATION OF YAM FARMERS, PROCESSORS AND MARKETERS which name was changed by Special Resolution and with my authority on the *Twenty-Fourth* day ***of*** *January, 2018.*

The trustees are:

AMBASSADOR AYUBA NGBAKO, PRINCE YANDEV AMAABAI, ENGR. PROF. SIMON IRTWANGE, CHIEF BERNARD OBI, HON. ISA ADAMS, CHIEF MATTHEW DANGWAN, HON. MRS. MARGARET FUNKE ADEWALE, HON. MISAN DAMOEROEM

Given under my hand and the Common Seal of the Corporate Affairs Commission at Abuja this *Twenty-Fourth* day ***of*** *January, 2018*

CONDITIONS AND DIRECTIONS

"This certificate is liable to cancellation should the objects or the rules of the body be changed without the previous consent in writing of the Registrar-General or should the body at any time permit or condone any divergence from or breach of such objects and rules."

Note:
This certificate does not bestow upon the Association the right to establish any institution, engage in any business and the like without permission from the appropriate authority.

1088305

AZUKA OBIAGELI AZINGE
Registrar - General

Motto & Vision

Motto: The motto of The Association is **"Food Security and Wealth Creation"**

Vision: To be an international player in the yam sub-sector of the agricultural industry.

NATIONAL YAM VALUE CHAIN ASSOCIATION

Objectives of the Association

- ☐ To promote the business of Yam value chain throughout the country.
- ☐ To collaborate with the Federal Government to transform the traditional methods of farming to mechanized systems.
- ☐ To organize and encourage group/cooperative farming systems.
- ☐ To supervise the proper distribution and use of Agribusiness facilities from Government, Banks and other institutions amongst members.
- ☐ To liaise with the Government on all matters regarding Yam subsector.
- ☐ To encourage members to produce and purchase Yam products for processing and marketing from the members.
- ☐ To organize Annual Yam and its value chain DAY.
- ☐ To encourage members of **NAY-FPM** to establish small scale processing industries and marketing of the products.
- ☐ To affiliate and subscribe to international Yam organizations in order to bring developmental projects and programmes to its members and the subsector.
- ☐ To promote the interest of Yam stakeholders by any lawful ways and means.

NATIONAL YAM VALUE CHAIN ASSOCIATION

Objectives of the Association

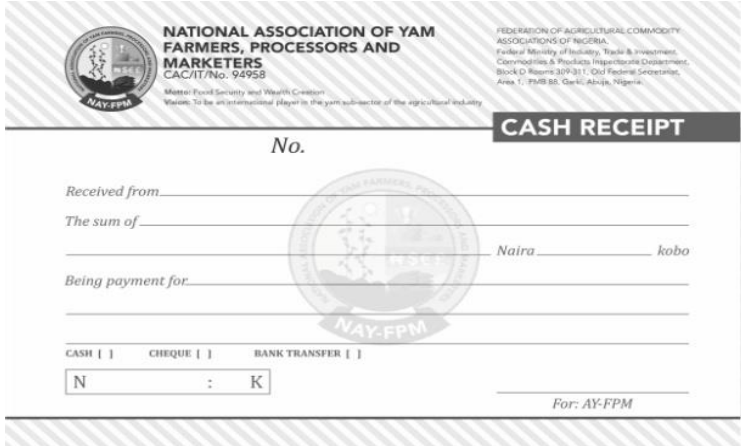
- ☐ To provide persons and corporate organizations interested in Yam business facilities for discussions and interchange of information and knowledge sharing.
- ☐ To arrange for deputations so as to ventilate the views of stakeholders to the Government and the public about conditions and difficulties affecting the Yam subsector.
- ☐ To organize workshop, conferences, training and seminar to deepen the knowledge of members in the Yam value chain.
- ☐ To promote yam outgrowers, producers, processors, marketers, exporters, aggregators, cooperatives & off takers partnerships arrangement throughout Nigeria.
- ☐ To enter into working agreements and affiliations with organizations or associations having similar objectives provided such agreements and affiliations do not in any way impede the operations of the constitution.
- ☐ To actively promote Nigeria yam export programme

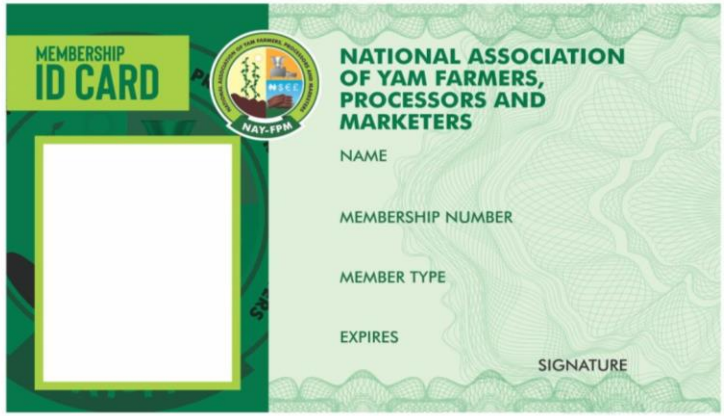
NATIONAL YAM VALUE CHAIN ASSOCIATION

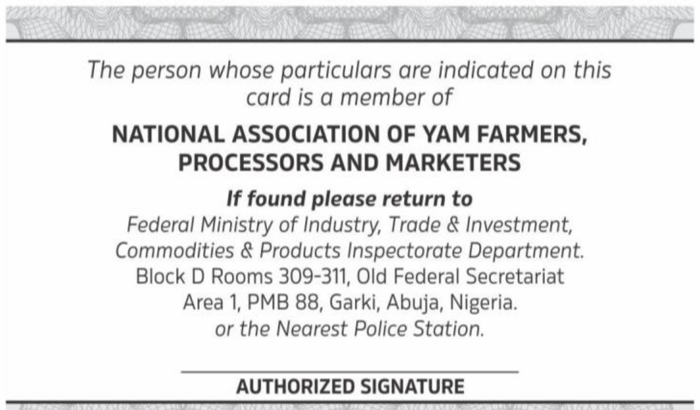
...ship

Membership of The Association is opened to all stakeholders in the Yam Production, Processing and Marketing value chain such as;

- ☐ Yam Farmers (Seed and Ware Yams),
- ☐ Yam Processors,
- ☐ Yam Marketers,
- ☐ Yam Transporters,
- ☐ Yam Exporters,
- ☐ Yam Aggregators,
- ☐ Yam Off-takers &
- ☐ Yam Affiliate Cooperatives.





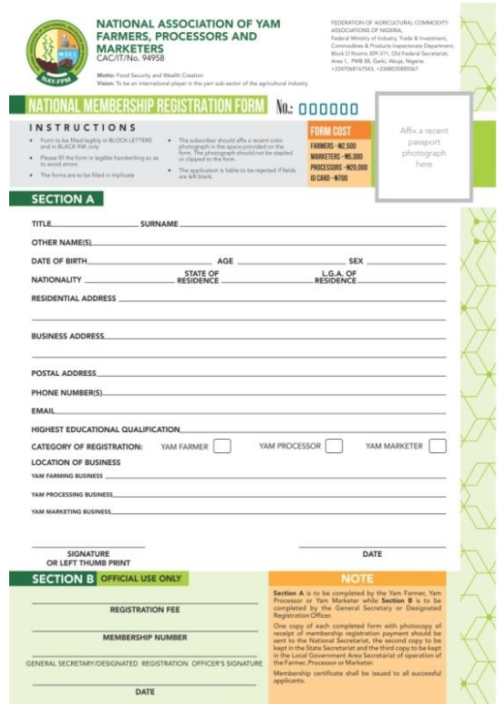

The person whose particulars are indicated on this card is a member of

NATIONAL ASSOCIATION OF YAM FARMERS, PROCESSORS AND MARKETERS

If found please return to

Federal Ministry of Industry, Trade & Investment, Commodities & Products Inspectorate Department.
Block D Rooms 309-311, Old Federal Secretariat
Area 1, PMB 88, Garki, Abuja, Nigeria.
or the Nearest Police Station.

AUTHORIZED SIGNATURE



NATIONAL YAM VALUE CHAIN ASSOCIATION

Board of Trustees &Officers of The National Working Committee

- 8 Member Board of Trustees
- Officers of The National Working Committee
  - National President
  - National Deputy President
  - Vice President (North Central)
  - Vice President (North East)
  - Vice President (North West)
  - Vice President (South West)
  - Vice President (South East)
  - Vice President (South South)

- National Secretary
- National Assistant Secretary
- National Treasurer
- National Financial Secretary
- National Publicity Secretary
- National Assistant Publicity Secretary
- National Organizing Secretary
- National Assistant Organizing Secretary
- Ex-Officio Members shall be Immediate Past National President/National Secretary

NATIONAL YAM VALUE CHAIN ASSOCIATION

Members of the National Executive Committee (NEC)

- ☐ All members of the Board of Trustees.
- ☐ All members of the National Working Committee.
- ☐ All State Chairmen and their Secretaries.
- ☐ All Chairmen or representatives of the major companies registered with The Association.
- ☐ Representatives of the Federal Ministry of Industry, Trade and Investment, Federal Ministry of Agriculture and Rural Development, and any other MDAs that NEC may approve from time to time.
- ☐ Representative of Federation of Agricultural Commodity Associations of Nigeria (FACAN)

NATIONAL YAM VALUE CHAIN ASSOCIATION

State Executive Committee (SEC) & LGA/BRANCH Executive Committee (LGAEC/BEC)

State Executive Committee (SEC):

- ☐ Chairman
- ☐ Deputy Chairman
- ☐ General Secretary
- ☐ Assistant General Secretary
- ☐ Treasurer
- ☐ Financial Secretary
- ☐ Publicity Secretary
- ☐ Organizing Secretary

LGA/BRANCH Executive Committee (LGAEC/BEC):

- ☐ Chairman
- ☐ Vice Chairman
- ☐ General Secretary
- ☐ Assistant General Secretary
- ☐ Treasurer
- ☐ Financial Secretary
- ☐ Publicity Secretary/Organizing Secretary

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Based on a proposal submitted to the Honorable Minister, Federal Ministry of Agriculture and Rural Development (FMARD), Chief Audu I. Ogbeh, OFR by Engr. Prof. Simon V. Irtwange, FNSE under the auspices of SIEA Integrated Solutions Ltd on September 29, 2016 and after a follow up presentation to officials of FMARD on Tuesday November 29, 2016, the Minister directed that a private sector led Technical Committee on Nigeria Yam Export Programme be constituted to drive the process.

tion & Membership

The Technical Committee was inaugurated on February 23, 2017 by the Honorable Minister, Federal Ministry of Agriculture and Rural Development, Chief Audu I. Ogbeh, OFR as follows:

- 11 Members from the Private Sector including AFEX Commodity Exchange Limited, the BOT Chairman, BOT Secretary, Ag. National President and Ag. National Secretary of the National Association of Yam Farmers, Processors and Marketers, among others
- Standards Organization of Nigeria (SON)
- Nigeria Agricultural Quarantine Services (NAQS)
- Nigeria Custom Service (NCS)
- Nigeria Export Promotion Council (NEPC)
- Nigeria Port Authority (NPA)
- Nigeria Shippers Council (NSC)
- Agribusiness and Market Development (ABM) Department, FMARD

Co-Opted:

- ADES African Foods and Drinks, United Kingdom (Representative for Africa and Asia)
- International Institute of Tropical Agriculture (IITA)
- Synergos, Nigeria
- Technical Adviser, Quality Control & Standards, Office of the Hon. Minister, FMARD, Abuja
- Dantata Foods and Allied Products Limited

SECRETARIAT: Agribusiness and Market Development (ABM) Department, FMARD

TECHNICAL COMMITTEE ON NIGERIA YAM EXPORT PROGRAMME

Reference

The Technical Committee's tasks as enumerated in the Terms of Reference (ToR) by the Minister were as follows;

- ☐ Develop a framework for establishment of Nigeria Yam Export Pack houses at Sea and Airports in which all documentations relating to yam exports are prepared.
- ☐ Facilitate the acquisition of warehouses at the receiving destinations.
- ☐ Rationalize bureaucracy of export with enforcement agencies located under one roof in the single designated Nigeria Yam Export Pack Houses: Nigeria Agricultural Quarantine Services (NAQS), Standard Organization of Nigeria (SON) and Nigeria Customs Services (NCS)
- ☐ Facilitate establishment of letters of credit, payment of export tax and the strict adherence to standards.
- ☐ Identify market outlets in Europe, USA, Canada, etc. and provide market information on weekly prices of yam at the major marketing Centres.

TECHNICAL COMMITTEE ON NIGERIA YAM EXPORT PROGRAMME

Reference

- ☐ Provide support for the development of relevant standards in conjunction with the Standards Organization of Nigeria to drive the yam export market;
  - Good Agricultural Practices for Nigeria (NIGERIAGAP): Part 1 – Code of Practice for Crop Production
  - Good Agricultural Practices for Nigeria (NIGERIAGAP): Part 2 -Compliance Criteria for the Code of Practice for Crop Production
  - Roots and Tubers – Specification for Fresh Yams
- ☐ Provide support for the establishment of yam pack house Centres to serve as collection Centres in the States of the Federation.
- ☐ Provide support for the Association of Yam Farmers, Processors and Marketers in States of the Federation and support the private sector participation in the production of packaging materials.
- ☐ Organize sensitization workshops and training of Stakeholders in yam value chain
- ☐ Facilitate industry visit to Ghana by Stakeholders of yam value chain to understudy the Ghana Yam Export market business.
- ☐ Carry out mapping of yam value chain stakeholders and create an enabling environment for private sector participation in the yam export business.
- ☐ Organize a flag off ceremony for the first batch of packaged Nigeria yams for export.

YAM EXPORT

Training and Awareness

The Technical Committee on Nigeria Yam Export Programme collaborated with SIEA Integrated Solutions Ltd, Nigerian Export Promotion Council (NEPC), Makurdi Export Assistance Office & Association of Yam Farmers, Processors and Marketers, NIGERIA in organizing a **2-Day Stakeholders Training and Awareness for Nigeria Yam Export Programme from April 6-7, 2017** at the Central Bank of Nigeria, Entrepreneurship Development Centre, North Central Zone, Makurdi, Benue State.

HIGHLIGHT:

On April 6, 2017 His Royal Majesty Tor Tiv V Orcivirigh Professor James Ayatse re-designated Yam as a **TRADITIONAL CROP** and instituted **ANNUAL YAM AND ITS VALUE CHAIN DAY** to be organized/celebrated in Benue State by the National Association of Yam Farmers, Processors and Marketers in collaboration with the Benue State Traditional Council. The Tiv Area Traditional Council (TATC) meeting of Friday17th August, 2018 further stated that farm produce festivities should be institutionalized and celebrated on the second Saturday of January every year at the Kindred, District, LGA levels with a central festival in Gboko as shall be determined by the TATC.

YAM EXPORT

...rs Training ...ness

- In this wise, there is need to understand the types of yam to be exported in terms of **varieties, quality, standards, sorting /grading, the spoilage factors; i.e. moisture, weather condition, micro-organism etc and packaging.**
- The criteria for yam export include **identifying the market requirement, yam condition, yam sizes/shape, weight of the yam, transportation/handling, climatic condition** and **importing country regulatory laws.**
- A case of yam production for export market includes good agriculture practice for all the stages involved in production processes, clearing/ridges, seedling – variety, planting, weed control, harvesting, post harvesting and storage/packaging.

- Not all yam tubers are of export quality. The following specifications are required:
  - ✓Slender
  - ✓Tuber to weigh averagely 2 kg
  - ✓Packed in cartons with gross weight of 20kg (50 cartons on a pallet for UK); 25kg (40 cartons on a pallet for USA)
  - ✓Between 9-11 tubers in a carton

YAM EXPORT

Oyo State Yam Export Programme

Nasarawa State Yam Export Programme

First phase in 2009			
First shipment	8th June, 2009	8.5 metric tones	340 cartons
Second shipment	18thJune, 2009	27.75 metric tones	1,110 cartons
Third shipment	29thJune, 2009	38.25 metric tones	1,530 cartons
	Total	**73.5 metric**	**2,980 cartons**

Second phase in 2010 /2011			
Only one shipment		***87,400 metric tones***	***3,800 cartons***

Launching of the yam export in the UK (11/7/09).

YAM EXPORT

Ghana Yam Export Programme

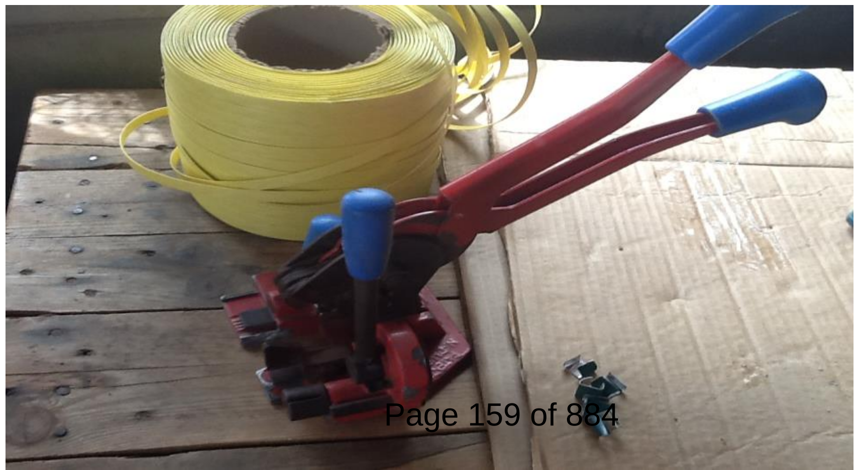
❖Establishment of a single designated National Yam Export Pack House in which all documentations relating to yam exports are prepared. This pack house is located at Tema, close to the Port. From here the consignments are trucked under seal to a scanning machine from where they are sent direct to the ships.

❖Rationalization of bureaucracy of export with agencies now located under one roof (Plant Protection & Regulatory Services Directorate (PPRSD) of the Ministry of Food & Agriculture (MOFA), The Ghana Standards Authority (GSA) and Customs, Excise and Preventive Services (CEPS)

YAM EXPORT

Ghana Yam Export Programme

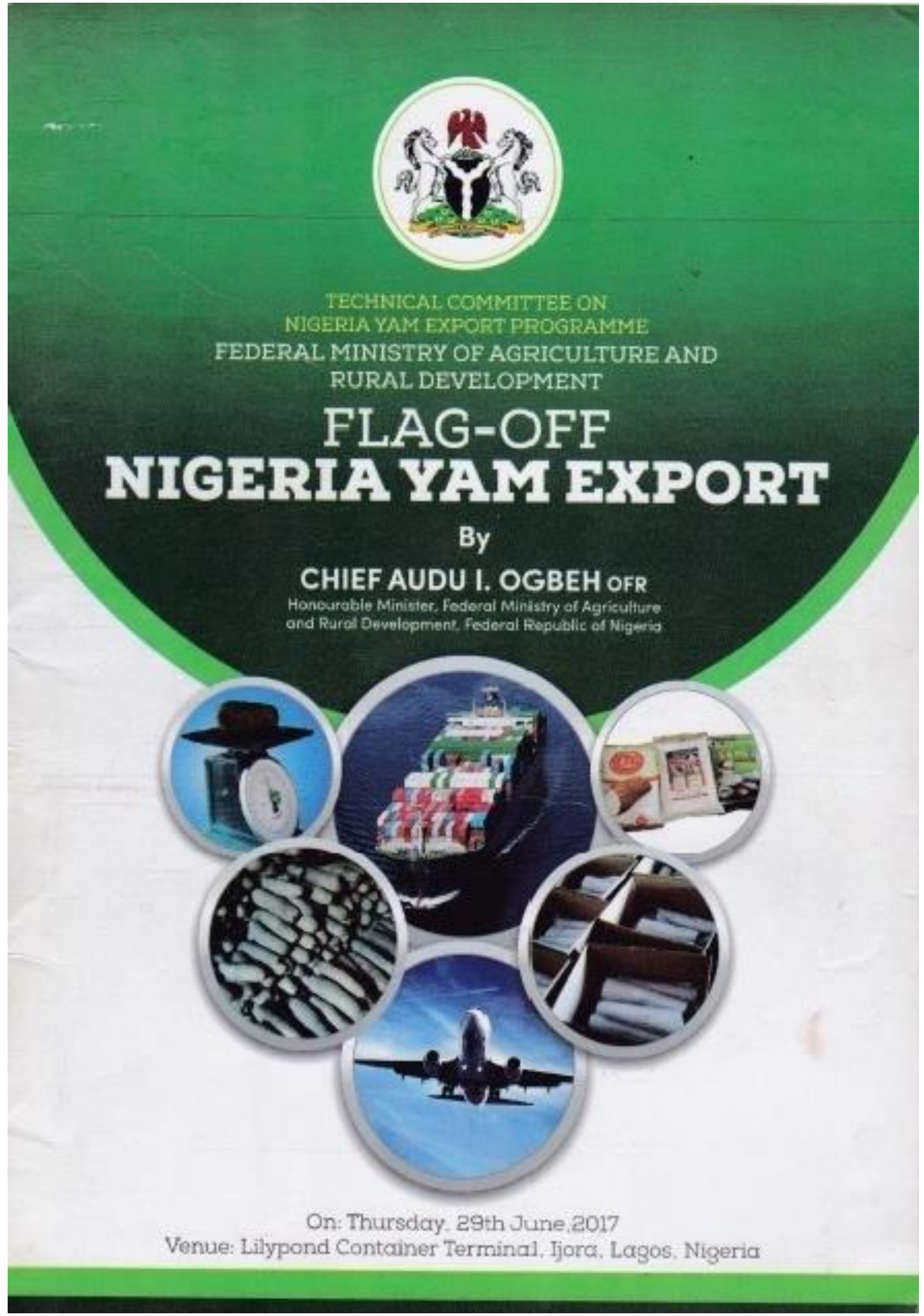
- ❖Redesignation of yam as a traditional crop, thereby bringing in regulations on establishment of letters of credit by the importers, payment of export tax and the strict adherence to standards, enforcement of which is done by the PPRSD, GSB and CEPS.
- ❖Provision of training for growers by Agricultural Extension Agents on good agricultural practices in yam production as well as good handling and storage practices, all meant to ensure that good quality yam tubers are produced and made available for sale.
- ❖Provision of market information on weekly prices of yam at the major marketing centres.



YAM EXPORT to the UK & USA

In line with the last term of reference, the Technical Committee organized the first ever flag off ceremony on home soil for the first batch of packaged 72 tons Nigeria yams for export to the UK & USA on 29th June, 2017.

The following participated in the export programme: **Ifeangel Nig. Ltd** exported to the UK with **ADES African Foods and Drinks** as off-taker while **Wan-Nyikwagh Farms Ltd** exported to the USA with **Founders Investments LLC** as off-taker.



Our Yams were not rejected but there were Several Challenges. Destructive Nigeria Media Reports were Politically Motivated

- There was to be a physical trial run/rehearsal on Monday, 19th June, 2017. APM Terminal made available their facilities for the purpose & ADES African Foods and Drinks, UK made a 40ft container of yam available at Lily Pond for shipment to the UK, which was transported by Dantata cold truck from the exporters warehouse/packaging facility in Makurdi to Lagos, but due to the gridlock at Apapa and other logistical failures, the container missed the ship. Consequently, the planned cold chain of transloading the yams from the cold truck into the REEFER container was broken and the yams were offloaded into a fumigated open space at the APM Terminal
- Consequently, the trial run/rehearsal yams bound for the UK became the flag off yams on 29th June, 2017. The real flag off yams were left behind in Makurdi as Dantata truck could not go back to lift the produce to Lagos and that shipment was eventually aborted because we were dealing with old yams purchased in the open market.

Our Yams were not rejected but there were Several Challenges. Destructive Nigeria Media Reports were Politically Motivated

- For the USA shipment, the yams were packaged in the yam conditioning facility provided by the Nigeria Export Promotion Council in Zaki-Biam with the assistance of NEPC staff and were transported in ordinary covered trucks to Lagos(since Dantata cold truck could not make the trip back to Makurdi) and arrived Lagos on 28th June, 2017 for the flag off next day
- Another challenge was with the production of cartons; they were produced in Ibadan, Oyo State, transported to Makurdi/Zaki-Biam in Benue State where packaging was done and then the packaged yams were now transported to Lagos, Lagos State.
- After the flag off ceremony, the UK bound container eventually (after two failed attempts due to the Apapa gridlock) left Apapa Port on NORDBALTIC Voyage No. 1710 on **16th July, 2017** via PORT TANGIER MEDITERRANEE, MOROCCO, discharged and reloaded on MAERSK SHANS and discharged at FELIXSTOWE TRINITY TERMINAL, UK on **25th August, 2017**

Our Yams were not rejected but there were Several Challenges. Destructive Nigeria Media Reports were Politically Motivated

- The USA yams departed Apapa port on **21st July, 2017** via RIO GRANDE EXPRESS Voyage No. 1727N, departed Tan med on 11th August, 2017 via TIHAMA Voyage No. 002W, departed Southhampton 17th August 2017 via WASHINGTON EXPRESS Voyage No. 103W, arrived Houston Texas on the 1st September and discharged **2nd September, 2017**.
- All the yams were cleared by the UK and USA authorities and released to the off-takers in both countries and were in the safe custody of their warehouses for sale to the public but as expected, an estimated 20% of the yams were rotten for the fact that they were old yams that had broken their dormancy and the undue delay in sea freight.
- The trial run was to provide learning points for the Technical Committee going forward and we had commenced compilation of the report. The USA off-taker for example sent in his report which indicated that the greatest disservice to the yams was that which was done by the Nigerian Quarantine Authorities by cutting off the head of the yams and waxing as rot was induced from the cut ends, among others.

Our Yams were not rejected but there were Several Challenges. Destructive Nigeria Media Reports were Politically Motivated

- We were in the process of compiling the report when news broke that our yams were rejected which has been proved to be false. Our yams were not rejected but as is usual with import/export of perishables, and even transportation of perishables from one place to another within the country, some tubers were rotten. It happens to Ghana shipment too, the only difference is that some Nigerians, for political reasons, decided to de-market our yams in the eyes of the international community. Nigeria yams remain the best globally and they were not rotten by the time they left the shores of Nigeria otherwise relevant agencies of Government would have refused giving the necessary clearances & certifications.
- The trade strategy was to take in our yams into the market by the time Ghana yams are not available but the success of the strategy was predicated on timely and seamless operations which Apapa gridlock cannot guarantee. However, with what we have seen of the quality of Ghana yams, Nigeria can go head-to-head with Ghana.

YAM EXPORT REPORT

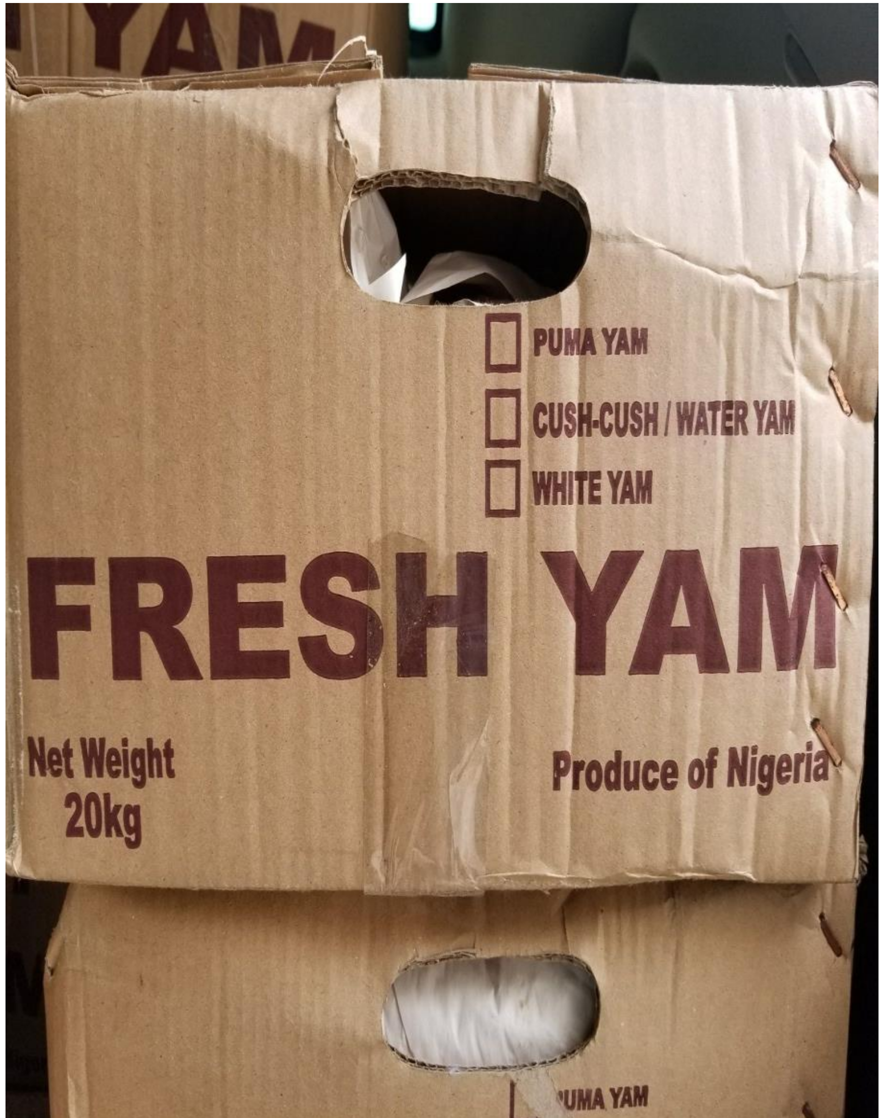
Our Yams were not rejected but there were Several Challenges. Destructive Nigeria Media Reports were Politically Motivated

The yams got to USA and were cleared by the Off-taker at a cost of $8,150.00 and transported into an air conditioned warehouse in Houston which he paid for before the arrival of the yams.

- **We received the first consignment of yams from Nigeria yesterday with some challenges**:
- **Off-taker Remarks 1**: “The specie of yam shipped was not ticked off on the labeling and packaging. This should be corrected in future shipments, or add a *Mixed* specie label for shipments that may not be one uniform variety.”

YAM EXPORT REPORT

Our Yams were not rejected but there were Several Challenges. Destructive Nigeria Media Reports were Politically Motivated



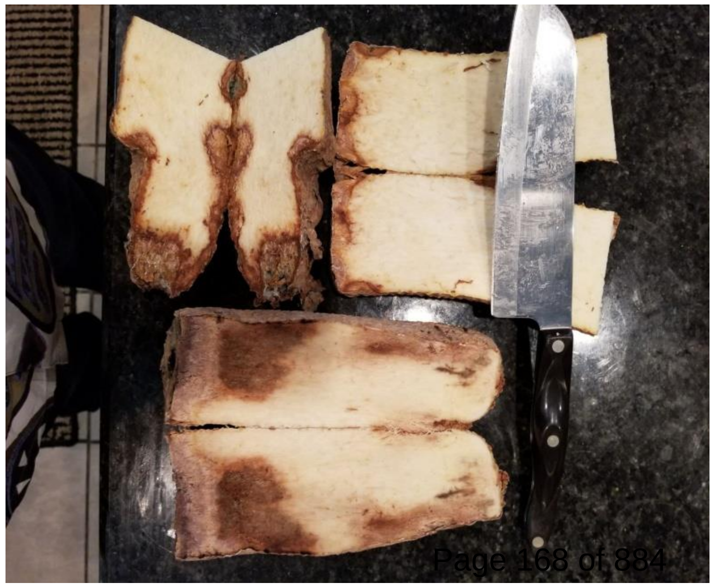
Off-taker Remarks 2:

“Our packaging size of 20 kg is different from what is obtainable in the market and from Ghana. Their boxes are bigger and 25 kg instead of 20 kg. We need to be at the size for uniformity and competitive pricing.”

Our Yams were not rejected but there were Several Challenges. Destructive Nigeria Media Reports were Politically Motivated

- **Off-taker Remarks 3:** "None of the boxes weighed up to 20 kg (44 lbs) as labeled. That's a huge issue! The actual confirmed weights per box here is between 14-16 kg. Apparently the boxes were weighed with whole tubers and not made up to the same weight after they cut off the heads. We need to actually overload the boxes by about 5% to allow for dehydration and weight loss in transit.

Our Yams were not rejected but there were Several Challenges. Destructive Nigeria Media Reports were Politically Motivated



Off-taker Remarks 4:

“The idea of cutting of the heads of the yams is a very bad idea. It induced rot from that end, some up to half of the tuber! It also makes a poor presentation to see black mold and rot on the cut end”

YAM EXPORT REPORT

Our Yams were not rejected but there were Several Challenges. Destructive Nigeria Media Reports were Politically Motivated

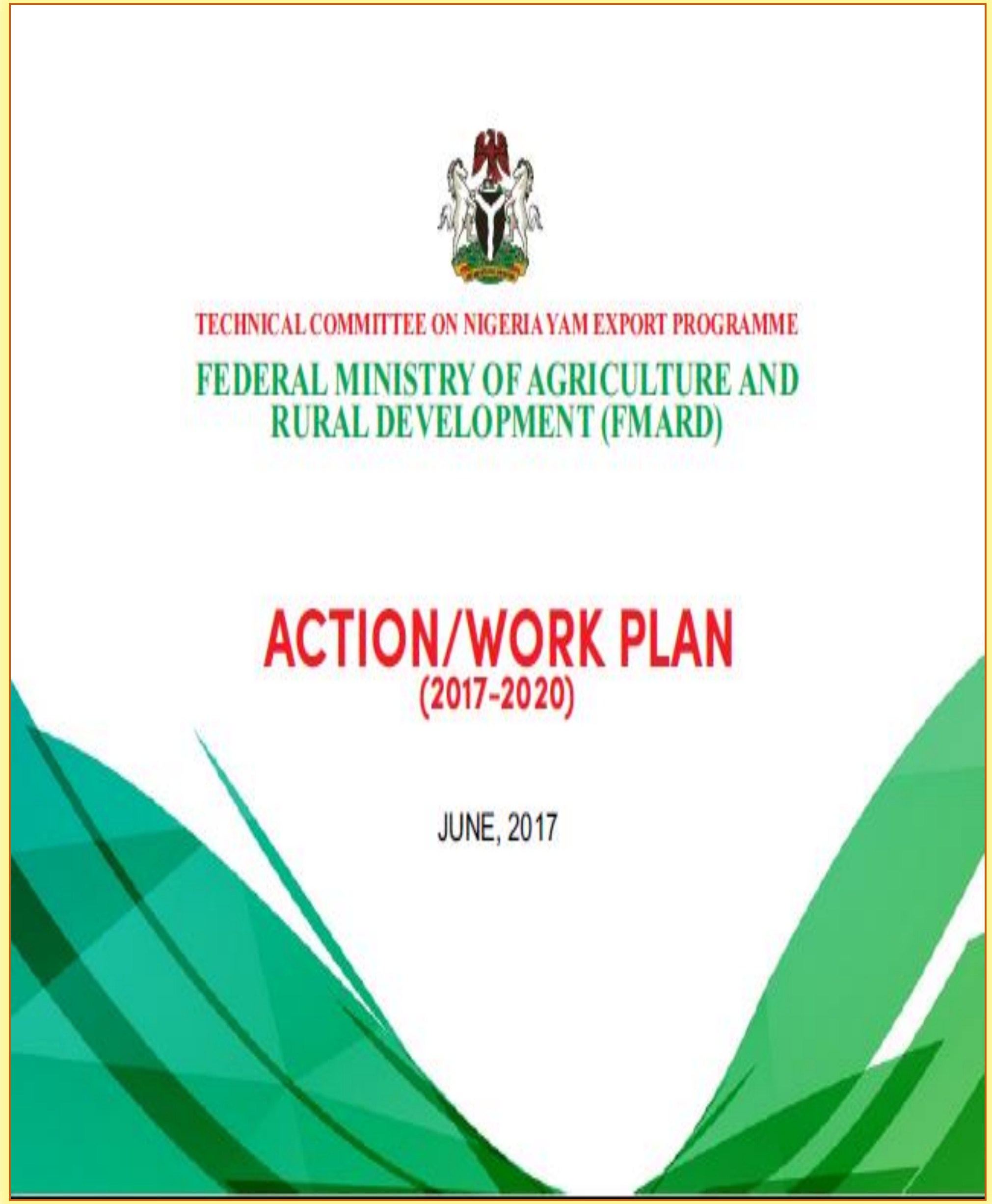
- **Off-taker Remarks 5**: “Cutting the yam bottoms is the worst service that the Nigerian authorities have done to our shipment. It is the major cause of rot in most of the yam tubers”
- **Off-taker Remarks 6**: “So far the estimated spoilage rate sampled is about 20% in transit”
- In spite of the challenges, the Off-taker concludes: “I want at least one container each every month going to the US ports of Houston, New York/New Jersey and Los Angeles”

YAM EXPORT

Strategy for Nigeria’s Yam Value Chain Development Going Forward

According to Government, the yam export policy has come to stay and the only action now is how to improve on the process based on lessons learned.

The Technical Committee has developed Action/Work Plan (2017 - 2020) going forward. The plan objective is to create an estimated one million jobs and earnings of at least USD10.0 billion annually in the next four (4) years. The total cost required to operationalize the Action/Work Plan for 2017-2020 is **₦3,139,166,718.00 ($10,463,889.06)**.



YAM EXPORT REPORT

Challenges & Opportunities in Yam Value Chain

- Farmers generally use traditional methods and tools;
- Limited access to credit is a major constraint for Yam Smallholders;
- Yam producers increasingly rely on hired labor to fulfill production requirements;
- Pests pose a major problem to production, and most farmers do not adopt comprehensive control measures;
- Fertilizer use is desired but inaccessible to most yam farmers;
- More women are participating in yam production, but with limited access to resources;
- Quality standards have been constraints at the international market; and
- Under explored opportunities in the value-added yam products, such as dry yam, animal feeds, yam chips, yam starch, yam extracts for alcoholic beverage.
- Packages for value-added yam products

ACTION/WORK PLAN (2017-2020)

FORWARD

This Action/Work plan identifies a set of priority areas that are key to improving/accelerating yam value chain development in Nigeria. It provides the strategic framework that is expected to provide employment, assure food and nutrition security, reduce poverty and make Nigeria economically prosperous. Strategies cutting across production, processing and marketing have been identified to achieve high impact in the priority areas of focus and thus achieve the objectives and targets of the plan. Activities in these strategic areas will be delivered through the existing institutional platforms to ensure maximum impact. The proposed activities are in line with vision of the agricultural promotion policy (2015-2020) of the Federal Government of Nigeria.

The Action/Work Plan that provides guidance and motivation to government and other stakeholders which may develop more in-depth or micro implementation plans for yam value chain acceleration in Nigeria. The plan represents the articulation of bold new thinking, resourcing and operationalization of evidence based, high impact interventions to drive and reposition the yam sector in Nigeria.

The strategic plan of action is costed to promote resource mobilization and resource allocation with the aim of promoting high impact interventions and to leverage resources. The Action/Work Plan for yam value chain development represents a decision template for the government to spell out clearly the level of investment they are willing to commit to accelerate the achievement of the set targets. It also provides a commitment plan to guide investors as they target the various value chains, to development partners as they choose their interventions, across the priority areas of focus. Successful implementation of the Action/Work Plan will depend on political will, sustained commitment of government, investors, farmer groups and other partners to invest and turn around agriculture in Nigeria.

Engr. Prof. Simon V. Irtwange, FNSE
Chairman, Technical Committee on Nigeria Yam Export Programme

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YAM EXPORT

Challenges & Opportunities in Value Chain

- Seed Yam Deployment
- Mechanization of Yam Production
- Irrigation of Yam Production
- Local Marketing Infrastructure
- Yam Products – Flour, Chips, Pharmaceutical Grade Starch (PGS), etc
- Yam Processing Equipment: Yam Peeling Machines, Yam Chipping Machines, Yam Blanching Machines, Yam Drying Machines, Yam Grinding Machines, Yam Flour Packaging Machines, Yam Planters, Yam Harvesters, Yam Heap/Ridge Making Machines, etc
- Yam Conditioning/Cooling Systems, Storage Warehouses & Pack Houses (Design and Standardization of Deep-Bin Pallets)
- Transportation – Cold Trucks (Inland Transportation)
- Carton Production/Packaging (Cartons, and Clean, Plain and Unglazed Wrapping Papers)

YAM EXPORT

Strategic Partnerships between Stakeholders

In tackling these challenges, it is imperative to build **Strategic Partnerships** between Stakeholders

YAM EXPORT

Strategic Partnerships between Stakeholders

Private Seed Companies:
BIOCROPS, Nwabudo Agro Seeds and Inputs Limited, Da-Allgreen Seeds Limited, PS Nutrac, etc to produce one-node vines from motherplants in aeroponics system, transplant hardened vines to the field and harvest basic seed yams for distribution

Research:
International Institute of Tropical Agriculture: Technical backstopping with aeroponics, vine cuttings, Temporary Immersion Bioreactor Systems, tissue culture & yam minisett technologies
National Root Crop Research Institute, Umudike: To produce pre-basic yam seeds to satisfy the need of yam producers
National Centre for Genetic Resources and Biotechnology: To produce pre-basic yam seeds to satisfy the need of yam producers
Raw Materials Research & Development: Products development, etc
Federal Institute of Industrial Research, Oshodi: Industrial uses of yam, etc

Regulatory Institutions:
National Agricultural Seeds Council: Seed yam quality control and certification
National Agricultural Quarantine Services: Phytosanitary certification, etc
Standards Organization of Nigeria: The following yam standards are currently undergoing review: NIS 657:2009 Standards for Fresh Yam Tubers, NIS 000: 2007 MT Specification for Domestic Yam Pounding Machine, NIS 457:2004 Standards for Whole and Composite Yam Flour

Target Beneficiaries
- **Farmers** – seed and ware yams, irrigated farming, purchase and plant high-yielding certified seeds that will be harvested and sold as premium tubers
- **Local seed entrepreneurs** - Seeds Entrepreneurs Association of Nigeria (SEEDAN), select farmers, likely aggregated into farmer groups to produce certified seeds
- **Marketers** – yam market operators, market store owners, storage
- **Corporate and Individual Aggregators** – warehouse operators & conditioning facilities
- **Processors** - yam processing into various products
- **Transporters**
- **Exporters**
- **Overseas Off-takers**: Retailers, Wholesalers, shop owners, food distributors off-shore

YAM EXPORT

Strategic Partnerships between Stakeholders

Non-governmental Organizations:
National Association of Yam Farmers, Processors & Marketers, DFID-PERL, Synergos, Bureau for Public Service Reforms (BPSR), Women based NGOs in Yams (such as Tiv Women Progressive Union made up of 48 Women Yam Associations), etc Farmer aggregation, coordination and capacity building,

Commercial Lenders, Financial Institutions, Funding Partners, Financial Consultants:
Banks, NIRSAL, etc: Enabling value chain actors with credit – seed companies, local seed entrepreneurs, farmers, aggregators, storage, transport, processing, export, agro dealers, etc

Inputs Dealers & Suppliers: Supply of appropriate fertilizers for yam, etc

Professionals: Nigerian Institution of Agricultural Engineers, Nigerian Society of Engineers, Nigerian Institute for Food Science & Technology, Local Fabricators & Manufacturers, Engineering and Financial Consultants & Marketing Experts

Logistics: Transportation & Sea/Air Freight Experts, etc

FGN/Governmental Ministries, Departments and Agencies: Rationalization of bureaucracy and simplification of processes

Target Beneficiaries

- **Farmers** – seed and ware yams, irrigated farming, purchase and plant high-yielding certified seeds that will be harvested and sold as premium tubers
- **Local seed entrepreneurs** - Seeds Entrepreneurs Association of Nigeria (SEEDAN), select farmers, likely aggregated into farmer groups to produce certified seeds
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YAM EXPORT

Partnership between FMITI & NSE/NIAE

Engr. Otis Anyaeji, *FNSE,FAEng,* President, The Nigerian Society of Engineers presented a Memorandum on Partnership with FMITI on **Mechanizing the Yam Value Chain** to the 9th Meeting of The National Council on Industry, Trade and Investment, from 7th - 10th November, 2017 at Giginya Hotel, Sokoto State

OBSERVATIONS:

1. There is need for yam conditioning Centers.
2. There is need for yam pack houses.
3. There is need for plants for production of cartons for yam packaging.
4. We have low level of yam processing Plants in the country.
5. There is need to train indigenous manufacturers of yam processing unit operations, like yam peeling machines, yam chipping machines, yam blanching machines, yam drying machines, yam grinding machines, yam flour packaging machines.
6. There is need for yam planters, yam harvesters, yam heap/ridge making machines.
7. There is need for development of facilities for Temporary Immersion Bioreactor Systems (TIBs) and Aeroponics.

PRAYERS:

1. We want to inform the Council that Nigerian Engineers have the capacity to design, and develop systems to handle all engineering activities along the yam value chain.
2. The Council should direct the setting up of a Technical Committee on Yam value chain mechanization, made up of Nigerian Engineers and other relevant technicians needed in industrializing the yam value-chain.
3. The Council should make budgetary provision/ funding support for the development of yam value chain engineering related activities.

Council accepted to set up a Technical Committee and make budgetary provision for its operations.

YAM EXPORT

Partnership between NRCRI & NAY-FPM

Both Parties, being partners of DFID Partnership to Engage, Reform and Learn-Engaged Citizens (PERL-ECP), propose this collaboration based on a spirit of reciprocity and mutual benefits with the objective of fostering partnership for provision of clean planting materials and related value chain services to Nigerian yam farmers and entrepreneurs.

National Root Crops Research Institute (NRCRI), Umudike makes the following commitments to the National Association of Yam Farmers, Processors and Marketers:

- Support for characterization & documentation/development of handbook for the over 60 yam varieties in Nigeria
- Identification & promotion of yam value chain mechanization equipment and capacity building for indigenous fabricators
- Mapping of yam production, processing, marketing and stakeholders across the country and development of comprehensive databank
- Enhancing the yam value chain for export through quality assurance and control through establishment of Quality Assurance & Control Laboratory
- Support for research on important traits for breeding such as tuber yield and adaptation to target regions; tuber and cooking quality (shape, appearance, poundability, oxidation, etc); resistance/tolerance to diseases and pests (virus, anthracnose, nematodes etc); abiotic stress tolerance (water, soil fertility etc); reproductive traits (flowering, dormancy etc), etc
- Quarantine study on pests and diseases of yams nationwide
- Support on yam specific fertilizers and yam irrigation studies and facilities
- Provision of foundation seeds to Cooperatives certified by National Agricultural Seed Council (NASC) to produce certified seeds with special attention on women and youth Cooperatives
- Knowledge sharing on post harvest management (temperature, sprouting, etc) and marketing with respect to yam storage and aggregation
- Assistance in cleaning of formal and informal seeds especially farmers' preferred varieties such as Faketsa, Pepa, Ogoja, Nwopoko, Dan Onicha, etc.
- All NRCRI sub-stations will be made available to support members of the National Association of Yam Farmers, Processors and Marketers for storage and other mutually acceptable uses
- Involve members of the National Association of Yam Farmers, Processors and Marketers across Nigeria in mutually agreed activities of NRCRI, Umudike
- Assist in developing protocols and standards for production of breeder, foundation and certified yam seeds

YAM EXPORT

Partnership between NRCRI & NAY-FPM

National Root Crops Research Institute (NRCRI), Umudike makes the following commitments to the National Association of Yam Farmers, Processors and Marketers:

•Collaborate on promotion and mass production of twenty one (21) improved varieties and five (5) registered landraces released by NRCRI, Umudike
•Collaborate in determining preferred yam varieties for the export market and print selling point commercials based on important traits and characteristics
•NRCRI to organize periodic training of NAY-FPM members to focus on, but not limited, to the following objectives:
✓Good Agricultural Practices in yam production as well as good handling and storage practices, all meant to ensure that good quality yam tubers are produced and made available for sale
✓Adoption of high ratio propagation technologies such as vine cuttings, aeroponics and bioreactor to address the constraints of quality and multiplication in seed yam production.
✓Development of efficient seed production, distribution and quality assurance systems
✓Specifications for yam tubers of export quality
✓Yam packaging standards for export
✓Improving the links between yam farmers and marketers in order to improve the quality and increase the quantity of yams provided by farmers.
✓Providing more secure advanced orders and increased market information to farmers
✓Development of a higher value domestic market to expand demand for quality produce
✓Improvement of seed yam quality to reduce fungal infections and using seed yams free from viral infection
✓Providing optimal curing, storage and transport conditions for a range of yam cultivars/species over a range of maturity as well as improving handling strategies
✓Feeding into breeding programmes for the production of yam cultivars with improved marketing potential
✓Strategies for improvement of quality during shipping for export by introducing temperature control, providing more accurate technical information to shippers, and clarifying the lines of responsibility
✓Improving methods of assessing quality both by sampling/destructive assessment and non-destructive quality assessment methods.
✓Production of extensive teaching/extension materials in the form of leaflets, photographic materials and videos with potential for use to train the stakeholders involved in the yam handling chain
✓Improving the efficiency and profitability of yam export marketing
✓Training of yam processors on all aspects of yam processing and marketing
•Support for any other request from the National Association of Yam Farmers, Processors and Marketers deemed appropriate by the Institute.

YAM EXPORT

Deployment

Despite the successful yam export trial, the Technical Committee has identified several areas of improvement – one of which is deployment of good quality seed yams.

Key demand drivers for seed yam are:

- Export Opportunity – There is need for quality yam that can meet stringent export standards (namely: uniformity, international phytosanitary standards, traceability, etc)

- Disease Pressure – Existing yam seed stock is under significant disease pressure due to the continued re-planting of the existing unimproved germplasm. This paradigm has contributed to the low country yields (8.3 MT/ha in Nigeria vs. 16.6 MT/ha in Ghana) and a meaningful supply/demand imbalance that long preceded the export market opening.

YAM EXPORT

Seed Yam Deployment

NATIONAL ROOT CROPS RESEARCH INSTITUTE
UMUDIKE
FEDERAL MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT
P.M.B. 7006, Umuahia, Abia, State. Nigeria.
Tel: 08166047266, 08187620664 E-mail: nrcriumudike@yahoo.com,nrcriumudike@nrcri.org. Website: http://www.nrcri.org

Variety Name	Original Name	National Code	Origin/Source	Developing Institute	Breeder/ Collaborating Scientists	Outstanding Characteristics/Potential Yields	Agro-Ecological Zones	Year of Release	Year of Registry
TDR 89/02677	TDR 89/02677	NGDR-01-1	NRCRI Umudike IITA, Ibadan	NRCRI Umudike IITA, Ibadan	Dr. S.K Hahn, Dr. R. Asiedu & Dr. G.C. Orkwor	Stable yield, very good cooking and pounding qualities, cream tuber parenchyma, 25% tuber dry matter content.	Forest and Southern Guinea Savanna	2001	2001
TDR 89/02565	TDR 89/02565	NGDR-01-2	NRCRI Umudike IITA, Ibadan	NRCRI Umudike IITA, Ibadan	Dr. S.K Hahn, Dr. R. Asiedu & Dr. G.C. Orkwor	Stable yield, very good cooking and pounding qualities, cream non oxidizing parenchyma, 35% tuber dry matter.	Forest and Southern Guinea Savanna	2001	2001
TDR 89/02461	TDR 89/02461	NGDR-01-3	NRCRI Umudike IITA, Ibadan	NRCRI Umudike IITA, Ibadan	Dr. S.K Hahn, Dr. R. Asiedu & Dr. G.C. Orkwor	Stable yield, very good as cooking and pounding qualities, cream parenchyma, 26.7% tuber dry matter.	Forest and Southern Guinea Savanna	2001	2001
TDR 89/02665	TDR 89/02665	NGDR-03-4	IITA, Ibadan NRCRI, Umudike	IITA, Ibadan NRCRI, Umudike	Dr. S.K Hahn, Dr. R. Asiedu & Dr. G.C. Orkwor	Stable yield, very good cooking and pounding qualities, cream non-oxidizing parenchyma, 35.3% tuber dry matter.	Forest and Southern Guinea Savanna	2003	2003

Seed Yam Deployment

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Tel: 08166047266, 08187620664 E-mail: nrcriumudike@yahoo.com,nrcriumudike@nrcri.org. Website: http://www.nrcri.org

Variety Name	Original Name	National Code	Origin/Source	Developing Institute	Breeder/ Collaborating Scientists	Outstanding Characteristics/Potential Yields	Agro-Ecological Zones	Year of Release	Year of Registry
TDR 89/01213	TDR 89/01213	NGDR-03-5	IITA, Ibadan NRCRI, Umudike	IITA, Ibadan NRCRI, Umudike	Dr. S.K Hahn, Dr. R. Asiedu & Dr. G.C. Orkwor	Stable yield, very good cooking and pounding qualities, white non oxidizing parenchyma, tuber dry matter = 29.8%	Forest and Southern Guinea Savanna	2003	2003
TDR 89/01438	TDR 89/01438	NGDR-03-6	IITA, Ibadan NRCRI, Umudike	IITA, Ibadan NRCRI, Umudike	Dr. S.K Hahn, Dr. R. Asiedu & Dr. G.C. Orkwor	Stable yield, very good cooking and pounding qualities, white non oxidizing parenchyma, tuber dry matter = 29.3%	Forest and Southern Guinea Savanna	2003	2003
TDR 95/01924	TDR 95/01924	NGDR-03-7	IITA, Ibadan NRCRI, Umudike	IITA, Ibadan NRCRI, Umudike	Dr. S.K Hahn, Dr. R. Asiedu & Dr. G.C. Orkwor	Stable yield, very good cooking and pounding qualities, white non oxidizing parenchyma tuber dry matter = 32.8%	Forest and Southern Guinea Savanna	2003	2003
DRN 200/4/2	DRN 200/4/2	NGDR-08-8	NRCRI, Umudike	NRCRI, Umudike	E.C. Nwachukwu	High yielding, pest and diseases tolerant, very good for fufu, frying and boiling (**35t/ha**)	Yam Zones of Nigeria	2008	2008
TDa 98/01176	TDa 98/01176	NGDA-08-9	IITA, Ibadan	NRCRI, Umudike	R.Asiedu & C.N. Egesi	High yielding, pests and diseases tolerant, good for pounded yam, frying and boiling, suitable for both rainy and dry season yam production (**26-30t/ha**)	Yam Zones of Nigeria	2008	2008

YAM EXPORT

Seed Yam Deployment

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Variety Name	Original Name	National Code	Origin/Source	Developing Institute	Breeder/ Collaborating Scientists	Outstanding Characteristics/Potential Yields	Agro-Ecological Zones	Year of Release	Year of Registry
TDa 98/01168	TDa 98/01168	NGDA-08-10	IITA, Ibadan	NRCRI, Umudike	R.Asiedu & C.N. Egesi	High yielding, pests and diseases tolerant, good for pounded yam, frying and boiling. (**24-28t/ha**)	Yam Zones of Nigeria	2008	2008
TDa 98/01166	TDa 98/01166	NGDA-08-11	IITA, Ibadan	NRCRI Umudike	R. Asiedu & C.N. Egesi	High yielding, pests and diseases tolerant, good for pounded yam, frying and boiling, suitable both for rainy and dry seasons yam production. (**26-30t/ha**)	Yam Zones of Nigeria	2008	2008
TDr 95/19158	TDr 95/19158	NGDR-09-12	IITA, Ibadan	NRCRI Umudike	R. Asiedu	High yielding, pests and diseases tolerant, very good for yam, fufu, frying and boiling (**29.4t/ha**)	Yam Zones of Nigeria	2009	2009
TDr 89/02602	TDr 89/02602	NGDR-09-13	IITA, Ibadan	NRCRI Umudike	R. Asiedu, J.G. Ikeorgu & E.C. Nwachukwu	High yielding, pests and diseases tolerant, very good for yam, fufu, frying and boiling (**31.5t/ha**)	Yam Zones of Nigeria	2009	2009
TDr 89/02660	TDr 89/02660	NGDR-09-14	IITA, Ibadan	NRCRI Umudike	R. Asiedu, J.G. Ikeorgu & E.C. Nwachukwu	High yielding, pests and diseases tolerant, very good for yam, fufu, frying and boiling (**31t/ha**)	Yam Zones of Nigeria	2009	2009

Seed Yam Deployment

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Variety Name	Original Name	National Code	Origin/Source	Developing Institute	Breeder/ Collaborating Scientists	Outstanding Characteristics/Potential Yields	Agro-Ecological Zones	Year of Release	Year of Registry
TDa 00/00194	TDa 00/00194	NGDA-09-15	IITA, Ibadan	NRCRI Umudike	R. Asiedu, C.N. Egesi & J.G. Ikeorgu	High yielding, pests and diseases tolerant, good for pounded yam, frying and boiling (**37.5t/ha**)	Yam Zones of Nigeria	2009	2009
TDa 00/00104	TDa 00/00104	NGDA-09-16	IITA, Ibadan	NRCRI Umudike	R. Asiedu, C.N. Egesi & J.G. Ikeorgu	High yielding, pests and diseases tolerant, good for pounded yam, frying and boiling (**30t/ha**)	Yam Zones of Nigeria	2009	2009
UMUDa-4	TDa 00/00364	NGDA-10-17	IITA, Ibadan	NRCRI Umudike	R. Asiedu, C.N. Egesi & J.G. Ikeorgu	High yielding, good for Amala, pounded yam, frying and boiling (**33.3t/ha**)	Yam Zones of Nigeria	2010	2010
UMUDr-17	TDr 95/19177	NGDR-10-18	IITA, Ibadan	NRCRI Umudike	R. Asiedu, E.C. Nwachukwu & J.G. Ikeorgu	High yielding under dry season yam cropping system. (**30t/ha**)	Yam Zones of Nigeria	2010	2010
UMUDr-18	TDr 89/02475	NGDR-10-19	NRCRI Umudike	NRCRI Umudike	R. Asiedu, E.C. Nwachukwu & J.G. Ikeorgu	High yielding, pests and diseases tolerant, very good for yam fufu, frying and boiling (**31t/ha**)	Yam Zones of Nigeria	2010	2010

Seed Yam Deployment

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Variety Name	Original Name	National Code	Origin/Source	Developing Institute	Breeder/ Collaborating Scientists	Outstanding Characteristics/Potential Yields	Agro-Ecological Zones	Year of Release	Year of Registry
UMUDr-20	TDr 98/00933	NGDR-16-20	IITA, Ibadan	IITA, Ibadan NRCRI, Umudike	Lopaz, A., Maroya, N., Asiedu, R., Nwankwo, I.I.M., Eke-Okoro, O.N., Ikeorgu J.G and Ikoro, A.I.	High yielding (**39.8t/ha**), pests and diseases tolerant -Dry matter content = 30.2% -Crude protein = 5.2% -Iron = 2.16mg/100gFW -Zinc = 0.38mg/100gFW -Starch yield = 21.3% -Flour yield = 28.7%	Rainforest, Southern and Northern Guinea Savanna	2016	2016
UMUDr-21	99/Amo/064	NGDR-16-21	IITA, Ibadan	NRCRI Umudike	Nwachukwu, E.C., Nwankwo, I.I.M., Eke-Okoro, O.N., Ikeorgu, J.G and Ikoro, A.I.	High yielding (**43.9t/ha**), pests and diseases tolerant -Dry matter content = 29.8% -Crude protein = 4.13% -Iron = 2.1mg/100gFW -Zinc = 0.53mg/100gFW -Starch yield = 20.14% -Flour yield = 26.2%	Rainforest and Guinea Savanna	2016	2016

YAM EXPORT

Seed Yam Deployment

NATIONAL ROOT CROPS RESEARCH INSTITUTE
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Landraces	Potential yield	Adaptation	Pests and diseases
UmuDr/022 (Obiaoturugo)	**27.78t/ha**	Southern Guinea Savanna & Rainforest agroecology.	Tolerant
UmuDr/023 (Amola)	**21.6t/ha**	Southern Guinea Savanna & Rainforest agroecology.	Tolerant
UmuDr/024 (Hembamkwase)	**29.4t/ha**	Southern Guinea Savanna & Rainforest agroecology.	Yam virus disease tolerant
UmuDr/025 (Ekpe)	**23.21t/ha**	Southern Guinea Savanna & Rainforest agroecology.	Yam virus disease tolerant
UmuDr/026 (Aloshi)	**27.6t/ha**	Southern Guinea Savanna & Rainforest agroecology.	Yam virus disease tolerant

SOLUTION

National Seed Yam Deployment Approach to Increase the Value of Yam Production

4 SEED YAM DEPLOYMENT CENTERS LOCATED IN KEY YAM PRODUCING STATES, EACH MANAGED BY A VETTED AND QUALIFIED NIGERIAN SEED COMPANY

Da-Allgreen Seeds Ltd

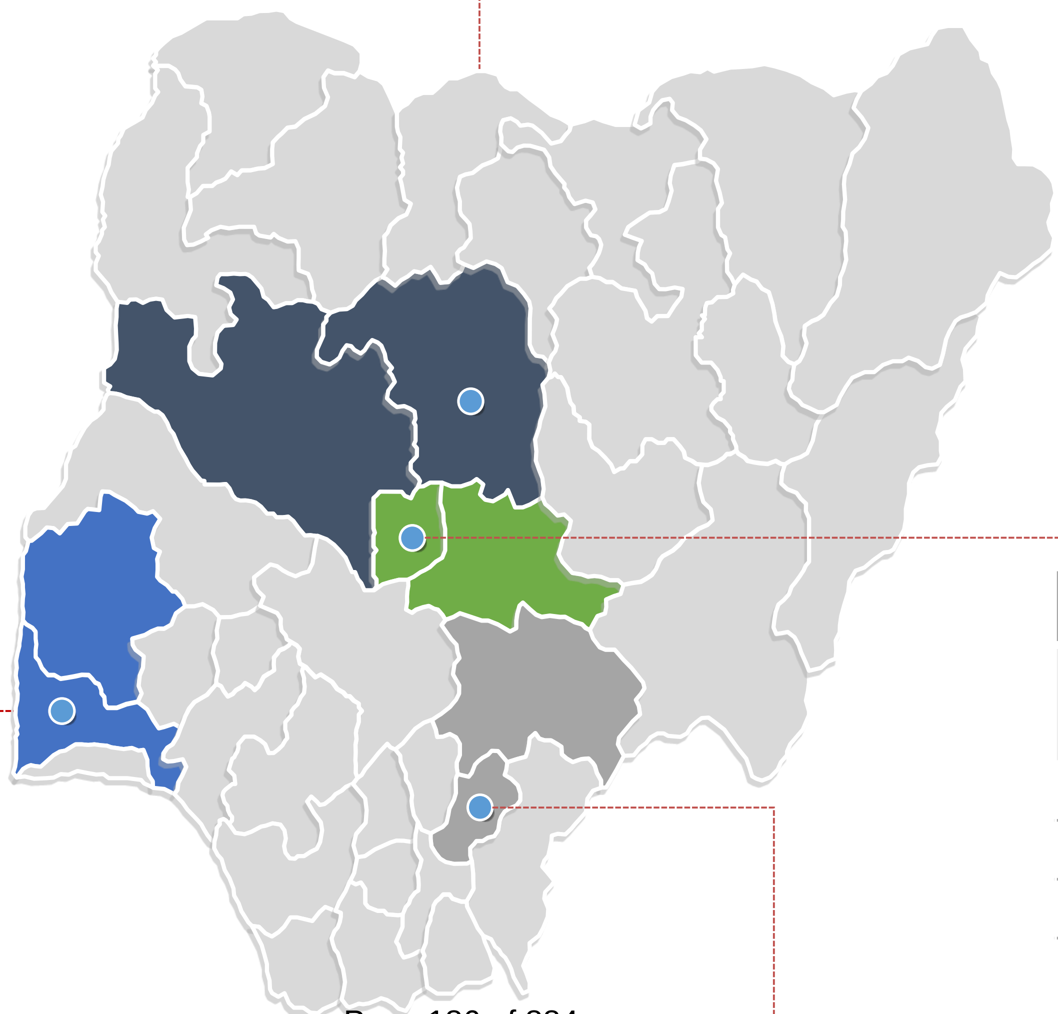
Kaduna & Niger
Deployment Center

Seed Yam Volume	59,616 Tonnes
Seed Yam in 250g Units	238 Million
Farmers Reached	150,000
Plantable Hectares	30,000

Biocrops Biotechnology Ltd.

FCT & Nassarawa
Deployment Center

Seed Yam Volume	59,616 Tonnes
Seed Yam in 250g Units	238 Million
Farmers Reached	150,000
Plantable Hectares	30,000



PS Nutraceuticals Intl. Ltd.

Ogun & Oyo
Deployment Center

Seed Yam Volume	59,616 Tonnes
Seed Yam in 250g Units	238 Million
Farmers Reached	150,000
Plantable Hectares	30,000

Nwabudo Agro Seeds Co. Ltd.

Benue & Enugu
Deployment Center

Seed Yam Volume	59,616 Tonnes
Seed Yam in 250g Units	238 Million
Farmers Reached	150,000
Plantable Hectares	30,000

TIMELINES

...ies are Targeting the 2019 ...on

Seed yam system for production of exportable ware yam complimented with appropriate agro organic and other inputs

	BREEDER SEED		FOUNDATION & CERTIFIED SEED			WARE YAM
	Motherplant Production Using Temporary Immersion Bioreactors		Yam Vines		Planting Yam Vines & Harvest Seed Yam (100-300g)	Ware Yam Production (>1000g)
	A	B	C	D	E	F
Stage	TIBs	Acclimatization (Hardening)	Aeroponics System	Nursery (One-Node Vines)	Foundation Seed Field Production	Yam Farmer Production
						
Who	Research Institutions & Select Private Sector Partners		Private Nigerian Seed Companies			Farmers
Cycle Time (Days)	56	14	180	14	180	270

YAM EXPORT

Terms of Offtake Agreement Agreed Upon & Executed between Seed Companies and NAY-FPM

Market Survey of the informal system (crude) seed yam in the market, used by our farmers

Period	Price of a basin of 100pcs	Average price per pieces	Average Equivalent price per kg (200- 300gms)
Time of Surplus	₦10,000 – ₦15,000	₦100 - ₦150/pcs	₦400 – ₦600/kg
Time of Scarcity	₦25,000 – ₦30,000	₦250 - ₦300/pcs	₦1,000 – ₦1,200/kg

Product: Certified Seed Yam
Weight Parameters: 200 to 300 grams
Price Per Kilogram: N400
Quantity: Up to 9,000,000 Seed Yam Units
Term: Anytime Before 29th March, 2019
Sellers: Biocrops Biotechnology Company Limited, Da-Allgreen Seeds Limited, Nwabudo Agro Seeds Limited, and PS Nutraceuticals International Limited
Buyer: National Association of Yam Farmers, Processors and Marketers

Total Potential Value of the Off-take Agreement is NI Billion

IITA 50 **Value of seed used in Nigeria per year**

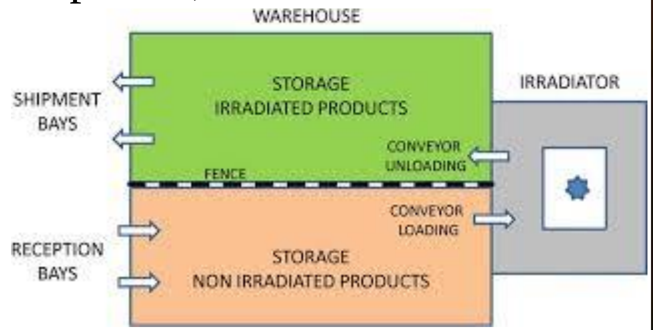
- **Current production area** = 5,416,400 ha
- At recommended rate of 10,000 plants/ha = **54,164,000,000 plants**
- **Cost/seed**: ₦80 per seed of 200 - 250 g (seed size ranges from 150 to 1000 g, and costs ₦50 - 150)
- Cost of seed for one hectare: 10,000 X 75 = **₦750,000**
- To plant 5,416,400 hectares will cost: 750,000 X 5416400 = **₦4,062,300,000,000 (₦ 4.01 trillion)**

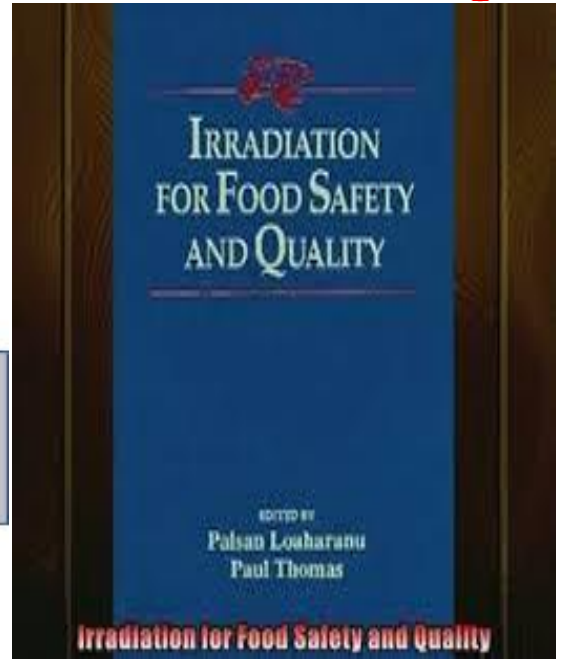
YAM EXPORT

Model Yam Pack House, Conditioning & Storage Facilities

Large warehouse fitted with:

- Temperature control using solar panels,
- Deep bin wooden pallets,
- Fork lifters,
- Irradiation facilities,
- Weighing scales,
- Cleaning facilities, etc
- Pallet Jack
- Office - computer, table, desk, internet access





Loading pallet bins of sweet potatoes into a new negative horizontal ventilation (NHV) facility

YAM EXPORT

Yam Processing (Flour, Chips, Pharmaceutical Grade Starch, etc)

Required Machines: **Yam peeling machines, Chipping machines, Blanching machines, Drying machines, Grinding machines, Packaging machines, etc**

- JAY JAY YAM FLOUR, Plot 357 Ugba Highway, Zaki-Biam, Benue State +2348063540292; jerryngene10@gmail.com
- BENUE YAM FLOUR, PE&I Foods Nigeria Ltd, Km 1, Yandev – K/Ala Road, Gboko, Benue State +2348181841376; +2348078215174; peifoodsnigeria@gmail.com
- 5IVE FOODS INT. VENTURE LTD, Km 19, Makurdi-Aliade Road, Gwer West, Benue State Nigeria +2348128747700; +2348176695797
- BENUE STATE GOVERNMENT YAM FLOUR INDUSTRY, K/Ala, Benue State
- Mr. Solomon Ocheche, Managing Director, SOLDUA POUNDO, OlaiOgwuche, Otukpa

Yam Products Development and Promotion

Peeling yam for cooking

Pounding boiled yam

'Pounded' yam flour

'Pounded' yam balls

There is need to develop more yam products beyond the traditional methods of consumption

YAM EXPORT

National Yam Export Pack House

Ikorodu Lighter Terminal in Lagos, Nigerian Ports Authority

- ☐ Develop a framework for establishment of Nigeria Yam Export Pack houses at Sea and Airports in which all documentations relating to yam exports are prepared.
- ☐ Facilitate the acquisition of warehouses at the receiving destinations.
- ☐ Rationalize bureaucracy of export with enforcement agencies located under one roof in the single designated Nigeria Yam Export Pack Houses: Nigeria Agricultural Quarantine Services (NAQS), Standard Organization of Nigeria (SON) and Nigeria Customs Services (NCS)


42 THE GUARDIAN, Monday, March 19, 2018

NIGERIAN PORTS AUTHORITY
26/28, MARINA LAGOS
www.nigerianports.gov.ng

PUBLIC NOTICE 4062

EXPRESSION OF INTEREST (EOI) FOR ENGAGEMENT OF A TRANSACTION ADVISER FOR THE CONCESSION OF IKORODU LIGHTER TERMINAL – INTERNATIONAL COMPETITIVE BIDDING

A. INTRODUCTION
Following the designation of Ikorodu Lighter Terminal as a dedicated terminal for agricultural produce export, the Nigerian Ports Authority hereby invites applications from reputable and competent Transaction Advisers (Consortia comprising Legal, Financial, Environmental, Technical, Estate Management and Port Specialist teams) for Concession of the aforementioned terminal.

the Company/Firm at the bottom of the page.
11. Company profile to include names, qualification and experience of key personnel (copies of relevant academic and professional qualifications of such personnel must be attached).
12. Evidence of successful completion of two (2) similar projects executed in the last five (5) years including letters of award, completion certificates, contract agreements, etc.

YAM EXPORT

Yam Production Infrastructure

Production (foundation/certified yam seeds and ware yams)

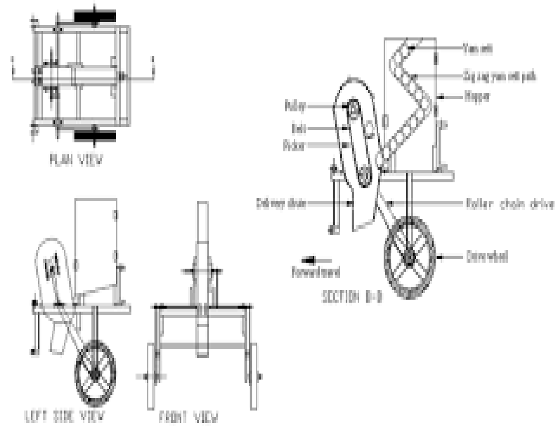
Tractor and accessories

Irrigation Facilities

Farms tools/implements

Seed yam planters

Ware yam harvesters



YAM EXPORT

Yam Harvesting machine by Engr. Prof. Isaac N. Itodo

Department of Agricultural & Environmental Engineering, University of Agriculture, Makurdi

Picture of the improved harvester in transport position, lifted by the tractor

Picture of the first designed yam harvesting machine

Picture of the improved harvester in trailed position for harvesting

YAM EXPORT

Yam heap making machine by NCAM

… Fabricates yam heap making machine
Published Date Oct 18, 2017 3:00 AM

Three months after the Minister of Agriculture and Rural Development, Chief Audu Ogbeh, mandated the National Centre for Agricultural Mechanisation, Ilorin to manufacture yam heap making machine, the centre yesterday showcased the first such equipment for yam farmers.

The Acting Director of the centre, Engr M. Y Kasali, told **Daily Trust** that although the report of the manufactured equipment has been submitted to the minister, he has not seen the machine yet, adding that he will be happy to see it exhibited few months after he gave them the mandate.

Already, yam farmers at the scene were excited seeing a machine that will make yam farming easier and large scale production possible.

Until now, many farmers considered yam heap making as the difficult aspect of yam cultivation and many aging farmers are unable to do large-scale production while the younger generation are not willing to undertake the difficult task.

Although the machine is new, the centre said its efficiency has been tested and found to be good for adoption by Nigerian farmers. The machines, according to the centre, are affordable and farmers' cooperatives can get them easily.

West African Journal of Applied Ecology, vol. **15**, 2009

Ridging, a Mechanized Alternative to Mounding for Yam and Cassava Production

S. A. Ennin[1]*, E. Otoo[1] and F. M. Tetteh[2]
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[2] *CSIR-Soil Research Institute, Academy Post Office, Kumasi, Ghana*
**Corresponding author; E-mail: stella@cropsresearch.org*

Abstract

A cassava seedbed preparation field study was established at Fumesua in the forest and Ejura in the forest-savanna transition agro-ecologies of Ghana in 2004/2005. The experimental design was split plot with three seed bed preparation methods as the main plots and three nitrogen rates as sub plots, with basal application of 45-90 kg ha^{-1} P_2O_5 - K_2O on the fertilized plots. A similar study was conducted on yam seedbed preparation in 2003/2004, with a 2^3 factorial design. Cassava and yams on ridges resulted in highest root and tuber yields, on both Lixisols in the coastal and forest-savanna transition and Acrisols in the forest agro-ecologies. However, yam tuber yield on mounds was not statistically different from yields on ridges. Number of roots per plant was identified as a major contributory factor to the yield increase of cassava on ridges. Seed bed preparation method was, however, not an important determinant of cassava root yield at high rates of fertilizer application of 90-45-90 kg ha^{-1} N-P_2O_5-K_2O. Planting on mounds resulted in slender, cylindrically shaped cassava roots and yam tubers, while ridging produced oblong shaped roots and tubers. Weeding and fertilizer application were easier on manual ridging than on manual mounds. The study points to ridging as a potential option to mounding for cassava and yam production, with the feasibility of mechanization of ridges to reduce drudgery associated with roots and tuber crop production in the West African sub-region.

YAM EXPORT

Yam Planting machine by Engr. Dr. John Okanagba Awulu

Department of Agricultural & Environmental Engineering, University of Agriculture, Makurdi

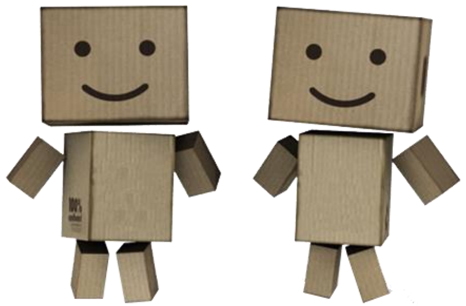
YAM EXPORT

Transforming the yam Farming Systems from Heaps to Ridges

✓Plants per ha: 4,000-5,000 on heaps; 10,000 on ridges for ware yams and 40,000 for seed yam
✓Allows for mechanization and development of yam planting & harvesting equipment, etc
✓There is no significant difference in yield in terms of weight/tuber
✓The preferred option under the Anchor Borrowers Programme

YAM EXPORT

Yam Packaging & Transportation Infrastructure



Packaging

Packaging materials (carton and clean, plan and unglazed, wrapping paper)

Inland transportation

Cooling vans/refrigerated trucks (24 tons) operated @ 14-18^{o}C for inland transportation of seed yams and ware yams

YAM EXPORT

Sea and Air Freight & Other Logistics

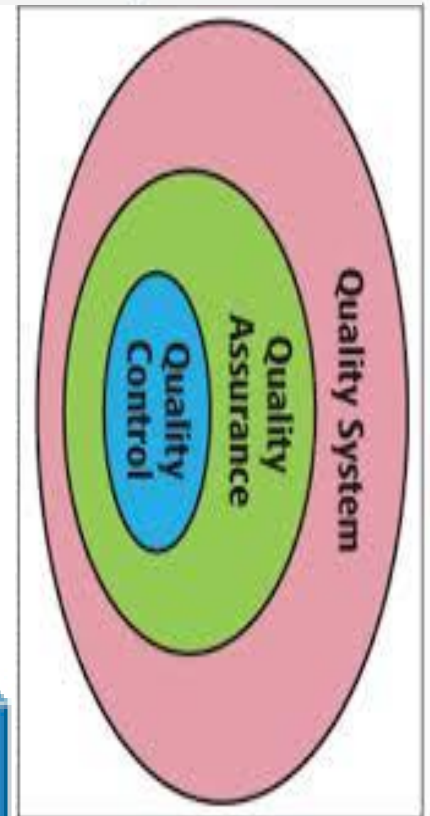
12 Actionable Steps for Successful Yam Export Entrepreneurship to the USA

1. Sourcing
2. Transportation
3. Warehousing in Nigeria
4. Export Packaging
5. Containerization
6. Shipping documentations and quarantine & other approval processes
7. USA sea port clearing documentations and fumigation process
8. USA transportation and warehouse delivery
9. USA refrigerated warehousing
10. USA online and offline marketing
11. USA customer delivery services and
12. Profit sharing among stakeholders

YAM EXPORT

Quality Assurance & Control

Quality Assurance & Control Laboratory
Establishment of Chief Audu Ogbe National Yam Value Chain Quality Assurance & Control Laboratory at the University of Agriculture, Makurdi (Purchase of equipment, chemicals and glassware)



YAM EXPORT REPORT

Yam Market Infrastructure

- Regional yam markets in Nigeria employing weighing scales of all types for local yam marketing (**Suppliers & Manufacturers**)
- Yams displayed in the sun is already cooked
- Conditioned Yam Stores in the markets

Below are some pictures of the yam market in Bouake, Cote d'Ivoire. All yam is sold by weight.

YAM EXPORT

Organized Training for National Association of Yam Farmers, Processors and Marketers

- Consultancy for capacity building, training, sensitization & advocacy targeted at stakeholders in the yam production, processing and marketing value chain such as;
  - Yam Farmers,
  - Yam Processors,
  - Yam Marketers,
  - Yam Transporters,
  - Yam Exporters,
  - Yam Aggregators,
  - Yam Off-takers &
  - Yam Affiliate Cooperatives.

- Production of yam investment guide
- Monthly or Quarterly yam magazine
- Robust website

YAM EXPORT

Organized Training for National Association of Yam Farmers, Processors and Marketers

Training to focus on;

- Improving the links between yam farmers and marketers in order to improve the quality and increase the quantity of yams provided by farmers. Purchase of tubers for export directly from farmers rather than through several middlemen would improve quality.
- Providing more secure advanced orders and increased market information to farmers.
- Development of a higher value domestic market to expand demand for quality produce
- Improvement of seed yam quality to reduce fungal infections and using seed yams free from viral infection.
- Providing optimal curing, storage and transport conditions for a range of yam cultivars/species over a range of maturity as well as improving handling strategies.

YAM EXPORT

Organized Training for National Association of Yam Farmers, Processors and Marketers

Training to focus on;

- ❖ Feeding into breeding programmes for the production of yam cultivars with improved marketing potential.
- ❖ Strategies for improvement of quality during shipping for export by introducing temperature control, providing more accurate technical information to shippers, and clarifying the lines of responsibility.
- ❖ Improving methods of assessing quality both by sampling/destructive assessment and non-destructive quality assessment methods including the use of electronic sensor arrays.
- ❖ Production of extensive teaching materials in the form of leaflets, photographic materials and videos with potential for use to train the stakeholders involved in the yam handling chain.
- ❖ Improving the efficiency and profitability of yam export marketing.

YAM EXPORT

Advocacy for the Repeal of Export Prohibition Act of February,1989

https://www.von.gov.ng/fg-repeal-export-prohibition-act-to-promote-yam-exportation-association-pleads/ April 21, 2018

FG, repeal export prohibition act – Yam farmers

- ☐ The Association of Yam Farmers, Processors and Marketers in Nigeria has appealed to the federal government and the National Assembly, to expedite action on the repeal of the Export Prohibition Act of 1989, to enhance yam export.
- ☐ The Acting President of the association, Professor Simon Irtwange, explained that the Act negated the diversification efforts and policies of the federal government.
- ☐ Irtwange, who is also the chairman of the Technical Committee on Nigeria Yam Export Programme, said the Act was discouraging yam exporters from conducting their business freely and coming out openly with yam export figures.

Advocacy for the Repeal of Export Prohibition Act of February,1989

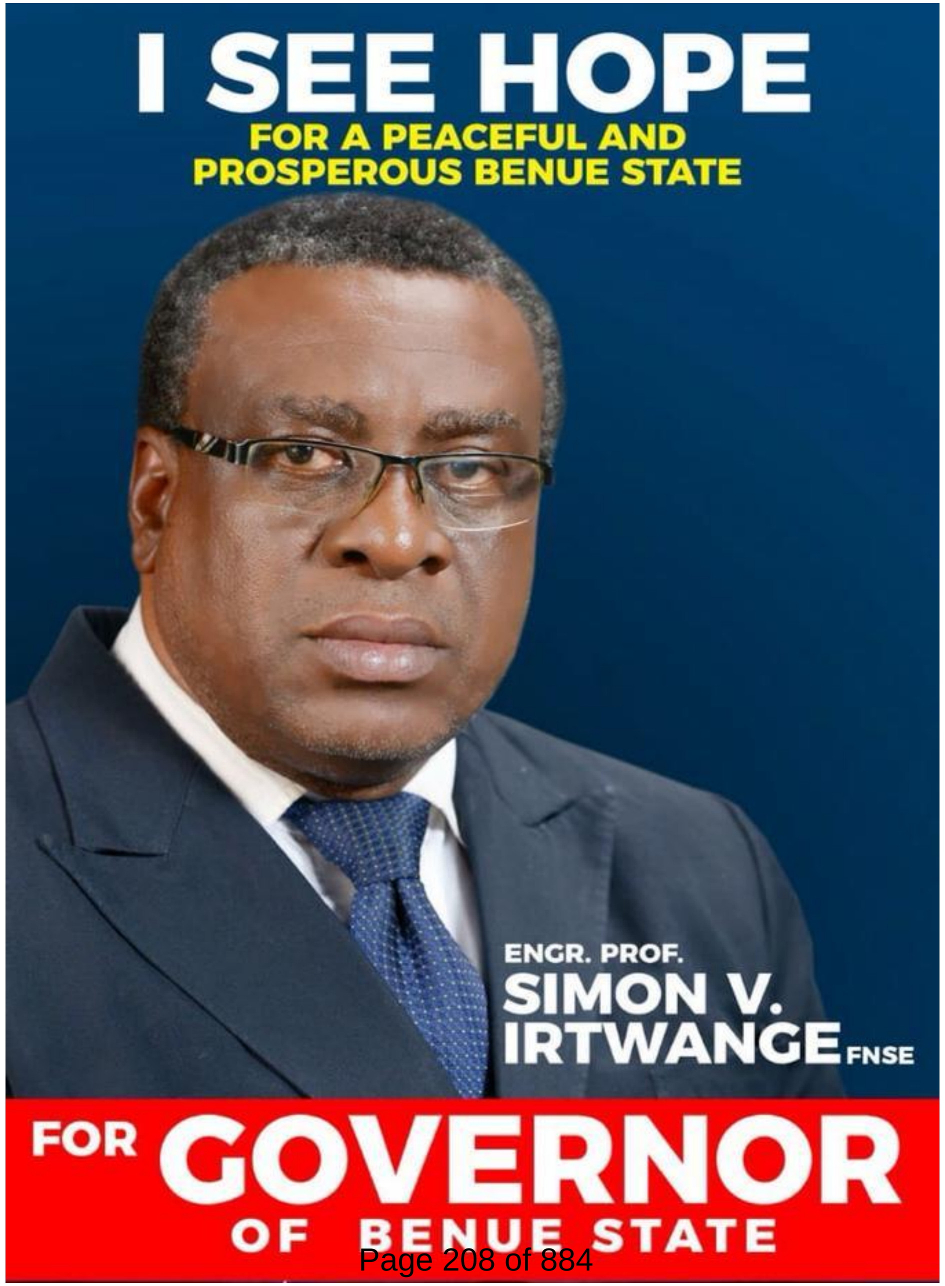
- According to him, the Act prohibits the export of five agricultural produce, which includes beans, cassava tuber, maize, rice, yam tuber and their derivatives.
- ***"The Export Prohibition Act is a big problem to us; it is difficult to come open with numbers when we know that there is a law on ground clearly prohibiting export of yams and its derivatives. The dilemma now is that you have a government policy encouraging export of agricultural produce but the Act is against it. There was an NGO that wanted to give us support and invest in the yam value chain, but as soon as they saw the law, they withdrew because these foreign organisations cannot support what Nigeria has prohibited,"*** he said.
- He explained that only export potential could drive production, adding that the Act was capable of discouraging production of yams across the country.

YAM EXPORT

Advocacy for the Repeal of Export Prohibition Act of February,1989

- ***"This yam export initiative serves as an incentive to farmers to drive production and once you open the commodity for export, you find that more people will go into production.***
  "Farmers produce for food security and also for export, but as it is now, there is no incentive for farmers to go and produce large quantity of yams," he added..
- The export prohibition act , which took effect from February 1989, stipulates that any person, who takes, causes to be taken, induces any other person to take, or attempts to take out of Nigeria, any of the goods specified, shall be guilty of an offence and liable on conviction to imprisonment for life.
- In addition to the penalty, the goods, as well as any vehicle, vessel, aircraft or other thing whatsoever used in connection with the exportation; and all the assets, movable or immovable, including motor vehicles, of any person convicted of the offence shall be forfeited to the federal government.

There is hope for yams in Nigeria



CREATING A SUSTAINABLE ECONOMY THROUGH AGRICULTURE

A KEY NOTE ADDRESS PRESENTED BY :
KOLAWOLE ADENIJI,
CHAIRMAN/PRESIDENT, NIJI GROUP

@

NIGERIA INSTITUTION OF AGRICULTURAL ENGINEERS (NIAE) – A DIVISION OF THE NIGERIA SOCIETY OF ENGINEERS (NSE); 19TH INTERNATIONAL CONFERENCE & 39TH ANNUAL GENERAL MEETING, LAGOS.
10TH – 14TH September, 2018.

What does this implies?

*Africa is a population of **1.216 billion people**. Africa is considered as one of the choice vegetation and most favourable agro ecological zones. Africa holds almost **60 percent** of world arable lands (600million hectares). (**Source**: Former President Olusegun Obasanjo CNN Special Report: How Africa could feed the world, Nov. 12th 2012). Every day in Africa over **239 million people** go to bed without food and 59 million children suffer acute undernourishment. (**Source**: UNICEF, WHO, World Bank Group Joint Child Malnutrition Estimates 2017 Key Findings). We (Nigeria) are a population of 196 million people (2016). We are approaching 200million. (**Source**: CIA World Fact Book 2017). We are **Africa's largest marketplace** and often humorously referred to as a consumer nation, largely dependent on oil (mono economy) with an inactive manufacturing sector.*

What does this implies?

*Nigeria has **92.4 million hectares** of arable lands with barely 40 percent cultivated. (**Source**: IFAD Retrieved 2018).*
Nigeria exports assets against importation of value – A well known syndrome associated with African countries. A huge differential still exist between local food consumption and local production.
*Smallholder farmers are responsible for over **90 percent** of food produced. Smallholder farmers are faced with yield challenges and low incomes.*
*Unemployment rate is growing faster than usual (now 18.8%). Youth unemployment (economically active individuals within the age of brackets of 18-35) shares 33.10% (which is **33million unemployed youths** out of nation's total of 111million). (**Source**: NBS, 2017 Quarterly Report).*

What does this implies?

1.8million Graduates *enter the labour market every year (Federal Ministry of Finance 2014 Report). This figure has increased rapidly in recent times.*

The global food market is ***$2.4 Trillion USD*** *(Source: Croplife International/FAO). World Bank valued the Africa food market $313 USD billion a year. This will be a trillion dollar in next 12 years according to AfDB President, Dr. Akinwunmi Adesina (**Source**: Saharareporters, New York, March 29th 2018). Nigeria's is* ***$10 billion*** *USD (The Nations Newspaper, 2017).*

Agriculture is the largest employer of labour in the world. It employs more than one third of the world population. In Nigeria 53% of the population is employed by Agriculture.

Breaking the silence:

We are tapping <u>FAR BELOW</u> our potentials.

Understanding economic sustainability & agriculture:

Entrepreneurs

*No useful social or economic change occurs without entrepreneurs. These are people that are ready and capable to take risk. The French economist, Jean-Baptiste considers entrepreneurship as the vehicle for creating economic development and balance. In his words, "entrepreneurs "**shift economic resources out of an area of lower and into an area of higher productivity and greater yield." Certainly**: this rightly fit into Australian minister of finance, Joseph Schumpeter summary that "**Entrepreneurs** are creative **disruptors**." They cause economic revolution. Entrepreneurs decide the pace of the economic progress of any nation.*

Understanding economic sustainability & agriculture:

Sustainability

*"Sustainability is a global challenge. It's a call to shared **social** and **economic** prosperity without undermining the goodwill of the **planet** that promises so much hope and life for the next generation. It means justice for those you may and will never meet." – L.K. Adeniji.*

*Nothing exists for a long term without been <u>**supported**</u> or <u>**managed**</u> in a certain way. Sustainability is a conceptual framework that captures activities intrinsic to meeting the needs of the present without compromising the ability of future generations to meet theirs.*

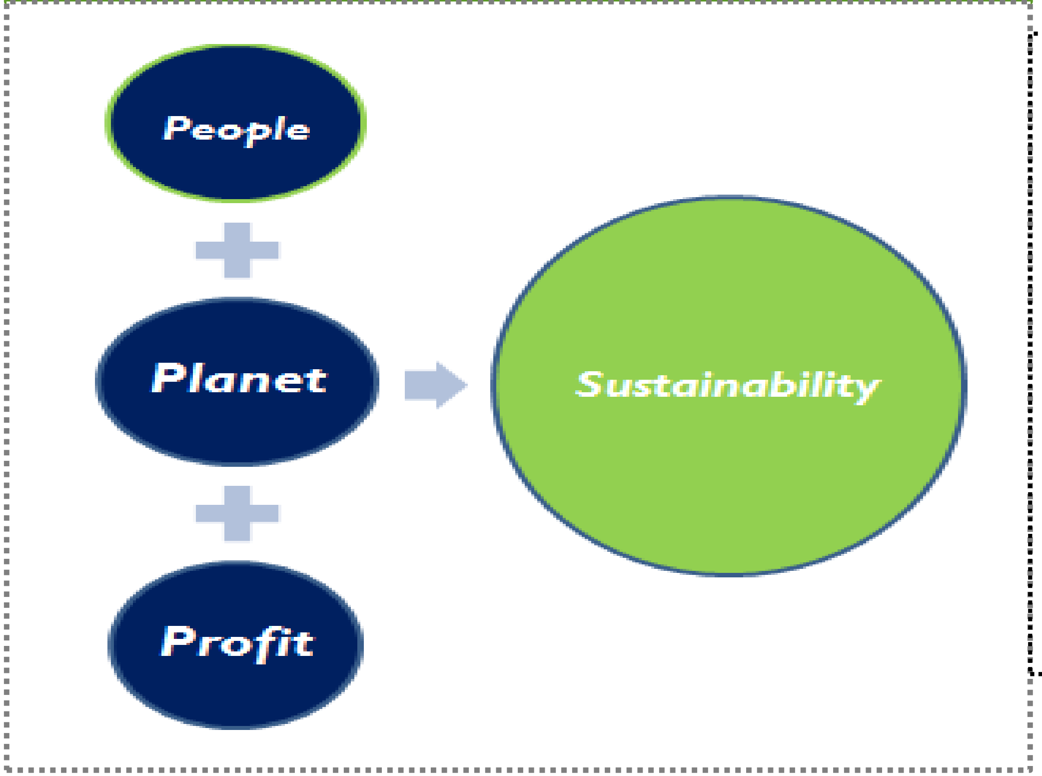
Understanding economic sustainability & agriculture:

Economics

Economy is the measure of a country's or region ***position*** *in terms of* ***production*** *and* ***consumption of goods and services and the supply of money.***

Understanding economic sustainability & agriculture:

Core Metrics of Sustainability



*The core metrics of sustainability are **people** (social), **planet** (environment) and **profit** (economics). The effective combination of these is what guarantees sustainable progress for all.*

Understanding economic sustainability & agriculture:

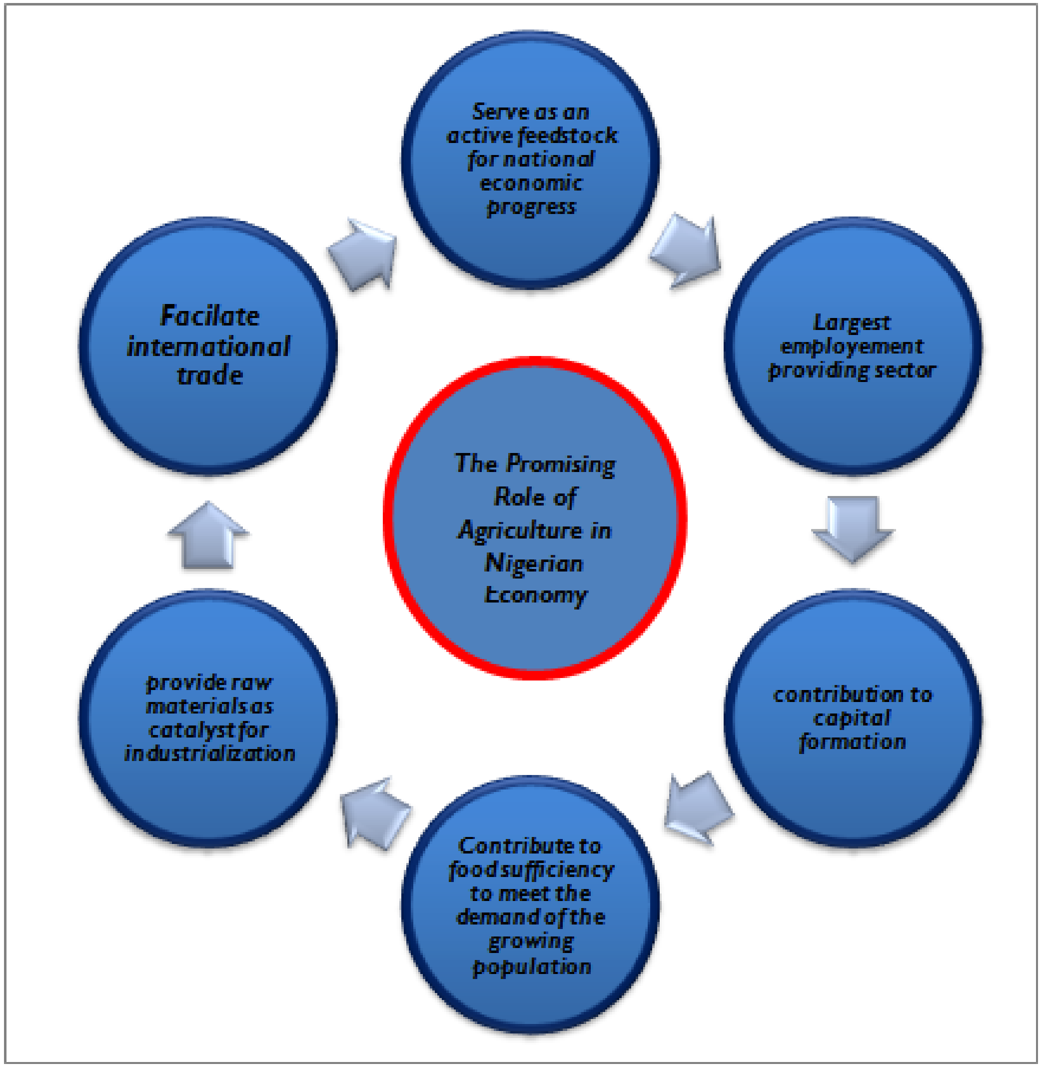
Agriculture

***"Agriculture is one of the strongest instruments for economic transformation.** If you know what weapon you have, you will cherish it. It is more than crop production as popular belief holds - it's the production of food and fiber from the world's land and waters. Without agriculture it is not possible to have a city, stock market, banks, university, church or army. Agriculture is the foundation of civilization and any stable economy." – Allan Savory (Zimbabwean ecologist and Co-founder, Savory Institute).*

Breaking the silence:

We (Nigeria) can be and may be on the path. But not yet a <u>diversified</u> <u>economy.</u>

The Economic Impact Flux of Agriculture



OBVIOUS UNLIMITED OPPORTUNITIES

DIRECT ACTIVITIES

Farming and processing of livestock's and crops.

ON-FARM OPERATIONS SUPPORT SERVICES

Land Clearing, Weed Management, Pest Control, Tractor Lease/hire

INPUT PROVIDERS:

Logistics & Supplies, marketing, digital technologies that connect farmers

Agriculture: What can't you do?

Contribute to food sufficiency to meet the growing demands of the population.

No nation ever achieves social or economic stability without first locally satisfying the food consumption of its growing population.

Provide raw materials as catalyst for industrialization.

China imports crude and exports value. Agriculture powers industrialization for an economically responsive nation. Where is Michelin? What else are we not importing in this nation?

Agriculture: What can't you do?

Facilitate international trade.

A nation's purchasing power parity is never an asset until there is a local feed to take advantage of the market base. Until our agricultural production rise beyond household and our manufacturing come to mainstream economy, Naira will never have value.

Largest employment provide sector.

Agriculture is the world largest employer of labour. More than any other sector, Agriculture will drop unemployment to the barest minimum in the nation. Cassava is a good example how it massively recruit individuals across the value chain.

Pathway to sustainability: bringing it all together and making it work.

Industrialized farming

Tractor operations going on at Niji Cassava Farms in Ilero, Oyo State. Niji Farms covers over 4000acres already cultivated, fully mechanized.

Baskets are for households and factories are for communities. The hoe can only do much but plots. Only industrialized farm can deliver impact in large scale. Volume is critical. If we must exploit our proven reserves of arable lands through commercialized mechanized farming is paramount.

Pathway to sustainability: bringing it all together and making it work.

Stimulating of local market through value addition

When smallholder farmers see the market to which they cultivate, they will be naturally encouraged. A good off-take system must be developed that appreciates the contributions of the smallholder farmers in the value chain. Continuous product innovation, research and development and value addition engaging locally adaptable processing technology will also stimulate local market.

Niji-Lukas Modular Fully Automated High Quality Starch Processing Plant.

Pathway to sustainability: bringing it all together and making it work.

Creating a city in an agrarian environment

Niji Agricity Model, Ipapo, Oyo State.

All leading global economies have their economic strongholds. We have never taken agriculture seriously as a nation. We must redesign our farm communities to foster productivity. Production targets must set and agro ecological advantages across zones must be explored. (Agricity Model).

Pathway to sustainability: bringing it all together and making it work.

Active Youth Participation

NISA – Fellows seeking real practice, Ilero, Oyo state.

No economy grows without the active participation of its youth population. More than the strength and vitality, they bring the required intellectual expertise. They bring innovations and zeal into the sector. We must effectively develop the agricultural value beyond cultivation to inputs, farm operations and supports, logistics and supply, marketing and agro tech to effectively accommodate the youths. The reason behind the phenomenal growth of the tech industry is obvious – youths.

Pathway to sustainability: bringing it all together and making it work.

Public private partnership

USAID FTF-P4I/NIJI Foods Partnership Meeting
January 31, 2017.

Government principal function is to coordinates economic activities. Let the private sector drive the agenda and criteria must be holistically and ethically set to rewards excellence and punish impunity.

My final words

The prediction of the world is correct. We can lead the conversation for Africa's leadership for the 21st century economy. We have it all – People, choice vegetation and potential sound economic stimulators.

But don't forget: **Until we develop capacity to feed, clothe and shelter herself is not wholly free. For now: We are harvesting less what is available for us.**

Africa biggest cassava farmer and 27 years standing Agribusiness development expert.

Kolawole Adeniji, MD/CEO, NIJI GROUP

THANK YOU

[WWW.NIJIGROUP.COM](http://www.nijigroup.com)

[WWW.NISA.NG](http://www.nisa.ng)

AGROPRENUSHIP FOR SUSTAINABILITY IN DIVERSIFIED ECONOMY- CASE FOR REVERSE ENGINEERING

BY

IDIAT ADEREMI AMUSU FNSE

At the 19th International Conference and 39th Annual General meeting of the Institution of Agricultural Engineers (NIAE)

holding between 10th – 14th September 2018 at the Akinrele Auditorium of the Federal Institute of Industrial Research , Oshodi,Lagos

WORLD FOOD PROBLEMS

- Population growth mainly in less developing countries
- I billion people are malnourished even as the world produce twice the present population
- Every year 40 million people die of undernourishment and malnutrition
- Africa imports $35 billion worth of food annually despite holding 60% of the world's arable land


for EVERY
1 HUNGRY
PERSON in
THE WORLD,
1.4 TONS
of FOOD is
WASTED
EACH YEAR

Food loss/waste

- The value of food lost in the industrialized countries is equivalent to the total net of food produced in South Sahara Africa (SSA).
- This means that what is lost or thrown away is enough to feed the whole of South Sahara Africa (SSA)

Nigeria situation

- Second largest economy in Africa

- 4.8 million Nigerians may face critical food insecurity situations in 16 states and the Federal Capital Territory (FCT) in 2018.
- Nigeria: Now World's Largest Producer of Cassava. 45 million metric tonnes
- Largest producer of yam

Food insecurity

Today, we

- import food to sustain the nation
- export our sweat abroad to enrich the farmers in Europe and other countries
- our farmers go to bed without food,

and

our population thrown in to poverty.

WHO IS THE NIGERIAN FARMER

- Has 7-10acres of farm land
- Subsistence farming practiced
- Still uses hoe and cutlass
- Dependent on middle men to sell produce
- Majorly women

The NIGERIA FARMER 1960 to DATE

The NIGERIA FARMER
1960 to DATE

CHALLENGES OF THE FARMER

- Shortage of water
- Declining soil fertility

  -use of inorganic fertilisers
- Effect of climatic change

- Decrease of fertile agriculture land

  -Agriculture land converted to other business such as property or factory

CHALLENGES OF THE FARMER

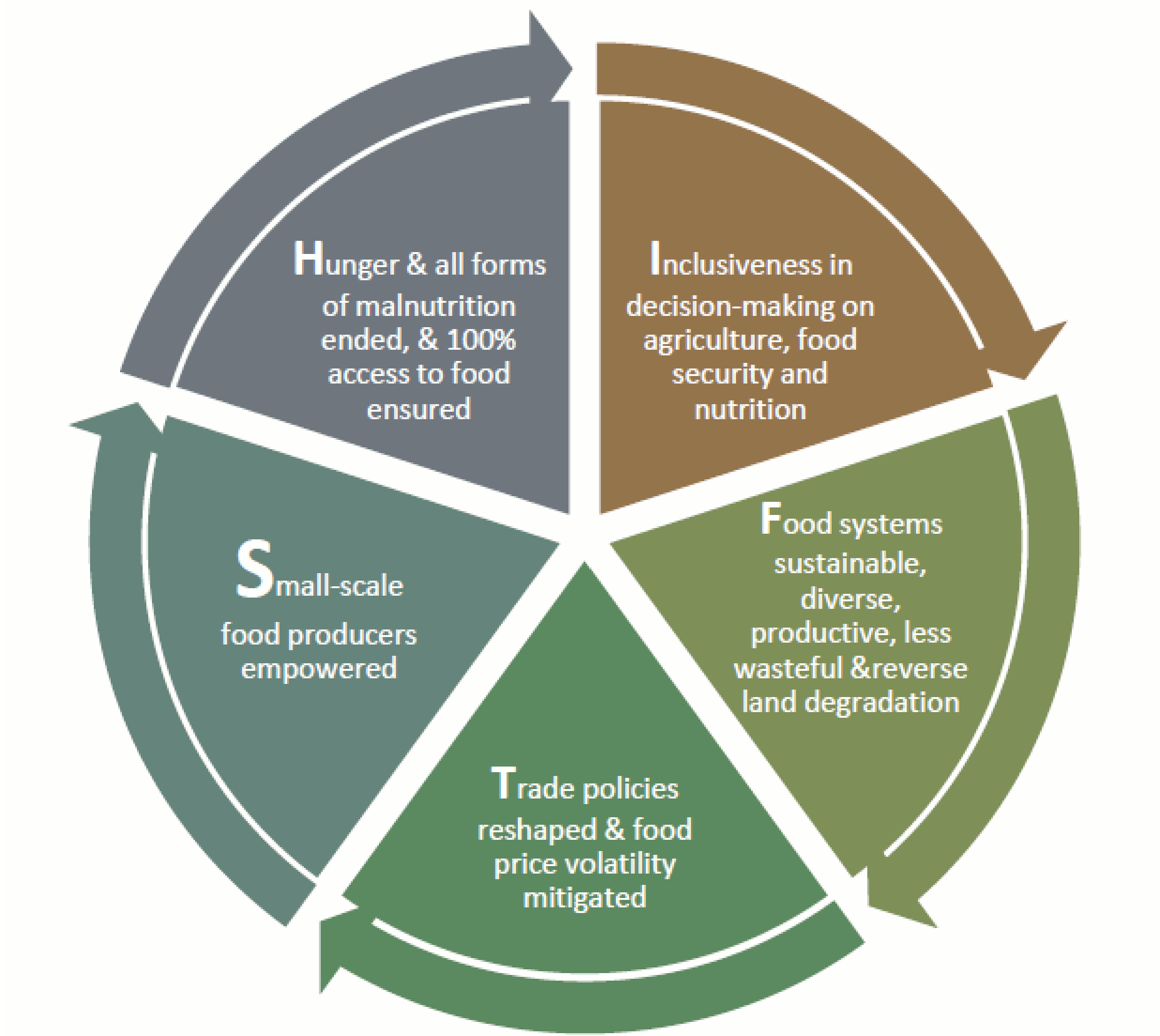
- Lack of awareness of the farmer of the power of agriculture

  -to create jobs towards diversification of the economy

  - to be Self employed

- Lack of interest of the youth makes the nation to be dependent of food import

SHIFT IN AGRICULTURE



Multifunctional agriculture...a must

AGROPRENUER

Agroprenuer

- An entrepreneur whose main business is agriculture or agriculture related
- Agriculture + Entrepreneur =Agroprenuer

AGROPRENUERSHIP

Has the concept of

- Generally ,sustainable, community-oriented, directly- marketed agriculture.

- Sustainable agriculture

a holistic, system oriented approach to farming that focuses on the interrelationships of social, economic and environmental processes

The agroprenuer
- Entrepreneurship in Agriculture

- amplify growth
- Create employment opportunities for the rural youth
- Control migration from rural to urban
- Sustain industrial development in rural areas
- Increase creation of wealth
- Cut down pressure on urban cities
- Increase quality of life

The agroprenuer

- To Sustain industrial development in rural areas there must be increased production of raw materials .
- Increased production demand appropriate equipment and implements

appropriate equipment and implements

Farm machinery, mechanical devices, including **tractors** and implements, used to farm to **save** labour

THE QUESTION?

- what did the Asian tigers do

to move their countries from low industrialized countries to highly industrialized nations?

- The answer

copy technology/imitation technology.

REVERSE ENGINEERING

- In addition to the following 4 factors
- LABOUR
- LAND
- CAPITAL
- ENTERPRENUERSHIP

reverse engineering

- **The era of relying on the application of reverse engineering for economic development based on the experience from South East Asia is here**

reverse engineering

- **The era of relying on the application of reverse engineering for economic development based on the experience from South East Asia is here**

Lesson

we have to learn from the Asian tigers that what led to their rapid industrialsation is

- **to produce for the use of the industry .**

Reverse engineering (RE)

- Reverse engineering (RE)

is a process of measuring, analyzing, and testing to reconstruct the mirror image of an object.

Reverse engineering (RE)

- The Society of Manufacturing Engineers (SME) defined reverse engineering as

"**starting with a finished product or process and working backward in logical fashion to discover the underlying new technology**" (Francis, 1988)

Re-engineering

- Re-engineering is

the adjustment, alteration, or partial replacement of a product in order to change its function, adapting it to meet a new need

APPLICATION OF REVERSE ENGINEERING

RE technique has been applied in many key areas of the industry in order to achieve the following:

- **Design of new components;**
- **Reproduction of an existing component;**
- **Recovery of a damaged or broken component; Development of model precision;**
- **Observation of a numerical data.**
- **when a component or its spare parts are no longer available,**
- **the component is failing or not functioning properly and the original manufacturer cannot provide the necessary engineering support to correct the problems.**

Reverse engineering (RE) in Nigeria

- FURNITURE MAKERS
- METAL FABRICATORS - Hospital equipment,
- SHOE MAKERS
- TRICYCLE PRODUCERS-
- auto parts- Nnewi the Japan of Africa
- MILITARY- ARMORED CARS-igirigi

Made in Nigeria armored vehicle by the military code named IGIRIGI (2013)

Is it RIGHT?

- **Some 40yrs ago, product and services from China were often call imitations, knock-offs, counterfeits, copies and fake. Same was also said of the Koreans, Taiwanese and Japanese products. TODAY THEY ARE THE PREFERED CHOICE**
- **At home, here we call any of such copies, made by our own local manufacturers "fake" "counterfeit" "Aba made**

AGRICULTURE- REVERSE ENGINEERING

Some are

- Processing equipment i.e. filter press . Attrition mills etc
- Cassava processing
- Palm oil processing
- Poultry industry

RE IN PRODUCTION

- Reduction of drudgery

- Replacement of tractor and implements?

THE PEDAL TRACTORS ARE FOR LOW POWERED JOBS ON THE FARM

- may speed up the ever-present tasks of seeding, weeding, and cultivating row crops on the small farm, without burning any fossil fuels.
- I am strongly in favor of anything that can reduce the need for bending over or kneeling or squatting quite as much during the growing season.

CULTICYCLE

Culticycle

the idea is nothing more than observing that a lot of the work a tractor does – shallow cultivation, seeding, flame weeding – requires very little of its available horsepower; and since these jobs are best done between 3 and 5 mph, a bike can be geared down low enough that a human can produce the necessary horsepower." - Culticycle

Trimer

Water sprayer

HONEY SCREW PRESS FOR REFINING HONEY

MOBILE CHICKEN PROCESSING UNIT

With RE in Agriculture

- Our rural economy can be linked with industrial growth
- Poverty can be reduced with increased employment with growth in Agriculture
- Agroprenuers can form linkages among farmers , marketing firms and government agencies to strengthen export and widen range of quality food for the domestic population

- Thank you

“Agriculture & Engineering: A Winning Team for Sustainable National Development

A paper presented by Engr. Anthony Egba, at the Nigerian Institute of Agricultural Engineers

Agriculture is one of the oldest professions on earth and it is the engine of human productivity. According to M.S Swaminathan, the father of Indian Green Revolution, “*If Agriculture fails, everything else will fail”.* This statement implies that Agriculture is the basic sustaining factor of any development in any nation. No nation can toil with Agriculture and survive.

Agriculture can be divided into two: Traditional and Modern Agriculture. Traditional agriculture is purely subsistent by nature while modern agriculture is commercial and mechanized by nature.

Traditional Agriculture as practiced by small holder farmers is characterized by low productivity resulting from low inputs and use of crude implements while Modern Agriculture is characterized by use of inputs like fertilizers, herbicides, improved varieties, etc. which results in high productivity.

Agricultural productivity is measured in terms of yield per ha. High productivity leads to low unit production cost. The implication of this is that agribusiness becomes viable and competitive. The farmers smile and the processors laugh while the consumers rejoice because of availability of nutritious food at affordable prices. This I refer to as food and nutrition security which is the major outcry of the international community.

Agricultural productivity becomes a mirage if engineering the custodian of innovation and technology is not engaged in the agricultural processes. Engineering is the basis of modern agricultural practices. Genetic and biotech engineering are engaged in the production of highly viable, highly nutritious, early maturing, high yielding, disease, drought and flood resistant varieties and improved breeds of livestock. Engineering practices are engaged in construction of appropriate livestock housing and fabrication of livestock production and processing equipment like incubators, milking machine, hatchers, dehorners, pasteurizers, fish smoking machines, dryers, refrigerators, etc. just to mention a few.

Engineering practices are engaged in construction of farmstead, farm infrastructures, irrigation facilities, farm machinery and equipment. Engineering is the backbone for farm mechanization.

Mechanization is fundamental to agricultural productivity. Using Cassava mechanization as the case study, we see the process of achieving productivity through farm mechanization.

Cassava as one of the most important food crops in Nigeria with enormous industrial potentials. However, industrial use of cassava in Nigeria, as of now, is limited because of high cost of manual production and low yields of cassava when produced traditionally.

Traditional method of cassava production depends on minima land preparation and low or no use of inputs.

Cassava is produced largely by small-scale farmers using rudimentary implements. The average land-holding is less than two hectares and for most farmers; land and family labor remain the essential

Inputs

Land is held on a communal basis, inherited or rented; cases of outright purchase of land are rare. Capital is a major limitation in agriculture; only few farmers have access to credit.

For cassava to be used as raw material, its production must be well planned and intensified. For adequate root supply year around, there must be cassava plantations ranging from 100 to 5000 hectares.

Cassava Mechanization Procedure

Site selection

Soil test

Soil Profiling

Land clearing

Land preparation

Training

Equipment Calibration

Planting material selection

Planting

Fertilizer application

Re supplying

Weed control (selective herbicide)

Top Dressing (additional Fertilizer)

Cultivator (incorporation of phosphorus into the soil)

Farm maintenance

Equipment Maintenance

With innovation and technology, all these operation for 500 Ha of cassava farm can be concluded within **100 days.**

Site Selection.

Apart from water logged land, cassava can be planted mechanically in any location with appropriate mechanization machines, Equipment and technology.

However it is important that soil survey, Mapping and soil profiling of such land to be used for commercial production be thoroughly carried out.

This exercise is important to know the kind of soil correction, treatment and fertilizer to be used for optimal production of the Land.

Soil Sampling

Soil sample is taken at two depths (0-200mm and 200-400mm) at several points from different parts of the farm and send to reputable laboratory for analysis and interpretation.

Soil Profiling

Soil Profile (Deep)

Soil profile will also be carried out to know the kind and level of the tillage during land preparation. Cassava yield is higher in a land with a very deep soil profile than soil with shallow profile

Land Clearing

Land clearing operation is very important in mechanization farming. The Job must be given to expert and experience agricultural land developer.

There is a big difference between land preparation for agricultural purposes and that of road construction / building project. Having a lot of land moving equipment does not necessary make a contractor a good agricultural land developer.

During land clearing, care must be taken to give minimum top soil disturbance and removal.

All stumps must be removed, it is important to clear the land across the slope and along the natural soil contour.

Windrow and bonds should also be made across the slope to prevent erosion.

The first law to observe during land clearing is that of top soil protection and conservation.

For farm mechanization, the stretch of the land to be clear must be at least 100m width that is the distance between two bonds and as long as possible, 1km minimum depending on the topography of the soil.

The choice of equipment to be used for land clearing is also dependent on the vegetation of the farm (Virgin forest land, secondary forest or grassland).

Land Clearing operation should start at the beginning of dry season and stop during raining that is between November and May in some locations and land clearing could be extended to June in some part of Northern Zone of the country. Land clearing is a capital intensive operation.

Cleared land ready for Rome Ploughing

Land Preparation.

Land preparation in Farm mechanization is very important as this unit operation determine to large extent the success of mechanization operation from planting to harvest.

Rome Ploughing

Land preparation with the kind of tractor and the implement used is majorly determined by the vegetation or type of the forest of the farm.

If the farm is a virgin forest where the root density is very high, the first operation necessary after the forest is cleared is Rome Ploughing.

In Virgin Land, two Rome plough operations are necessary with disc plough of 36” minimum diameter. After the first Rome ploughing, then root picking operation will take place and the farm will be Rome ploughed the second time.

Chemical Land preparation

Application of Glyphosate Herbicide

Application of Glyphosate Herbicide is a very sensitive operation based on the weather situation. The aid of very accurate weather prediction tools is very important.

This is because rain during the operation or immediately after operation can render your herbicide impotent. You have to repeat the operation within 24 hours of the first application. Otherwise you must take further action to pay attention to weed in this plot in future.

Rain after two hours of application of good glyphosate may not have much adverse effect on the efficacy of your herbicide and your operation.

Application on a very windy time too is not advisable as this will affect the rate of application per square area and the efficacy of the chemical. If the wind velocity suddenly increases during the operation, it is advisable to lower the arms of the boom or you stop the operation until the wind slows down.

Concentration of the herbicide and the expiring date is also of important as these may impair on the effectiveness of your Herbicide.

Boom Sprayer calibration

Boom sprayer of 2000 litres capacity calibrated to deliver 200 litres of water/Ha. When fully loaded, the boom sprayer can cover 10 Ha per batch. And this operation could be done in one hour by experience Operator.

After 72hrs of Applying the Herbicide, you can start the first Rome Harrowing.

It is important to leave the space of two weeks between the first Rome ploughing and the second Rome ploughing. This enables the weed to die properly and also allow the weed in seed bank to germinate for the second operation to kill the weed seedling.

2nd Rome harrow

For good level ground the use of disc plough should be totally discouraged in mechanical farming as this creates a lot of problems for planting and weed control. Disc plough make it very difficult to have uniform depth for cassava stems and this also leads to reduction in the rate of germination of the cassava and invariable affects the productivity of the farm.

After Rome ploughing, the farm is the Harrowed with good and heavy harrow. Preferably with Rome harrow. For good level ground two harrowing is preferable.

Time interval between these two operations is also good for weed control.

PLANTING

A lot of operations are required for good planting that will lead to optimum production and productivity

Weight Balancing

Adjustment of width of the Tractor

All the tractors you want to use in the same field for farming operations must carried the same tyre width

Planter Spacing Adjustment

Plant Population

Your planter spacing determined the plant population per Ha. Spacing has a serious effect on your productivity.

The minimum cassava plant population in Ha should be 10,000 Stand per Hectare

Training

TRAINING ON STEMS PREPARATION

Selection of Planting Materials.

The selection of right planting materials is very important in cassava mechanization. The variety must be the straight stems, high yield and high starch content variety.

STEM HANDLING AND TRANSPORTATION

Correct Stem Transportation

YOU MUST GET ALL YOUR INPUT READY

Planting:
This is the process of using cassava stem planters to establish the farm. The idea of using manual labour under this project should be ruled out because the primary aim is make it attractive to young people and to entice them embrace agriculture as a business. Most often, the planting goes with fertilizer application which is being applied simultaneously. However, there is the need to be careful with the quality of planting materials and fertilizers.

The planter requires that the stems to be fed into it, must be sturdy and fully matured. Also, friable (free flowing) fertilizers should be supplied since caked fertilizer would not easily pass though the fertilizer chute and subsequently block the fertilizer path.

Apart from causing problems for the plant, additional cost would be incurred to break the fertilizer lumps into granules that would flow easily in the combined fertilizer and cassava stem planter.

In the execution of the cassava mechanization project, there is the need for proper adjustment of machines in order to have uniform plant population per hectare across the FAR. This includes adjusting the row spacing as well as inter plant spacing (along and between the row).

Mechanical Planting

Planting with 2 Tractors

Weed Control

GOOD HERBICIDE APPLICATION IS IMPORTANT

Mechanical Harvesting

With technology and innovation it is also possible to attract the younger generation to agriculture.

With innovation and Technology cassava productivity is very high and it is easy to produce 30 tons of cassava per Hectare

HIAB LOADING THE TRAILER

The University has a lot of roles to play in this area of research and innovation that will make agriculture more profitable and sustainable in order to attract the next generation to Agricultural Business

Catch them young

.

With Technology and innovation, we will be able to produce our crops in such a competiveness price that will enable us to attract foreign investors and be able to open export market for our produce.

Impacts of Agricultural Productivity on National Development
With the application of engineering practices in Agriculture leading to agricultural productivity, national development is being strengthened in the following areas:

Food & Nutrition Security is Enhanced- Production of high quality food in large quantity at very low production prices leading to availability of highly nutritious food at affordable prices. This improves food security.

Improved Health

The result of the food and nutrition security is improved individual health which enhances individual productivity which aggregates to National Productivity and national development.

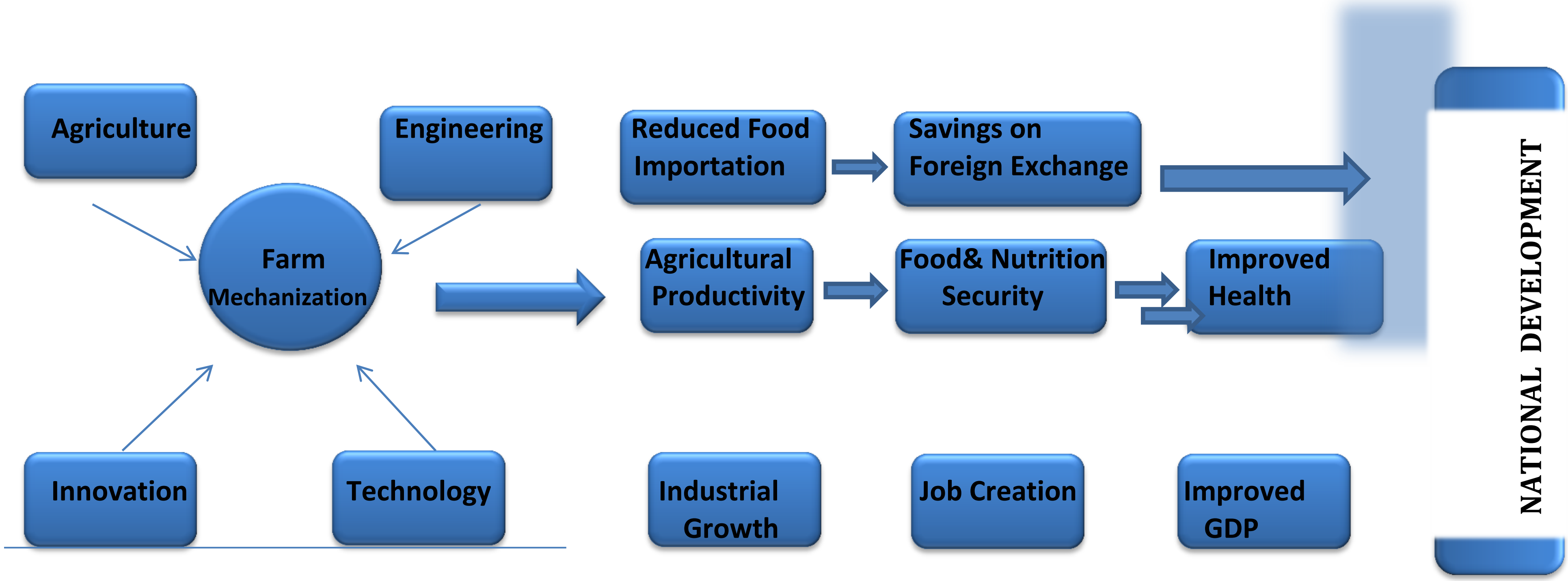
Reduced Food Importation and enhanced Food Exportation

High productivity leads to reduction in food importation which results in reduction in government expenditures on food importation while more foreign exchanged is earned from food exportation.

Industrial Growth

High agricultural productivity enhances production of agricultural raw materials needed for agro-based industries sustenance and up scaling. High productivity leads to development of cottage industries to process the farm produce to semi- finished products to supply other industries or for exportation. All these lead to industrial growth which enhances job creation and national development.

The diagram below represents the relationship between Agriculture, Engineering and national development



Conclusion

The synergy between Agriculture and Engineering leads to the evolvement of technology and innovation which is the bedrock of farm mechanization as a component of Agricultural development. National Development will be a mirage if agricultural development is not achieved.

AGROPRENEURSHIP FOR SUNSTAINABILITY IN A DIVERSIFIED ECONOMY

12 September 2018
Lagos, Nigeria

Delivered at the Conference of the Nigeria Institution of Agricultural Engineer

Outline

- Background
- Market Opportunities
- IITA’s Experience
- Conclusion

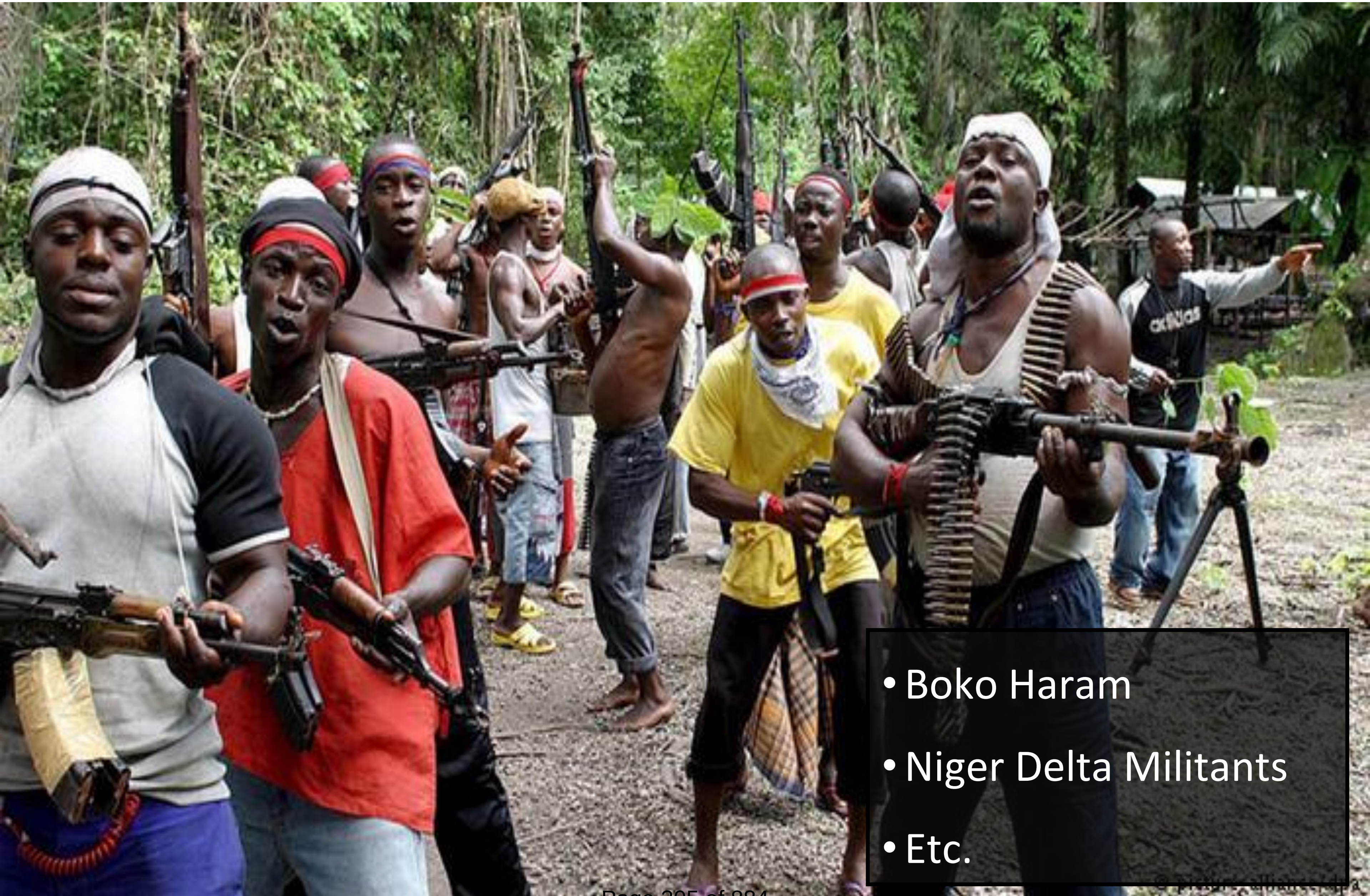
African Youth in Crisis

- A total population of over 190M
- The economically active population or working age population (ages 15-64)
- The youth account for 70% of all the unemployed in Nigeria
- 26.06 million unemployed as at Q2 2016 (25% unemployment rate)
- Youth unemployment rate was 33.1% at July 2017

Source: NBS 2016, Trading Economics 2018

Reality

Youth become marginalized, many attracted to dangerous lifestyles.



- Boko Haram
- Niger Delta Militants
- Etc.

“What a man thinks of first each day is what to put in his belly.”

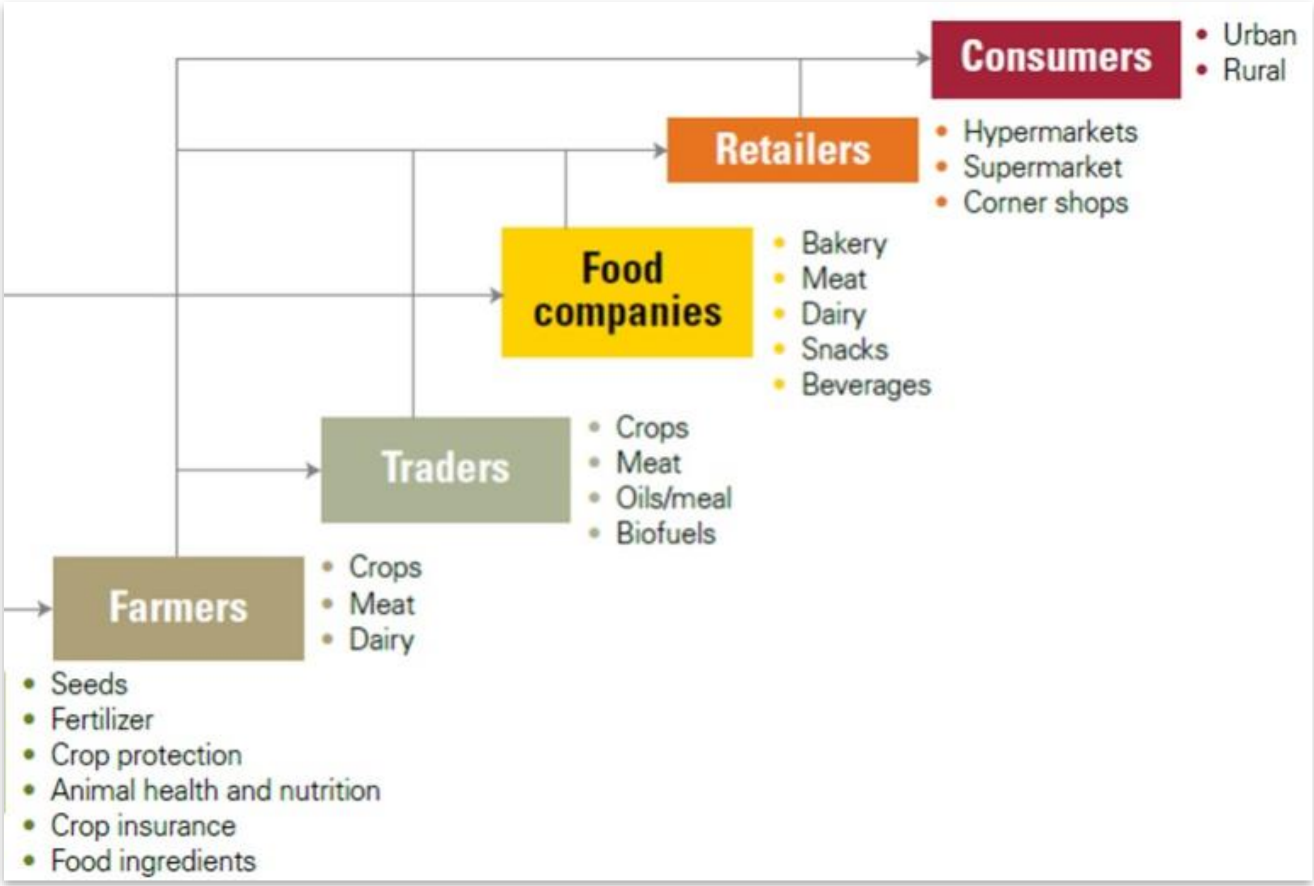
More youth must become job creators, rather than job seekers, through agribusiness startup and growth. Under-employed university graduates best situated to achieve this!

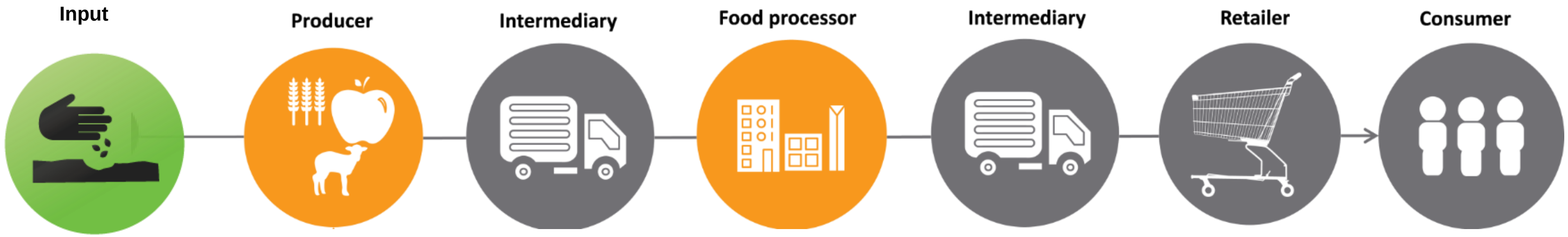
Market Opportunities

- Maize worth N12.8billion from Ukraine, USA and Argentina
- Frozen meat worth N5.5 billion from Netherlands
- Sugarcane worth N60.6billion from Brazil
- Chemical fertilizers worth N7.7billion from Morocco
- Herbicides worth N22.9billion from China
- Durum wheat seed worth N40.7 billion from United States

Source: NBS, 2017

Simple Value Chain





Why Youth Engagement?

- Farming is a business
- Food will always be of high demand
- Nigerian population is increasing at alarming rate
- Governments are now aware of the importance of agriculture

YIA Model

The overall goal of IYA is to reorient rural youth towards productive engagement in agriculture particularly through expanded opportunities in agribusiness

YIA Model

- Designed to direct unemployed youth toward careers in modern agriculture and agribusiness
- Based upon experiential learning within pilot agricultural enterprises leading to independent business plans
- With learning enterprises for incubation in 6 countries
- Quickly recognized as a potent means to address youth empowerment

Examples of Agribusiness Incubations

Nigeria

Cassava Production

Catfish Production

Poultry Production

Uganda

Vegetable Production

Sales via ICT platform

Recently Funded Business Start-ups

Business Name	Type of Business/Commodity	Startup Fund
Frotchery	Partnership (Smoked and Frozen Cat fish)	$5,483
Gracevine	Proprietorship (Packaged Pepper Beans & Beans Flour	$5,600
TAC	Proprietorship (Grain Production)	$3,175
Afribroilers	Partnership (Poultry- meat production)	$14,000

As at August 2018, 161 agribusiness enterprises has been supported with business start-up fund

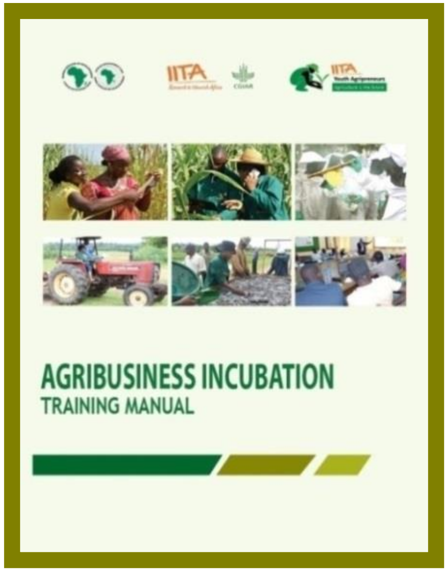
Case Study: Frotchery Farms Ltd

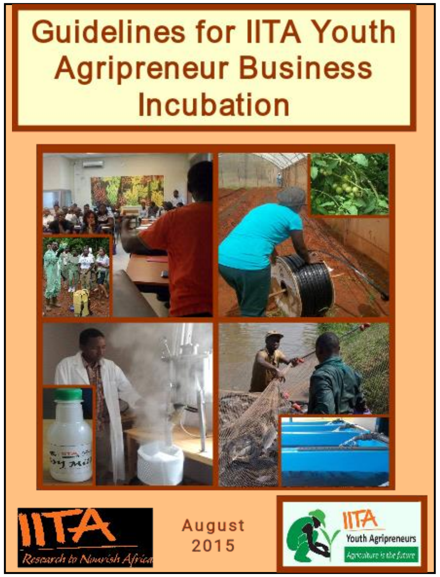
- **Partnership of 3**
- **Start-up funds of $5,483**
- **Catfish Processing**
- **B.C.R of 1.5**

Case Study: Grace Vine Ventures

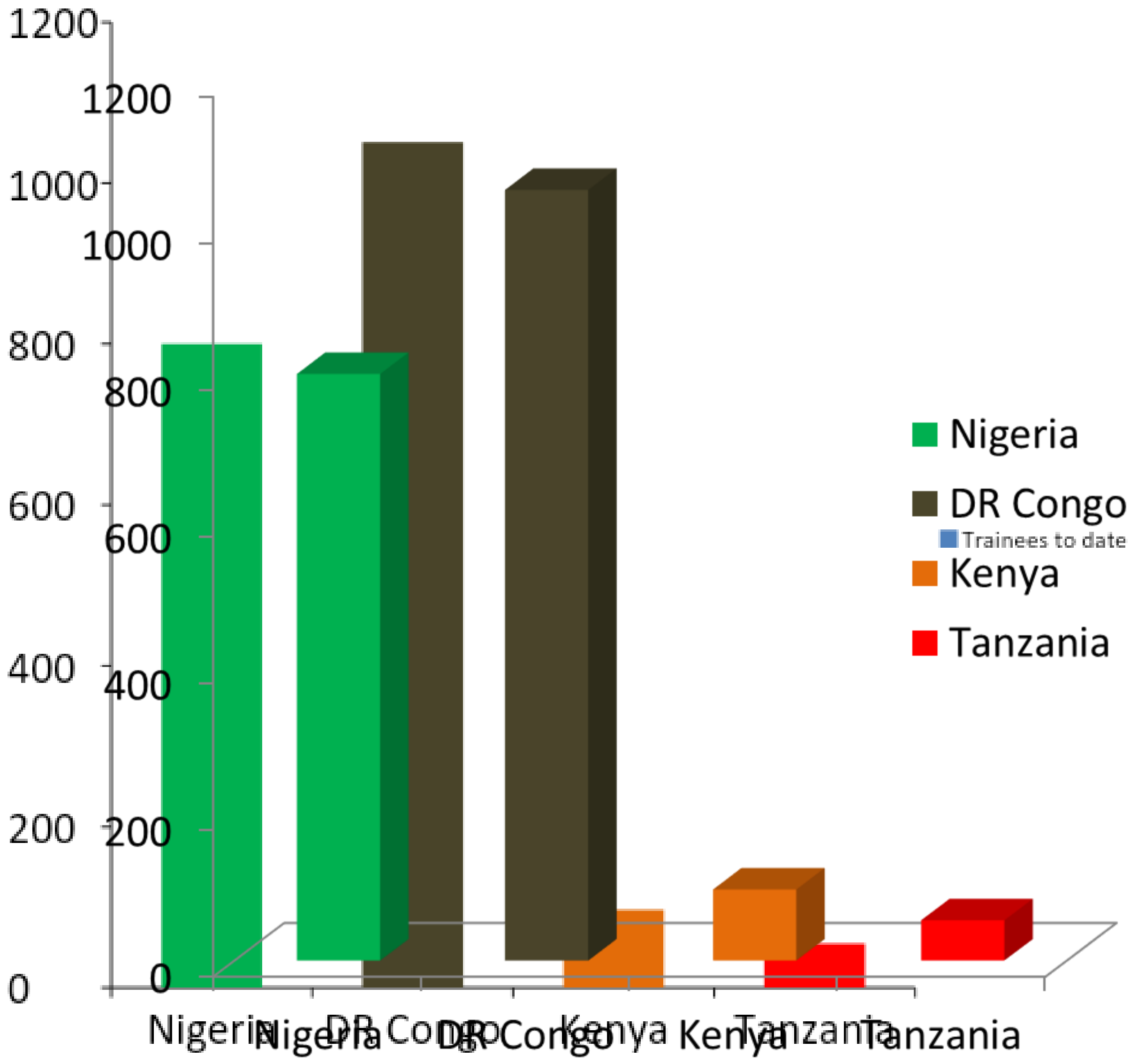
- Sole Proprietorship
- Start-up funds of $5,600
- Cowpea Processing
- B.C.R of 1.5

Capacity Development





Available in English, French, and Arabic



Training Projections: 2018 and beyond

Hello Tractor Project

Community Youth in Agribusiness Project

THE ENABLE Youth PROGRAM

TaT

Tri-Annual Training

And 2 other projects in the pipeline

Over 30,000 trainees across 5 years

ENABLE TAAT ENABLER

ENABLE TAAT Project

Goal: to reduce the economic marginalization of African youth through the introduction of modernized agricultural technologies in a way that leads to new agribusiness and greater employment opportunities

Components

- **Agribusiness Completion**
- **Agribusiness Incubation**
- **Advocacy**
- **Youth Registration**

TARGETS

- **Investing in at least 19 African countries**
- **Reach 5,000 youth in 3 years**
- **At least 39 start-up enterprises as quick win in year 1**

Objectives

- **Expand Agribusiness Opportunities**
- **Provide Agribusiness Support**
- **Improve Human Nutrition**
- **Advance Youth Empowerment Mechanisms**

Benin, Burundi, Cameroon, Cote d'Ivoire, DRC, Ghana, Kenya, Liberia, Madagascar, Malawi, Mali, Nigeria, Senegal, Sierra Leone, Sudan, Tanzania, Togo, Uganda and Zambia

ENABLE Youth Program

Components

Enabling Environment

Favourable policies enhanced

Entrepreneurship and Agribusiness Incubation

12 month training incubation of young graduates as business men and women in agribusiness.

Business Development and Financing

Innovative financing scheme
Transformation into credit worthy Agripreneurs
Deploy risk sharing mechanism

Project Management

Operating at multiple level for coordination

Targe

USD 12.5 billion to support enterprise and job creation for youths & women

Investing in about 32 African countries

1.25 million agribusiness jobs in the next 5 years

At least **350 000** agribusiness enterprises to be created in Africa

At least **10 000** unemployed graduates (50% women) trained and financially empowered in each country

Algeria, Benin, Burkina Faso, Burundi, Cameroon, Cote d'Ivoire, DRC, Ethiopia, Ghana, Guinea Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Morocco, Mozambique, Nigeria, Rwanda, Senegal, Sierra Leone, Sudan, Tanzania, Tunisia, Uganda and Zambia

Hello Tractor

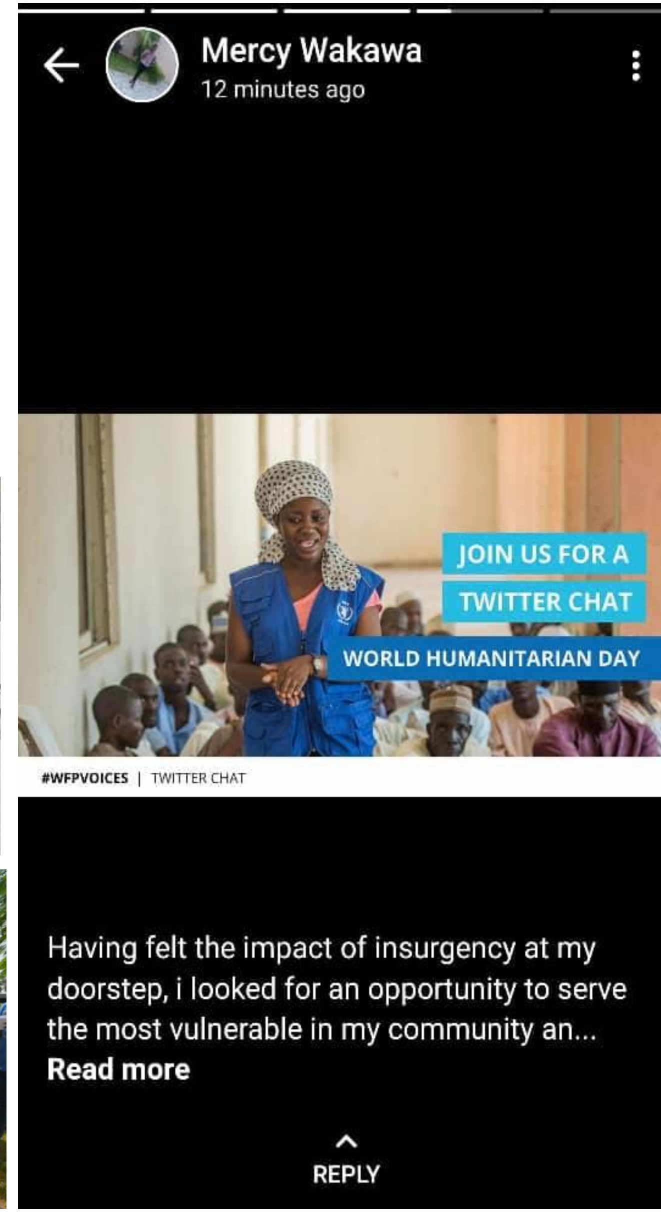
- Hello Tractor (USAID)
- 100 youth
- 3 smart tractors / youth
- Oyo, Abuja & Kano

Chevron Nigeria

- **120 youth (38% female)**
- **Niger-Delta**
- **Cassava, Fish & Plantain (8 additional enterprise through value chain)**

Bill & Melinda Gates Foundation

127 youth (20% female) trained mainly in science-driven agricultural production technologies, entrepreneurship and writing of bankable business plans, including industrial internship where necessary



Revitalized Facilities at Imo

Poultry Production

Imo AgriStars

Vegetable Production

- IITA challenged to contribute to agricultural diversification in Imo state.
- An opportunity to test the new Rolling Cadre approach on abandoned facilities.
- Profitable fish, poultry and vegetable enterprises established within six months.
- Local youth recruited to join the Agripreneurs.

Lessons learned

Mindset change of youth about agriculture

Connect Agripreneurs to excellent sources of technology and knowledge

Coaching and Mentoring activities to motivate youth

Thank You!

PART TWO

SECTION ONE

FARM POWER AND MACHINERY

COMMON FAILURES ASSOCIATED WITH TILLAGE IMPLEMENTS DURING FIELD OPERATIONS IN EDO STATE, NIGERIA

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ABSTRACT

The study presents common failures associated with the use of tillage implements like disc plough, mould-board plough, disc harrow, chisel plough and disc ridger during field operations in agricultural mechanization establishments/organizations; educational institutions; local government councils as well as some selected privately owned mechanized farms in Edo State of Nigeria. Information gathering was accomplished through the use of well structured questionnaires administered during field visits while additional information were gathered through personal communication.A total number of thirty locations involved in mechanization activities were visited thereby ensuring even spread and ninety respondents comprising of experienced tractor operators, agricultural machinery mechanics and mechanization supervisors were selected during the field visits. Data collected were analyzed using descriptive statistics, which include frequency and percentages. Result shows that disc ploughs and disc harrows are the mostly commonly used tillage implements for farm operations in Edo State, Nigeria. Component failures like breakage of bearings; bent gang shafts and damage hub; broken bolts and nuts/disc spacers; damaged disc edge and cracking of scrapers are the most common failures associated with the use of tillage implements during farm operations. The study observed that the repair of these components could easily be accomplished, if there were available spare parts or if funds were quickly released to procure these parts when not available in the store. Different factors are attributed to the cause of components failure like poor handling due to unskilled nature of some tractor operators; poor maintenance culture; environmental and ecological factors of soil condition, vegetation and topography; and improper implements storage were identified during the study. It was recommended that untrained personnel should not be allowed to operate tractors and implements as this does not augur well for sustainable agricultural mechanization practice; there is the need for change of attitude by government officials and other managers of farm machinery and implements to encourage training and retraining of their tractor operators' at relevant training institutions in Nigeria; mechanization supervisors should ensure strict compliance of tractor operators' and implements in the area of tractors/implements maintenance; adjustment and matching of implements to power source during field operations; qualified repair and maintenance personnel should be recruited including standard workshop equipment and facilities should be put in place to enhance effectiveness of both maintenance and repair activities whenever there is any implement

components failure amongst other suggestions in order to reduce failures during operation to the bearest minimum.
Keywords: *Tillage implements, Components, Failure, Field operations*

1.0 INTRODUCTION

Tillage is the mechanical manipulation of the soil for any desired purpose, but in agriculture the term is usually restricted to the manipulation of soil conditions for crop production. One of the major objectives of tillage is to create optimum soil conditions for plant growth. This is achieved by providing a good seedbed, which involves breaking, stirring, turning or conditioning the soil surface to a certain depth (Kaul and Egbo, 1985). Soil tillage aims include the control of weeds, incorporation of organic matter into the soil and improvement of soil structure (Marakoglu and Carma, 2003).

Most common tillage operations include primary tillage, secondary tillage, etc. The tillage which constitutes the initial major soil-working operations is referred to as primary tillage. This tillage type displaces and shatters the soil to reduce its strength and to bury or mix plant materials/residues and fertilizers in the tilled layer. Primary tillage is more aggressive, deeper and leaves a rougher surface. The subsequent operation after the primary tillage works the soil to a shallower depth, provides additional pulverization, kills weeds, levels the seedbed surface and firms the soil. This is referred to as secondary tillage. It is also designed to create refined soil conditions before seeding, create specific soil surface configuration and to control weed growth. The implements used for soil tillage operations are referred to as tillage implements. A tillage implement consist of a single tool or a group of tools, together with associated frame, wheel, hitch, control and protection devices, and any power transmission component (Ahmed, 2006). According to Spoor (1984), tillage implements are classified as ploughs, harrows, cultivators and levelers or clod crushers, etc. Primary and secondary soil manipulations are the basic operations required for cultivation of any kind of crop.

To prevent soil structural damage and, also to restructure or ameliorate the soil, soil tillage must be managed adequately and meticulously with reference to the soil type, soil conditions and machine(s) in use. By this meticulous management, the desired tillage virtues aimed towards enhancement of arable farming are also exploited (Imonigie, 2015). In doing this, emphasis has to be placed on the provision of optimum soil tillage that is not only cost effective but less prone or susceptible to soil structural damage (Imonigie, 2015). Therefore, soil manipulating implements should be able to withstand adverse field conditions such as the presence of hardpan, small rocky formation, stumps and stubble during soil engagement without failure. Soil working implements such as disc ploughs, mould-boards ploughs, disc harrows and ridgers have long been accepted and successfully used by farmers under average field conditions (Gupta ***et al.,*** 2004).

According to David (2001), failure is define as a change to performance specification. Failure is also define as a state of breakdown or decline in the performance of material (Encarta, 2003). Failure of engineering components in service may not be actually due to one cause, it could be by combination of causes. The causes could be associated to bad material selection, production method, post-production treatments and the application or service condition to which the component is subjected to. Failure of tillage implements occurs when the degradation reaches a critical level. Therefore, tillage implement components that fails randomly should either undergo minimal repairs at the time of failure or undergo perfect repair through replacement at the time of failure (Okapi and Salihu, 2009; Imonigie, 2015).

However, it is important to note that any material/structure can fail in service if it is subjected to excessive load/force beyond the designed and endurance limits (Godwin and Spoor, 1977). Many failures of engineering components (structural or mechanical) in service usually results in rupture of some parts of the components and the first step to be taken is the identification of the origin and causes of the failure and then carefully examine the ruptured surface/parts so as to obtain useful information on the exact actions that took place before failure. It is also important before analyzing the failure to gather as much information as possible on the characteristics and functions of the failed parts as well as the exact circumstances that would lead to the failures (Deferri, 1979).

Moreover, failure analysis is the determination of the primary causes of failure of an engineering component/structure using systematic techniques involving expert investigation and careful analysis of the data collected during investigation. In failure analysis, the contribution of other secondary factors to the failure and corrective actions that can prevent future and similar failures are also assessed and brought out (Godwin and Spoor, 1977). However, so far, no comprehensive study has been conducted in recent times on the failures of tillage implements during field operations in Edo State, Nigeria. The objectives of the study, therefore, was to identify common failures associated with the use of tillage implements during field operations in Edo State, Nigeria with a view to recommending suggested measures that will reduce it to the bearest minimum.

2.0 MATERIALS AND METHODS

2.1 Preparation for the Execution of the Survey

The study area was stratified into three (3) zones based on the original three senatorial districts in Edo State namely Edo-South, Edo-North and Edo-Central.

(i). Six Local Government Areas in Edo North visited include Akoko-Edo, Etsako-Central, Etsako-East, Etsako-West, Owan-East and Owan-West .Other farms/organizations/ institutions visited in this zone include Leventis Farms, Agenebode; Egbi Farms Limited, Igara; Abbis Farms Limited, Afuze; Agro-Palace Limited, Igarra; Papadion Venture, Igarra; Adeleke Poultry and Agro Allied Farms, Ibillo; Ita Farms, Afuze; DaudaHaruna Farms, Okpela; Damfa Farms, Okpela; Tractor Hiring Unit headquarters in Auchi and Sabongida-Ora; College of Agriculture, Agenebode; Auchi Polytechnic, Department of Agricultural & Bio-Environmental Engineering Technology, Auchi.

(ii).Seven Local Government Areas in Edo-South visited include Uhunmwode, Ovia North-East, Ovia South-West, Oredo, Ikpoba-Okha, Egor and Orhionmwon. Other farms/organizations/institutions visited in this zone include University of Benin, Faculty of Agriculture, Benin-City; Wells and Carlos Farms, Okada; Diacs International Farms Limited, Benin; Agricultural Development Programme, Benin-City; Tractor Hiring Units headquarters in Benin-City, Iguobazuwa and Ehor; Ministry of Agriculture, Benin-City; Federal Ministry of Agriculture and Rural Development, Benin-City; College of Agriculture, Benin-City.

(iii).Five Local Government Areas in Edo-Central include Esan-Central, Esan-West, Esan North-East, Esan South-East and Igueben. Other farms/organizations/institutions visited in this zone include Tractor Hiring Unit headquarters, Irrua; Ambrose Ali University, Faculty of Agriculture, Ekpoma.

2.2 Data Collection and Analysis

The survey was carried out in all agricultural mechanization establishments/organizations; educational institutions, local government councils as well as some selected privately owned mechanized farms in Edo State, Nigeria. Information gathering was accomplished through the use of well structured questionnaires administered during field visits while additional information were gathered throughpersonal communication. Information sought include types of tillage implements commonly used, main types and causes of tillage implement failures, component parts of tillage implements that frequently fails during operation, tillage implements that require less maintenance, types of maintenance practices carried out on tillage implements, type of operation commonly use tillage implements to carry out on the farm, suggestive measures that can be adopted towards preventing failures while using tillage implements during farm operations.

A total number of thirty locations involved in mechanization activities were visited by ensuring even spread and a total number of ninety respondents comprising of experienced tractor operators, agricultural machinery mechanics and mechanization supervisors were selected. They were selected to ensure accurate information collection during the field survey. The information obtained from the completed questionnaires was compiled and analyzed using descriptive statistics which include frequency and percentages. Although, the usual survey bottlenecks of respondents' reluctance to provide information were experienced, this was considered inconsequential as there were many respondents to interview and obtain similar information. In addition, reluctant respondents were further persuaded with extensive explanation on the aim of the study and most especially on the part of the questionnaire requesting information on different factors attributed to the cause of components failure associated with the use of tillage implements during field operation to avoid implications by their various managements.

3.0 RESULTS AND DISCUSSION

The major findings from the study which are directly related to the objectives of this study are presented in Tables 3.1 to 3.9:

As shown in Table 3.1, 39% of the respondents were from the government establishments/organizations, 56% of the respondents were from the private mechanized farms while 5% of the respondents were from educational institutions.

Table3.1: Types of Implements' Ownership

OWNERSHIP TYPES	NO OF RESPONDENTS	PERCENTAGE (%)
Government establishments	35	39
Private mechanized farms	50	56
Educational institutions	05	05
Total	90	100

As shown in Table 3.2, 61% of the respondents are tractor operators, 17% of the respondents are agricultural machinery mechanics and 22% of the respondents are mechanization supervisors.

Table 3.2: Ranks of Personnel/Respondents

TYPES OF OCCUPATION	NO OF RESPONDENTS	PERCENTAGE (%)
Tractor Operators	55	61
Agricultural-Machinery Mechanics	15	17
Mechanization Supervisors	20	22
Total	90	100

As shown in Table 3.3, 11% of the respondents hold the West African School Certificate (WASC) while 89% of the respondents possess qualifications like the National Diploma and City & Guilds Certificate.

Table 3.3: Level of Education of the Respondents

LEVEL OF EDUCATION	NO OF RESPONDENTS	PERCENTAGE (%)
No Formal education	Nil	Nil
Primary education (FSLC)	Nil	Nil
Secondary education (WASC)	10	11
Others (ND/City & Guilds)	80	89
Total	90	100

As shown in Table 3.4, 11% of the respondents had 1 to 5 years working experience, 20% of the respondents had 6 to 10 years working experience, 27% of the respondents had 11 to 15 years working experience while 42% of the respondents had 16 years and above working experience.

Table 3.4: Respondents' Number of Years Working in the various Organisations/Institutions/Establishments/Farms

NUMBER OF YEARS	NO OF RESPONDENTS	PERCENTAGE (%)
Less than one year	Nil	Nil
1-5	10	11
6-10	18	20
11-15	24	27
16 and above	38	42
Total	90	100

As shown in Table 3.5, 46% of the respondents used disc ploughs, 6% of the respondents used chisel ploughs, 28% of the respondents used disc harrows, 20% of the respondents used disc ridgers and none of the respondents used mould-board plough. It can therefore be concluded that the most commonly used tillage implements for field operations are the disc ploughs and disc harrows. The tillage which consists of the initial major soil-working operations is the primary tillage and disc plough is normally used to cuts, invert partially or completely, a layer of soil and bury the surface material. The subsequent operation following primary tillage is carried out to further breakdown the clod and prepare the seedbed ready for planting is referred also to as secondary tillage and disc harrow is used to create such refined and requisite soil conditions before the seed is planted.

Table 3.5: Commonly used tillage implements for field operations

TYPES OF IMPLEMENTS	NO OF RESPONDENTS	PERCENTAGE (%)
Disc harrow	25	28
Chisel plough	05	6
Disc plough	42	46
Disc ridger	18	20
Mould-board plough	Nil	Nil
Total	90	100

As shown in Table 3.6, 33% of the respondents attributed poor maintenance culture as a factor attributed to cause of failure in tillage implements. Since maintenance can be preventive or breakdown, preventive maintenance according to Onwualu, 1996 involve a number of things like daily, weekly and periodic checks and services that have to be done whether the implements are in use or not, are not adhered to in the majority of the establishments/organizations/institutions visited; 36% of the respondents attributed poor handling due to unskilled operators as a factor attributed to cause of failure in tillage implements. This may be due to improper adjustments and poor matching of implements to the power source including overworking of tillage implements; 9% of the respondents attributed poor land clearing finish as a factor attributed to cause of failure in tillage implements. The use of tractors and implements in a farm that was initially poorly cleared can result in premature failure of tillage implements. For initial clearing of bush or forest, specialized machinery such as bulldozer, tree pushers and power saws are suppose to be used. Contrary to this fact and for tillage operation like ploughing which is very common in the study area, if disc ploughs are used on such land with stumps, stones, etc accelerated wear and tear of the implement will occur. 2% of the respondents attributed improper storage of implements as a factor responsible to cause of failure in tillage implements. Poor storage of implements commonly practiced in most study locations like keeping implements outside in the open air exposes them to weather hazards especially during the off-season results in some components failure like bearing. 20% of the respondents attributed environmental factors of soil condition, vegetation and topography as a factor responsible to cause of failure in tillage implements. Onwualu (1996) reported that the some soil conditions can result in premature failure of agricultural machines like too low soil moisture content, soil texture with a large percentage of gravel, high dry density, high shear and bearing strength including high resistance to penetration. When tillage implements are used in areas of bad topography, some parts of the implements may be subjected to abnormally high stresses while others may not. Such unforeseen circumstances can lead to premature failure of implements components. It can therefore be concluded that the major factor attributed to cause of failure in tillage implements as revealed in the study was poor maintenance culture.

Table 3.6: Factors attributed to the Cause of Components failures in Tillage Implements

FACTORS ATTRIBUTED	NO OF RESPONDENTS	PERCENTAGE (%)
Poor maintenance culture	30	33
Poor handling due to unskilled operators	32	36
Poor land clearing finish	8	9
Improper storage of implements	2	2
Environmental and ecological factors (soil condition, vegetation, topography, etc)	18	20
Total	90	100

As shown in Table 3.7, 61% of the respondents attributed hub-bearing breakage as a component failure in tillage implements like disc plough and disc harrow during field operation;6% of the respondents attributed damaged disc edge as a component failure in tillage implements like disc plough and disc harrow including disc ridger during field operation; 11% of the respondents attributed bent shaft/shaft wears as a component failure in tillage implements during field operation; 16% of the respondents attributed damaged nuts and bolts as a component failure in tillage implements during field operation; 6% of the respondents attributed cracking of scrapers as a component failure in tillage implements during field operation. It can therefore be concluded that hub-bearing breakage was a major component failure in tillage implements during field operation in the study area.

Table 3.7: Components failure of Tillage Implements during Field Operations

COMPONENTS	NO OF RESPONDENTS	PERCENTAGE (%)
Hub-bearing	55	61
Disc	05	6
Shaft	10	11
Nuts and bolts	15	16
Scrapers	05	6
Total	90	100

As shown in Table 3.8, 33% of the respondents used to carry out daily maintenance on their tillage implements, 17% of the respondents used to carry out periodic maintenance on their tillage implements while 50% of the respondents used to carry out end of season maintenance practice on their tillage implements. It can therefore be deduced that end of season maintenance practice is very common on tillage implements in the study area.

Table 3.8: Types of Maintenance Practices carried out on tillage implements

PREVENTIVE MAINTENANCE PRACTICE	NO OF RESPONDENTS	PERCENTAGE (%)
Daily maintenance	30	33
Periodic maintenance	15	17
End of season maintenance	45	50
Total	90	100

As shown in Table 3.9, 13% of the respondents agreed that disc ploughrequires lessmaintenance, 21% of the respondents agreed that disc harrow requires lessmaintenance, 22% of the respondents agreed that disc ridger requires lessmaintenance while 44% of the respondents agreed that chisel plough requires lessmaintenance. It can therefore be concluded that chisel plough require less maintenance among the tillage implements commonly used in the study area because it does not have hub- bearing.

Table 3.9: Tillage Implements that requires less maintenance

IMPLEMENTS	NO OF RESPONDENTS	PERCENTAGE (%)
Disc plough	12	13
Disc harrow	18	21
Disc ridger	20	22
Mould-board	Nil	Nil
Chisel plough	40	44
Total	90	100

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

This study has examined the common failures associated with the use of tillage implements like disc plough, mould-board plough, disc harrow, chisel plough and disc ridger during field operations in Edo State, Nigeria. Incidence of breakage of bearings; bent gang shafts and damage hub; broken bolts and nuts/disc spacers; damaged disc edge and cracking of scrapers are the most common failures associated with the use of tillage implements during farm operations. The most commonly used tillage implements for field operations are the disc plough and disc harrow while chisel plough require less maintenance because it is operated with spring while other implements like disc plough and harrows operates with hub-bearings which frequently experience failure during field operation. Different factors were also attributed to the cause of components failure like poor handling due to unskilled nature of some tractor operators; poor maintenance culture; environmental and ecological factors of soil condition, vegetation, topography; and improper implements storage during the study.

4.2 Recommendation

With respect to the various findings from the study, the following recommendations are hereby suggested to further bring about improvements in the operation of tillage implements in all the agricultural mechanization establishments/organizations; educational institutions; local government councils as well as some selected privately owned mechanized farms in Edo State, Nigeria in order to reduce implement failures to the bearest minimum.

- ✓ Untrained personnel should not be allowed to operate tractors and implements as this does not augur well for sustainable agricultural mechanization practice.
- ✓ There is the need for change of attitude by government officials and other managers of farm machinery and implements to encourage training and retraining of their tractor operators' at relevant training institutions in Nigeria.
- ✓ Mechanization supervisors' should ensure strict compliance of tractor operators' and implements in the area of tractors/implements maintenance, adjustment and matching of implements to power source during field operations.
- ✓ Qualified repair and maintenance personnel should be recruited including standard workshop equipment and facilities should be put in place to enhance effectiveness of both maintenance and repair activities whenever there is any implement components failure.
- ✓ Availability and stocking of spareparts in the store for easy replacement after components failure in tillage implements should be encouraged in all the agricultural mechanization establishments/organizations; educational institutions; local government councils as well as some selected privately owned mechanized farms in the state.
- ✓ Local fabrication of replaceable spare parts should be encouraged by government in order to boost mechanization development in Nigeria. This will also reduce the present rate ofunserviceability of tillage implements in the state.
- ✓ Managers of farm machinery should introduce incentives as a way of boosting operators' morale after work. This will tend to reduce various corrupt practices often times engaged by tractor operators while using implements on the field of operation.

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DESIGN, FABRICATION, AND TESTING OF A COW DUNG ANAEROBIC BIO-DIGESTER

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ABSTRACT

There is a large dependency on non-renewable sources of energy in Nigeria, but this could be reduced by the development and implementation of bio-digester that can be a major energy source for heating and other processing purposse both at homes and the farms. The rate of environmental pollution and greenhouse gases emissions in most of the livestock slaughter farms in Nigeria is a major problem. Another issue is the poor waste management during the rendering and processing of beef. No doubt there is enormous economic opportunities in converting the cow dungs from the slaughterhouses in into useful biofuels. The bio-digester is a simple technique of producing biogas that can be used to produce energy. Some features were taken into consideration such as loading rate, toxicity and the C/N ratio. Biogas from Cow Dung serves as a suitable alternative fuel for satisfying the energy needs of human society. This paper aims to design, fabricate and test an 8.0m^3 biogas digester. The materials used in the construction of the plant were, sand, cement, aggregate, water, mild steel bars, stainless steel bars and mild steel plates. The mild steel plates were used in the original construction of the body of the bio-digester. 10 mm mild steel bars were used in framing the base of the biogas digester to increase yield was highlighted. A restriction with regard to controlling the inside pressure to increment abdicate has also been highlighted.

Key Words: Bio-digester, *Biogas, Cow Dung,* S*laughterhouses, Waste management*

1.0 INTRODUCTION

The development of new methods of production and use of renewable energy sources that suit the economic and the geographical conditions of the developing countries will be required in order to solve the problems of the energy crisis and climate change. Today, climate change is everyone's concern and is among the leading problems if not the only one linking the international community and drawing much attention. Fossil resources were given much attention in the past before climate change became a major concern. The time has come, and the time is now where attention should now be shifted from fossil fuels to renewable energy sources. The anaerobic bio-digester process is not a new technique of converting waste material such as cow dung into a usable product (Deublein, 2008).

The waste products that come from bovine species of animals is called cow dung or cow manure. The species that are in the study are such as yak, bison, water buffalo and cattle. The undigested residue that is cow dung consists of plant matter that moves through the gut of the species of animals. In the end, faecal matter is dropped and is composed of important minerals. The faecal colour can be in a range such as blackish to greenish but will darken once exposed to air. A traditional use of cow dung is as fertilizer, however, the recent research on cow dung has developed its use to global biogas production. Gasses produced have a high composition of methane. Such production of gases is being implemented in the Indian rural areas. Pakistan and some examples of countries in Africa also use the same method of methane production (Walter & Dinesh, 2017).

Through conventional means, the process of anaerobic digestion has to happen in an anaerobic environment that lacks freely available oxygen. The use of anaerobic technologies of digestion has helped in the reduction of greenhouse gas emission by various ways;

- Replacing fossil fuels.
- Energy footprint elimination and reduction of waste plant treatments.
- Reduction of methane production in landfills.
- Displacement of chemical fertilizers produced in industries.
- Reduction of vehicle movement.
- Reduction of transportation losses in electrical grids.
- Reduction of LP gas usage in cooking.

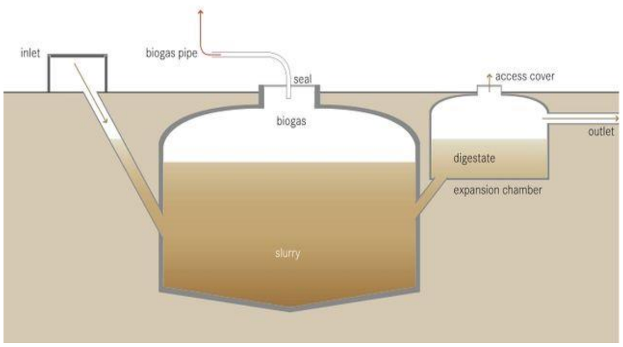


Figure 1 Schematic of a typical anaerobic digester

1.1 Important features for optimum production of biogas.

- C/N ratio
  C:N represents carbon to nitrogen ratio. Optimum digestion environment is enabled at 20 to 30:1 ratio. This ratio shows the 20 to 30 times use of carbon by the bacteria in digestion than to nitrogen. However, too much carbon slows down digestion to an eventual stop while too much nitrogen leads to exhaustion of carbon thus fermentation ceases (Stephan, Iris, Jochen, & Andreas, 2017). (Stephan *et al*., 2017)

- Temperature
  The reaction rate in the digester is affected by temperature. Reaction rate increases with temperature with the optimum temperature being around 350 – 380 ^{0}C. There is a reduction in gas production when the temperature hits 200 and stops when 100 is reached.
- Retention time.

This comprises of the theoretical time taken in the exposure of material in anaerobic reaction. It can be calculated as the digester volume being divided by daily added feedstock. The retention time is displayed in days. Anaerobic conditions slow down digestion hence longer durations incurred. Indian digesters entail demarcation in solid and liquid form due to dilution. Here, the biomass is washed out making the Hydraulic retention Time to be the same the Solid Retention Time (New, 2015).

- Loading Rate

  This is the total raw material amount that is fed into the digester on daily basis per unit volume. An occurrence of reactor overload means the acid accumulation is intended to be greater than later influences the production of biogas. If the digester is underloaded, there will be a negative influence in the gas production design.

- Toxicity

  There are small mineral quantities that include potassium, sodium that are key in stimulating the bacteria growth in the materials fed into the digester. On the other hand, toxic materials such as the heavy concentration of detergents and heavy metals negatively influence the process of digestion since they are toxic to bacterial growth.

- Solid content.

  Cow dung consists of around 80% amount of moisture. This leaves a portion of about 0% that is solid. The solid content needs to be in a ratio 1:1 making the solid content to be about 8% hence increasing the digestion of the materials.

- Nutrients.

  There are crucial nutrients that need to be present in a bio-digester. They include; O_2, C, N_2, H_2, S and P. P and N_2 are always inadequate in materials thus phosphorus rich materials are included.

2.0 MATERIALS AND METHODS

2.1 Bio-digester Design Concept

Materials and shape during bio-digester construction affect the design phase. Cylindrical shape was considered and mild steel that has a black coating that enables reaction prevention with the materials fed into the digester was used for the construction. In the digester, there should be an impeller or a mixer that facilitates the mixing of the contents as the digester temperature is taken to ensure a range of 32 – 45 ^{0}C all-round the materials. The principle of operation is like the conventional digester with the difference occurring in the monitoring of pressure in the digester (Benjamin, 2017).

2.2 Selection of Construction Materials

The construction of properly working digester structure requires a high cost of investment that shifts with the generational development and advancement of technology that entails improved material production. Also, the cost of materials has been lowered in the market recently. Materials used in the building of bio-digester depend upon the local and geological condition together with the materials that are obtainable for construction. Various materials have been used for this construction and they include polyethene and polyvinylchloride. One feature that needs to be considered in the selection of these materials is the lifespan. Considering the design of digester being used, the lifespan can be shorter such as the steel drum digester is susceptible to heavy corrosion thus reducing its lifespan (David, 2015).

2.1 Selection of Installation Site

Selection of installation sites are mainly governed by the following factors:

- The site selected ensured easy access.
- The site selected ensured easy operational activities like the feeding of the plant, composting and mixing of the cow dung to form the slurry.
- The site was selected to ensure the effective functioning of bio-digester. The right temperature of 20ºC – 35ºC was maintained.
- To mix the dung and water to the digester, a considerable amount of water is required. Hence, we decided to install a storage tank of 2.5 m^3 adjacent to the digester.
- The site selected to be close to the student's farm since part of the sludge was used as manure to the farm.

Figure 2 Installation and Experimentation site of the Bio-digester in Auchi Polytechnic Demonstration farm

4.0 RESULTS AND DISCUSSION

4.1 Design Considerations for the Fabrication of the Biogas Digester Plant

If the volume of the cylindrical tank is 8.0 m^3

$V = 8.0\ m^3$

And $V = \frac{\pi D^2}{4} H$

Let height, H = 3m, we can determine diameter

$$D^2 = \frac{4V}{\pi H}$$

$$D = \sqrt{\frac{4V}{\pi H}}$$

$$D = \sqrt{3.395}$$

$$D = 1.842\ m$$

The diameter of the tank is 1.842 m. Now we can now start designing the sections (Vgs, Vc, Vf, Vs).

We already have;

$$V_{gs} + V_f = 6.40\ m^3$$

The volume of the slurry $V_s = V - \left(V_{gs} - V_f\right)$

$$V_s = 8.0 - 6.40$$

$$V_s = 1.60\ m^3$$

$$H_s = Height\ of\ the\ slurry$$

$$H_s\ from\ V_s = \frac{\pi D^2}{4} H_s$$

$$H_s\ = \frac{4V_s}{\pi D^2} = 0.6004\ m$$

$$H_s\ = 0.6004\ m$$

That is the height of the slurry is $H_s\ = 0.6004\ m$

Volume calculated for hydraulic chamber

$$V_{gs} = 1.792\ m^3$$

$$V_f = 4.608\ m^3$$

$$V_d = 0.0827\ (D^3)$$

And D =1.842 m

$$V_d = 0.0827\ (1.842^3)$$

$$V_d = 0.516\ m^3 = 516\ litres$$

R_d radius of the dome = 0.725 D

= 0.725 (1.842)

$$R_d = 1.335\ m$$

Height of dome $h_d = \frac{D}{5} = \frac{1.842}{5} = 0.3684\ m$

$$h_d = 368.4\ mm$$

$$V_c = V_{gs} - V_d = 1.792 - 0.5168$$

$$V_c = 1.2752\ m^3 = 1275.2\ litres$$

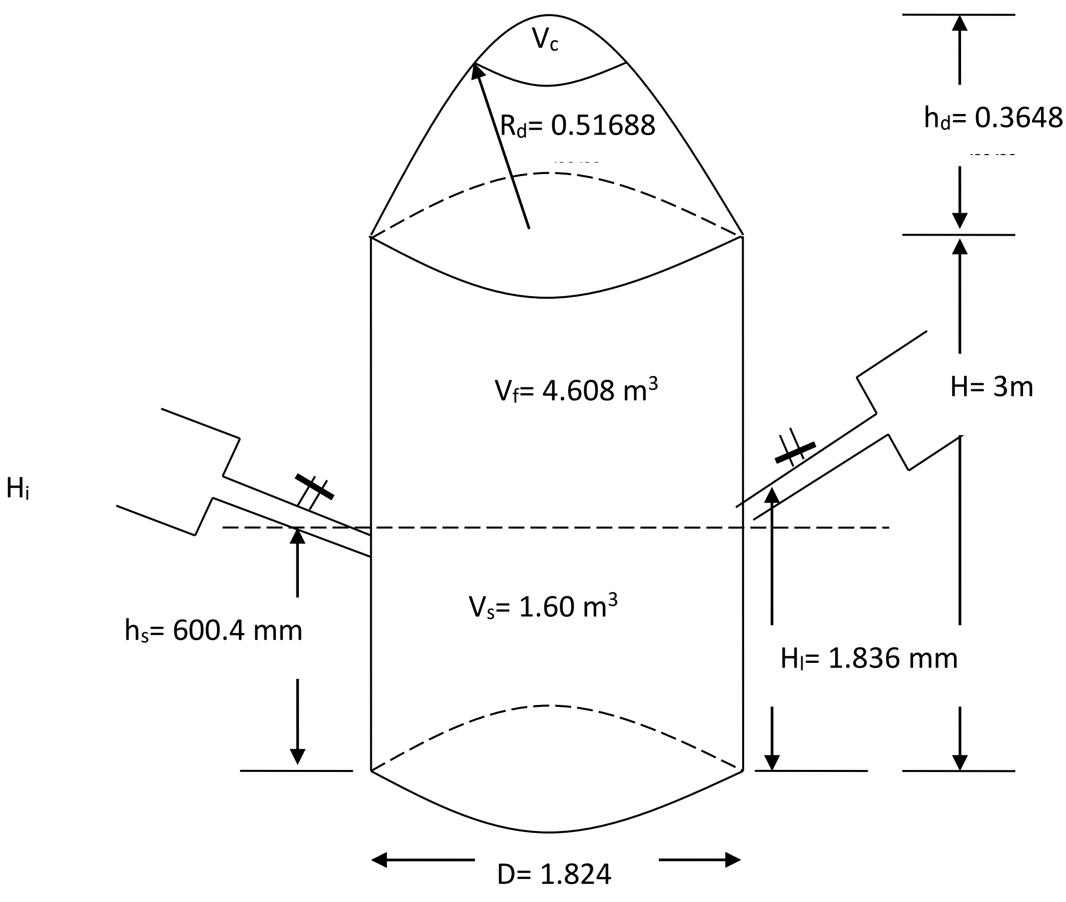
$$V_c > V_d$$

Radius of the dome, R_d= 0.725D = 0.725 (1.824)

R_d= 1.3224 m

Height of dome $h_d = \frac{D}{5} = \frac{1.844}{5} = 0.3684\ m$

$$h_d = 0.3684\ m$$



$$V_s = \left(\left(V_f - V_{gs} \right) - \left(\frac{\pi D^2 H_e}{4} \right) \right)$$

$$= \left((6.4) - \left(\frac{3.142 \times \ 1.824^2 \times H_e}{4} \right) \right)$$

$$1.60 = (6.4 - 2.613 \times H_e)$$

$$1.60 - 6.4 = -2.613 \times H_e$$

$$-4.80 = -2.613 \times H_e$$

$$H_e \ = 1.836\, m$$

1m^3/0.04 m^3 of cow dung = 25 kg of dung

i.e. 1 kg of cow dung yield 0.04 m^3 of biogas

x kg of cow dung yield 8 m^3 = 200 kg

Table 2: Plant size and daily feedstock requirement

Plant size (cm3)	Daily dung requirement/day (kg)	Quantity of water required (litres)
1	25	25
2	50	50
3	75	75
4	100	100
5	X	x
6	150	150
7	200	200
8	250	250

Source: www.agrimoon.com (accessed 22/10/17)

It is important to note that when the bio-digester is underfed gas production will be low, the pressure of the gas may not be sufficient to fully displace the slurry in the outlet chamber. Again, when excess material is fed into the digester and the volume of gas is consumed, the slurry may enter the gas pipes.

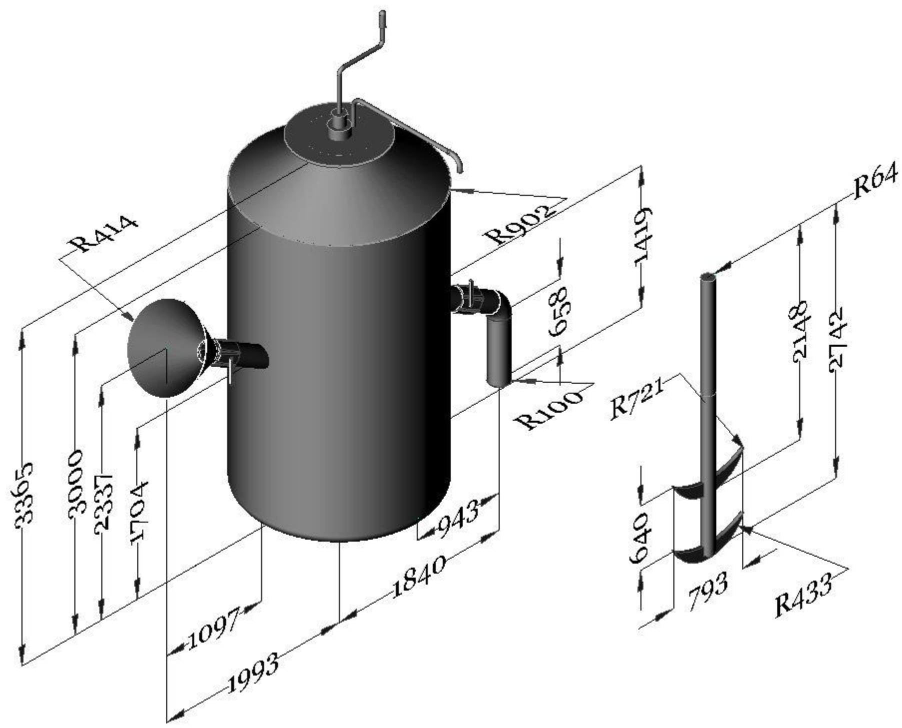


Figure 3: The 3D Detailed Dimension view of the constructed Bio-digester

5.0 Conclusion

The potential use, design, sizing calculations and development of bio-digester have been presented in this paper together with their review. There was a note regarding the limit in internal pressure regulation that enhances yield increase. Also, taking a consideration to choose relevant bio-digester that can be practical is a key consideration when designing. The design phase takes in factors such as geological conditions, required solid material in the digester, loading rate, toxicity and temperature (Publications, 2015). Also, materials for construction are also very important as they determine the lifespan of the digester.

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DEVELOPMENT OF A MOBILE SNAILERY

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ABSTRACT

Consumption of snails has been done for a long time by human beings. Snails have a high protein content that is about 12 – 16% and comes packed with iron too of around 45 – 50 mg/Kg. Snails have low-fat content and come with most amino acids required by humans. Taking the chance of snail mass production is an attainable goal since they can be produced by rearing in either small scale or the large-scale systems of production. This study, therefore,talks about fabrication and testing of mobile snailery, with the capability of simulating the snails' natural habitat. The mobile snailery is a housing system is developed in breeding different species of snails that can be carried anywhere hence, it is not stationary. Thus, it is mobile and can help create an artificial climate for the effective growth of the snails. Materials selection in the development of the mobile snailery, had required consideration of climatic, biological and physical factors that affect raising of snails. In the completion of fabrication, density affecting snail growth was tested and results were that high density reduced their growth over the three-month period. Adults were smaller, and eggs were fewer. Therefore, densely packed snails may never breed due to accumulated slime. Also, there is increased parasitism and disease transmission.

Key Words: *Artificial Climate, Fabrication, Housing, Mobile Snailery, and Snails*

1.0 INTRODUCTION

The recent times have shown a decline in the population of wild snails, an impact of anthropogenic factors coming from humans. Deforestation and exploitation of these animal species have led to a reduction of the species. Also, snails are being collected before reaching maturity. Snail trade is developing in North America, Africa and Europe. There is a need to improve snail mass production since they can be reared either in small scale or large-scale farming systems (Michael, 2017). Snailery (housing system) dimensions and types are considered by taking note of the growing system intended to be implemented and the snail quality that one intends to produce. The housing features in snailery systems can be intensive, extensive or semi-extensive. These features also vary in their financial input, complexity and management. Majorly, this study focuses on fabrication and testing of mobile snailery (Michael, 2017).

There is a need for a constitutional role of facilitating apolitical and economic environment that encourages investment. Such investments will facilitate youth involvement in many economic activities such as snailery farms. All that is required is patience, understanding and support by the government to develop such a project. Such an act can lead to thecreation of about 38,000 agricultural jobs. There is a big opportunity for youth investment for snail production due to its consumption by anyone interested and its nutrient properties (Bafs, 2015).

2.0 METHODS AND MATERIALS

2.1 Selection of Materials

Material selection takes in important factors that include the biological, environmental, physical and climatic requirements (Heinz, 2015). These factors are important since snails are characterized as cold-blooded hence can sense atmospheric changes in temperature and humidity. A number of building materials can be used in the construction of snailery as seen in figure 1. Materials involved are affected by their availability and price. Such materials are ;

- Mud bricks or concrete blocks.
- Polythene sheets or galvanized sheets.
- Nylon mesh or mosquito nets.
- Termite and decay-resistant timber.
- Second-hand oil drums or tyres.

Since the selection of materials is influenced by some factors, these are the factors that led to the choice of material used in building the proposed snailery (Bafs, 2015);

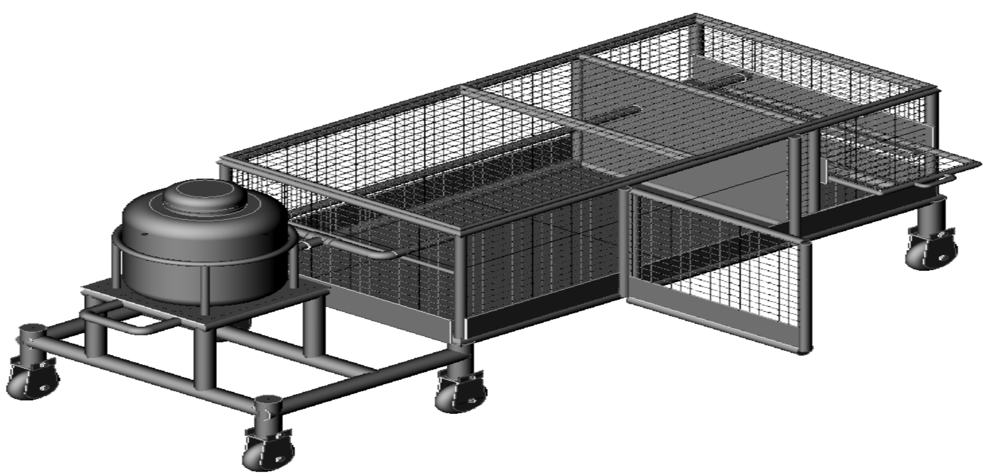

Figure 1: Isometric view of the mobile snailery

2.2 Climatic Factors.

There is an intended development of artificial climate by using a well-aerated wire mesh, provision of good feeding and delivery of water in the proposed snailery ensuring breeding and growth of snails at any given month of the year. Materials that can be used to implement this can be of bamboo, PVC, sand and wire mesh. A general view is to develop a mobile snailery that can use materials helping in the creation of artificial climate leading to the successful commercial production of snails.

2.3 Physical Factors.

- **Space**: Snails have various growing stages in their lives. Stages include hatchings to juveniles followed by breeding snails and lastly the matured that can be fattened to facilitate consumption. Overcrowding in any of these stages leads to the risk of diseases thus an appropriate rearing density is > 100m^2 in hatchings and about 10 m^2 in breeding snailsReference.
- **Escape roof**: snails can escape when given any slight opportunity hence there needs to be a preventive factor that keeps them under control.
- **Security**: predator, poachers as well as insects need not get access to the snails being reared.
- **Accessibility**: the snailery has to be easily accessed and can be worked with or in easily. This ease placing of feed, snail handling and cleaning tasks (Austin, 2015).

2.4 Environmental Factors

Environmental factors include temperature. Giant African Snail areverya sensitivity to temperature as this could make them dormant if not appropriate. Dormancy involves retraction of the whole body of the snail into the shells and sealed off to prevent water loss. The temperature that is higher than 30^{0}C and humidity lower than 75% make snails aestivate while temperature lower than 5^{0}C leads to hibernation thus affecting their growth. Hence materials such as bamboo can simulate environmental and climatic conditions required for snail growth.

2.5 Mobile Snailery Size

The dimension of the proposed snailery to be built is affected by the quality of snail production and the size of snails and stages of growth. The rearing densities for snailery are > 100 m^2 in hatchling snailery and about 10 m^2 in breeding snailery (Bafs, 2015).

1. **Construction Layout**

The housing system involves welding of any metal joints. The snailery intended to be fabricated is the intensive system and needs to have control over the climate creating artificial climate simulating the natural snail habitat. At the base, there are four rollers that support and allows movement (Fund, 2006) . More materials used include;

- Perforated galvanized sheets (fully coated and painted for avoid corrosion) that will carry the breeding soil.
- Polythene sheets that cover juvenile snails.
- Water drum as a primary water source.
- PVC pipes to supply water by drip irrigation.
- Wire mesh for protection of the snailery.
- Roller tyres for snailery mobility.

This snailery has taken in the following general considerations;

- Maintenance of adequate humidity by drip irrigation.
- Safety of the snailery from weather conditions and predators.

3.0 RESULT DISCUSSION

In the completion of fabrication, density affecting snail growth was tested and results were that high density reduced their growth over the three-month period. Adults were smaller, and eggs were fewer. Therefore, densely packed snails may never breed due to accumulated slime.Also, there is increased parasitism and disease transmission. Snail weight was proposed to be about 1.5 kg per m^2. Plate 1 and 2 below show snails in the mobile snailery (Robert, Rebecca, & Norine, 2015). Robert *et al*., 2015

Plate 1: Mobile snailery with snails

It is advisable for snail farmers to begin with less dense snailery as they get more familiar with their habitat. The density can be increased with the experience attained.

4.0 CONCLUSION

The work herein is the development of a mobile snailery, Snail meat has been consumed by humans worldwide since prehistoric times. It is high in protein (12-16%) and iron (45-50mg/kg), low in fat and contains almost all the amino acids needed by humans. The aim of this research is to draw the attention of public intellectuals, unemployed youths, and government to the excellent economic, nutritional and social attributes of snails, which can reduce to some extent the country's malnutrition, undernourishment problems, the roles it plays in the medical and pharmaceutical fields. In the fabrication of this housing system, the electrical arc-welding system was used during the metal joining stages. Also, we have decided to fabricate the snailery to be an Intensive system, this is in a bid to control the climate or create an artificial climate system that simulate the snails original natural or living habitat. The Snailery is supported at the base by four roller tyres that allow for the movement of the snailery to any location to simulate their natural environment. This snailery is therefore recommended to snail breeders and also for mass production and youth empowerment.

5.0 RECOMMENDATION

Mature snails that can reproduce are preferable and should weigh 100 – 125 g each. The best starting point of snail farm is in the wet season as it is the breeding time. Obtaining snails can be from the wild or bought during peak season when they are cheap (Heinz, 2015). The snails are then to be fattened and produced until the snailery is sustainable. The collection is best done at night or cloudy or foggy weather since they are most active during these times. An expected high mortality level is characteristic of purchased snails due to adjustment to various conditions hence it is advisable to purchase snails from well-known breeders.

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DEVELOPMENT AND EVELUATION OF A MILLET DESTONER

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ABSTRACT
Post-harvest processes of millet rely on labour-intensive manual operations in Nigeria while its end-products is associated with contaminants. A manually-operated destoner was developed and evaluated to add grain value for commercial production and reduce drudgery involved. Grain geometric diameter increases progressively from 3.51-4.22mm as moisture content increases. Screen aperture was determined a 3.5mm. Grains' surface area, volume and sphericity increased from 22.67-34.82mm², 8.19-13.98mm³ and 0.691-0.776g respectively. Mass, true density and terminal velocity of 1000 seed increased from 13.56-43.84g, 1548.91-1689.87kg/m³ and 2.69-4.58m/s respectively. The bulk density of millet increases as moisture content increased but decreases beyond 12.5% moisture level indicating that millet floats can be transpoted with the aid of an auger. 50kg of milletegrai filled the destoner when ⅔ of its capacity was filled with water. Destoner output was $3.00t/h$ *at 95% efficiency.This could free processor's time to pursue alternate activities and save cost and time in millet processing.*

Keywords: *Destoner, Millet, Processing, Properties*

1. INTRODUCTION

Pearl millet (*Pennisetumglaucum*(L.) is a tropicalcereal indigenous to Africa. Millet is one of the oldest foods known to humans and possibly the first cereal grain to be used for domestic purposes.It is uniquely adapted tocultivation in dry and harshenvironmentalgrowing conditionsin sub-Saharan Africa. Millet constitues a major source of energy and protein for millions of people in Africa and Asia.Itis highly nutritious, non-glutinous and is not an acid forming food. It is also soothing and easy to digest. Millet is tasty, with a mildly sweet, nut-like flavor and contains a myriad of beneficial nutrients. Itconsists of about 15% protein and contains high amounts of fiber, B-complex vitamins. Millet serves as a major source of beverages (such as *kunu*and*siro* - Hausa) in many countries including Nigeria. About 400 million people rely on millet world wide for their survival.Millet is also used as feed for poultry, swine, fish and livestock, Hulse, (1980); Kent, (1983) and Raily, (2006).
Traditionally, millet panicles are threshed by pounding the harvested heads in a mortar and pestle action in ahollowed out log (*Turmi*, in Hausa) or on the floor. The grain is separated from the chaff by winnowing.Sometimes the heads are pounded on a cemented floor. Storage is then followed depending on the needs of the farmer. These methods of threshing produces a mixture of broken and sound grains mixed with sand and pebbles thereby predisposing the millet to high

vulnerability to poor quality of finished products due to contamination with dirt's, stones and other impurities. Women are primarily responsible for the labour-intensive and time consuming post-harvest processing operations. Because of its enormous utilization in sahelian Africa and other Asian, a device (the destoner) that is capable of removing these contaminants was designed, constructed and evaluatedto reduce, if not eliminate, drudgery associated with the traditional processing methods in orderto improve the health and economics of millions of families relying on it for food and also for commercial processing.

2. MATEIALS AND METHODS

Materials required for the construction of the destoner include a 200 litre iron drum; gauge 12 galvanized steel plate for the construction of the perforated seive, auger and grain outlet; 25 X 25 angle iron for the frame; 10 mm Ø mild steel rod for constructing the main shaft and the crank handle; and a piece of wood that would be used to cover the handle, (Appendix I). However, before undertaking the design work, many factors are taken into consideration. It is recognised that millet has a very unique characteristics, particularly its tiny size (less than 4mm) and colour, as such it becomes necessary to properly study these charateristics before designing the thresher.

2.1 Determination of physical properties of millet

To construct the destoner sieves, physical properties of the millet grains were determined. These propertiesinclude; shape, size, and moisture content. The physical dimensions of one thousand randomly selected grains were determined.It was considered that this would be adequate to give the sample mean that would be very close tothe entire population mean. Their dimensions were measured with precision digital Verniercallipers thatmeasure to the nearest 0.01. Since millet is relatively round in shape, the principal axis of the grain considered was its thickness (diameter) as suggested by Mohsenin, (1986); Oje, (1993); Olaniyan, and Oje, (1999); and Firouzi, Vishgaei, and Kariami, (2009). This was used to calculate the various aperture sizes ofthe sieve of the destoner as suggested by Mohsenin, (1986) and Galedar, *et al*. (2008).

2.2 Description of the Millet Destoner

From the results of physical properties of the grain determined in 2.1, a millet destonerwas designed and constructed. The following are the descriptive structure of the main componenets of the destoner as shown in Figure1:

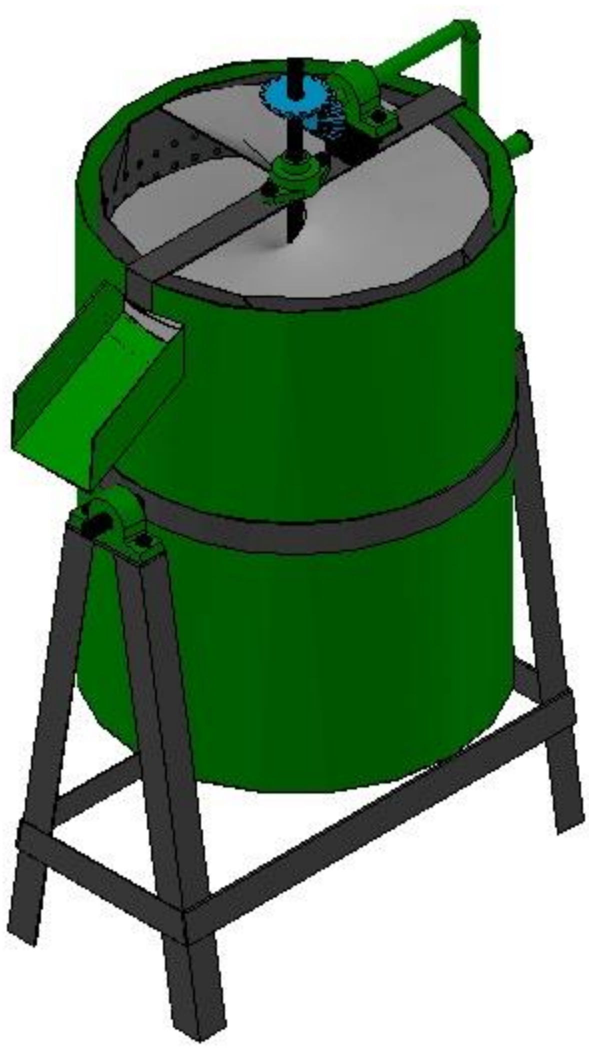

Figure 1: Pictorial view of the Millet Destoner

2.2.1 Main Drum

Thedrum serves as the main component of the destoner. It houses the entire destoning components. For ease of construction, it was made from 200 litresiron drum that could be accessed in almost every rural community where millet is produced. Its diamentions are 600mm diameter and 800mm hieght. The upper portion is completely cut off for ease of inserting the inner components. Atthe extreme top end is a discharge outlet to enable clean millet exit, while at the lower part a discharge tap was fixed for draining water used in the destonning/cleaning process.

2.2.2 Perforated Drum

Closely alligned with the main drum is a perforated drum. It is made of galvanised steel 540mm diameter. It was welded with shaft and perforated with tiny round holes of 3.5 mm diametre to allow stones and other contamimants pass through and discharge at the lower outlet by gravity. The actual separation of millet and contaminants takes place here since the millet grains to be separated are poured in this compactment. The perforated drum is coated to avoid corrosion since water is used as the transport medium.

2.2.3 Auger

The auger is the spiral component that was welded to the main shaft of the destoner. It is made with 5 mm thickness galvanized steel. Its function is to transport millet from the the bottom of the destoner to the discharge outlet. Its agitation also aids removal of other contaminants that might have been carried along with the millet.

2.2.4 Crank Handle And Main Shaft

The crank handle is the component through which rotary power is transmitted to the destoner through a set of driving gears to main shaft. The shaft is made of mild steel rod of 10 mm diameter. It is 850 mm longand 10 mm diameter. The handle is covered by a wood to provide comfort for the operator. The auger is welded to the main shaft, thus providing the motion needed for the separation. The assembly is supported by a flat bar mounted on top of the main drum.

2.2.5 Frame

A tilting support that serves as a frame was fixed at the bottom of the main drum such that the it could be turned to a convienient position to discharge the water and contaminants at any given time. It is 700mm high and 300mm from the datum to accommodate a retainer for water drainage. The isometric view of the destorner is shown in Appendix II.

2.2.6 Power Source

The source of power for the design is basically the human operator (human power). Because of the low scale production of the millet farmers as well as their poor economic situation, the cheap and availability of manual labour particularly at the village level of rural Nigeria that has an army of unemployed youth, the manual source of power is choosen for this design.

The normal output of human operator is about 0.075kW which may be reduced to 0.022kW when working continously(Akinsanmi, 1975). Therefore, the power unit considered is capable of operating the destoner successfully for a maximum of 5hrs a day. However, with increased poduction capacity of the farmer, the destoner output could be increased by providing motorized/mechanical source of power. This could be done by removing the manual handle and attaching a pulley on the shaft such that power could be trasmitted from the prime mover via a belt.

2.3 Determination of destoner output

Agricultural equipment’s performance is measured by the rate and quality at which operations were completed. Performance could also be measured by damage to product due to machine’s operation. Such performance was determined in terms of machine capacity and throughput capacity. Throughput capacity of the machine is the total mass of the material that passes through the grader at a particular time. The mass includes kernels, chaff and straws that enter the grader. It is given by:

$$C_{tp} = W_p \left(\frac{kg}{min}\right) \times \frac{1}{1000}\left(\frac{t}{kg}\right) \times 60 \left(\frac{min}{h}\right) \qquad 1.0$$

where:

$$C_{tp} = \text{throughput capacity of the grader, kg/h}$$
$$W_p = mass \text{ of groundnut in} - \text{shell to be graded, kg}$$

Mechanical efficiency measures the effectiveness of the destoner in separating the foreign materials from the millete grains. It is measured as a ratio of the measured performance to the ideal performance of the destoner:

$$Efficiency = \frac{Measured\ Performance}{Ideal\ Performance} \qquad 2.0$$

2.4 Principles of Operation of the Destoner

Thedestoner (Figure1) was designed to be operated by two people. While one cranks and operates it via a handle, the other feeds in the millet grains through the upper portion of the destoner as well as collects the cleaned grains from the discharge outlet. The grain fed into the perforated drum filled with water to about ⅔ capacity fall by gravity towards the bottom of the rotating auger. While rolling on themselves, the grains are progressively carried upwards as the crank handle is being agitated. Heavier contaminants such as stones and metals would sink down by gravity since their respective densities were more than that of water, the transport medium.

Similarly,contaminants such as animal excreta would be washed off and/or dissolved in the water, thus further cleaning the grains. Whlie agitation and upwards movement of the grains continues, tiny stones and similar contaminants are forced out of the inner drum through its perforations and were returned to the base of the main drum. As the process continues, clean grains that reaches the top of the augerwere collected through the grains outlet. The outlet is fitted with a stopper that regulates and control grain discharge. Finally as the operator is satisfied that the grains have been cleaned and discharged from the system, the run-off tap at the lower part of the main drum would be opened to discharge the contaminants and the dirty water.

3. RESULTS AND DISCUSSION

3.1 Physical properties of millet

The physical properties of millet have been evaluated as a function of grain moisture content varying from 8, 10 and 20 % as suggested by Baryeh (2001). Graingeometric diameter increase progressively from 3.51– 4.22 mm; this means loss of grains through perforated openings of 3.5mm diameter would be minimal.Simlarly,the grains' surface area, volume and sphericity increased from 22.67 to 34.82 mm², 8.19 to 13.98 mm³ and 0.691 to 0.776g respectively. The 1000 seed mass, true density and terminal velocity increased from 13.56– 43.84g, 1548. 91– 1689.87 kg/m³ and 2.69 to 4.58 m/s respectively. The bulk density of millet was noted to increase as the grain moisture content increases but decrease beyond 12.5 % moisture levelindicating that millet could float and be easily transpoted upwards by water as the transport medium with the aid of the auger.

3.2 Destoner Output

50 kg of millete was then found to be ideal for filling the destoner when ⅔ of its capacity was filled with water. Therefore, from equation (1), the destoner output was determined as:

$$C_{tp} = 50 \ \times \ \frac{t}{1000} \ \times \ \frac{60min}{h} \ = \ 3.00\, t/h \ = 3{,}000\, kg/h$$

3.3 Mechanical Efficiency of the Destoner

By its design, 50 kg of millet was was supposed to be the capacity of the destoner⅔ of its capacity was filled with water. To measure its performance, 40 kg of millet was mixed with 10 kg of stones and were introduced into the destoner to be cleaned or destorned. At the end of the exersice, 38 kg of millet was recovered. The efficiency of the destoner was, thus determine as (from equation 2.0):

$$Efficiency = \frac{38}{40} = 95\%$$

4. CONCLUSION

The design, development and evaluation of a millet destonerhas been successfully carried. The device would be capable of washing, cleaning and separating grains from dirts,stones and other contaminant thereby increasing the quality of millet grains as well as reducing the drudgery involved in traditional methods of cleaning of the grain. It is expected to clean about 3,000kg/hr. All materials used are locally sourced, while device is portable for ease of transpotation from one field to another.

Millet destoning is crucial because of its potential to regain and increase rural earnings. Such improvements alsoguarantee sustainability of its farming systems in Nigeria and many producing countries in West Africa where it plays a key rolein their agriculture-dependent economies. This will impact on rural employment, trade and purchasing power forsmallholder farming families, strengthen the economic capacity of women and improve household nutrition. Development of the technologywould also facilitate processing of the grain and would have asignificant impact in freeing women's time to pursue alternative family or entrepreneurial activities and would provide cost savings to existing grain processors and convenience to other millet-related food processors.

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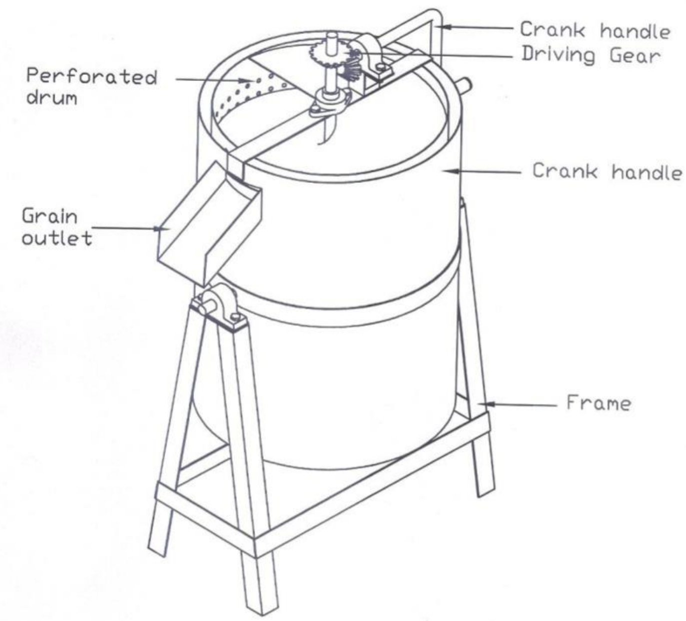
APPENDIX I

MATERIAL REQUIREMENTS

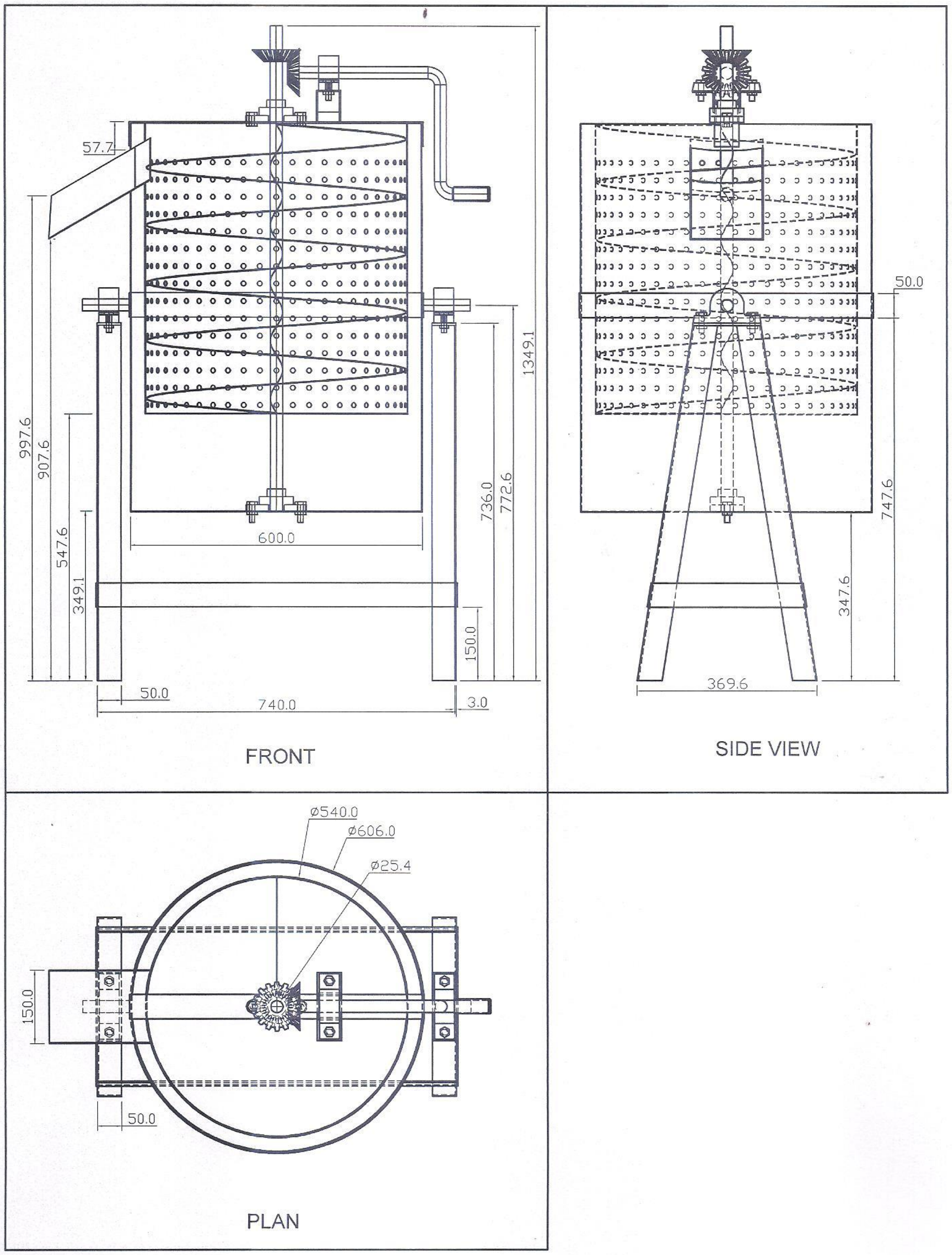
S/N	Part Name	Material	Specifications(mm)	Qty
1.	Main Drum	Oil Drum	200litres capacity	1
2.	Perforated Drum	Mild Steel	540 x 600	1
3.	Frame	Angle Iron	25 x 25	½length
4.	Crank Handle	Steel Rod	Ø10	1
5.	Main Shaft	Steel Rod	Ø15	1
6.	Auger	Mild Steel	50 x 600	1
7.	Grain Outlet	Mild Steel	100 x 200	1

APPENDIX II

ISOMETRIC AND OTHORGRAPIC PROJECTIONS OF THE DESTONER



ISOMETRIC PROJECTION



ORTHOGRAPHIC PROJECTION

DEVELOPMENT OF MANUALLY OPERATED TOMATO SLICING MACHINE

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ABSTRACT

A manually operated tomato slicing machine was designed, fabricated and tested. The machine was developed based on the slicing principles applied of fresh fruits and the average force exerted by the human hand. It is intended to add value to ripped tomato by slicing and exposing the water cells for easy drying in a dryer on an industrial scale. The sliced dried tomato chips gotten were packed for storage in order to improve its shelf life. The performance evaluation of the fabricated machine was carried out and found to be efficient in slicing the tomato. The machine was made to cut tomatoes in 2cm thickness. The slicing capacity, feed rate and slicing efficiency of the machine were determined to be 5.41 kg/min, 3.12 kg/min and 95.46 %, respectively.

KEYWORDS: *Design, development, tomato, slicing, knives*

1.0 INTRODUCTION

Tomato (Selenium lycopersicum L.) is a fleshy fruit that belongs to the family "Solanaceae". It is second to potato as the most widely grown horticultural product in the world, in terms of area and the first in industrialized volume (Nadia *et al*, 2014). Tomato is grown in practically every country of the world in outdoor fields, green houses and net houses. It is said to have originated from western South America, and domestication is thought to have occurred in Central America (Oriaku*et al.* 2014). It is grown principally for its fruit which vary in shape, size and colour. The round red-fleshed tomato predominate in the fresh vegetable markets, but the red- and yellow-fleshed, plum (roma), cluster, cherry, grape, and mini-pear types are also available.

Tomato is an important vegetable crop that is essential, nutritionally as a fruit or vegetable for its vitamin. It is a tasty and an important condiment in most diets as it serves as a good source of vitamins A and C. Kamaldeen and Awagu (2013) reported that tomato is believed to; benefit the heart among other organs; help in maintaining the capillaries, bones, teeth; and aid in the absorption of iron. Tomato also contains carotene lycopene, one of the most powerful natural antioxidants.

China is the world's top grower, accounting for more than one-quarter of the world's tomato acreage (FAO, 2017). Nguyen and Nguyen (2015) reported that Egypt and India together account for more than one-fifth of the world total, while Turkey and Nigeria are the other major tomato producing countries. The crop is grown on more than 5 million ha with a production of nearly 129 million tones. In Nigeria, tomato is cultivated in a large proportion with about 70 to 80 % production from the northern part of the country. Oriaku*et al.* (2014) reported 6 million tones as the annual production level in Nigeria.

Tomato is a climatic fruit that have a short shelf-life under ambient storage conditions. Large wastages are usually incurred during its harvesting, handling, transportation and storage processes. Oyeniran (1988) reported that as high as 50 % of the produce are lost between rural production and town consumption in the tropical areas. The seasonality of the produce also causes scarcity of the fruit immediately the harvesting season is over. Tomato is processed into a range of products, such as concentrated juice and pulp, which needs high cost technology for good quality products. Therefore, development of low cost processing methodologies to produce shelf-stable convenient products is the prime requirement of the present competitive market. Nadia *et al* (2014) reported that drying is the most suitable method to fulfill the above requirements. Dried tomato products are used as important ingredients for pizza, various vegetable condiments, spicy dishes and the increasing interest in the antioxidant carotenoid. Dried tomato could, furthermore, be milled to dust and packaged as grounded dried tomato for easy cooking.

1.1 Statement of problem

Tomatoes are best dried when sliced and slicing of tomatoes had been considered difficult operation as it is done manually. The essence of drying is to expose the water cells of the tomato fruit for easy drying (Oriaku*et al.*, 2014). The manual means of slicing tomatoes is energy and time consuming and off course prone to injury when not done carefully. There is, therefore, a need to develop a tomato slicer that would be capable of slicing hundreds of tomatoes at a time, thereby conserving human energy, reducing time spent in slicing, providing safety to the users and serves as a source of income to individual.

1.2 Objectives

The objective of this work is to design and evaluate the performance of a tomato slicing machine as one of the equipment that will facilitate the drying of tomato in order to reduce wastage incurred during harvesting period. The research also aim at providing conditions necessary for preserving tasty tomato fruits over longer periods in order to take care of the scarcity of the particular fruit.

1.3 Significance of research

i. The tomato slicing machine is important because it will reduce the drudgery and time in slicing tomato manually.
ii. The simplicity of operating the machine, will make it user friendly.
iii. Dried tomato sliced will reduce scarcity of the fruit existing after the harvesting season due to the produce's seasonality.

2.0 MATERIAL AND METHOD

2.1 Description of machine

The machine has a height of 1100mm, length of 1000 mm and width of 450 mm. The size, weight and volume of the machine were considered for easy loading (by an average of two people, manually) into a tractor trailer and other similar transportation facilities. Tomato is fed into the sliding compartment of the machine for cutting through a small sliding lid at the top of the compartment. The sliding compartment is a rectangular formation of 18,000 cm^3, volume and circular bars (quarter rods) were used on the to- and fro- sliding sides of the chamber to guide the tomato from moving outside the movable volume. It is mounted on the outside of the main casing via grooves and bearings for easy sliding. The set of knives are arranged 2 cm apart, parallel to the direction of sliding. The knives are inclined gently at a slope of 15^0 in the same direction with the top cover of the sliding compartment. The groove is also inclined at 15^0 in an opposite direction to enable a travel distance that ends where the top of the compartment get in contact with the set of knives.

2.2 Design Consideration

The design of the tomato slicing machine is based on the following consideration.

- The safety of the operator.
- Average human effort exacted by hand.
- Ease of feeding tomato into the hopper.
- Degree of ripeness of tomato
- Sharp and serrate nature of the knives, and
- The simplicity and Cost of the machine for small and medium scale farmers.

2.3 Machine Component Design

The machine parts were fabricated and assembled based on design (Figures, 1 and 2) in the prototype workshop of the Department of Agricultural and Bio-Environmental Engineering Technology, NuhuBamalli Polytechnic Zaria, Samaru-Kataf Campus. Table 1 presents a description of the machine components while Plate 1 and 2 gives a photographic view of the machine during the testing process in the workshop and the samples of the sliced tomato by the machine. The main components of the machine include; the structural frame, main casing, sliding groove, sliding compartment (feed hopper), ball bearings, strips of circular metal bars, discharge spout, and set of stationary knives.

i. Sliding compartment

The sliding compartment has a height of 25cm, breadth of 18cm and length of 40cm as its outer dimension and a height of 23cm, breadth of 16cm and a length of 38cm as its inner dimension. The compartment weighs 5.91N and its total and hopper volumes are determined using equation 1 as:

$$Volume = length\ x\ breadth\ x\ height \qquad (1)$$

$$Total\ volume \quad = 40\ x\ 18\ x\ 25$$

$= 18{,}000cm^3$

$volume$ of hopper $= 38\ x\ 16\ x\ 23$

$= 13{,}984cm^3$

ii. Bearing

Two (2) ball bearings with bearing number of 200, bore diameter of 10 mm, outside diameter of 30 mm and 9 mm width were used to securely hold to the groove and ensure one directional, to-and-fro movement of the sliding compartment. The dynamic equivalent radial load (W) for the roller bearing under combined radial and axial loads is obtained using equation 2 as given by Khurmi and Gupta (2005).

$$W = XVW_R + YW_A \qquad (2)$$

where:

$W =$ Equivalent dynamic radial load

W_R = Radial load (average human effort exerted by the hand is 12.38N),

W_A = Axial load (weight of sliding compartment = 5.91N

$V =$ Inner ring rotation factor = 1

X = Radial load factor = 0.56

Y = Axial load factor = 1

iii. Knives

Twenty (20) stationary knives made of mild steel of 1050mm, length; 4mm, thickness and 15mm, width were used for the cutting/slicing action. The knives are inclined at an angle of 15^0 on the main casing.

iv. Structural frame

The supporting structure is made of 1.5" x 1.5" angle bars of 4 mm thickness and mild steel sheet of 1.5 mm thickness is used for the metal casing. The structural materials wasselected based on the required strength and available standards.

Table 1. Description and Specification of Tomato Slicing Machine

S/N	**Description and specification**	**Quantity**	**Material**
1.	Hopper (250 x 180 x 400mm)	1	M.S. sheet (Gauge 18)
2.	Bearing (Ø10 inner & Ø10 outer)	2	
3.	Knives	20	M.S. sheet (Gauge C40)
4.	Frame (15 x 15 x 4mm angle iron)	1	M.S Angle iron
5.	Bolt (Ø10mm)	16	M.S. sheet (Gauge C30)
6.	Casing (1000 x 500 x 480mm)	1	M.S. sheet (Gauge 18)
7.	Steel rod (8x 400 mm)	18	M.S. sheet (Gauge 18)
	Scale		
	1:5		
	Dimension in mm		

v. Human effort by hand

Kamaldeen and Awagu (2013) reported that the average human effort exerted by the hand is 12.38N. This research hence, adopts the value as the average effort required to move the sliding compartment.

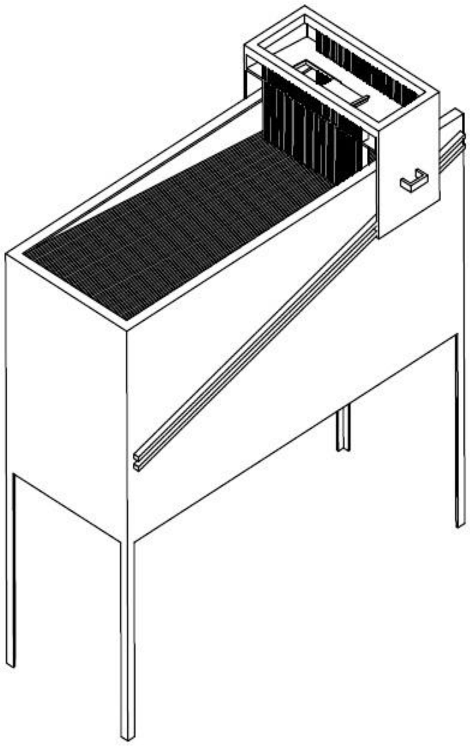
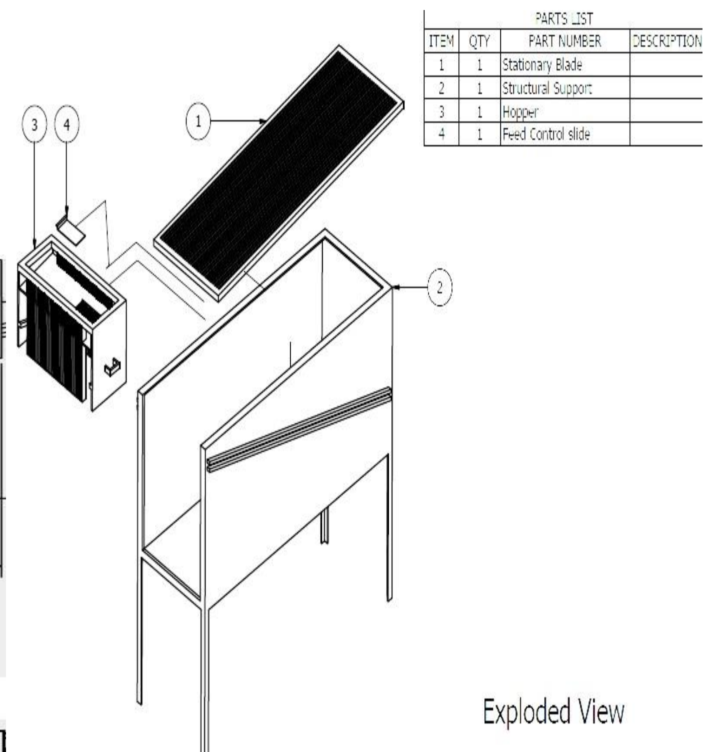


Figure 1: Isometric and Exploded views of the slicing machine



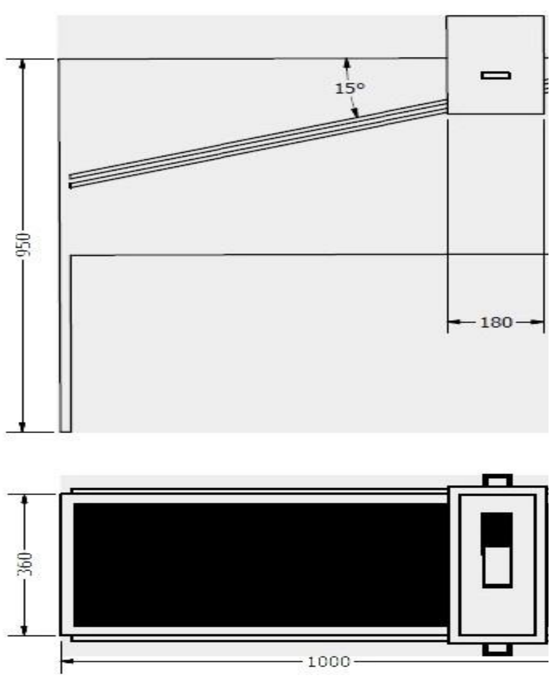


Figure 2: Orthographic view of the slicing machine

2.4 Principle of cutting (slicing)

The application of impact force to slice tomato would result to shattering or shredding of the product rather than smooth cutting or slicing. Shearing action is, therefore preferable using a knife or set of knives. The knives for cutting could be stationary or translational or rotary motion. Kamaldeen and Awagu (2013) reported that slicing could be achieved in any of the following ways:

i. A knife moving against a stationary one while getting the food cut in-between.
ii. Two knives or cutting elements moving in opposite directions against one another and thereby getting the food item sliced in the process.
iii. A knife moving against a stationary part of the machine.

3.0 PERFOMANCE EVALUATION OF MACHINE

The test was conducted by feeding several quantities of measured tomato into the machine at a given time. The feeding and slicing times (periods) were observed, measured and tabulated. Ishaya (2013) reported that about one (1) hour is required to slice an average of 480 tomato (2.2 kg) manually, into 2cm sliced cuts. Testing was done with varied loads of fresh tomato of weights; 2.0, 4.2, 5.6, 7.1 and 10.0, 12.3 kg, respectively, which were replicated five times each. The standard error for the replications was obtained.

4.0 RESULTS AND DISCUSSION

The results obtained from the performance evaluation are shown in Table 2.

Table 2: Results obtained for machine performance

S/N	Weight of Tomato (kg)	Feed time (min)	Feed rate (kg/min)	Slicing time (min)	Slicing rate (kg/min)
1	2.00 (0.001)	0.8 (0.002)	2.50 (0.002)	0.31 (0.001)	6.45 (0.002)
2	4.20 (0.001)	1.4 (0.002)	3.00 (0.001)	0.78 (0.002)	5.38 (0.003)
3	5.60 (0.003)	1.9 (0.001)	2.95 (0.002)	1.02 (0.001)	5.49 (0.001)
4	7.10 (0.002)	2.5 (0.002)	2.84 (0.003)	1.54 (0.003)	4.61 (0.001)
5	10.00 (0.001)	2.8 (0.001)	3.57 (0.002)	2.01 (0.001)	4.98 (0.003)
6	12.30 (0.002)	3.2 (0.001)	3.84 (0.001)	2.21 (0.001)	5.57 (0.002)
Total	**41.20**	**12.6**	**18.7**	**7.87**	**32.48**
Mean	**6.87**	**2.10**	**3.12**	**1.31**	**5.41**

The results from Table 2 indicates the weight of test samples, feed rate, slicing time and the slicing rate obtained. The standard error obtained by varying the weight are within acceptable limit. The result shows that an average of 1.31 minutes is required to slice 6.87 kg of tomato and about 2.10 minutes to feed the same quantity of tomato into the machine. The mean feed rate and slicing rate using the machine are 3.12 kg/min and 5.41 kg/min respectively. Ishaya (2013), reported a machine capacity of 5.25 kg/min and machine performance efficiency of 89.6 %, for a manual tomato slicer while Kamaldeen and Awagu (2013) reported 540.09 g/min and 70 % as the machine capacity and performance efficiency respectively for a manual tomato slicing machine they developed. Oriakuet. al. (2014) obtained 2.04 kg/s and 1.5 kg/s as the feed rate and slicing rate, respectively for a motorized slicing machine.

The slicing efficiency of the machine was determined three time using 10.5kg mass of tomato each. The average number of neatly sliced tomato and the average total number of slice cut from the three cases was obtained and the efficiency of sliding determined using equation 3 as:

$$Slicing\ efficiency = \frac{Average\ number\ of\ neatly\ sliced\ tomato}{Average\ number\ of\ total\ sliced\ tomato}\ x\ 100 \qquad (3)$$

$$= \frac{463}{485}\ x\ 100$$

Slicing efficiency = 95.46%

Plate 1: Samples of tomato and slice cuts

Plate 2: photographic view of the machine during the testing process in the workshop

5.0 CONCLUSION

The machine was designed, fabricated and tested. The feed rate, slicing rate and the efficiency of slicing using the machine were obtained as 3.12 kg/min, 5.41 kg/min and 95.46 %, respectively.

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DEVELOPMENT OF A PEDAL POWERED BREADFRUIT DEHULLER

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ABSTRACT

A pedal powered breadfruit dehuller was developed to obviate the drudgery, low capacity with high energy demands, and the high cost associated with manual dehulling, hand operated, and motoriseddehullers, respectively. The physical and mechanical properties of breadfruit were considered in designing various components of the dehuller. The minimum man-power and ergonomics of the machine were also considered for smooth operations and good working condition. The effects of moisture content and pedalling speed were parameters used in evaluating the performance of the machine. Tests results showed that the machine capacity of 17.5, 9.3 and 4.16 kg/h were obtained at 65, 60 and 55 rpm average speeds, respectively. The best dehulling results were obtained at 6.5%mc (dry basis) and pedalling speed of 65 rpm.

***Keyword**: Breadfruit, dehuller, pedal-power, ergonomics, machine efficiency*

1.0 INTRODUCTION

African breadfruit (*Treculiaafricana*) is a food plant that is native to west and central Africa. It belongs to the genus Treculia and the family of Moraceae. The tree provides raw materials for industries, food for human and animals (Nwaigbo*etal*., 2008). African breadfruit has a spongy texture that is filled with seeds and the fruit is spherical in shape. The seeds are enclosed by the hull which must be removed before consumption. The hull is used in feeding domestic animals like goats. The potential of breadfruit has not been fully harnessed, and part of the problem of under-utilization of the crop is because the manual processing of the seed produces a low yield and increases the cost of processed seeds. Among the postharvest operations, dehulling remains pivotal in the processing stage. Dehulling is the removal of the hull from the grain. African breadfruit dehulling is mainly carried out in farming communities by women and children. It requires a lot of time and energy to accomplish. Dehulling is usually done utilizing human power (manually, hand operated dehuller, pedal operated dehuller) and motor power. Manual dehulling has been discouraged (Ajav and Mogekwu, 2015) because of drudgery and low output despite high energy requirement. Motor powered dehullers are expensive and does not benefit rural dwellers where power supply is non-existence, inadequate or unaffordable. On the other hand, hand-operated machines require more energy with less output compared to pedal operated machines (Ghodkhande*etal*., 2015). Pedal operation is the most efficient way of utilizing power from human muscles (Parmanand*etal*., 2015). A man can produce 1/4hp by pedalling than by hand-turning (Ghurde*etal*., 2016). At the rate of 1/4hp, non-stop pedalling should be possible for just brief periods, about 10 minutes, but pedalling at a large portion of this power (1/8 hp) can be supported barely for hour, or so (Ghurde*etal*., 2016). Although a healthy athlete can produce an average of 75W power (Modak and Bapat, 1987), the effective average rate of pedalling is in the range of 50-70 rpm (Tiwari*etal*., 2011). Two types of pedal mechanisms are used for the design of pedalling machines, namely; the rotary pedal (bicycle pedal) and the reciprocating pedal (sewing machine pedal) (Manjunath and Radha, 2017).

The use of pedal power in agricultural engineering operations has been investigated by many researchers. Gandhare*etal*. (2015) developed pedal operated multi-point pesticide spraying machine. Manjunath and Radha (2017) developed a pedal operated vegetable cutter using a reciprocating type pedal, akin to the pedal operated sewing machine. Lazaro*etal*. (2014) developed a pedal operated soghumdehuller for dehulling tempered sorghum grain. They achieved 90.1% dehulling efficiency for the Jumbo variety and 83.4% for the Dionje variety. Sushrut*etal*. (2017) designed and fabricated foot pedal operated corn deseeding machine using sprocket and chain mechanism like in the case of a bicycle. A pedal operated integrated potato peeler and slicer was developed by Chand *etal*. (2013). Their machine saved 88% and 54% energy consumption when compared to manual peeling-slicing and hand operated peeler-slicer machine, respectively. They obtained a capacity of 65 kg/hr and efficiency of 88.5%. Hatwalne*etal*. (2011) developed a pedal operated flour mill. With their machine, an average of 1 kg requiring 20 minutes operating time was found to the best in terms of efficiency and human working comfort. Ghodkhande*etal*. (2015) designed a pedal operated groundnut decorticator that has a capacity of 25-30 kg/hr. Pedal operated castor decorticator was developed by Sanglikar*etal*. (2017) for small and medium scale farmers. They obtained a decorticating capacity of 49.25 kg pods/hr and efficiency of 94.91%

The objective of this work is to develop a pedal operated dehuller to solve the high energy demand but low capacity of hand operated dehulling and high costly challenge of motorized dehulling of breadfruit seeds. The benefit of this pedal dehuller is to eliminate the drudgery associated with manual dehulling, saves energy and time of operation, enhances the post-harvest operations of the crop, increases operation capacity of the farmers, encourages more production, and offers the farmer better profit for their products.

2.0 MATERIALS AND METHODS

2.1 Design considerations

Work related musculoskeletal disorders (WRMDs) under strenuous physical work are major issue that leads to ergonomic considerations in machines involving humans (Khayer*etal*., 2017). As a result, the anthropometric information of the workers (both genders) was considered so as to avoid compromising comfort and safety of the operator in a bid to achieve efficient machine. Hence, the machine was designed to give a good efficiency, comfort and minimum stress on the operator (with female operator as the benchmark for input power consideration). Other considerations are ease of operation (no expertise required), simple to maintain and service, affordable and durable.

2.2 Conception of the Machine

The machine was conceptualized to consist of a frame made of angle iron of adequate thickness for stability, two disk plate (one rotating and the other stationary), a hopper that will hold reasonable quantity of seed before refilling, a chain drive that will connect the sprocket to the shaft, a discharge chute, a pedal for transmission of power to the chain drive, operator’s seat and handle.

2.3 Design of dehuller components

The components of the dehuller were designed using standard equations.

2.3.1 The shaft diameter

The shaft diameter was calculated (Equation 1) with 10% factor of safety added, and from the standard sizes, a shaft of 20mm diameter was selected.

$$d^3 = \frac{16}{\pi S_s}\left(\sqrt{(K_b M_b)^2 + (K_t M_t)^2}\right) \qquad (1)$$

K_b = combined shock and fatigue factor applied to bending moment (1.5-2.0 for minor shock)
K_t = combined shock and fatigue factor applied to torsional moment (1.0-1.5 for minor shock)
Ss = allowable combined shear stress for bending and torsion for steel shaft
M_b and M_t = bending and torsional moments

2.3.2 The hopper

The hopper of the machine was designed using the angle of repose of the breadfruit obtained experimentally as 28.60^0 and using the following volume equation (Etoamaihe*etal*., 2010):

$$v = \frac{h}{3}\left[A_1 + A_2 + \sqrt{(A_1 + A_2)}\right] \qquad (2)$$

v= volume of hopper (m^3); A_1 = area of top (m^2); A_2 = area of base (m^2); h= height of the hopper (m).

2.3.3 Bearing

The bearing that will withstand the radial force of the shaft was selected, and the radial force acting on the shaft was obtained thus (Krutz*etal*., 1984):

$$F = \frac{KW \times 19.1 \times 106 \times k}{PD \times RPM} \qquad (3)$$

F = radial force of shaft (N); KW = power transmitted (kW); PD = pitch diameter of sheave (mm); RPM = shaft speed (rpm); k = drive tension factor.

2.3.4 Chain drive design

The pitch diameter (D), which is a function of the chain pitch (p) and the number of teeth in the sprocket (N) is given as (Srivastava*etal*., 1996):

$$D = \frac{P}{\sin\left(\frac{180}{N}\right)} \qquad (4)$$

The length of the chain is given as:

$$L = \frac{2C}{P} + \frac{N_1 + N_2}{2P} + \frac{(N_2 - N_1)^2}{4\pi^2\left(\frac{C}{P}\right)} \qquad (5)$$

where$C$ = the centre distance between the sprockets; N_1 and N_2 are the number of teeth on the two sprockets

The chordal speed is given by:

$$\frac{\Delta v}{v} = \frac{\pi}{N}\left(\frac{1}{sin\left(^{180}/_{N}\right)} - \frac{1}{tan\left(^{180}/_{N}\right)}\right) \tag{6}$$

wherev is the chain velocity, and it is given as:

$$v = NPn \tag{7}$$

wheren is angular speed (rev/s).

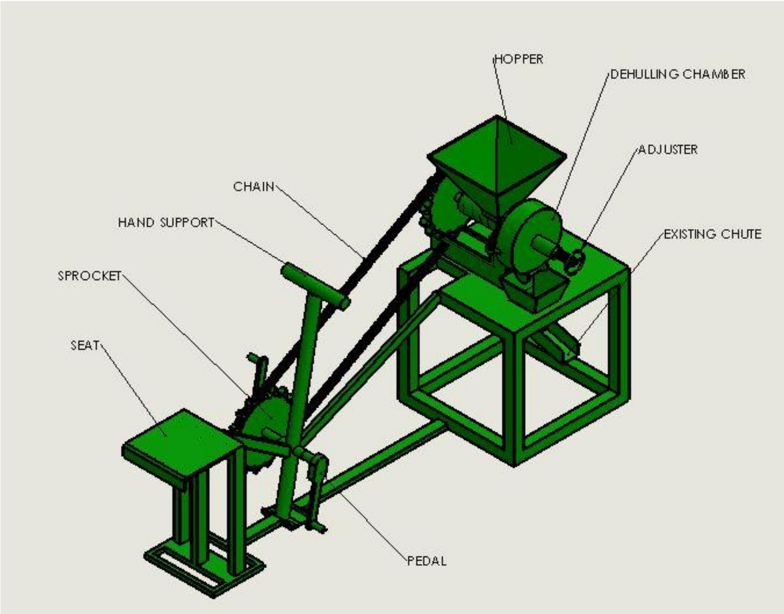

Fig. 1: The pedal-powered dehuller

3.0 RESULTS AND DISCUSSION

The result of the performance test carried out on the machine at three different moisture contents of the seeds is shown in Table 1.

Table 1: Performance of pedal operated breadfruit dehulling machine

Sample	**6.5% m.c.**	**8.5%m.c.**	**10.5%m.c.**
x_1	3000g	3000g	3000g
x_2	1800g	1650g	1591g
x_3	600g	880g	950g
x_4	400g	300g	360g
x_5	200g	170g	99g

Where x_1 = total quantity of input per hour (g); x_2 = weight of dehulled breadfruit seed per hour (g); x_3 = weight of undehulled breadfruit seed per hour (g); x_4 = weight of partially dehulled breadfruit seed per hour (g); x_5 =weight of chaff (g).

The dehulling efficiency *(DE)* and dehulling capacity *(DC)* are given as (Etoamaihe*etal*., 2010):

$$DE = \frac{m-c}{m} \times 100\% \tag{8}$$

$$DC = \frac{m}{t} \tag{9}$$

Where m = mass of breadfruit seeds fed to the machine (kg); c = mass of undehulled breadfruit seeds (kg); t = time of dehulling (h).

It was observed that the dehulling efficiency increases as the moisture content decreases at an average human speed range of (60 rpm). At moisture content of 6.5% (dry basis), 1800 g of seeds were dehulled, 600 g of seeds undehulled, 400g of partially dehulled seeds and 200 g of chaff. Whereas at 10.5%mc about 1591 g seeds were dehulled, 950g were undehulled, 360 g were partially dehulled, 99 g were recorded as chaff. The machine capacity at 65, 60 and 55 rpm average speeds were 17.5, 9.3 and 4.16 kg/h, respectively. The best dehulling results were obtained at 6.5%mc (dry basis) and pedalling rate of 65 rpm. This speed of 65 rpm falls within the effective average rate of pedaling range of 50-70 rpm (Tiwari*etal*., 2011).

4.0 CONCLUSIONS

An African breadfruit pedal operated dehulling machine was developed for adoption in areas where power supply is costly, inadequate or unavailable. The machine which can be operated at the rated human power of 89.48 Watts has advantage of replacing hand operated and motor powered dehullers in rural areas. The machine capacity obtained were 17.5 kg/h, 9.3 kg/h and 4.16 kg/h at 65 rpm, 60 rpm and 55 rpm, respectively. The efficiency and capacity of the machine are affected by seed's moisture content and the operating speed of the machine.

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RENEWABLE ENERGY USAGE FOR AGRICULTURAL PRACTICES: A REVIEW

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ABSTRACT
Agricultural practises in the less developed and some developing countries is still being carried out manually with crude tools while the usage of fossil fuel in developed countries has contributed immensely to global warming and environmental degradations. This study aimed at reviewing the level of renewable energy sources used for agricultural practices, limitations and possible solutions. Renewable sources studied include biomass, geothermal, wind, solar, hydropower and fuelwood. Harnessing these energy sources in agriculture is termed clean energy farming because switching from fossil fuel burning for energy production to renewable energy sources lowers the total amount of carbon released into the atmosphere. In combination with energy conservation practices, farmers can produce their own energy to become even more self-sufficient by reducing external inputs, not only does renewable energy help the farmer save money; it also combats the effects of global warming. Potential renewable energy sources for the rural agricultural sector like biomass (including fuel wood, sawdust, crop and animal residue/waste and biogas), wind, solar power, and hydropower can be used for various agricultural practices to reduce the energy deficit battling various agricultural practices both in rural and urban areas and lessen the rate of environmental degradation. Also, adequate agricultural extension service is needed to educate, enlighten, and transfer this knowledge to rural areas for alternative energy development, management, monitoring, and evaluation.

Keywords: *biomass, geothermal, wind, solar, hydropower, clean energy,*

1.0 INTRODUCTION

The significance of energy resources cannot be overemphasized, as they are essential in virtually all sectors of the economy (Okundamiya*et al.*, 2014) for socioeconomic development and poverty eradication (Oyedepo, 2012; WNA, 2018). A major difference between less developed, developing and developed countries is the energy consumption and applications for certain operations like agricultural production and practises. Much of the world's agriculture was and is still carried out manually with crude tool in less developed and some developing countries (Pimentel and Pimentel, 1996). Energy is the capacity to do work and the basic driving force in man's development; it is both the fuel and feedstock for agriculture and a fundamental requirement for human development is energy capable of transforming communities (Bamgboye and Jekayinfa, 2007), it exists in many forms which can be generally classified as renewable and non-renewable (Figure 1).

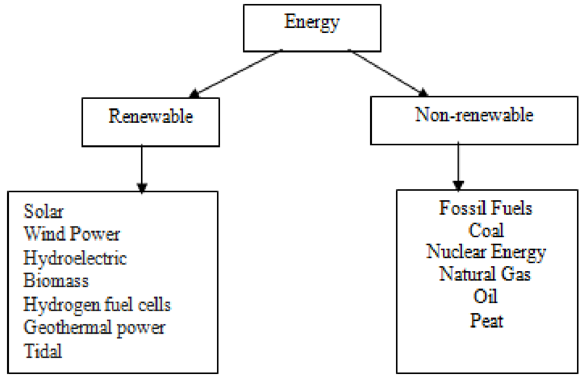

Figure 1: Energy Sources

Nigeria's energy sources for agricultural production include the use of human power to operate hand tools, animal power for drawn implements, carbon fuel for motorized and mechanically-driven post-harvest handling and processing machines, and pumps for irrigation (Mac-Anthony, 2010). There are no reliable estimates of the country's total energy use but out of the conventional (non-renewable) energy, only fuel wood has substantial use in rural areas. Agriculture requires energy as an important input for production and processing through transformation of various energy sources into food and fiber for human beings (Fluck and Baird, 1980; Jekayinfa, 2006). Energy consumption by the agricultural sector can be broadly categorized into direct and indirect energy use. Agriculture uses energy directly as fuel or electricity to operate machinery and equipment, to heat or cool buildings and for lighting in the farm and indirectly in the fertilizers and chemicals produced off the farm (Uhlin, 1998). Energy's share in agricultural production varies widely by the kind of activities, production practices applied, geographic location of the production area and environmental conditions such as soil and climatic factors (Esengun *et al.,* 2007). The agricultural sector, like other sectors, has become increasingly dependent on energy resources such as electricity, fuels, natural gas and coke. This increase in energy use and its associated increase in capital intensive technology can be partially attributed to low-energy prices in relation to the resource for which it was being substituted (Gowdy *et al.,* 1987). Modernization and mechanization of agricultural operations increases its energy consumption thus effective and conservative energy use is required in order to sustain agricultural production (Pimentel, 1980; Pervanchon *et al.,* 2002). In addition, with the limited availability of suitable land for agriculture, the only chance for producers to increase total output will be using more energy input efficiently. It is substantial to investigate the level of energy use for various agricultural practices due to the dependence of the agricultural sector on energy to supply more food to the ever increasing populace considering the limited natural resources, as well as the impact of using energy sources on environment and human health. If, as projected, human numbers continue to increase at the current rate of 1.5%, supplies of fossil energy will be unable to support a secured food supply thus, fossil energy supplies which is finite in nature will no longer be adequate and affordable. Thus, the main aim of this study was to review the level of renewable energy use for agricultural production, possible challenges and probable solutions.

1.1 Renewable Energy Sources for Agricultural Practices

Harnessing renewable energy systems in agriculture is termed CLEAN ENERGY FARMING (SARE, 2006; Chel and Khausik, 2011) because switching from fossil fuel burning for energy production to renewable energy sources lowers the total amount of carbon released into the atmosphere as CO_2 gas. In combination with energy conservation practices, farmers can produce their own energy to become even more self sufficient by reducing external inputs. Not only does renewable energy help the farmer save money, it also combats the effects of global warming. Potential renewable energy sources for the rural agricultural sector like biomass (including fuel wood, sawdust, crop and animal residue/waste and biogas), wind, solar power, and hydropower can be used for various agricultural practices. Anne (2009) reported that with a little initial investment, energy can be made for free from renewable sources such as the sun, wind, and water. Six main types of renewable energies have been employed in industrialized places for this purpose (Table 1).

Table 1: Renewable Forms of Energy

Energy source	% Used	Description	End Product
Biomass	53	Burning of plant materials and animal wastes	Heat and gas
Hydropower	36	Water owing from higher to lower elevations through dams	Electricity
Wind	5	Capture of wind by turbines	Electricity
Geothermal	5	Capping stream and hot water from the earth's mantle	Heat and electricity
Solar	1	Absorbing and storing heat from the sun	Heat and electricity
		Emerging Technologies	
Source	*Description*		*End Product*
Hydrogen fuel	Burning hydrogen gas		Power for movement
Nanotechnology	Using the unique properties of materials on the size scale of molecules or atoms		Electricity
		Ancient Technologies	
Water	Water wheels, dams, weight		Power, motion
Wind	Windmills, sails		Power, motion
Movement (kinetic energy)	Animals, human exertion		Power, motion

Renewable technologies may be either modern advances in energy generation or ancient technologies that some parts of the world continue to use. Many renewable energy sources do not produce usable energy directly; additional equipment may be required to convert one type of energy into another form. Sambo (2005) reported the potential renewable energy sources and capacity for agricultural production and processing (Table 2).

Table 2: Potential sources of energy for rural based agricultural production and processing activities

Energy Source	Potential/Reserves	Energy capacity
Fuelwood	80 million m^3/year	6.0×10^9 MJ
Sawdust	1.8 million tons/year	31,433,000 MJ
Crop residue	83 million tons/year	5.3×10^{11} MJ

Animal waste	227,500 tons daily	2.2 x 10^9 MJ
Biogas	6.8 million m^3 daily	2.7 m^3 produces 79.11 MJ
Wind	2 – 4 m/s at 10m height	5 MW
Solar	6.25 hours daily	6.25 – 7.0 kWh/m^2 per day
Small hydropower	0.143 billion tons	734.2 MW

Source: Sambo (2005)

***1.1.1 Biomass*:** Plant and animal derived materials used for energy are known as *Biomass* and the fuel produced from biological materials are known as *Biofuel*. Biofuels are a renewable energy alternative which can be made from crops grown on the farm to fuel vehicles. Biomass such as sugars and oils from plants can be used to make fuel for vehicles (popularly known as Biofuel or Biodiesel) and the burning of biomass for heat or electricity is simply called *Biopower*. Biodigestors; a fairly simple closed system for decomposition of waste may be needed for biomass production (Williams *et al.,* 1976; Satyanarayan and Shivayogi, 2010;Potivichayanon*et al.,* 2011; Bryan *et al.,* 2011; Eze*et al.* 2011; Cengiz and Sina, 2015; Ojomo*et al.* 2018).Huge volumes of agricultural wastes in the form of livestock manure, corn cobs, cassava peelings, rice husks, groundnut shells, sawdust, bagasse, human excreta and the resultant gas (biogas) can be converted into potential sources of energy that can be plowed back into agricultural production and processing activities with the use of a biodigester (Tejoyuwonu, 1982). Presently, biogas is not widely used in Nigeria's rural economy due to poor knowledge of its energy potential as well as limited resources to purchase the required equipment for its conversion. However, biomass crops such as switchgrass, corn, or fast growing trees can be pelletized and burned for heating buildings such as greenhouses or converted to electricity by way of steam. Again, a cooperative purchase of a pelletizer may be sufficient for farmers wishing to burn pellets for heat, several researchers have designed and developed various pelletizer for producing biomass effectively from certain agricultural wastes and products like: *Eupatorium odoratum*(Odeyemi, 1981), pigeon droppings (Aliyu*et al.,* 1995), mixed weed specie (Bamgboye and Abayomi, 2000), farm wastes (El-Shinnawi*et al.* 2001), alfalfa (Tabil and Sokhansanj, 1996, 1997; Adapa*et al.,* 2003;), onion bulbs (Abubakar*etal.,* 2004), cassava tubers (Anunpultikul and Rodtong, 2004a and b), cassava leaves and sewage sludge (Odeyemi, 2004), animal dung (Tambawal, 2004), rattan furniture waste (Olorunnisola, 2004), sludge (Sial*et al.,* 2007), banana and plantain peels (Bori*et al.* 2007), coal tailings and spent mushroom compost (Ryu*et al.* 2008)cassava peels with major livestock waste (Adelekan and Bamgboye, 2009), microbial flora of Animal wastes (Ofoefule*et al.,* 2010), starchy wastes (Karve, 2008; Bolarinwa and Ugoji, 2010), sorghum stalk, corn stover, wheat straw, and big bluestem (Theerarattananoon*et al.,* 2011), food waste and manure (Bryan *et al.,* 2011), water hyacinth (Ighodalo*et al.,* 2011), wheat straw (Stelte*et al.*2012a and b), cassava (Oduntan*et al.,* 2012), sugarcane bagasse (Qiang*et al.,* 2013), agro-resideues and waste paper (Tamilvanan, 2013), corn stalk rind (Xun*et al.,* 2016).

Biomass has been used in the past and more recently to produce electricity (Freiberg *et al.,* 2018; Asibey*et al.,* 2018, Yusniati*et al*., 2018), and it has been proven enough potential to supplement current production from hydropower to meet growing demand. Despite the numerous advantage of biomass, policy and institutional arrangements do not easily allow generation and extension for communal benefits thus, there is need for a relook at existing policy and institutional arrangements to help promote this alternative source of energy for efficient and sustainable domestic and industrial uses also, ensuring efficiency in energy generation calls for thorough research and development into the commercial potential of biomass and exploring more efficient means of managing industrial and other agro wastes in developing economies.

***1.1.2 Geothermal Energy*:** The word geothermal was developed from two Greek words, “geo”, meaning earth, and “thermos”, meaning heat; it is thus the power extracted from heat stored in the earth. It originates from radioactive decay of minerals, and from solar energy absorbed at the surface. Geothermal energy represents about 5,500^{0}C at the Earth’s core – about as hot as the surface of the sun (Martha, 2009). Geothermal energy is utilized in many parts of the world especially those that are located on plate boundaries or tectonically active regions, it has been used most extensively in agriculture for greenhouse heating during the last 25 years (Jenei, 2009). The largest group of geothermal power plants in the world is located at The Geysers, field in California, United States. As of 2004, five countries (El Salvador, Kenya, the Philippines, Iceland, and Costa Rica) generate more than 15% of their electricity from geothermal sources (WEA, 2004).

Geothermal resources vary in temperature from 30-350^{o}C, and can either be dry steam, two-phase (a mixture of steam and water) or just liquid water. In order to extract geothermal heat from the earth, water is the transfer medium. A typical Geothermal Power Station and its application to heating processes in a green house is presented in Plates 1a and b.

a b

Plate 1: a-Olkaria II power station, commissioned in 2003, b- Geothermal greenhouse heating at Oserian Company, Kenya (Martha, 2009)

Popovski and Popovska-Vasilevska (2001) reported that although there are differences in the treatment and approach to development of geothermal energy use between countries, in no one are all the answers available hence, one should not be misguided with the rather good situation in some countries (Italy, Iceland, New Zealand, etc) because they are also faced with serious problems. The limitations of geothermal energy as given by Popovski and Poovska-Vasilevska, (2001); Popovski (2010); Alyssa *et al.* (2007) and Martha (2009) include: high investment costs, high level of knowledge of different scientific disciplines, high level of organization, need for environmental protection because geothermal brines can pollute the environment both chemically and thermally. The main uses of geothermal energy (Roberto and Claudio, 1999; Lund and Freeston, 2000; Andri and Dedy, 2003; Sverrir, 2005; Babi*et al.*, 2007, Jack, 2011) include: replacement of fossil fuel for greenhouse heating, aquaculture and crop drying as well as in leisure and therapeutic uses. Lund and Freeston (2000) reported categories of utilization of geothermal energy worldwide as presented in Table 3.

Table 3: Categories of Utilization of Geothermal Energy Worldwide

Category	Capacity	MWt	Utilization	TJ/yr
Geothermal Heat pumps	6,849	1,854	23,214	14,617
Space heating	4,954	2,579	59,696	38,230
Greenhouse Heating	1,371	1,085	19,035	15,742
Aquaculture Pond heating	525	1,097	10,757	13,493
Agricultural drying	69	67	954	1,124
Industrial uses	494	544	10,536	10,120
Bathing and swimming	1,796	1,085	35,892	15,742
Cooling and snow melting	108	115	968	1,124
Others	43	238	957	2,249
TOTAL	16,209	8,664	162,009	112,441

Source: Lund and Freeston (2000)

The utilisation of geothermal fluid depends heavily on its thermodynamic characteristics and chemistry. These factors are determined by the geothermal system from which the fluid originated. Geothermal fluids have been classified differently by different authors (Dickson and Fanelli, 2004). Farm buildings and homes can use geothermal heat pumps to exchange air temperature and ground temperature year round, keeping buildings cool in summer and warm in winter. While geothermal systems are more expensive to purchase and install than a typical fossil fuel burning furnace, the payback time is 5-10 years given the free fuel. A geothermal system is best suited for new construction considering the extensive excavation process involved.

1.1.3 Hydropower: The term hydro-power is usually restricted to the generation of shaft power from naturally falling water. The power is used for direct mechanical purposes or, more frequently, for generating electricity. Hydropower is the most mature, reliable and cost-effective renewable power generation technology available (Brown *et al.*, 2011). Hydropower is the largest renewable energy source, and it produces around 16 % of the world's electricity and over four-fifths of the world's renewable electricity. Currently, more than 25 countries in the world depend on hydropower for 90 % of their electricity supply (99.3 % in Norway), and 12 countries are 100 % reliant on hydro. Hydro produces the bulk of electricity in 65 countries and plays some role in more than 150 countries. Canada, China and the United States are the countries which have the largest hydropower generation capacity (IPCC, 2011). One key advantage of hydropower is its unrivalled "load following" capability (i.e. it can meet load fluctuations minute-by-minute). In addition to grid flexibility and security services (spinning reserve), hydropower dams with large reservoir storage be used to store energy over time depending on size to meet system peaks or demand decoupled from inflows. As a result of this flexibility, hydropower is an ideal complement to variable renewable as, when the sun shines or the wind blows, reservoir levels can be allowed to increase for a time when there is no wind or sunshine. Similarly, when large ramping up or down of supply is needed due to increases or decreases in solar or wind generation, hydro can meet these demands (Brown *et al.*, 2011). In agriculture, it is used in the following areas; electricity on the farm for pumping water for irrigation, processing and storage of agric produce, and for lighting farm houses and environment, direct use of water for irrigation from the hydro power dams and use of dams for fish farming. Against these, the disadvantages include: site-specific technology, season dependability, conflicts with fisheries interests on low-head schemes, and with irrigation needs on high head schemes, lack of familiarity with the technology and how to apply it inhibits the exploitation of hydro resources in many areas, poor management of dam leading to flooding of the down-stream sector of the dam.

***1.1.4 Solar*:** The sun's energy can be used for passive heating such as greenhouses, as solar thermal heating for hot water systems, or with photovoltaics (PV) it can be converted and used to produce electricity. There are various types of solar cookers including the concentrating solar type, parabolic solar type, panel solar type, double exposure solar cookers, thermal storage type solar cookers, hot box solar type, square and rectangular box type solar cookers (Aremu and Ogunlade, 2014). PV can be used to power lighting, electric fencing, small motors, fans, pumping water, or charging batteries. In rural areas or sections of the farm away from power lines PV can be the only option. Nigeria receives an optimal supply of solar radiation (5.5 kilowatt hours per square meter unit). Of this amount, however, only about 0.005% is actually converted into energy. The energy challenge mentioned above could substantially be met by solar if 1 percent of the available solar energy can be tapped (FEC, 1984). Solar power has been successfully used in controlled drying of agricultural products, domestic cooking, and pumping water for irrigation in rural areas of China, India, Finland, Kenya, and Bangladesh among others. The limiting factor in rural Nigeria is the lack of technology and funding. The foundation of all agricultural production rests on the unique capability of plants to convert solar energy into stored chemical energy. The success of agricultural production is measured by the amount of solar energy that is captured and converted into food per unit land area as a result of manipulating, plant, land, water, and other resources. Agricultural success can be enhanced by finding ways to augment solar energy using human, animal, and fossil energy power. An estimated 30% of the total solar energy reaching the earth is harvested by humans as food and forage, while an additional 20% is harvested as forest products. Thus, humans are harvesting for their use approximately half of the solar energy reaching the earth.

***1.1.5 Wind*:** Turbines used to produce electricity from wind can provide a large portion of the average power needs of a farm however, it must be located in high wind areas and generally require at least one acre of land to produce enough energy. Despite the huge cost of wind turbines, the benefits of a wind turbine can outweigh the costs of installation if local utility costs are high, you chose a turbine that fits the wind speed of your location, and ultimately on how you use and maintain your system. Wind energy is available when solar energy is not. It is strongest in fall, winter, and spring, as well as at night when hot air rises from the earth's surface, increasing air flow. The use of wind power for rural agricultural production activities is practically adaptable for residents located along coastlines and in dry regions of Nigeria. This is useful in reducing the human energy involved in activities such as winnowing in rice mills. Since wind is not available in a sustained manner, it limits its usage for many farm activities in Nigeria.

1.1.6 Fuel wood: About 50 percent of Nigeria's total energy consumed for agriculture and other domestic food processing activities is from fuel wood. The current reserve potential of 80 million cubic meters per year is reported to be poorly utilized (CREDC, 2008). Only a fraction of the wood is effectively used with traditional stoves. Improved wood/solid fuel stoves and coal briquettes of various designs have been shown to have 10 to 20 percent thermal efficiency, while traditional stoves have 5 to 7 percent thermal efficiency (Sambo 2010). The wood/fuel stoves can be used for cooking, fish smoking, and preservation. Nevertheless, its unregulated consumption could result in environmental decay such as deforestation, soil erosion, desertification, and carbon emissions.

2.0 CONCLUSION

Human power and use of draft animals are the dominant inputs into rural agricultural production and processing activities in Nigeria. This study reviewed the usage of alternative renewable energy sources such as biomass, geothermal, wind, solar and hydropower by looking at their limitations, prospects and current applications for agricultural practices. This energy sources could serve to reduce the energy deficit various agricultural practices both in rural and urban areas and lessen the rate of environmental degradation however, adequate agricultural extension service is needed to educate, enlighten, and transfer this knowledge to rural areas for alternative energy development, management, monitoring, and evaluation. The strengthening of local institutions, such as rural cooperatives, could also be used to promote awareness of renewable energy sources and also serve to ensure security and sustainability of rural installations for farm production and processing activities.

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SECTION TWO

FARM STRUCTURES AND ENVIRONMENT

ANALYSIS OF PHYSICO-CHEMICAL PROPERTIES OF SISAL LEAVES FIBRE (*Agave sisalanaIa*) FOR COMPOSITES APPLICATIONS IN ENGINEERING

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Abstracts

This paper evaluates the physico-chemical properties of sisal hemp leaves fibre for its possible utilization in engineering. The fibre was extracted from Agave sisalana leaves obtained locally in Adamawa state, Nigeria using water retting extraction procedure. Studies were carried out on its physical and chemical properties relevant to engineering applications. The parameters evaluated were Moisture absorption ranging from (3.00 % to 3.17 %), density ranging from (0.610 g/cm^3 to 3.167 g/cm^3), fiber diameter which was found to range between (1.933 µm to 2.50 µm), lumen width ranged between (1.00 µm to 1.50 µm), from a wall thickness of (0.50 µm. Proximate analysis was carried out for cellulose content, hemicelluloses, lignin and ash content which was found to range between 70.00 % to 83.33 %, 16.67 % to 23.33 %, 55.00 % to 75.00 % and 30.00 % to 30.50 % respectively. Statistical package for social sciences (SPSS) was used to determine significantly different means, and the (ANOVA) table and bar chart for chemical compositions were constructed from which observations, conclusions and recommendations were made. The results show that agave sisalana leaves fiber were characterized by low density, high cellulose content, and low moisture absorbency in comparison with other leave fibers in its category. Therefore it is recommended for possible utilization in pulp and paper making, textile, and automobile products such as brake parts, car interior e.t.c.

Introduction

Fiber is defined as flexible material having a high ratio of length to width and cross section (Herman and Raymond 1988). Fibers has been classified into natural and manufactured. Natural fibers have made a remarkable impact as a potential substitute for conventional synthetic fibers like aramid and glass fiber over a past few decades. Owing to their mechanical properties, good thermal insulation properties, low density, nonabrasive nature, easy availability from replenish able sources, cheaper prices and recyclability of natural fiber reinforced polymer composites have attracted the composite industry, both for structural and nonstructural applications. Glass fibers being non-degradable pose serious health and environment hazards. They can’t be easily thermally recycled as they melt at very high temperatures and remain as a residue which can damage the furnace and are quite abrasive in nature. However the main focus of this review is to realize the potential of some unique natural fibers as a replacement for glass fibers, a key component in the automobile and structural composites. The chemical composition of lignocelluloses is inherent according to the particular needs of the plants. Celluloses, hemicelluloses and lignin are the three main constituent of any lignocelluloses source and proportion of these components in a fibre depends on the age, source of the fibre and the extraction condition used to obtain the fibres (Batra, 1985).

Materials and Methods

Materials

The materials used in this research work include the following; Sisal (*agave sisalana)* leaves obtained locally in Adamawa State, sisal fibre from the leave, NaOH, H_2SO_4, potassium Sulphate, Safranin red, potassium chromate, HCl, HNO_3, distilled water and water. Tools and equipment used was electronic oven dryer M/C NO.11/084 Mod.,and Motic electric microscope.

Methods

Fiber extraction

The sisal (*agave sisalana)* leaves was cut from the main stock using a sharp knife object at the base of the stalks at matured leaf length. The leaves were tied in bundles, weighed and submerge in a water pond for a period of three (3) weeks to allow the bacteria and fungi in the environment to remove non cellulose substance. The fiber was extracted from the core by hand stripping, clean and dries as describe by Sahay and Singh (2001), Narendra and Yang (2005) and Paridah*et al*., (2011) and adopted by TAPPI (1980)

Chemical treatment of fibre

After the extraction of the fiber, 400 g of sodium hydroxide (NaOH) was dissolved in 8 litres of distilled water which is equivalent to 5 % preparation of NaOH solution, about 990 g of fibre was immersed into the solution for 48 hours at room temperature as a method described by Ray *et al* (2001) and Mishra *et al* (2001). The fibre was removed from the solution and then dried for 48 hours at room temperature, followed by oven drying at 100^{o}C for 6 hours.

Analysis of fibres physical properties

In accordance with Ververis*et al.,* (2004), Sharma *et al.,* (2011), for fibre length dimension, small silver was obtained and macerate with 10ml of 67% HNO_3 and boil in a water bath (100$\pm$2^{o}C) for 10minutes. The silvers were then washed and placed in a small flask with 50ml distilled water and the fibre bundles were separated into individual fibre using a small brush with a plastic end to avoid fibre breaking. The macerated fibre suspension was finally placed on a glass slide (7.5cm X 2.5cm) by means of a rubber pepette. For the fibre diameter, fibre lumen width and fibre cell wall thickness determination, cross sections was obtained from the same height as mentioned above and was stained with 1:1 aniline sulphite –glycerine /safranin red mixture to enhance cell wall visibility. Sisal fibre cell was viewed under calibrated motic electric microscope on ×10 objective lence.

Determination of the fibre Moisture absorption (Regain)

American society for testing and material (1997) standard testing method for moisture regain as reported by Brindha et al., (2013) was adapted to determine moisture absorption of sisal fibre at matured stage. Sisal fibre samples were conditioned for 24hours using ice blocked at 27 $\pm$ 2^{o}C and the weight taken as (L). The conditioned fibre sample was oven dried at temperature of 105^oC for 4hrs and the weight was taken as (W). Moisture absorption percentage of the sample was calculated according to equation 2 below;

Moisture Absorption % $= \frac{L-W}{L} \times 100$
(1)

Determination of the fibre density

Technical Association of Pulp and Paper Industries (TAPPI) standard method was adopted as reported in Modibbo et al., (2009). The density plant fibre at matured stage was determined by conditioning the fibre sample for 24hrs at 27$^oC\pm2^oC$ using water ice blocked before the test was carried. 2g of the sample was accurately weighed out for each fibre sample. The weight was immersed in toluene in a calibrated glass tube (30ml measuring cylinder) and volume of toluene displaced was determined and equal to the volume of sisal fibre immersed. The density of the fibre sample was calculated as follows;

Density = $\frac{Mass\ of\ fibre}{Volume\ of\ fibre}\ in\ g/cm^3$
(2)

Analysis of the Fibre Chemical Properties
Proximate analysis of the fibre was carried out to determine the percentage content of cellulose (alpha-cellulose), hemicelluloses (beta and gamma cellulose) lignin and ash as described by Technical Association of pulp and paper industries (TAPPI, 1980).

Determination of cellulose content
The alkali solubility test for Alpha – cellulose which involved treating 3g of sample with 100mls of 18% NaOH at 25^oC $\pm2^oC$, was carried out using water ice blocked. The weight of the undissolved residue which is the alpha-cellulose was expressed as a percentage of the initial weight of the dry ground sample (TAPPI, 1980).

Determination of hemicellulose content
Following the 18% alkali solubility test for the alpha cellulose, the dissolved cellulose portion (aliquot) was collected separately at the end of one hour and treated with 0.1N dilute H_2SO_4. The treatment caused a precipitate form, which was the beta cellulose. The cleared portion (aliquot) was further oxidized with potassium chromate and potassium iodine was added. The aliquot was back treated with 0.1N solution of potassium thio-sulphate. The titration caused a precipitate form, which was the remaining dissolved gamma cellulose. The weight of the beta and gamma cellulose was added together and got the weight of the hemicelluloses which was then be expressed as a percentage of the initial dry weight of the ground fibre sample (TAPPI, 1980).

Determination of lignin content

The dry specimen of ground sisal fibre was chilled in ice beaker and treated with 38% concentrated HCL, stir and left to cool in the ice under a fume cupboard. Thereafter, concentrated H_2SO_4 was added drop wise to the mixture, stir and left over night at room temperature. The mixture was diluted with distilled water and boiled to coagulate the lignin which was then filtered hot and rinsed alternatively with concentrated HCL and water. The coagulated lignin was dried, weight and expressed as percentage of the initial weight of the dry specimen.

Determination of ash content
Proximate analysis as described by Aisha *et al*., (2013) was adopted in determining the quality of ash content in the fibre, crucible was washed dried in an oven at temperature of 180^oC for 30mins, cooled and then weight as M_0(g). 2g of the fibre sample was placed into the crucible and weighted again as M_1(g). Crucible with the fibre sample, transferred into the muffle furnace whose temperature set at 600^oC and allow for 3hrs

until the content becomes whitish in colour. Afterward, the crucible was brought out, cooled in the desiccators and weighted as M_2(g). The percentage of ash content was calculated as follows;

$$\%\text{Ash Content} = \frac{Mass\ of\ ash\ (g)}{Mass\ of\ sample\ (g)} \times 100 \quad (3)$$

Statistical Analysis

Statistical package for social science (SPSS) was used to determine the analysis of variance (ANOVA) and the means that were significantly different between the samples at 5% level of probability. The chemical properties were subjected to bar-chart and the percentages compositions were determined from which the observations, conclusions and recommendations were drawn for further studies.

Plate I: Sisal Matured Leaves for Fibre Extraction

Plate II Extracted Fibre from matured sisal leaves.

Results and Discussion

Results

Table 1Determined Fibre dimensional Parameters

Fibre Length FL (µm)	Fibre Diameter FD (µm)	Fiber Lumen Width FLN (µm)	Fibre Wall Thickness FWT (µm)
153.0	2.167 ± 1.444	1.267 ± 0.844	0.50 ± 0.333
190.0	2.00 ± 1.333	1.00 ± 0.667	0.50 ± 0.333
243.3	2.033 ± 1.356	1.067 ± 0.711	0.50 ± 0.333
265.3	1.933 ± 1.289	1.00 ± 0.667	0.50 ± 0.333
316.7	2.50 ± 1.667	1.50 ± 1.00	0.50 ± 0.333

Fibre Dimensional Parameters

The results obtained from the characterization of extracted fibre from sisal (*agave sisalana*) leaves into dimensional, derived, physical, chemical and mechanical properties were tabulated and discussed in the following sectors.

Fibre diameter

The mean values of fibre diameter at different stages of fibre length as in Table 3 were 2.167µm, 2.00µm, 2.033µm, 1.933µm, and 2.50µm for the length of 153.0µm, 190.0µm, 243.3µm, 265.3 µm and 316.7µm respectively. The diameter at all stages of length evaluated was higher than that of corn husk fibre ranged between 0.021 µm to 0.15 µm (Taiwo*et al.*, 2014). The result shows that the diameter increases with an increase in fibre length, and cellulose content also increase. This is nearly in agreement with the report of Sahin and Young, (2008) that, the chemical solution used to determined cellulose influence the percentage of cellulose content in plant fibres, and high percentage of cellulose in plant fibre produces fiber with lower diameter in micron.

Fibre lumen width

The mean values of fibre lumen width of agave sisalana leave fibre evaluated at different stages of fibre length as in Table 3, were 1.267µm, 1.00µm, 1.067µm, 1.00µm and 1.50µm for the length of 153.0µm, 190.0µm, 243.3µm, 265.3µm and 316.7µm respectively. The result in Table 3 shows that, in all stages of fibre length investigated the lumen width were lower than that of rice husk fibre and wheat straw fibre (Agu*et al.*, 2002). This is also lower than that of corn husk which has short fibres similar to various hard woods, whose length is <2mm, fibre diameter (21.89±5.1µm), lumen width (6.63±3.5µm) and cell wall thickness (7.63±2.3µm) (Taiwo*et al.*, 2004). This is in contrast with the result reported by Sharma *et al.*, (2011) that, lager fibre lumen width produces better in beating of the pulp due to penetration of the liquid in fibre lumen, but in agreement with the report of (Ogbonnaya*et al.*, 1997) that, fibre length, lumen width and wall thickness were not enough to justify the strength of the papers produced from the plant fibres.

Fibre wall thickness

The mean values of fiber wall thickness of agave sisalana leave fibre evaluated at different stages of fibre length were the same at all stages investigated as 0.50±0.333 for length of 153.0µm, 190.0 µm, 243.3µm 265.3µm and 365.7µm respectively. The analysis result in table 3, shows that, the fibre wall thickness in all stages of fibre length investigated were the same irrespective of changes of fibre diameter due to increase in length. This is in agreement with the report of (Msahli*et al.*, 2006) that, the fibre with uniform characteristic perform well where instantaneous force act on the fibre during the use of end product. The result in all cases were higher than that of castor plant fibre and cotton fibre (Maduako*et al.,* 2011), but lower than bambusatulda (Sharma *et al.,* 2011).

Fibre Physical Properties

Moisture absorption

The mean values of moisture absorption evaluated at different stages of fibre length was presented in Table 5 and were found to be 3.0 %, 3.0 %, 3.0 %, 3.2 % and 3.1 % for the length of 153.0 µm, 190.0 µm, 243.0 µm, 265.3 µm and 316.7 µm respectively. It was observed that the moisture absorption at all stages investigated were lower than cotton fibre of 8.0 – 25.0 % (Naveen *et al.,* 2014), flax of 6.2 – 7.0 % (Brindha, *et al.,*2013), and *Agave Americana* with moisture absorption ranged between 8-9% (Ashish*et al.,* 2015). This is in agreement with the report of (Saheb, 1999) that, fibre with low moisture absorption capacity is suited for different application as composite due to its moisture resistance. The moisture absorption increase to 3.16 % with further increase of fibre length (265.3 µm) but decrease to 3.133 % at fibre length of 316 µm. this might be due to the differences in fibre diameter from the bottom to the top. The analysis of variance (Table 3) shows that moisture absorption is not significant at 5 % probability level.

Fibre density

The density values measured at different stages of length as presented in Table 2, were 0.667 g/cm^2, 0.654 g/cm^2, 0.621 g/cm^2, 0.647 g/cm^2 and 0.610 g/cm^2 for length of 153.0 µm, 190.0 µm, 243.0 µm, 265.3 µm and 316.7 µm respectively. The results revealed that the density of sisal fibre ranged between 0.610 ±0.407 to 0.667±0.445. The results were in agreement with the studies investigated on natural fibres by (Pai, *et al.,*2015) and reported that, good quality natural fibres most possess good thermal insulation properties, low density, noon abrasive nature, easily available from replenish able sources, recyclable in nature and sustained good application as composite for structural and non-structural applications. It was observed that fibre density decrease with an increase in fibre length. The analysis of variance (Table 3) indicates that the density of the fibre investigated at all stages of length were significant at p≤0.05 level for the replications and not significant for the treatments.

Table 2 Determined Fibre Physical Properties

FIBRE LENGTH (µm)	Mean Moisture absorption (%)	Mean Density g/cm^3

153.0	3.0 ± 2.000	0.667 ± 0.445
190.0	3.0 ± 2.000	0.654 ± 0.436
243.0	3.0 ± 2.000	0.621 ± 0.414
265.3	3.167 ± 2.111	0.647 ± 0.431
316.7	3.133 ± 2.089	0.610 ± 0.407

Table 3 Analysis of variance (Mean Square) for fibre moisture absorption and density

Sources of Variation	DF	Moisture Absorption (%)	Density (g/cm^3)
Replication	2	297.295^{ns}	30.045*
Treatment	4	73.492^{ns}	18.075^{ns}
Error	8	10.256	6.013
Total	14		

Fibre Chemical Properties

Table 4 Determined Fibre Chemical Properties

Parameters	Base T_1	Middle T_2	Top T_3
Cellulose (%)	83.33±55.553	76.67±51.113	70.00±46.667
Hemicelluloses (%)	17.77±11.847	23.33±15.553	16.67±11.113
Lignin (%)	75.00±50.00	55.00±36.667	65.00±43.333
Ash (%)	30.50±20.333	30.50±20.333	30.00±20.000

Celluloses content

The mean values of cellulose content of *agave sisalana* leaves fibre as shown in Table 4 were 83.33%, 76.67% and 70.00% for the fibre length at base, middle and top respectively. The celluloses content decrease from the base to top level of the fibre as presented in Figure 1. The values in all stages were lower than seed flax, kenaf, ramie, jute, abaca, but falled within the ranged of Henequen, fibre flax (Xue*et al.*, 2007), *Agave Americana* (Ashish*et al.*, 2015). The content in all stages investigated were 70% and above, this is in agreement with (Ververis*et al.*, 2004) and (Sharma et al., 2011) that, investigated plant materials using standard rating system and recommended that plant material with 34% and above cellulose content were characterized as promising plant for pulp and paper manufacturing from chemical composition point of view. It was observed from the results that the cellulose content was high in comparison with other plant fibres, and the higher the cellulose content the smaller the fibre diameter and proves that the fibre will be stronger in accordance with (Ishak*et al.,* 2009). Also in agreement with the report of (Mohanty*et al.,* 2000) that, cellulosic fibres changes their dimensions and properties with varying moisture content.

Hemicellulose content

The hemicellulose content of *agave sisalana* leaves fibre as shown in Table 4, were 17.77 %, 23.33 % and 16.67 % for the fibre length at the base, middle and top respectively. The hemicellulose content increases from the base level to the middle and decrease to top level. This is in agreement with the reports of (Ebringerova*et al.,* 2000) that, hemicellulose content of plant fluctuate due to presence of sugar, glucose, xylems, galactose, arabinose in its composition. It was observed from the result in Figure 1 that, in all stages investigated the hemicellulose content was higher than henequen with 4-8 %, abaca with 15-17 %, ramie 5-16.7 %. But lower than seed flax 30 – 45 %, (Xue, *et al*., 2007). It was also observed that, the hemicellulose content of the fibre was very low, and this is in agreement with (Agu*et al*., 2012) that, low hemicellulose content in fibre is responsible for less water absorbing capacity which has advantages in utilization in different applications as composites.

Lignin content

The values of lignin content determined were presented in Table 4 and were found to be 75.00 %, 55.00 % and 65.00 % for the fibre length at base, middle and top respectively. The result showed that the lignin content were decrease from base to the middle and increase to the top level (Figure 1). But in all cases investigated the lignin was higher than pineapple crown leaves, rice straw, kenaf and bagasse (Khristova*et al.,* 2002; Tran, 2006; Huang, *et al.*, 2007). Lignin content in fibre improved the fibre strength and makes it suitable for paper making and other strong applications (Waranyou, *et al*., 2010).

Ash content

The values of ash content determined as shown in Table 4 were 30.50 %, 30.50 % and 30.00 % for the fibre length at the base, middle and top respectively. The result shows that the ash content at the base and middle were the same, but decrease with 0.50 % at the top. The content was higher from the base to the middle and lower at the top level as presented in Figure 1. This is in agreement with (Steyn*et al.,* 2006) that, natural plant fibres are subject to growth irregularities to extent of the same plant possess different sizes and properties. The content in all stages investigated were higher than borassusfibre with 0.64 %, rice straw with 9.2 %, jute leaves with 8.8 % (Basak*et al*., 1996), kenaf with 4 % (Khristova*et al*., 2002) and bagasse with 1.5% (Khristova, *et al*., 2006). Chemically sisal leaves fibre was rich in cellulose, and the higher the cellulose, the higher the ash content and vice versa (Waranyou, *et al.,* 2010). The higher the ash content, the easier the processing techniques of materials during application (Namessan, 2008). It was observed that, sisal fibre has high ash content in comparison to other natural plant fibres, therefore, it will have good processing ability in most of its applications.

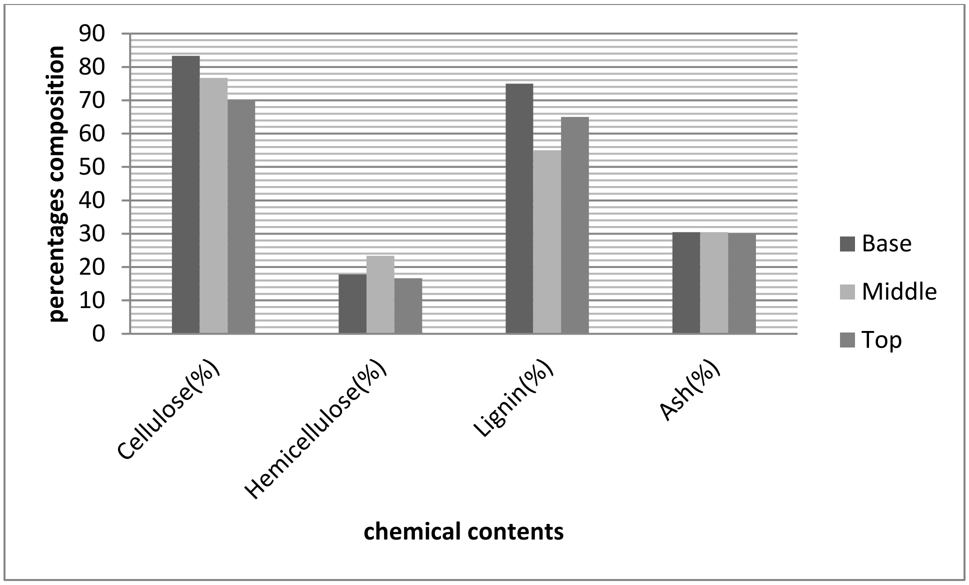

Figure1 Chemical Properties Distribution Chart

Conclusions and Recommendations

Conclusions

Agave sisalana leaves fibre extracted from the leaves obtained locally from Maiha L.G.A of Adamawa state, were studied for its physico-chemical properties for engineering application. The fibre was extracted using water retting procedure and treated with alkaline (NaOH).

The following conclusions were drawn; the fibrerunkle ratio in some stages of length (153.0 and 190.0) were less than one (<1) while slenderness ratio in all stages of fibre length were greater than seventy (>70) which is considered good for paper production. It was fond that the fibre has moisture absorption is 3.1 % and the density of 0.64 %, cellulose ranged between 70 – 83 % and this can be used in many applications due to its moisture resistance ability and is within the standard rating system of fibre with 34 % and above. Fibre cellulose content with this percentage is characterized as promising plant for pulp and paper manufacturing from the chemical point of view.

Recommendations

Based on this study conducted on Physico-chemical properties of sisal hemp (*agave sisalana*) leaves fibre at different stages of fibre length and thickness, the following recommendations were made;

1. It was recommended for pulp and paper making due to its high cellulose content >70%.
2. It was recommended for application in piteado technique for leather embroidery and plaster of paris (POP) due to its high tensile strength and low density.
3. Based on these finding, the design and construction of machine for processing of sisal fibre should be carried out.

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DESIGN, CONSTRUCTION AND EVALUATION OF A WOODEN SILO FOR THE STORAGE OF WHEAT GRAIN

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ABSTRACT

It has been said severally that variations in weather conditions prevailing on the surface of the earth affect the total population of grains and other food materials necessitating alternative ways of storage of farm produce. A deep wooden storage silo capable of storing 250 kg of wheat grains and having a volume of 0.32 m^3 was constructed using locally available materials. The availability of wood, low heat conductivity as well as low coefficient of thermal expansion and ease of construction makes wooden silo to be preferred to other silos. The objectives of this work were to design, construct and evaluate a wooden silo of 250 kg capacity for the storage of wheat grain, investigate heat and moisture transfer in the silo and to investigate the effect of environmental parameters on the stored wheat. Wheat grains of 250 kg was stored in the silo for a period of 92 days (3 months). Parameters such as internal silo temperature, ambient temperature, ambient relative humidity and grain moisture content were measured. The ambient temperature ranged from 20.5 ^{0}C to 35.6 ^{0}C. The minimum moisture content of the grain was 13.5% (wb) and the maximum moisture content was 15.1% (wb) giving an increment of 1.6%. The ambient relative humidity ranged from 75.3% to 94.3%. It was observed that the external relative humidity has the greatest effect on the moisture content of the stored wheat grain. A regression model of the form MC = $0.368X_0 - 0.647X_1 - 0.086X_2 + 0.200X_3 + 3.516$ was generated which can be used to predict any of the parameter once other variables are known.

Key Words: *Wooden Silo, Wheat grains, Moisture content, Temperature, Relative humidity*

1.0 INTRODUCTION

Wheat (*Triticumspp*.) is a cereal grain, originally from the Levant region of the Near East but now cultivated worldwide (Belderock, 2000). In 2013, world production of wheat was 713 million tons, making it the third most-produced cereal after maize (1,016 million tonnes) and rice (745 million tonnes), (Debashis.*et al.*, 2015). Wheat was the second most-produced cereal in 2009; world production in that year was 682 million tonness, after maize (817 million tonnes), and with rice as a close third (679 million tonnes) (Dale, 2014). Presently, the world production is 754 million tons while the consumption stands at 736 million tons (Statista 2018).

About 30 percent of valuable foods, after harvesting, constitute post-harvest losses which are now very serious problems throughout the world (Proctor, 1994). According to FAO (2014), about 1.3 billion tons of food are globally wasted or lost per year. To reduce these losses, there should be provision for effective crop storage systems. Farmers throughout the whole world and in every nation store grain under cold or hot climate (Alabadan, 2002). They store in traditional storage structures like mud rhombus, bag storage, storage cribs made of exclusively plant materials, calabashes, gourds and earthenware pots, underground storage and granary or in modern storage structures like silo and warehouses. They usually make use of storage techniques that are most suitable to them and their pocket at a point in time. For the purpose of this work, silo was considered because stored grain parameters can easily be monitored and controlled within the structure.

A silo is a structure for storing bulk materials. Silos are used in agriculture to store grain or fermented feed known as silage. Silos are more commonly used for bulk storage of grain, coal, cement, carbon black, woodchips, food products and sawdust (Adejumo, 2013). Silos are used to store loose grain, which has replaced the traditional storage in bags. This makes shipping in bulks easier. Smaller size silos are sometimes built to so that grains can be moved into many different storage tanks depending on the type of grain or other factors.

The first indigenous silo in Nigeria was a ventilated outdoor concrete type designed and erected at the Institute of Agricultural Research and Training, Moor plantation, Ibadan in 1965. In furtherance of the search for suitable materials for silo construction in Nigeria, a wooden silo was designed and constructed at the Department of Agricultural Engineering, University of Ibadan in 1989 and further evaluated with maize in 2002 (Mijinyawa, (1989), Alabadan, (2002) and Babarinsa, (2011). The wall and floor of the silo consisted of double layers of plywood sheet incorporating a 50 mm air-gap. While the inner and outer layers for the wall panels were respectively 12mm by 6mm, those for the floor were respectively 18mm and 6mm. the silo was tested for temperature fluctuations and moisture condensation (Adejumo, 2013). The test results showed that the wooden silo had the potentials of reducing the range of temperature fluctuations within the silo and eliminate moisture condensation when compared to a metallic one.

The objectives of this work were to design, construct and evaluate a portable wooden silo of 250kg capacity for the storage of wheat grain, investigate heat and moisture transfer in the silo and to investigate the effect of environmental parameters on the stored wheat.

2.0 MATERIALS AND METHODOLOGY

2.1 Site Location

A wooden silo was constructed of hard wood materials. The wooden silo was placed under the shed of the Agricultural Engineering Department at Obakekere in the Federal University of Technology Akure, Ondo State, Nigeria.

2.2 Design considerations for the wooden silo

A design was sought for which is durable and affordable and one that will require minimal maintenance. A deep silo is preferred in this context because it takes wall friction into consideration meaning that the vertical load is partly supported by the wall forming an imaginary arch.

2.3 Designs calculations

2.3.1 Load Imposed by the Stored Grain

1. **The Lateral Pressure:** This is the variation in pressure as a function of elevation as a result of wall friction. This is calculated using Janssen's formula quoted by (Mijinyawa, 1989).

Lateral load on vertical walls$L = \frac{WD}{4\mu}(1 - e^{-4k}\mu\frac{H}{D})$ 1

Where, L is the lateral pressure, kg/m^2; W is the material density, kg/m^3; D is the bin diameter or equivalent diameter, m; K is the ratio of lateral to vertical internal pressure, = $\frac{(1-sin\theta)}{(1+sin\theta)}$; $\theta$is the angle of repose; $\mu$is the coefficient of friction of material on wall; H is the depth of fill.

Density = $\frac{mass}{volume}$; Volume = $\frac{mass}{density}$; Volume of the structure = $\frac{250}{780}$; Volume = 0.32m^3

L is calculated to be 325N/m

2. Horizontal Pressure: This is the pressure imposed on the retaining wall of the silo as a result of wall friction. It is calculated using the formula by (Muir, 2001)

P = kL 2

Horizontal pressure P is calculated to be 55.9N/m

where P is the horizontal pressure, k is the ratio of lateral to vertical pressure ratio (Janssen's constant), and q is the lateral pressure

3 **Vertical friction.** This is calculated by using the formula by (Adedutan, 2015).

$V = (\gamma Y - L)R$ 3

where V is the vertical friction; γ is the weight per unit volume of the stored material; Y is the height of the silo and R is the hydraulic radius of the silo

Vertical friction is calculated as 175.57N/m

2.3.2 Determination of the Dimension of the frame's timber Board

It is essential to determine the dimension of the frame's timber board, and this can be determined using Janssen's formula as stated by Sawant, 2015

$L = \frac{WD}{4\mu}\left(H + \frac{D}{4k\mu}e^{-4k}\mu\frac{H}{D}\right) - \frac{WD^2}{16k\mu^2}$ 4

Dimension 0.5m ×0.5m ×1.28m is ok

2.3.3 Determination of the thickness of retaining wall

Retaining walls are required for materials stored in bulk to withstand the pressure the grains will exert on the wall. This is calculated using Rankine formula by (Nicholas, 2007);

Maximum bending momentB.M = $\frac{wh^3}{6}$ 5

Where; W is the density of the grain; h is the height of the storage structure

The width is calculated as 7.5 cm and the thickness is calculated as 9cm thick using afara timber

2.4 Description of the silo

The exploded view and the orthographic view of the wooden silo is as shown in figure 1 and figure 2. It consists of five main parts, namely; the roof, storage compartments, inclined floor and slides, a hopper and the supporting frame. The storage structure has two compartments which can store 250kg of the wheat grain. The volume of the silo is 0.32m^3. The roof has two inlets through which grains can be fed into the storage compartments and this grain will hen rest on the inclined floor and slide.

Table 1: Properties of Wheat Grains used for the Experiment.

Properties	Values
Bulk density	780kg/m^3
Angle of Repose	45^0
Angle of friction	27^0
Coefficient of friction	0.47
Weight of wheat grain stored	250kg
Moisture content of wheat grain stored	13.5%

(Source: FAO, 2010)

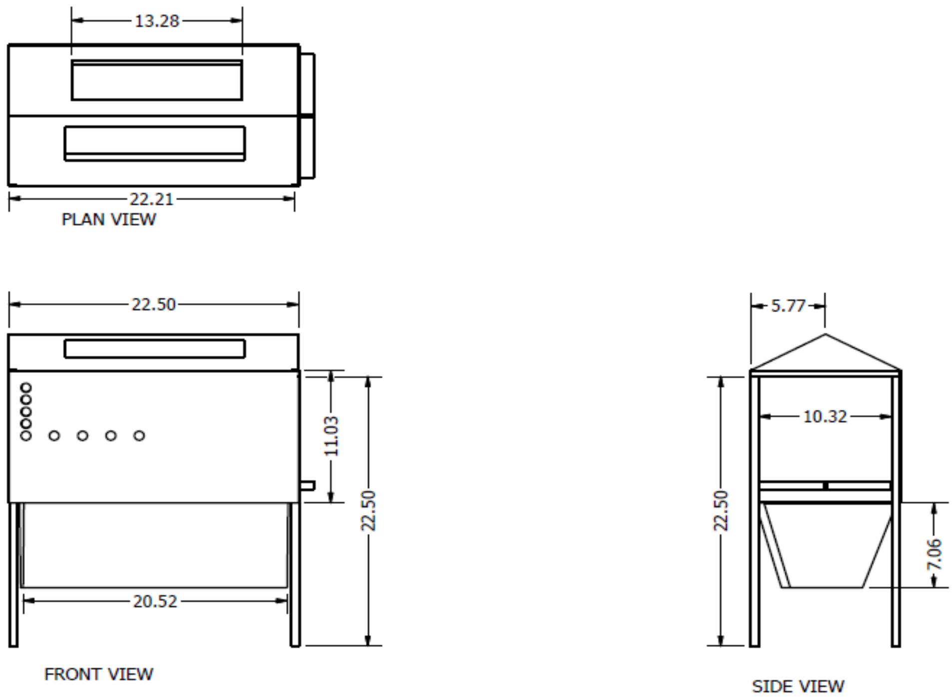
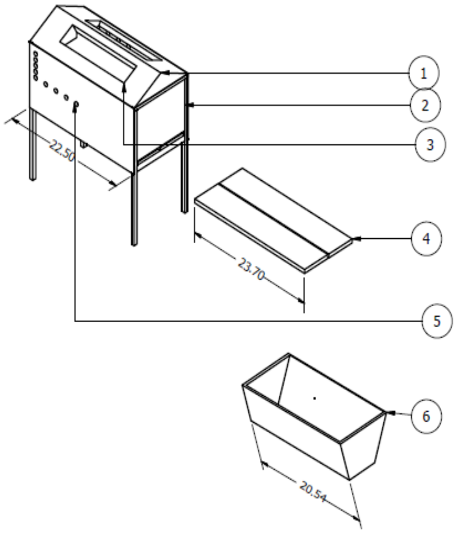


Figure 1: Orthographic view of the wooden silo



PARTS LIST		
ITEM	QTY	PART NAME
1	1	FRAME COVER
2	1	FRAME
3	2	INLET
4	2	STOPPER
5	5	SENSOR PROBE
6	1	OUTLET
4	1	Part10
5	1	Part1

Figure 2: Exploded view of the wooden silo

2.5 Evaluation of the Structure

The wooden silo was placed at the back of Agricultural Engineering Department of the Federal University of Technology, Akure at Obakekere. 250kg of wheat grains was stored for a specific period of 3months. The moisture content of the wheat was determined using digital grain moisture meter. Temperatures inside and outside the silo were measured using digital temperature probes and automatically logged into a data logger every five hours' interval (morning, afternoon, and evening). Temperatures were measured at the wall, between wall and centre, centre, mid-surface and the surface inside the silo to determine possible temperature variations in the transverse and radial directions. The evaluation took place from January 2016 to April 2016. A period falling between dry season and beginning of raining season.

2.6 Evaluation of Environmental Parameters

Environmental conditions in the silowere monitored and recorded for three months using portable data logger. Temperature and relative humidity inside the silo were measured using digital thermometer and hygrometer respectively. The equipment was obtained from the Federal University, Akure, Ondo State.The ambient temperature (AT) and relative humidity (RH) were measured daily (morning, afternoon and evening) using a standard thermometer (Harris, England) with a 42 calibration and a standard hygrometer (Harris, England) with a 50 calibration.

2.7 Data Analysis

Experimental data were analyzed as appropriate using version 21.0 of Statistical Package for Social Science (SPSS) and Microsoft Excel spread sheet. Linear plots and graphical representation were generated and estimated using the aforementioned packages likewise. Stepwise Linear Regression was used to analyze the relationship that exists between the various parameters and their respective effect on the stored grain.

3.0 RESULT AND DISCUSSION

3.1 Effects of Temperature

The mean weekly internal temperatures at different points during the experiment and ambient temperatures are shown in Figures 3 and 4. It was observed that the temperature of the silo wall, between wall and centre, centre, mid-surface and the surface ranged from 19.4^{0}C – 27.9^0 C; 19.5^{0}C – 29.7^{0}C; 19.7^{0}C – 30.6^{0}C; 19.5^{0}C – 30.7^{0}C and 19.7^{0}C – 34.6^{0}C respectively. The lowest and highest temperatures within the silo were 19.4^{0}C and 34.6^{0}C respectively. This observation is similar to the works of Swantet *al.*, (2012) and Alabadan and Oyewo, (2005). The internal temperature of their wooden silos ranged from 24^{0}C to 31^{0}C. This might be as a result of the seasonal changes in the period of storage. Drop in temperature of grain inside the silo were observed in week 5 and week 7 while there was increase in the temperature in week 6. These observed fluctuations might also be due to changes in the weather during this period.

The lowest ambient temperature recorded was 20.5^{0}C while the highest temperature was 35.6^{0}C. It was cooler at the centre of the silo in the morning while the temperature at the grain surface was higher than at the remaining part of the silo. As shown in Fig. 4, there was decrease in environmental temperature until week 3 and thereafter, the temperature continued to increase particularly in the morning (ATM) and afternoon (ATA) during the period of the storage. Similar trend can be observed in week 9 for temperatures in the morning (ATM) and evening (ATE) while the afternoon temperature was fairly constant around 28 ^{0}C. After week 10, morning temperature started increasing while evening temperature started decreasing.

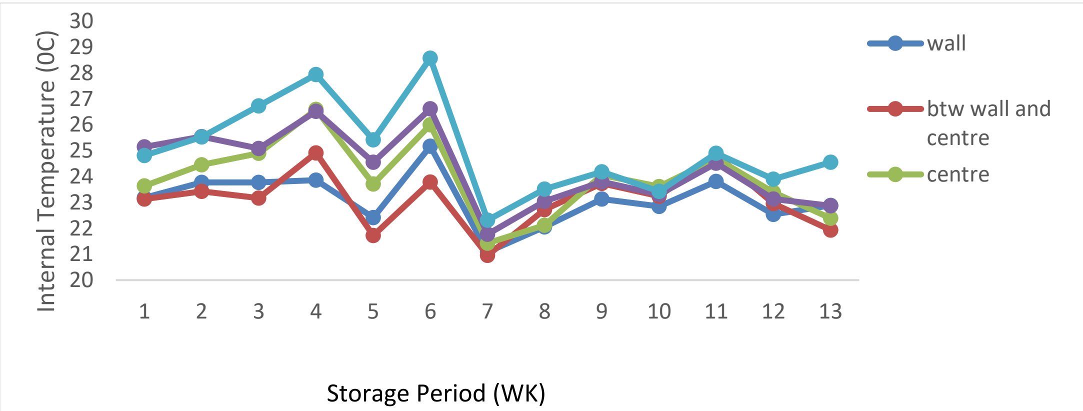


Fig. 3: The mean weekly internal temperature during the storage period

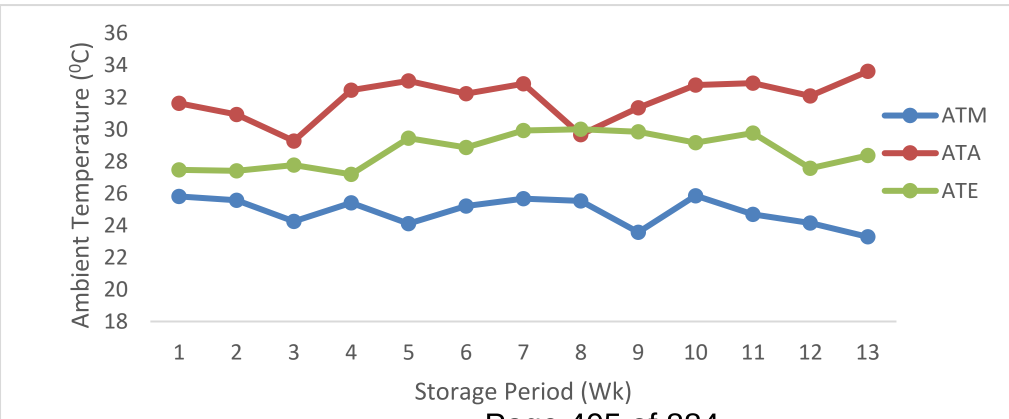


Fig. 4: The Mean weekly ambient temperatures during the storage period.

3.2 Grain moisture content

Figure 5 shows the moisture of wheat grain at different points during storage period. It was observed that the moisture of the grain was increasing gradually. The increment implied that the grain was interacting with the environment surrounding it. From the graph, the minimum moisture content is 13.5% while the maximum moisture content is 14.9 % at the top, and 14.3 % at the centre of the silo. According to Alabadan, (2002), the safe moisture content of wheat grains is below 15%. The experiment was terminated in April at the onset of raining season and it is expected that the moisture content of the wheat might not increase further throughout the period of raining season because the environmental temperature which is considered a major driving force of mass transfer will be reduced.

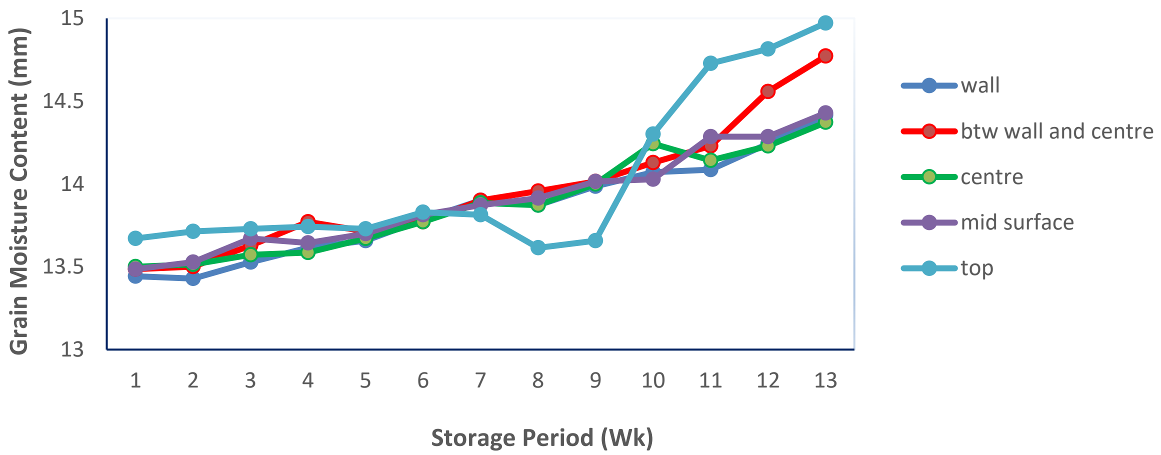


Fig 5: Moisture Content of wheat grain during storage period

3.3 Relative Humidity

The relationship between the ambient relative humidity and the silo (internal) relative humidity during the storage period is shown in Figure 6. The ambient relative humidity ranged from 75.3% to94.3% while the relative humidity inside the silo ranged from 60.3% to 93.5%. The lowest relative humidity recorded outside the silo was 75% while the lowest relative humidity 62% was recorded inside the silo. The highest ambient relative humidity and the highest silo relative humidity were 94.3% and 93.5% respectively. The ambient relative humidity recorded in similar research works conducted by Alabadan (2002),Alabadan and Oyewo (2005), and IRRI (2009) which ranged from 30% to 100%, 59% to 86% and 40% to 100% respectively.

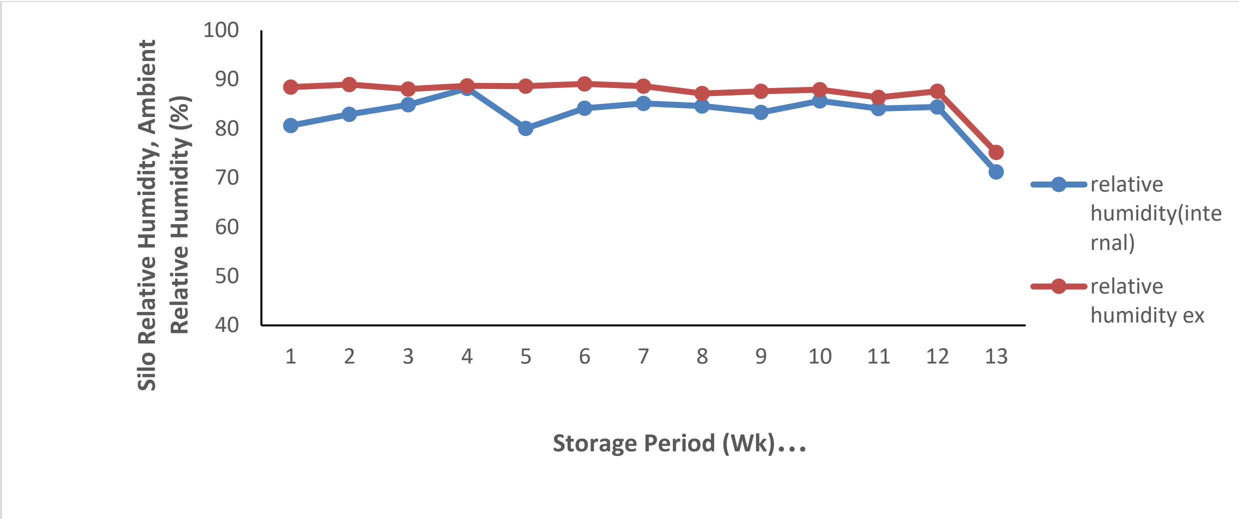


Fig. 6: Relative humidity profile inside and outside the silo during the storage period

Modeling the Effect of Environmental Factors on the Stored Grains

Table 2 shows the various effects of environmental variables on the moisture content of the wheat grain.The result shows that the external relative humidity has a greater effect on the moisture content of the stored wheat. The external relative humidity has a significant value of 0.015 which indicates that external relative humidity of the storage structure played a significant role in moisture level of the stored grain.

Table 2: Linear regression table showing the respective effect of the various parameters on the moisture content of the stored wheat grain.

	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	T	Sig.
(Constant)	13.926	5.15		3.961	.004
IRH	.034	.021	-.368	1.623	.143
ERH	-.054	.018	.647	-3.071	.015
ITEMP	-.035	.095	-.086	-.364	.725
ETEMP	.098	.124	-.200	.790	.452

From the stepwise regression table, a model was generated which can be used to predict any of the variables once the other parameters are known. Moisture content is the dependent variable and other variables are independent.

From the table;$MC = \beta_0 X_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + C$

Where MC is the moisture content; β_0 is the standard coefficient for internal humidity; $X_0$is the value of the internal relative humidity; $\beta_1$is the standard coefficient for the external

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relative humidity; X_1 is the value of the external relative humidity; β_2 is the standard coefficient for the internal temperature of the silo; X_2 is the value of the internal temperature of the silo; $\beta_3$is the standard coefficient for the external temperature of the silo; $X_3$is the value for the external temperature of the silo, and C is a constant.

Thus, the model is of the form;

MC = $0.368X_0 - 0.647X_1 - 0.086X_2 + 0.200X_3 + 3.516$

This model is similar to the model of Ilknur (2012) for vacuum dried red chili pepper and Sarsavadia*et al.*(1999).

4.0 CONCLUSIONS AND RECOMMENDATION

4.1 Conclusions

A wooden silo was designed, constructed and valuated for the storage of wheat grains for three months. The grain moisture of the wheat grains in the silo increased from 13.5% to around 15 % (wet basis) during the storage period. After the storage period, a physical observation carried out on the stored wheat showed that wheat grain wasin good condition, showing that the structure is good for the storage of wheat grain, the temperature in the silo showed an increasing trend with time. The relative humidity in the silo was 0.8% higher than the ambient relative humidity.

External ambient temperature and relative humidity played important role on the moisture content of the stored grains. A model of the form MC = $0.368X_0 - 0.647X_1 - 0.086X_2 + 0.200X_3 + 5.15$ appropriately described the relationship between the moisture content, relative humidity and temperature of the stored product.

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AN ESTIMATION OF SAWDUST GENERATION AND ENERGY POTENTIALS IN KWARA STATE, NIGERIA

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ABSTRACT

The global concerns about the rise in anthropogenic gases have resulted in alternative clean energy sources. Biomass is one of the most prominent sources of renewable energy which can be found in wood and wood wastes, agricultural crops and their waste byproducts, Municipal Solid Waste (MSW), animal wastes, waste from food processing, aquatic plants and algae. Wood and wood wastes obtained from forest biomass stand at the centre of Renewable Energy Source (RES) due to its availability and usefulness in most developing countries. Sawdust is one of the wood processing residues that are in excess of local demand because of the near absence of its industrial demand in Kwara State. Data relating to it availability, industrial usage and energy potentials are rarely available. This study investigates it availability and inherent energy potentials that can be a vital tool for energy policy, planning and development. Wood wastes generated in the state were estimated to be 8012.8 m^3/yr with inherent energy potential of 31298 GJ. By putting sawdust seen as wastes in most wood processing plants into efficient use will help reduce the competition for wood as source of heat for cooking and heating.

Keywords: Biomass, Wood logging, Sawdust generation, Industrial demand, Energy potential

1.0 INTRODUCTION

The concerns for environmental sustainability through commitments to decreasing greenhouse gas emission have geared interest in Renewable Energy Sources (RES). Reliance on conventional energy source (fossil fuels) is being threatened due to depletion, price fluctuations and massive contribution to green house gasses. There have been growing interest in bio-energy (energy obtained from biomass) because of its inherent benefits in enhancing rural populace lives through poverty reduction, supply of the energy needs at all times without expensive conversion devices, energy delivery in all forms needed by people (solid, liquid and gaseous fuels, heat and electricity), carbon dioxide (CO_2) neutral and can even act as carbon sinks, and it helps to restore unproductive and degraded lands, increasing biodiversity, soil fertility and water retention (Demirbas, *et al*., 2009). Bio-energy has proven to be an important alternative and more sustainable energy supply. This form of energy can be obtained from living or dead organic matters such as wood and wood wastes, agricultural crops and their waste byproducts, Municipal Solid Waste (MSW), animal wastes, waste from food processing, aquatic plants and algae. Wood and wood wastes is the most prominent of bio-energy materials as it account for 64%, follow by Municipal Solid Waste (24%), agricultural wastes (5%), and landfill gases (5%) (Demirbas, 2008 and Demirbas, *et al.*, 2009).

Wood is used to cook and keep warm for years and it continues to be the largest biomass resource. It can be in solid or processed (pelletized) form for use in residential, institutional, and commercial heating. Waste wood from the forest and lumber processing industry include bark, sawdust, trimmings, planner shavings and board ends (FAO, 1993, Thran and Kaltschmitt, 2002; Parikka, 2004). The size of these wood waste resources depends on how much wood is harvested for lumber, pulp and paper. These waste materials with modern technologies can be processed into useful solid, liquid and gaseous fuels (Vesterines and Alakangas, 2001; Sims, *et al.,* 2006). These fuels produce very low emissions, generate relatively few acid rain and smog causing particles, and have a minimal impact on the environment when converted to energy correctly.

Different tropical hardwoods and softwoods species are available to service and sustain the many wood processing industries in the state. Wood based industrial activities include timber logging, sawmilling, wood-based panel products manufacturing (e.g. plywood, fibre board and particle board), furniture, pulp and paper making, and match making, wood seasoning and the manufacture of various wooden items such as tool handles, sport goods, weaving equipment and wooden craft. Saw milling is the process of converting round wood from the forests into lumber by using a variety of machines. Such machines include band mills capable of splitting logs into desired specifications and re-sawing machines for processing the cants and flitches into specified and marketable dimensions (Lucas, 1995). Sawdust and other wood wastes are important biomass resources associated with the lumber industry. Enormous quantities of these are generated during logs conversion and these depend on factors such as wood properties, type of operation and maintenance of the plants (F.A.O., 1992; Warensjo, 1997; Aina, 2006). Residues derived from the forest industries can have alternative uses such as chips for pulp production, raw materials for particle board and fibre board production, or as fuel. The level of utilisation is dependent on demand for their use as alternative materials or input for production of other valuable products.

Wood wastage during log processing has been a major factor responsible for the fast depletion of the state timber resources. Minimizing wood wastes during sawmilling process will help reduce the number of trees cut per annum. Wood wastes can be in the form of avoidable and unavoidable wastes (Adekunle, *et al.,* 2010). Unavoidable wastes cannot be avoided (prevented) even where the saw kerf is minimal and the mill workers are efficient. Examples of such wastes include sawdust, inconvertible slabs and strips. Avoidable wastes are caused by lack of pre-inspection of trees and logs, inadequate saw maintenance and poor harvesting techniques. These residues left in the forest are in the form of branches, tree crowns, off cuts, twigs, stumps and small diameter sized timbers. Both the avoidable and unavoidable wood wastes generated during harvesting and conversions are enormous and when pooled together can be used in the production of other valuable products such as charcoal, pellet and briquette.

Biomass assessments for energy utilization have been the focus of many researchers in developed economies. These have helped in their energy policy planning and implementation with increased inclusion of bio-energy in their energy supply matrix. Waste materials seen as assets in this developed economies are often disposed off by burning in many developing countries. This further pollutes the environment and creates serious health hazards to human life. The need to address this is the focus of this research, as it aimed to assess the sawdust generated from log processing and inherent energy potentials in Kwara State, Nigeria.

2.0 MATERIALS AND METHODS

2.1 Description of the Study Area

The study was carried out in Kwara State, located in the North Central area of Nigeria on coordinates 8° 30′ 0″ N, 5° 0′ 0″ E. The State has a total land area of 36,825 sq km (14,218.2 sq mi) and bounded in the North by Niger State, in the South by Oyo, Osun and Ekiti States, in the East by Kogi State and in the West by Benin Republic. There are thirty-two protected forest reserves occupying a total area of 5,792 km^2 (17.82%) of the total land area. The high forest area within the reserves occupies 12.31 km^2 (99.78%). There are only two communal forest reserves in the state, occupying a total land area of about 0.24 km^2. The climate of the state is tropical with distinct wet and dry seasons. The mean annual temperatures vary from 26^{o}C in South to 28^{o}C in North. Annual rainfall is from March to October and varies from less than 750 mm in the North to nearly 1500 mm in the Southwest. There are sixty-five sawmills scattered all over the State. The vegetation patterns affect sawmills distribution in the state. The state produces about 9,579 m^3operating system sawn wood per annum with most of the logs processed in the State (www.google.com/kwarastate).

2.2 Data Collection and Analysis

Information was sourced on the numbers and distribution of sawmills in Kwara State from the Ministry of Forestry and Environment. There are 65 sawmills in the state, 10 were randomly picked to estimate the quantities of sawdust generated during processing. Three working days was allocated to each sawmill investigated with each day comprising of 8 hours of work. Any day with power challenge was continued the next day to make up the 8 hours of work per day. Data on logs processed and sawdust generation were collected from the selected sawmills. Measurement using a 16ft measuring steel tape was taken of the log height/length, diameters at the base, the middle and the top positions of the logs to be processed. Stem volumes of all lumbers converted were estimated using the Newton's formula (Husch*et al.*, 1982)

$$V_{1=\pi(d_b{}^2+\,4d_m{}^2+d_t{}^2)}\,{}^{L}/_{24} \tag{1}$$

where V_1 is the volume of log (m^3), L the log length/height(m), and d_b, d_m and d_s are the diameters at the base, middle and top of the log respectively. This expression was used in estimating the volume of each log before processing.

The total volume of the various dimension lumbers obtained per day from timbers in (1) above was obtained using equation 2.

$$V_2 = [L \times B \times H]n \tag{2}$$

where V_2 is the volume of sawn lumbers, m^3; L, B and H are the length, the breadth and the thickness, mm respectively and n the total number of lumbers gotten. For each 8 hrs working day, the volumes of all lumbers converted were determined and subtracted from those obtained from the log volumes before processing. The difference is the volumes of wood waste as expressed in equation 3. Data collected wereanalysed using a Microsoft excel tools to obtain the overall sawdust generated from sawmilling activities in Kwara State.

$$V_w = V_1 - V_2 \tag{3}$$

where V_w is the volume of waste (m^3), V_1 is volume of round logs before conversion (m^3) and V_2 is volume of lumbers obtained after conversion (m^3)

2.3 Energy Potential Estimation

The energy potential from the generated waste was estimated using an expression given by Edward *et al.,* 2007

PR = IRW x p x pr [Gm^3 $year^{-1}$] or [EJ $year^{-1}$] (4)

where PR the bio-energy potential of wood processing residues, IRW the consumption of industrial round wood, p is the wood processing residue generation fraction and pr is the wood processing residue recoverability fraction.

Wood processing residue generation fraction (p) is the fraction of consumed wood that is converted into residues during the processing of wood. Different values had been used in many studies (Hall *et al*., 1993; Heath *et al.*, 1996; Sohngen and Sedjo 2000).The World Resources Institute reported a figure of 0.30 for the best sawmills in Europe and the USA and 0.7 for many developing countries (GFTN/WWF 2000). This study used 0.41 for p based on the ratio of consumed wood and waste generated per day from the study. Wood processing residue recoverability fraction (pr) is the fraction of processing residues that can be realistically collected. Data on the recoverability fraction found in the literature vary considerably; roughly from 0.33 (Hall *et al*., 1993) to 0.75 (Johanssen*et al*., 1993; Williams 1995). Yamamoto and co-workers (1999) reported a recoverability fraction of 0.42 for sawmill residues in developing countries and 0.75 in developed countries. This study used a recoverability fraction of wood processing residues of 0.42 because there was no data on alternative use of the waste generated.

Also, the ultimate analysis for typical biomass materials as given by Clarke, *et al*, 2011 for wood waste is 18.6 MJ/kg.

Recall:

$$\rho = \frac{M}{V}$$

Mass of wood waste (kg) = $\rho x V$

where

ρ = density of wood waste , kg/m^3 ($\rho = 210\ kg/m^3$)

V = volume of wood wastes generated, m^3

3.0 RESULTS AND DISCUSSION

3.1 Sawmills Distribution and commonly found Wood Species in Kwara State

Wood harvesting for sawmilling has been on the increase in the State as the numbers of wood processing factory have been on the increase. Processed wood consumptions have also increased due to urbanization and improvement in the populace standard of living. Sawmills and distribution in the State are as shown in Table 3.1. The highest number of sawmills was found in Baruten Local Government Area. Most of the sawmills relied on power supply from the National Grid. Some are in clusters at a certain location with single industrial generator to supplement power supply from Power Holding Company of Nigeria (PHCN).

Table 3.1: Sawmills and distribution in Kwara State, Nigeria

S/N	Local Government Areas	No. of Sawmills
1	Ilorin East	1

2	Ilorin West	10
3	Ilorin South	Nil
4	Irepodun	8
5	Kaiama	11
6	Ekiti	7
7	Baruten	14
8	Oke-Ero	Nil
9	Offa/ Oyun	3
10	Edu	Nil
11	Moro	5
12	Isin	1
13	Patigi	4
14	Asa	1
15	Ifelodun	Nil
	Total	**65**

Source: Kwara State Ministry of Forestry and Environment

Both hardwoods and softwoods species were found in sawmills across the State. Table 3.2 present the results of some of the common local wood species as observed from the investigation.

3.2 Wood Conversion and Waste Generation

The average number of round logs converted per day in each of the sampled sawmills ranges from 18-28. This is mostly affected by the logs size, operators' efficiency, condition of the bandmills, nature of the logs converted but most importantly level of power supply per day. The maximum number of round logs converted per day was 28 as recorded in sawmill 6 while the least with 18 logs was observed in sawmill 1.

Table 3.2: Some common local wood species in Kwara State, Nigeria

S/N	Local name of wood	Scientific Name (s)
1	Iya	*Danieliaoliveri*
2	Apa	*Afzeliaspp*
3	Ara	*Pterocarpuserincious*
4	Ayan	*Distemonanthusbenthamianus*
5	Ayin	*Anogeissusleoccarpus*
6	Apado	*Berliniaspp*
7	Igbaa	*Prosopisafricana*
8	Mahogany	*Khayaspp*
9	Iroko	*Miliciaexcelsa*
10	Teak	*Tectonagrandis*
11	Ahun	*Alstoniacongensis*
12	Oro	*Antiarisafricana*
13	Aye	*Sterculiarhinopetela*
14	Araba	*BombaxSpp*
15	Idigbo	*Terminaliaivorensis*
16	Sapele	*Entandophragmacylindricum*

17	Opepe	*Naucleadiderrichii*
18	Ayinre	*Albizialebbek*
19	Oriri	*VitexIdoniana*
20	Oro	*Antiarisafricana*

Table 3.3: Mean volume of logs converted, lumbers produced and waste generated.

Sawmill	Mean of logs converted/day	Mean of volume of logs converted /day (m^3)	Mean number of lumbers produced/ day	Mean volume of lumbers produced/ day (m^3)	Mean wood waste generated/day (m^3)
SM1	**18**	0.9142	310	0.4581	0.4561
SM2	19	0.9716	406	0.5484	0.4232
SM3	23	**1.1150**	541	0.6296	0.4855
SM4	22	1.0218	478	0.5469	0.4748
SM5	22	1.0146	472	0.6065	0.4081
SM6	**28**	0.9303	610	0.5835	0.3468
SM7	26	0.8779	488	0.5445	0.3333
SM8	25	0.8846	543	0.6230	0.2616
SM9	19	1.0225	422	0.5646	0.4580
SM10	20	**0.8726**	451	0.6043	0.2683
Total	**223**	**9.6251**	**4721**	**5.6935**	**3.9316**

The mean volume of logs converted in the sawmills ranges from 0.8726 $m^3$to 1.1150 m^3. The highest volume of logs converted was recorded in Sawmill 3 while the least was from sawmill 10.The mean volume of lumbers produced per day ranges from 0.4581$m^3$to 0.6296m^3. In all the sampled sawmills the average volume of lumbers obtained was greater than the volume of waste generated. The output per sawmill was greatly influenced by the power supply per day, the size of logs converted the condition of the band mills and operators' skill. The mean total volume of wood waste generated from the 10 sampled sawmills was 3.9316m^3. The total volume of wood wastes that can be generated from the 65 sawmills in the state was estimated at 25.60 m^3per day. In a year considering 6 working days per week, 8012.8 m^3/ yr of wood wastes will be generated. These can serve as raw materials for production of some other valuable products. But this enormous volume of wood waste are seen littering the premises of these sawmills in the form of huge piles of sawdust and other wastes. In most cases these are burnt with the smoke given off during burning causing environmental pollution and health hazards, Figure 1.

Figure 1: Disposal of sawdust by burning

3.3 Estimated Energy Potential from the Wood Wastes Generated

An estimated 9.6251 m^3volume per day of round wood processed was obtained from the 10 sampled sawmills. This translate to 62.56 m^3 volume of round wood consumed per day in the 65 sawmills in the state. For a 6 working day per week, 19581.28 m^3/yr of round wood was consumed in the state. The energy potentials inherent in the wood wastes were estimated to be 31298 GJ. This can be integrated to the national grid to meet the energy need of the State.

4.0 CONCLUSION AND RECOMMENDATION

The study assessed wood wastes generated from saw milling activities in Kwara State with inherent potential energy value. From the 65 functional sawmills in the state, 8012.3 m^3/yr of wood wastes can be generated. The energy potentials inherent in the wood wastes were estimated to be 31298 GJ. These enormous volumes of wood wastes are seen littering the premises of these sawmills in the form of huge piles of sawdust, slabs and off-cuts. In most cases these are burnt with the smoke given off during burning causing environmental pollution. Harnessing these as input for other valuable products will help to mitigate environmental pollution caused by indiscriminate burning of sawdust as seen in most of the log processing plants. Therefore, the state has tremendous potentials to develop solid, liquid and gaseous fuels through the applications of wood residues.

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POST HARVEST AND FOOD ENGINEERING

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PRODUCTION OF BIO-PLASTIC FROM WASTE OF CASSAVA

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ABSTRACT

In this study, the use of agricultural waste for production of bioplastic was explored. The project seeks to reduce environmental pollution by the use cassava peels to produce bioplastic to replace the existing products currently in market that are not environmentally friendly. The study also developed protocols for the production of biodegradable plastic cassava peel. The optimum mix of cassava peel starch, acetic acid and glycerol is 200:2 0:10 to form a good bioplastic resin. While The tensile strength, strain, energy and extension ranged from 1.30-2.87MPa, 0.086-0.093, 0.1-0.278J and 5.83-7.06mm respectively and within values obtained from previous researches. The research work will have considerable impacts on the vision of bio-economy launched by many African countries, which is to be achieved through the creation and growth of novel industries that generate and develop bio-based services and products. It will also support the local content initiative of Nigeria government.

INTRODUCTION

Globally, 140 billion metric tons of biomass is generated every year from agriculture. This volume of biomass can be converted to an enormous amount of energy and raw materials. As raw materials, biomass wastes have attractive potentials for large-scale industries and community-level enterprises especially in bioplastics which are used for packaging food and non-food materials. This in turn reduces the carbon footprints in the system.

Plastics are synthetic polymers consisting of long-chain molecules made up of repeated units joined together usually solid in nature (Ticona, 2006). They have a wide range of utilization hence they are used in agriculture for crop mulches, greenhouse coverings, labels, and silage wraps and also as components or parts in computers, cars, refrigerators etc., which tends to enhance their aesthetic qualities (Brodhagen *et al.*, 2017; Koushal *et al.*, 2014). As the demand of these plastics increases, plastic waste also increases concomitantly thereby constituting nuisance to the environment due to its non-biodegradability. For instance, in Europe, the overall increase in the generation of plastic waste is 5.7MT between 2008 and 2015 as the production of plastic is also projected to have been increased by 24 percent (Sánchez *et al.*, 2014). While in Nigeria, the average solid waste generation including plastic waste is 0.58Kg per person per day (Babayemi and Dauda, 2009).

Various methods have been employed to manage plastic waste generation such as incineration, recycling and landfill all which have impacts on the environment. Incineration is the most commonly used practice for plastic waste control. It reduces the stress on landfill facilities but is expensive and dangerous, incinerating plastic waste generates greenhouse gases such as methane (CH_4) and carbon-di-oxide (CO_2) which significantly contribute to the depletion of ozone layer. Landfilling is the most convenient approach for waste management. Unavailability of land is the major constraints in both the developed countries and countries with high population densities. Globally, plastic waste accounts for 18–20% volume in landfill. However, some major drawbacks of plastic waste management in landfills are leachates which adversely affect soil microbial flora, leading to soil infertility and ground water and water supply contamination.

In developing countries however, recycling of plastic waste is not economically viable. Rather the use of virgin material is recommended because of the cost of haulage with respect to the density of plastic waste. More so, comprehensive report of the environmental impact assessment on plastic recycling is hardly available. That is, little information can be found on assessing the environmental aspect of recycled plastic product for high-value applications or everyday application (Gu *et al.*, 2017). Throughout the world, high volume of plastic debris dumped by the road sides, parks, beaches, oceans and natural areas tends to create an eye sore (Gómez and Michel, 2013). Therefore, for a sustainable environment to be established and also to zero the possible disposal of recalcitrant plastic waste in the environment, a lot of attention has now been diverted to the production of bioplastics due to their biodegradability and eco-friendly nature (Emadian *et al.*, 2016).

Bio-plastics are polymeric materials derived from renewable carbon sources that naturally decompose to carbon-di-oxide (CO_2) and water under aerobic conditions or methane (CH4), CO2 and water under anaerobic conditions (Heimann *et al.*, 2016). Bioplastics can be bio-based and/or biodegradable. While biobased refers to the material's origins, biodegradable refers to the end of its life cycle (FoodValley, 2015). They can also be prepared from several biological sources, including plant and animal materials, of which starch-based bioplastics are currently the most commonly manufactured bioplastics on the industrial scale. When compared to their petro-plastics counterparts, bioplastics are biodegradable, sustainable, and more environmentally friendly in terms of lower greenhouse gas emission and fossil fuel usage and also their renewable option. However, bioplastics have not reached their full potential as viable and permanent solution to replace petro-plastics. Regardless of any limitations, bioplastics remain a forefront number as a suitable replacement for petro-plastics (Harding *et al.*, 2017; Sudesh and Iwata, 2008). Therefore, for biodegradable plastics to be suitable for food packaging and other applications, several performance criteria such as strength, flexibility and moisture resistance need to be investigated.

MATERIALS AND METHODS

Materials

Freshly processed cassava peels were bought at a local cassava processing site at Eleyele in Ibadan, Oyo state, South-West of Nigeria while banana peel was bought from a Ikire and Akure in Osun state and Ondo state, also in the South Western Nigeria. Chemicals used were purchased from local chemical stores.

Methods

Extraction of starch from cassava peels

Washed cassava peel was milled into paste. The cassava paste is mixed with water until it become homogenous. The mixture is trained through 100 mesh and later strained through Whatman paper. The filtrate was placed in white buckets to settle for 48hour for appreciable quantity of starch to be obtained. The top clear liquid was decanted to collect the thick cassava peel starch, that settled at the bottom of the bucket and sediment (starch) was sun dried for 24h and stored.

Production of Bioplastic

Cassava peel starch paste of 10% (w/v) was prepared by dissolving in distilled water. Five (5) samples each of 200g of cassava peel paste were mixed with 20g of acetic acid and the quantity of glycerol (5g - 40g) were varied while the mix was heated at 100°C and stirred for 5minutes. These mixtures were cast in trays and dried at room temperature for 48hours and some samples were dried at 45°C for 24hours to determine plastic resin with optimum physical, chemical and biological properties. The experiment was repeated with 10g of acetic acid and 5 - 40g of glycerol.

Testing and Analysis of samples

Tensile test

Tensile tests were carried out in accordance with ASTMD882-02, (2002) with an Instron tensile testing machine (model 3369, USA) having maximum load of 50kN. The test specimens were cut into a dumbbell like shape of dimension of 167mm× 20mm. Tensile tests were carried on 3 samples from each material at ambient temperature (plate 1 and 2) with a constant deformation rate of 5 mm/min

Plate 1: Loading of Specimens

Plate 2: Tensile Test on Specimen

Biodegradability Test

This method was carried out in accordance with the procedure reported by Thakore *et al.* (2001) where humus soil were dug and filled with rectangular polymer samples of different size at a depth of about 12cm. The degradation of the samples was studied at 3 days interval for 27days. After intervals each sample was carefully removed from the soil and washed gently with distilled water to remove the soil adhering on the surface. Weight loss of the polymer with respect to time was recorded as a measure of degradation.

$$\text{Percentage Biodegradation (\%)} = \frac{\mathrm{w}_2 - \mathrm{w}_1}{w_2}$$

where w_2 isthe initial weight of the polymer before degradation and $w_1$is the final weight of the sample after degradation

Fourier Transform Infra-red (FTIR) Spectroscopy

FTIR was carried out in accordance with Oyerinde and Bello, (2016) where the mid-infrared spectra of powdered sorbitol composite and glycerol composite were obtained in Fourier transform spectrometer at Central laboratory, University of Ibadan, Oyo state. Potassium bromide (KBr) is the alkali halide as a medium to measure the spectrum. The supporting software was Microlab software and the FTIR spectrometer employed diamond attenuated total reflectance (ATR) sample interface system.

Product Development

Sample of the bioplastic was taking to L & K Nigeria Ltd in Lagos for product development, 1Kg of the sample was blown inside the company machine to produce a part. The existing mould on the machine is used to produce table slider (normally hooked on table legs as shown in the attached pictures in appendix A). Samples of the table slider were produced from our sample.

RESULTS AND DISCUSSIONS

Effect of Acetic acid and Glycerol concentration on Bioplastic resin formation

From Table 3.1 and observed products formed, it is confirmed that treatment of cassava peel starch with acetic acid and glycerol formed plastic resin. However, Sample A gives no visible change in physical appearance and no change in colour but dried to powdery starch with reduction in weight from 220g to 112.4g giving 95.73% moisture loss. This sample is non-biodegradable because there is no moisture to sustain the growth of micro-organisms.

Table 3.1: Determination of the effect of Acetic Acid, Glycerol and Heat on Cassava Starch

	Cassava Paste (g)	Acetic Acid (g)	Glycerol (g)	Dried Weight (g)	Moisture Loss (g)	Moisture loss (%)	Dried at 60°C (min)
A	200	20	-	112.40	107.6	95.73	-
B	200	20	-	129.78	90.22	69.52	60
C	200	40	100	259.27	80.73	31.14	60
D	200	40	-	133.94	106.06	79.18	60

Sample B gelatinized when heated with change in colour from pale white to dark brown, plasticized after 1hours and this dried up to hard plastic after 48hours at room temperature. There is reduction in weight due to moisture loss from 220g to 129.78g while when oven dried it turned to a very brittle and very hard plastic with glass interface when broken.

Sample C gelatinized while been heated, plasticized after 2hours but failed to dry at room temperature though there is moisture loss from 340g to 259.27g having 31.14% moisture loss. The oven dried part caked on the surface and cracked with time. This failed to turn neither plastic nor rubber but remains a gel. The increased quantity of acetic acid causes more moisture loss but the presence of glycerol encourages the plastic formation.

Sample D gelatinized while been heated, plasticized after 2hours and this dried up to very hard plastic after 48hours at room temperature. When oven dried it turned very brittle.

Constant amount of acetic acid of 20g was used in this experiment and quantity of glycerol varies between 5g to 40g and the following observations were recorded. All samples gelatinized when stirred at 100°C for 5minutes but failed to dry at room temperature however, they all shrink at varying degrees after being dried in the sun for 24hours and turned brown after drying. Also as can be seen from Table 3.2, the moisture loss increases from Sample A – Sample B but the moisture loss starts to decrease from Sample C – Sample D. Considering the physical texture of the dried plastic samples. Sample A is very brittle with little degree of elasticity. Sample B has better elasticity and dried very fast. Good quantity of moisture loss,

Table 3.2: effect of Varying Glycerol content on Bioplastic resin formation

and this makes the sample free from microbial attack and a better plastic. Sample C- Sample D though look tougher but remain like gel and thus may require thermosetting to become plastic. The moisture loss in Sample A is less than that of sample B, this is as a result of

	Cassava	Acetic Acid	Glycerol	Initial Weight	Dried Weight	Moisture Loss	Moisture loss (%)
A	200g	20g	5g	225g	50.59g	174.41g	77.51
B	200g	20g	10g	230g	50.58g	179.42g	78.01
C	200g	20g	20g	240g	69.28g	170.72g	71.13
D	200g	20g	30g	250g	93.45g	156.55g	62.62
E	200g	20g	40g	260g	103.73g	156.27g	60.10

limited glycerol and this caused the surface of sample A to cake very fast.

Comparing Tables 3.1 and 3.2 it can be observed that the optimum mix of cassava peel starch, acetic acid and glycerol is 200:20:10 to form a good bioplastic resin.

Bio-degradability of Bioplastic from Cassava Peel

From Table 3.3, it can be seen that the bioplastic produced is biodegradable and the rate of biodegradation is very rapid. The maximum number of days base on this observation is 9days, while by 12th day, the bioplastic turned to soil.The result showed that the degradability rate ranged from approximately 14% (day 3) to 86% (day 12)

Table 3.3: Rate of Deterioration of Bioplastic in the Soil

Days	Weight (g)	Rate of degradation (%)
0	11.04	100
0 – 3	9.54	13.59
4 – 6	5.32	50.81
7 - 9	3.12	71.74
10 - 12	1.51	86.32

Tensile Strength

The results of the tensile test on bioplastic produced from cassava peel are shown in Table 3.4. The tensile strength, strain, energy and extension ranged from 1.30-2.87MPa, 0.086-0.093, 0.1-0.278J and 5.83-7.06mm respectively. These values are similar to those obtained by Bourtoom, (2008), Gontard *et al.*, (1993). As shown, bioplastics made with sorbitol have higher tensile strength and energy in comparison with those made from glycerol. This observation is similar to the report of Ooi *et al*., (2012) who recorded higher tensile strength in composites made from sorbitol in comparison with those of glycerol. Statistical analyses

(ANOVA) revealed that apart from tensile strength, the strain, energy and extensions of bio-composites were not significantly ($P < 0.05$). This means that the plasticizers used in this work significantly affected the tensile strength of the bioplastics.

Table 3.4: Flexural Strength

Materials	Stress (MPa)	Strain	Energy (J)	Extension (mm)
CP +Sorbitol	2.87^{A}	0.086^{A}	0.278^{A}	6.50^{A}
CP+Glycerol	1.13^{B}	0.093^{A}	0.100^{AB}	7.06^{A}

* Significant at 5% level of probability ($P< 0.05$).
* Means with the same letters and in the same column are not statistically different.

FTIR Test for Cassava Peels (CP) starch, Plasticizer and Acetic AcidMixtures

The FTIR analyses are shown in Tables 3.5−3.6 and depicted in Figure 1-2. The functional groups present in the CP starch and glycerol and acetic acid mixtures are hydroxyl, alkane, carbonyl, alcohol, ester and alkenes. These components have no hazardous environmental effects. The hydroxyl group plays the important role of eliminating some greenhouse gases like methane such as the one present in Alkane group and ozone. The presence of ester carbonyl group increases the absorption capability. Therefore, exposure such material to sunlight will gradually decreases the molecular weight, discoloration, surface cracking, and deterioration in physical properties.

Table 3.5: FTIR Functional Group of CP starch, Glycerol and Acetic Acid Mixtures

Type of bonds	Functional Groups	Frequency/Peak Values(cm^{-1})
$\boldsymbol{O - H_{st}}$	Free Hydroxyl group (alcohol)	3789
$\boldsymbol{C - H_{st}}$	Alkane	2921
$\boldsymbol{C = O_{st}}$	Carbonyl	1755
$\boldsymbol{C - O}$	CO of alcohol or ester	1160-1033
$\boldsymbol{C = C}$	Alkene	1665

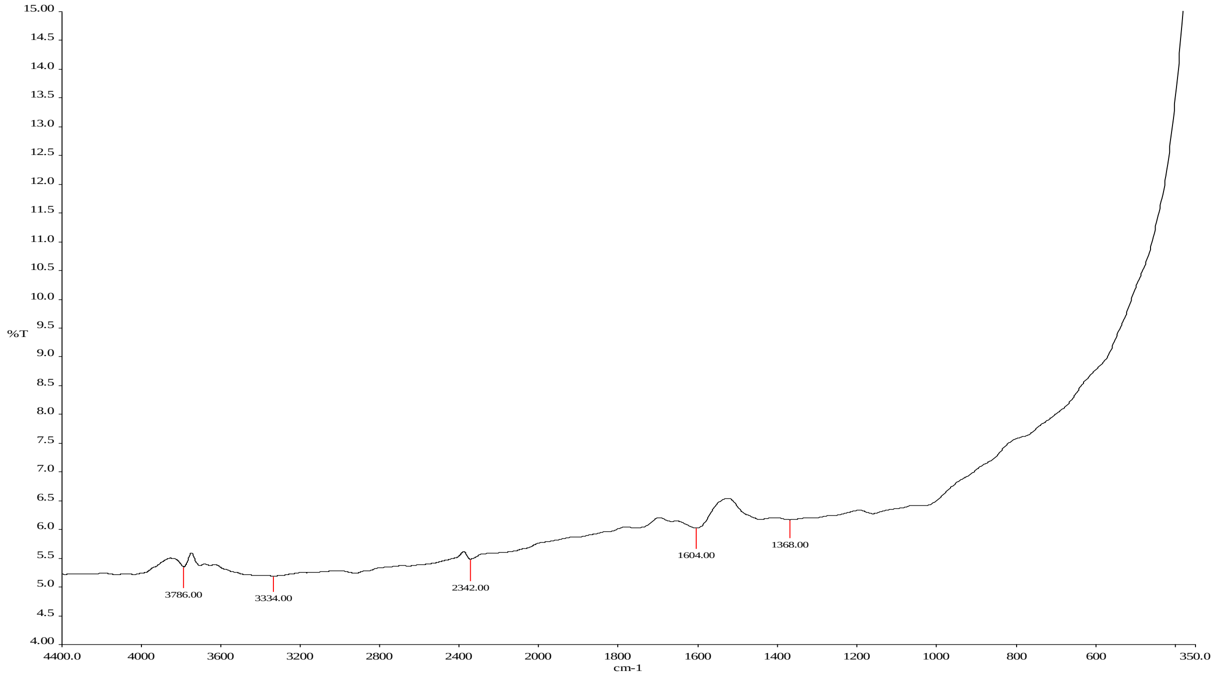

Figure 1: Spectrum of Transmittance and Wave Number for Starch, Glycerol and Acetic Acid

Table 3.6: FTIR Functional Group of CP starch, Sorbitol and Acetic Acid Mixtures

Type of bonds	Functional Groups	Frequency/ Peak Values(cm^{-1})
$O-H_{st}$	Hydroxyl group (H-bonded alcohol)	3424
$C-H_{st}$	Alkane	2924
$C=O_{st}$	Carbonyl	1743
$C=C$	Alkene (substituted)	1661
$C-O$	CO of alcohol	1162

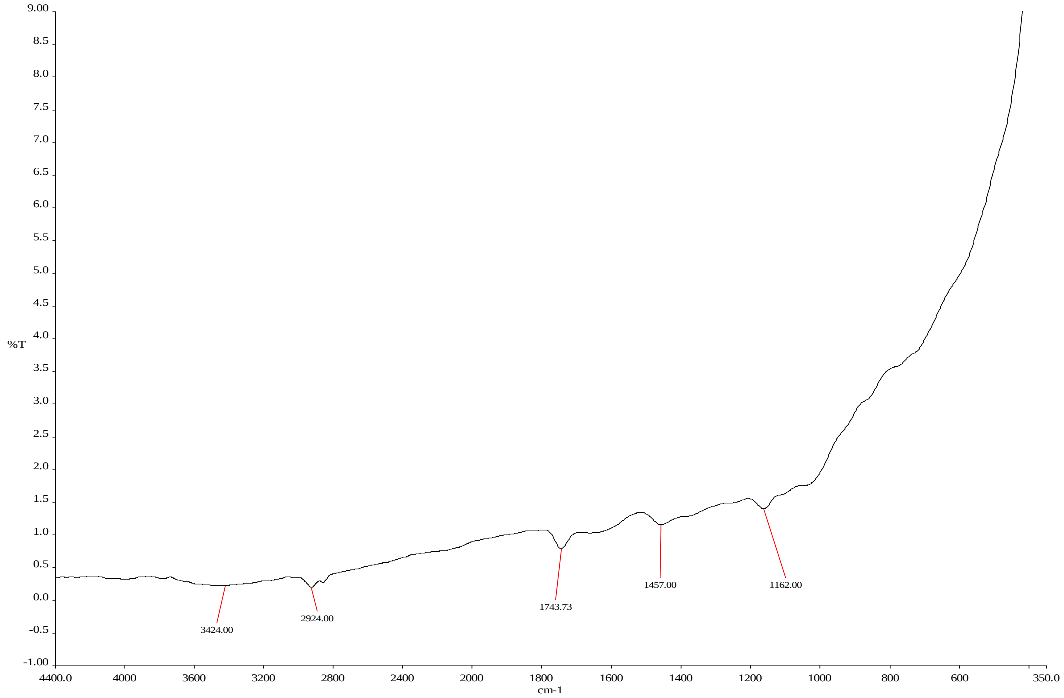

Figure 2: Spectrum of transmittance and Wave for Starch, Sorbitol and Acetic Acid

One kilogramme (1 kg) of the sample was blown inside the company machine to produce a part. The existing mould on the machine was used to produce table slider (normally hooked on table legs as shown in the attached pictures in Plates 3a and b). Samples of the table slider were produced from our sample.

The product developed compares with the original product however, it was observed that the sample is not smooth and also have rough edges compared with the one produced from pure material as shown alongside two samples of our own. However, the company machine uses rubber for production, and advice that we approach another company for better and smooth product. The product have potential use as dampers in machines, automobile doors and furniture. Further study aims to use the methods described by Asiru *et al.* (2011), Ewemoje and Raji (2011) and Raji (2008) for determination of smoothness by Artificial Neural Network training to compare the two products (rubber and bio-product). The product can also be extruded and blown to produce degradable containers. Bleaching or colour additives can result in different colouration of the bioplastic depending on the end use as shown in Fig 4.

(a)

(b)

Plate 3. Product Development from Bioplastic Sample

CONCLUSIONS

Bioplastic was produced from cassava peel successfully using acetic acid and glycerol. The optimum mix of cassava peel starch, acetic acid and glycerol is 200:20:10 to form a good bioplastic resin. The bioplastics from cassava peels has appropriate strength properties and also higher degradable rate as confirmed in the FTIR. The tensile strength, strain, energy and extension ranged from 1.30-2.87MPa, 0.086-0.093, 0.1-0.278J and 5.83-7.06mm respectively. The result also showed that the degradability rate ranged from approximately 14% (day 3) to 86% (day 12). However, more work need to be done to improve on stability of the bioplastic for effective utilization in real life situation.

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MODIFICATION OF AN EVAPORATIVE COOLING DEVICE FOR FRUITS AND VEGETABLE

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ABSTRACT

An electric powered evaporative cooling device for storage of fruits and vegetables was modified to solar powered in order to improve the shelf life of stored crops for small scale farmers in rural communities where electricity is not available. Temperature and relative humidity for both ambient and the cooling device wererecorded daily using a wet bulb and dry bulb thermometer and digital humidity - temperature meter. Weight loss was measured with adigital weighing balance. The device was evaluated in terms of drops in temperature, weight loss andincreased relative humidity and evaporative effectiveness for 14 days *using sweet orange and tomatoes in ambient condition and in the cooler. The average temperature drop and saturation efficiency in the cooler during the no-load test were 7°C and 41%, respectively. Weight losses in citrus and tomatoes in ambient condition were 20.22% and 45.56% respectively, while those stored at cooler temperature were 6.54% and 19.98% for citrus and tomatoes respectively. The cooler's ambient temperature varied from 23.0℃ to 26.0℃ and ambient relative humidity from 73.9% to 99.0%. The device is a very simple and cost efficient system that will serve local farmers by increasing their economic returns from their farming activities. The overall cost of this cooling device was 49,000 naira.*

Keywords:*Evaporative cooling, storage, tomatoes, citrus, temperature, humidity*

INTRODUCTION

Fruits and vegetables are generally classified as perishable crops that must be quickly preserved after harvest, if not they shrivel, whither or rot away rapidly, especially under hot conditions due to loss of moisture, change in composition and pathological attack (Ndirika and Asota, 1994; Sanni, 1999). In order to maintain freshness in these products, they have to be stored in low temperature and high relative humidity (Ndukwu, 2011; Liberty et al., 2014). Adequate storage prolongs usefulness, checks market gluts, and provides a wider selection of fruits and vegetables throughout the year.

Fruits and vegetables form an essential part of a balanced diet. They are important sources of digestible carbohydrates, minerals and vitamins A and C. In addition, they provide roughage (indigestible carbohydrates), which is needed for normal healthy digestion (Salunkhe and Kadam, 1995). Most of the post-harvest losses incurred on fruits and vegetables in developing countries are due to lack of adequate storage facilities. Refrigerated cool stores are the best method of preserving fruits and vegetables but the cost of installation and maintenance is by far beyond the reach of peasant farmers (Taye and Olorunisola, 2011). It has been observed that several tropical fruits and vegetables, e.g. banana, plantain and mango cannot be stored in domestic refrigerator for a long period of time as they are susceptible to chilling injury (NSPRI, 1990).

Fruits are very important in human daily diet because they are ready sources of vitamins and minerals. Fruits and vegetables are highly perishable commodities and cannot be kept for long period due to their perishable and seasonal nature. It is therefore important that they are preserved in seasons (Mogaji and Fapetu, 2011). The quality of fresh fruits and vegetables depends on post-harvest handling, transportation and storage (Haider and Demise, 1999). Due to climatic condition in Nigeria, fruits tend to loose moisture quickly which leads to loss of quality, nutrients and firmness even before it get to the consumers from the farmers. Nigeria post - harvest losses of fruits and vegetables amount to 35-45% of the annual production. The post-harvest losses occur during transportation, storage, and marketing which caused by poor handling and inappropriate storage facilities (Daramola 1998; Babaremu 2016).

The knowledge of storing fruits in cold environment has been in existence for a long time as far back as our forefathers, they used clay pots to retain cold and moisture of the fruits which has led to the advancement of evaporative cooling system to achieve the same purpose in a modern form but the erratic nature of electricity supply in Nigeria is a challenge leading to the reduction of their shelf life. The problem of epileptic power supply causes a need for solar evaporative cooling system for storage of fruits and vegetables.

Evaporative cooling is a system that utilizes heat to evaporate the water, resulting in a drop in the air temperature and increase in relative humidity. The efficiency of an active evaporative cooler depends on the rate and amount of evaporation of water from the pad; which is dependent on the air velocity through the pad, pad thickness and the degree of saturation of the pad (Ogbuagu et al., 2017).

Cooling through evaporation is an ancient but effective method of lowering temperature. The main objective of this study was to modify an electric powered evaporative cooling system to solar powered in order to improve the shelf life of stored crops for small scale farmers in rural communities where electricity supply is either not readily available or stable. The specific objectives were to evaluate the modified evaporative cooler to determine shelf life of citrus and tomato. Thistresearch effort will assist both the farmers and the marketers aliker improve their income on fruits and vegetables.

2. MATERIALS AND METHODS

2.1 Description of the Designed Cooler

The solar powered evaporative cooling device for small scale storage of perishable crops such as tomatoes, oranges and banana consists of a charcoal transfer medium, storage cabin, suction fan, solar panel, lead acid battery, and water distribution components. The water distribution components comprise of a water pump, pipes, overhead tank, and a collection tank as shown in Figures 1. The transfer medium was installed at the top left corner of the cooler and the suction fan is directly behind the transfer medium. An overhead tank was installed on top of the cooler from which water drips on to the charcoal through a pipe laid on top of the transfer medium holder. There is a collection tank at the bottom of the water to collect excess water from the transfer medium. The solar panel powers the fan and the pump at the same time charges the battery. The battery was used to power the fan at night when there is no sunlight. Charcoal was used as transfer medium for this experiment due to its moisture retention capacity. Figure 2 exploded views of the device.

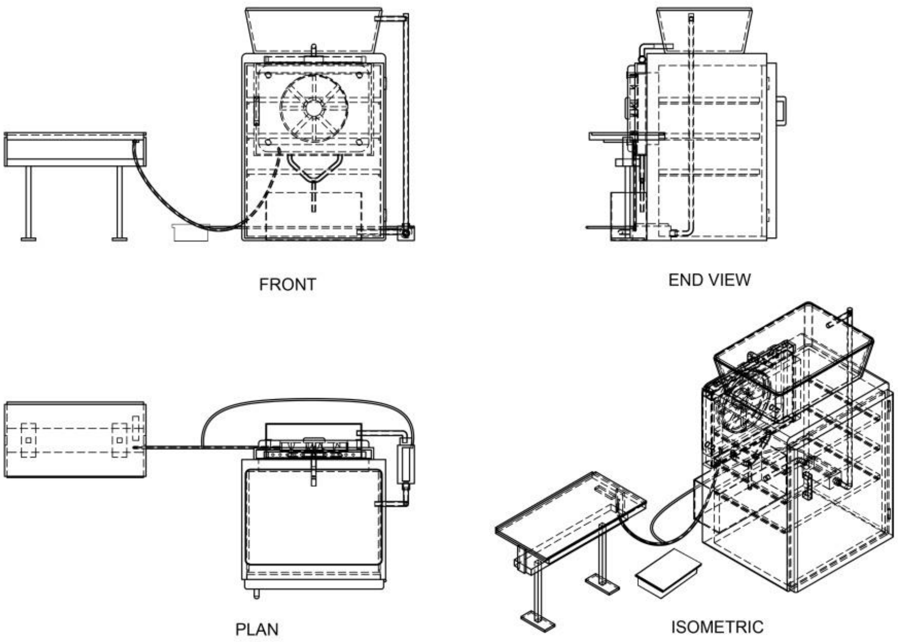
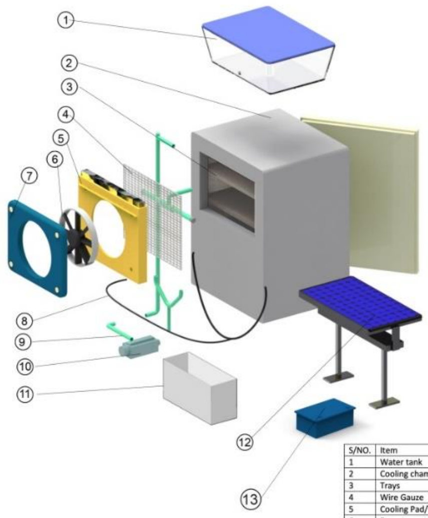


Figure 1: Isometric and orthographic representation



S/NO.	Item	Material	Quantity
1	Water tank	Plastic	1
2	Cooling chamber		1
3	Trays	Mild Steel	4
4	Wire Gauze	Mild Steel	1
5	Cooling Pad/Transfer medium	Mild Steel/Charcoal	1
6	Fan	Plastic	1
7	Screws	Mild Steel	4
8	Wiring		
9	Water piping	PVC	
10	Pump		1
11	Water collector	Mild Steel	1
12	Solar Panel		1
13	Battery		1

Figure 2: Exploded diagram of the cooling device

2.2 Design Considerations and Material Selection

The main design considerations were the specific volume of the crops to be stored, the thermal and mechanical properties of the materials of construction, as well as the power required to pump cooling water at the desired speed through the pad materials.

2.2.1 Solar Panel: Solar panel was selected based on the rated power of the cooler. As rated power of cooler is 184 W. Assuming 6 hrs of operation per day, would require about 1104 or 1200 watt hrs per day. Considering the losses and the availability of panels, 220 W, 12V solar panel was selected.

2.2.2 Battery: 100 Amp 12V battery available in market can store 1.2 kW of electricity. Hence this battery was chosen for the purpose.

2.2.3 Pad: Choice of charcoal for the transfer medium was based on its porosity, water absorption (and evaporation), availability, and cost. The medium was framed from steel and covered by a wire mesh.

2.2.4 Suction Fan: A 33 cm swept depth diameter fan was selected. Its major work was to suck air from the environment and force the dry warm air through the wetted charcoal to cause cooling effect inside the chamber.

3. EXPERIMENTAL PROCEDURES

Evaluation of the fabricated solar powered evaporative cooling was carried out at Soil and Water Laboratory of Agricultural and Biosystems Engineering Department, Landmark University. Sweet orange and tomatoes obtained from market were used for evaluation. Evaluation was conducted in two parts. In the first part, the cooler was operated under no load condition without crops to ascertain its conditions. Temperature readings of the cooler and the ambient were recorded using a thermometer. Relative Humidity (RH)readings of the cooler and the ambient relative humiditywere taken using a hygrometer. The readings were taken 3 times in a day (8 am, 3pm and 9pm) for 2 weeks.

Second part of evaluation was load test to ascertain efficiency of the cooler when loaded was with crops. All procedures and all calculations were repeated and all observations were recorded.

Physiological weight loss was determined by weighing five samples of sweet orange and tomato randomly sampled and labeled 1 to 5 to be used to measure physiological weight loss using a digital weighing scale (Constant 14192-1F model, China), and expressed as percentage weight loss using the following formula (Fred *et al.*, 2018);

$$\text{Percentage Weight Loss} = \frac{W1-W2}{W1} \times 100$$

where;
w_1= Initial weight of sample (kg), W_2 = Weight of sample after storage (kg).
Firmness was measured using a fruit hardness tester (FTH-05 model, Guangzhou, China) fitted with a 3.5mm probe. Five samples of sweet orange and tomato fruits were used for destructive analysis described by Fred *et al.* (2018*).*

4. RESULTS AND DISCUSSION

4.1 Weight loss

Weight losses that occurred during storage of the biological materials were determined. This was done through percentage loss estimate. Percentage cumulative weight loss in sweet orange and tomatoes are shown in Figure 3 and Figure 4. It was observed that the weight loss of sweet orange (18.94%) and tomatoes (38.61%) in ambient condition were greater than that of weight loss of sweet orange (5.13%) and tomatoes (14.25%) recorded inside the cooler. This is as a result of the reduction in temperature and increase in relative humidity of the cooler, and also to the evaporation of water and respiratory losses, which were dependent on the temperature and the relative humidity of the surrounding the produce.

Jahun *et al*., (2014) observed that weight of tomatoes stored in open air was maintained for only 8 days after which there was a sharp decline in weight from approximately 40.00 to 15.453kg. But tomatoes in the evaporative cooling cabinet had their weight relatively maintained at 39kg within one week of storage with only an approximate 2.95 loss in weight. In a similar study by Olosunde et al., (2015), weight loss changed from 1.38 to14.5% and from 10.25 to 33.95% after 3 and 21 days fortomatoes stored in the evaporative cooler and underambient conditions, respectively. Olosunde (2006) observed that mango, tomatoes, banana and carrot stored in the ambient air lost more weight than produce stored in the cooler. Babaremu (2016) also noted that the release of ethylene which is a ripening hormone was very rapid in the tomatoes stored in ambient condition but ethylene production of the produce in the cooler was low. Therefore, weight loss increases rapidly in ambient condition due to the respiratory activities that occur, as fruits and vegetables are biological materials, the low relative humidity outside the cooler increased the ripening process causing deterioration in the produce.

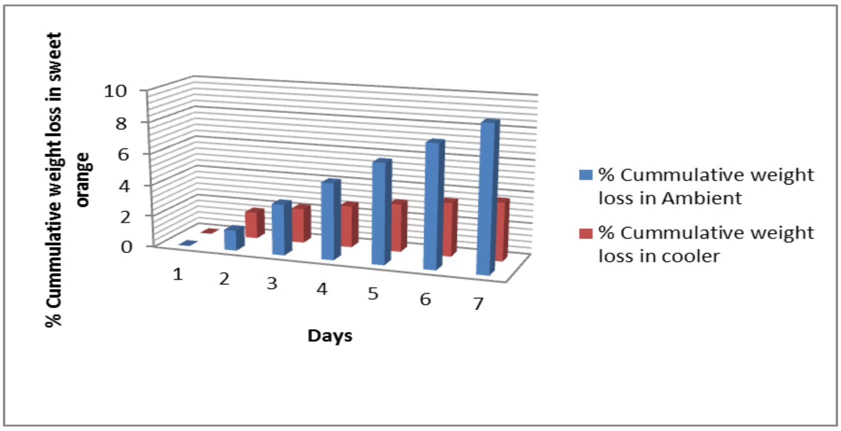


Figure 3: Percentage weight loss in sweet orange

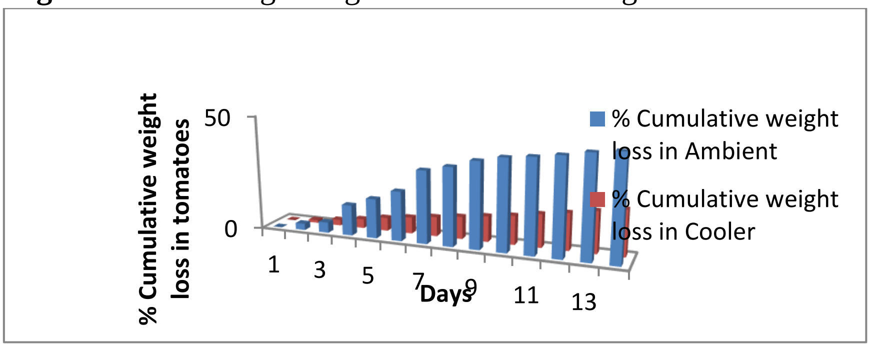


Figure 4: Percentage weight loss in tomatoes

4.2 Relative humidity difference

Figure 5 shows the effectiveness of the cooler through the obvious difference between the relative humidity of the ambient which was 73.9% and the cooler 99.0%. This was an indication that the cooler is effective as it reduces temperature and increases relative humidity causing reduction in deterioration rate that is an increase in shelf life. The main characteristic of an evaporative cooler is low temperature and high relative humidity (Babaremu, 2016).

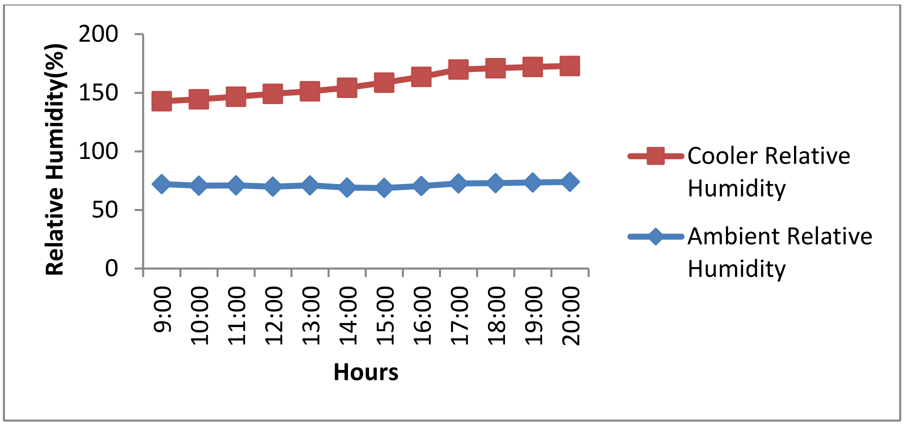


Figure 5: Ambient and cooler Relative Humidity

4.4 Temperature difference

Figure 6 shows the relation between the ambient temperature and the temperature of the controlled environment which is the cooling system in a no load test. During the no-load test the relative humidity of the cooler was high and the temperature was low but when the cooler was loaded with fruits and vegetable, the relative humidity dropped and the temperature rose because the produce are biological materials that respire. The device was evaluated for temperature variations from morning to afternoon at an interval of 1hour for 8hours. The results are as shown in Figure 6. The ambient temperature was observed to be increasing with time while the cabinet experienced drop in temperature. Average temperature inside the cooling device varied from 23^{0}C to 26^{0}C while the ambient air temperature varied from 28^{0}C to 30^{0}C for tomatoes and an average of 22.8 to 24.5^{0}C inside the device while in the ambient air temperature was from 28 to 30.5^{0}C for orange. Thus, temperatures in the evaporative cooling system were lower than the corresponding ambient air temperaturesduring the hottest time of the day. These results clearly demonstrate that the evaporativecooling system is useful for a short term preservation of farm products.

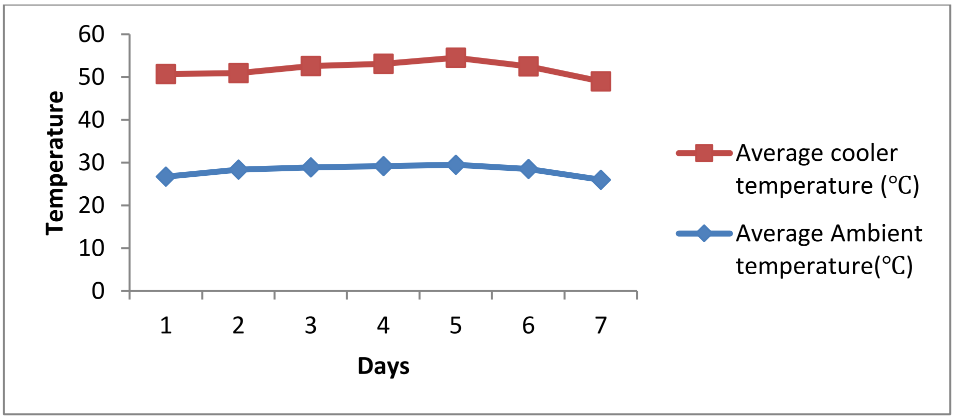


Figure 6: Ambient and Cooler Relative Temperature

4.5 Colour changes

The initial colour of the orange was light green before storage but during the evaluation process the colour of the orange began to change to yellowish, while the one in the cooler had a change in colour that could almost go unnoticed. Color changes of tomatoes stored in ambient condition was observed from the third day. The color changed from yellowish red to a deep red color while few ones turned reddish black by the sixth day. However, tomatoes in the cooling system retained their color after six days with no visible color changes in most of the tomatoes.

5. CONCLUSION AND RECOMMENDATIONS

An electric powered evaporative cooling device was modified to solar powered using locally available material. Its evaluation revealed an effective machine since temperature reduction from 26.0 ℃ to 23.0 ℃ and increased relative humidity of 73.9% to 99.0% was achieved. The design mechanism was very simple that it helps reduce the shelf deterioration rates of fruits. Saturation efficiency was increased by powering with solar. This led to an extension of fruit shelf life and freshness relative to ambient storage. The evaporative cooler will serve the local farmers in preserving their crops and thereby increasing their economic returns from their farming activities. The following are recommended;

1. This efficiency of the system would drop during continuous rains. It is recommended that an alternative power supply be made available in such a situation,
2. There should be provision for extra battery during the use of the cooler to give room for charging while the other is working.
3. After such research has been carried out, an extension program should be organized for end users especially, the peasant farmers.
4. In this research, charcoal was used as a transfer medium, further work should be done using other materials so that a comparative study can be carried out to determine the effect of different materials as transfer medium (cooling pads).

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FOOD SECURITY, SUSTAINABILITY AND POST-HARVEST TECHNOLOGY AS A TRIPOD FOR NATIONAL SECURITY

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ABSTRACT

Food security exists when all people at all times have physical, social and economic access to sufficient, safe and nutritious food. Food security is one of indicators of assessing gross domestic Product (GDP), impacts on human well-being outcomes and National security; it depends on food availability, access, utilization and stability. Sustainability foods systems are affected by factors which include price volatility, climate change, food losses and waste. The term "Sustainable food" has been used as a way to combine the concepts of food security and sustainability. Both food security and sustainability depend upon the post-harvest technology for their stability. This paper seeks to illuminate the potential of review of literatures on climate change, food security, sustainability and post-harvest Technology. Relationship between food systems, and food security were examined, whilethe concept of post-harvest technology and roles in sustainable food production for food security was addressed. Interrelationships between food security, sustainability and Post-harvest Technologywere enumerated.

Keywords: Climate change, food security, sustainability, post-harvest technology and national security

INTRODUCTION

Food security exists when all people at all times have physical, social and economic access to sufficient, safe and nutritious food. Food security is one of indicators of assessing gross domestic Product (GDP) and also has impacts on human well-being outcomes; it depends on food availability, food access, food utilization and stability.Climate change is the worst threat to food security and the projections are devastating. Soon, our agricultural practices may not be able to meet the world's demand for food due to impacts of climate change. The absence of sustainability measures today implies a social and moral responsibility from governance, policy makers, farmers, and consumers to do their part in combating world hunger.Reducing risks to food security from climate change is one of the major challenges of the 21st century. Researchers' such as Lobell *et al*. (2011), Creighton et al. (2015) and Herrero et al. (2015) recognised impacts of climate changes on agriculture which has being given the serious threats to food security.There is growing global recognition of the urgent need to identify and implement strategies that make food systems more resilient in the face of increasing climate variability. Africa is one of the world's most vulnerable regions to climate change (FAO, 2005, FAO, 2010), becausemost Africans' livelihoods and agri-food systems rely on rainfed farming. This climate change has created uncertainties on level of agricultural production globally; because not knowing exact shape of future climates or even next season, and these uncertainties are unlikely go away in the next decade (Heal and millner, 2014). Agriculture is important for food security in two ways: it produces the food people eat; and(Perhaps even more important) it provides the primary source of livelihood. Lack of attention to broader food security determinantsattributed to uncertainties about the impacts of climate changes on food security. Climate change always has impacts on all dimensions of food security, namely availability, access, utilisation and stability, and has impacts over the whole food system (Vermeulen *et al*., 2012). It also has an impact on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows (FAO, 2010). Food availability is probably most frequently used as a measure of food security and it has a channel with climate change which directly affects food security (Thompson, *et al*., 2010).The major direct impact of climate change is expected to have on food security is through food availability component due to changes in agricultural productivity (Wlokas, 2008). This climate change reduces crop yields and in turn increase the price of food that force people to change production and consumption patterns and directly reduces calorie intake (European Commission, 2009). Sustainability foods systems are affected by these factors include price volatility, climate change, biofuels, and food losses and waste (FAO, 2011).Food losses have an impact on food security for poor people, on food quality, safety, on economic development and on the environment. Food losses represent a waste of resources used in production such as land, water, energy and inputs, therefore, it affecting both food security and sustainability (Kader, 2005). Although minimizing postharvest losses of already produced food is more sustainable than increasing the production to compensate for these losses (Kader, 2003). Economically, avoidable food losses have a direct and negative impact on the income of both farmers and consumers. A major challenge in achieving sustainable food systems is the food security. The environmental and sustainability factors affecting long-term conditions for a food secure future. A sustainable food system supports food security, makes optimal use of natural and human resources, is culturally acceptable and accessible, environmentally sound and economically fair and viable. Besides, it provides the consumer with nutritionally adequate, safe, healthy and affordable food for present and future generations (FAO, 2011). Sustainability should be considered as part of the long-term time dimension in the assessment of food security. The concept of sustainable food could play a key role as a goal and a way of maintaining nutritional well-being and health, while ensuring the sustainability for future food security.

1.2. Objectives

The content of the study is set out in the terms of reference as follows:

(i) concept of Food security and Sustainability
(ii) examine the factors affecting both food security and sustainability
(iii) concept of post-harvest technology and interrelationship between sustainability and post-harvest technology for National security

2. MATERIAL AND METHODS

The report was based on

- A review of literature
- Personal observation and group discussion

2.1 Food security: It is defined by the United Nations' Committee on World Food Security, is the condition in which all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 1996). Food Agricultural Organization (FAO, 2011) highlighted that "food security depends more on socio-economic conditions than on agroclimatic ones, and on access to food rather than the production or physical availability of food". Food security is built on four pillars: availability, access, utilization and stability. It stated that, to evaluate the potential impacts of climate change on food security, "it is not enough to assess the impacts on domestic production in food-insecure countries. One also needs to (i) assess climate change impacts on foreign exchange earnings; (ii) determine the ability of food surplus countries to increase their commercial exports or food aid; and (iii) analyse how the incomes of the poor will be affected by climate change" (FAO, 2005).The food systems were linked to food security by "dynamic interactions between and within the biogeophysical and human environments lead to the production, processing, preparation and consumption of food resulting in food systems that supported food security" *(*Gregory, et al., 2005).

Food availability: It refers to the existence of sufficient quantities of food with appropriate quality, and supplied through domestic production or import (Thompson et al., 2010). Food availability is probably most frequently used as a measure of food security and it has a channel with climate change which directly affects food security (Oyija et al., 2011). The major direct impact of climate change is expected to have on food security is through food availability component due to changes in agricultural productivity (Wlokas, 2008).

Food accessibility: Access to food refers to the ability of individuals, communities and countries to purchase food in sufficient quantities and quality (Ludi, 2009). Accessibility depends on the transport infrastructure; fewer roads mean reduced food access.

Food utilization: Itdepends on how food is used, whether food has sufficient nutrients and whether diet can be maintained. Food utilization refers to the individual or household capacity to consume and benefit from the food (FAO, 2011). Although food availability and access are necessary conditions for food utilization, they are not sufficient conditions to reduce malnutrition. A household which has physical as well as economic access to food could be food insecure if it cannot get a balanced and nutritious diet (FAO, 2009). The utilization component of food security is generally related to nutritional aspects of food consumptionEvidence indicates that more frequent and more intense extreme weather events (droughts, heat and cold waves, heavy storms, floods), rising sea levels and increasing irregularities inseasonal rainfall patterns (including flooding) are already having immediate impacts on not only food production, but also food distribution infrastructure, incidence of food emergencies, livelihood assets and human health in both rural and urban areas.

Food system stability: The concept of stability can therefore refer to both the availability and access dimensions of food security.

2.2. Food Systems: It is sometimes referred to as a food chain. Global Environmental Change and Food Systems (GECAFS/FAO, 2003) defined food systems as processes that encompassed (i) activities related to the production, processing, distribution, preparation and consumption of food; and (ii) the outcomes of these activities contributing to food security (food availability, with elements related to production, distribution and exchange; food access, with elements related to affordability, allocation and preference; and food use, with elements related to nutritional value, social value and food safety). The outcomes also contribute to environmental and other securities (e.g. income).

2.3. Sustainability: It is based on concept of sustainable food. There is no legal definition of 'sustainable food,' Our working definition for good food is that it should be produced, processed, distributed and disposed of in ways that:

- Contribute to thriving local economies and sustainable livelihoods
- Protect the diversity of both plants and animals and the welfare of farmed and wild species,
- Avoid damaging or wasting natural resources or contributing to climate change;
- Provide social benefits, such as good quality food, safe and healthy products, and educational opportunities.

FAO and Bioversity International (2010) reported that sustainability should be considered as part of the long-term time dimension in the assessment of food security. From such a perspective the concept of sustainable food could play a key role as a goal and a way of maintaining nutritional well-being and health, while ensuring the sustainability for future food security.A major challenge in achieving sustainable food systems is the food security. Infrastructures contribute to food sustainability. Sustainability is affected by price volatility, biofuel, infrastructures, food losses and waste. Inadequacy of food infrastructure could lead to food losses and waste. The factors affecting food security also affect sustainability. It is not possibility of achieving a food secure in the world without sustainable development. The main objective of sustainability focuses explicitly on food by seeking to "end hunger, achieve food security and improved nutrition and promote sustainable agriculture which leads to National security. This objective can be achieved only by application of on climate change adaptation and mitigation and application of post-harvest technology. Characteristics of a sustainable food system are outline below (Dilb, 2013):

(i) is secure, and therefore reliable and resilient to change (including climate change, rising energy prices, and others) and accessible and affordable to all members of society:
(ii) is energy efficient'
(iii) is healthy and safe;
(iv) is environmentally beneficial or benign'
(v) contributes to both community and ecological health;
(vi) builds soil quality and farmland through the recycling of organic waste;
(vii) supports multiple forms of urban as well as rural food production'
(viii) ensures that food processing facilities are available to farmers and processors;
(ix) preserves biodiversity in agro-ecosystems as well as in the crop selection;
(x) Reduction of losses and waste

The connection between food security and food system sustainability include the reduction of food losses and waste (Franzo et al., 2012). Franzo et al (2012) highlighted that Food Security for achieving food and nutrition security involves (a) ensuring consistent availability and accessibility of sustainably produced, nutritious and safe food; and (b) reducing and/or eliminating losses and waste in food production, processing and consumption. Food production and availability should be increased in ways that are environmentally, socially and economically sustainable.

2.3.1. Food losses and food waste

Definition of food losses and food waste: Food losses refer to the decrease in edible food mass throughout the part of thesupply chain that specifically leads to edible food for human consumption. Food losses take place at production, postharvest and processing stages in the food supply chain (Parfitt*et al*., 2010). Food losses occurring at the end of the food chain (retail and final consumption) are rather called "food waste", which relates to retailers' and consumers' behaviour. (Parfitt*et al*., 2010)

Food" waste or loss is measured only for products that are directed to human consumption, excluding feed and parts of products which are not edible. Per definition, food losses or waste are the masses of food lost or wasted in the part of food chains leading to"edible products going to human consumption. In the developing world, most food is wasted before it reaches the consumer. Inadequate anti-pest safeguards such as proper silos account for significant loss, whilst poor road infrastructure and lack of proper refrigeration leads to goods spoiling whilst in transit. Adverse weather conditions and disease can also have a significant impact.

2.3.2. Causes and prevention of food losses and waste

The causes of food losses and preventive have been reported byBartz and Brecht (2002); Gross et al, (2002); Kader (2002, 2005); Choudhury, 2006; Rolle, 2006and Stuart (2009) which includes:

(a) ***Inadequate Marketing Systems*****:** This problem exists mostly in developing countries. It is accentuated by lack of communication between producers and receivers, and lack of market information (Kader, 2005).

Preventive*:*Marketing cooperatives should be encouraged among producers of major commodities in important production areas. Advantages of marketing cooperatives include: providing central accumulation points for the harvested commodity, purchasing harvesting and packing supplies and materials in quantity, providing for proper preparation for market and storage when needed, facilitating transportation to the markets, and acting as a common selling unit for the members, coordinating the marketing program, and distributing profits equitable (Kader, 2005).

(b) ***Inadequate Transportation Facilities*****:** In most developing countries, roads are not adequate for proper transport of agricultural products. The majority of producers have small holdings andcannot afford to own their own transport vehicles(Gross et al, 2002).

Preventive:In a few cases, marketing organizationsand cooperatives have been able to acquire transport vehicles, but they cannot do muchabout poor road conditions (Gross et al, 2002). .

(c) ***Production exceeds demand***. In order to ensure delivery of agreed quantities while anticipating unpredictable bad weather or pest attacks, farmers sometimes make production plans on the safe side, and end-up producing larger quantities than needed, even if conditions are "average".(Stuart, 2009)

Preventive: *Communication and cooperation between farmers.* Cooperation among farmers could reduce of overproduction by allowing surplus crops from one farm to solve a shortage of crops on another (Stuart, 2009).

(d) ***Lack of Information*****:** Most handlers involved directly in harvesting, packaging, transporting, and marketing in developing countries have limited or no appreciation for the need for, or how, to maintain quality(Stuart, 2009).

Preventive**:**An effective and far-reaching educational(extension) program on these aspects is needed critically now and will continue to beessential in the future (Stuart, 2009)

(e) ***Poor Maintenance*:**In many developing countries, some good facilities that were built a few years agoare currently “out of order” or not functioning properly because of lack of maintenanceand unavailability of spare parts. This problem is especially true of public-sectorfacilities (Bartz and Brecht, 2002).

Preventive:Any new project should include in its plan adequate funds for maintenance toensure its success and extended usefulness (Bartz and Brecht, 2002)

(f) ***Lack of processing facilities***. In many situations the food processing industry doesn’t have the capacity to process and preserve fresh farm produce to be able to meet the demand. Part of the problem stems from the seasonality of production and the cost of investing in processing facilities that will not be used year-round (Rolle, 2006).

Prevention: develop contract farming linkages between processors and farmer. Governments should create a better ‘enabling environment’ and investment climate, to stimulate the private sector to invest in the food industry and to work more closely with farmers to address supply issues (Rolle, 2006).

(g) ***Poor storage facilities and lack of infrastructure****:* Fresh products like fruit vegetables, meat and fish straight from the farm or after the catch can be spoilt in hot climates due to lack of infrastructure for transportation, storage, cooling and markets(Rolle, 2006, Stuart, 2009).

Preventive:Governments should improve the infrastructure for roads, energy and markets. Subsequently, private sector investments can improve storage and cold chain facilities as well as transportation (Choudhury, 2006)

2.4. Post-Harvest Technology

Post-harvest technologies constitute an inter-disciplinary science and techniques applied to agricultural commodities after harvest for the purpose of preservation, conservation, quality control/enhancement, processing, packaging, storage, distribution, marketing, and utilization to meet the food and nutritional requirements of consumers in relation to their needs Postharvesttechnologyinvolvesalltreatmentsorprocessesthatoccurfromtimeofharvestinguntilthefoodstuffreachesthefinalconsumer’s table.

2.4.1. Importance of Post-harvest Technology: The important are as follows:

(i)Prevents post-harvest losses; (ii) improves nutrition; (iii) adds value to agricultural products; (iv) opens new marketing opportunities, introduction high yielding varieties,and (v) generates new jobs

The three main objectives of applying postharvest technology to agricultural produce are: (1)to maintain quality (appearance, texture, flavour and nutritive value);(2) to protect food safety, and (3) to reduce losses between harvest and consumption.

2.4.2. Post-Harvest Industries

The post-harvest industry includes the following main components:

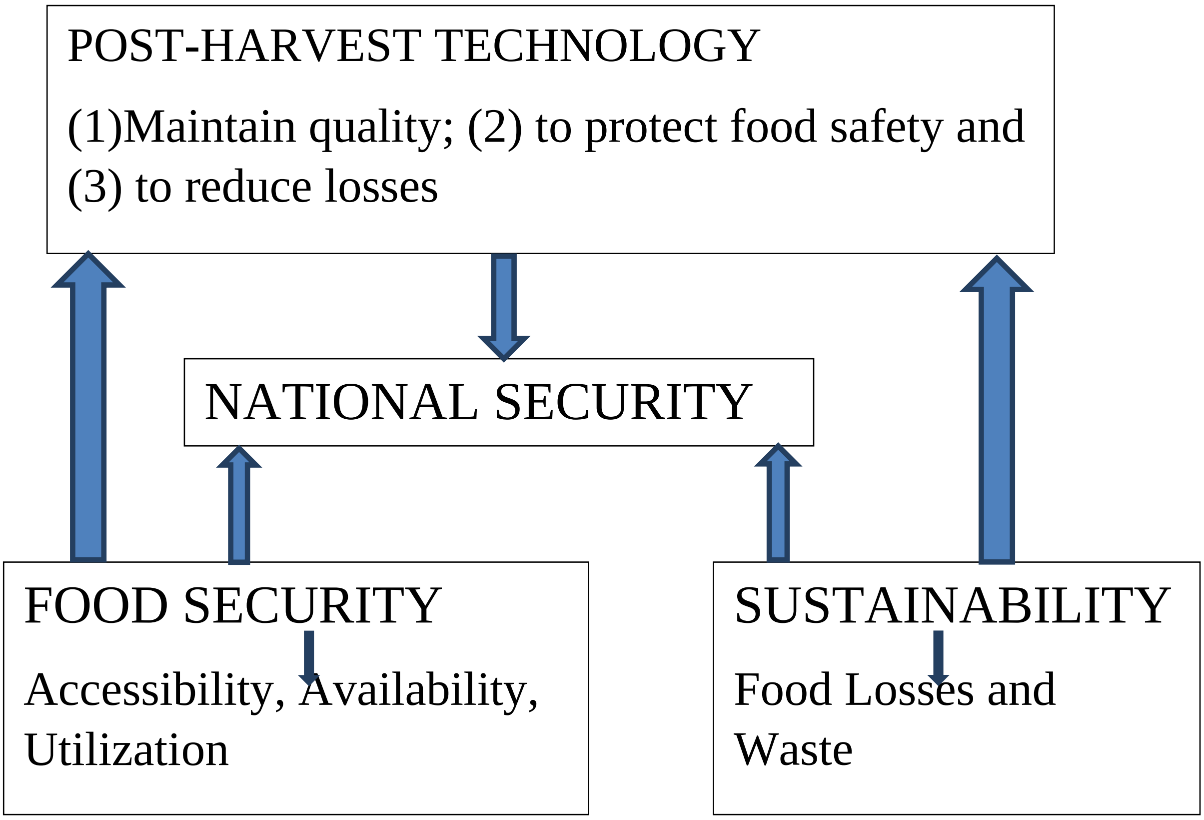
Harvesting and threshing; Drying and storage; Processing (conservation and / or transformation of the produce); Utilization by consumer including home processing

Other components of the system include**:**

Transportation and distribution; Marketing; Grading and quality control; Pest control; Packaging; Communication among all concerned; Information, demonstration and advisory systems; Manufacture and supply of essential equipment and machinery; Financial control; Price stabilization, and Management and integration of the total system.

2.5. The Interrelationship between Food Security, Sustainability and Post-harvest Technology

Food security components are the accessibility, availability and utilization. All the components depend on post-harvest Technology industries for their stability. Sustainability can be referred to sustainable food and it is affected by food losses and waste. The food losses and waste can be preventive by post-harvest technology. The interrelationship between food security, sustainability and post-harvest Technology is presented in Fig. 1. Food security must be national security priority.



Conclusions and Recommendations
Conclusions
Both food security and sustainability are affected by climate change. Food security depends on availability, accessibility, utilization and stability, while sustainability is affected by price volatility, biofuel, infrastructures, food losses and waste. Sustainability diets are goal and way of maintaining nutritional well-being and health and also ensuring the sustainability for future food security.Postharvest technology research and education have a major impact on reducing food losses and waste, enhancing sustainability and food security, leading to improved human well-being outcomes (access to food, shelter, clothing, education and health) which promoting national security

Recommendations

- Cultivar adjustment (e.g., developing new crop varieties that are tolerant to drought, heat and salt via breeding or genetic modification)
- Sustainability should be an integral part of food security planning
- Private should involve in large agricultural production
- Government should provide Policies that support agriculture's enabling environment and also invest on research, innovation and rural infrastructural development
- Relocating buildings and roads that have experienced repeated flooding can reduce future risk.
- Government should ensure that food security as integral to its national security.
- An integrated approach for postharvest science and education from grade school through trade school or university could help to reduce global food losses, by integrating postharvest information into the general agricultural curriculum in each country or state and their extension services, with much more emphasis on preventing losses, maintaining quality and nutritional value after harvest and ensuring food safety.
- Establishing a Postharvest Working Group in each country could be very useful in providing a forum for communications among all those concerned with postharvest biology and technology research and outreach. A link among the various Postharvest Working Groups in each region would further facilitate exchange of information and regional collaboration on training and other areas of mutual interest, and help to reduce duplication of efforts.
- Actions should not only be directed towards isolated parts of the food chain, since what is done (or not done) in one part has effects in others.
- Crop storage structure should be located on a land where there is no chance of flood
- Creation of procurement and warehouses in the federal and State levels

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EFFICACY OF MULTIPLE CELLOPHANE BAGGING IN THE CONTROL OF COWPEA BRUCHIDS *(CALLOSOBRUCHUS MACULATUS)*

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ABSTRACT

An experiment was conducted to study the efficacy of multiple cellophane bagging in the control of cowpea bruchid (Callosobruchus maculatus). The treatments consisted of single, double, triple, 4- layer and 5-layer low density cellophane bagging along with a control. The experiment was laid out in a laboratory using a completely randomized design in five replications. Each batch of seed stored weighed 2 kg and was stored under the same environmental conditions in the laboratory. Data collected after four months of storage included bruchid oviposition , population, number of holes/seed and weight loss. Minitab statistical software was used to carry out the analysis of variance for all the data collected and the treatment means were compared using 95% confidence interval test. Results indicated that bruchid oviposition, population and number of holes/seed decreased significantly (P<0.05) with increasing cellophane layers. Multiple cellophane bagging therefore presented a high potential for use in the control of cowpea bruchids.

Keywords: *Cowpea bruchids, cellophane bagging, density, population.*

INTRODUCTION

Cowpea *(Vigna unguiculata L.)* is an important grain legume which serves as a vital source of protein in the diets of the peoples of the developing tropical countries where consumption of animal protein is rather low because of social and economic reasons. More than 70% of the world's cowpea production is concentrated in three countries, namely: Nigeria, Brazil and Niger with Nigeria being the World's leading producer (Singh *et al*.,1989).

Preservation and storage of cowpea poses a great challenge to cowpea producers in West and Central Africa because of losses arising from bruchid infestation. Many farmers sell cowpea grain at low harvest-time prices rather than risk losses by bruchids during storage. Losses are both quantitative and qualitative where in heavy infestation, loss of grain weight, viability, nutritional value, market value and taste occur. A conservative estimate of cowpea storage loss is put at 25% (Mousa, 2006). Cowpea bruchids are seed beetles that develop and reproduce rapidly in stores of cowpeas. A female bruchid which has just emerged from the seed and newly mated can produce 60 – 120 eggs (Fox, 1993) most of which hatch into larvae and survive to adult-hood. The short life cycle of five weeks and the large number of eggs laid at a time by a female bruchid ensure rapid population build up within a short period of time.

The need to develop alternative safe, cheap and chemical-free cowpea storage techniques is apparent owing to the fact that the use of synthetic pesticides has presented quite a number of problems to producers, consumers and the environment. Apart from increased cost of pesticides and the handling hazards, there are concerns about threat to human health and the environment. In 2009 alone, food poisoning arising from improper chemical storage of cowpea resulted in 10 deaths and 20 more hospitalised after eating contaminated cowpea in the Northern Nigerian State of Kano (IPS, 2009). Public awareness of these risks has increased interest in finding safer chemical-free alternatives.

Purdue University in the USA initiated the Purdue Improved Cowpea Storage (PICS) which is a triple layer bagging (hermetic storage) technology involving the use of triple – layer High Density Polyethylene (HDPE) bags with thickness of about 80 microns cowpea storage in the West and Central Africa (Baribusta *et al.*, 2010),

This study was carried out with the objective of evaluating the efficacy of low density multiple cellophane bagging in the control of cowpea bruchids.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at the Federal Polytechnic, Bauchi, Nigeria in the Post-Harvest Processing Laboratory of the Department of Agricultural and Bio-Environmental Engineering Technology.

Sources of Experimental Materials

Local variety of cowpea known to be highly susceptible to bruchid attack, were purchased from Muda Lawal market in Bauchi Local Government Area of the State at harvest season. The seeds were picked for the experiment. Low density transparent cellophane bags were also purchased from the same Market.

Treatments and the Experimental Design

The treatments consisted of single, double, triple, 4-layer and 5-layer cellophane bagging and a control. The control was a woven nylon or polypropylene bag. The experiment was laid out in the laboratory using a completely randomized experimental design in five replications. Each batch of seed stored in the laboratory weighed 2 kg and were all stored for a period of 4 months before opening.

Data Collection and Analysis

At the end of 4 months of storage, data on bruchid oviposition/seed, bruchid population/kg of seeds, mean number of holes created per seed, and the weight loss were recorded. One-way analysis of variance was carried out on the data collected to test for the significance of the treatment effects using Minitab software. The treatment means were compared using individual 95% confidence interval generated by the Minitab software.

RESULTS AND DISCUSSION

The results of the effect of treatment on the mean number of bruchid eggs laid/seed after 4 months are presented in Table 1. The results indicated that the treatment effect was significant at both 5% and 1% levels of significance.

The highest mean oviposition of 19.86 which is approximately 20 bruchid eggs/seed was recorded with the control. The values of oviposition decreased steadily with increasing number of cellophane layers up to 5-layer bagging where almost zero oviposition was recorded. In the same vein, bruchid population decreased significantly (P<0.05) from 896 live bruchids/kg of seeds in the control to just about 18 in 5-layer cellophane bagging (Table 2). Similar was recorded by Sanon *et. al.,* (2011),when the layers of polyethylene bags were increased from 2 layers to 4 layers where the bruchid numbers and seed damage were significantly reduced. The above pattern of observation could be explained from the fact that in hermetic storage, insects respire aerobically and thus utilize the oxygen in the airtight container while also raising the CO_2 level.

According to Margam (2009), once the oxygen level falls sufficiently low, the beetles cease feeding and become inactive. The state of inactivity itself causes growth and development to cease and in turn reproduction stops. This must have accounted for the decrease in bruchid population as the cellophane layers increased. When oxygen becomes deficient and the state of inactivity sets in, the beetles begin dying, the early instar larvae and pupae appear to be particularly vulnerable.

The results of the effect of treatments on the mean number of holes/seed are presented in Table 3. The results showed that the mean number of holes created by bruchids/seed was highest with the control and lowest with 5-layer cellophane. Approximately, 4 holes/seed were recorded with the control which decreased significantly (P<0.05) to almost zero in the 4-layer and 5-layer cellophane bagging respectively. This therefore indicated an evidence of a strong cowpea grain protection against the bruchid attack in the multiple cellophane bagging.

CONCLUSION

The study assessed the efficacy of multiple cellophane bagging in the control of cowpea bruchids. The multiple bagging techniques based on the principle of hermetic storage which is chemical-free and therefore poses no health hazards to consumers. Besides, it is also cheap and readily available.

Single, double, triple, 4-layer and 5-layer low density cellophane bagging and a control were assessed. In all the characters assessed, it was observed that bruchid infestation and damage decreased significantly with increasing cellophane layers. Multiple cellophane bagging therefore presents a high potential for use in the control of cowpea bruchids.

Table 1: One-Way ANOVA, treatment means and the 95% confidence interval test for number of eggs
laid/seed after 4 months of storage.

Analysis of Variance

Source	DF	SS	MS	F	P
Treatment	5	1160.7	232.1	21.61**	0.000
Error	24	257.8	10.7		
Total	29	1418.5			

```
                              Individual 95% CIs For Mean
                              Based on Pooled StDev
Level      N    Mean    StDev  -----+---------+---------+---------+-
Control    5   19.860   5.981                  (---*----)
1-Layer    5   12.120   3.798          (---*----)
```

2-Layer	5	10.940	3.614	(----*---)
3-Layer	5	9.060	0.802	(---*---)
4-Layer	5	4.260	0.744	(---*---)
5-Layer	5	0.104	0.027	(---*---)
				-----+---------+---------+---------+-
Pooled StDev =		3.277		0.0 7.0 14.0 21.0

Table 2: One-Way ANOVA, treatment means and the 95% confidence interval test for bruchid
population after 4 months of storage.

Analysis of Variance

Source	DF	SS	MS	F	P
Treatment	5	2890752	578150	238.46**	0.000
Error	24	58189	2425		
Total	29	2948941			

Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	-+---------+---------+---------+-----
Control	5	896.00	73.10	(-*)
1-Layer	5	766.40	57.52	(-*)
2-Layer	5	572.80	43.30	(*-)
3-Layer	5	443.20	51.41	(-*)
4-Layer	5	164.80	36.49	(*-)
5-Layer	5	17.60	6.69	(-*)
				-+---------+---------+---------+-----
Pooled StDev =		49.24		0 300 600 900

Table 3: One-Way ANOVA, treatment means and the 95% confidence interval test for number of holes/seed after 4 months of storage

Analysis of Variance

Source	DF	SS	MS	F	P
Treatment	5	42.751	8.550	83.26**	0.000
Error	24	2.465	0.103		
Total	29	45.216			

Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	--+---------+---------+---------+----
Control	5	3.6480	0.3213	(-*--)
1-Layer	5	2.7080	0.3890	(--*-)
2-Layer	5	2.4120	0.4510	(-*--)
3-Layer	5	1.8740	0.1299	(--*-)
4-Layer	5	0.7300	0.3733	(-*--)
5-Layer	5	0.1080	0.0449	(--*-)
				--+---------+---------+---------+----
Pooled St Dev =		0.3205		0.0 1.2 2.4 3.6

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EFFECT OF MOISTURE CONTENT ON ENGINEERING PROPERTIES OF MORINGA OLEIFERA SEEDS

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ABSTRACT

The effect of moisture content on the engineering properties ofMoringa oleifera seeds was investigated. The research was carried out at four moisture content levels namely, 13, 18, 23 and 28 % (dry basis). Some of the engineering properties investigated were the size, 1000 seed weight, angle of repose, terminal velocity and drag coefficient. It was observed that most of the properties increased with increase in moisture content. The reverse was however the case for true density and terminal velocity which decreased from 0.58 to 0.49 kg/m^3 and 1.20 to 0.57 m/s, respectively as the moisture content increased.

Keywords: *Moisture content, terminal velocity, angle of repose and drag coefficient*

1 INTRODUCTION

Moringa oleifera is a fast-growing softwood tree indigenous to Sub-Himalayan tractsof Northern India. It is one of 13 species within the same genus, and has become the most diffuse intropical and subtropical areas at altitudes up to 2000 m (Leone *et al*, 2015). Nowadays, *M. oleifera* is mainly found in the Middle East, in African and Asian countries, although its adaptability has resulted in its rapid spread to other areas including tropical and subtropical regions.
All parts of the Moringa tree (leaves, seeds, roots and flowers) are suitable for human and animal consumption. The leaves, which are rich in protein, minerals, carotene and antioxidants, are used not only for human and animal nutrition but also in traditional medicine (Leone *et al.,* 2015). The seeds have attracted scientific interest as *M. oleifera* seed kernels contain a significant amount of oil (up to 40%) with a high-quality fatty acid composition (oleic acid > 70%) and, after refining, a notable resistance to oxidative degradation (Anwar, 2005). The oil is known commercially as "Ben oil" or "Behen oil".

Engineering properties of *M. oleifera* seed are essential for the design of equipment for handling, separation, conveying, drying, storing, aeration and processing. Size and shape are important in their electrostatic separation from undesirable materials and in the development of sizing and grading machinery (Mohsenin, 1986).

Until very recently, under-utilized crops, in general, and Moringa, in particular, have not attracted much research interests when compared with other more popular species. The Millennium Development Goals are far from being achieved. Time is running out and intervention programs have not led to serious improvements. There is therefore, an urgent need to look inwards for solutions. It is unfortunate that despite the search for a sustainable solution to hunger, malnutrition and food insecurity, Moringa-based research has attracted little attention from both government and non-governmental organizations. There is need to promote the utilization and consumption of some under-exploited species particularly moringa.

It is believed that results from this work will promote agricultural biodiversity by increasing moringa cultivation, utilization and consumption. Agricultural biodiversity has been shown to increase food availability in food insecure communities and improve household food choices thus ensuring dietary diversity, better nutrition and health. The findings of this study will provide vital information to the food processor, consumers, researchers, nutrition policy makers etc as regards moringa, its processing and handling.

The aim of this research work was to determine selected engineering properties of *M. oleifera* seed. Some of the physical properties determined include size, sphericity, true density, bulk density, percentage porosity, angle of repose and surface area. Other properties determined are aerodynamic properties such as terminal velocity and drag coefficient of *M. oleifera* seed at four moisture content levels.

2 MATERIALS AND METHODS

2.1 Material Collection and Preparation

Five kilograms (5kg) of dry moringa seeds were purchased from Alkaleri market in Alkaleri LGA in Bauchi State, Nigeria. Fresh seeds were also collected from a mother tree at Gida Dubu Area of Bauchi LGA, Bauchi State. The seeds were cleaned and kept safe from insects infestation as prescribed by Abodenyi (2016). These seeds were labeled A, B, C and D of 100 seeds each.

2.2 Moisture Content Determination

The moisture content of the seeds was determined by using the oven method. Four samples were heated in the oven until constant weight was reached (Abodenyi *et al.*, 2015). The experiment was replicated five times and the average weight recorded. The moisture content was calculated using Equation 1.

$$\mathrm{M.C}_{(\mathrm{w.b})} = \frac{\mathrm{M_{b-}\,M_a}}{\mathrm{M_{b-}M_c}} \times 100\% \qquad (1)$$

Where:

MC_{wb} = moisture content (% wet basis)

M_b = the weight of moisture can plus sample weight before oven-drying (g)

M_a = the weight of moisture can plus sample weight after oven-drying (g)

M_c = weight of moisture can (g)

2.3 SizeDetermination

Moringa seed size (geometric mean diameter) was determined by measuring the dimension of the principal diameters on three axes – major (L), intermediate (W) and minor (T), for 100 seeds that were randomly selected. Digital vernier caliper with accuracy of ±0.01 mm was used to determine these dimensions. The geometric mean diameter (D_g) was calculated using Equation 2 (Abodenyi, 2016).

$$Dg = (LWT)^{1/3} \qquad (2)$$

Where: L = Major diameter, W = Minor diameter, T = Intermediate diameter.

2.4 Sphericity

The sphericity of moringa seeds was calculated by using the following relationship in Equation 3 (Davies, 2010).

$$\boldsymbol{\varphi} = \frac{\mathbf{D_g}}{\mathbf{L}} \qquad (3)$$

Where: φ= sphericity, Dg = Geometric mean diameter (mm), L = Major diameter (mm)

2.5 Surface Area

The surface area of the samples was determined using Equations 4 (Arthur, 2009).

$$S = \pi(D_g)^2 \quad (4)$$

Where: S = surface area (mm^2), Dg = Geometric mean diameter (mm)

2.6 1000 seed weight

100 seeds were randomly selected from the samples and the weight was determined using the weighing balance. Each weight was multiplied by 10 to obtain the 1000 seed weight and the mean of four replicates was calculated and recorded.

2.7 True Density

The seed volume and true density as a function of moisture content were determined by water displacement method (Davies and Zibokere, 2011). One hundred seeds of known average weight was dropped into a container filled with water. The net volumetric water displacement by the seed were noted and recorded. The experiment was repeated five times. The true density of moringa seed was then evaluated using Equation 5.

$$\rho_T = \frac{m}{v} \quad (5)$$

Where: ρ_T = true density (kg/m^3), m = mass of the sample (kg), V = volume (m^3)

2.8 BulkDensityand Percentage Porosity

The bulk density was determined as the ratio of the mass sample of the moringa seeds to its volume according to Equation 6. It involved using a container of 300 mm height and 200 mm diameter. The container was filled with the sample from a height of about 150mm, (Karababa, 2006; Abodenyi, 2016). The electronic balance was used to weigh the samples.

$$\rho_B = \frac{M_{\rho 2} - M_{\rho 1}}{V} \quad (6)$$

Where: ρ_B = bulk density (kg/m^3), $M_{\rho 2}$ = mass of cylinder plus seeds (g), $M_{\rho 1}$ = mass of empty cylinder (g), V = volume of the cylinder (cm^3)

The porosity (ε) of the bulk seed was computed from the values of the true density (ρ_T) and bulk density (ρ_B) of the seeds according to Equation 7.

$$\varepsilon = \frac{\rho_T - \rho_B}{\rho_T} \times 100 \quad (7)$$

2.9 Coefficient of Friction

Four sided plywood, aluminum and plastic with dimensions of 150 mm by 100 mm by 40 mm were filled with the seeds and placed on an adjustable tilting surface. The structural surface with the box on its top was gradually raised by means of a screw device until the box just started to slide down. The angle of inclination was read from a graduated scale and the coefficient of friction was taken as the tangent of this angle (Olaoye, 2000). The same procedure was repeated for other materials. The mean value of five replicates were recorded, (Alonge and Adegbulugbe, 2005; Abodenyi, 2016). The coefficient of friction was calculated using Equation 8.

$$\mu = \tan\alpha \quad (8)$$

2.10 Angle of Repose

Angle of repose (θ) was determined using an open-ended angle of repose box. The box has a plate diameter of 20.3 cm and was raised from a platform of 10 cm. Equation 9 was used to calculate the angle of repose (Dash *et al*., 2008)

$$\theta = \tan^{-1}\left(\frac{2H}{D}\right) \quad (9)$$

Where: θ = angle of repose, H = the height of the cone (cm), D = diameter of cone (cm)

2.11 Determination of Aerodynamic Properties

2.11.1 Terminal velocity

The terminal velocity of the Moringa seed was determined by using an air column as used by Adedeji (2012) and Abodenyi (2016). It is made of vertical wind tunnel of diameter 42.30 mm and height of 500 m. A voltage regulator and a digital anemometer (model AM- 4812) were used to determine the air speed. The respective velocity (m/s) near the location of the seed suspension was measured with the help of the digital anemometer having accuracy of ± 0.1 m/s. The experiment was replicated five times and the readings recorded.

2.11.2 Drag coefficient

The drag coefficient was calculated from equation 10 (Mohsenin, 1986).

$$CD = \frac{2mg}{Ap\rho A\mathrm{Vt}} \text{ ------------------------------ } \quad (10)$$

Where: *CD* = Drag coefficient, *M* = weight of the seed at terminal velocity (g), g = acceleration due to gravity (m/s^2), A_ρ = area of the particle (m^2), ρ_A = density of air (kg/m^3), V_t = terminal velocity of the particle (m/s)

3. RESULTS AND DISCUSSION

3.1 Physical Properties

It was observed from Table 1 that the major, minor and intermediate diameters increased from 10.68 to 12.37 mm, 9.29 to 10.15 mm and 8.70 to 9.24 mm for the major, intermediate and minor diameters, respectively. These results are in line with that of Abodenyi (2016) for two breadfruits seed varieties.

For 1000 seeds weight, surface area and sphericity, it was also observed from Table 1 that with increase in moisture content, these parameters also increased from 266.6 to 396.4 g, 286.28 to 351.40 mm^2 and 85 to 89%, respectively. This result is similar to that Abodenyi (2016) for two varieties of breadfruit seed. Surface area and sphericity are useful in the design of hopper and conveying equipment for seeds.

It was also observed that as the moisture content increases from 13% to 23% the true density decreases from 0.58kg/m^3 to 0.49kg/m^3 while the bulk density increases from 0.162kg/m^3 to 0.194kg/m^3.

Table 1, also shows the effect of moisture content on percentage porosity of *M. oleifera*. Increase in moisture content decreased the porosity of the seeds. The porosity of *M. oleifera* ranges from 67.0% to 67.1%. This shows that a pack of *Moringa* is more porous when dried than when wet. This property is required in the aeration process in agricultural material handling.

The result from table 1 shows that increase in moisture content from 13% to 28% (wb) increased the angle of repose from 48^o to 55.3^o for the *M. oleifera* seed. According to Abodenyi (2016), the angle of repose is important in designing hopper openings, storage bins, side wall slopes and chutes for bulk handling. Therefore, moisture content of the seeds should be considered while designing for handling equipment.

It was observed from table 1, that coefficient of friction on the three surfaces increased as the moisture increases. On plywood, it increased from 37.98 to 42.08, from 32.04 to 39.90 on aluminum, and 27.7 to 37.1 on plastic. This property is needed in the design of agricultural machine hopper and other conveying equipment; it determines the flowability of the material in handling operation (Taheri, *et al*., 2010).

Aerodynamic properties

The mean effect of moisture content on terminal velocity is shown in Table 1. The result of the experiment for terminal velocity of *M. oleifera* at four moisture content decreased from 1.20m/s to 0.57m/s from 13 to 28% (wb). This is a good parameter for effective separation. Terminal velocity has practical application in calculating volume of air stream for seed and chaff separation, such as fan and sieve arrangement of the thresher (Abodenyi, 2016).

From Table 1, it was observed that as the moisture content increased the drag coefficient for *Moringa oleifera* increased from 0.32 to 0.41. These values show the resistance of the seed in

Table 1: Physical and Aerodynamic Properties of *Moringa oleifera* seed

Physical Properties	**Moisture Content Levels**			
	13%	**18%**	**23%**	**28%**
Length (mm)	10.68(±1.26)	11.07(±0.99)	11.12(±0.97)	12.37(±0.92)
Width (mm)	9.29(±0.66)	9.31(±0.76)	9.42(±0.68)	10.15(±0.78)
Thickness (mm)	8.70(±0.75)	8.70(±0.05)	8.78(±0.65)	9.24(±0.64)
Geometric Mean (mm)	9.49(±0.78)	9.69(±0.62)	9.71(±0.62)	10.52(±0.69)
Surface Area (mm^2)	286.28(±46.41)	294(±37.49)	296.66(±38.23)	351.38(±47.74)
Sphericity (%)	0.85(±0.05)	0.87(0.04)	0.88(±0.05)	0.89(±0.07)
1000 seeds weight (g)	266.6(±0.19)	277.1(±0.14)	368.0(±0.18)	396.4(±0.18)
True Density (kg/m^3)	0.58(±0.008)	0.58(±0.011)	0.56(±0.011)	0.49(±0.008)
Bulk Density (kg/m^3)	0.162(±0.003)	0.185(±0.003)	0.191(±0.003)	0.194(±0.003)
Porosity (%)	66.7(±0.41)	66.8(±0.67)	67.0(±1.32)	67.1(±1.13)
Coefficient of Friction				
Plywood	37.98(±0.23)	39.46(±0.31)	40.3(±0.48)	42.08(±0.85)
Aluminum	32.04(±0.59)	35.2(±0.27)	38.68(±0.25)	39.9(±0.75)
Plastic	27.7(±0.28)	30.0(±0.11)	35.6(±0.43)	37.1(±0.52)
Angle of Repose (^{0})	48.0(±1.88)	52.1(±0.37)	53.7(±0.57)	55.3(±0.45)
Aerodynamic Properties				
Terminal Velocity (m/s)	1.20 (±0.011)	0.96 (±0.008)	0.76 (±0.027)	0.57 (±0.007)
Drag Coefficient	0.32(±0.011)	0.34(±0.065)	0.36(±0.114)	0.41(±0.114)

Standard deviation in parenthesis

a flow environment. This aerodynamic property is required in the design of cleaning and sorting machine (Abodenyi, 2016).

4 CONCLUSION

The determination of some of the engineering properties of moringa seed has provided useful information for the design of moringa processing machine.

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EFFECT OF MOISTURE CONTENT VARIATION ON THERMO-PHYSICAL PROPERTIES OF BROWN VARIETY TIGERNUT (*CYPERUS ESCULENTUS*)

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ABSTRACT

*Knowledge of thermo – physical properties is essential to the food processing industries. The properties are useful in modelling of thermal behavior of seeds during processing operations such as frying, baking, boiling fermentation and drying. To this end, the thermo physical properties (*bulk density, porosity, surface area, thermal conductivity, thermal diffusivity and specific heat capacity*) of brown variety tigernut (Cyperus esculentus) were investigated as a function of moisture content. In this study, Thermal conductivity and specific heat capacity were determined by transient state heat transfer (line heat source) and mixture methods respectively, whereas, thermal diffusivity, bulk density, porosity and surface area were determined using formula methods. The evaluation was conducted at 5 moisture levels (20, 25, 30, 35 and 40% w.b) with 5 replications. The thermal conductivity and diffusivity increased from 0.03 $Wm^{-1}k^{-1}$ to 0.13 $Wm^{-1}k^{-1}$ and from 7.24 x $10^{-7}m^2s^{-1}$ to 11.06 x $10^{-7}m^2s^{-1}$ as the moisture content increased from 20 to 40% respectively. The specific heat increased from 10.55 $JKg^{-1}K^{-1}$ to 18.75 $JKg^{-1}K^{-1}$, while the bulk density and surface area showed an increase from 421.40 kgm^3 to 639.80 kgm^3 and from197.26 mm^2 to 413.21 mm^2 as moisture content increased. However, porosity decreased in value from 61.84 to 32.33% with an increased in moisture. The effect of moisture on the tigernut was statistically significant ($p < 0.05$). The obtained results will find use in the selection of suitable methods for processing of tigernut products, in a quality assessment of optimal modes of technological processes, and in the development of modern processing and handling equipment.*

Keywords: *Tigernut, thermal conductivity, thermal diffusivity, brown variety, thermophysical Properties*

1. INTRODUCTION

Knowledge of thermo-physical properties is of primary importance to the food industry. This information is required to make proper design of food processing equipment such as tanks, pumps, pipes, chillers and evaporators (de Moura *etal.*, 1998). The thermal conductivity of materials can be influenced by a number of factors such as the moisture content of the material, porosity and fibre orientation of the material (Mohsenin, 1990; Stroshine and Hamann, 1994). Several researchers including Rahman (1993) and Yang, *et, al.*, (2002) have emphasized the need for thermal properties of foods in general and seafood in particular. Thermal properties are useful in modeling thermalbehavior of seeds during thermal processing operationssuch as drying, boiling, baking and frying(Alagusundaram *et al.*, 1991; Yang *et al.*, 2002). The primary thermal properties of food and agricultural products are specific heat capacity, thermal conductivity and thermal diffusivity. Specific heat is the property needed in the estimation of the amount of energy required to change the temperature of a product, whilethermal conductivity and thermal diffusivity are involved in the determination of the rate of heat transfer for efficient process and equipment design. (Aviara, *et, al.,* 2003). Knowledge of thermo-physical properties is a basic condition for describing material's behavior during food processing. There is, however, dearth of information on the thermo-physical properties of tigernut which has limited its utilization in the food industry in Nigeria.

Tiger- nut (*Cyperus esculentus var. sativus),* an emergent grass- like plant belonging to the sedge family, is also found to be a cosmopolitan perennial crop of the same genus as the papyrus plant that is common in seasonally flooded wetlands (Vilmorin, 2010). It is widely distributed in the temperate zones within South Europe as its probable origin, and has become naturalized in Ghana, Nigeria and Sierra Leone (Anorn, 1992). Tiger- nut is one of the earliest domesticated crops and in fact, was found in vases, and in Nigeria, tiger nut is available in fresh, semi-dried and dried form in the markets where it is sold locally and consumed as snacks in its uncooked form. Tiger nuts are grossly under-utilized due in part to fewer information on their nutritional potential (Rita, 2009). Tigernut grows mainly in the middle belt and northern regions of Nigeria, it is known in Nigeria as'Ayaya in Hausa, 'Imumu' in Yoruba and 'Akiausa' in Igbo where three varieties (black, brown and yellow) are cultivated (Osagie & Eka, 1998). Among these, only two varieties, yellow and brown are readily available in the market. The yellow variety is preferred over others because of its inherent properties like its large size, attractive colour and fleshier nature. The yellow variety also yields more milk, contains lower fat, higher protein and less anti-nutritional factors especially polyphenols (Okafor *et al.*, 2003; Belewu & Abodunrin, 2005; Ebringa, 2007). The tubers contain up to 30% of non-drying oil which is used in cooking, soap making, starch and flour preparation (Shaker *et al.,* 2009; Muhammad et al., 2011).

The selected properties thermo-physical (specific heat capacity, thermal conductivity, thermal diffusivity, bulk density, porosity and surface area) for this present study are important in many problems associated with the design of machines and the analysis of the behavior of the product during agricultural process operations such as handling, planting, harvesting, threshing, cleaning, sorting and drying. Solutions to problems in these processes involve knowledge of their physical and engineering properties (Irtwange, 2000; Varnamkhasti *et al.,* 2008; Tavakoli *et al.*, 2009). The understanding of these thermal properties of food and their responses to process conditions is necessary not only because they affect physical treatment received during processing but also because they are the commonest indicators of other properties and qualities. Hence, the main objectives of this study is to determine the effect of moisture content variation on the thermo-physical properties of brown variety tiger-nut.

2. MATERIALS AND METHODS

2.1. Sample Preparation

The brown varieties of tigernut used for this study was obtained at a local market in Bauchi, Nigeria. The tubers were cleaned manually to remove all foreign matters such as dirt, stones, immature and broken seeds. The initial moisture content of the samples was determined by oven drying method at 103 ºC for 48 hr. as used by Sacilik *et al.*; (2003). Selected samples were moistened with a calculated quantity of distilled water and conditioned to raise their moisture content to the desired different levels. Equation (1) was used to calculate the quantity of distilled water used according to Coskun *et al.* (2006).

$$Q = Wi \, \frac{(mi - mf)}{100 - mf} \qquad (1)$$

Five levels of moisture contents were used for the brown variety, 20, 25, 30, 35 and 40% (w.b). The samples were then stored in an airtight polythene and kept at 5 ^{o}C in a refrigerator for a week to achieve uniform moisture distribution within the sample.

2.2. Determination of Bulk Density

The bulk density is the ratio of the mass of a sample of a seed to total volume (Shafiee *et, al.,* 2009). Bulk density for all the samples were determined by filling an empty 300 mL beaker with tiger-nut seeds and weighing it. The weight of the seeds was obtained by deducting the weight of the empty beaker from the weight of the seed-filled beaker. To achieve uniformity in bulk density, the beaker was tapped 10 times for the seeds to consolidate in the beaker (Ahmadi, *et, al.,* 2009). The beaker was filled with seeds dropped from a 15 cm height and a sharp–edged, flat metal file was used to remove excess seeds to level the surface at the top of the graduated beaker (Nalbandi,*et, al.*, 2010). Bulk density was calculated using equation (2):

$$\rho b = m/v \qquad (2)$$

This was replicated five times and the mean calculated for each sample.

2.3. Determination of Porosity

The porosity (ε) values were calculated from the values of true density and bulk density using the relationship in the Equation (3) as reported by Bup, *et, al.,* (2013).

$$\text{Porosity } (\varepsilon) = (1 - \frac{\rho b}{\rho t}) \text{ x } 100 \qquad (3)$$

2.4. Determination of Surface area

The surface area was determined by analogy by using Equations (4) and (5) as reported by Balami, *et, al.,* (2014).

$$Sa = \frac{\pi d a 2}{2a - d} \qquad (4)$$

Where,

$$d = (b\ c)^{0.5} \qquad (5)$$

2.5. Determination of Specific Heat Capacity

The method of mixtures has been the most common technique reported in the literature for measuring the specific heat of agricultural and food materials (Singh and Goswani, 2000; Nouri Jangi *et al*., 2011). For the determination of specific heat in this study, the method of mixtures was used. Sample of brown variety tiger nut of known mass, temperature and moisture content was dropped into a copper calorimeter containing water of known mass and temperature. The calorimeter was well insulated so as to prevent heat loss to the room in which the experiment was performed. The mixture was stirred continuously using a glass rod stirrer. The equilibrium (final) temperature was noted and the specific heat determined using equation (6) as used by Aviara and Haque (2001).

$$Cs = \frac{(McCc + MwCw)\,[Tw - (Te + tR)]}{\text{Ms}\,[(\text{Te}+\text{tR}) - Ts]} \qquad (6)$$

2.6. Determination of Thermal Conductivity

The thermal conductivity of the seeds was determined at five different moisture levels, using the transient line heat source method assembled in a thermal conductivity probe. The probe was passed through the center of the seed and a fall in temperature occurred. A fall in temperature continued until a constant temperature was obtained. A rise in temperature occurred after a constant temperature period and at this point, the time was taken against the temperature. The thermal conductivity was calculated from equations (7) and (8) as reported by Sadiku and Bamgboye (2014):

$$K = \frac{QT}{4\pi(T1 - T2)} \ln(t2/t1) \qquad (7)$$

Where,

$$Q = VI/L \qquad (8)$$

2.7. Determination of Thermal Diffusivity

The thermal diffusivity was calculated using experimental values of specific heat, thermal conductivity and bulk density using Equation (9) as reported by Vijay (2013).

$$\alpha = K / (\rho b\ Cs) \qquad (9)$$

2.8. Statistical Analysis

The data generated were analyzed using the Analysis of variance (ANOVA) to determine which treatment effect was significant or not and Tukey's studentized range ($p < 0.05$) was used to determine significant difference between means using statistical analysis system (SAS9.2) 2010.

3. RESULTS AND DISCUSSION

3.1. Results

Table 1: **ANOVA** on effect of moisture content on thermal properties of brown variety tigernut

Source	Df	SS	MS	F- Value	Pr > F
Properties (BV)	5	6020489.673	1204097.935	9922.34**	< .0001
Replication	4	349.557	87.389	0.72^{ns}	0.5799
Moisture Content (MC)	4	93925.097	23481.274	193.5**	< .0001
Properties* MC	20	247091.85	12354.592	101.81**	< .0001

**highly significant, ns = not significant

Table 2: Effect of moisture content on thermophysical properties of brown variety tigernut

Property	Unit	Moisture Content (%)				
		20	25	30	35	40
Bulk Density	kg/m^3	$421.4^{d}\pm2.61$	$475.2^{c}\pm0.45$	$564.8^{b}\pm1.10$	$620^{a}\pm0.71$	$639.8^{a}\pm1.1$
Porosity	%	$61.84^{i}\pm3.16$	$52.27^{g}\pm2.46$	$48.52^{g}\pm1.83$	$33.47^{i}\pm2.39$	$32.33^{i}\pm1.2$
Surface Area	mm^2	$197.26^{f}\pm28.68$	$211.07^{f}\pm10.73$	$221.93^{f}\pm26.98$	$298.21^{e}\pm27.24$	$413.21^{d}\pm34$
Specific Heat Capacity	$kJkg^{-1}\,^{o}C^{-1}$	$10.55^{i}\pm0.18$	$12.37^{i}\pm0.15$	$14.39^{i}\pm0.17$	$15.92^{i}\pm0.61$	$18.75^{j}\pm0.4$
Thermal Conductivity	$Wm^{-1}\,^{o}C^{-1}$	$0.032^{j}\pm0.00$	$0.056^{j}\pm0.00$	$0.081^{j}\pm0.00$	$0.106^{j}\pm0.00$	$0.133^{j}\pm0.0$
Thermal Diffusivity	$x\ 10^{-8}\ m^2\ s^{-2}$	$7.24^{i}\pm0.13$	$9.45^{i}\pm0.43$	$9.94^{i}\pm0.34$	$10.59^{j}\pm0.48$	$11.06^{j}\pm0.3$

Values in the same row followed by different letters are significantly different (*p* <0.05).

3.2. Discussions

3.2.1. Analysis of Variance (ANOVA)

Analysis of variance (ANOVA) was conducted to ascertain the significant effect of moisture content variation on the thermophysical properties (Specific heat capacity, Thermal conductivity, Thermal diffusivity, Bulk density, porosity and Surface area) of brown variety tigernut as shown in Table 1. The results of the ANOVA showed that there were highly significant differences ($F = 9922.34$, $p = 0.0001 < 0.05$) among the values obtained for the properties of brown variety tigernut. This indicates that the values of the properties were highly influenced by moisture content. The effect of replication from the ANOVA was not significant ($F = 0.72$, $p = 0.599 > 0.05$), this may be due to minimized error in the performance of the experiment in the laboratory. The variation in moisture content was highly significant ($F = 193.5$, $p = 0.0001 < 0.05$), this means as moisture increased, the values of thermophysical properties either increased or decreased. However, the interaction between the properties and moisture content indicate a highly significant difference ($F = 101.81$, $p = 0.0001 < 0.05$). The interaction effect shows that the relationship between tigernut properties and moisture content depends on the amount or variation of the moisture content.

3.2.2. Effect of moisture content on bulk density

The bulk density of brown variety tigernut increased linearly from 421.4 to 639.8 kgm^{-3} as moisture content increased from 20 to 40% as presented in table 2.The increase in the bulk density was due to increase in the mass of tigernut with a gain in moisture which was higher than the volumetric expansion of the bulk (Pradhar *et, al.*, 2008). The effect of seed moisture content on bulk density was statistically significant ($p< 0.05$). Similar increasing bulk density with variation in moisture content was reported by Baryeh and Mangope (2002) for QP – 38 variety pigeon pea, Kingsley et, al., (2006 for dried pomegranate seeds, Nikoobin *et, al.*, (2009) for chickpea seeds and Oyerinde and Olalusi (2013) for two varieties of tigernut, Table 1 presents the variation of bulk density with moisture content for brown variety tigernut.

3.2.3. Effect of moisture content on porosity

Porosity of materials usually is dependent on the bulk as well as the true densities (Oyerinde and Olalusi, 2013). The porosity of the brown variety tigernut decreased from 61.84 to 32.33% as moisture content varied from 20 to 40%. Similar trend was reported by Oyerinde and Olalusi (2013) for two variety tiger-nut. This decrease may be due to the changes in the mass and density value of the tiger-nut as it absorbed water. Higher porosity at low moisture content indicates that high number of tigernut tubers can be stored at lower moisture content than at high moisture content due to an increase in the cohesion of the cell structure of the tigernut as moisture increases (Abano and Amoah, 2011). Table 2 presents the variation of porosity with moisture content for the brown variety, and the effect of moisture on porosity was statistically significant ($p < 0.05$) except between 25 and 35%moisture content.

3.2.4. Effect of moisture content on surface area

The effect of moisture content on the surface area of the tigernut is presented in Table 2. The surface area increased linearly from 197.26 to 413.21 mm^2 as the moisture content varied from 20 to 40%. The values for surface area were statistically significant ($p < 0.05$) from 30 to 40%, however, a reverse trend was reported for black variety tigernut by Abano and Amoah (2011). Hence, the results may be due to the different shape assumption of the tuber and this suggests that it's advisable to store the tubers at lower moisture content when the surface area is lowest for the tuber to present less surface area for moisture absorption during storage (Abano and Amoah, 2011).

3.2.5. Effect of moisture content on specific heat capacity

Specific heat capacity is needed in estimating the amount of heat energy required to change the temperature of material by 1^oC (Sadiku and Bamgboye, 2014). The specific heat capacity of brown variety tigernut increased from 10.55 to 18.75 $kJkg^{-1}\ ^oC^{-1}$ as moisture content increased from 20 to 40% and the result (Table 2) was not statistically significant ($p > 0.05$). Similar trend was reported for Parkia seeds (Sadiku and Bamgboye, 2014) which indicated an increase from 2.74 to 4.38 $kJkg^{-1}\ ^oC^{-1}$ for a moisture increase of 5.9 to 28.2%.

The increasing trend in specific heat capacity with moisture content correlates with work done by other researchers on Cumin seeds (Singh and Goswani, 2000),Lentil seeds (Tang, *et, al.,* 1991), Potato (Wang and Breman, 1993) and Pistachio nuts (Razii and Taghizadeh, 2007), all of which shows similar trend with brown variety tigernut. The increased specific heat capacity with moisture is due to high specific heat of water compound to dry material (Sadiku and Bamgboye, 2014).

3.2.6. Effect of moisture content on thermal conductivity

Thermal conductivity is the possibility of transmitting heat within seeds in bulk. Hence, the thermal conductivity of brown variety tigernut increased from 0.032 to 0.133 $Wm^{-1}{}^{o}C^{-1}$ as moisture increased from 20 to 40%, this indicates that heat transmission within the tigernut is less when dried and more if wet (Sadiku and Bamgboye, 2014). The increase in thermal conductivity as moisture increased was because the increased moisture, increases the bulk thermal conductivity as moisture has higher thermal conductivity than that of air (Vijay, 2013). Similar results were reported for borage seed by Yang; *et al.,* (2002), soya bean pod by Mohsen; *et al.*, (2013), coriander seed (Vijay, 2013) and three varieties of melon (Isa, *et al.*, 2014). The result for thermal conductivity of brown variety tigernut is in agreement with the findings of Sadiku and Bamgboye (2014) for Parkia seeds. The effect of moisture content on the thermal conductivity of tigernut was presented in Table 2, though the moisture effect was not statistically significant ($p > 0.05$). The relationship between thermal conductivity and moisture content of tigernut was linear (Table 2).

3.2.7. Effect of moisture content on thermal diffusivity

The variation of thermal diffusivity with moisture content is presented in Table 2. Thermal diffusivity of tigernut increased from 7.24 x 10^{-8} m^2 s^{-2} to 11.06 x 10^{-8} m^2 s^{-2} as the moisture content increased from 20 to 40%. The increase in thermal diffusivity at different moisture content may be due to the fact that the value of bulk density decreased at these moisture levels (Singh and Goswani, 2000). Bamgboye and Adejumo (2010) also reported similar results for Roselle seeds. The results for the thermal diffusivity of brown variety tigernut is in agreement with the findings of Aviara and Haque (2001), that thermal diffusivity of sheanut kernel increased with moisture content, but disagreed with the findings of Subramanian and Viswanathan (2003), for minor millet grain and flour, Singh and Goswani (2000), for cumin seeds and Aremu and Fedele (2010), whose obtained values for doum palm fruits showed an inverse relationship with moisture content. This ascending and descending trend of relationship between moisture content and thermal diffusivity is because the magnitude of thermal diffusivity depend on the combined effect of thermal conductivity, bulk density and specific heat capacity (Yang; *et, al.,* 2002).

4. CONCLUSION

Thermophysical properties of brown variety tigernut(*Cyperus esculentus*) were determined for the typical ranges of moisture content. The results showed the significant variations in thermo-physical properties values with changing moisture content. All the properties increased as the moisture level increased, with the exception of porosity, which reduced as moisture increased.The bulk density and surface area increased from 421.40 kg/m^3 to 639.80 kg/m^3 and from197.26 mm^2 to 413.21 mm^2 as moisture content increased. However, porosity decreased from 61.84 to 32.33% with an increase in moisture.The specific heat increased from 10.55 $JKg^{-1}K^{-1}$ to 18.75 $JKg^{-1}K^{-1}$, while the thermal conductivity and diffusivity increased from 0.03 $Wm^{-1}k^{-1}$ to 0.13 $Wm^{-1}k^{-1}$ and from 7.24 x $10^{-7}m^2s^{-1}$ to 11.06 x $10^{-7}m^2s^{-1}$ as the moisture content increased from 20 to 40% respectively. The results presented in this paper can find utilization in food industry in such processes where heat transport and storage properties of tiger-nuts are indispensable. They can be applied for instance for the adjustments of drying rate, for the calculations of the economical drying time and for the determination of energetic balances of drying processes.

5. NOTATION

Q, mass of added water, kg
W_i, mass of sample, kg
m_f, final moisture content, % w.b basis
m_i, initial moisture content, % w.b basis
ρb, bulk density, kg/m3
m, mass of bulk tigernut seeds, kg
α, Thermal diffusivity, $m^{-2}\ s^{-1}$
L, length of heater wire, m
M, moisture content of Tigernut seeds, %
Ts, Initial temperature of sample, ^{0}C
Tw, Initial temperature of water, ^{0}C.
Cs, specific heat of sample, kJ $kg^{-1} {}^0C^{-1}$
V, Voltage, v
K, Thermal conductivity, $Wm^{-1}K^{-1}$
Q_T, Heat input, Wm^{-1}.
Sa, Surface area, mm^2
a, major diameter, mm
b, intermediate diameter, mm
c, minor diameter, mm
ρ_t,, True density, Kg/m^3
v, Volume of sample, mm^3
I, Current, A
Cw, specific heat of water, kJ $kg^{-1}\ {}^0C^{-1}$
m_c, mass of calorimeter, kg
m_s, mass of sample, kg
m_w, mass of water, kg
t, time taken for the sample and water mixture to come to equilibrium, sec.
Te, Equilibrium temperature of sample and water mixture, ^{o}C
R, rate of temperature fall of mixture after equilibrium, ^{o}C s^{-1}

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DEVELOPMENT OF A TRADITIONAL BASKET FOR PACKAGING FRESH TOMATO FRUITS

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ABSTRACT
Tomato fruits are highly perishable as a result of the high water content and thereby susceptible to rapid deterioration soon after harvest, hence, the need for proper packaging and storage if not consumed immediately. An alternative tomato packaging container was developed and tested using palm fronds. The heat stress, required ventilation, and container volume were calculated. A compressive test was done using Denison Universal Testing Machine. Results obtained revealed that the maximum load and stress the basket could bear when stacked on one another during transportation was 4 kN (407.9 kg) and 7.2 kN, respectively. The basket was found to obey Hooke's law and can be conveniently stacked up to 8 levels without severe damage to the tomato fruits and the baskets. This study recommended that a verification trial be conducted and an effective extension techniques be used to ensure the baskets adoption for packaging fresh tomato fruits.

Key words: *Tomato, Baskets, Packaging, Compression.*

1 INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a staple fruit vegetable and one of the most important vegetables worldwide (Saeed-Awan *et al.*, 2012). It is considered as an important cash and industrial crop in many parts of the world (Ajagbe *et al.*, 2014) and has become popular over the last century. Tomato is a tender and compression-sensitive fruit (Babarinsa and Ige, 2014). It is a member of the *Solanaceae* family, botanically known as berry (Abdullah *et al.*, 2004). The tomato fruits are fleshy berry that are globular to oblate in shape having a diameter of 2 – 15 cm with immature fruits being green and hairy. The size of tomato varies with the species. The small cherry tomato is about 2.54 cm in diameter. The plum type is 5.08 to 10.16 cm long and between 2.54 and 5.08 cm in diameter though, less juicy and have fewer seeds than other varieties. The common round type is 5.08 to 12.7 cm in diameter and varies in weight between 0.85 kg and more than 0.91 kg. The colour of ripe fruits are mostly between yellow, orange and red usually round, smooth or furrowed. Seeds are numerous, kidney or pear shaped. Tomato is known by different names around the world, few among the names are: *tomate* (Spain, France), *tomat* (Indonesia), *faanke'e* (China), *tomati* (West Africa), *tomatl* (Nahuatl), *jitomate* (Mexico), *pomodoro* (Italy), *nyanya* (Swahili) (Shankara *et al.*, 2005). Also, the three major tribes in Nigeria (Hausa, Yoruba and Ibo) call it *"tomato".*

The importance of fruits and vegetables cannot be overemphasized as their vitamin contents are known to be nutritionally superior when compared to many cereal and leguminous crops. Tomato is an important vegetable that play a major role in the provision of vitamins and minerals for humans, hence, necessary in the preparation of many local dishes and very important in the diet of both rural and urban dwellers in Nigeria (Olayemi *et al.,* 2010). It is high in water soluble vitamins and minerals, essential amino acids, sugars, dietary fiber, low in fat and calories; main source of vitamins A, B, C, iron, phosphorous, protein, edible oil and lycopene (Ayandiji and Adeniyi, 2011; Achoja and Okoh, 2014). Tomato is used as condiments for stew which is a regular feature of African meals and accounts for about 18% of the average daily consumption of vegetables in Nigeria (Ebimieowei and Ebideseghabofa, 2013b). It has presently been considered as an important cash and industrial crop in numerous parts of the world (Saeed Awan *et al.*, 2012). Tomato fruits are highly perishable as a result of the high water content and thereby, susceptible to rapid deterioration soon after harvest, hence, the need for proper packaging and storage if not consumed immediately.

The effects of packaging materials on stored tomato was studied by Saeed *et al*. (2010) with due considerations given to the fruits firmness in selected packaging materials such as wooden crates, corrugated cardboard boxes and nylon mesh bag. Fresh tomato fruits were stored for 12 days at room temperature of about 20^{o}C. Their results was that fruits stored in corrugated cardboard box have 69.00 g fresh weight and 11.05 g dry weight while those stored in open container and mesh bags were observed to have accelerated fruit decay resulting from faster fungal sporulation and mycelial spread. Their conclusion was that fruit quality is linked with air circulation and tomato firmness. Also in India, Girja et al. (2009) studied the pattern of packaging fresh tomato fruits and developed a corrugated fiberboard cartons called "peti box" having capacities of 15 and 20 kg for long distance transport. Compression-drop and vibration tests were done to determine its strength and weakness for long truck journeys. The two containers developed were subjected to laboratory tests and actual road journeys. The tests specifications were bursting strength 11±1, number and diameter of ventilations 8 and 24.5 mm as shown in figure 1. The laboratory and field trial tests pre-conditioned the boxes for 72 hours in a room with relative humidity of 50% and a room temperature of 23 ^{o}C was maintained.

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Plate 1: Developed Corrugated fiber boxes

Compression test revealed that both boxes were capable to withstand 250 kg load with 6 mm deformation, though, the damage increases as the number of drops increase. Vibration test revealed that damage to produce increase with exposure time as the smaller box retained its structural integrity while the larger one failed after 33-55 minutes. The boxes are generally acceptable by its users despite the deficiency of use during rain resulting in transporting products in covered van. The National Stored Products and Research Institute (NSPRI) transported 2.1 tons of tomatoes from Kano to Ibadan (Nigeria) in 1985, using six selected packages namely perforated paper carton, perforated polypropylene boxes, slatted wooden boxes (small), slatted wooden boxes (large), plywood ventilated boxes and traditional wicker basket. Evaluation revealed that polypropylene, traditional basket and slated wooden boxes were the most appropriate packaging container.

Moreover, Bani et al.(2006) evaluated the performance of a wooden crate with dimension 620 mm length by 480 mm deep to transport tomatoes in an open truck from farm gate to market center at an estimated distance of 815 km. Ten out of fifty crates was sampled using unit loss assessment system. A 20% transit loss was observed, caused by surface roughness, uneven run of vehicle and collapsing of the crate. Idah *et al*. (2012) simulated a laboratory transport study conducted to assess the performances of the traditional wicker baskets and a plastic container for tomato fruit handling. Vibrations and impact was excited on each of the container packed with tomato using a developed vibrating table. Their results revealed that 40%, 37.50% and 45% of the samples of tomato fruits selected from the top, middle and bottom of the traditional basket respectively were severely bruised after four hours of excitation, while a corresponding values of 44.18%, 30.23% and 18.60% were recorded for the plastic container. ANOVA showed that the mean values of bruise areas differed significantly ($p \leq 0.05$) between the two packaging containers. They concluded that the plastic container reduces mechanical damage resulting from impact and vibration than the traditional basket solely used in the transportation of fresh tomato fruits in Nigeria. Similarly, Abubakar (2009) developed and evaluated the performance of an improved packaging for mass transportation of tomato. He developed a rectangular traditional packaging container using palm fronds as presented in figures 2. His results revealed that the rectangular basket has a compression strength of 9.86 kN, hence, can be stacked to 10 layers. His design also claimed to eliminate the shortcomings of the conical basket, because the depth and volume were designed to transport more tomatoes at low cost per unit time.

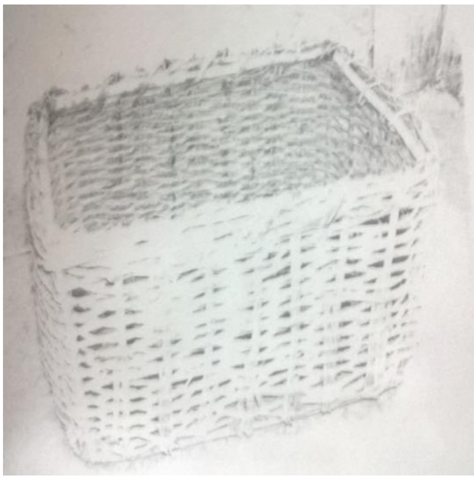

Plate2: Developed rectangular wicker basket

Food losses are on the increase in recent times. About 1.3 billion tons of food is predicted to be lost each year (Gustavsson *et al.,* 2011). In Nigeria where the agriculture sector contributes more than 30% of the GDP and employs about 70% of the labor force (Olayerni *et al.,* 2012), high postharvest losses has continued to be observed in food supply chains of perishable agricultural commodities like fruits and vegetables (Idah *et al.,* 2007a; Parfit *et al.,* 2010). The production of bulk fresh tomato fruits in Nigeria is in the Northern part of the country mainly by irrigation whereas the consumption and utilization is widespread throughout the country. Unfortunately, tomato fruits are not only seasonal, but highly perishable and deteriorate few days after harvest, losing almost all their required quality attributes and some could likely result to total waste. Conservatively, 90% of food supply from developing nations like Nigeria is wasted as a result of deterioration (Onifade *et al.,* 2013); another estimated loss of 40 – 50% of tomatoes are at post-harvest stages (Olayemi *et al.,* 2010). Furthermore, Idah *et al.* (2007b) stated an estimated loss of fruits and vegetables commonly in the tropics occurred between production areas and consumption points to be between 50 – 70%.

Verbal interviews was conducted by the researcher. Some major tomato marketers, who at different interviews confirmed that loss of their tomato fruits was majorly as a result of the packaging containers used. It was agreed that if a better packaging container is used, it will greatly reduce the postharvest losses associated with transporting tomato. It was on this resolution that this study conceived an alternative tomato packaging container and developed the container from palm fronds as used in the case of conventional baskets.

2.0 METHODOLOGY

The interview conducted with different tomato producers, marketers and processors around Kano, Kaduna and Katsina States prompted this research to weave a traditional baskets from palm fronds with preference to a moderate weight of 23 kg that can be carried easily and stacked on one another during transportation. The palm frond was a high strength graded one that has smooth inner walls. It was carefully woven to ensure adequate ventilation when the fresh tomato fruits are packaged in the container. The container strength, durability, and volume (wide and shallow) were considered during the development as recommended by Clement *et al.* (2009).

3.0 DESIGN CALCULATIONS

3.1 Heat stress

The expected temperature rise in the packaging container was computed using Equation 1.

$$Q = mc_p \delta t \qquad (1)$$

Q = total heat produced by the tomato (sensible), (J)

C_p = Specific heat of tomato – (J/kg^{0}C)

δt = Temperature rise – (^{0}C)

3.2 Ventilation of the package

The Anaerobic compensation point (ACP) of tomato from CIGR (1999) handbook ranges between 1 – 3% O_2. The highest value was chosen so as to maintain the organoleptic properties of tomato.
The Oxygen (O_2) in air = 21%,
If 100% air passes through the packaging container, it is expected to have 21% O_2,
At ACP, X% pass of air through the container will give 3% O_2
If mathematically expressed,

$$X = \frac{3x100}{21} = 14\%$$

For adequate ventilation of the packaging container, 14% porosity was adopted for the container.

3.3 Container Volume

The container was designed to assume a frustum shape from the conventionally used woven basket. The container weight was limited to 20 kg based on the studies conducted by Idah et al. (2007a) and Abubakar (2009) that revealed the baskets weights commonly used for packaging and transporting fresh tomato fruits in Nigeria.

$$\text{Volume} = \frac{1}{3}\pi h\left[r_1^2 + r_2^2 + r_{1.}.r_2\right] \qquad (2)$$

3.4 Procedure for Development

A mature palm tree was identified and the fronds cut and processed as presented in Plates 3. The processing was necessary to achieve a smooth inner wall that will not bruise the packaged tomato fruits. The diameters of the cover and container (233.25 cm, 220.11 cm) were measured and cut out, so was the cover and container height (90 cm, 250 cm) of the packaging container. The traditional basket was carefully woven and the final product presented in Plates 4a and b. The cost of each basket was ₦1,800 but if mass produced, it will cost ₦600 each.

Plate 3a: Palm tree processing into palm fronds process

Plate 3b: Packaging container weaving

Plates 4a&b: Finished alternative packaging container

3.5 Performance Evaluation

The paramount use of baskets is for transporting fresh tomato fruits. During transportation, several baskets are stacked on one another, not minding the weight and sizes. However, in this experiment, the woven basket is filled with fresh tomato fruits and weighed (Plates 5a and b) before subjecting the empty baskets to a compressive test in the laboratory. The compression test was conducted on the basket to ensure its strength when stacked on top of one another during transportation. The compressive test was carried out on the baskets at the Strength of Materials Laboratory of Mechanical Engineering Department, Ahmadu Bello University, Zaria. A Denison Universal Testing Machine (UTM) as presented in Plates 6 - 8 was used to apply a lateral pressure on the woven baskets (plate 6). The pressure applied and the distance (compression height) were recorded at every 5 seconds. The derived values were used to compute the strain as presented in Table 1.

Plates 5a&b: Developed basket filled and weighed with fresh tomatoes

Plates 6a&b: Baskets before and during pressing

Plate 7: Pressure scale showing deflection **Plate 8:** Steel rule used for reading height

4 RESULTS AND DISCUSSIONS

Table 1: Results of the compression test conducted on the woven baskets

S/No.	Applied Pressure (kN)	Distance (m)	Duration (Secs)	Strain (m)
1.	0	0.4	0	-
2.	0	0.38	5	0.02
3.	0	0.37	10	0.03
4.	0.5	0.36	15	0.04
5.	1.0	0.36	20	0.04
6.	1.5	0.36	25	0.04
7.	2.0	0.355	30	0.45
8.	2.4	0.35	35	0.05
9.	3.0	0.35	40	0.05
10.	3.5	0.35	45	0.05
11.	4.0	0.35	50	0.05

Note: Initial and final diameter of the weaved basket = 35 cm

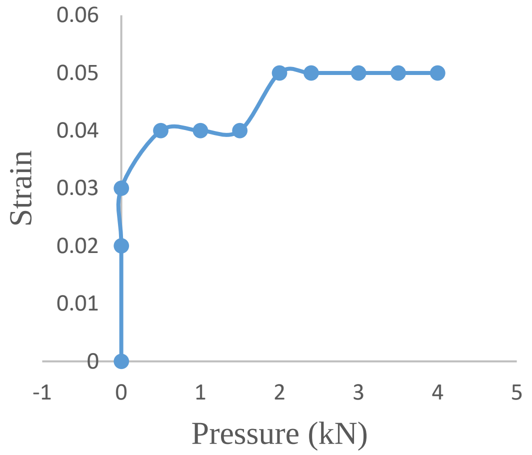

Fig 3: Chart of the compression test

4.1 Discussions

The tests conducted on the baskets revealed that initial pressures applied on the baskets was found to be insignificant. This could result from the gradual closure of the air openings on the baskets. As the pressures was further applied and increased to 1.5 kN, a significant reduction in the height of the baskets was noticed. Since the pressure applied was a gradual one, a decimal decrease in the basket height (0.36 m) was also experienced resulting in a convex bend of the baskets walls. This decrease could be associated with the elastic tendency of the palm fronds in weaving the baskets. An assertion that was corroborated with the studies of Carl-Magnus *et al.* (2013) and Thomas and Johan (2015).

The maximum load the basket could bear was 4.0 kN (407.9 kg) at a stress of 7.2 kN/m^2. This implies that if the baskets are filled with fresh tomato fruits and stacked on one another during transportation, the basket at the bottom is expected to bear the load of 15 number of baskets (maximum pressure applied) without causing severe damage to the tomatoes or the baskets itself. However, with continuous use of the baskets, the provided pores created during weaving for inflow of air reduces due to frequent stacking. This results were consolidated with the study of Böröcz (2015).

It was equally observed during the test, that the basket started obeying Hooke's law at a load of 2.4 – 4.0 kN; any load applied beyond 4.0 kN will cause the container to go beyond its elastic limit (yield point), hence, break.

Conclusion

The abundance of the materials used for weaving the baskets make it cheap and affordable(₦600). The tendency of the baskets to be stacked during transportation with minimal postharvest losses incurred, adequate ventilation and its cost make it adequate for use by tomato merchants. It was found to be able to withstand a pressure of 7.2 kN obeying Hooke's law when compressed and can be stacked up to 15 levels of baskets without severe damage to the tomato fruits and the basket. However, stacking up to 15 levels is not recommended, this could lead to tilting of vehicles, bad road terrain resulting in postharvest losses and other circumstances that could prevail during transportation. Rather, a stack of 8 is recommended.

Recommendations

Obviously, there are some sort of unison in the acceptability of baskets allowed to be used for tomato sales in several Nigerian markets. It was observed that the reported 75% postharvest losses in many studies are caused by the packaging container used, especially during transportation.

It is here by recommended that:

i. A verification trial be conducted on the developed baskets and
ii. The baskets should be adequately publicized using an effective extension techniques.

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PRODUCTION AND QUALITY EVALUATION OF BISCUITS FROM BLENDS OF BAMBARA NUT, COWPEA AND WHEAT FLOURS

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ABSTRACT

Biscuits was produced from bambara nut, cowpea and wheat flour blends. This study was carried out to evaluate the effects of varying the proportions of these flours on the nutritional quality and general acceptability of the biscuits. Five blends of composite flours were prepared by mixing wheat, bambara nut and cowpea (WBC) flours in the proportions: T_1(90:5:5), T_2(80:10:10), T_3(70:15:15), T_4(60:20:20), T_5(50:25:25) and 100% whole wheat flour was used as the control(T_0). Composite flours produced were subjected to functional and proximate analysis while the biscuits made from the flour blends were also subjected to sensory evaluation and proximate analysis. The use of composite flour for the production of biscuits from cowpea and bambara nut flours as supplement for the wheat flour has improved the nutritional contents of the biscuits with protein value being highest at mixing ratio T_5. The functional properties of the biscuits showed some significant differences ($p<0.05$) when compared with whole wheat biscuits. The results showed that biscuits produced from T_5 formulation with proximate composition of 11.87% moisture, 2.90% ash, 18.61% protein and 75.62% carbohydrate was selected as the best product.

Key words: *Biscuits formulation, composite flour, wheat, cowpea, and bambara nut*

INTRODUCTION

Biscuit is an important edible confectionary crisp product of wheat majorly consumed with tea by human especially children and used as weaning food for infants (Ferial and Azza, 2011). The primary ingredients used for the production of biscuit (wheat flour, butter, salt, baking powder, fortified milk, whole eggs, sugar and vanilla) are deficient in protein which could be enhanced by supplementing the wheat flour with more nutritional pods and other leguminous crops (Yao, *et al;* 2015).

Biscuit is an essential food material usually sold in ready to serve form contributing valuable quantities of 20ppm iron, 12ppm calcium, 100ppm protein, 20ppm calories, 40ppm fibre and some of the B-vitamins to our diet and daily food requirement (Barca *et al*., 2010).

Wheat flour used for the production of biscuits is insufficient in many regions of the world resulting in importation of the flour by regions with limit supplies (Zouari *et al.*, 2016). There is therefore, a compelling need to develop an adequate substitute for wheat flour. This substitute should be readily available, cheap and capable of replacing wheat in functionality.

Bambara nut (*Vigna subterranean L.*)has been used by researchers as composite flour for baking because of its nutritional value. Bambara nut is high in protein that play important role in human nutrition. Study shows that it contains 20-26% crude protein (high in lysine; 6.6%); and makes an excellent source of supplementing proteins in the diet (Nwosu, 2013).
Bambara nut are consumed in many ways: in many West African Countries, the fresh pods are boiled with salt and pepper, roasted seed can be boiled crushed and eaten as relish and eaten as a snack while in Cote d' Ivoire, the seed is used to make flour, which makes it more digestible. In East African, the beans are roasted, then pulverized, and used to make soup, with or without condiments while in Zambia used for the production of bread (Goli, 1995). Other common uses of bambara nut is for the production of various fried or steamed products such as '*akara'* and '*moimoi'* in Nigeria. Bambara nut milk was examined along side with cowpea, pigeon pea and soybean and was ranked first while all other milks were found to be acceptable (Goli, 1995). Adu-Dapaah and Sangwan, 2004 reported that the seed is regarded as a balanced food because when compared to most legumes, it is rich in iron and the protein contents high lysine and methonine and in addition it is known to contain 63% carbohydrate, 18% oil and fatty acid content is predominantly linoleic, palmitic and linolenic acids (Minka and Bruneteau, 2000).

Cowpea is one of the most drought tolerant crops and has big potential as food security crop for many poor African subsistence farmers. Cowpea also has high quality proteins that could compete favourably with soyabean protein when substituted in diets at equivalent protein content (Obatuli *et al.,* 2003 and Aguirre *et al.,* 2003). A limited number of studies have also demonstrated that cowpeas have high antioxidant capacity (Siddhuraju and Becker, 2007) and that the antioxidant properties may be improved by heat processing or fermentation (Doblado *et al.,* 2005). Recent evidence also suggests that whole cowpea is effective at binding cholesterol and lowering blood cholesterol in hamsters (Frote *et al.,* 2008).

Cowpeas (*Vigna Unguicutala*) are grown extensively in 16 African countries. Nigeria and Niger put together produced 49% of the world crop. Available data (FAO, 2004) indicated that cowpea is a cash crop in Burkina Faso, Ghana, Nigeria, Mali, Mauritania, Niger and Senegal. Among these, Nigeria is the largest producer both in the West African sub-region and in the world at large. More than 2.5 million metric tonnes of cowpea are produced annually. Nigeria has unfavourable climate condition for wheat cultivation, but suitable for other cereals (sorghum, maize, millet and acha); legumes (soybean, groundnut, bambara nut, cowpeas) and vegetable (Ferial and Azza, 2011).This research however aimed at improving the quality of biscuit based product by the addition of bambara nut and cowpea as supplement to wheat flour at varying ratio.

MATERIALS AND METHODS

The wheat, cowpea and bambara nut seeds used for this work were purchased at Muda - Lawan market in Bauchi, Bauchi State, Nigeria. Other ingredients; granulated sugar (1.25g), fortified milk (15ml), baking powder (2.0g), whole eggs (1.25g), butter (33g), salt (0.2g) and vanilla (1.0g) used in the production of the biscuits formulation were also obtained from the same market.

Flour Preparation: Bambara nut flour was prepared using the method described by Nwosu, (2013). Bambara nut seeds were cleaned manually to remove all foreign materials such as dust, dirt, small branches and immature seeds. The cleaned sample were sorted and steeped in water for 12hrs; it was then dehulled and oven dried using Genlab oven, at 60^0C for 3hrs and finely ground to powder (0.60 mm) form with a high speed grinding machine and sieved using 500µm sieve to obtain fine flour (Figure 1).

Cowpea seeds was manually cleaned and sorted to remove the foreign materials. 1304g was measured. In preparing the flour, sample were soaked in water for 5minutes after which it was dehulled with hand to remove the coat, then water was decanted alongside the coats. It was allowed to drain off and then dried in the oven dryer at 40^{0}C for 3 hrs. The dried seeds were finely ground using milling machine and sieved to obtain the flour (Figure 1).

Bambara nut Seed → Cleaning → Sorting → Steeping in Water → Dehulling → Drying at 60^{0}C for 3hrs → Grinding → Sieving → Bambaranut Flour

Cowpea Seed → Cleaning → Soaking → Dehulling → Drying → Milling → Sieving → Cowpea Flour

Figure 1: Bambara nut and cowpea flour Preparation
Source: Nwosu, (2013).

Table 1: Composite

Treatment	Wheat flour	Bambara nut flour	Cowpea flour
T_0(Whole Wheat flour as Control)	100	0	0
T_1 (5% Bambara nut flour, 5% Cowpea flour)	90	5	5
T_2 (10% Bambara nut flour, 10% Cowpea flour)	80	10	10
T_3 (15% Bambara nut flour, 15% Cowpea flour)	70	15	15
T_4 (20% Bambara nut flour, 20% Cowpea flour)	60	20	20
T_5 (25% Bambara nut flour, 25% Cowpea flour)	50	25	25

Biscuit Making

The mixing ratio of the biscuit formulations were as presented in Table 1 while the biscuit was prepared using the method described by Oma and Okafor, (2015). The flours (200g), butter (33g) and salt (0.2g) were mixed together manually for 5 mins to get a creamy dough. The baking powder (2.0g), fortified milk (15ml), whole eggs (1.25ml), sugar (1.25g), vanilla (1.0g) was mixed thoroughly. 65ml of water was gradually added using continuous mixing until good texture, slightly firm dough is obtained. The dough was kneaded on a clean flat surface for 4 mins. It was manually rolled into sheets and cut into shapes using the stamp cutting method. The cut dough pieces was transferred into fluid fat grease pans and baked in an oven at 180^0C for 20 mins, cooled and packed for further analysis.

Proximate Analyses of Wheat, Bambara Nut and Cowpea Flours.

The wheat, Bambara nut and Cowpea flours were analyzed for moisture content, ash content, crude fibre, crude fat and crude protein as prescribed by the standard setup in AOAC, (2002). Total carbohydrate was determined by simple difference method. Initial nutritional compositions of the three composite flours were determined in triplicates to evaluate effect of the treatment on the end product.

Physical analysis of biscuits

The diameter (width), thickness and spread factor of the biscuit product for each blend was determined as prescribed by AOAC (2000).

Spread factor is the ratio that depends on the values of the thickness and diameter of the biscuits. Spread factor (SF) was determined from the diameter and thickness using the formula:

$$SF = \frac{D \times CF \times 10}{T}$$

Where: CF is a correction factor at constant atmospheric pressure, T = Thickness of biscuits (mm), D = Diameter of biscuits (mm) as its value was 1.0 in this case (AOAC, 2000).

Sensory evaluation of biscuits

The Biscuit formulations at the specified mixing ratios described in Table 5 were evaluated for quality and overall acceptability using 10 panelists; the sensory evaluation was carried out for colour, flavour, crispness, texture and overall acceptability (Table 5).

Statistical analysis

The data obtained from this study was statistically evaluated using IBM SPSS 21.0 statistical tool while the mean significant differences of triplicate values were separated by Duncan Multiple range method using analysis of variance (ANOVA) at $P < 0.05$.

RESULTS AND DISCUSSION

The mean initial proximate compositions of bambara nut, cowpea and wheat flourare presented in Table 2. The results indicates that total carbohydrate content of the flours at raw stage were significantly higher in wheat flour than bambara nut and cowpea flour with 52.50%, 21.06% and 15.82% respectively; while bambara and cowpea flour were statistically higher in protein contents than wheat flour which are 43.40, 57.02 and 21.4%, respectively. Crude fat contents was higher in cowpea than bambara nut and wheat flour (Table 2).

The results of proximate compositions of biscuit products at varying mixing ratios of bambara nut, cowpea and wheat flour indicates that there are statistical significant difference in the output ($P < 0.05$). However, crude protein contents was observed with high significant value of 18.61 ± 0.01% at mixing ratio T_5 (25% Bambara nut flour, 25% Cowpea flour and 50% wheat flour) as compared with the control (T_0) and others treatments (Table 3).

Table 2: Initial Nutrient Values of Samples (Bambara nut, Cowpea and Wheat) flour

Parameter	Bambara nut	Cowpea	Wheat
Moisture (%)	3.68 ± 0.14	3.84 ± 0.29	12.3±0.24
Ash (%)	8.41 ± 0.37	7.93 ± 0.17	3.68±0.43
Crude Protein (%)	43.40 ± 0.35	57.02 ± 0.43	21.4±0.55
Crude fibre (%)	5.86 ± 0.18	6.08 ± 0.21	6.18±0.27
Crude Lipid (%)	4.40±0.811	4.820±0.19	0.18±0.57
Carbohydrate value (%)	21.06±0.53	15.82±0.21	52.5±0.60
Calorific value (kcal)	5784.55±0.12	6260.10±0.52	1704±0.45
Ether extract (%)	17.59 ± 0.23	19.27±0.11	15.01±0.63
Nitrogen	6.94±0.51	9.12±0.76	3.43±0.42
Phosphorus	14.62±0.34	17.89±0.61	0.146±0.71
Calcium	2.63±0.62	1.09±0.51	0.104±0.51

High crude protein value experienced in the sample could be as a result of increase in bamara nut and cowpea flour proportion which concur with previous finding of Boateng *et al.,* 2013. This is an indication that the T_5 blending ratio can effectively supplement biscuit production from wheat flour to improve the protein requirement by consumers. General trend of the results of biscuit products in this work also indicates that T_5 consists of higher moisture content, crude ash, crude fat, crude fibre, calcium and sodium content as compared with other blending ratios (Table 3) but have least carbohydrate contents of 75.62±0.03%. High ash content has been attributed to high mineral which invariably could increase the mineral content of the consumers and are good for the bones as reported by Ayo *et al.,* (2007). High values of crude fat content agrees with the findings of Agu *et al.,* (2014) which can be improved on subsequently to serve as added advantage in improving product shelf stability along side with observed high moisture content (11.87%) although within acceptable limit in terms of food storage as recommended by USDA, (2017) which states 13 – 15% safe moisture contents as optimal range for storage of food and cereal grain. High value of fibre contents could also improve the digestion and aid waste elimination in the body and guide against anthracites (Ayo and Okoliko, 2003). Low value of carbohydrate content could be as result of initial low contents obtained in bambara nut (21.06±0.53) and cowpea flour (15.82±0.21) value which actually increased significantly in the final biscuit product as compared with the initial value of wheat flour (52.5±0.60) (Table 2).

Physical characteristics

The effect of biscuit prepared from different mixing ratios of bambara nut, cowpea substituted wheat flour as control (100% wheat flour) are shown in Table 4 while the physical characteristics of the product is shown in Plate 1.

The spread ratio of the sample ranged from 51.45% in T_1 and T_2 to 76% in T_5 while the control (T_0) has 58%. An increase the spread ratio could be as a result of relatively increase in oil contents contained in the mixing ratio of bambara nut and cowpea flour which could enhance the attribute and added advantage as it will prevent breaking during post handling of the biscuit. The mean diameter of the biscuit product as shown in Table 4 indicates varying significant difference ($P < 0.05$). Data revealed that highest was observed in biscuits prepared from T_5 (304 mm) whereas the lowest was observed in T_2 (194 mm). this is an indication that increase in the mixing formulation contribute to an increase in the size of the product, this conform with the findings of Ferial *et al.,* (2011). Thickness of biscuit was found highest in the formulation with

Table 4: Physical Characteristics of Biscuits

Sample	Thickness (mm)	Diameter (mm)	Spread factor
T_0	47.33	274.5	58.00
T_1	38	195.5	51.45
T_2	37.67	194	51.45
T_3	50	315	63.00
T_4	39.33	244	62.04
T_5	40	304	76.00

Sensory Evaluation Results

The results of the sensory evaluation of the biscuits produced from T_5 (25% Bambara nut flour, 25% Cowpea flour and 50 % wheat flour) has overall acceptability while the quality of biscuits from T_3 and T_4 was rejected by the panellists (Table 5).

Table 5: Sensory attributes of composite biscuit from Bambara nut, cowpea and wheat

Treatment	Colour	Flavour	Crispness	Texture	Overall acceptability
T_0	4.93 ± 0.03^{cd}	5.00 ± 0.58^{abc}	5.00 ± 0.58^{b}	5.33 ± 0.33^{ab}	4.97 ± 0.29^{a}
T_1	4.30 ± 0.35^{bc}	5.33 ± 1.20^{bc}	3.00 ± 0.58^{a}	5.27 ± 0.54^{ab}	4.27 ± 0.45^{a}
T_2	5.8 ± 0.76^{d}	5.97 ± 0.29^{c}	5.33 ± 0.88^{bc}	6.23 ± 0.23^{b}	7.00 ± 0.58^{b}
T_3	3.33 ± 0.88^{ab}	3.20 ± 0.17^{a}	4.00 ± 0.58^{ab}	4.80 ± 0.35^{a}	5.00 ± 0.00^{a}
T_4	3.05 ± 0.03^{a}	3.80 ± 0.15^{ab}	4.67 ± 0.33^{ab}	4.83 ± 0.17^{a}	4.67 ± 0.17^{a}
T_5	8.20 ± 0.06^{e}	8.10 ± 0.15^{d}	7.07 ± 0.23^{bc}	8.20 ± 0.31^{c}	8.13 ± 0.23^{c}

Values are Means $\pm$ S.D of triplicate determinations.Values in the same column with different superscripts were significantly ($p<0.05$) different

CONCLUSION

The study demonstrated use of composite flour for the production of biscuits from bambara nut and cowpea flours substituted for wheat flour which positively improved the nutrient contents of biscuits with high value in protein, crude fat, crude fibre. Increase in the carbohydrate content in T_5 compared with initial value of wheat is also encouraging in term of balancing the vulnerable group diet. Overall acceptability of T_5 is a justification for the recommendation of biscuits production at 25% bambara nut flour, 25% cowpea and 50% wheat flour ratio which will enhance nutritional requirement for consumers and increase economic value of bambara nut and cowpea produce for possible application in the production of Biscuit.

Table 3: Chemical Composition of Biscuit Products

Treatments	Moisture content (%)	Crude Ash (%)	Crude protein (%)	Crude Fat (%)	Crude fibre (%)	Carbohydrate (%)	Ca	Na
T_0	8.57 ± 0.06^{a}	1.97 ± 0.00^{a}	13.11 ± 0.00^{a}	1.89 ± 0.00^{a}	2.98 ± 0.01^{f}	81.03 ± 0.03^{e}	0.04 ± 0.00^{a}	0.04 ± 0.00^{a}
T_1	10.26 ± 0.01^{b}	2.10 ± 0.00^{b}	13.46 ± 0.00^{b}	0.97 ± 0.01^{b}	2.24 ± 0.01^{e}	81.24 ± 0.01^{f}	0.05 ± 0.00^{a}	0.04 ± 0.00^{a}
T_2	10.83 ± 0.01^{c}	2.14 ± 0.01^{c}	13.94 ± 0.00^{c}	1.05 ± 0.01^{c}	2.02 ± 0.01^{d}	80.86 ± 0.21^{d}	0.05 ± 0.00^{a}	0.04 ± 0.00^{b}
T_3	11.16 ± 0.01^{d}	2.23 ± 0.00^{d}	14.64 ± 0.01^{d}	1.10 ± 0.01^{d}	1.95 ± 0.01^{c}	80.09 ± 0.01^{c}	0.06 ± 0.00^{a}	0.05 ± 0.00^{d}
T_4	11.59 ± 0.01^{e}	2.55 ± 0.00^{e}	15.20 ± 0.01^{e}	1.43 ± 0.01^{e}	1.81 ± 0.01^{b}	79.02 ± 0.01^{b}	0.24 ± 0.18^{a}	0.05 ± 0.00^{d}
T_5	11.87 ± 0.01^{f}	2.90 ± 0.00^{f}	18.61 ± 0.01^{f}	1.96 ± 0.01^{f}	1.44 ± 0.01^{a}	75.62 ± 0.03^{a}	0.07 ± 0.00^{a}	0.06 ± 0.00^{e}

Values are mean $\pm$ SEM, T_0 = 100% of whole wheat, T_1 = 90% of wheat, 5% of Bambara nut and 5% of Cowpea, T_2 = 80% of wheat, 10% of Bambara nut and 10% of Cowpea, T_3 = 70% of wheat, 15% of Bambara nut and 15% of Cowpea, T_4 = 60% of wheat, 20% of Bambara nut and 20% of Cowpea, T_5 = 50% of wheat, 25% of Bambara nut and 25% of Cowpea

Sample T_0 Sample T_1 Sample T_2 Sample T_3 Sample T_4 Sample T_5

Plate 1: Physical appearance of biscuit production from composite flours

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OVERCOMING FOOD IMPORTATION: A PANACEA TO FOOD INSECURITY, POVERTY REDUCTION AND JOB CREATION AMONG RURAL FARMING POPULATIONS IN NIGERIA

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ABSTRACT

The greatest potential for sustainable growth lies in the agricultural sector; this sector has suffered extremely low productivity due to over-reliance on food importation, oil and gas, etc. In the 60s and 70s, agriculture, produces abundant food for Nigerian citizenry, and formed the largest part of the country's GDP. Various kinds of agricultural produce, food and cash crops were exported from Nigeria to other countries. Today, Nigeria now imports a significant amount of food to sustain her rapidly population growth. Agricultural imports in the country has reached an all-time high in the year 2016 compared to when Nigeria's food imports bill rose to ₦ 6.6 trillion Naira. The efforts of the present Government has shifted positive and encouraging attention to agriculture through the diversification of the economy from the oil and gas to agriculture and other resources. This research overview various ways of achieving more successes on food sufficiency, import substitution, economy diversification and job creation; as it translates to reduced poverty amidst rural populations and increasing the contribution of agriculture to the annual GDP. Some of the challenges identified in the cause of the study were: criminal neglect of the agricultural sector as a whole; rapid population growth, urban-rural migration, neglect of extension providers, defective agricultural policies, and poor execution. Conclusively, the study recommended among other things the fiscal and monetary policies: lower interest rate, import restriction on agricultural products which should be adopted by relevant authorities; alongside other measures that may improve local production content in other to meet both local and international demands, promote agricultural export, employment opportunities, incorporation of private-public partnership, strengthening of micro-finance institutions and other credit facilitators with single digit interest, provision of more lands for agricultural and industrial production; raising foreign exchange earnings etc. All these are expected to translate into sustainable economic growth and a permanent exit to the country's economic downturn.

Keywords: *food importation, poverty alleviation, job creation, rural farming population,* agricultural *policies.*

1.0 INTRODUCTION

According to the Food and Agriculture Organization of the United Nations (Adesina, 2013), the world population will reach 9.1 billion by 2050, and to feed that number of people, global food production will need to grow by 70%. For Africa, which is projected to be home to about 2 billion people by then, farm productivity must accelerate at a faster rate than the global average to avoid continued mass hunger, food scarcity, and insecurity.

The challenges of food insecurity and poverty in Nigeria are multi-faceted; nonetheless, rising population, is a greatest threat to low farm productivity; worsened by weather/climate changes; shorter fallow periods, overpopulation and rural-urban migration that deprives farming communities of young people. Hence, the combination of higher food demand, stunted yield potential, and increasingly worse farmland must stimulate a redesigned agro-sector for assured food security.

Agriculture accounts for more than 30% of the continent's GDP and employs more than 60% of its working population which cannot produced for his over teeming populations (Ekekwe, 2017). This was corroborates by Akinbamijo (2015), who reported that the shift in focus away from agriculture to petroleum is brought about severe underinvestment in the sector by the public and private sectors which was further accentuated by weak, unenforced, poorly implemented and often conflicting policies at all levels of the country's governance structures (Nwuneli, 2010). However, the over-reliance on food importation, oil and gas exploration in Nigeria cannot be over emphasized. According to Federal Republic of Nigeria (2017), Agriculture is the most significant sector in the Nigerian economy as it employs about 38.0 percent of Nigerians and consequently contributes 23.1 percent of the country's Gross Domestic Products (GDP). The sector later grew by 4.88 percent in the third quarter of 2016; to as much as 13 percent in previous years, suggesting immense unrealized potentials; this was caused by inconsistency from subsequent government reforms, programs and agendas. Unfortunately, the performance of the sector at the international trade over the years shows declines and stagnation, having lost its position in the export of key commodities(FMARD, 2011). Following the shift from agriculture to crude oil and gas in the late 1960s; Nigeria's growth has continued to be driven by consumption of high oil prices. Consequently, the structure of Nigeria economy is largely import dependent, consumption driven and undiversified. Oil accounts for more than 95 percent of export and foreign exchange earnings while the manufacturing sector accounts for less than one percent of total exports (FRN, 2017).

According to United Nation reports (2017), about 75% of food produced in Nigeria are wasted due to improper food processing and handling; technical know-how of improved technologies; lack of fertilizer application and or improved inputs which causes poor growth and harvesting. In strict relations, imports of food (agric products) to Nigeria dropped from 7.5% in the previous year to N844. 0 million in June, 2017; other crude oil products (-14.8%) and manufactured goods (-23.3%). Hence, Nigeria is a net importer of agricultural produce with import of above N630 billion (Anonymous, 2017).

Bakare (2011) also agrees with the agriculture export shrank from the traditional 12-15 commodities of the 1960s when Nigeria became the net importer of the basic food it normally exported. Presently, majority of Nigerians remained under the burden of poverty, inequality, underemployment or and unemployment. Similarly, FMARD (2011) revealed that Nigeria which was a leading exporter of groundnut with a world's share of 42%, had 27% of the world's palm oil export, 18% of cocoa and 14% of cotton respectively. The economic performance is also undermined by deplorable infrastructure, consumption and mismanagement of public finances (FRN, 2017). This glory however declined significantly over the years, with the dominance eclipsed by its competitor. Aside these, youth unemployment became rife particularly in the Niger Delta and North East Region. Youth's unemployed however transit from school to unemployment has been difficult (IFAD, 2017).

Furthermore, in order to address illegal smuggling of agricultural products accompanied with at least equal measures to ensuring the sustainable growth of agricultural products and other mono-cultural products in the country. Hence, these developments are not unconnected to limited access to technical skills, insufficient, inappropriate and inaccessible finance, and negative effect of climate change and the perception of agriculture as unattractive for generating income and sustaining life. However, as desirable as agriculture is to economic well-being in many countries, Nigeria is yet to optimize their potentials**.** Comparatively, all these challenges are not unconnected to the relegation of agriculture to subsistence farming, non-prioritization of agribusiness at the different levels of governance, lack of infrastructure, poor storage facilities, poor research, and poor disjointed value chains occasioned by discovery of oil (Anaebonam, 2015).

Currently, the Green Alternatives (Agricultural Promotion Policy) of President Muhammad Buhari has been putting things together in other to have a new breaking ground on agriculture: food security, job opportunities, economic diversification, import substitution, boosting of GDP and foreign reserves, and promotion of raw materials or agro-industries etc.

Agriculture can be Africa's new oil spinner by year 2030 if the critical solution to myriads of problem confronting her since economic recession in the late 2000s are resolve. However, the negligence of agriculture by successive government has invited a number of repercussions such as decline in agriculture's contribution to national GDP from 60 percent in the early 1960s to 48 percent in the 1970s and 22 percent in the 1980s (World Food Summit, 1996) and vulnerability of the nation to hunger and a net importer of food agricultural transformation Agenda (ATA), 2011 and Onwualu, 2012; coupled with less than 10 percent budgeted on agriculture in the past two decades.Conversely, this is far fromMaputo declaration of 2003 where all African countries leaders pledge to contribute minimum of 10% of government spending on agriculture. Fourteen years after, many countries have not even reached 7%.

This study therefore look into ways of overcoming food importation and achieving more food sufficiency, by providing alternative to scarcity of agricultural products and inputs, insecurity, and other challenges confronting agricultural development; creating more jobs and reducing poverty amidst rural farming populations; hence making Nigeria's agriculture a major contributor to the annual GDPs and export earner's.

2.0 OVERVIEW OF FOOD IMPORTATION AND POLICIES IN NIGERIA

Nigeria, like some other developing countries is principally an agrarian nation who still face an ever increasing food crisis as the level of food production is yet to keep pace with demand. There is worsening food insecurity, even with massive food importation as evidenced by rising food import bill (Okoye, et al, 2008). In Akinsanmi (2009) remarks, he noted that Nigeria is one of the worst hit countries globally given her unprecedented level of acute food shortage and its accompanying ravaging malnutrition. Though endowed with vast expanse of arable land for crop production and fresh waters for fish breeding, reports still show that Africa's largest country cannot produce food crops required for her rising populations and had thus been depending on food importation to meet her domestic demands (Adepoju and Awodunmuyila, 2008). Agricultural economy was the basic economic feature of the long and short distance traders who traded substantially across the trans-Saharan trade routes. Nigeria could-not boast of sustainable local food production which was essentially subsistence alongside the cash crop production among its contemporaries after trade liberalization. The major issue here was that subsequent government's administration does not favour agriculture and local contents although, in part, has disarticulated and disorientated the local agricultural and food production philosophy, and eliminate the primary objectives of food production (Adebowale, 2013). This corroborates Ogbeni Rauf Aregbesola, the Governor of Osun State who claimed that statistics reveals that over 80 percent of the foods in the state are imported (The Nation, 2011). This experience appears worrisome as Nigeria, the greater part of the African continent imports its food. Nigeria which was known for surplus agricultural and food production in the early 60's is now deficient in production and other line of food postharvest handling. A country that was at a time able to point to a history of food sufficiency even in the colonial era appears to continue to pay lip services to the dreadful problems of food shortages, scarcity, hunger and undernourishment.

For instance, there is a growing advocacy for improving Nigeria agricultural production so as to achieve sustainable food security. These was in line with Eze (2009) who noted that a lot of efforts has been directed at finding appropriate institutions for organizing millions of small scale farmers towards achieving food security (through increased food production) which has been described as the appropriate vehicle for harnessing and polling the resources of millions of smallholder farmers for both producers and processors together in other to enjoy the benefits of large scale production. However, numbers of studies have indicated that agricultural production in Nigeria is still characterized by small farm holders (Onugu, 2008; Obinyan, 2000; Ijere and Mbanasor, 2000). According to (Guy, 2001;Obinyan, 2000; Olujenyo, N. D) food production could be affected by the farmers age, access to credit, gender, farm size, educational level, farming experience etc. it is on record that 50% of world's population is dependent on subsistence agriculture. Considering the prime importance of agricultural production to achieving food security and its crucial role in the nation's socio-economic transformation in terms of its contribution to the GDP and the fact that domestic supply has not been able to meet up with its demand.

In spite of successive governments efforts over the years to achieve food security in the country, through the setting up of a number of agricultural development institutions and policies such as special programmes and projects which include: National Accelerated Food Production Progamme, NAFPP (1972/73); Agricultural Development Programme, ADP (1975); Operation Feed the Nation, OFN (1976); National Seed Service, NSS (1977); Agricultural Credit Guarantee Scheme ACGS (1977); Rural Banking Programme, RBP (1977-1991); Green Revolution Programme GRP (1979/80); Directorate of Food, Road and Rural Infrastructure, DFRRI (1986); Community Banking Programmes, CBP (1991–2007); National Agriculture Land Development Authority, NALDA (1992); Root and Tuber Expansion Programmes, RTEP (2000); National Fadama Development Project, NFDP I ,II, and III (1992, 1999 and 2008 respectively); Nigeria Agricultural Cooperative and Rural Development Bank, NACRDB (2000); National Agricultural Development Fund, NADF (2002); National Special Programme on Food Security, NSPFS (2002); Commodity Marketing and Development Companies, CMDC (2003); the Presidential Initiatives on selected crops (2004-2005); 7-Points Agenda with emphasis on Food Security (2009); the Agricultural Transformation Agenda (2012) and more recently; The Green Alternative i.e. Agricultural Promotion Policy (2016-2020), which is the continuation of Agricultural Transformation Agenda (ATA) of the former President Goodluck Jonathan.

Nigeria has witnessed several policies aimed at addressing and resolving arrays of problems in agricultural practices and food production e.g. Microfinance policy, Presidential Initiative on Agriculture, 2002 (cassava, maize, sorghum, wheat, groundnut, rice, etc.); Presidential Initiative on Cassava Production and Marketing Reports, (2003); Preferred Sector Allocation of Credit; Civil Service Reform (2004). Unfortunately, the large proportions of Nigerians are still poor, starved, abandoned, deprived of food availability, shelter, and improved healthy environment.

On the contrary, the recent crisis between farmers and Fulani's herdsmen, inter-communal cries has further threaten the relative peace which the farmers has been according to the herders in the past; this claim has continue to bring conflict/ drift between the cattle rustlers, farmers farm and his community which is a greatest challenge to food production and productivity among farmers populace and further threaten the relative peace; and hence leads to scarcity of food increment in the staple food prices. This situation is not different in some of Nigerian states such as Benue, Taraba, Plateau, Nasarawa, Bauchi, Abia, Enugu, Niger, Oyo, Ogun, etc); as this insecurity causes fear to farmers and hence slow down the food production in this crises-ridden states.

3.0 CHALLENGES POSED BY IMPORT DEPENDENCY ON AGRICULTURAL DEVELOPMENT IN NIGERIA

In reviewing agricultural development in Africa, Lynn (1989) noted that a quarter of a century after independence, few would dispute that the African industrial sector was in crisis. His survey revealed that 343 factories in over 16 countries, spanning sectors as diverse as beverages, textiles, pulp and paper, flour milling, sugar refining and cement, 23 percent of the companies were found to have ceased production and a further 57 percent were functioning at less than 70 percent of nominal capacity-well below their break-even point. It appears that no African country has been spared.
The slight dropped in food production has resulted to increase in food importation, however, in other to clear the excesses demand over supply of food in the country there should be more commitment in food production. In 2016/17, The Federal Ministry of Agriculture and Rural development estimated that over 68 million people in Nigeria are hungry, which is about 33 percent of the country's total population of approximately 180 million; and 52 percent live under the poverty line (Anonymous, 2017). Nigeria has attained self-sufficient in food production and a net exporter of food to other regions of the continent in the 1950s and 1960s.

Hence, this picture of steady decay explained why a formerly sufficient continent in food production now imports almost all its food to prevent hunger and starvation among its poor people. Nigeria is not excluded from this general picture of backwardness, policy somersault, local content and steady decay in food production, importation and industrialization.

Over the years, previous Nigerian government have attempted (through various programme initiatives and policies), to addressed the challenges facing agriculture, moreover to ensure its development. This is posited by Okuneye (1995) in his inaugural lecture titled "Nigerian agriculture on the run: yet refuses to move", he reported that it is paradoxical to note that with its abundant resources, Nigeria still exhibits high levels of food insecurity. The number of hungry people in Nigeria is put at over 53 million which is about 30 per cent of the country's total population of about 150 million**.** Consequently, the incomes of most families are not adequate for the basic sustenance of life. Moreover, according to the International Food Policy Research Institute, Global Hunger Index classified Nigeria's hunger situation as "serious". It further posited that Nigeria is also one of the five countries with half of the world's malnourished children (IFPRI, 2010). Adewumi et al. (2010) also mentioned that in 2009, about 6 million children are said to be malnourished in Nigeria. They both added that malnutrition is a major cause of child mortality, which tends to reduce labour availability for farm work. This in turn leads to low farm output causing higher food prices. The yearly loss of about 6 million children may reduce the number of farmers in our villages/communities, since majority of the rural dwellers in Nigeria are not poor but uninformed about their nutritional status. Despite huge resources from oil, Nigeria is characterized by hunger, high rate of youth unemployment, insecurity, food crises, job cuts and high food imports with the attendant result that more than 50 percent of the population is living below the poverty line of $2.75 per day. Hunger and malnutrition continues to outbreak in Nigeria's population. During the period

1970-1979, the average annual deficit in per capita daily calories intake was 24.4 per cent. This declined to 23.58 per cent within 1980-1989. By 2006, it fell to as low as 11.34 per cent (CBN, 1993; ADB, 2007). However, this trend hasrose to 17% in the first–quarter of 2018.

The growth of Nigerian economy with reference to agriculture has been import-driven rather production-driven. This challenge confronting Nigeria's agriculture is related to the problem of low productivity in production resulting from inefficient use of resources and crude implements.

Munack, (2002) also reported that in the world today, the demands on agriculture was imposed by different groups are numerous; the society asks agriculture for competitiveness, protection of the environment and social compatibility; while the consumer wants qualitatively excellent products at low prices, all over the year; palatable, healthy and nutritious foods (Spore, 2006); landscaping with no disturbance by noise or odour; the industry demands are: high-quality, low-cost food and raw materials; renewable resources; pharmaceutical products; while the farmers demand for increase in their incomes; labour safety and reduction in working time; clear and reliable legal principles for future development of the farm. Comparatively, Oni (2013) also identified various challenges affecting agricultural development; this includes policy framework, political commitment, agricultural technology, and infrastructure deficit, finance and risk management, and institutional realignment etc. However, from the listed above challenges; Nigeria is facing two key gaps in the agricultural sector namely inability to meet domestic food requirements and to export quality products required for market success. Therefore putting Nigeria's agricultural sector on the lifeline. There's need to boost agricultural production which will impact significantly on growth and development. In swift reaction or addressing this challenges, government should evolve market based policy that is anchored on three main pillars, in line with the constitutional provision for the role of the Federal Government in agricultural development; these are promotion of agricultural investment; financing of agricultural development programs; research for agricultural innovations and productivity.

Aside petroleum exploration, agricultural productivity is a major component of the nation's gross domestic products as it creates more employment opportunities and alleviate hunger among the rural populations. The sector contributed 41.59% to the Gross Domestic Product (GDP) of the Nigerian economy in the second quarter of year 2011 (CBN, 2011). On the average, the trends in the sector's contribution to the nation's GDP hovered around 35% between 2010 and first quarter of 2015. Consequently, the sector later grew by 4.88 percent in the third quarter of 2016 and by as much as 13 percent in previous years, suggesting immense unrealized potentials (Federal Republic of Nigeria, 2017). Although, survey statistics showed a slight increase in per capita daily calorie intake with decline in the proportion of undernourished people from 13 per cent in 1990-1992 to 9 per cent in 2000-2002 and 7 per cent in 2002-2004 (FAO), 2005; IFPRI, 2006). The fact however remains that domestic production of most food commodities, urbanization, inflation and demand from neighboring countries are among some of the factors that continued to affect food availability and accessibility to most Nigerians (Vision 20:2020, 2009). The noted improvement could therefore be traceable to the continued dependence of the country. Furthermore, the All Farmers Association of Nigeria (AFAN) reported that Nigerian Government spend over $ 6 billion dollars to import fish and frozen chicken annually, this is very sad for 'giant of Africa'. This has further increased to about N2.2 trillion (Anonymous, 2015). In later development of the last quarter 2016; Agro-Info (2015) reported that Nigeria spends an estimated 125 Billion Naira in importing fish every year. This means that Nigerian farmers can therefore decide to be a major player in the farming sector.It further corroborates the problems facing poor households in Nigeria. The cost of inadequate diets to families and nations which are considerably high. These include increased vulnerability to diseases and parasites, reduced strength for tasks which requires physical efforts, reduction of the benefit from schooling and training programmes, lack of vigor, alertness and vitality. The outcomes of these are reduction in the productivity of people in the short and long terms, sacrifice in output and incomes, and increasing difficulties for families and nations to escape the cycle (Omotesho, et.al, 2006).

On this note, Agricultural sector must not only be seen to grow but must match the per capita needs of the population of that society (Weblow, 1997). These concerns were further aggravated by the global economic downturn of 2008 which led to the collapse of many developed and developing economies.

4.0 OVERCOMING FOOD IMPORTATION THROUGH HOLISTIC AGRICULTURAL DEVELOPMENT

Nigeria has witnessed several policies aimed at addressing and resolving problems in agricultural practices and food production.Regrettably, the large proportions of Nigerians are still under abject poverty, starved, abandoned, deprived of food availability, shelter, and improved healthy environment.

To increase food production and alleviate the widespread poverty in sub-Saharan Africa given the incidence of galloping growth in population and limited possibility for expansion of cultivated area, there is a need for green revolution (Diao et.al, 2008). Green revolution enhances crop yield per unit of land by using high-yielding varieties, irrigation technology, fertilizer and agro-chemicals such as pesticides and herbicides but the speed and scale at which this technology solved the food problem were remarkable and unprecedented; this however contributed to a substantial reduction in poverty and launching of broader economic growth in many Asian countries (Otsuka and Kijima, 2010). Nigeria as a state is not left out of this information. According to (FAO, 2013) the main barriers in adoption of agricultural technology are large investment costs, the perceived risk of a technology, long gestation period for the perceived benefits of the technology to materialize, access to information and extension services, land tenure system, culture and recent outcomes of the technology. Likewise, socio-economic status such as family income, educational level, parental occupation and social status all affect adoption (Demarest, *et. al*., 1993).

Agriculture still remained the mainstay of the economy of most African states, yet current estimates indicates that some 200 million or 28 percent of Africa's population are chronically hungry (Iheke, 2008). The high population growth rate has led to increase in the demand for agricultural products, natural and human disaster (drought, flood, fuel, food scarcities, land degradation) as well as civil conflicts in some parts of Africa which contributes to this alarming situation and accounted for high imports and dependence on food aids by most African countries thereby posing huge problem of food insecurity (NEPAD 2004), fuel and food scarcities.

However, for agricultural development to be meaningful and impactful, it must of necessity be holistic and sustainable. Without be-labouring the fact, the bulk of Nigerian imports are on agricultural commodities. For this trend to be reversed and to turn Nigeria to a net exporter of agricultural commodities, urgent action must be taken on several fronts to ensure a quantum leap in agricultural productivity.

The Agricultural Transformation Agenda (ATA-2011) of the immediate past administration is a laudable initiative, whose potential have been tampered with by the perennial Nigerian factor syndrome. Being that as it may, giant strides have been made to jump-start development in the agricultural sector. Contributions of this sector to the GDP, as earlier noted, have increased appreciably. The numbers of jobs created under this agenda (about 58 million) have been massive; even though the actual numbers may not be as claimed. Also, President Goodluck Jonathan noted that the country's food production has expanded by 21 million metric tons within three years. It also reported that a food import bill has declined from N1.1 trillion in 2009 to N634 billion by 2013 and continues to decline. It should be recalled that before now, Nigeria with over 84 million hectares of arable land was spending billions of naira importing basic food items which it can produce. Of recent, the number of seed companies has increased from 11 to 134 within the past three years, making high quality seeds available to farmers. The fertilizer sector is booming accordingly (former President Jonathan) with N900 billion naira ($5 billion dollars) of new investments that can make Nigeria self-sufficient in fertilizer and turn us into a net exporter of fertilizer. The price of fertilizers is expected to decline and farmers will be able to afford more fertilizers to boost their food production since more private sector investors are into fertilizer production. Within the past three years (2012-2015), over 14.5 million famers have been reached through the Growth Enhancement Scheme (GES) program (Tribune, 2015). This GES arm of the ATA of the former administration has major positives that should be supported and promoted. It is a holistic approach of providing inputs to farmers at subsidized and affordable rates compared to others. Relatively, State Government partnerships with foreign investors must be encouraged and monitored to give the desired objectives. For example, Taraba state is in partnership with US investor-Dominion Farms to produce rice on 30,000 ha of land; Ekiti, Enugu, Kaduna, Rivers and Ogun States are also in partnership with Agricultural Industry Companies (AGCO) the manufacturers of Massey Ferguson in an investment worth over $100 million in new tractor assembly plants, (tractor parts) and supply services (Olomola, et.al, 2014). Partnerships between FMARD and states that have promoted the development of both crops and livestock's under the growth enhancement support (GES) scheme needs to be fostered and encouraged. The cooperation of these three tiers of government in the area of value chain development of fruits concentrates which are produced in Benue and Cross River States; while Tomatoes and sorghum processing plants are in Kano and Jigawa States respectively. This value addition cooperation if well sustained and up-scaled across the country it will encourage import substitution and invariably increases production (Olomola, et.al, 2014).

The momentum must be sustained and even increased in other to achieve more of the several targets set under the ATA initiative.

Conclusively, cassava, maize and rice sub-sectors have particularly enjoyed massive investment which if sustained, will in the not too distant future drive down the import bills incurred by the country on food by about 70% with government commitment to world food supply and inputs to agriculturally standard. In view of these, Matanmi (1991) advocated that the main problem facing the developing world today particularly Nigeria, is not the lack of efficient technologies and scientific discoveries needed for economic growth and rural change but that of their effective utilization for the social and economic transformation of the country. This, he contended would depend to a great extent, on the speed with which the technology is transferred from the source (Agricultural Universities, Research Institutes, Technologies Development Centre's and Extension Agencies) to the ultimate users so that they clearly understand, accept (adopt) and apply it in their day-to-day agricultural practices. However, with the very high population growth trends in the country (about 3.5% per annum) coupled with the crude agricultural production methods employed, there is the fear that the resultant low productivity cannot match the food demand of the nation. This situation may worsen in the nearest future if drastic measures are not taken immediately to arrest the imminent food crisis or insecurities. The place of agriculture in the development and growth of the Nigerian economy was summarized in the Technical Reports of the Committee on Vision 20: 2020 (Vision 2020; 2009). Firstly, the committee recognized the fundamentals of food production and the need for agricultural development. Secondly, it was obvious that policies should be directed towards financing, irrigation, mechanization, infrastructures, and provision of inputs. Thirdly, institutions were also created to meet the needs for the provision of surplus food in order to avert poverty, malnutrition, hunger and climate change. The Tables (1, 2) and chart (figure 1) that follow shows the trend of the steady decline of the contribution of agriculture to Nigeria's GDP especially since the discovery of oil in the 70s. This downward trend was checked and the GDP hovered around 35 % for most of the years especially after year 2000. The present realities of the dwindling oil revenues and the economic recession makes the reversal of this trend a top priority of the Nigerian government. This has been enunciated by no less a personality than President Muhammadu Buhari who stated that agriculture will be one of the main focuses of his administration.

Table 1: Sectorial contributions to gross domestic products (GDP) in Nigeria (1960-2002)

Sector	1960	1970	1980	1990	2000	2002
	(%)					
Agriculture	64.1	47.6	30.8	39.0	35.7	28.35
Manufacturing	4.8	8.2	8.1	8.2	3.4	5.5
Crude petroleum	0.3	7.1	22.0	12.8	47.5	40.6
Others	30.8	37.1	39.1	40.0	13.4	25.55

Source: (CBN, 2000).

Table 2: Food production and demand with shortfalls and importation (Million Mt)

Description	1994	1995	1996	1997	1998	1999	2000	2001
Production	86.70	89.25	93.35	95.64	98.74	100.41	102.12	103.86
Food demand	87.23	89.55	96.26	99.03	101.87	104.63	107.46	110.37
Shortfall	(0.53)	(0.30)	(2.91)	(3.43)	(3.13)	(4.22)	(5.34)	(6.51)
Food import	0.67	0.58	2.95	3.47	3.24	4.48	5.59	6.91

Source: (FOS, 2002).

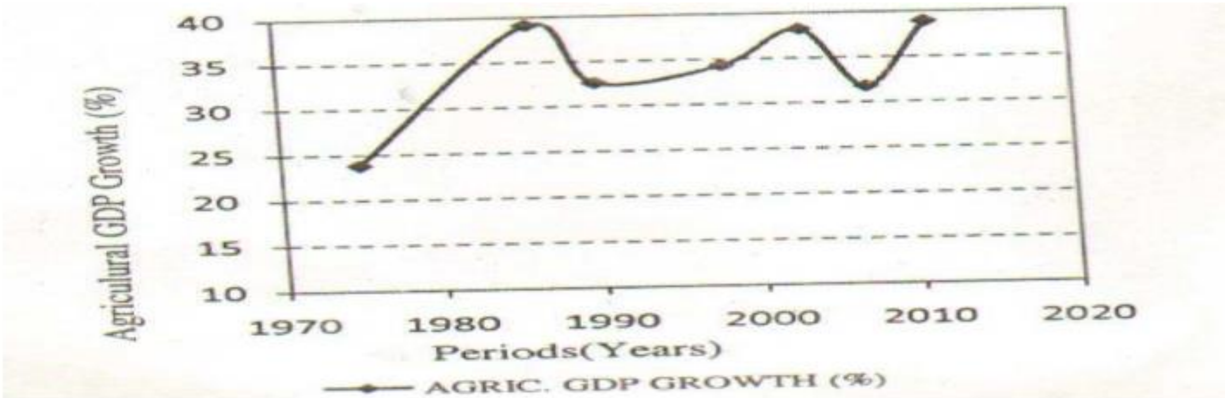

Figure 1: AGRICULTURAL GDP GROWTH TRENDS from 1970-2020

5.0 AGRICULTURAL EXPORT PROMOTION THROUGH POLICY IMPLEMENTATION AND INSTITUTIONAL SUPPORT

The food policy of Federal Government of Nigeria (FGN) has been hinged on the principle of self-sufficiency in all major staple food items. For this policy to generate the desired impact, food items should be readily available throughout the year, in quantity and quality, time and space and at competitive prices that are within the reach of her citizenry. This policy was almost a success until the 1970's when domestic food production witnessed a drastic downturn as a result of the shift from agriculture to oil exploration (CBN, 1997).

Achieving food security as a people is priority if we are to make the needed savings on massive food imports. This will ensure that funds are available for infrastructural development needed to boost the Nigerian economy. We however, need to look beyond this and aim to promote our agriculture to a level where we become a major exporter of food and agricultural raw materials. This is achievable because we were once there. The right combination of political will, appropriate and workable policies, as well as establishment and strengthening of relevant institutions will make this a reality. The mention of political will as the first in the right mix of ingredients of transforming Nigeria to an exporter of agricultural commodities is deliberate. It is a well-known fact that well-crafted policies and establishment of well-designed institutions have not been our major challenge as a people. Where we seemed to have missed it consistently is in the area of having the right political will of these laudable programs scale through. It is hoped that the present government led by President Muhammadu Buhari will provide the much needed political will to return Nigeria to the golden era where agriculture was the mainstay of the economy. With respects to formulating the right policies, the President has stated that, the goal of his administration is for Nigeria to attain self-sufficiency in food production and export over 10 million metric tonnes of grains and processed foods to the ECOWAS region and beyond 2020 during one of his commendation speech at the ECOWAS summit in 2015 (Nigerian Dailies, 2015). Policies need well established, well-funded, monitored and well-motivated institutions to drive and execute them. Existing Institutions such as Federal and State Ministries of Agriculture, Universities and other Research Institutes, Nigeria Export Promotion Council (NEPC), Nigerian Export-Import Bank (NEXIM), CBN, Anchored Borrowers Scheme, Bank of Industry (BOI), Bank of Agriculture (BOA), Marketing Boards, NIRSAL, ACGSF, National Quarantine Services, IFAD, IITA, ICRISAT, USAID and other agencies, need to be strengthened and given the needed support to carry out their statutory responsibilities. Other institutions may be established to cater for other areas not covered by these institutions.

The Agricultural Promotion Policy (APP: 2016-2020) strategy was evolved overtime to solve the core issues of limited food production and delivery of quality standards which was thrust on partnering of private-public investors across farmers groups and companies, to develop end to end value chain solutions that will improve supply of inputs as well as increase use of high yielding technologies, leading to improved distribution system of products and produce. Between 1999 and 2007; there was a policy focus on inclusion of 20% cassava flour in bakery and confectionary production in Nigeria, through cassava initiative programme of former President Obasanjo's administration. This was meant to reduce foreign earnings spent on wheat importation and at the same time stimulate local economy; regrettably, despite the huge or massive vision of the programs; failure was manifested in lack of preparation to take care of the gluts arising from massive cassava cultivation from the then Federal Government. We hope President Muhammad Buhari will look into this grey areas especially aftermath of Agricultural Promotion Policy (Green alternatives) syndrome.

6.0 CONCLUSION AND RECOMMENDATIONS

In other to meet the global competitiveness, there exist sustainable agricultural development in food production and productivity for rural households. Nigeria's agricultural potential is one of the highest that can be obtained on the planet. The over-reliance on food importation, oil and gas is greatly causing a setback to rural farmer's production and population as it risen poverty and job insecurity in Nigeria. Agriculture, which produces abundant food to its citizenry and exported excess food to other countries now imports a significant amount of food to sustain its rapidly growth and population. Having acknowledged that our main food challenge began with the discovery of the black gold (petroleum) in the late 1960s. The present reality where oil prices have nosedived requires that we return to our first love; Agriculture. Agricultural imports in the country has reached an all-time high in the year 2016 compared to when Nigeria's food imports bill rose to ₦ 6.6 trillion Naira (about three-quarter of the country's annual budget 6.06t). The paradox however, is that with these huge agricultural resources, by 2030, agriculture will be the new oil spinners as well as the way out to Nigeria myriads of problem.

The agricultural sector in Nigeria and other developing countries suffers extremely low productivity due to financial aids, unimproved seeds, agrochemicals, fertilizers, climate change and poor weather conditions, improved technologies, irrigation. The identified challenges were criminal neglect of the agricultural sector such as rapid population growth, urban-rural migration, neglect of extension providers, defective agricultural policies, and poor execution etc. The efforts of President Buhari has being yielding a number of positive results especially in agriculture and diversified economy.

The study further recommends among others the fiscal and monetary policies such as lower interest rate, import restriction on agricultural products and other agribusiness/agro-enterprises should be adopted by relevant authorities; alongside other measures which may improve local production content in other to meet both local and international demands thereby promoting agricultural export, employment opportunities, incorporation of private-public partnership, strengthening of micro-finance institutions, provision of more lands for agricultural production, industrial production, raising foreign exchange earnings which can translate to sustainable economic growth and thus lead the country out of recession.

A holistic approach must be taken to agricultural development through the formulation of appropriate policies supported by strong institutions. All stakeholders in the agricultural sector must brace up to this challenge. We can then reclaim our position of becoming the giant of Africa in agricultural production and export if we are all committed to it.

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Postharvest Loss in the Era of Population Explosion in Nigeria and Food Security Implications: The need for Postharvest Technologies

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Abstract

Nigeria is witnessing population explosion which is increasing at an alarming rate. The rate at which the population is growing (2.7%) is higher than the rate of agriculture growth (1.2%). The explosion in population is a primary threat to food security. However, the threat is worse due to losses farmers incur after harvest. Postharvest is mainly caused by poor produce handling and lack of storage facilities. The alarming rate of growth in the population coupled with the huge postharvest loss incurred by farmers have caused an enormous demand-supply gap in major crops produced in the country, which constitute the worse threats to food security of the Nigerian people. Therefore, government should put in place policies that would address the current population growth rate as well as encourage farmers' use of modern processing techniques such as threshing machine, winnowing machine, milling machine, mechanized dryer as well as modern storage techniques such as silos, improved warehouse, improved rhombus and ventilated cribs for improved postharvest handling and food secured nation.

Keywords: *Postharvest loss, population explosion, crop production, food security*

Introduction

Nigeria is the largest Black Country in the continent of the world. According to Worldometer (2018), the current population of **Nigeria** is estimated at **196.0 million people (Table 1).** In 2017, the total population in Nigeria was estimated at 191 million people while the population was estimated to be 186.0 million people in 2016 and 181 million people in 2015, compared to the population of the country which was estimated at 45.1 million people in the year of 1960. The population of Nigeria grew by 2.61 % in 2018 over the year 2017 figure, 2.63 % in 2017 over the year 2016 figure and 2.65 % in 2016 over the year 2015 figure. The population growth rate between 2015 and 2018 was 2.7 percent. The historical population figure of Nigeria and growth rate in the population between 1955 and 2018 is contained in Table 1.

Nigeria accounts for approximately 2.5 % of the world's total population. The country is ranked **7th** in the list of countries of the world based on population figure. The growth rate in the population of the country is alarming. The growth rate and population expansion of the country requires government efforts to fortify her agriculture sector in order to provide food for the teeming growing population.

Table 1: Population of Nigeria 1955-2018

Year	Population	% increase
2018	195,875,237	2.61
2017	190,886,311	2.63
2016	185,989,640	2.65
2015	181,181,744	2.70
2010	158,578,261	2.68
2005	138,939,478	2.58
2000	122,352,009	2.52
1995	108,011,465	2.54
1990	95,269,988	2.64
1985	83,613,300	2.62
1980	73,460,724	3.0
1975	63,373,572	2.51
1970	55,127,214	2.23
1965	50,127,214	2.12
1960	45,137,812	1.90
1955	41,085,563	1.65

Source: Worldometer (www.worldometers.info), Retrieved, 2018.

Apart from food production role, agriculture sector is still the major employer of labour in Nigeria. The sector employs over two-third of the country's population (Adeoti, 2002 and Peters, 2017). Though majority of the Nigeria population engage in agriculture but could not meet the food demand of the country. The scenario of food demand-supply gap is primarily traced to the characteristics of Nigerian agriculture such outdated land tenure system that constraints access to land, low level of irrigation development, low adoption of research findings and technologies, high cost of farm inputs, extreme low access to credit, inefficient fertilizer procurement and distribution, inadequate storage facilities and poor access to markets among others (FAO, 2018). Statistics show that the mean farm size in Nigeria is 1.8 ha/farming household) and less than 1 percent of cropped land is under irrigation (FAO, 2018). This has created enormous demand – supply gap in the country (Table 2).

Table 2: Demand-supply gap in Nigeria crop production

Crop	Supply (MT)	Demand (MT)	Demand- Supply gap (MT)
Yam	40,000,000	60,000,000	20,000,000
Cassava	42,000,000	53,800,000	11,800,000
Irish potato	900,000	8,000,000	7,100,000
Sweet potato	1,200,000	6,000,000	4,800,000
Wheat	400,000	4,000,000	3,600,000
Ginger	310,000	650,000	340,000
Rice	5,300,000	7,200,000	1,900,000
Maize	10,500,000	15,000,000	4,500,000
Local soybean	750,000	2,000,000	1,300,000
Beni seed	78,000	187,000	109,000
Sesame	200,000	600,000	400,000

Wheat	200,000	1,400,000	1,200,00
Castor	94,000	510,000	496,000
Tomato	2, 500,000	6,000,000	3,500,000
Sorghum	11,000,000	12,500,000	1,500,000

Source: Business Day (2017)

Table 2 shows the enormous demand-supply gap in the major crops consumed in the country that needs aggressive policy and program intervention to bridge the gap. From the table, the demand-supply gap for yam was 20MMT while the demand-supply gap were 11.8MMT, 7.1MMT, 4.8MMt and 4.5MMT for cassava, irish potato, sweet potato and maize, respectively (Federal Ministry of Agriculture Report, 2017). The enormous demand-supply gap poses great threat to food security status of the Nigerian people. The gap is not unconnected to the rising population which is increasing at an alarming rate, slow growth rate in food production and losses incurred in crop output after harvest (post-harvest). The Nigerian population is growing at an average rate of 2.6% and it will hit 300 million in 2050 (World Population Prospects, 2017) while food production is growing at a rate of 1.2% (FAO, 2018).

Postharvest Technologies utilization in Nigeria and Policy Need

Postharvest technologies are the remedies for the loss incurred after harvest. Traditional processing and storages techniques are still the most widely used ones in Nigeria, hence the incessant demand-supply gap witnessed in Nigeria. The use of modern postharvest handling techniques is still very low in Nigeria (Owolade, 2011; Elemasho *et al*., 2017). They added that poor information system negatively influenced postharvest technologies adoption while education is a positive determinant of postharvest technologies usage. Okoedo-Okojie and Onemolease (2009) showed that Nigerian yam farmers mainly used traditional methods of yam storage such yam ban, heaping and covering of yam tubers, bare floor/ground, raised platform and pits/holes dug in ground. They added that these techniques cause losses ranging from 20-30% during storage.

Atibioke *et al* (2012) stated that education is the major determinant of postharvest technologies adoption among grains farmers in Nigeria while Oparinde *et al* (2016) reported that cost of structure is the determinant of modern postharvest technologies adoption.

Policy of importance is needed to addressing poor utilization of modern postharvest technologies. Government and her agencies should put in place measures that would educate farmers on the needs of appropriate postharvest technologies as well as provide funding to smallholder farmers that would aid acquisition of modern processing and storage facilities.

Postharvest Losses in Nigeria

Postharvest loss is a great threat to agricultural development and food production in Nigeria. Postharvest loss encompasses the loss incurred across the food supply chain beginning from harvesting of crop through to consumption (Aulakh *et al*., 2013). Loss begins from harvest but occurs mainly during storage of crops due to inadequate and complete absence of needed infrastructure by farmers (Kumar and Kalita, 2017). There are two categories of losses during storage which are direct or physical loss and indirect or nutritional (quality) loss. Several factors are responsible for loss during storage. These factors are broadly classified into two, namely, biotic factors such as insect, rodents, fungi, and others, and abiotic (weather) factors such as temperature, humidity, rain etc (Abedin *et al*., 2012). Postharvest loss is more in developing countries due to complete absence or availability of processing and storage facilities in insufficient amount (Kumar and Kalita, 2017). The loss may be higher in Nigeria due to lack of investment in postharvest handling.

According to Elemo (2017), Nigeria's post-harvest losses have risen to over $9 billion annually. She stated that post-harvest losses in Nigeria are estimated to be about 50 per cent of food produced. According to her, the loss is more in fruits and vegetables due to their perishable nature. Peters (2017) showed that more than 51.3 metric tonnes of food are lost due to postharvest food losses for all the agricultural produce from the country. He added that the losses were much higher in rural communities because of inadequate presence of basic postharvest facilities and infrastructure. The estimated postharvest losses by crops were grains (15%), roots and tubers (35%), fruits and vegetable (50%) and livestock and fisheries (30%). These losses constitute great threats to food security of Nigeria people, poverty among farming households and the country's Gross Domestic Party (GDP).

Population Explosion, Postharvest Loss and Food Insecurity Implications

The global population is increasing in an alarming rate. The world population is estimated to hit 10 billion in 2050. To meet the food demand of this exploding population requires that food production be raised by about 70% (Hodges *et al*., 2011). It becomes a great challenge to the global community on how to meet the food demand of a rapidly growing population. This shows a red flag to the global food security. The story is not different in Nigeria as Nigeria population grows almost at the same rate as that of the global statistics. Nigeria population is expected to hit 300 million by 2050 (World Population Prospects, 2017), which further poses threats to food security among Nigerian people. The increase translates into 60 % more people's mouths to feed in the country. This implies that the current demand for food is expected to increase by more than half. With this figure, Nigeria is a great contributor to the expected 10 billion world population in 2050 and food threats.

Aside the challenge of population growth, food losses during postharvest period is another case that calls for urgent response. Postharvest loss ranges from 15-50% in major crops consumed. The loss is least (15%) in grains and highest (50%) in fruits and vegetables. The population factor and food losses figure pose red flag for the country's food security status. Elemo (2017) stated that there are approximately 12.9 million hungry Nigerians. She added that 37 per cent children under 5 are stunted, which is a function of nutritional insecurity or hidden hunger, 18 per cent children under 5 grossly malnourished, while 29 per cent children under 5 are underweight. However, just 35 per cent children within the age bracket 6-23 months consume iron in their diets, while 52 percent children within the age bracket 6-23 months are fed according to recommended infant feeding practice. The components of food security (food availability, accessibility and affordability) have been threatened by the incessant population growth and alarming food losses. It implies that the duo of population factor and postharvest loss constitute negative implications to food security of Nigerian people.

Postharvest Loss in Nigeria: The Needs for Modern Postharvest Technologies

The primary cause of incessant postharvest loss in Nigeria is the use of traditional processing and storage technologies among smallholder farmers (Abedin et al., 2012). Smallholder farmers account for majority of the farming population in Nigeria with characteristics ranging from use of crude tools and implement, poverty and small land holdings. Reducing postharvest losses in Nigeria farming system calls for the use of modern postharvest processing techniques such as threshing machine, winnowing machine, milling machine mechanized dryer and storage techniques such as the use of silos, improved warehouse, improved rhombus, ventilated cribs etc. Smallholder farmers should be encouraged to use modern postharvest technologies to reduce losses incurred after harvest. The encouragement should be backed up with government and development agencies' intervention through appropriate policies and programmes.

Conclusion

Population growth is a great threat to food security in terms of food availability, accessibility and affordability. The threat becomes worse in the face of incessant postharvest losses especially when a significant proportion of what is produced is lost after harvest. The demand-supply gap would be enormous while the available quantity would go for high price. This makes affordability difficult as ordinary people may not be able to afford food prices. Therefore, government should put measures in place that would make food available, accessible and affordable by increasing food production, improving distribution, and reducing the losses in produce through creating environment that would help farmers adopt modern postharvest processing and storage techniques as well as addressing population growth rate.

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Determination of Selected Engineering Properties of watermelon (*Citrullus lanatus*)

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ABSTRACT

Engineering properties of watermelon like any other biomaterial is a fundamental basis that facilitates the design and development of equipment. To this end, selected engineering properties of watermelon fruits and seeds were determined using standard methods. The physical properties which include the axial dimensions, mass, volume and angle of repose were measured directly on the sample and the others were determined using standard relationships. The mechanical properties were determined using the universal testing machine. The physical properties of the fruit showed that the length, arithmetic mean diameter, weight, surface area, volume and density of whole watermelon fruit were 169.3±4.7 mm, 555.7 ± 155.1 mm, 2.427 ± 0.213 kg, 43.24 ± 12.37 mm, 2369.60 ± 160.29 cm^3 and 1.03 ± 0.09 g/cm^3 respectively. The angle of repose of the fruit as determined on surfaces such as wood, glass, mild steel and stainless steel were 12±2.75^o, 9.70±3.86^o, 9.90±3.54^o, and 8.70±3.20^o respectively. The seeds length, width, thickness, sphericity and bulk density were 8.80±0.44 cm, 5.88±0.43 cm, 2.29±0.21 cm, 51-66% and 1.11-1.35 respectively. The compressive test showed maximum compressive stress and energy at break of 2.427±0.213 MPa and 0.08868 J respectively for the rind. The data provided in this study would serve as a database for further research in developing processing equipment for watermelon.

Keywords: Whole watermelon, watermelon seeds, physical properties, mechanical properties

1. Introduction

Watermelonis a warm-season fruit andisgrown worldwide, usuallyintheregions thathavealong warmgrowingseason (Snowdon, 1990). According to Simmonds (1976), watermelon(*Citrulluslunatus*)belongstothe familycucurbitaceousand isbelievedtohaveoriginatedfromthedry a r e a s ofSouthernAfrica.Theprincipaluseof watermelon is the consumptionofitscrisp, succulent,refreshingpulp asadessertor snack.

Watermelon contains about 6% sugar and 91% water by weight. As with many other fruits, it is a source of vitamin C. (Inuwa *et al.*, 2011). Watermelon rinds, usually a light green or white colour, are also edible and contain many hidden nutrients. They are sometimes used as a vegetable. Pickled watermelon rind is also commonly consumed in the Southern US (Rattray, 2012).

Alam *et al*. (2012) reported that watermelonhasathin,firmexternal rind,alayerofwhite-fleshed internal rindthatvaries inthickness,andaninterioredibleflesh while Anon (2008) stated that watermelon isrichinvitaminC,vitaminA,vitamin B,aminoacidandalsocarotenoid lycopene and that the red fleshofwatermeloncontainssomevitaminA.

The knowledge of engineering properties of watermelon like any other biomaterial is fundamental because it facilitates the design and development of equipment for harvesting, handling, conveying cleaning, delivering, separation, packing, storing, drying, mechanical oil extraction and processing of agricultural products, and hence their physical properties have to be known (Aviara *et al.,* 1999). Many equipment used in processing watermelon have been generally designed without taking into cognizance the physical and mechanical properties of watermelon which include the size, mass, bulk density, true density, sphericity, porosity, coefficient of static friction, angle of repose, compressive stress, modulus of elasticity, energy at break and compressive strain and the resultant systems leads to reduction in working efficiency and increased product losses (Manuwa and Afuye, 2004; Razari *et al.,* 2007). The engineering properties of some agricultural materials have been studied by several researchers such as soybean (Manuwa and A fuye, 2004), caper fruit (Sessiz *et al.*, 2005) cocoa bean (Bart-plange and Baryeh, 2003), pigeon pea (Shepherd and Bhardwaj, 1986), locust bean seed (Ogunjimi *et al.,* 2002) and pistachio nut and its kernel (Razari *et al.,* 2007).

Several authors have reported on properties of watermelon: juice/pulp (Johnson *et al.*, 2012), peel/rind and seed (Parmar and Kar, 2009; Lakshmi and Kaul, 2011; Fila *et al.*, 2013 and Gin *et al.*, 2014). Anthony (2015) reported Moisture-dependent physical properties of melon (*Citrullus colocynthis L.*) seed and kernel relevant in bulk handling.

Jha *et al.* (2004) investigated the physical and mechanical properties of mango fruit. The properties determined were: shape, sphericity, weight, width, breadth, length and moisture content. Koyenikan (2002) investigated the physical and mechanical properties of two varieties of ripe and unripe tomatoes. The moisture content, volume, size, shape, sphericity, weight, density, surface area, the coefficient of friction, compressive strength and Young's modulus of elasticity were measured. The objectives of this study, therefore, is to determine the physical and mechanical properties of watermelon necessary for the design of its processing equipment.

2. MATERIAL AND METHODS

Fresh Sugar Baby watermelon fruits were purchased from Oba market in Akure, Nigeria. In this experiment, the watermelon was used in two forms: the whole watermelon and the seeds. Other materials used include*clean water, thread, toluene, digital weighing balance, measuring cylinder, digital Venier caliper, micrometer screw gauge, kitchen knife, sliding box and* Instron Universal Testing Machine.

2.1 Determination of moisture content

The moisture content of the whole watermelon fruit and seeds was determined using the American Society of Agricultural Engineers (ASAE) standard method (ASAE, 1983). A weighed amount of the samples was dried in a hot-air oven at 105±2 ℃ and weighed at time interval until the bone dried weight was achieved. The moisture content was therefore calculated using the following relationship:

$$MC_{wb}\,(\%) = \frac{weight\ of\ moisture}{weight\ of\ wet\ product} \times 100 \qquad (1)$$

Where; MC_{wb} (%) = Moisture content (wet basis) %

2.2 Determination of geometric properties

2.2.1 Axial dimensions

To determine the size and shape of the whole watermelon fruit, the three linear dimensions of each material: major (L), intermediate (B) and minor diameter (T) was measured by a vernier caliper with reading accuracy of 0.01 mm while for the seeds, a micrometer screw gauge, was used to get the dimension of one hundred seeds which were randomly selected.

2.2.2 Arithmetic and geometric mean diameter

The arithmetic mean diameter, geometric mean diameter and sphericity of the watermelon seeds were calculated according to Galedar *et al*. (2008), Mohsenin (1980), Kiani-Deh-Kiani *et al.* (2008) and Shkelqim *et al.* (2010). The equivalent diameters of an agricultural material are usually expressed using the following equation proposed by Mohsenin (1986). The sphericity was calculated based on Koocheki *et al*. (2007), Erica *et al.* (2006); Garnayak *et al.* (2008); Davies and Zibokere (2011) and Milani (2007).

$$\text{Arithmetic Mean Diameter } (\mathrm{D_a}) = \frac{L+W+T}{3} \qquad (2)$$

$$\text{Geometric Mean Diameter } (\mathrm{D_g}) = (LWT)^{\frac{1}{3}} \qquad (3)$$

$$\text{Sphericity } (\emptyset) = \frac{(L\times B\times T)^{1/3}}{L} \qquad (4)$$

Where L is the major diameter (Length) in mm; B is intermediate diameter (Breadth) in mm and T is the minor diameter (Thickness) in mm.

2.2.3 Surface area and aspect ratio

The surface area was found by the following relationship reported by McCabe *et al*. (1986) and Jouki and Khazaei (2012)

$$\text{Surface Area } (S_\mathrm{a}) = \pi {D_g}^2 \qquad (5)$$

The aspect ratio (Ra) is another term used to express the shape of a material. It is calculated using the length (L) and the width (W) of the sample as reported by Oyelade, (2005). The aspect ratio was calculated by applying the following relationships given by Maduako and Faborode, (1990)

$$\text{Aspect Ratio } (\mathrm{R_a}) = \frac{L}{W} \qquad (6)$$

2.3 Gravimetric properties of watermelon fruit and seeds

The weight of the whole watermelon in ten replications and the melon seed in 100 replications was determined directly by using digital electric weighing balance. The unit volume of 100 individual watermelon seed was determined as cited by Galedar *et al*. (2008). The 1000-unit mass was determined using the precision electronic balance to an accuracy of 0.01g. To evaluate the 1000-unit mass, 100 randomly selected melon seeds were weighed and multiplied by 10. The reported value was a mean of 10 replications. The bulk seeds were put into a container with known mass and volume (500 ml) from a height of 150 mm and measured the bulk mass and density as reported by Ozarslan (2002); Sacilik *et al.* (2003); Ibrahim (2007); Garnayak *et al*. (2008) and Sharma *et al*. (2011).

2.3.1 Density of watermelon fruit and seed

The true density was estimated for whole watermelon fruit while the true and bulk density were estimated for watermelon seed using the ratio of weight to the volume.

$$\rho_t = \frac{m_t}{V_t} \quad (7)$$

$$\rho_b = \frac{m_b}{V_b} \quad (8)$$

Where ρ_t is the true density, ρ_b is the bulk density, m_t is the unit mass m_b is the bulk mass, v_t is the true volume and v_b is the bulk volume.

2.3.2 Porosity

The porosity of consolidated agricultural product can either be represented experimentally using the porosity tank techniques or theoretically from bulk and true densities of the material. The porosity of the bulk seed was computed from the values of the true density and bulk density of the seed by using the relationship reported by Mustafa (2007).

$$Porosity\ (\%) = (1 - \frac{\rho_b}{\rho_t}) x100 \quad (9)$$

2.4 Frictional properties

2.4.1 Static coefficient of friction

The static coefficient of friction of the watermelon whole fruit and seeds samples was determined against four different structural materials, namely, plywood, stainless steel, glass and galvanized steel. The watermelon fruit samples were placed on an adjustable tilting plate of the sliding box. The structural surface area of the watermelon sample resting on it was raised gradually with screwed device until the cylinder just start to slide down when the angle of tilt can be read in a compass used as a graduated weighing scale (Singh and Goswami, 1996; Suthar and Das, 1996; Dutta *et al.,* 1988). The static coefficient of friction (μ) was then calculated based on the equation:

$$\mu = \tan \alpha \quad (10)$$

Where$\mu$the coefficient of friction and α is the tilt angle in degrees.

2.4.2 Angle of repose

The angle of repose was determined using topless and bottomless cylinder of 0.15 m diameter and 0.25 m height. The cylinder was placed at the centre of a raised circular plate having a diameter of 0.35 m and was filled with watermelon seeds. The cylinder was raised slowly until it formed a cone on a circular plane. The filling angle of repose (θ_f) was calculated by the formula as given by Razavi *et al*. (2007):

$$\text{Angle of Repose } (\theta_f) = \tan\left[\frac{2H}{D}\right] \quad (11)$$

2.5 Some selected mechanical properties

The mechanical properties of the watermelon was carried out by selecting two different watermelons. The compression test analysis was carried out on the two samples each laterally, longitudinally, and transversely. The universal testing machine (Model No: 3344, Instron Incorporated, USA) with an accuracy of ± 0.2% was used for the compression test analysis.

2.5.1 Compressive strain (**Toughness)**

This is the strength of the watermelon to uphold sudden loading or to absorbing energy before it breaks. The toughness was measured in terms of modulus of toughness.

2.5.2 Young modulus

This is the measure of the stiffness and rigidity of watermelon. It determines how easily the watermelon sample was deformed.

2.5.3 Tensile strength

The tensile strength of selected watermelon fruit was determined using a recording tension force gauge using the universal testing machine. One sample was placed between the two ends of the measuring instrument and the reading was immediately taken as displayed by the digital force gauge. The process was repeated for another sample laterally, transversely and longitudinally respectively to be able to compare results obtained.

2.5.4 Energy at yield point

The energy at yield was obtained with the hardness tester. The upper, middle and lower parts of the instrument were used at different times for longitudinally, laterally and transversely for two watermelon samples. The slots were screwed to a different end on each experiment. The first sound made by each sample at each time of the experiment indicates the energy at yield.

2.3.5 Energy at the breaking point

The Instron universal materials testing machine was used to obtain the energy at break of the material. The slots were screwed to compress the sample placed between them. The reading was taken immediately the material was broken.

3. RESULTS AND DISCUSSION

3.1 Moisture Content of Watermelon

The initial moisture content of watermelon seed, rind and pulp were 25.68±0.51, 77.51±0.05 and 90.03±0.25 respectively.T**he various physical and mechanical properties of each part of the watermelon were determined at the above stated initial moisture contents. The moisture contents obtained in this research are not far from the ones reported by** Inuwa *et al*. (2011), United States Department of Agriculture (USDA, 2010), Arocho *et al*. (2012), Shofian *et al.* (2011) and Yau *et al*. (2010) for watermelon seeds and rinds.

3.2 **Physical Properties of Watermelon fruit**

The Table 1 and 2 shows the summary of the results obtained for the physical properties of watermelon whole fruit and seed respectively.

The length, width and thickness dimensions of the whole watermelon fruits were 16.93±0.47 cm, 75.17±36.59 cm and 84.60±14.71 cm respectively. The mass of the fruit was also observed to be 2.43±0.21 kg while the volume as determined by water displacement method was 2369±160 cm^3. Other values got were the density of the fruit (1030±90 kg/m^3), sphericity (2.52±0.7%), the arithmetic and geometric diameters (55.57±15.51 cm and 43.24±12.37 cm respectively). The angle of repose as determined on four different surfaces such as wood, glass, mild steel and stainless steel showed values ranging from 12±2.75º, 9.70±3.86º, 9.90±3.54º and 8.70±3.20º respectively.

These values are similar to the findings of Eliwa and Elfatih (2012), which reported that height, diameter, mass; volume and density of watermelon fruit were 151 mm, 115 mm, 1820 g, 1790 cm^3 and 1.03 g/cm^3.

Table 1: Physical properties of watermelon whole fruits

Physical Properties	Average	Min	Max	Sd
Length (cm)	16.93	16.30	17.90	0.47
Width (cm)	65.17	13.78	96.76	36.59
Thickness (cm)	84.60	45.02	98.01	14.71
Sphericity (%)	2.54	1.35	3.20	0.70
Mass (g)	2427.10	2044.00	2713.00	212.51
Volume (cm^3)	2369.60	2035.00	2550.00	160.29
Arith mean diameter (cm)	55.57	25.57	70.44	15.51
Geo. mean diameter (cm)	43.24	22.36	54.03	12.37
Surface area (cm^2)	6307.65	1570.47	9173.82	3008.98
Aspect Ratio	0.47	0.17	1.18	0.44
Density (g/cm^3)	1.03	0.95	1.26	0.09
Angle of Repose				
Wood	12.00	10.00	19.00	2.75
glass	9.70	5.00	17.00	3.86
Mild steel	9.90	5.00	17.00	3.54
Stainless steel	8.70	5.00	16.00	3.20

3.3 Physical properties of watermelon seed

For the watermelon seeds, the length, width and thickness dimensions were 8.80±0.44mm, 5.88±0.43 mm and 2.29±0.21 mm respectively. Also determined were the arithmetic and geometric mean diameters (5.66±0.26 cm and 4.90±0.25 cm respectively), sphericity (0.56±0.02%) and the surface area (75.78±7.49). The mass of 1000 seed mass was 116.67±1.53 g, the bulk volume was 95±10 cm^3 and the bulk density was 1.24±0.12 g/cm^3 while the unit density was 0.00124±0.00012 g/cm^3. However, Eliwa and Elfatih, (2012) reported the length, width and thickness of watermelon seeds as 13.70, 8.19, 2.99 mm respectively which is also similar to the one reported in this study. The difference in the dimensions of the seeds could be due to the difference in the variety, method of cultivation, soil type and geographical area of cultivation.

Table 2: Physical properties of watermelon seeds

Physical Properties	Average	Min	Max	SD
Length(mm)	8.80	6.26	9.56	0.44
Breadth (mm)	5.88	3.13	6.68	0.43
Thickness (mm)	2.29	1.80	3.05	0.21
Arithmetic mean (mm)	5.66	3.90	6.04	0.26
Geometric Mean (mm)	4.90	3.56	5.46	0.25
Sphericity (%)	0.56	0.51	0.66	0.02

Surface Area (mm^2)	75.78	39.79	93.77	7.49
Aspect Ratio	1.50	1.29	2.00	0.11
Mass of 1000 seeds (g)	116.67	115.00	118.00	1.53
Bulk Volume (cm^3)	95.00	85.00	105.00	10.00
Bulk Density (ρ)	1.24	1.11	1.35	0.12
Unit Density	0.00124	0.00111	0.00135	0.00012

3.4 Mechanical Properties of Watermelon

3.4.1 Tensile properties

Table 3 shows the results of tension test on watermelon fruit. The maximum tensile stress was observed to be 0.815 MPa while the energy at maximum tensile stress was 0.065 J for watermelon rind with thickness 3.91 mm. Also, the load required to yield was 46.225 Figure 1 shows the graph of tensile stress-strain plot of the watermelon.

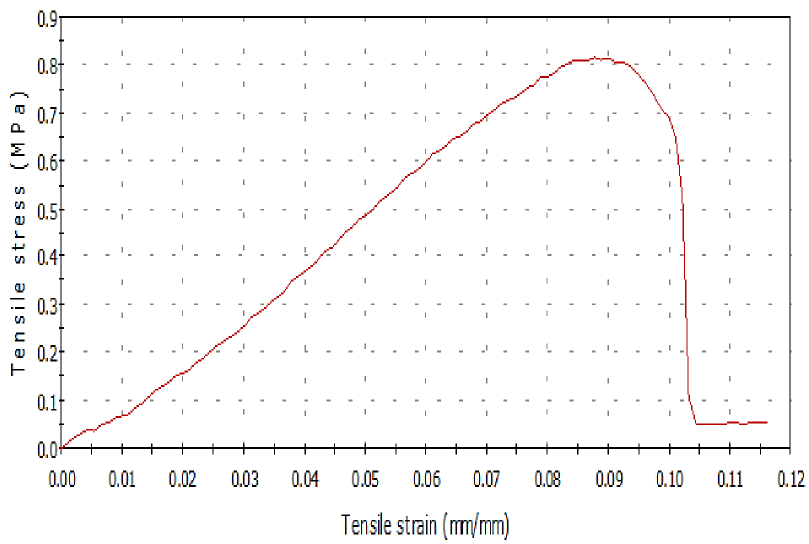

Figure 1: Tensile stress-strain plot for watermelon

Table 3: Tension test on watermelon

Properties	
Maximum Tensile stress (MPa)	0.815
Load at Maximum Tensile stress (N)	46.22
Energy at Maximum Tensile stress (J)	0.065
Tensile stress at Break (Standard) (MPa)	0.053
Energy at Break (Standard) (J)	0.082
Tensile stress at Yield (Zero Slope) (MPa)	0.815
Load at Yield (Zero Slope) (N)	46.225
Modulus (E-modulus) (MPa)	-----

3.4.2 Compressive properties

The maximum compressive stress, the energy at maximum compressive stress, and the compressive load at maximum compressive stress were 0.0593 MPa, 0.0828 J, and 23.7360 N respectively. From the test also, the load at maximum compressive and energy at break were 23.736 N and 0.0887 J (Table 4). Figure 2 shows the graph of compressive stress-strain of the watermelon

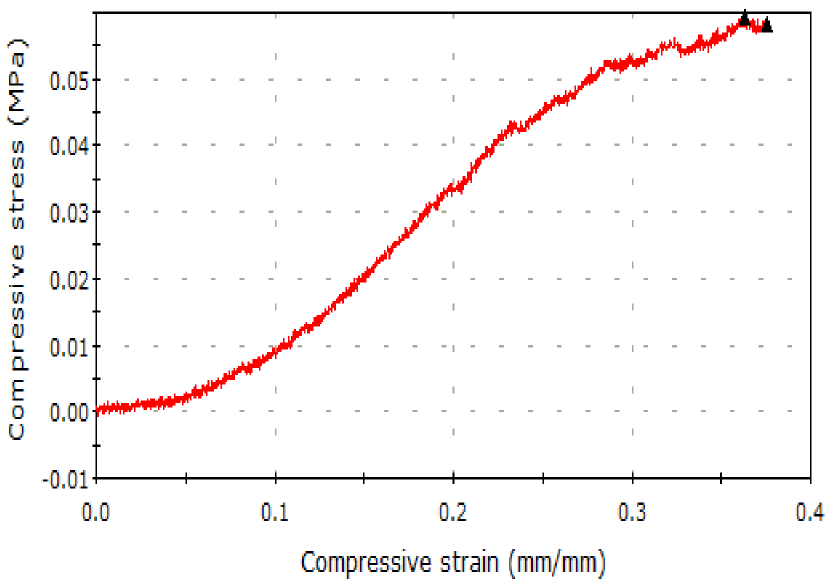

Figure 2: Graphical represent of compressive stress-strain of the watermelon fruit

Table 4: Compressive properties of watermelon fruit

Compressive properties	
Maximum Compressive stress (MPa)	0.05934
Compressive strain at Maximum Compressive stress (mm/mm)	0.36334
Energy at Maximum Compressive stress (J)	0.08282
Compressive load at Maximum Compressive stress (N)	23.73603
Compressive stress at Break (Standard) (MPa)	0.05833
Compressive load at Break (Standard) (N)	23.33385
Compressive strain at Break (Standard) (mm/mm)	0.37598
Load at Maximum Compressive stress (N)	-23.736
Extension at Maximum Compressive stress (mm)	-7.26675
Compressive extension at Break (Standard) (mm)	7.51962
Energy at Break (Standard) (J)	0.08868

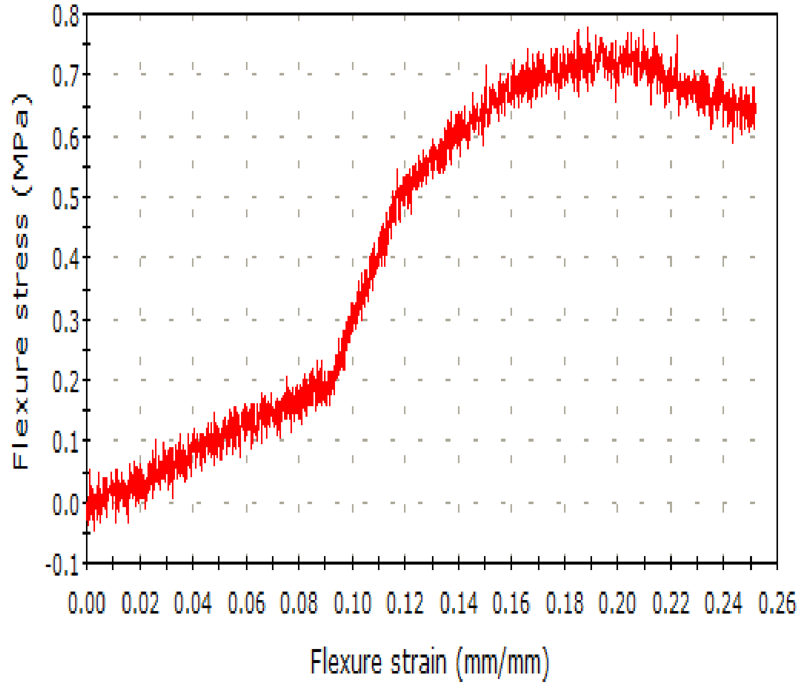

Figure 3: Flexural stress-strain plot of watermelon rind

3.4.3 Flexural properties

In the flexural analysis, a 3-point flexure test was carried out on the watermelon rind of thickness 5.15 mm (Table 5); the maximum flexure stress was 0.7756 MPa while energy at break was 0.1205 J. The flexure stress at yield was 0.7756 and the flexure load at break and at yield were 0.6425 N each. Energy at yield was also observed to be 0.0713 J. Figure 3 shows the stress-strain behaviour of watermelon rind under flexural load.

Table 5: Flexural properties of watermelon rind

Flexural properties	
Fixture type	3-point
Maximum Flexure stress (MPa)	0.77564
Load at Maximum Flexure stress (N)	-6.42475
Flexure strain at Maximum Flexure stress (mm/mm)	0.18869
Flexure stress at Break (Standard) (MPa)	0.68094
Flexure strain at Break (Standard) (mm/mm)	0.25159
Energy at Break (Standard) (J)	0.12048
Flexure stress at Yield (Zero Slope) (MPa)	0.77564
Flexure load at Yield (Zero Slope) (N)	6.42475
Energy at Yield (Zero Slope) (J)	0.07129
Modulus (E-modulus) (MPa)	-----

4. Conclusion

Selected engineering properties of watermelon (fruit and seed) have been studied. The physical properties of the seeds showed that length, width, thickness, sphericity and bulk density of the seeds ranged from 6.26-9.56 mm, 3.13-6.68 mm, 1.80-3.05 mm, 51-66 % and 1.11-1.35 g/cm^3 respectively. For the whole fruit, the length, the arithmetic mean diameter, the weight, surface area, volume and density were 169.3±4.7 mm, 555.7±155.1 mm, 2.427 ±0.213 kg, 43.24±12.37 mm, 2369.60±160.29 cm^3 and 1.03±0.09 g/cm^3. After been subjected to compressive test in a universal testing machine, the rind was observed to have a maximum compressive stress and energy at break of 2.427±0.213 MPa and 0.08868 J respectively.

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RESPIRATION RATE AND PHYSIOLOGICAL LOSS IN STORED ONION (*Allium cepa*) AS AFFECTED BY TEMPERATURE AND RELATIVE HUMIDITY

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ABSTRACT

The study was conducted to evaluate the respiration rate and physiological loss of stored onion bulbs under controlled laboratory storage temperature of 14^{o}C±2^{o}C, 27^{o}C±2^{o}C and 34^{o}C±2^{o}C and relative humidity of 64%±1, 75%±1 and 80%±1. At the storage intervals of 14, 28 and 42 days, the results showed that gas composition (O_2 and CO_2) and physiological loss of onion bulbs in the storage chambers were significantly affected by temperature and relative humidity of the storage chambers. The highest and lowest O_2 compositions of 19.5% and 11.4% were recorded in the chambers maintained at the temperatures of 34^{o}C and 14^{o}C at 63.7% and 80.3% relative humidity, respectively. While the highest and lowest composition of 0.16% and 0.04% CO_2 were obtained at the temperatures of 34oC and 14oC relative humidity of 63.7% and 80.3%, The highest and lowest percent weight loss of 22.19% and 1.56% and scale-drying of 12.56% and 1.26% were obtained in storage chambers maintained at the temperature of 34^{o}C and 14^{o}C and relative humidity 63.7% and 80.3%, respectively. The lowest percent bulb sprouting and rooting of 0.31% and 0.63% were observed in chambers maintained at 34^{o}C and 63.7%. The lowest percent bulb rotting of 0.94% was obtained in the storage chambers maintained at 63.7% and 14^{o}C.

Keywords: *Onion storage; Controlled atmospheres: Physiological behaviour; Ambient conditions*

1.0 INTRODUCTION

Onion (*Allium cepa* L.) is one of the oldest and most important bulb vegetable crops known to mankind and grown in many tropical countries (Sristava, 1993). Valued for its pungent flavour, nutritional and medicinal properties, bulb onion, either as green leaves, mature or immature bulbs, is not only popular for culinary purpose, but also rich in minerals such as potassium, phosphorous, sodium and calcium (Marwat *et al*., 2011; Sohany *et al*., 2016). Onion is a perishable crop with high moisture content at harvest; hence it cannot be stored for long periods (Sentana, 1998; Ojha and Michael, 2006). Two major advantages of onion storage are to provide the best conditions to regulate physiological and metabolic activities in stored onion bulbs and to ensure availability during off-season as many cultivars do not keep long in ambient storage condition after harvest (NABARD, 2011; Enderlew *et al*., 2014; Sharma and Lee, 2015). Natural ventilated storage at 25-30^{o}C temperature and 65-70% relative humidity has been found quite satisfactory for onion storage in the tropics (Endalew *et al*., 2014). This environment reduces the storage losses due to physiological weight loss, sprouting and rotting.

Nigeria ranks among the world onion producing countries and is the leading producing country in sub Saharan Africa, but the supply of the commodity to the local market does not meet the increasing national demand. This is consequent to poor post-harvest management with improper storage technique which results in about 50-76% post-harvest loss (Denton and Ojeifo, 1990), poor quality and ultimate acute shortage of the product and annual fluctuation in market price (Gulma, 2012). High respiration with heat generation greatly enhances sprouting of onion bulbs during storage, causes moisture loss and reduces its shelf-life (Trevisan *et al.*, 1999; Petropoulos *et al.*, 2017).

Decrease in temperature results in decrease in O_2 composition in a storage environment as well as the respiration rate of the stored materials (Willson *et al.*, 1998; Kader, 2002).The rate of respiration in biological materials is twice in every 10^{o}C temperature rise over a range of 5 - 25^{o}C and can be expressed as Q10= 2 (Diop, 1998; Silva, 2015). Respiration in stored materials increases rapidly to a maximum at the intermediate temperature of 10-15^{o}C, drops progressively at high temperatures of 25-30^{o}C and rises up again at the temperature of above 35^{o}C (Jamali *et al*., 2012).

Physiological changes which occur during post-harvest handling of onion are basically heat and moisture production which usually result in weight loss, sprouting, rooting, rotting and scale-drying, (Benkeblia, 2003).External factors affecting transpiration rates are temperature, relative humidity, air velocity and atmospheric pressure. At higher temperature weight loss is mainly due to desiccation. High temperatures, low relative humidity and high air velocity increase transpiration rates of stored onion bulbs, leading to high percent bulb weight loss and scale-drying (CIGR, 1999).Sprouting and rooting are the major limiting factors of the storage life of bulb onion (Baninasab and Rahemi, 2006; Sharma *et al.*, 2015).After harvest, bulb dormancy period varies with cultivar and storage temperature (Chope *et al.*, 2006).Dormancy in onion bulbs naturally terminates as soon as the inner sprout growth commences. But at this stage, the commercial storage life and market value of the bulbs are not affected unless there is a visible sprout or root growth, with the roots appearing first before the sprouts (Chope *et al.*, 2006; Ilic *et al*., 2009).Removal of roots inhibited the induction of cytokinine (Miedema 1994). Exposure of onion bulbs continuously above 25ºC has been found to successfully inhibit the induction of cytokinine as well as inhibiting sprouting (Miedema and Kamminga 1994).Generally, onion bulbs remain naturally dormant at low (0-5^{o}C) and high (25-30^{o}C) temperatures, while sprouting is favoured at intermediate (10-20^{o}C) temperatures with associated relative humidity of 65-85% (Ilic *et al*., 2009; Rawat and Ansari, 2010; Singh, 2012). High percent bulb rotting of stored onion is attributed to high (>35^{o}C) temperature and associated high (>80%) relative humidity (Ramin, 1999).

The objective of this study was to evaluate the effect storage temperature and relative humidity onrespiration rate and physiological loss in stored onion.

2.0 MATERIALS AND METHODS

2.1 Sampling Technique

Bulk sample of harvested and cured bulbs *Kano-red* onion obtained from a local market was used for the study. The bulbs were cleaned, sorted and hand-graded for uniformity and medium sized (4-6cm dia) bulbs were selected for the storage experiment. The study was conducted in the Crop Processing and Storage Laboratory of Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Nigeria.

2.2 Experimental Procedure

Three galvanized aluminum cabinets (A, B and C), each with three storage chambers of dimensions 400 x 400 x 400mm^3(Figure1) were used for the laboratory storage. Partitioning the chambers into upper and lower compartments, a wire mesh- knitted thatch was used to demarcate the compartments. The 3 cabinets were maintained at14^{o}C±2^{o}C, 27^{o}C±2^{o}C and 34^{o}C±2^{o}C, while the 9 storage chambers were interchangeably controlled at 64%RH±1, 75%RH±1 and 80%RH±1, using saturated salt solutions of sodium chloride (NaCl), sodium nitrite ($NaNO_2$) and ammonium sulphate [$(NH_4)_2SO_4$], respectively. Plastic containers with the saturated salt solutions were placed in the lower compartments while 3kg weight of onion (38bulbs) was loaded on the upper compartments of the chambers. Fume or vapour of soluble salt was allowed to circulate around the stored bulbs to generate and control the predictable relative humidity in the chambers.

2.3 Storage Behaviour

A battery-powered digital temperature/relative humidity sensor (Thermo Hygro-Clock, model TA218/B) was used to monitor each chamber daily. Gas (O_2andCO_2) composition in the chambers was monitored, using a gas analyzer (RASI 700 model), after every 7days. Physiological loss parameters namely weight loss (WL), bulb sprouting (BS), bulb rotting (BRtt), bulb rooting (BRt) and bulb scale-drying (BScD), were monitored after 14, 28 and 42days of storage. Percent loss due to each physiological loss parameter was determined as adopted by Kukanoor (2005), Jamali *et al*. (2012) and Bedada (2014).

2.3.1 Per cent Weight Loss

The percent weight loss of the stored bulbs was determined based on the cumulative sample weights after 14, 28 and 42days of storage and the initial weight of sample before storage, expressed as follows.

$$WL\ (\%) = \left[\frac{Wi - W1 - W2 - W3}{Wi}\right] \times 100 \qquad (1)$$

Where, WL (%) = percent weight loss, Wi = initial weight of bulb sample before storage, W1, W2 and W3 = final weight of bulb sample after 14, 28 and 42days of storage, respectively.

2.3.2 Percent Bulb Sprouting

The cumulative number of sprouted bulbs after 14, 28 and 42daysof storage and initial number of sample bulbs before storage were computed to estimate the percent bulb sprouting of the stored onion bulbs.

BS (%) = $[\frac{N1+N2+N3}{Ni}]$ x 100 (2)

2.3.3 **Per cent Bulb Rotting**

The number of rotten bulbs after recorded each storage interval were counted and discarded to avoid double counting. The cumulative number of rotten bulbs was used to estimate the percent bulb rotting as in the expression below.

BRtt (%) = $[\frac{N1+N2+N3}{Ni}]$ x 100 (3)

2.3.4 Per cent Bulb Rooting

The cumulative number of rooted bulbs after 14, 28 and 42days of storage and initial number of sample bulbs before storage were computed to estimate the percent bulb rooting of the stored onion bulbs.

BRt (%) = $[\frac{N1+N2+N3}{Ni}]$ x 100 (4)

Where in Equations 2,3 and4, Ni = initial number of onion bulbs in a chamber before storage and N1, N2 and N3 = number of sprouted, rotten or rooted bulbs recorded after 14, 28 and 42 days of storage, respectively.

2.3.5 Per cent Bulb Scale-Drying

Randomly selected number of onion bulbs before storage were transversely sliced and the number of fresh scales counted andrecorded.After14, 28 and 42 days of storage, same number of bulbs were randomly selected, transversely sliced and the number of dried scales recorded. The percent bulb scale-drying was determined as follows.

BScD (%) = $[\frac{\text{Ndsc1 + Ndsc2+Ndsc3}}{\text{Nfsc}}]$ x 100 (5)

Where, Nfsc. = average number fresh scales per bulb before storage and Ndsc1, Ndsc2 and Ndsc3 =average number of dried scales per bulb after 14, 28 and 42days of storage.

3.0 RESULTS AND DISCUSSION

Effect of temperature and relative humidity on gas composition (O_2 and CO_2) and physiological losses of onion is given in Figures 1-2 and 3-7, respectively.

3.1 Gas Composition in Storage Chambers

Figure1 and 2 showed that temperature and relative humidity greatly influenced$O_2$and CO_2 compositions in the storage chambers.

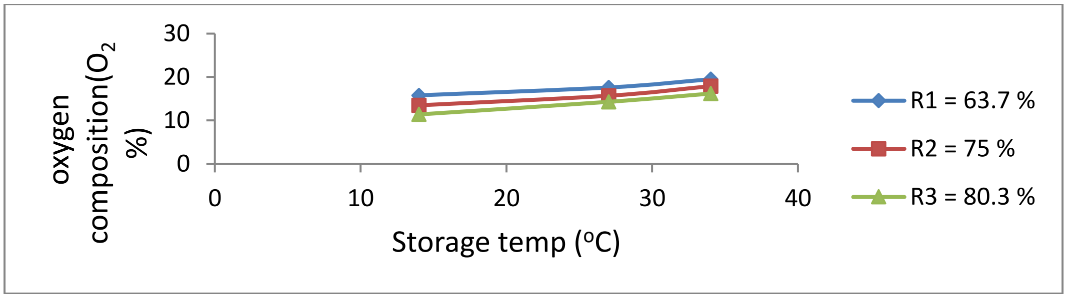

Figure 1: Percent oxygen (O_2) composition in storage chambers

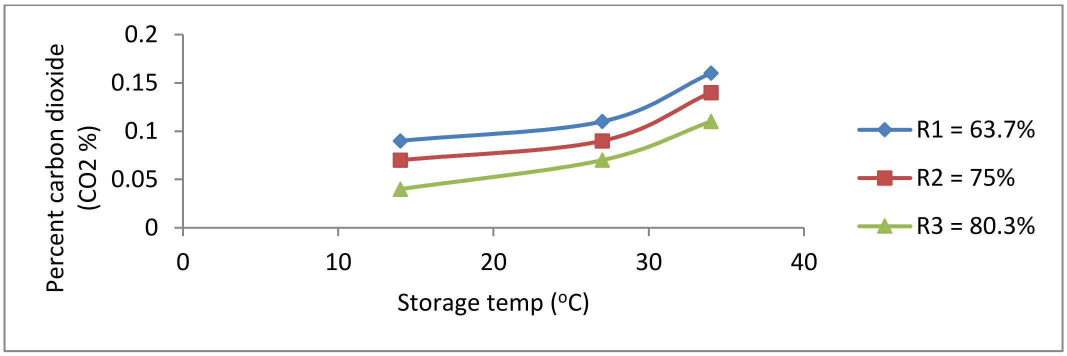

Figure 2: Percent carbon dioxide (CO_2) composition in storage chambers

In Table1, the highest and lowest O_2 compositions of 19.5%and 11.4% were recorded in storage chambers controlled at 34°C ; 63.7% RH and 14°C; 80.3% RH, respectively. Whereas in Table2, the highest and lowest CO2 compositions of0.16% and 0.04% were obtained in storage chambers maintained at 34°C; 63.7%R and 14°C; 80.3%RH, respectively. The results suggest that at high storage temperature and intermediate humidity, $O_2$and CO_2compositions are high and low at intermediate temperature and high relative humidity. These results agree with Kader (2002), Mahajan *et al*. (2014) and Silva (2015) that respiration rate is temperature dependent; hence increase in storage temperature leads to decrease in O_2 and increase in CO_2 compositions in storage environments.

3.2 Physiological Losses of Onion Bulbs in Storage Chambers

The results of effect of temperature and relative humidity on physiological losses of stored onion due weight loss (WL), bulb sprouting (BS), bulb rotting (BRtt), bulb rooting (BRt) and bulb scale-drying (BScD) are presented in Figures 3-7. The results showed that the investigated physiological loss parameters were significantly influenced by temperature and relative humidity of the storage chambers.

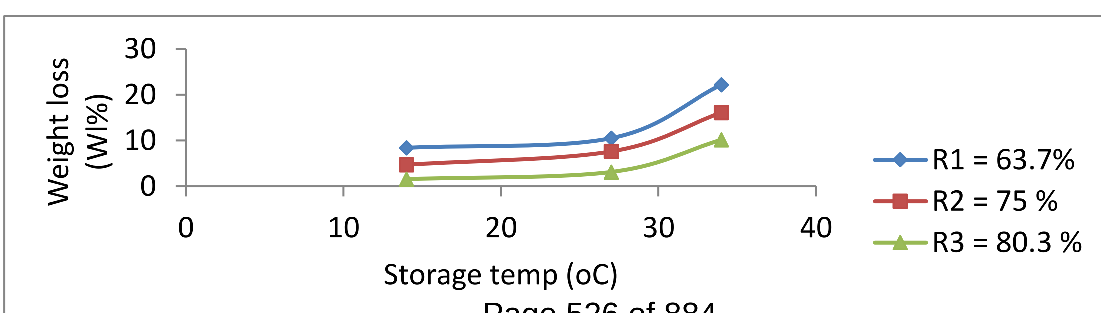

Figure 3: Percent weight loss of onion bulbs in storage chambers

The result in Figure 3 shows that the highest percent weight loss of 22.19% was observed in the storage chamber maintained at a high temperature of 34°C and intermediate humidity of 63.7%. The lowest percent weight loss of 1.56% was however obtained in the storage chamber maintained at the intermediate temperature of 14°C and high relative humidity of 80.3%. The results depict that at low storage temperature and high relative humidity, physiological weight loss is minimized. This result corroborates the reports by Maini and Chakrabarti (2000) that storage of onion at high (25-30°C and 30-35°C) temperature and low (<60) air relative humidity resulted in a larger proportion of losses due majorly to weight loss compared to rotting and sprouting. Moisture loss in stored onion bulbs depends on the difference between the water vapour pressure within the bulbs and the water vapour of the surrounding air (Connolly-Boutin (2007).

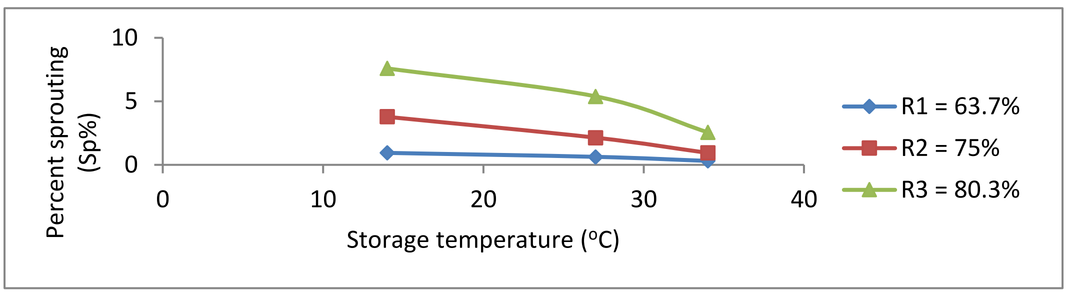

Figure 4: Percent bulb sprouting of onion in storage chambers

Figure 4shows that the storage chambers maintained at 34oC and 63.7% RH recorded the lowest percent bulb sprouting of 0.31%. The highest percent bulb sprouting of 7.59% was however obtained in the storage chambers maintained at temperature of 14°C and relative humidity of 80.3%. The result suggests that increase in storage temperature with decrease in the relative humidity minimizes bulb sprouting in stored onion. This result conforms to the reports that sprouting of stored onion is favoured at intermediate temperatures of 9─20°C with associated high relative humidity of above 75% (Rawat and Ansari, 2010; Singh, 2012).

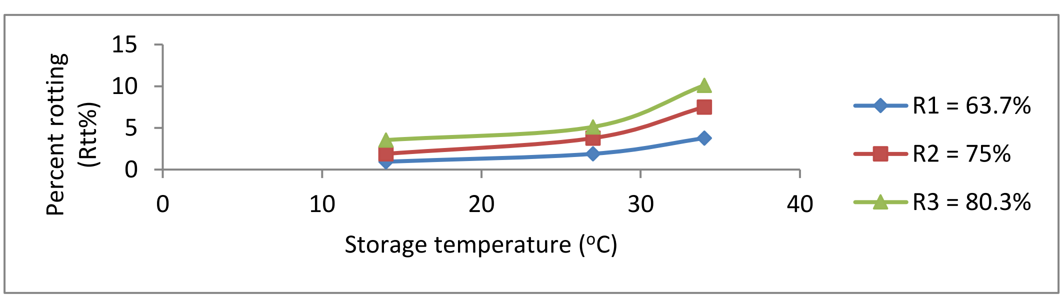

Figure 5: Percent bulb rotting of onion in storage chambers

In Figure 5the result shows that the lowest and the highest percent bulb rotting of 0.94% was obtained in a storage chamber maintained 14°C and 63.7% RH, while the highest percent bulb rotting of 10.11% was recorded in a storage chamber maintained at the temperature of 34°C and 80.3% RH. This result depicts that high storage temperature (> 34°C) and relative humidity (>80%) aggravate bulb rotting in stored onion (Currah and Proctor, 1990; Maini and Chakrabarti, 2000). This confirms the report that increase in O_2 concentrations around and within a stored commodity results in higher levels of free radicals which can damage plant tissues, leading to product decay or rotting loss (Kitinoja and Kader, 2004).

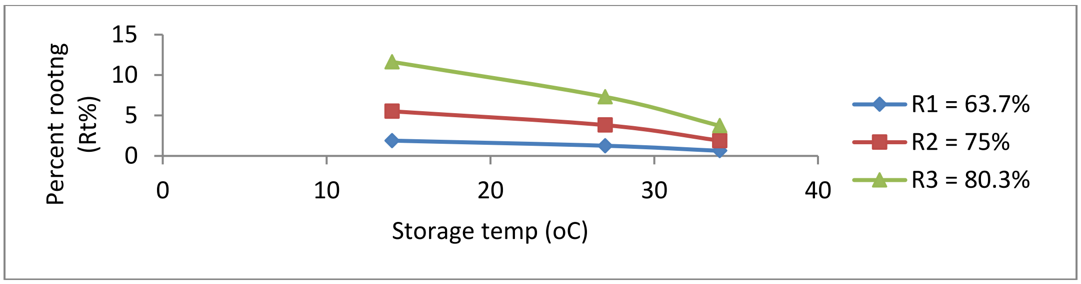

Figure 6: Percent bulb rooting of onion in storage chambers

Figure 6 showed that onion bulbs stored in the chamber controlled at 34°C and 63.7%RH recorded the lowest percent bulb rooting of 0.63%. The highest percent bulb rooting of 11.63% was observed in a storage chamber maintained at 14°C and 80.3%RH. The result suggests that bulb rooting in stored onion is favoured at intermediate temperatures and high relative humidity. This agrees with Currah and Proctor (1990) and CIGR (1999) that onion bulb rooting is favoured at temperatures in the range of 10- 20°C and high relative humidity of above 80%.

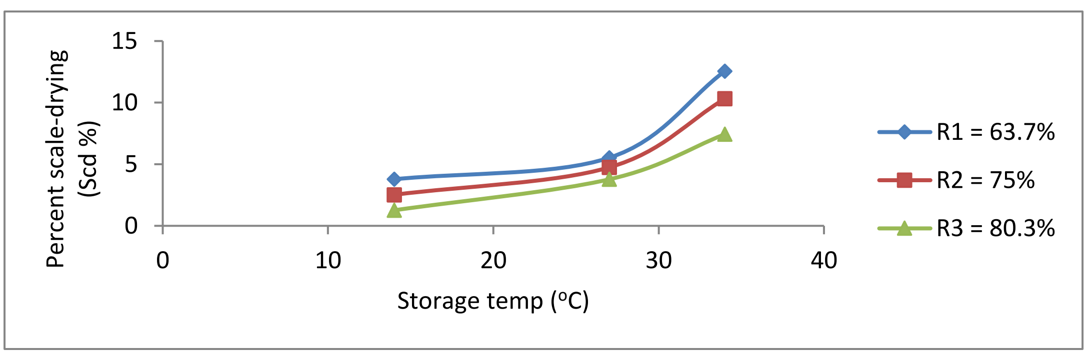

Figure 7: Percent scale-drying of bulb onion in storage chambers

In Figure 7the result shows that the highest percent bulb scale-drying of 12.56% was recorded in a storage chamber controlled at 34°C and 63.7%RH. The lowest percent scale-drying of 1.26% was observed in a chamber maintained at 14°C and 80.3% RH. The result depicts that Increase in temperature with decrease in relative humidity resulted in increase in scale-drying of the stored onion. According to Futos (2012) Scale-drying losses increase rapidly when the humidity of the storage environment is controlled at below 60 % RH and high temperature (>30°C).

4.0 CONCLUSIONS

Based on the results of this study, the following conclusions are drawn:

i. Temperature and relative humidity level of each storage chamber significantly influenced the rate of respiration of the stored onion bulbs and their physiological behaviour.

iii. Increase in temperature in storage chambers resulted in decrease in O_2 composition as O_2 uptake of the stored bulbs increased with increased CO_2 composition.

iv. Increase in temperature (>30°C) with low relative humidity (<60%) minimized percent weight loss and scale-drying of the stored onion bulbs, while increase in temperature (>30°C) with high relative humidity (<75%) increased percent bulb rotting of the stored onion.

v. Decrease in temperature (< 14) with high relative humidity (> 75%) increased the percent bulb sprouting and rooting of the stored onion.

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Plate1: Three cabinets of galvanized aluminium sheets for laboratory storage of onion bulbs.

PAPER: NIAE/ EKO/ D020

Physico-chemical Properties of Yellow Oleander (*Thevetia peruviana*) and their effect on the Qualities of Biodiesel

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ABSTRACT

This study investigates the effects of physico-chemical properties of Thevetia peruviana on quality of biodiesel. The seeds were processed and extraction of oil was done using solvent extraction method, hence the biodiesel was produced from the extracted oil using trans esterification process. The physical and chemical properties of Thevetia peruviana biodiesel were determined using theASTM standard test procedures. The biodiesel contains little sulphur and has exhibited a higher cetane number of 55 that exceeds the minimum limits of 47 and 51 prescribed in EN 14214 and EN 590 respectively, which is a good indication of fuel's ignition and combustion quality. The kinematic viscosity of the biodiesel at 40°C was 4.81 mm^2/s, which is within the range specified by EN 14214. The density at 15°C was found to be 0.89g/cm^3 which is well within the range specified by EN 14214. It is prescribed in ASTM D6751 and EN 14214 that the maximum limit of acid value for biodiesel should not exceed 0.50 mg of KOH/g and 0.16 mg of KOH/g was obtained. The calorific value of the biodiesel produced from Yellow oleander seed oil was found to be 40.42 kJ/g which indicates good fuel properties(such as density, ignition quality, viscosity, cetane number, heating value and flash point). The carbon residue of the biodiesel was 0.14 mass%. The quality of the biodiesel produced was conformed to standards set for biodiesel standard EN14214 and petroleum diesel standard EN590.

Keywords: *Biodiesel, Thevetia peruviana, Energy, physical, chemical properties*

1 INTRODUCTION

Due to rapid population growth and economic development, the worldwide energy demand is constantly increasing. The energy demand is fulfilled mainly from the conventional energy resources like coal, petroleum and natural gas. But, the petroleum reserves concentrated in certain regions of the world are fast depleting day by day and at the current usage rate, these sources will soon be exhausted (Baruaet al., 2014; Basumatary,2013; Khanet al, 2009; Vyaset al., 2010).The search for alternative sources of fuel to supplement or replace fossil fuels so as to cater fortheir increasing demands, uncertain availability and to reduce the related pollution problems of their combustion has drawn our attention towards fuels of biological origin (Encinar *et al*., 1999; Marchenko and Semenov, 2001),which provides a regenerable feedstock. The most commonfeedstock being developed and used at present are biodiesels, which are fatty acid methyl esters (FAMEs) of seed oils and fats.

Biodiesel has been chosen as one of the interesting alternative fuels and has been receiving a lot of attention throughout the world as it is renewable, biodegradable, non-toxic and environment-friendly fuel(Basumatary and Deka, 2012; Basumatary, 2013; Basumatary *et al*., 2013).Biodiesel, an alternative and renewable fuel for diesel engines, consists of mono-alkyl esters of long chain fatty acids, more commonly methyl esters and is typically made from nontoxic, biological resources such as edible and non-edible vegetable oils, animal fats, waste cooking oils and oil from algae by transesterification with methanol (Basumatary and Deka, 2012; Basumatary, 2013; Basumatary *et al*., 2013; Takase*et al*., 2014).Biodiesel produces lower emissions, possesses high flash point, better lubrication, and high cetane number and has very close physical and chemical characteristics to those of conventional diesel fuel allowing its use either on its own (pure biodiesel, B100) or mixed with petroleum based diesel fuel (preferred ratio 5– 20%, B5–B20) with very few technical adjustments or no modification(Basumatary, 2013; Basumatary *et al*., 2014;Biswas*et al.*, 2010; Fazal*et al*., 2011).A myriad of edible and non-edible oils could be used as bio-diesel feed stocks, but traditionally, biodiesel has been produced from edible oils due to their low free fatty acids. However, their use has elevated some issues such as food versus fuel and many other problems that have negativelyaffected their economic viability. Therefore, exploration of non-edible oils may significantly reduce the cost of biodiesel especially in poor countries which can barely afford the high cost of edible oils.One of these non-edible feed stocks is Thevetia peruviana oil.

Thevetia peruviana commonly known as milk bush is an evergreen, dicotyledonous shrub which is believed to have originated from the forest of tropical America, Precisely from Central America, but has naturalized in the tropical and subtropical regions of the world. It is abundantly available in Nigeria, where it is mainly grown as an ornamental plant. The seed of the plant contains about 60% oil and the defatted seed cake is about 37% protein (Olatunji, 2010).

Thevetia has revolved around the clinical, toxicological, pharmacological, etc aspects. Probably this is the reason for limited research on oil and protein of Thevetia that would have promoted its industrial and domestic potentials. Though literatures are available on Thevetiaplantanditsoilcharacteristics(Ibiyemi*et al*.,2002), a few study is available on its physicochemical properties. Therefore, this work aims at investigating the effects of physical and chemical properties of Thevetia peruviana on quality of biodiesel.

2 MATERIALS AND METHODS

2.1 Collection and Preparation of *Thevetia peruviana* Seeds

The ripe and matured *Thevetia peruviana* was harvested and collected from *Thevetia peruviana* plants in Iseyin metropolis, Iseyin Local Government Area of Oyo State, Nigeria. The succulent green outermost layer of the fresh fruits was removed manually using a knife to peel off the outer layer from the seed and the seeds separated from the peels manually. The peeled seeds were then decorticated manually using a stone to impact force on the seed in order to open the seed shell and free the seed kernels from its compartments. The mixture of the contents was winnowed to separate the seed kernels from the empty shells. The cleaned seed kernels collected were then sun dried for about 7 days in order to reduce its moisture content to about 10-11% wet basis required for oil bearing seed processing. The dried seed kernels were pound in a mortar and pestle into paste (cake) in order to weaken or rupture the kernel walls to facilitate oil extraction using solvent extraction method. The grind seed kernel paste was then packed in a plastic container for further processing.

For oil extraction, 250 g of *Thevetia peruviana* paste was placed on the cotton wool inside the thimble and 300 ml of n-Hexane was poured in the round bottom flask and processed. The heating chamber was switched on and set to the predetermined heating temperature and the heating process allowed for the required predetermine heating time. The vapour condensed and accumulated in the thimble and gets siphoned into the distillation flask. After the heating process, the thimble was carefully removed to collect the mixture of both n-Hexane and oil extracted. The mixture collected was then separated using rotary evaporating device. The procedure was repeated up to 14 more times with the same quantities of *Thevetia peruviana* paste and n-Hexane to obtain enough oil quantity for the biodiesel production. The n-Hexane removed was stored and reused for subsequent extraction operation, while the oil collected was stored for biodiesel production. Oil yield was determined using Equation 1.

$$\%\, Oil\ yield = \frac{Weight\ of\ oil\ obtained\ (g)}{Weight\ of\ sample\ (g)} \times 100 \qquad 1$$

2.2 Conversion of Extracted oil to Biodiesel

The free fatty acid of the oil was firstly determined in order to use the value in biodiesel production. The methanol and sodium hydroxide were mixed inside the conical flask and the sodium hydroxide was allowed to completely dissolve in the methanol and heated to 40^{0}C on the hot plate. One litre of the oil extracted was taken into flat bottom flask and heated to the 50^{0}C temperature on the hot plate. The warmed methoxide was poured into the oil slowly, heated and stirred vigorously using magnetic stirrer for the required time and temperature. The mixture was poured into the container and allowed to cool to 40 ºC temperature (Berchmans and Hirata, 2008).

2.3 Biodiesel separation, washing and drying processes

The mixture obtained after the transesterification process was transferred into a separating funnel which was mounted on a retort stand to separate biodiesel from glycerol. The lower layer (glycerol and soap) was collected from the bottom of the separating funnel. After the separation, the mono methyl ester (Biodiesels) separated still contain traces of sodium hydroxide, methanol, and glycerol. Warm water was then used to wash the biodiesel to remove any excess glycerol and soap that remain in the funnel. This was done by mixing the hot water with the biodiesel several times and then separating the water from the biodiesel until the clear water was seen below the biodiesel in the separating funnel. Then, the biodiesel was dried by placing it on a hot plate where excess water was removed at 110^{0}C. The quantity of biodiesel collected was measured and recorded. The procedures were repeated by varying the required molar ratio of *Thevetia peruviana* oil to methanol, heating times and heating temperatures (Berchmans and Hirata, 2008).

2.4 Physicochemical Properties of *Thevetia peruviana* Biodiesel

The physical and chemical properties of *Thevetia peruviana* biodiesel were determined using the ASTM standard test procedures. The fuel properties of biodiesel such as Ignition quality, viscosity, Cetane number, heating value, flash point and carbon residue were compared with commercially available diesel. Moisture determination, FFA content, Density, Ignition quality, viscosity, Cetane number, heating value, flash point, carbon residue of biodiesel were determined in the laboratory and compared with both biodiesel and petroleum diesel standards.

2.4.1 Moisture determination of seed kernel

About 2 g of the *Thevetia peruviana* oil sample was weighed into a previously weighed crucible. The crucible plus sample was then transferred into oven set at 100°C to dry to a constant weight for 24 hours, the crucible plus sample were removed from the oven and transferred into desiccators to cool for 10 minutes and weighed. The moisture content (d.b.) was evaluated from equation 2.

% moisture content (d.b.) = $\frac{W_2 - W_3}{W_3 - W_1}$x 100 ……………………....... 2

Where:

W_1=Weight of empty crucible, (g)

W_2 =Weight of sample plus crucible before drying, (g)

W_3 =Weight of crucible plus oven dried sample, (g)

2.4.2 Flame test of oil

The nature of the flame of burning oil sample was determined by heating the oil in a stainless saucer, and placing a clean white ceramic plate above the oil sample and the ceramic plate was removed after a period of about 10mins and the presence of soothe was observed using ASTM Standard D93.

2.4.3 pH of the oil

pH of the *Thevetia peruviana* oil was determined using Soil and Water Analyzer using ASTM Standard D6751.

2.4.4 Ash content of oil

About 2.0 g of the *Thevetia peruviana* oil was weighed into a porcelain crucible. It was then transferred into a muffle furnace set at 550ºC and was left 4 hours for it to turn to white ash. The crucible and content were then cooled in the air to about 100°C, then at room temperature in desiccators and was weighed using ASTM Standard D6751.

2.4.5 Density of biodiesel

Density of the oil was determined using a density bottle at 25ºC. This was determined by weighing the sample and comparing it with its volume. The ratio of the mass of the oil to its volume was then determined by Equation --3 using ASTM standard D93.

$\rho = \frac{M}{V}$- ……………………………………………………………….. 3

Where:

ρ= Density (kg/m^3)

M = Mass of the sample (kg)

V = Volume of the sample (m^3).

2.4.6 Ignition quality of biodiesel

The Cetane Number (CN) of the fuel is one such important parameter which is responsible for the delay period. Ignition quality tester was used to determine the cetane number using ASTM standard D445 .

2.4.7 Viscosity of biodiesel

Sample dispersed with concentration ranging from 0.4 to 2.0% (w/v) are prepared with distilled water at room temperature. The dispersion was hydrated for 2hours at room temperature under continuous stirring (monostir magnetic stirrer). The viscosity of the hydrated dispersion was measured at 25^0C using the NV sensor of the Haake – Rotovisco viscometer (Haake – Rotovisco GMBH Germany) using ASTM standard D445.

2.4.8 The congealing temperature of biodiesel

The congealing temperature was determined by putting 10ml of the oil sample in a 100ml beaker and inserting a laboratory thermometer into the oil and putting it in a freezer. The oil was closely monitored as the oil sample starts getting jelly, and the temperature at which gelation took place within the oil was also noted.

2.4.9 Flash-point of biodiesel

Flash point measures the lowest temperature at which application of the test flame causes the vapor above the sample to ignite. It is used to assess the overall flammability hazard of a material. Specifically, flash point is used in safety regulations to define "flammable" and "combustible" materials. It can be determined using Pensky-Martens Closed Cup Tester. Higher values indicate materials that are less likely to ignite accidentally. D 975 requires a minimum of 52°C. The biodiesels would be considered significantly safer with temperatures between 128°C and 167°C using ASTM Standard D93.

2.4.10 Carbon residue of biodiesel

Carbon residue of a fuel is the tendency of the fuel to form carbon deposits at high temperature in an inert temperature. High carbon residue value is undesirable for a fuel. Carbon residue is the percentage of amount of carbon (coke) left by heating the oil to a high temperature in absence of air using ASTM standard D445.

2.4.11 Calorific value of biodiesel

The calorific value measures the available energy in a fuel and a critical property of fuel intended for use in weight-limited vehicles. This was determined using bomb calorimeter using ASTM standard D445.

3 RESULTS AND DISCUSSIONS

3.1 Physicochemical Properties of Yellow Oleander Oil and Biodiesel

The analysis of the physicochemical properties of the yellow oleander oil extracted is as presented in Table 1. The table shows that the oil extracted from yellow oleander kernel was found to be suitable for biodiesel production as its free fatty acid value was found to be 1.21 mg KOH/g. Oil yield was found to be 62.44% which is within the range reported for the seed. Iodine value of Thevetia peruviana oil (68.2 g I_2 /100 g) was also far below the maximum limit of 120 prescribed in EN 14214. The acid value of Thevetia peruviana was found to be 0.16 mg of KOH/g. p^H value was found to be 6.8 neutral which means the oil is save for biodiesel production as stated by Adebayo *et al*. (2011). The oil was congealed at 4°C and was also frozen.

Table 1: Some physicochemical properties of yellow oleander oil

Properties	Unit	Biodiesel standard	Yellow oleander oil
Free fatty acid	mg KOH/g	NS	1.21
Iodine value	I_2/100g	120 max	68.2
Acid value	mgKOH/g	0.5 max	0.16
Moisture content	wt %	NS	1.86
Oil yield	wt %	NS	62.44
Specific gravity			0-89
Congealing temperature	°C		4.0

Freezing temperature	°C		1.0
p^H value			6.8

Table 2 shows the analysis of the physicochemical properties of the biodiesel produced from the *Thevetia peruviana* oil extracted.The biodiesel contain little sulphur and has exhibited a higher cetane number of 55 that exceeds the minimum limits of 47 and 51 prescribed in EN 14214 and EN 590 respectively, which is a good indication of fuel's ignition and combustion quality. The kinematic viscosity of the biodiesel at 40°C was 4.81 mm^2/s.This is within the range specified by EN 14214. The density at 15°C was found to be 0.89g/cm^3 which is well within the range specified by EN 14214. It is prescribed in ASTM D6751 and EN 14214 that the maximum limit of acid value for biodiesel should not exceed 0.50 mg of KOH/g. The European standard EN 14213 for use of biodiesel as heating oil prescribes a minimum heat of combustion of 35.0 kJ/g. The calorific value of the biodiesel

Table 2: Comparison of Physicochemical Properties of Yellow Oleander Biodiesel with petroleum diesel standards

Properties	**Unit**	**Biodiesel standard**	**Petroleum diesel**	**Yellow oleander biodiesel**
Specification		**EN 14214**	**EN 590**	**NS**
Density 15	^{0}C (g/cm^3)	0.86 - 0.90	0.82 - 0.845	0.89
Viscosity (@ 40^0C)	mm^2/s	3.5 - 5.0	2.0 - 4.5	4.81
Flash point	^{0}C	120 min	55 min	142
Sulphur	mg/kg	10 max	350 max	3.0
Carbon residue	% mass	0.3 max	0.3 max	0.14
Cetane number		51 min	51 min	55
Calorific value	KJ/g	35		40.42
Biodiesel yield				83.17

produced from Yellow oleander seed oil was found to be 40.42 kJ/g indicating good fuel properties. The carbon residue of the biodiesel was 0.14 mass%. The results also conform to the one gotten by (Adebayo et al., 2011).

4 CONCLUSION

This study has shown that biodiesel produced from *Thevetia peruviana* oil is a potential replacement for fossil diesel while the production and effective usage of biodiesel will help to reduce the cost of protecting the atmosphere from the hazards in using fossil diesel and hence will boost the economy of the country. The quality of the biodiesel produced conformed to standards set for biodiesel standard EN14214 and petroleum diesel standard EN590.

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SOME PROCESSING FACTORS AFFECTING THE YIELD AND QUALITY OF OIL EXPRESSED FROM CATFISH

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ABSTRACT

An investigation was carried out on the effects of applied pressure, pressing time and heating temperature on the yield and quality of catfish oil. Mechanical expression of the oil was carried out using a laboratory oil press. The pressure was varied at 5.05, 7.20, 10.81 and 14.41 KPa. Heating temperature was varied at 50, 55, 80, 90 and 110^oC. The pressing time was between 2 – 10 mins at 2 minutes interval. The quality parameters analyzed were: Saponification value, iodine value, peroxide value, acidic value, specific gravity and density. The highest percentage of oil obtained was 10.5 % at 14.416KPa and at pressing time of 10 mins. Results showed that oil yield increased with pressing time and applied pressure. From the non-linear regression carried out, R^2 highest value of 0.9995 was obtained at a heating temperature of 110^oC when oil was expressed at pressure of 14.416KPa and pressing time of 10 mins. The Saponification value, iodine value, peroxide value, acidic value, specific gravity and density are respectively 107.525, 7.0853, 6.9, 6.52, 0.917 and 1.08. The oil yield parameters obtained from this work are useful for design of equipment for expressing oil from catfish and the quality test on the expressed oil shows that oil from catfish could be an alternative to oil obtained from oil bearing seeds.

***Keywords:** Catfish, expression, oil yield, oil quality,*

INTRODUCTION

Catfish oil is rich sources of natural bioactive lipid components. These lipid components are commercially used in the pharmaceutical and food industries and as human health supplements (Mate *et al.,* 1991). Moreover, fish is being considered an importance diet duce to its polyunsaturated fatty acids content. Fish represent one of the most consumed foods across the world. Moses (1993) defined fish as poikilothermic aquatic vertebrates that breathe by the means of gills and move by the means of fins. This is due to its protein content and the fact that it came as an affordable among the vowels proteins foods available. Wagner (1995) states that, fish is a food of excellent nutritional value that contains high quality protein and a waste variety A and D, phosphorus magnesium, and iodine in marine fish. There is need to provide alternative oil that can be obtain from animal source, since most of the oil (vegetable oils) available are from oil bearing seed like Groundnut oil, palm kernel oil etc.

Catfish (*Clarias gariepinus***)** is fresh water specie which can be found primarily in the Southeast Asia especially in Malaysia and Thailand. The local catfish is usually found in swampy areas, lowland rivers, paddy fields and mining pools. The catfish becomes a very valuable resource in many countries. This catfish also has become a cheap source of protein for communities. The catfish contains higher yield of oil in their body (flesh) than viscera. Numerous investigations showed that the catfish oil has been extensively used for many years and for different purposes. Omega -3 fatty acids, Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA) contained in the catfish oil are important in biomedical application and dietary supplementation. A recent study showed that catfish oil contain 30% of dietary crude protein and 0.5 to 0.7% of the dietary essential fatty acids, the oil is extracted from the important organs of the fish and the oil is yellow to brown in color, it has a strange flavor and it is insoluble in water (Chantachur *et al*., 2000, Brown, 1979).

Pressing and solvent extraction are the common method used for oils that hare, bear extracted are unstable if exposed to air due to high level of the polyunsaturated fatty acids. These polyunsaturated fatty acids make the fish oil more vulnerable to spoilage (Moses, 1993). The yield of catfish oil was found to be 65.7% (King, 2009).

The therapeutic studies have shown that fish oil is found useful in combating high blood pressure, high triglyceride, rheumatoid arthritis. The consumption of fish oils are beneficial for heart brain functioning and regeneration of nerve cell. They keep blood from clotting too quickly; they inhibit the progress of atherosclerosis (Conor, 2000). The anti-inflammatory effects of EPA and DHA helps some people with kidney diseases and help protect chronic obstructive pulmonary disease (Mate *et al.*, 1991). The curative and preventive effects are well recognizing in treating cardiovascular disease, autoimmune disorder, various kinds of inflammation (Huss, 1988).

The commonly used methods for evaluation of fish oil stability and monitoring of deterioration during storage include saponification value, iodine value, peroxide value, acidic value. Regulatory agencies have established the limits for quality and acceptability of oils for human consumption, the analysis for their thiobartituric acid value is important, which is a measure for the level of secondary oxidation products. These secondary oxidation products are famedupon breakdown of the peroxides and are responsible for off-flavour. Peroxide and hydroperoxide concentrations increase would initiate a series of reactions that led to increase in the productions of aldehydes, ketones, hydrocarbons and other termination stage products and thus contributed to rancidity of the fish oil. Oxidative stability is one of the most important quality indicators in fish oils. The TBA values are expressed by the level of malanadehyde, used as maker for the total and of aldehydes (Moses, 1993 and Swen, 1945).

This research is aimed at determining the effects of some processing factors like particle size, pressing time, heating temperature, and applied pressure on the oil expression yield from catfish, and to evaluate the quality parameters of the oil expressed which include: Saponification values, Acidic values, Iodine values, Peroxide value.

MATERIALS AND METHODS

Materials Preparation

The species of Catfish used in this research is Clarias gariepinus. Matured live and fresh catfish were obtained from a fish farm in Ikorodu, each weighing about 1.2 gram. The fishes were cut, degutted, washed thoroughly and drained.

Laboratory Oil Press

The presses consist of a lever arm with a drum attached to the end of the arm. A known weight was added to the drum to generate the required pressure. The pressing cylinder was made from stainless steel pipe with a diameter of 64mm and height 15mm.The cylinder was welded to a stainless steel that served as the base for the pressing cylinder. Holes 1mm in diameter were drilled in the section of the meal plate covering the pressing cylinder. The holes allowed the oil to pass from the pressuring cylinder to the measuring cylinder through the funnel. A metal disc was placed in the cylinder to distribute its pressure from the pressing raw evenly on the sample. The measuring cylinder was used to measure the volume of oil expressed over a period of time. Figure 1 showed the schematic diagram of the laboratory oil press.

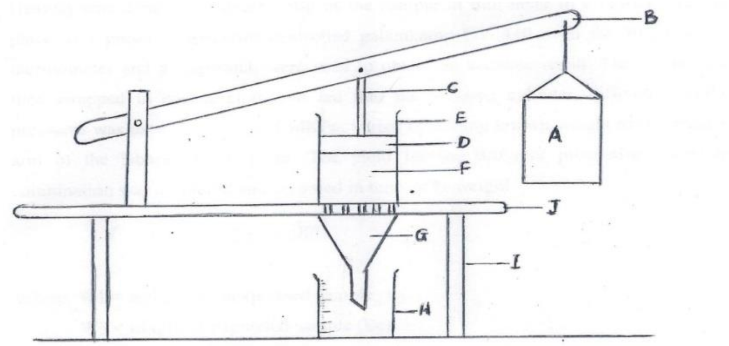

Figure 1: Schematic diagram of Laboratory Oil Press

A- Drum, B- lever arm, C- Pressing ram, D-disc, E- pressing cylinder, F- fish sample, G- funnel, H- measuring cylinder, I- support for pressing cylinder and J- Metal plate.

Source: Aina and Adebanjo, 2004

Experimental Procedure

Samples of the freshly prepared catfish were placed in an oven and spread in layers, after the pre-heating temperature has been set. The different pre-heating temperatures used were 50, 55, 80, 90 and 110^{o}C. After pre-heating, the catfish were deboned and blended to reduce to coarse particle size based on past work that smaller size piece are better for oil removal, but if the pieces are too small, they may contaminate the oil and be difficult to remove from the final product (Taylor and Francis, 1989). 40g of samples were weighed using electronic weighing balance; the weighed samples were then wrapped in a piece of muslin cloth before oil was pressed. Fish oil was expressed from the catfish samples with a laboratory press at varied pressures of 5.04, 7.21, 10.81, and 14.41KPa and for different pressing times: 2, 4, 6, 8, and 10min. The expressed oil contained some amount of water, a centrifugal instrument was used to spin the solution in order to separate the oil from water and the pure fish oil was obtained. The oil obtained for the different processing parameters combination was measured and data recorded. Procedure was repeated thrice for each combination of parameters. The Physicochemical properties of the catfish oil was analyzed according to the procedures stated by AOAC (2000) and Pearson (1970)

Physicochemical Properties of Fish Oil

The physicochemical properties of the catfish oil were determined to assess its quality and purity. These include, free fatty acids content, saponification value, iodine value, peroxide value, density and specific gravity. These six quality indices would be used to determine the quality of the extracted oil.

Determination of Saponification Value of Oil

Saponification value is defined as the number of milligrams of potassium hydroxide required to saponify 1g of fat or oil. It is a measure of the average molecular weight of the fatty acids present in given oil.2ml of the oil was measuredinto a flask and exactly 50cm^{3}of 1m strength alcoholic KOH solution was added with a few pieces of porous pot. A condenser was set-up and the mixture was gently refluxed for (40-45mins) while still relaxing, 50ml of the KOH solution was titrate against 1m HCL.

Saponification value = $\frac{56.1 \times N(A-B)}{W}$ ……………….(3)

where.
N is Normality of HCL acid used, A is the Volume of HCL for lank (ml), 56.1 is equivalent weight of potassium hydroxide, and W is the weight of oil used.

Determination of Peroxide Value

Peroxide Valueis a measure of the peroxide contained into a sample of fat and oil. The peroxide value is usually volumetrically by a method which was largely developed by LEA.
Procedure: 1g of oil was transferred into a 250ml volumetric flask, 30ml of chloroform was added to dissolve the fat by swirling. Then 15ml of glacial acetic acid and 1ml of fresh saturated potassium iodine solution was added. The flask was corked with a stopper, shaked for 1min and then placed in the dark for about 5mins. 75ml of H_2O was added. Free iodine was titrated against with 0.1M sodium thiosulphate solution using 1% soluble starch as an indicator. A blank titration was also carried out.

Determination of Iodine Value

Iodine value is the number of iodine required to absorb 100g or 100kg by weight of fatty acid present in fat. It is significant in the quality control of fat and oil because it gives the value of saturation and instauration of fat and oil and also gives the level of impurity of fat and oil.
Procedure: 2g of oil sample was weighed into a dry conical flask of 250ml capacity and 10ml of carbon tetrachloride was added to the oil, 20ml of Wij's was added and was allowed to stand in the dark for 30mins. 15ml of (10%) potassium iodide and 100ml of water was added and then titrated with 0.1M of sodium thiosulphate solution using starch as indicator just before the end point.

Iodine Value=$\frac{(B-A)00317 \times 0.001269 \times 100}{weight of sample}$ …….(2)

where:
B is Blank Titre value, and A is Sample Titre.

Determination of Acid Value

This is also known as free fatty acid value (FFA Value). Acid value is a measure of the amount of free fatty acids present in a fat. Acid value of a fat and oil is the number of milligram of alkaline required to neutralize free fatty acid present in fat or present in food sample containing fat.
Procedure: 2g of homogenized oil was weighed into 250ml of conical flask and warmed gently to melt the fat. 15ml of alcohol ether was added with 5ml of chloroform and shaked well. 1ml of 1% phenolphthalein was used as an indicator and was titrated against 0.1M NaOH until a pink colour persist for a few seconds.

Acid Value = $\frac{A \times 5.6}{weight of smple}$.….(3)

where:
A is Titre Value

Determination of Specific Gravity

Specific Gravity can be defined as the density of an object when compare to the density of pure water. An object that has a specific gravity of 1.5 has a density which is one and half ($1^1/_2$) times that of water. Specific gravity is the ratio of the weight of volume of the substance of that of pure water at specific temperature 20-23ºC.

*Procedure:*500ml of the sample was measured into a weighed measuring cylinder (700ml) and the hydrometer was deep into it, while the specific gravity was read directly on the scale. A measuring cylinder was weighed with its content that is sampled ensuring its 50ml with a weighed measuring cylinder. The same volume of water was weighed with the same measuring cylinder records and the specific gravity of the sample was calculated.

Specific Gravity =$\frac{weight of fish oil}{weight of volume of water}$ ….. (4)

Determination of Colour

Colour is an important quality of many foods. It is a quality attribute which together with flavor and texture plays an important role in food acceptability. Colour can be defined as a psychological interpretation of physical stimulus of light radiation at different wavelengths.

Procedure: The colour of oil was measured in comparison with standard coloured glasses.

Statistical Analysis

The non-linear regression analysis was performed using SIGMA PLOT 10.0. The goodness of fit of the tested mathematical models to the experimental data was evaluated with the correlation coefficient (R^2) and Sum of Square error (SS).The closer the value of R^2 to one(1) and the closer the value of SS to zero, the better the goodness of fit, the statistical tool allows the effects between and within the parameters to be tested simultaneously.

RESULTS AND DISCUSSION

Effects of Heating Temperature, Applied Pressure and Pressing Time on Oil Yield

Tables 1-4 below shows the catfish oil yield at different pressing time, pre-heating temperature and applied pressure. It was observed that oil yield increases as pressing time increased; also that as applied pressure increases there is increase in the oil yield at every pressing time and heating temperature. The highest value (10.6) of oil yield was obtained at the highest applied pressure of 14.41KPa. Heating temperature of fish is the most significant factor affecting the yield of oil from preheated catfish. As showed in tables 1-4, oil yield obtained from samples which were conditioned to a heating temperature 110ºC were higher than that of other temperature. This result is in agreement with Fasina *et al* (1989) who worked on oil yield from Conophor nut. Pressing has the purpose of squeezing out as much liquid from solid fish pulp, this is important not only to improve the oil yield and the quality of the meal, but also to reduce the moisture content of the press cake as far as possible. The result obtained from this work is in agreement with previous research done, Fashina *et al*, 1989) represented that the oil bearing seeds was directly proportional to the square root of the pressure.

Table 1: Effects of Heating Temperature and Pressing Time on Percentage Oil Yield from Catfish expressed at 5.0KPa.

	Heating Temperature (^oC)				
Time(min)	**50**	**60**	**80**	**95**	**110**
2	0.7	1.6	3.6	3.9	5.7
4	0.9	2.0	3.9	4.6	5.7
6	1.3	2.9	4.1	4.9	5.7
8	1.2	3.5	4.9	5.2	5.9
10	1.6	3.5	5.2	5.8	6.0

Table 2: Effects of Heating Temperature and Pressing Time on Percentage Oil Yield From Catfish Expressed At 7.21KPa.

	Heating Temperature (^oC)				
Time(min)	**50**	**60**	**80**	**95**	**110**
2	1.4	1.8	3.9	4.3	5.3
4	1.9	1.8	4.0	4.5	5.2
6	2.4	3.0	4.4	5.0	5.3
8	3.2	3.5	5.0	5.8	5.7
10	3.6	4.0	5.3	6.2	6.3

Table 3: Effects Of Heating Temperature And Pressing Time On Percentage Oil Yield From Catfish Expressed At 10.81KPa.

	Heating Temperature (^oC)				
Time(min)	**50**	**60**	**80**	**95**	**110**
2	2.3	3.1	4.0	4.6	5.3
4	2.8	3.6	4.3	4.7	6.0
6	3.1	3.8	4.4	5.1	6.5
8	3.6	4.0	4.9	5.7	7.0
10	3.6	4.2	5.5	6.3	7.5

Table 4: Effects Of Heating Temperature And Pressing Time On Percentage Oil Yield From Catfish Expressed At 14.41KPa.

	Heating Temperature (^oC)				
Time (min)	**50**	**60**	**80**	**95**	**110**
2	5.1	5.6	5.8	6.1	6.2
4	6.4	6.3	6.6	6.6	8.8
6	6.9	7.1	7.4	7.5	9.7
8	7.6	7.6	7.8	8.3	10.1
10	7.9	8.1	8.1	9.0	10.5

Regression of percentage oil yield (means) on pressing time, as shown in table 5-7, indicate that an increase in heating temperature brings an increase in the percentage oil yield at each pressing time expressed. From the non-linear regression carried out, R^2 highest value of 0.9995 and X^2 lowest value of 0.0160were obtained at a heating temperature of 110^oC when oil was expressed at pressure of 14.416 KPa and pressing time of 10 mins. The data obtained can be utilized in the development of effective processing equipment for expression of oil from catfish.

Table 5: % oil yield model constants and statistical parameters for oil express at 5.0465KPa using f = y_o+ax

Heating Temp.(°C)	y_o	A	R^2	SS	MS
50	0.51	0.105	0.8963	0.051	0.017
65	0.99	0.295	0.9745	0.091	0.0303
80	3.08	0.21	0.9525	0.088	0.0293
95	3.56	0.22	0.9738	0.052	0.0173
110	5.32	0.10	0.6579	0.208	0.0693

Table 6: % oil yield model constants and statistical parameters for oil express at 7.208KPa, using f = y_o+ax

Heating Temp.(°C)	y_o	A	R^2	SS	MS
50	0.8700	0.2650	0.9781	0.0630	0.0210
65	0.9900	0.3050	0.9378	0.2470	0.0823
80	3.3800	0.1900	0.9576	0.0640	0.0213
95	3.6300	0.2550	0.9662	0.0910	0.0303
110	4.8100	0.1250	0.7512	0.2070	0.0690

Table 7: % oil yield model constants and statistical parameters for oil express at 10.812KPa, using f = y_o+ax

Heating Temp.(°C)	y_o	A	R^2	SS	MS
50	2.0600	0.1700	0.9414	0.0720	0.0240
65	2.9600	0.1300	0.9494	0.0360	0.0120
80	2.9600	0.1300	0.9494	0.0360	0.0120
95	3.9600	0.2200	0.9453	0.1120	0.0373
110	4.8400	0.2700	0.9945	0.0160	0.0053

The oil yield obtained from catfish at 110°C expressed at 5.046 KPa, 7.20 Pa, 10.81 KPa and 14.41Pa was 6.0%, 6.3%, 7.5% and10.5% respectively, pressed for 10 minutes. Figures 2-5 showed that oil yield increases as the pressing time increases for all the pressure applied on each samples. A further test using SIGMA PLOT 10.0 at each pressure stated shows that there was significant difference in percentage of oil yield obtained at different pressing time.

From Tables 5-7, it can be deduced that the values of the correlation coefficient (R^2) were close to one (1) and the values of sum of square error (SS) were close to zero, which gives better goodness of fit. Also Regression of percentage oil yield on pressing time shows that an increase in heating temperature brings an increase in the percentage of oil yield at each pressing time expressed.

3.2 Physicochemical Properties

The Physicochemical Properties of Catfish oil expressed are shown in Table 8, the Saponification value, iodine value, peroxide value, acidic value, specific gravity and density are respectively 107.525, 7.0853, 6.9, 6.52, 0.917 and 1.08. The quality test on the expressed oil shows that oil from catfish could be an alternative to oil obtained from oil bearing seeds.

Table 8:Physicochemical Properties of Catfish oil expressed

Parameters	Experimental values	StandardMean
Saponification value (mg/g)	107.525	181.4 ± 2.60
Free Fatty Acidic level (mg/KOH/g)	9.52	5.78±7.28
Iodine Value (g/100g)	0.00154	80 ±106
Specific Gravity (kg/m^3)	0.917	0.9 ±1.16
Density (kg/m^3)	1.08	
Peroxide Value (m/mol/kg)	NIL	
Oil color	pale yellow	

Conclusion

Pressing time, Heating temperature, applied pressure was found to affect the oil yield from catfish significantly. Maximum yield of oil was obtained when sample are pressed with 14.41KPa for 10min.However, oil expressed has pale yellow colour which is expected of fish oil.

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DRYING KINETICS OF OSMOTICALLY PRETREATED CATFISH (*Clariasgariepinus)*

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ABSTRACT

The drying kinetics of catfish was studied using a 2x2 factorial experiment. Catfish of two different sizes, 250 - 400 g (age 3-4 months) and 800 -1000 g (age 4-5 months) were osmotically pre-treated with sodium chloride (25 ^{o}brix) at 40 ^{o}C for 6 hours then dried at two different temperatures, (70 ^{o}C (low) and 150 ^{o}C (high) using sawdust–powered smoking kiln. Result shows that the samples dried in the falling drying rate period and salt has significant effect on drying. From the result it was evidence that at temperature 150 ^{o}C the equilibrium moisture content was attained at the reduced time compared to that of 70 ^{0}C. The drying behaviour of the two sizes of catfish was tested with twelve model equations. The results were compared for their goodness of fit in terms of correlation coefficient (R^2), reduced chi square ($\chi 2$) and root mean square error (RMSE). Modified Henderson and Pabis model best describes the drying behaviour of Clarias gariepinus at both 70 and 150 ^{0}C for both and small sizes pretreated with osmotic solution of 25%.

Keywords: Moisture ratio, Drying rate, Catfish, Equilibrium moisture content

INTRODUCTION

Fresh fish contains up to 80% of water. It is a highly perishable material and having a short storage life (Bala and Mondol, 2001). It is well known and documented that a large percentage of the fish caught in the developing countries are lost through poor handling. James (1986) estimated 4.2 million tons while Esser, (1991) estimated 3 million tones as annual global fish postharvest losses. Dada and Gnanados, (1983) documented 50%, Tobor, (1984), 30-50% and Essuman, (1992), 20-30% as post-harvest fish losses in Nigeria.

Abiodun (2002) estimated fish loss in Kainji Lake area to worth 256,008 naira in 1996 and 163,604 naira in 2001. Therefore, there is need for improved processing and preservation techniques by striving to employ the best method possible in handing fish to maximize returns on processing investment (Davies, 2005). Since water is essential for the activity of all living organisms its removal will slow down, or stop, microbiological or autolysis activity and can thus be used as a method of preservation (Clucas, 1982)

Osmotic dehydration is the incomplete removal of water from a food product by means of an osmotic agent (usually either sugar or salt solution). It is a pre-treatment in air drying or freezing Collignan and Raoult-Wack, 1994) and has been used for fish (Iseya *et al.,* 2000; Mujaffar and Sankat, 2005). The main advantage of this process is its influence on the principal drying method, shortening of the drying process, resulting in lower energy requirements. Considering that heat is not applied in this stage, osmotic dehydration offers higher retention of initial food characteristics, such as colour, aroma, and nutritional value.

Mass transfer in osmotic dehydration

In osmotic dehydration, there are three types of counter mass transfer phenomenon (Ponting, 1973). First, water outflow from the food tissue to the osmotic solution, second, a solute transfer from the osmotic solution to the food tissue, third, a leaching out of the food tissue's own solutes (sugars, organic acids, minerals, vitamins) into the osmotic solution. Two quantities represent adequately these processes are: the water loss (WL) and the solid gain (SG). The first is the amount of water, which diffuses from the submerged animal or plant tissue to the solution due to differences in the osmotic pressures of tissue and surrounding hypertonic solution, and the second one indicates the solids which diffuse from the solution to the tissue (Waliszewiski *et al.*,1999).

Drying

Drying a solid is usually regarded as the removal of water or other liquid from the solid material till an acceptable low value (McCabe *et al.*, 1993). In traditional method of preserving fish, the action of the sun and wind is used to effect evaporative drying; In recent times, smoking kilns and artificial dryers are used to obtain product of high quality. According to Sablani *et al.*, (2002), kilns helps to minimize the drudgery; reduce labour operation, and unsanitary and inherent unhygienic handling that are mostly involved in the traditional manual operations. It functions without any electrical or sophisticated mechanical appliances to generate heat, but with the help of natural air convection through air vents.

There are two distinct stages in fish drying process: removing moisture on the surface and removing moisture within the fish which are termed "constant rate and falling rate" respectively.

Mathematical modelling

Mathematical models are useful for the simulation and design of driers and drying operations aimed at improving product quality as well as saving energy. Besides, simulation models are also important for the project of new or for the improvement of existing drying systems as well as for the control of the drying operations (Guine *et al.*,2008) The transport properties of both the material and the drying medium, air in most cases, allow describing the drying kinetics. In the drying of food products, it is typically used the drying constant, k, which combines all the transport properties and may be defined by a thin layer equation(Togrul & Pehlivan 2003). Thin layer drying is a common method and widely used for agricultural products (Kadam *et al.,* 2010) The drying kinetics of food is a complex phenomenon and requires simple representations to predict the drying behaviour, and for optimizing the drying parameters. The prediction of drying rate of agricultural materials under various conditions is important for the design of drying systems. It can be generally evaluated experimentally by measuring the weight of a drying sample as a function of time.

Drying model equations for semi-theoretical as suggested by Jayas *et al* (1991) an equation that assumes the rate of change in moisture content is proportional to the difference between moisture content and equilibrium moisture content of the food.

$$MR = \frac{Mt - Mc}{Mo - Mc} = \exp(-Kt) \qquad 1$$

Where MR= moisture ratio

Mt= moisture content at time, t (% w.b)
Mc =equilibrium moisture content (% w.b)
Mo = initial moisture content (% w.b)
K = drying constant determined from the experimental data (h^{-1})
t = time(h)

Other authors argue that for long drying times equation1 can be simplified to

$$MR = \frac{Mt}{Mo} \quad 2$$

due to the fact that values of equilibrium moisture content is very low, M_c are relatively small compared to M_t or M_o (Doymaz and Pala, 2002; Doymaz, 2004). Because of its simplicity, equation 2 has been widely used to describe drying of different crops (Bruce,1985).

Goodness of Fit for the Drying Models

Drying models are evaluated and compared by using statistical measures. Consequently, the quality of the fitted models is evaluated. Some of these measures can be described as follows:

Root mean square error (RMSE): Lower values of root mean square error are chosen as criteria for goodness of fit (Demir *et al*., 2004; Doymaz, 2005;Wang*et al* ., 2007) RMSE=

$$[\frac{1}{N}\sum_{i=1}^{N}(MRpre,i - MRexp,i)] \quad 3$$

Reduced chi square ($\chi 2$): It is the mean square of the deviations between the experimental and calculated moisture levels (Lopez *et al.,* 2000;Panchariya et al., 2002;Iguaz *et al* .,2003)$\chi 2$=

$$\frac{\sum_{i=1}^{N}(MRexp,i - MRpre,i)2}{N-n} \quad 4$$

Correlation coefficient (R^2): This is equivalent to the ratio of the regression sum of squares (SSR) to the total sum of squares i (SST). R^2 explains the proportion of variances accounted for in the dependent variable by the model. It evaluates how well the model fits the data. Higher values for R^2 are used as goodness of fit for the models. (Saeed *et al.*, 2006; Singh *et al.*, 2006; Doymaz,2007a; Doymaz, 2007b).The SSE and the SST can be calculated from the following formulae:

Regression sum of squares: $$R^2 = \frac{\sum_{i=1}^{N}(MR\ i - MRpre,i)*(MRi - MRexp,i)}{[\ [\sum_{i=1}^{N}(MRi - MRpre,i)2*[\sum_{i-1}^{N}(MRi - MRpre,i)2]]^{1}/_{2}} \quad 5$$

where,
N is the number of sampling times and
n is the number of constants in the drying model.
R^2 is called the coefficient of determination
MR $_{exp,i}$stand for the ith experimental moisture
MR $_{pre,i}$is the ith predicted model moisture ratio

MATERIALS AND METHOD

This study was carried out using *Clarias gariepinus* of two different sizes 250 - 400 g (small) and 800 - 1000 g (big) cleaned and bent into horse-shoe shape. Salt solution (NaCl) (25 ^{o}brix) was prepared for the osmotic dehydration. The fresh weight of the samples was determined using electronic weighing balance, the ratio of solute to small catfish was 7:1w/w, while that of big catfish was 4:1w/w. The osmotic dehydration was done at 40 ^{o}C for a period of six hours. Weighing of the fish was being done at every interval of 1 hour for the entire six hours ofor osmotic dehydration. Prior to drying the moisture content was determined. The osmotically dehydrated samples were smoked dried in a smoking kiln at 70 and 150 ^{o}C differently. At intervals of 1 hour the samples were being weighed until a constant three consecutive weight was recorded. These readings were used to calculate the moisture ratios which were fitted into available twelve model equations.

RESULTS AND DISCUSSION

Table 1 shows the calculated moisture ratio for osmotically dehydrated smoked catfish at 70 and 150 ^{o}C using sawdust with the corresponding drying time (hour). The sample has initial average moisture content of 74% dry basis. It was observed that the moisture of all the samples was decreasing as drying time was progressing, whereby the overall weight measured was decreasing. It took the small sample 25 hours at 70 ^{0}C to reach equilibrium moisture ratio of 0.18. The small size samples dried at 150 ^{o}C, witnessed much faster rate than that at 70 ^{o}C. It was able to attain equilibrium moisture ratio of 0.01 after ten hours of drying.

Table 1: Moisture Ratio of Pretreated Small and Big Catfish Sizes Dried at 70 ^{o}C and 150 ^{o}C

DRYING HOUR	70 ^{o}C		150 ^{o}C	
	Small Size	Big Size	Small Size	Big Size
0	1.00	1.00	1.00	1.00
1	0.72	0.90	0.65	0.70
2	0.64	0.87	0.47	0.57
3	0.60	0.85	0.30	0.45
4	0.55	0.82	0.16	0.35
5	0.51	0.80	0.07	0.28
6	0.47	0.78	0.03	0.23
7	0.44	0.77	0.01	0.19
8	0.41	0.75	0.01	0.17
9	0.39	0.73	0.01	0.17
10	0.36	0.72	0.01	0.17
11	0.34	0.71		
12	0.32	0.70		
13	0.30	0.69		
14	0.29	0.68		
15	0.28	0.67		
16	0.26	0.66		
17	0.25	0.65		
18	0.24	0.64		
19	0.23	0.63		
20	0.22	0.62		
21	0.21	0.61		
22	0.20	0.60		
23	0.19	0.59		
24	0.18	0.58		
25	0.18	0.58		
26		0.57		
27		0.56		

28	0.55
29	0.55

The drying pattern was observed with pretreated big size catfish, only that there were differences in drying times and equilibrium moisture ratios attained. The pretreated big size catfish dried at 70 ^{0}C took 29 hours to attain equilibrium moisture ratio of 0.55 while that at 150 ^{0}C took 10 hours to attain 0.17 equilibrium moisture ratio.

Fittings of Drying Data

The moisture ratio were fitted into available twelve model equations and the best model to describe pattern of catfish was based on the highest coefficient of determination (R^2), least of reduced chi-square ($\chi 2$) and root mean square error (RMSE). The higher the values of R^2, and lower the values of $\chi 2$ and RMSE, the better the goodness of fit **(**Doymaz *et al*., 2005, Yaldiz and Ertekin, 2001 and Gunham,2005).

The twelve models were used to model big and small pretreated samples dried at 70 and 150 ^{o}C.

For the twelve examined models in Tables 2 and 3, modified Henderson and Pabis gave the results for the overall best fits for R^2 = (0.9988, 0.9997), $\chi 2$ = (1.96 x 10^{-5}, 1.1 x 10^{-05}) and RMSE = (0.00399, 0.0043) for 70 and 150 ^{0}C drying temperatures respectively for big size. Likewise in Tables 4 and 5 for drying of small size of catfish, Modified Henderson and Pabis model gave a better correlation between the moisture ratio and drying time**,** with the highest R^2 (0.9997, 0.998) and lowest χ^2 (6.6 x 10^{-5}, 7.3 x 10^{-3}) and RMSE (4.7x10^{-3}, 1.6x10^{-2}) at 70 and 150 ^{0}C respectively. This indicates that Modified Henderson and Pabis model represent the drying behavior for hot-air drying of pretreated both small and big catfish dried at 70 and 150 ^{o}C using sawdust.

Table 2: Modeling Results for 70 ^{0}C big catfish size

Model Name	Model Constants	χ^2	R^2	RMSE
Newton	a=0.0236	0.0033587745	0.7543	0.057042202
Page	a=0.0938, k=0.5413	0.0000204847	0.9985	0.00438228
Modified Page	a=0.012,k=0.541	0.0000204847	0.9985	0.00438228
Henderson & Pabis	a=0.8875,k=0.0172	0.0007940083	0.9438	0.02728338
Logarithmic	a=0.433,k=0.0725,c= 0.5125	0.0001877472	0.9871	0.013044
Two-Term	a=0.1697,k=0.3284c=0.8131,g=0.0131	0.0000756982	0.9950	0.008138546
Two-Term Exponential	a=0.0976,k=0.1933	0.0015321777	0.8915	0.037900087
Wang & Singh	a=-0.0322,k=6.00E-04	0.0010777520	0.9237	0.031786672
Diffusion Approach	a=0.1782,k=4.08E-01 c=0.0332	0.0000832669	0.9943	0.008686808
Verma *et al*	a=0.1782,k=0.405 c=0.0135	0.0000832669	0.9943	0.008686808
Modified Henderson &Pabis	a=0.0825,k=2.1325 c=0.2308,g=-0.0957	0.0000196369	0.9988	0.003994371

Table 3: Modeling Results for 150 ^{0}C big catfish size

Model Name	Model Constants	χ^2	R^2	RMSE
Newton	a= 0.0588	0.004543829	0.8601	0.097472
Page	a =0.1618,k= 0.6112	0.0000977495	0.9971	0.013982
Modified Page	a =0.0508,k=0.6112	0.0000977495	0.9971	0.013982
Henderson &Pabis	a =0.8642, k=0.0465	0.00150889	0.9556	0.054934
Logarithmic	a = 0.638,k=0.1099,c =0.2949	0.000433756	0.9878	0.028776
Two –Term	a=0.7721,k=0.0383,c=0.219,g=0.6824	0.000238611	0.9936	0.020829
Two –Term Exponential	a =0.1482,k=0.3192	0.001851081	0.9454	0.060845
Wang & Singh	a =-0.066,k=1.68E-03	0.002232466	0.9342	0.060845
Diffusion Approach	a= 0.2236,k=0.7503,c=0.0515	0.000230632	0.9935	0.020983
Verma *et al*	a =0.2236,k=0.7503,c=0.0386	0.000230632	0.9935	0.020983
Modified Henderson and Pabis	a =0.8412,k=0.0526,c=7.41E-03,g=-0.1092	0.000011137	0.9997	0.004269

Table 4: Modeling Results for 70 ^{0}C small catfish size

Model Name	Model Constants	χ^2	R^2	RMSE
Newton	a = 0.2477	0.0026218	0.9713	0.048275
Page	a =3.52E-01,k=0.7659	0.0005021	0.9952	0.019762
Modified Page	a=0.2559,k=0.7659	0.0005021	0.9952	0.019762
Henderson & Pabis	a =0.9414,k=0.231	0.0022639	0.9783	0.041962
Logarithmic	a =0.8596,k=0.3446,c=0.1272	0.0004116	0.9966	0.016565
Two –Term	a= 0.8596,k=0.344,c=0.1272,g=3.59E-11	0.0004939	0.9966	0.016565
Two –Term Exponential	a=2326,k=0.8273	0.000994	0.9918	0.025742
Wang & Singh	a=-0.2161,k=0.0137	0.0024904	0.9762	0.044011
Diffusion Approach	a=0.8693,k=0.3536,c=2.04E-10	0.0004473	0.9963	0.017268
Verma et al	a=0.8693,k=0.3536,c=1.15E-12	0.0004473	0.9963	0.017268
Modified Henderson and Pabis	a=0.1082,k=212.667,c=5.91E-04,g=-0.4964	6.611E-05	0.9997	0.004694
Midilli Kucuk	a=0.9955,k=0.3301,c=0.8986,g=7.98E-03	0.0003436	0.9976	0.013817

Table 5: Modeling Results for 150 ^{0}C Small catfish size

Model Name	Model Constants	χ^2	R^2	RMSE
Newton	a= 0.4371	0.001177	0.9914	0.03235
Page	a=0.3685, k= 1.1569	0.000744	0.9952	0.024053
Modified Page	a=0.4219,k= 1.1569	0.000744	0.9952	0.024053
Henderson &Pabis	a =1.0161,k= 4.43E-01	0.0011376	0.9917	0.0317994
Logarithmic	a =1.0428,k=0.3992,c= -0.0372	0.0009497	0.9948	0.0251625
Two –Term	a=0.5183,k=0.4432,c=0.4978,g=0.4432	0.00182	0.9917	0.031799
Two –Term Exponential	a =1.6465, k=0.5556	0.000861	0.9953	0.023956
Wang & Singh	a=-0.2794,k=0.0187	0.003118	0.98	0.04925
Diffusion Approach	a =-115.7337,k=0.676,c=0.9956	0.0007951	0.9956	0.0230231
Verma *et al*	a =-0.0898,k=512.1541,c=0.4715	0.00128265	0.993	0.02924211
Modified Henderson and Pabis	a =0.8013,k=1.08E-1.4193,c=2.217,g=-2.0272	0.00731	0.998	0.01561
Midilli Kucuk	a=0.9886,k=0.3581,c=1.1729,g=1.27E-11	0.0010157	0.9954	0.0237547

CONCLUSION

The results of this study showed that Modified Henderson and Pabis model is best fit to describe the drying behavior of pretreated small and big sizes of catfish dried at low temperature of 70 ^{0}C and high temperature of 150 ^{0}C using saw dust.

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Effect of Processing Methods on the Residual Heavy Metals in Gari made from Cassava Harvested fromOloibiri Oil Field

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ABSTRACT

Cassava (Manihot esculenta) is a major staple crop and is particularly important in Nigeria and Africa as a whole. The amount of carbohydrate contained in dry cassava roots is higher than other staple crops such as maize and cereals and its protein content is very low. Cassava roots are very rich in starch and contain significant amount of calcium (50 mg/100g), phosphorus (40 mg/100g) and vitamin C (25 mg /100g). Oil exploration and other human activities have been incriminated with contamination of agricultural produce with heavy metals. The unit operations investigated were fermentation, dewatering and frying. Selected heavy metals such as Cr, Cu, Ni, Pb, Zn, Fe, Cd, and Mn in cassava leaf, farm soil, cortex, peel, flour, raw cassava, fermented cassava and gari sample were digested and analyzed using atomic absorption spectrophotometer (GBC avanta version model 2.02).The concentration of the metals Cr, Cu, Ni, Pb, Zn, Fe, Cd and Mn in cassava leaf, soil, cortex, flour, fermented cassava, raw cassava and gari ranged between 0.02-4.86mg/kg, 0.03-3.11mg/kg, 0.02-6.81mg/kg, 0.01-1.15mg/kg, 0.02-2.40mg/kg, 0.04-1.13mg/kg, 0.02-1.41mg/kg and 0.01-1.67mg/kg respectively for Oloibiri; and 0.01-1.24mg/kg, 0.01-1.99mg/kg, 0.01-2.73mg/kg, 0.11-2.03mg/kg, 0.14-4.42mg/kg, 01-1.27mg/kg, 0.01-2.37mg/kg and 0.08-2.03mh/kg respectively for Atan. Results showed that the level of these heavy metals Cr, Cu, Ni, Pb, Zn, Fe, Cd, and Mn in the samples from the two locations did not exceed the permissible limits proposed by WHO/FAO. It was concluded that fermentation was a veritable operating unit in reducing heavy metals from the production of cassava into gari.

Keywords: *Processing, soil, metal, fermentation, cassava, gari, oil field*

1. INTRODUCTION

Nigeria joined the league of oil producing nations on August 3rd, 1956 when crude oil was discovered in Oloibiri, a village in Ogbia Local Government Area Bayelsa State. Today, the nation ranks as the leading oil and gas producer in Africa and the 6th largest oil exporter in the world (Ugbomeh and Atubi, 2010). Crude oil generally has strong negative impacts on the plant community (Osu *et al.,* 2006). Vegetation is often destroyed after a heavy spill; such impacts have been reported on farming activities (Asuquo *et al.*, 2001). According to (Ogbogbodo *et al.*, 2004), oil spillage leads to oxygen deprivation of plant roots, because the oxygen in soil is exhausted by hydrocarbon-degrading micro-organisms, since oil degrading micro organism compete with plants for mineral nutrients.

Heavy metal also refers to any metallic chemical element that has a relative highly density and is toxic or poisonous at low concentrations. Heavy metal can be essential. The essential elements are sometimes called trace elements or micro nutrient because they are essential to plant growth at very low concentrations and an insufficient supply of an essential element will cause deficiency diseases (Batra, 2012). Heavy metals such as Zinc(Zn), Aluminium(Al), Arsenic(As), Barium(Ba), Iron(Fe), Lead(Pb), Cobalt(Co), Chromium(Cr), Manganese(Mn), Mercury(Hg), Cadmium(Cd), Antimony(Sb), Nickel(Ni), and Vanadium(V) have been known to be important group of pollutants in environment (Li *et al.,* 2001).

Heavy metals may find their way into many environments through agricultural crops, soil surface and ground water where they undergo a process of redistribution and are now detected at different levels of concentration in the food chain (Oviasogie and Ukpebor, 2003). Heavy metal contents of soil are of major significance because of their non-degradable nature and ability to accumulate for long period of time, the uncontrolled input of heavy metal in soil through oil spillage is undesirable because once accumulated in the soil, the metals are generally very difficult to remove (Oviasogie and Ukpebor, 2003).

Cassava (*Manihot esculenta)* is originated in Brazil and Paraguay (Jimoh *et al*., 2016). Cassava tuber is a major farm produce in Southern Nigeria. It is usually processed into a variety forms before getting to the consumers. During processing, effluents and other solid wastes are discharged into the environment without any form of treatment. Apart from the fact that cassava effluents contain high cyanide content which has adverse effect on the soil pH, the cassava effluents and other wastes may contain metal ions and other pollutants (IITA, 2005).

In Africa, Cassava processing procedures vary, depending on products, from simple processing (peel, boil and eat) to complicated procedures for processing into *gari,* for example, which involve many more steps, namely peeling, grating, pressing, fermenting, sieving and frying. Some of these steps reduce cyanide more effectively than others. Processing techniques and procedures differ with countries and localities within a country according to food cultures, environmental factors such as availability of water and fuel wood, the cassava varieties used, and the types of processing equipment and technologies available.

Gari is a creamy-white, granular flour with a slightly fermented flavor and a slightly sour taste made from fermented, gelatinized fresh cassava tubers. *Gari* is widely known in Nigeria and other West African countries. It is commonly consumed either by being soaked in cold water with sugar, coconut, roasted groundnuts, dry fish, or boiled cowpea as complements or as a paste made with hot water and eaten with vegetable sauce. When properly stored, it has a shelf-life of six months or more. (IITA, 2005). In view of this, it is imperative to compare the concentration of heavy metals in soil sample due to the environmental degradation by oil spillage and bioaccumulation in gari made from cassava harvested in Oloibiri. This is necessary so as to establish the effect of processing on the residual metals.

2. MATERIALS AND METHODS

2.1 Materials

Cassava roots, cassava leaf and soil samples were obtained from Otuabagi Community, in Ogbai Local Government Area of Bayelsa State. The farm is located at Shell Location 13 in Oloibiri oil field. The same samples were equally obtained from a farm located at Igbele Ajana Village in Atan-Ota community, Ado-Odo / Ota Local Government Area of Ogun State. The non oil field serves as control experiment.

2.2 Methods

2.2.1 Study site

The study site for this research includes Oloibiri Oil spillage, Oloibiri community in Otuabagi, Ogbia Local Government Area of Bayelsa State where there is oil spillage and Atan community in Ado-Odo / Ota Local Government Area of Ogun State. The analyses were done in Food Technology Laboratory of Food Technology and Nutrition, and Central Teaching Research Laboratory, Bells University of Technology, Ota, Ogun State, Nigeria.

2.2.2 Collection of sample and preparation

The cassava roots were harvested from the selected areas in the site. Soil samples, and cassava leaves were also collected from both sites while cassava cortex and peel were obtained from the cassava tuber. 50kg of cassava root was harvested from the site and processed into *Gari* and labeled together with other samples accordingly for analysis.

Cassava tuber
↓
Harvest / Sorting of cassava
↓
Peeling
↓
Washing
↓
Grating
↓
Fermentation → Three Days
↓
Pressing / Dewatering → Two Days
↓
Sieving
↓
Frying
↓
Cooling
↓
Sieving (optional)
↓
Packaging

Fig. 2.1: Process Flow Chart of *Gari*from Cassava Tuber Source: (Oluwole *et al.*, 2004)

Cassava peels harvested from Oloibiri oil field and Atan as shown in Table 3.1 and Table 3.2 revealed that the mean concentrations of heavy metals Cr, Cu, Ni, Pb, Zn, Fe, Cd, and Mn recorded as 1.12 mg/kg, 0.17 mg/kg, 0.30 mg/kg, 0.14 mg/kg, 0.77 mg/kg, 2.17 mg/kg, 0.02 mg/kg and 2.40 mg/kg; 1.89 mg/kg, 0.14 mg/kg, 0.14 mg/kg, 0.37 mg/kg, 0.36 mg/kg, 0.82 mg/kg, N.D and 4.42 mg/kg respectively. It was observed that Cr, Fe and Mn has the highest concentration value of heavy metals in the cassava peel 1.12 mg/kg, 2.17 mg/kg and 2.40 mg/kg; 1.89 mg/kg, and 4.42 mg/kg respectively. Cu from Oloibiri has the least recorded value while Cu from Atan is not detected. It was also observed that all values recorded in cassava peel from the locations were higher than the values recorded in cassava cortex which indicated that absorption of heavy metals from the soil was high.

Plate 2.1:Oloibiri Oil Well

Source: Samuel *et. al*., 2015.

2.3 Digestion Procedure for Analysis of Samples

Heavy metal was determined using Aqua Regia Digestion Method. 130 ml concentrated HCL was added into 120 ml water and mixed; 150 ml of these solution was added to 50 ml concentrated HNO_3 and mixed. One (1.0) g of sieved soil, cassava mash, cassava flour, roasted *gari*, cassava leaf, cortex, and back were weighed into Kjeldahl flask and 15 ml of aqua regia and swirl was added to wet the sample and stand overnight. The next day, the flasks were placed in the heating block and heat at 50 ^oC for 30 minutes, raise the temperature to 100 ^oC and continue heating for 2 hours; cool and 0.25 ml HNO_3 was added and filtered through a Whatman no. 541 filter paper; flask and filter paper were washed with small aliquots of 0.25 ml HNO_3 and then transfer the filtrate and washings into a 50 ml flask and make up to the mark with 0.25 ml. The samples were analysed / determined by Atomic Absorption Spectrometer (AAS Model 451).

2.4 Determination of heavy metals (lead, zinc, iron, cadmium, copper, nickel, chromium, and manganese).

The lead, zinc, iron, cadmium, copper, nickel, chromium and manganese content in the sample solutions were determined using an Atomic Absorption Spectrophotometer (GBC Avanta Version Model 2.02) with air acetylene flame at specific wavelength for each metal. The digested sample was passed into the burner through a mixing chamber, the air met the fuel gas (C_2H_2), acetylene supplied to the burner at a given pressure and this mixture was burnt, the radiations from the resulting flame were read.

3. RESULTS AND DISCUSSION

3.1 Metal Concentrations in Soil, Cassava Roots and Other Cassava Products from Oloibiri, Bayelsa State and Atan, Ogun State.

The cassava leaf, fermented cassava, farm soil, cassava cortex, cassava flour (from cassava root to flour), cassava peel, raw cassava and gari samples from oil field and non oil field area (Oloibiri and Atan) investigated reveal varying concentrations on all eight analyzed heavy metals (Cr, Cu, Ni, Pb, Zn, Fe, Cd and Mn). The result of all the samples metal concentrations were shown in Tables 3.1 and 3.2 respectively.

The mean concentrations of heavy metals in soil sampled at Oloibiri oil field recorded 1.01 mg/kg, 0.19 mg/kg, 0.28 mg/kg, 0.52 mg/kg, 0.67 mg/kg, 5.88 mg/kg, 0.03 mg/kg, and 3.11 mg/kg for Cr, Cu, Ni, Pb, Zn, Fe, Cd, and Mn respectively. At Atan non oil field (control) mean concentrations of Cr, Cu, Ni, Pb, Zn, Fe, Cd, and Mn recorded 1.88 mg/kg, 0.10 mg/kg, 0.17 mg/kg, 0.45 mg/kg, 0.19 mg/kg, 1.99 mg/kg, 0.01 mg/kg, and 3.36 mg/kg respectively (table 4.5a and 4.5b). There was a slight significant difference between farm soils sample from Oloibiri oil field and Atan oil field. It was observed that Fe had the highest mean concentration of 5.88 mg/kg from Oloibiri oil field and Mn has high mean concentration of 3.36 mg/kg from Atan non oil field, while Cd had the least mean concentration of 0.03 mg/kg and 0.01 mg/kg at both locations respectively as shown in Table 3.1 and Table 3.2.

Table 3.1 and Table 3.2 further shows that cassava leaf has high metal concentration values. The mean concentrations from Oloibiri oil field recorded are 0.3 mg/kg, 0.09 mg/kg, 0.15 mg/kg, 0.06 mg/kg, 0.98 mg/kg, 4.86 mg/kg, 0.02 mg/kg and N.D for Cr, Cu, Ni, Pb, Zn, Fe, Cd, and Mn respectively. At Atan, mean concentrations of Cr, Cu, Ni, Pb, Zn, Fe, Cd, and Mn recorded are 1.24 mg/kg, 0.09 mg/kg, 0.14 mg/kg, N.D, 0.64 mg/kg, 0.37 mg/kg, 0.01 mg/kg and N.D respectively. It was observed that Cd from Table 3.1 and Table 3.2 has the least value 0.02 mg/kg from Oloibiri and 0.01 mg/kg from Atan while Fe has the highest value 4.86 mg/kg from Oloibiri and Cr has highest value 1.24 mg/kg from Atan. It was recorded that Mn from both Tables were not detected likewise Pb from Atan .

Table 3.1: **Concentration of Heavy Metals in Soil, Cassava Leaf, Peel, Cortex, Flour, Raw cassava, Fermented Cassava and *Gari* Harvested from Oloibiri Oil Well, Bayelsa State.**

Sample	Cr	Cu	Ni	Pb	Zn	Fe	Cd	Mn
OFS	1.27 ± 0.01	0.19 ± 0.02	0.28 + 0.23	0.52 ± 0.04	0.67 ± 0.05	5.88 ± 0.63	0.03 ± 0.03	0.11 ± 0.24
OCL	0 .36 ± 0.04	0.09 ± 0.01	0.15 ± 0.01	0.06 ± 0.01	0.98 ± 0.07	4.86 ± 0.18	0.02 ± 0.01	N.D
OCP	1.12 ± 0.07	0.17 ± 0.03	0.30 ± 0.02	0.14 ± 0.04	0.77 ± 0.15	2.17 ± 0.21	0.02 ± 0.01	2.40 ± 0.99
OCC	0.67 ± 0.01	0.05 ± 0.01	0.15 ± 0.01	0.35 ± 0.17	1.35 ± 0.19			

						6.81 ± 0.83	0.02 ± 0.00	1.04 ± 0.12
OCF	0.95 ± 0.04	0.01 ± 0.01	0.11 ± 0.00	0.04 ± 0.04	0.73 ± 0.38	1.15 ± 0.66	0.01 ± 0.00	0.59 ± 0.36
ORC	1.07 ± 0.02	N.D	0.07 ± 0.01	N.D	0.47 ± 0.00	1.41 ± 0.02	0.02 ± 0.01	0.14 ± 0.01
OFC	0.52 ± 0.02	0.01 ± 0.01	0.07 ± 0.01	0.04 ± 0.03	0.42 ± 0.01	1.13 ± 0.11	0.61 ± 0.03	0.12 ± 0.01
OGA	1.00 ± 0.01	N.D	0.08 ± 0.12	N.D	1.01 ± 0.01	1.67 ± 0.07	0.01 ± 0.01	0.14 ± 0.00

Mean value ± standard deviation

Key:
OFS = Oloibiri farm soil *OCP = Oloibiri cassava peel* *OCF = Oloibiri cassava flour* *OFC = Oloibiri fermented cassava*
OCL = Oloibiri cassava leaf *OCC = Oloibiri cassava cortex* *ORC = Oloibiri raw cassava* *OGA = Oloibiri gari*

Table 3.2: Concentration of Heavy Metals in Soil, Cassava Leaf, Peel, Cortex, Flour, Raw cassava, Fermented Cassava, and *Gari* Harvested from Atan Non Oil Field, Ogun State.

Sample	Cr	Cu	Ni	Pb	Zn	Fe	Cd	Mn
AFS	1.88 ± 0.02	0.10 ± 0.01	0.17 ± 0.00	0.45 ± 0.05	0.19 ± 0.02	1.99 ± 0.87	0.01 ± 0.01	3.36 ± 0.68
ACL	1.24 ± 0.01	0.09 ± 0.02	0.14 ± 0.02	N.D	0.64 ± 0.29	0.37 ± 0.02	0.01 ± 0.01	ND
ACP	1.89 ± 0.02	0.14 ± 0.01	0.14 ± 0.00	0.37 ± 0.03	0.36 ± 0.01	0.83 ± 0.02	N.D	4.42 ± 0.10
ACC	1.68 ± 0.02	0.01 ± 0.00	0.11 ± 0.01	0.28 ± 0.05	0.45 ± 0.01	2.73 ± 0.06	0.03 ± 0.01	0.65 ± 0.01
ACF	2.03 ± 0.04	N.D	0.13 ± 0.01	0.24 ± 0.02	0.23 ± 0.01	0.85 ± 0.08	N.D	0.11 ± 0.00
ARC	2.37 ± 0.13	N.D	0.08 ± 0.00	0.32 ± 0.05	0.18 ± 0.02	0.61 ± 0.06	0.01 ± 0.00	0.01 ± 0.00
AFC	1.27 ± 0.01	N.D	0.06 ± 0.00	0.10 ± 0.03	0.24 ± 002	0.58 ± 0.03	0.01 ± 0.01	0.01 ± 0.01
AGA	2.03 ± 0.04	N.D	0.13 ± 0.01	0.24 ± 0.02	0.23 ± 0.01	0.85 ± 0.08	N.D	0.11 ± 0.00

Mean value ± standard deviation.

Key:

AFS = Oloibiri farm soil ACP = Oloibiri cassava peel ACF = Oloibiri cassava flour AFC = Oloibiri fermented cassava
ACL = Oloibiri cassava leaf ACC = Oloibiri cassava cortex ARC = Oloibiri raw cassava AGA = Oloibiri gari

In the cortex of cassava roots harvested from Oloibiri oil field and Atan, the mean values of heavy metals for Cr, Cu, Ni, Pb, Zn, Fe, Cd, and Mn were recorded as 0.67 mg/kg, 0.05 mg/kg, 0.15 mg/kg, 0.35 mg/kg, 1.35 mg/kg, 6.81 mg/kg, 0.02 mg/kg and 1.04 mg/kg respectively while Atan were recorded as 1.68 mg/kg, 0.01 mg/kg, 0.11 mg/kg, 0.28 mg/kg, 0.45 mg/kg, 2.73 mg/kg, 0.02 mg/kg and 0.65 mg/kg respectively with Fe being the highest value of 6.81 mg/kg and 2.73 mg/kg while Cu and Cd have least value of 0.02 mg/kg and 0.01 mg/kg as shown in Table 3.1 and Table 3.2. It was also observed that all concentration values of cassava cortex recorded are lower than the values recorded in cassava peels samples which indicated that heavy metals accumulation in cassava is reduced when the peel particularly the corky layer is removed.

All heavy metals in cassava flour (cassava roots was peeled, dried and grind into flour) at Oloibiri oil field recorded higher values than cassava roots at Atan, except for Cu and Cd which were not detected at Oloibiri oil field. In the cassava roots harvested at Oloibiri oil field, the mean concentrations of heavy metals Cr, Cu, Ni, Pb, Zn, Fe, Cd, and Mn recorded 0.95 mg/kg, 0.01 mg/kg, 0.11 mg/kg, 0.04 mg/kg, 0.73 mg/kg, 1.15 mg/kg, 0.01 mg/kg, and 0.59 mg/kg respectively. And Atan mean concentrations of Cr, Cu, Ni, Pb, Zn, Fe, Cd, and Mn recorded 2.03 mg/kg, N.D, 0.13 mg/kg, 0.24 mg/kg, 0.23 mg/kg, 0.85 mg/kg, N.D, and 0.11 mg/kg as shown in Table 3.1 and Table 3.2) respectively. It was observed that Fe is high from Oloibiri oil field while Cr is high from Atan, Cu and Cd were the least from Oloibiri oil field while Cu and Cd were not detected in Atan. It was observed that all the values recorded from farm soil were higher than the values recorded from cassava root (flour) samples which indicated high accumulation of heavy metals in soil.

In the raw cassava (cassava mash) harvested at Oloibiri oil field, the mean concentrations of heavy metals Cr, Cu, Ni, Pb, Zn, Fe, Cd, and Mn recorded are 1.07 mg/kg, N.D, 0.07 mg/kg, N.D, 0.47 mg/kg, 1.41 mg/kg, 0.02 mg/kg, and 0.14 mg/kg respectively. And Atan mean concentrations of Cr, Cu, Ni, Pb, Zn, Fe, Cd, and Mn recorded are 2.37 mg/kg, N.D, 0.08 mg/kg, 0.32 mg/kg, 0.18 mg/kg, 0.61 mg/kg, 0.01 mg/kg, and 0.01 mg/kg as shown in Table 3.1 and Table 3.2 respectively with Cu being not detected from the locations and Fe from Oloibiri oil field and Cr from Atan has been revealed to be high and Cd to be the least from the two locations.

From Table 3.1 and Table 3.2, the mean value of heavy metals in fermented cassava from Oloibiri oil field and Atan were recorded as follows: 0.52 mg/kg, 0.01 mg/kg, 0.07 mg/kg, 0.04 mg/kg, 0.42 mg/kg, 1.13 mg/kg, 0.61 mg/kg, 0.12 mg/kg; and 1.27 mg/kg, N.D, 0.06 mg/kg, 0.10 mg/kg, 0.24 mg/kg, 0.58 mg/kg, 0.01 mg/kg, and 0.01 mg/kg respectively. The results showed that there was a slight significant difference in cassava harvested from Oloibiri oil field and Atan after fermentation which shows that fermentation and dewatering process actually reduced slightly compared to Atan samples. Cr, Zn, Fe, and Cd have the high concentration value of heavy metals (1.27 mg/kg from Atan, 0.42 mg/kg, 0.24 mg/kg, 1.13 mg/kg, 0.58 mg/kg and 0.61 mg/kg) respectively while Cu is not detected from Atan samples.

In the gari produced from cassava harvested from Oloibiri oil field and Atan shows that heavy metals actually reduced from cassava after processing. The mean concentrations of heavy metals Cr, Cu, Ni, Pb, Zn, Fe, Cd, and Mn are 1.00 mg/kg, N.D, 0.08 mg/kg, N.D, 1.01 mg/kg, 1.67 mg/kg, 0.01 mg/kg, 0.14 mg/kg and 2.03 mg/kg, N.D, 0.13 mg/kg, 0.24 mg/kg, 0.23 mg/kg, 0.85 mg/kg, N.D and 0.11 mg/kg respectively. Cr and Fe have the highest concentration value of 1.00 mg/kg and 1.67 mg/kg for Oloibiri; and 2.03 mg/kg and 0.85 mg/kg for Atan. and Cd from Oloibiri oil field has the least value while Cu from both location were not detected, Pb and Cd from Oloibiri oil field and Atan were not detected as well.

4. CONCLUSION AND RECOMMENDATION

Crude oil spillage on agricultural lands in Niger Delta, Oloibiri precisely has led to the building up of ample heavy metals in the soil. The study revealed that Oloibiri soil is contaminated with heavy metals particularly Cu, Pb, Zn, and Fe. Cassava plants grown on this soil accumulate reasonable amount of these metals. These elements are essential because they are associated with enzyme systems and other biochemical processes in the body. In spite of these benefits, they cannot be regarded as essential to life if they are higher than WHO recommendation in human body. Cr and Ni are higher with 1.27±0.01 mg/kg and 0.28±0.23 mg/kg respectively as against recommended concentration 0.09 mg/kg and 0.10 mg/kg respectively (Reilly, 2004). Once the total body burden is exceeded, disease conditions may arise. It is therefore pertinent to educate both vendors and consumers on the need for proper handling of food in the face of our polluted environment.

The result of this study has shown that processing methods are veritable tools in reducing the heavy metal content of cassava. Fermentation reduced some of the heavy metals present in the harvested cassava from Oloibiri oil field and when cassava is processed into gari, it gives appreciable safety.

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Influence of Moisture Content on Thermal Properties of Neem (*Azadirachta indica*) Seeds in Adamawa State, Nigeria.

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ABSTRACT

This study investigated the influence of moisture content on thermal properties of neem (Azadirachta indica) seeds from the three senatorial districts of Adamawa State. A randomized complete block design comprising of twelve treatments with three replications were used. The initial moisture contents of the neem seeds were determined before and after oven drying. Moisture conditioning was obtained in four moisture levels (12.1, 14.6, 17.5 and 20.4% d.b). The study revealed that thermal properties determined were directly influenced by moisture content. The results obtained showed an increased range of 1197.10 – 3186.47 J/kgK, 0.01327 – 0.02229 W/mK and 9.35 x 10^{-9} – 1.21 x 10^{-8} m^2/s for specific heat capacity, thermal conductivity and thermal diffusivity respectively. The bulk density (559.99 – 706.1 kg/m^3) of the neem seeds increased with increase in moisture. The effect of moisture content on the thermal properties was found to be significant ($p \leq 0.05$) with the exception of thermal conductivity which is not significant at 5% level. The results obtained will provide useful information for potential processors and engineers in handling, processing and developing neem seed processing machines. Further studies on other engineering properties of neem seed (physical, terminal velocity, aerodynamics etc) are needed to have comprehensive data in the study area.

Keywords: *Moisture content, Azadiracta indica, Seeds, Bulk density, Thermal properties, Adamawa State, Nigeria.*

1.0 INTRODUCTION

Neem (*Azadirachta indica* A. Juss) is a plant of the Meliaceae family belonging to the Indian subcontinent (Nde *et al.,* 2013) and later introduced into many tropical countries of America and Africa and adapted favourably to the sub-sahelian Nigeria with severe drought, poor, shallow and even saline soil. Neem trees occupy above 3,500 ha of land in Kebbi, Sokoto, Borno and Zamfara in Northern Nigeria, with a density of about 1,200 trees per ha to serve as wind break (Fujinmi *et al.,* 1990). It grows on almost all types of soils including clayey, saline and alkaline soils, it prefers a soil pH of 6.2-7.0, but can grow within a range of pH 5.0-10.0 (Stoney, 1997). It is an ancient belief that neem growing inside the house can keep the surrounding air clean of impurities and thereby control environmental pollution and desertification. Also, hanging neem twigs on the door of a house is said to offer protection against pollution and disease (Girish and Shankara, 2008). Thass (2008) stated that neem seeds have high concentration oil and is used to cure diseases related to glands, leprosy, ulcers, rheumatism (external application), hair tonic, sore throat, soap production, medicines, pesticides and coating urea to reduce nitrogen loss in fertilized soil. The oil and powder are also used in medicated soaps, both pastes and washing soap etc. Neem Oil is generally recommended for skin diseases while neem leaves are used for beauty purposes. Neem leaves can also be used against mosquito proliferation, as insect repellent and to protect crops against locust infestations. It has been described as the most researched tree in the world (Girish and Shankara, 2008) and is said to be the most promising tree of 21st century (Nde *et al.,* 2013). However, potential processors find it difficult to store neem seeds (including its fruits/kernel) and develop machines for its processing. The difficulty ranges from preferred moisture content for storage, processing and thermal properties (including other engineering properties/parameters) in processes such as drying, boiling, roasting, canning and for the design of food processing equipment. This study determined the moisture content of the neem seeds at harvest and the effects of moisture content on the thermal properties of the seeds in order to provide useful information and data on the behavior of neem seeds as a function of moisture in a bid to optimize the various unit operations involved in its post-harvest processing.

2.0 MATERIALS AND METHODS

2.1 The study Area

Adamawa State is located on the north eastern part of Nigeria. It lies between latitude 7° and 11°N, and longitude 11° and 14°E of the Greenwich Meridian and shares boundaries with Taraba State in the south- western part, Gombe State in the north-western part and, Yobe and Borno States to the north. Adamawa State has an international boundary with the Cameroun Republic up along its eastern side. The state covers a land area of about 38,741 Sq. km. The mountainous land-forms between Adamawa State and the Cameroun Republic provide an effective political boundary (Alfred and Mathias, 2015). The major vegetation formations in the state are the Southern Guinea Savannah, Northern Guinea Savannah and the Sudan Savannah. Within each formation is an inter species of thick tree savannah, open grass savannah and fringing forest in the river valleys (Akosim *et al.,* 1999).

2.2 Sample Preparation

Ripe neem (Azadirachta indica) fruits were obtained from the three Senatorial Zones of Adamawa State and used for the purpose of this study. They are manually cleaned to remove all contaminants/foreign materials and damaged or broken ones. The fruits from the different locations were depulped separately to obtain the seeds, which were sundried for three days (Kawuyo *et al.,* 2011) to reduce the moisture content to a level at which mould growth and prevent germination. The moisture content at this stage was calculated using Equation 1;

$$M.C\ \% = \frac{M_i - M_f}{M_f} \times 100 \qquad (1)$$

Where; M.C is the Moisture Content (%), M_i = the initial moisture content of sample (%) and M_f = the final moisture content of sample (%)

2.3 Moisture conditioning

The initial moisture contents at (d.b) of the seeds were determined by oven drying (at 103$\pm$1 ^oC) the samples until a relatively constant weight was achieved/reached (Adedeji *et al.,* 2015 and

Kawuyo *et al.*, 2011). Distilled water was added to the sample and sealed in separate polythene bags which were kept in a refrigerator at 4°C (Yang *et al.*, 2002) for seven days to allow even distribution of water to the seeds. The quantity of distilled water added was calculated as;

$$Q = \frac{W_i(M_f - M_i)}{(100 - M_f)} \quad (2)$$

Where; Q = the mass of water added (kg), W_i = the mass of sample (kg), M_i = the initial moisture content of sample (%) and M_f = the final moisture content of sample (%)

The moisture content determination was replicated three times and the mean and standard deviation values were calculated. The thermal properties considered were determined by using fifty (50) seeds for each of the properties.

2.4 Bulk density

The bulk density was determined by weighing an empty cylinder and then filling it with seeds and re-weighing. The data obtained was used to compute the bulk density using equation 3. Three replicas were carried out and their mean and standard deviation values determined.

$$\rho = \frac{M_2 - M_1}{V} \quad (3)$$

Where; ρ = bulk density of seed (kg/m^3), M_1 = mass of empty cylinder (kg), M_2 = mass of cylinder plus seed (kg) and V = volume of cylinder (m^3)

2.5 Specific heat capacity

The primary thermal properties of food and agricultural products are specific heat, thermal conductivity and thermal diffusivity. Specific heat is the property needed in the estimation of the amount of energy required to change the temperature of a product, while thermal conductivity and thermal diffusivity are involved in the determination of the rate of heat transfer for efficient process and equipment design (Wallapapan and Sweat, 1982 and Aviara *et al.*, 2008)..The specific heat also called specific heat capacity of the calorimeter was determined by method of mixture as described by Ojo and Ugbor (1991). The data obtained were used in equation 4 to obtain the specific heat capacity of the calorimeter used. This method was prescribed by Aviara and Haque (2001). Three replicates of 50 seeds each were carried out and their mean recorded.

$$C_c = \frac{M_{hw}C_w(T_{hw} - T_e) - M_{cw}C_{cw}}{T_e - T_{cw}} \quad (4)$$

Where; M_{hw} is the mass of hot water, (kg), M_{cw} is the mass of cold water, (kg), T_{hw} is temperature of hot water, (K), T_e is the temperature at equilibrium, (K), T_{cw} is the temperature of cold water, (K) and C_w is the specific heat capacity of water = 4200 J/kg/K. To determine the specific heat of the seeds, a sample of known mass, temperature and moisture content (12.1, 14.6, 17.5 and 20.4% d.b) were dropped into the calorimeter containing water of known mass and temperature. The mixture was stirred continuously usinga copper stirrer and the temperature was recorded at a specific interval. At equilibrium, the final temperature was noted and the specific heat was calculated using the equation (Aviara and Haque, 2001):

$$C_s = \frac{(M_cC_c + M_wC_w)[T_w - (T_e + t'R')]}{M_s[(T_e + t'R') - T_s} \quad (5)$$

where: C_C, $C_S$and C_W= the specific heats of calorimeter, sample and water, respectively (J kg^{-1} K^{-1}), M_C, $M_S$and M_W = the masses of calorimeter, sample and water (kg), respectively, R' = the rate of temperature fall of the mixture after equilibrium (Ks^{-1}), *Te* = the equilibrium temperature of the sample and water mixture (K), T_S, and T_W= the initial temperatures of sample and water, respectively (K), and *t'* = the time taken for the sample and water mixture to come to equilibrium (s). The term *t'R'* = the heat of hydration and heat exchange with the surroundings (Ikegwu and Ezeh, 2012). The experiment was replicated three times at each moisture content level and the average values of the specific heat were recorded.

2.6 Thermal conductivity

Walter (1970) stated that thermal conductivity K is the rate of flow of heat through the material, per unit area, per unit temperature gradient. For the calculation of the thermal conductivity of the grain bulk, the amount of heat absorbed by water was determined. The thermocouple reading was taken to signify the temperature at the cross-section (Alagusundaram *et al*., 1991). The thermal conductivity is measured using the following relationship:

$$K = \frac{QL}{A\delta T} \qquad (6)$$

Where; K = Thermal conductivity (W/mk), Q = Quantity of heat supplied (W/m), δT = Temperature gradient (K), A = Area of sample (m^2) and L = Thickness of sample (m)

2.7 Thermal diffusivity

The thermal diffusivity was obtained using the known value of thermal conductivity; specific heat and bulk density. The relation is given in equation 7 below;

$$\alpha = \frac{K}{\rho C_p} \qquad (7)$$

Where; α = thermal diffusivity (m^2/s), K= thermal conductivity (W/mk), ρ = bulk density (kg/m^3) and C_p = specific heat (J/kgK)

3.0 RESULTS AND DISCUSSION

The initial moisture contents of the neem seeds were determined before drying were 21.66, 20.75 and 21.40% (d.b) and the corresponding values after oven drying were 9.7, 7.5 and 8.9% (d.b) for the samples from Adamawa north, central and southern senatorial districts respectively. These seeds were later conditioned to 12.1, 14.6, 17.5 and 20.4% (d.b) moisture levels which were used for the experiments. The bulk density of the neem seeds increased (559.99 – 706.1 kg/m^3) with increase in moisture (Figure 1). The bulk density increased because of an increase in mass due to increase in moisture absorbed by the seeds. Bulk density of agricultural products is important in the design of silos and bins, maturity and quality evaluation of products which are essential in grain marketing (Fabunmi *et. al.,* 2013). Similar results were reported for neem fruits, seeds and kernels (Nde *et. al.,* 2013), Desma seeds (Fabunmi *et. al.,* 2013).

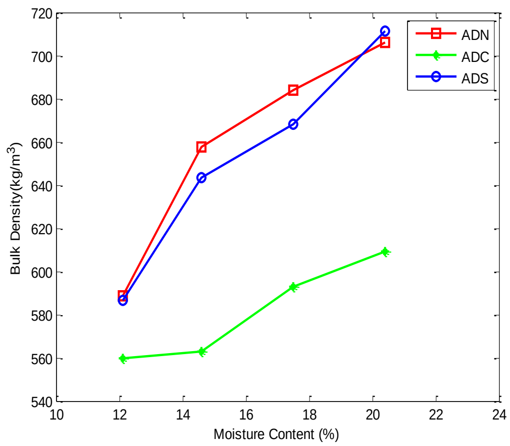

Figure 1: Relationship between Bulk Density and Moisture Content

Figure 2 shows an increasing trend with moisture content with respect to specific heat from 1197.1 to 1889.5 J/kgK, 1413.28 to 2880.9 J/kgK and 1939.98 to 3186.47 J/kgK for northern, central and southern senetorial districts respectively as the moisture increased from 12.1 to 20.4%. This means that less energy is needed to heat neem seeds from the nothern zone than those from the two other zones to reach drying temperatures during drying process. The specific heat will be useful in thermal processing of seeds and especially in predicting its thermal behavior and designing of the drying process. Nauri *et al.* (2011) observed same for two varieties of barley, Singh and Goswami (2000) for cumin sseds, Aviara *et. al.* (2008) for guna seeds and Yang *et. al.* (2002) for borage seeds.

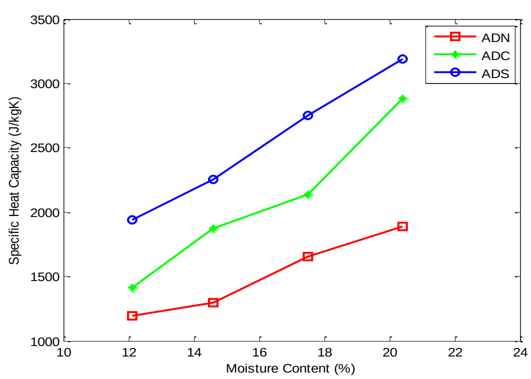

Figure 2: Relationship between Specific Heat Capacity and Moisture Content

The thermal conductivity of the neem seeds was observed to increase with increase in moisture content from 12.1 to 20.4% in the three zones. The thermal conductivity ranges from 0.01494 to 0.01613 W/mK, 0.01582 to 0.02229 W/mK and 0.013278 to 0.01531 W/mK for northern, central and southern zones respectively. The variation might be due to the climatic variation of the three zones. This also means that heat transmission in neem seeds is better when wet than dried. Similar trends were observed by Abioye *etal.* (2016) for Bambara groundnut, Aremu *et al.* (2010) for Duom palm fruits, and Rashid *et al.* (2015) for chia, kaniwa, triticale and farro seeds. The effect of moisture content was not significant ($p \leq 0.05$) on thermal conductivity (*Table 1*).

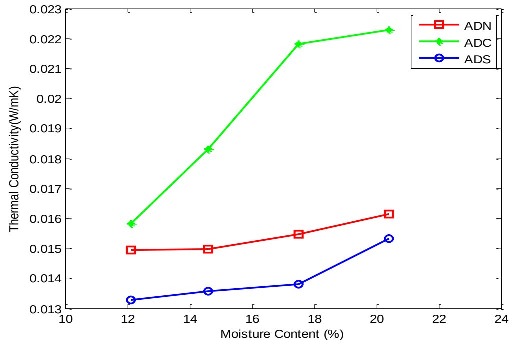

Figure 3: Relationship between Thermal Conductivity and Moisture Content

However, *Figure 4* shows that thermal diffusivity from the three zones investigated varied from 2.12×10^{-8} to 1.12×10^{-8} m^2/s, 2.00×10^{-8} to 1.27×10^{-8} m^2/s and 1.17×10^{-8} to 6.75×10^{-9} m^2/s for Adamawa northern, central and southern zones respectively. This shows that there is decrease in thermal diffusivity with increase in moisture content. The decrease might be due to the fact that the value of bulk density increases with increase in moisture content. Similar resuls were reported by Ikegwu and Ezeh (2012) for kerstingiella seeds, Aremu and Fadele (2010) for doum palm fruits, Aviara *et al.* (2008) for guna seeds and contrary to Aviara and Haque (2001) for shear nut to have increased with increase in moisture moistue contents. *Table 1* shows that the effect of moisture content was significant ($p\leq0.05$) on thermal diffusivity.

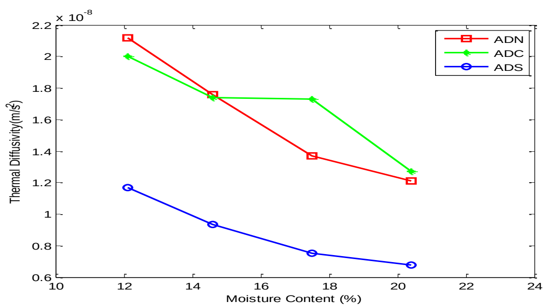

Figure 4: Relationship between Thermal Diffusivity and Moisture Content

4.0 CONCLUSION

The results obtained in this study showed that moisture content influences specific heat capacity and thermal diffusivity but did not have influence on thermal conductivity. These results provide useful information for potential processors and engineers in handling and developing neem seed processing machines. The data provided on thermal properties are useful in processes such as drying, boiling, roasting, canning and for the design of food processing equipment. The results obtained for these seeds and others should be used to establish a database of engineering properties in Adamawa State for farmers, processors, food scientists and agricultural engineers. Further studies on other engineering properties of neem seed (physical, terminal velocity, aerodynamics etc.) are needed to have a comprehensive data in the study area.

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Table 1: Analysis of Variance (Mean Square) for Bulk Density (kg/m^3), Specific Heat Capacity (S.H.C) (J/kgK), Thermal Conductivity (T.C) (W/mK) and Thermal Diffusivity (T.D) (m^2/s) of Neem Seeds.

Sources of Variation	DF	Bulk Density	S.H.C	T.C	T.D
Replication	2	137.9729^{ns}	1753465.263^{ns}	0.000338^{ns}	$4.1091\times 10^{-19\ ns}$
Treatment	11	9602.7198*	1182386.432^{ns}	0.006085^{ns}	$6.8315 \times 10^{-17\ *}$
Zone	2	6321756.75*	65662293.95*	0.004335^{ns}	3.0961×10^{-15} *
Moisture Content (M.C)	3	4214545.87 *	43760920.87*	0.002833^{ns}	2.0725×10^{-15} *
M.C*Zone	6	4232130.177*	45935600.21*	0.002972^{ns}	2.1935×10^{-15} *
Error	22	245.258	1314008	0.00298	2.1583×10^{-19}

** Significant at 0.05% level, ns not significant*

Parameter	Units	Zones	Moisture Content 12.10%	14.60%	17.50%	20.40%
Bulk Density	kg/m^3	AND	588.51±7.60	657.56±4.99	683.78±5.07	706.10±0.63
		ADC	559.99±10.80	563.14±6.38	592.80±18.45	609.47±14.20
		ADS	586.43±7.58	643.39±9.15	668.36±7.28	711.40±8.84
Thermal Properties						
Spec. Heat Capacity	J/kgK	AND	1197.10	1292.57	1654.54	1889.50
		ADC	1413.28	1870.70	2133.46	2880.29
		ADS	1939.98	2254.49	2750.65	3186.47
Thermal Conduct.	W/mK	AND	0.01494	0.01498	0.01548	0.01613
		ADC	0.01582	0.01830	0.02183	0.02229
		ADS	0.01327	0.01356	0.01379	0.01531
Thermal Diffusivity	m^2/s	AND	2.12×10^{-8}	1.76×10^{-8}	1.37×10^{-8}	1.21×10^{-8}
		ADC	2.00×10^{-8}	1.74×10^{-8}	1.73×10^{-8}	1.27×10^{-8}
		ADS	1.17×10^{-8}	9.35×10^{-9}	7.50×10^{-9}	6.75×10^{-9}

Table 2: Thermal Properties of Neem (*Azadirachta indic*a) Seed

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DETERMINATION OF MOISTURE DIFFUSIVITY AND ACTIVATION ENERGY IN DRYING OF PRAWN FILLETS

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ABSTRACT

Effective moisture diffusivity and activation energy are important parameter needed for designing, modeling and optimizing drying of food products. This study investigated the moisture diffusivity and activation energy obtained from thin layer drying studies of prawn fillets. Freshwater prawns were filleted and pretreated by brining in different levels of sodium chloride solutions (2, 4 and 6%) with a control (untreated) and dried in a laboratory oven at three temperatures of 50, 60 and 70 °C. Drying rate curves were developed for the different experimental treatment. The moisture diffusivity was then determined using Fick's second law from drying data obtained. Results showed that thin layer drying of the prawn fillets was predominately in the falling rate drying period as the constant rate drying period was brief hence it could be said to be a diffusion controlled process. The effective moisture diffusivity ranged from 3.66×10^{-7} to 7.52×10^{-7} m²/s for prawn fillets while the value of activation energy varied from 39.09 to 40.86 kJ/mol at different levels of pretreatment. Results obtained are useful in ascertaining the moisture migration mechanism of seafood products for optimization of drying process and equipment design.

Keyword: *Moisture Diffusivity, Activation Energy, Drying, Prawn, Fillets*

1.0 INTRODUCTION

Freshwater prawns of the genus *Macrobrachium* is a highly relished crustacean commonly found in Niger Delta region of Nigeria. It is a very popular spice in the tropics where they are used as nutritional flavour and valuable human food and are sold in fish markets all over the world. It is a rich source of protein, lysine, sulphur and amino acids and is therefore suitable for complementing high carbohydrate. It is also a good source of thiamine, riboflavin, vitamin D and A, phosphorus, calcium and iron. It is high in poly-saturated fatty acids which are important in lowering blood cholesterol level. Therefore diets made of prawns are highly appreciated by many climes. But these nutritious and tasty biomaterials are highly perishable and post harvest losses of 35% of the daily catches are estimated (Ikrang *et al*., 2015), hence the need to reduce these losses by means of preservation. Amongst all the preservation methods available in this locale, drying is the cheapest and easiest.

Moisture removal is one of the methods employed to preserve agricultural and food products after harvesting (Akulich and Militzer, 1998; Kulasiri and Woodhead, 2005; Akpan *et al*., 2016). The drying of agricultural and food materials involves simultaneous heat and mass transfers to and from materials (Murugesan *et al*., 2002; Magaris and Ghiaus, 2007). Hence, internal mass transfer has been known to be a major limiting factor in the drying of biomaterials (Luikov, 1970; Doymaz, 2005). For capillary-porous colloidal foods like fish, meat, prawns, vegetables and tissues, the moisture migration mechanisms takes place due to vapour diffusion as a result of partial vapour pressure gradient and thermo-gradient effects. Consequently, several drying kinetics theories on the mechanism of moisture migration have been proposed for food materials. Therefore, knowledge of transport properties such as moisture diffusivity and activation energy is needed for application in modeling and simulation of mass transfer processes during drying and storage (Karanthanos, 1999; Krokida *et al*, 2003; Burubai, 2017). To optimize the drying process, studies must be conducted to understand the drying behaviour of freshwater prawns which has scarce information in literature. The knowledge of effective moisture diffusivity and activation energy is necessary for designing and modelling the mass transfer processes such as dehydration or moisture adsorption during storage. The main objective of this work was to determine the effective moisture diffusivity and activation energy of prawns (*M. felicinum*) during thin layer drying process as influenced by drying air temperatures and pretreatments.

2.0 MATERIALS AND METHODS

2.1 Drying Experiments

Fresh prawns (*Macrobrachium felicinum*) were obtained from Ibeno Ishiet in Akwa Ibom State and scientific classification was carried out at the fish culture laboratory, Department of Zoology, Obafemi Awolowo University, Ile-Ife, Nigeria. Prior to the drying process, the prawn samples were washed, heads removed, descaled and divided into four portions of 200 g each; three of the portions were pretreated by brining in different levels of sodium chloride (NaCl) solutions (2, 4 and 6%) while one portion was used as control (untreated sample). The thin layer drying of the filleted prawns was carried out at three different drying temperatures of 50, 60 and 70 ºC, respectively. The samples were weighed at intervals of 30 minutes during the drying process and their weight loss recorded until a constant weight was observed for three consecutive measurements; at this point the dried prawns were assumed to have attained equilibrium moisture content with the drying air condition. This method was also documented by (Mujaffar, 2006; Niamnuy *et al*., 2007; Sacilik, 2007; Ikrang *et al*., 2014 and Olaoye *et al*., 2017). The initial and final moisture contents of the prawn fillets were determined at 103 ºC for 4 hours using oven drying method (AOAC, 2000).Data obtained from the thin layer drying process was used to determine the drying rate and the influence of drying temperatures and pretreatments on the effective moisture diffusivity and activation energy of prawn (*Macrobrachium felicinum*) fillets was investigated.

2.2 Theoretical principle

The drying rate of prawns was calculated according to Omid, *et al*., 2006 as follows

$$DR = \frac{M_{t+dt} - M_t}{dt} \tag{1}$$

Where:
DR is drying rate, g/min
M_t is mass at time t, g
$M_{t+dt}$is the successive mass, g
dt is time interval, min.

The effective moisture diffusivity for an infinite slab was calculated using Fick's second law based on Equation (2) as reported by Crank, 1975

$$MR = \frac{M}{M_o} = \frac{8}{\pi^2}\sum_{n=0}^{n-1}\frac{1}{(2n-1)^2}exp\left(-\frac{(2n-1)^2\pi^2 D_{eff}t}{4L^2}\right) \quad (2)$$

Where:

MR is the moisture ratio
M is the moisture content at any time (g water/g dry matter)
M_o is the initial moisture content (g water/g dry matter)
t is time of drying (s)
$D_{eff}$is effective moisture diffusivity (m^2/s)
$L$is the thickness of the fillets (m)

For long drying periods as in the case of prawn fillets, Eq. (2) can be further simplified to only the first term of the series (Tutuncu and Labuza, 1996). Thus equation (3) can be written in the logarithmic form as:

$$\ln(MR) = ln\left(\frac{8}{\pi^2}\right) - \left(\frac{\pi^2 D_{eff}t}{4l^2}\right) \quad (3)$$

The effective moisture diffusivity (D_{eff}) was calculated using the method of slope. The effective moisture diffusivity was determined by plotting experimental drying data in terms of ln(MR)versus drying time(t). The plot yields a straight line with a slope k as in Eq. (4), from which the effective diffusivity was computed.

$$k = \frac{\pi^2 D_{eff}}{l^2} \quad (4)$$

Where:

k is the slope
$D_{eff}$is effective moisture diffusivity (m^2/s)
L is thickness of the fillets (m)

The activation energy was calculated using an Arrhenius type equation (Simal, *et al.*, 2005):

$$D_{eff} = D_o \exp\left(-\frac{E_a}{RT_a}\right) \quad (5)$$

Where:

$E_a$is energy of activation (kJ/mol)
$R$is universal gas constant (8.3143kJ/mol K)
$T_a$is absolute air temperature (K)
$D_o$is pre-exponential factor of the Arrhenius equation (m^2/s)

From Eq. (5), the plot of natural logarithm of D_{eff} against inverse of the absolute temperature gives a straight slope of K_1 from which activation energy (E_a) was computed.

$$K_1 = \frac{E_a}{R} \tag{6}$$

Linear regression analyses were used to fit the equation to the experimental data to obtain the coefficient of determination (R^2).

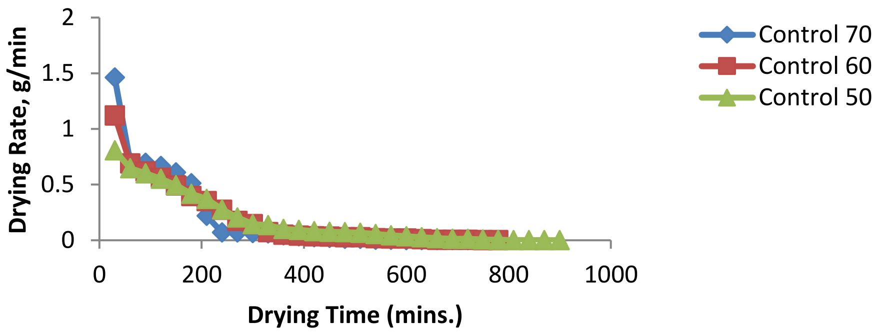
3.0 RESULTS AND DISCUSSION

The initial moisture content of the filleted prawns ranged from 392.13 to 503.87% (d.b) while the final moisture content values varied from 6.04 to 8.71% (d.b). The variation of the drying rate with the drying time at different drying air temperatures for pretreatment levels of untreated, 2, 4 and 6% brine are presented in Figure 1. From Figure 1, it was observed that the drying operations occur in the falling rate period and it is an indication that internal moisture movement mechanism was more of diffusion. It is obvious that the drying rate is higher at the beginning of the drying process and decreases continuously with increase in the drying time. This trend is similar to the observations from researches carried out for tilapia by Kituu *et al*. (2011), salted sardine by Bellagha *et al*. (2002), chelwa fish by Jain and Pathare, (2007) and shrimp (Tichangtong, 2001; Namsanguan *et al*., 2004; Namsanguan, 2007; Guochen *et al*., 2009). The drying rate increased with an increase in the temperature of the drying air, the highest values of the drying rate was obtained at the drying air temperature of 70 °C in all experiments. At a higher temperature, moisture removal is higher and occurs within a short drying time. An increase in the drying rates with an increase in temperature was reported in earlier studies for drying of shrimp (Namsanguan, *et al.*, 2004; Hosain *et al*., 2012; Ajala and Ajala, 2014), Tilapia zilli (Ikrang *et al*., 2014), codfish (Boeri *et al*., 2011), Shark (Park, 1987; Cornejo, 1987; Torrano and Okada, 1977; Bastos, 1977).

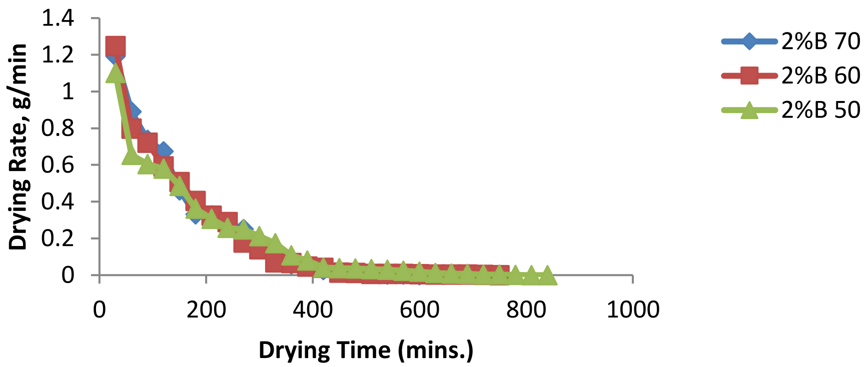
3.1 Effective Moisture Diffusivity of Filleted Prawn

The values of the effective moisture diffusivity, D_{eff} for different temperatures and pretreatment are presented on Table 1. The highest moisture diffusivity value of 7.52×10^{-7} m^2/s was obtained for 4 % brine samples, dried at a drying temperature of 70 ºC while the lowest was 3.66×10^{-7} m^2/s at 50 ºC. Moreover, the effect of temperatures and pretreatments on the effective moisture diffusivity is also observed in Table 1 which shows an increment from 3.66×10^{-7} m^2/s at 50 ºC to 7.52×10^{-7} m^2/s at 70 ºC. This clearly showed that moisture diffusivity increased as the temperature increased and pretreatments also gives rise to high moisture diffusivity. The implication is that, at higher temperatures, the vapour pressure inside the sample increases causing more water molecules to diffuse outwards at a faster rate.

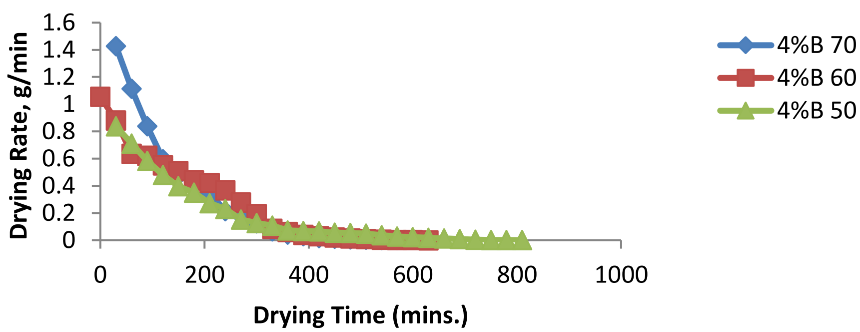
The moisture diffusivity in prawn fillets was influenced by both drying temperatures and pretreatments. This influence may be due to an increase in drying rate with application of pretreatments and increasing internal mass transfer with drying temperature (Figure 2). A close result of the influence of drying temperature on the moisture diffusivity during drying has been observed by some authors such as Ajala, *et al.* (2012), Guine *et al.* (2009), Abraham *et al*. (2004) and Jaya and Das (2003). Besides, Jangham *et al.* (2010) asserts that not only the temperature affects D_{eff} but also moisture content of the material being dried. As shown on Table 1, the values of D_{eff} in this work fall within the range of food products (10^{-12} to 10^{-6} m/s^{-2}) as reported by Doymaz, (2007); Erbay and Icier, (2010). Moreover, the D_{eff} values reported in this work are more than the values for fish dried in microwave with values of 7.158×10^{-8} to 3.408×10^{-7} m^2/s as reported by Hosain *et al.* (2012). Also the values are more than the values (3.14×10^{-9} to 11.0×10^{-9} m^2/s) for clams dried in a cabinet dryer as reported by Betty-Tello *et al.* (2004). However, the values are comparable with that reported by Tirawanichakul *et al*. (2008) with values of 1.056×10^{-7} to 1.7989×10^{-7} m^2/s for Hybrid convection and infrared drying of shrimp at inlet drying temperature of 40-70 ºC and lower than the values of shrimp and shark fillets dried in the cabinet with the values of 6.96× 10^{-6} to 7.34 × 10^{-5} m^2/s and 1.1 × 10^{-6} to 7.0 × 10^{-6} cm^2/s as reported by Burubai, (2017) and Mujaffar and Sankat, (2011). This variation could be attributed to the bulk density difference in the muscles of the food products.



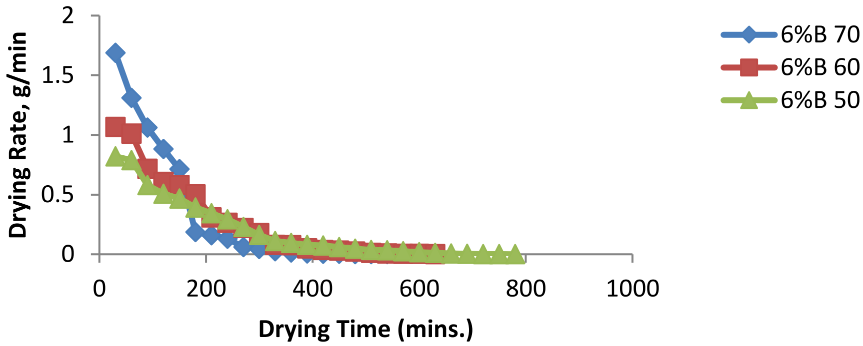
(a.) Control (untreated)



(b.) 2% Brine



(c.) 4% Brine



(d.) 6% Brine

Figure 1: Drying rate against drying time for prawn samples dried at different temperatures.

Table 1: The Effective Moisture Diffusivity values for different temperatures and pretreatment

Samples	**D_{eff} × 10^{-7} m^2/s**
Control 70°C	6.04
60°C	4.67
50°C	3.66
2%Brine70°C	6.94
60°C	5.66
50°C	4.51
4%Brine 70°C	7.52
60°C	7.42
50°C	4.04
6%Brine 70°C	7.22
60°C	6.97
50°C	4.66

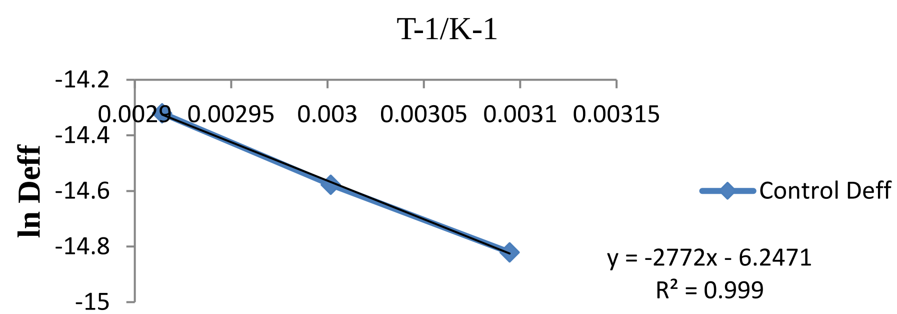
3.2 Activation Energy of Prawn Fillets

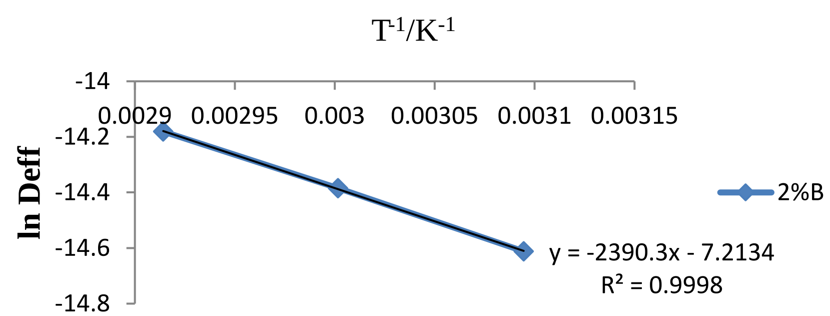
The activation energy which is the energy required to initiate moisture movement within the sample was obtained from equation 6 and presented in Table 2.

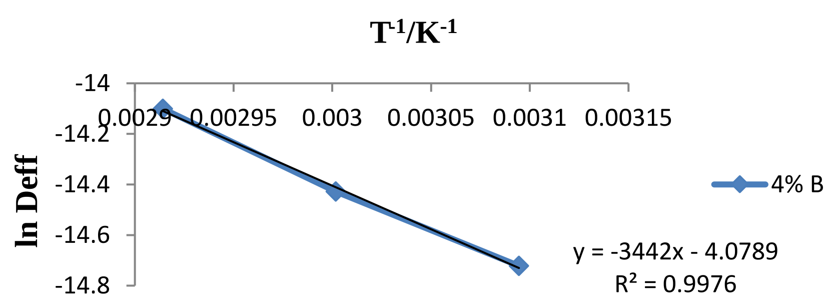
Table 2: The activation energies of untreated, 2, 4 and 6% Brine samples dried at different drying temperatures.

Temperature	**Control**	**2% Brine**	**4% Brine**	**6% Brine**
70	40.86	40.46	40.23	40.34

60	40.38	39.84	39.09	39.27
50	39.82	39.26	39.55	39.17
R^2	0.999	0.999	0.997	0.996







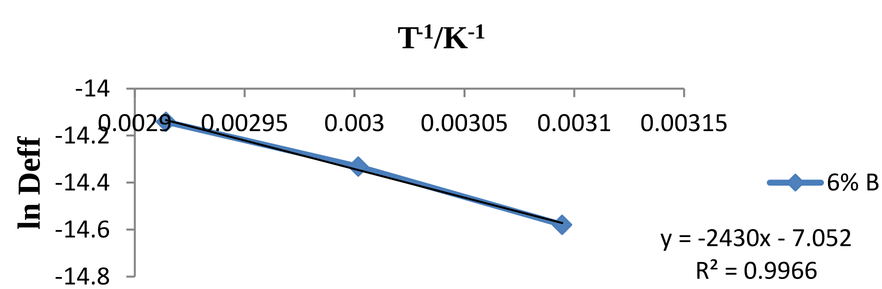


Figure 2: Influence of air temperature on the effective diffusivity for different pretreated crayfish samples.

The value of activation energy ranged from 39.093 to 40.855 kJ/mol, depending on pretreatment as presented in Table 2. From Table 2, it can be observed that application of pretreatments lead to reduced activation energy of the filleted prawns. The energy of activation (Ea) obtained in this work (Table 2) is lower than that of existing literatures by Mujaffar and Sankat (2011) for shark fillets (51.1 kJ/mol) and higher than that reported by Toujani *et al*. (2013) for silverside fish (37.2625 kJ/mol), Mehran *et al*. (2013) and Ajala and Ajala, (2014) for shrimp (32.16 kJ/mol). Values of the energy of activation lie within the general range of 12.7–110 kJ/mol for food materials (Zogzas *et al.,* 1996). The relationship between the activation energy and pretreatments was found by regression analysis as shown in Figure 2. Both the effect of pretreatments and drying temperatures were significant ($p < 0.05$) on activation energy for mass diffusion (Table 3). Moreover, the effect of interaction between pretreatments and drying temperatures was significant on the activation energy of prawn fillets.

Table 3: ANOVA Table for Activation Energy of Prawn fillets sample

Source	Degree of freedom	Sum of Squares	Mean Square	F value	P value
Pretreatments	3	1.444046	0.481349	34.66057	3.43E-06
Drying Temperatures	2	5.130008	2.565004	184.6988	9.7E-10
Pretreat*Temp	6	0.723792	0.120632	8.686369	0.000849
Residual	12	0.16665	0.013888		

4.0 CONCLUSIONS

In the present study, the drying of freshwater prawns as dictated by the internal moisture migration mechanism took place in the falling rate stage. This implies that the moisture removal from the product was governed by diffusion phenomenon. The highest effective diffusion was found to be 7.52×10^{-7} m^2/s at the air temperature and pretreatment of 70 ºC and 4% brine, respectively. The lowest effective diffusion was 3.66×10^{-7} m^2/s at the drying air temperature and pretreatment of 50 ºC and control respectively. It was deduced that moisture diffusion for the untreated (control) samples was low and increase in the levels of pretreatment by brining leads to increase in the moisture diffusivity. The activation energy for the prawn fillets in the drying experiments ranged from 39.09 to 40.86 kJ/mol.

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PAPER: NIAE/ EKO/ D028

A Technical Assessment of Grain Storage Structures in Oyo North Senatorial District of Oyo State, Nigeria

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ABSTRACT

The need for updated information on storage practices by subsistence farmers in Oyo North Senatorial district of Oyo state, Nigeria necessitated a technical assessment of grain storage structures with particular interest on availability and features as well as associated postharvest losses. Small-scale farmers who are not occupying government-owned farm settlements were surveyed. Ten Local Government Areas, namely; Iseyin, Kajola, Iwajowa, Saki-West, Saki-East, Orelope, Irepo, Olorunsogo, Itesiwaju and Atisbo were surveyed. A total of 250 respondents, identified to be lead-farmers and storage facility owners, were interviewed using structured questionnaires. About 35.9% of respondents still make use of thatched rhumbu but rainfall and insect damage pose a major challenge to grains stored within. Lack of adequate design and poor maintenance culture are major causes of structural failure. Efforts to reduce postharvest losses must include provision of adequate storage facilities to small-scale farmers where most crops are produced.

KEY WORDS: *Grain Storage, Storage Structures, Construction Materials, Postharvest Losses*

INTRODUCTION

Storage in agricultural parlance refers to the process by which crops are kept for future use (Nukenine, 2010). In most regions of the world, crops are produced on a seasonal basis but consumed continuously throughout the year. However, due to the limited agricultural mechanization available for smallholder farmers in developing countries, almost all agricultural practices are conducted traditionally (De Groot *et. al*., 2013). More than 70% of the sub-Saharan African population is reported to be directly involved in agriculture as the primary source of income and food security (Wiggins*et. al*., 2010; Kanu *et. al.*, 2014). Increased agricultural production in quality and quantity are critical towards eradicating extreme poverty and hunger in the continent. Sadly however, agricultural productivity in sub-Saharan Africa coupled with the per-capita value of agriculture output is the lowest in the world (FARA, 2006; World Bank, 2011). It is estimated that about 33% of the African population (approximately 200 million people), is malnourished. Attaining food security is possible by increasing agricultural productivity and reducing pre- and post-harvest crop losses (Collier and Dercon, 2014).

Agricultural products need to be stored from one harvest to the next in order to maintain constant supply year-round and to preserve its quality until required for use (Hell *et. al*., 2000; Diao *et. al*., 2010). For small scale farmers in Africa, the main purpose of storage is to ensure household food supplies and seed for planting (Abass *et. al*., 2014). However, traditional storage practices in developing countries cannot guarantee protection against major storage pests of staple food crops like maize, typically leading to losses up to 20-30% particularly due to insects, pests and grain pathogens (Ritcher*et. al.*; Tadsesse and Eticha, 2000; Tefera *et. al*., 2011). For instance, Midega *et. al*., (2016) reported that traditional storage structures provide limited protection against fungal growth, insect and rodent damage, especially in areas where the climate is warm and humid or where grain is stored for extended periods. Bad postharvest practices such as when grains are placed on the bare floor of storehouses usually encourage attacked by pests e.g. weevils and rodents (Adejumo and Raji, 2007).

The Oyo North Senatorial district has a considerable agrarian land mass and is considered to be the grain-belt of Oyo state, Nigeria. Reduction in postharvest losses in this region will positively impact the food and feed industry in Oyo State and beyond. Information about smallholder farmers who own grain storage structures in this region, and who cultivate on privately owned lands is required for any meaningful interventions. This study was therefore designed to carry out a technical evaluation of grain storage structures, most especially at the farm level with a view to identifying problems and constraints which contribute to postharvest losses and to suggest ways to mitigate them.

2.0 MATERIALS AND METHODS

2.1 Study Area

The Oyo North Senatorial District of Oyo State otherwise known as *Oke-Ogun* is shown in Figure 1. The climate is equatorial, notably with dry and wet seasons with relatively high humidity (Riehl, 1979; Barry, 2009). The dry season lasts from November to March while the wet season starts from April and ends in October. Average daily temperature ranges from 25–35°C almost throughout the year. The study area comprises of 10 different Local Government Areas (LGA) which includes Iseyin LGA, Kajola LGA, Iwajowa LGA, Saki-West LGA, Saki-East LGA, Orelope LGA, Irepo LGA, Olorunsogo LGA, Itesiwaju LGA and Atisbo LGA where varieties of crops are grown such as maize, sorghum, potatoes, yam, vegetables and beans.

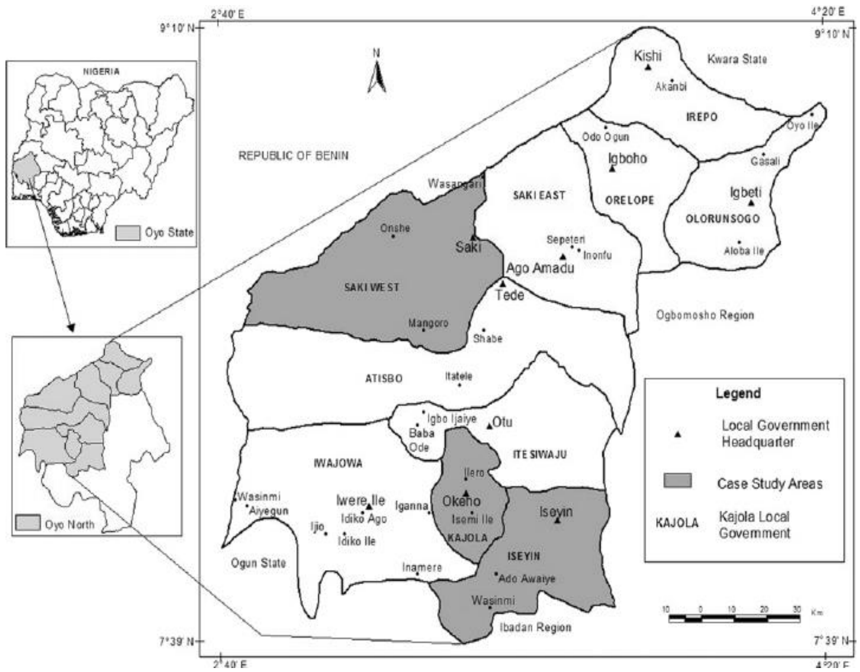

Figure 1: Map of Oyo North Senatorial Local Governments Oyo State

2.2 Data Collection

Field trips were made to all Local Governments in the study area and data collection was through questionnaires, interviews and physical observation. 25 lead farmers were randomly sampled in each local government of the study area. A total of 250 respondents from 10 local governments were interviewed. Visits were made to survey, interview and discuss with farmers and storage structure owners in each study location. The survey was conducted from August 2017 to October 2017. A duration of approximately 45mins was used to complete a questionnaire. Existing structures were examined and evaluated based on materials of construction, height above the ground in the case of cribs, vent area for stores and mud houses, construction site and maintenance practices. Data analysis and presentation was done using SPSS (Version 20). Data were analyzed using descriptive statistics and cross-tabulation summarized as percentages.

3.0 RESULTS AND DISCUSSION

3.1 Demography

Demographic distribution in the study area revealed the predominance of males in farming with over 79% being males. Age distribution also reveals the absence of youths among these farmers which show a poor motivation on the part of the younger generation many of whom are not attracted to rural farming life. Level of formal education among farmers were 37.1% for those with primary education, 22.6% at the secondary school level and merely 2.0% for farmers with B.Sc., while those without any formal education were 30.6%. This indicates that pre- and postharvest activities at the farm level in this region is largely in the hands of those who lack formal education and the likelihood of adopting new techniques in postharvest storage practices may be difficult. Marital status showed that over 94% of respondents were married. This again underscores the need for postharvest loss reduction because a lot of families depend on proceeds from these farms. Table 1 presents basic information on the farmers surveyed. Number of years of farming experience was highest (62.9%) for those who have spent between 20 to 39 years in crop cultivation and postharvest management of harvested produce. It is important to note that over 74% of these farmers reported not having received any formal training on postharvest issues.

Table 1. General information on surveyed farmers

Variable	Category	No. of Household (%)
Gender	Male	79.8
	Female	20.2
Age (years)	>50	47.2
	40-49	46.4
	30-39	6.5
	20-29	0
	<20	0
Marital Status	Single	1.6
	Married	94.8
Educational Level	No Education	30.6
	Primary	37.1
	Secondary	22.6
	OND	4.0
	HND	3.2
	BSc	2.0
	MSc	0.4
Years of Experience	0-19	34.3
	20-39	62.9
	40-59	2.8

Source: Field Survey 2017

3.2 Storage Practices and Challenges

Data obtained showed that farmers who carry out routine monitoring once a month were about 40.7% while those who do not routinely check their grains were about 2.8% as shown in Figure 2. Farmers rely on physical observations only because devices based on modern technologies are not readily available to the farmers. A larger percentage of the farmers, about 55.6% have grains in storage for about 4-7 months while less than 5% store grains above one year (4%). The farmers reported problems with insect damage, mold damage, rodent damage, theft, rain and a combination of these in some cases e.g. two factors (i.e. insect and mold damage), three factors (insect, rodent and mold), and a combination of four factors (insect, rodent, mold and rain) as shown in Figure 3. Most of the structures are positioned in areas near bushy vegetation where rodents are prevalent.

With respect to sanitation, about 6.9% reported cleaning the storage area every month as a routine while most of the respondents (above 80%) reported doing this anytime they feel like as shown in Figure 4. This practice is not good because regular monitoring and sanitation is important in ensuring the grains are in proper condition. Only about 3.6% of the farmers discard moldy grains. The rest find a way to use moldy grains by feeding about 25% of such grains to livestock while others wash in water and process the grains for consumption mostly through wet-milling. About 5.2% reported processing and consuming moldy grain irrespective of the danger, 21.4% dry further and store, 5.6% process into local liquor, 16.5% sell it immediately at reduced price while 21.8% apply insecticide. Irrespective of what is done by the farmers, economic losses are incurred.

Observations at the farms also reveal the prevalence of rhumbu (both thatched and clay-walled types as shown in Figures 5a and 5b), cribs (Figure 6), and mud-walled structures (plastered and un-plastered types, Figure 7) are prevalent in the region. With respect to the distribution of these structures in the farms visited, the thatched rhumbu was prevalent at 35.9%, clay rhumbu at 29%, mud-walled structures (15.3%) and cribs (19.8%). Respondents revealed that the thatched rhumbu has very little resistance to rodent infestation and the thatched roof does little to prevent rain drops or humid air from direct access to the grains. Embankments at the bottom of the thatched rhumbu provide additional support. Cribs found in the region on the other hand had bamboo or wooden planks as the frame, corrugated iron sheet as roof and wire mesh as the wall. Height above the ground to the deck varied between 600-1100 mm, height above the deck varied between 2000-2300 mm, and width varied between 1000-1200 mm. There are several variations of cribs depending on the financial capability of the owners. Construction expertise does not follow any particular design but depends solely on the experience of the local artisans and they are only useful during the dry season.

For the mud-walled storage structures, wall height vary between 2000-2400 mm and width of between 1500-2000 mm. They are usually fitted with small windows of about 500 by 500 mm from which the un-shelled grains stored within are monitored. It has longer service period compared to thatched rhumbu but also susceptible to rodents and insect attack as well as moisture ingress that can lead to molding of grains. Generally, maintenance activities are not frequently carried out on these structures except shortly before the harvesting season when the structures are needed for storage.

While using these structures; typical problems include leakage from the roof or capillary action of water through the foundation in the mud structures (15.7%), bending or buckling in cribs (7.7%), rusting roofs and wire-mesh (1.2%), joint failure in cribs (4%), cracking of walls in much structures (14.1%), total collapse (8.1%), or a combination of these. The farmers reported also reported specific challenges with respect to their storage activities as shown in Figure 8. These include field to store insect infestation (85%), inadequacy of their storage infrastructure (43.5%), lack of funds to carry out routine maintenance on existing structures and facilities (57.3%), poor technical know-how on modern methods of grain management (54.4%), and the poor state of the farm roads (73.8%).

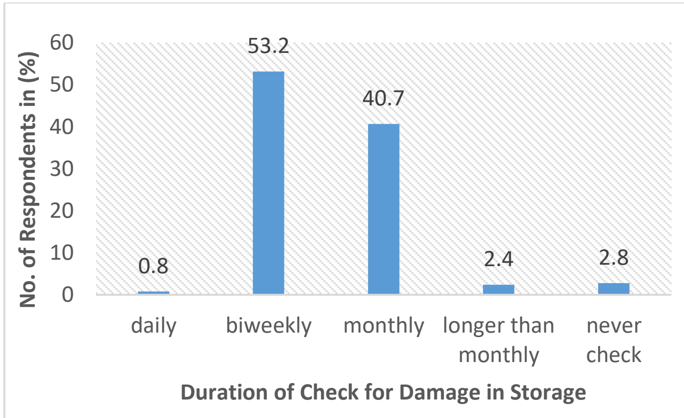

Figure 2: Frequency of grain monitoring during storage

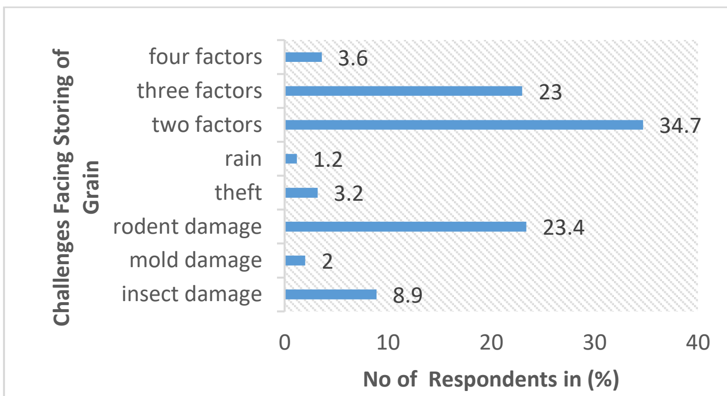

Figure 3: Challenges facing storage of grains

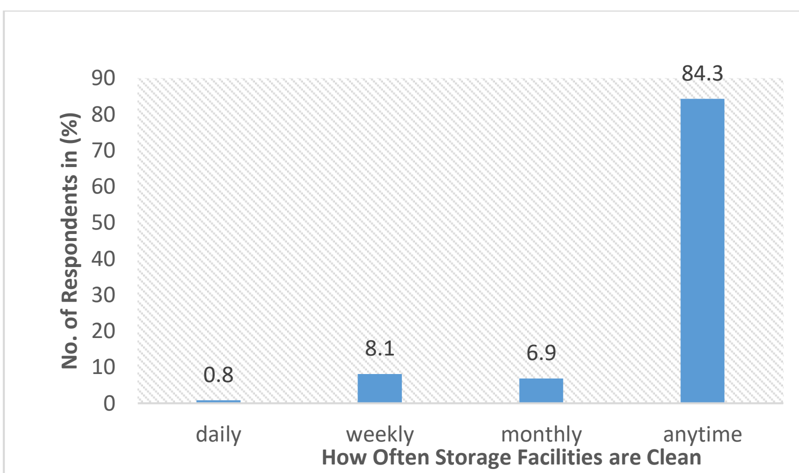

Figure 4: Frequency of cleaning of storage facilities

Figure 5a: A Thatched rhumbu Supported with Embankment Figure 5b: Mud Rhumbu

Figure 6: Maize Crib in Itesiwaju Local Government of Oyo State

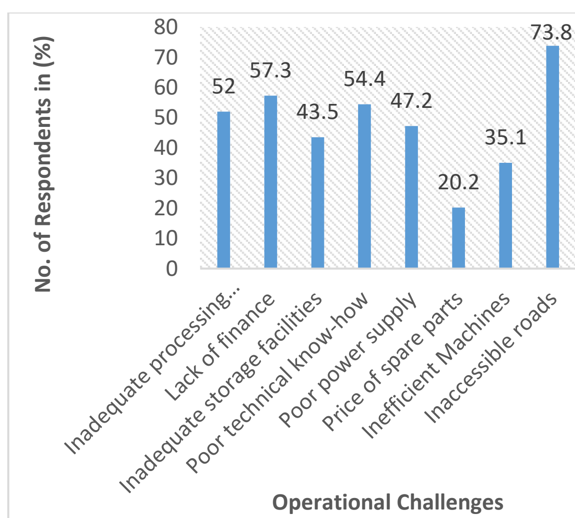

Figure 7: Un-plastered mud-walled granary   Figure 8: Operational challenges in storage activities

As precarious as the on-farm storage situation is in this region, only about 49% of the respondents believe there should be an improvement in the existing system despite the fact that over 90% experience storage losses. In addition, only about 54% of respondents were aware of the dangers of aflatoxin contamination by molds, especially the harmful effect to humans and livestock.

4.0 Conclusion

Efforts to improve the food security situation in sub-Saharan Africa must begin from the farm level in order to ensure a meaningful impact across the entire value chain. Inefficient storage structures and poor postharvest handling of crops remain a major challenge that must be solved. Adequate information as regards new storage technologies and activities seem not to be reaching farmers and storage structure owners in the study area. Grain infestation mostly starts from field where the grains are left to dry after reaching maturity. This results in increased use of pesticides during storage of grain, which is another avenue for contamination. Efforts should be stepped up to provide or improve necessary infrastructure in the farming areas in order to reduce postharvest losses which makes many farmers operate at a loss. An effective medium of information dissemination to farmers and grain aggregators must be devised.

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DETERMINATION OF PHYSICAL AND MECHANICAL PROPERTIES OF SOME SELECTED VARIETIES OF COWPEA

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ABSTRACT:
The knowledge of physical and mechanical properties of some existing and newly developed varieties of cowpea in Institute of Agricultural Research (IAR) like any other biomaterial is fundamental to facilitate the design and development of their processing machinery. One hundred pods of each variety; SAMPEA 7, SAMPEA 8, Kanannado and Ironbean were randomly picked from the samples for the determination of size, shape, coefficient of friction, bulk density, moisture content, angle of repose, and crushing strength based on the selected procedures. The average values were taken for each of the properties determined, hence the arithmetic mean diameters, geometric mean diameters, mass and volume of 1000seeds, sphericity, roundness, bulk densities, true densities, coefficient of friction, angle of repose, and crushing strength were found to be 6.41–9.18mm, 6.24–8.84mm, 201.5–350.0g, 268.5–534.2cm^3, 70.45–77.85%, 64.92– 69.74%, 0.655 – 0.750g/cm^3, 0.702–0.806 g/cm^3, 0.25–0.33, 23–31^o, and 0.0076–0.0126kg/mm^2 respectively. The cowpea varieties; SAMPEA7 and SAMPEA8 were found to be Rhomboid while Kanannado and Ironbean were Ovoid and Kidney in shape respectively but the results signify that the varieties can be processed with the same machine.

KEY WORDS: *Cowpea crops, Basic geometric, Complex geometric, Physical, Mechanical*

1.0 Introduction

Cowpea is one of the most economically and nutritionally important indigenous African grain legumes produced throughout the tropical and subtropical areas of the world (GATE, 2008).In Africa, despite the values of cowpea, the methods involved in its production, harvesting and shelling are mostly manual. For instance, shelling is done by pounding in a mortar with a pestle or spreading the dried crop on the floor where it is beaten with a stick (Dauda, 2001). Most of the imported shelling machineries are very costly and hence beyond the reach of Nigerian small-scale farmers. Some have been found unsuitable for shelling the local varieties (Adewumi *et al.*, 2007). If there has to be increased production of cowpea, farmers have to be provided with the means by which their products can be processed with minimum drudgery, cost and achieving good quality products. Despite the economic potential of cowpea little is known about the physical properties of some of its varieties though many researchers such as; Alonge and Adigun (1999), Adigun and Alonge (2000), Oje *et al*., (2001), and Alonge (2003) carr

ied out studies on physical and mechanical properties of some agricultural products. This study was therefore carried out to determine the basic geometric (length, width, thickness, geometric mean diameter, arithmetic mean diameter, mass, and volume), complex geometric (sphericity, roundness, surface area, true density, bulk density, and porosity), and some mechanical (angle of repose, coefficient of friction and crushing strength) properties of four different varieties of cowpea for the purpose of multi crop shelling machine design.

2.0 Materials and Methods

Four different varieties of cowpea (SAMPEA 7, SAMPEA 8, Kanannado and Ironbean) were used for the experiment carried out at Institute for Agricultural Research (IAR), Samaru - Zaria, Nigeria. One hundred pods of each variety were randomly picked from the samples for the determination of size, shape, coefficient of friction, bulk density, moisture content, angle of repose, and crushing strength. These were achieved using the procedure outlined by Maduako and Hannan (2004);

2.1 Determination of crops sizes

The length, thickness and width of the pods and seeds of each cowpea varieties were determined by measurements using Vernier caliper for the determination of the arithmetic and geometric mean diameters. Twenty samples were randomly selected from the bulk of one hundred cowpea pods (Maduako and Hannan, 2004).

$$d_a = (L + W + T)/3 \qquad (2.1)$$

$$d_g = (LWT)^{1/3} \qquad (2.2)$$

Where: d_a = arithmetic mean diameter (mm), d_g = Geometric mean diameter (mm),
L = Mean length of the seeds/pods (mm),W = Mean width of seeds/pods (mm)
T = Mean thickness of the seeds/pods (mm)

The seed sizes were classified into three categories namely small, medium and large based on their length. The dimensional classification wasbased on the calculated average dimension ($\bar{X}$) and the associated standard deviation (σ_x). Then, small, medium, and large size seeds were so defined that their specific (X) dimension satisfies the following three inequalities (Pradhan *et al.*, 2013):

Small size group $X < \bar{X} - \sigma_x$ (2.3)

Medium size group $\bar{X} - \sigma_x < X < \bar{X} + \sigma_x$ (2.4)

Large size group $X > \bar{X} + \sigma_x$ (2.5)

2.2 Determination of crops shapes

The shapes of the crops were determined from the measured aforementioned dimensions. However, the shapes of the pods and seeds were expressed in terms of roundness (R) and sphericity (S) index by Karaj and Muller (2010);

Roundness, R (%):

$$R = (W/L + T/L + T/W)/3 \qquad (2.6)$$

Sphericity, S (%):

$$S = (L * W * T)^{1/3}/L \qquad (2.7)$$

The shapes of the seeds were further classified according to Mazhar *et al.* (2013): when the ratio of length to width (L/W) fall within the range of 1.51 - 1.71 the variety was classified *Ellipticus* which is ellipsoid in shape, when the ratio fall within 1.85 - 2.31 the variety was classified *Oblongus* which is long cylindroids in shape and when the product of length and the ratio of width to thickness (W/T)*L fall within the range of 1.29 - 2.08 the variety was classified *Subcompressus* which is sub – compressed and long in shape, while for 2.17-3.51 the variety was classified *Compressus* which is more compressed and broad in shape.

2.3 Determination of coefficient of friction

The coefficient of friction of pods and seeds were determined on plywood, glass and galvanized steel surfaces using a tilting table. The angle of inclination of the table to the horizontal at which samples started sliding were measured with the protractor attached beside the inclined plane apparatus (Maduako and Hannan, 2004). Measurements were replicated five times for each sample and the coefficient of friction was calculated from the relation;

$$\mu = \tan\alpha \tag{2.8}$$

Where: μ = Coefficient of friction, α = Angle of inclination of the table to horizontal (^{o})

2.4 Determination of angle of repose

A cylindrical container was filled with pods of different varieties and gently lifted up 20 mm above the surface where the bottom of the container was uncovered. The lifting of the container continued gradually until all the pods formed a conical heap on the floor. The height and diameter of the heap were measured (Maduako and Hannan, 2004). The procedure was repeated 5 times. The same procedure was adopted for determining the angles of repose for the crops seeds and the angle of repose was calculated from these measurements as;

$$\theta = \tan^{-1}(2H/D) \tag{2.9}$$

Where: H = Height of the heap (mm) and D = Diameter of the heap (mm)

2.5 Determination of bulk and true density

A container (63.00 mm height and 64.03 mm diameter) was filled with pods and weighed using an electric weighing balance of 0.001g accuracy. The procedurewas repeated five times using different sets of pods and the bulk density was calculated from the weight of the pods divided by the volume of the container. The same procedure was used for the bulk density of crops seeds.

$$\rho_b = W/V \tag{2.10}$$

Where: W = Weight of the pods (kg) and V = Volume of the container (m^3)

The true density was determined using liquid displacement method where a container of known volume was filled with water and 1000 pods were immersed while the amount of water displaced was collected and measured. The procedure was repeated five times and same procedure was used for the true density of crops seeds (Ozturk *et al*, 2009).

$$\rho_t = Mu/Vu \tag{2.11}$$

Where: Mu = Unit mass of the pods (kg) and Vu = Unit Volume of the pods (m^3)

3.0 Results and Discussion

3.1 Basic geometric properties

The basic geometric properties of the crops varieties are presented in Tables 3.1 below.

Table 3.1: **Basic Geometric Properties of theSeeds and Pods for Crop Varieties**

Crop/Variety	Length (mm)	Thickness (mm)	Width (mm)	Mass (1000)(g)	Arithmetic Diameter D_a (mm)	Geometric Diameter D_g (mm)	Volume (1000) (cm^3)	Unit Volume (cm^3)

				PODS				
SAMPEA 7	166	6.17	9.02	1745	60.39	20.98	13122	7.4
SAMPEA 8	138.8	6.29	8.58	1660	51.21	19.56	11828	6.4
KANANNADO	117	7.4	9.5	2475	44.63	20.18	18042	8.8
IRONBEAN	148	8.2	10.54	3387	55.58	23.38	23280	10
				SEEDS				
SAMPEA 7	8.91	4.56	7.08	223.8	6.85	6.601	322.2	0.3
SAMPEA 8	8.02	4.55	6.67	201.5	6.413	6.244	268.5	0.25
KANANNADO	10.33	5.93	7.37	252.8	7.877	7.671	383	0.36
IRONBEAN	12.55	6.44	8.55	350	9.18	8.841	534.2	0.46

3.1.1 Crops sizes and classification

i) Crop sizes:

The basic geometric properties of the crops were determined as presented in Tables 3.1. The mean length, thickness, and width of the cowpea pods ranged from 117 – 166 mm, 6.17 – 8.20 mm, and 8.58 – 10.54 mm respectively. The arithmetic and geometric mean diameters were 44.63 – 60.39 mm and 19.56 – 23.38 mm respectively. A variety, SAMPEA 8, comparatively has the lowest mean diameter while Ironbean, is larger in size having the largest mean diameter. However, Kanannado and SAMPEA 7 exhibit similar properties; the two varieties were found to have relatively similar mean diameters. The mean length, thickness, and width of the cowpea seeds ranged from 8.02 – 12.55 mm, 4.55 – 6.44 mm, and 6.67 – 8.55 mm respectively. The arithmetic and geometric mean diameters were 6.41 – 9.18 mm and 6.24 – 8.84 mm respectively hence, these are similar to the findings of Mazhar *et al*, (2013) and Ozturk *et al* (2009). An improved variety, SAMPEA 8, comparatively has the lowest mean diameter while Ironbean, is larger in size having the largest mean diameter.

ii) Classification of crop sizes:

Both the pods and seeds of all cowpea varieties used were classified based on small, medium and large sizes. For the cowpea pods, the percentage distribution of the classes indicated a range of 40 – 55% and 45 – 60% for small and large sizes respectively while the medium class covers only 0 – 5% but SAMPEA 7 was the only variety with 5%. SAMPEA 8 was found to have the highest percentage in terms of smaller sizes but least in terms of larger sizes while Kanannado was found to have the highest percentage in terms of larger sizes but least in terms of smaller sizes. For the cowpea seeds, the percentage distribution of the classes indicated a range of 45 – 55%for both small and large sizes while the medium class was zero percent in all cases (Table 3.2). Kanannado was found to have the highest percentage in terms of smaller sizes but least in terms of larger sizes while SAMPEA 7 was found to have the highest percentage in terms of larger sizes but least in terms of smaller sizes. However, these results do not agree with the findings of Hossain and Haque (1999) which could be due to the difference in their dimensional properties particularly the length.

Table 3.2: Cowpea Pods and Seeds Classification to Small (S), Medium (M), and Large (L) sizes

Cowpea Varieties	Dimension	% Distribution of Classes			Min-Max Values	Mean±SD
		S (%)	M (%)	L (%)		
PODS						
SAMPEA 7	Length(mm)	45	5	50	123.0-196.0	166.0±13.6
SAMPEA 8		55	0	45	98.00-165.0	139.0±2.02
KANANNADO		40	0	60	76.00-155.0	117.0±14.7
IRONBEAN		50	0	50	109.0-165.0	148.0±3.18
SEEDS						
SAMPEA 7		45	0	55	7.550-10.67	8.910±0.60
SAMPEA 8		50	0	50	6.660-9.250	8.020±1.11
KANANNADO		55	0	45	9.220-12.24	10.33±0.22
IRONBEAN		50	0	50	10.63-14.30	12.55±1.50

3.1.2 Mass and volume of the crops varieties

The mass and volume of 1000 pods of cowpea varieties were found to have a range of 1660 – 3387 g and 11828 – 23280 cm^3 respectively while that of cowpea seeds were found to be 201.5 – 350.0 g and 268.5 – 534.2 cm^3 respectively (Table 3.1). However, the results are in closed range with the findings of Mazhar *et al*, (2013). A variety, Ironbean, was found to have the highest mass and volume while SAMPEA 8 has the least mass and volume for both crop pods and seeds. However, the results indicated that Ironbean is larger in size while SAMPEA 8 was smaller, hence, the pattern could be due to the fact that the change in mass and volume is proportional to the change in crop size though the mass could be affected by the void space between the cotyledons of the seeds.

3.2 Complex geometric properties

The complex geometric properties of the crops varieties are presented in Tables 3.1 below.

Table 3.3: Complex Geometric Properties of the Seeds and Pods for Crop Varieties

Crop/Variety	Sphericity Ø (%)	Roundness R (%)	Bulk Density ρ_b (g/cm^3)	True Density ρ_t (g/cm^3)	Porosity Ɛ (%)	Surface Area (mm^2)

			PODS			
SAMPEA 7	12.64	25.85	0.133	0.236	43.6	1383.4
SAMPEA 8	14.1	28.01	0.14	0.259	45.89	1202.6
KANANNADO	17.25	30.78	0.137	0.281	51.23	1280.3
IRONBEAN	15.8	30.15	0.145	0.339	57.05	1718.5
			SEEDS			
SAMPEA 7	74.09	65.02	0.695	0.746	6.897	136.9
SAMPEA 8	77.85	69.37	0.75	0.806	6.89	122.5
KANANNADO	74.26	69.74	0.66	0.702	6.01	184.9
IRONBEAN	70.45	64.92	0.655	0.761	13.89	245.6

3.2.1 Crops shapes and classification

i) Sphericity and roundness of crops pods and seeds:

The sphericity and roundness of the pods of cowpea varieties were found to be 12.64 – 17.25% and 25.85 – 30.78% respectively (Table 3.3). It could be clarified from Fig. 3.1 that the varieties are more of round than spherical in shape because all varieties indicated higher percentage in terms of roundness than sphericity though their percentages in terms of both sphericity and roundness is relatively low, in fact less than 31%. This could be attributed to the fact that the cowpea pods are lengthy in nature hence could not be classified either spherical or round in shape. The sphericity and roundness of the seeds of cowpea varieties show a range of 70.45 – 77.85% and 64.92 – 69.74% respectively (Table 3.3). These results are similar to the findings of Saeeid *et al* (2009) and Mazhar *et al*, (2013). It could also be clarified from Fig. 3.2 that the seeds of cowpea varieties are more of spherical than round in shape because all varieties indicated higher percentage in terms of sphericity than roundness.

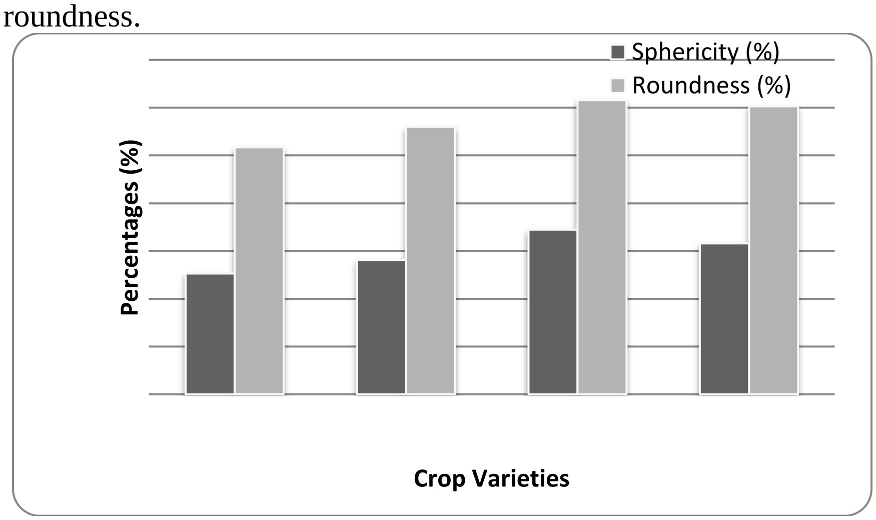

Fig. 3.1: Variation of the Sphericity and Roundness of Pods for the Crop Varieties

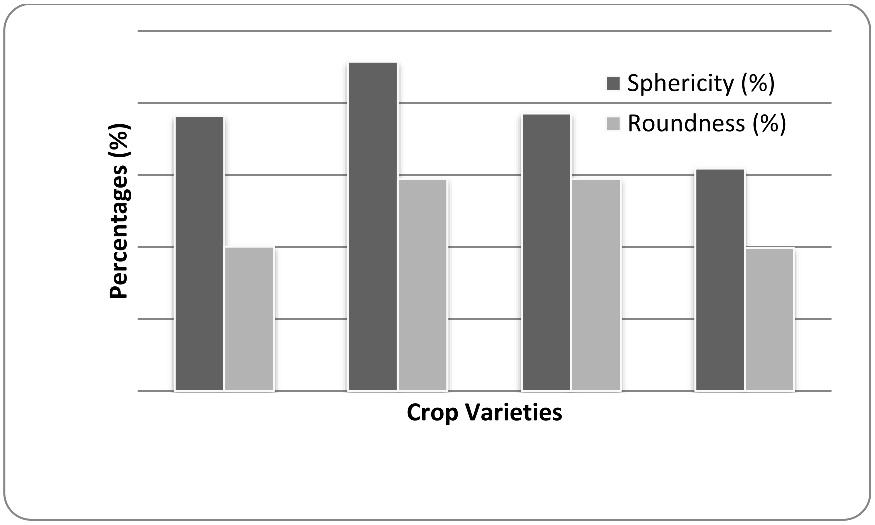

Fig. 3.2: Variation of the Sphericity and Roundness of Seeds for the Crop Varieties

ii) Seeds shape classification:

The seeds of cowpea varieties were subjected to the USDA (2009) classification. The shapes of cowpea varieties used were compared with the diagrammatic illustrations provided by USDA (2009) and classified according to the terms used to describe the corresponding shape. However, the varieties SAMPEA 7 and SAMPEA 8were found to be *Rhomboid* while Kanannado and Ironbean were *Ovoid* and *Kidney* in shape respectively (Table 3.4).

Table 3.4: **Seeds Classification Based on their Shapes**

Crop/Variety	Length (mm)	Thickness (mm)	Width (mm)	L/W	(W/T)L	Class
SAMPEA 7	8.910	4.560	7.080	1.258	13.83	**Rhomboid**
SAMPEA 8	8.020	4.550	6.670	1.202	11.76	**Rhomboid**
KANANNADO	10.33	5.930	7.370	1.402	12.84	**Ovoid**
IRONBEAN	12.55	6.440	8.550	1.468	16.66	**Kidney**

3.2.2 Bulk and true density of the crop varieties

The bulk and true densities of the pods of cowpea varieties were found to be 0.133 – 0.145 g/cm^3 and 0.236 – 0.339 g/cm^3 respectively while that of the seeds were 0.655 – 0.750 g/cm^3 and 0.702 – 0.806 g/cm^3 respectively. These do not agreed with the findings of Mazhar et al (2013) which could be due to difference in sizes of the seeds (Table 3.3).A variety, Ironbean, was found to have highest bulk and true densities of unshelled crop with other varieties having relatively similar values though SAMPEA 7 has the least values. A variety, SAMPEA 8, was found to have highest bulk and true densities of the seeds with other varieties having relatively similar values though Kanannado has the least values. It could be seen from Table 3.3 that the porosity is more pronounced with the cowpea pods than the seeds which is due to relative percentage pore spaces between the pods and the seeds as indicated by the difference between the bulk and true densities in figure 3.3 and 3.4 for pods and seeds respectively.

3.3 Some mechanical properties of the crop varieties

The mechanical properties of the crops varieties are presented in Tables 3.5 below.

Table 3.5: **Some Mechanical Properties of the Crop Varieties**

Crop Varieties	Pods coefficient of friction (μ)/Surfaces			Seeds coefficient of friction (μ)/Surfaces			Angle of Repose ϴ (°)	Crushing strength (kg/mm²)
	Wood	Glass	Iron	Wood	Glass	Iron	(Seeds)	(Pods)
SAMPEA 7	0.43	0.38	0.43	0.32	0.26	0.30	24.57	0.0076
SAMPEA 8	0.45	0.47	0.47	0.29	0.29	0.31	24.93	0.0121
KANANNADO	0.38	0.40	0.38	0.33	0.27	0.27	30.26	0.0126
IRONBEAN	0.42	0.39	0.47	0.27	0.25	0.25	27.55	0.0086

3.3.1 Coefficient of friction of the crop varieties

The coefficient of friction of cowpea pods with the wooden, glass, and galvanized iron surfaces were found to have a range of 0.38 – 0.45, 0.38 – 0.47 and 0.38 – 0.47 respectively (Table 3.5). Among cowpea varieties, Kanannado has the lowest coefficient of friction with most of the surfaces while other varieties were having relatively similar values. These could be related to the differences in varietal basic geometric properties (Fig. 3.5). The coefficient of friction of the seeds on the wooden, glass, and galvanized iron surfaces were found to have a range of 0.27 – 0.33, 0.25 – 0.29 and 0.25 – 0.31 respectively (Table 3.5). However, these were not similar to the findings of Saeeid *et al* (2009) which could be due to some differences in geometric properties of the crops. Among the cowpea varieties, the seeds of Ironbean have the lowest coefficient of friction with all the surfaces while other varieties were relatively similar. These could also be related to the differences in varietal geometric properties (Fig. 3.6).

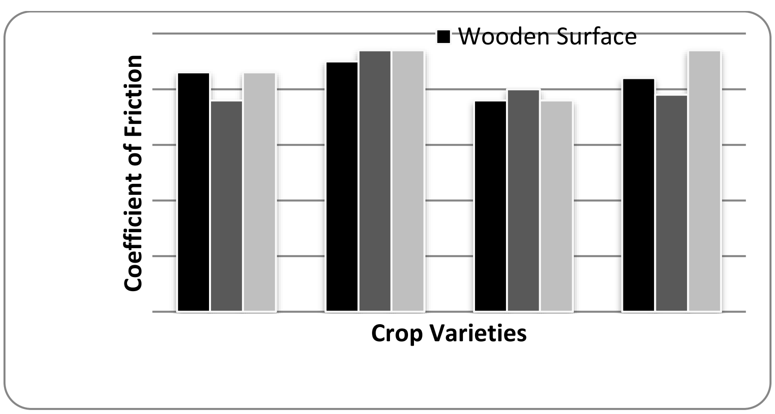

Fig. 3.5: Variation of the Coefficient of Friction for the Pods of Crops Varieties

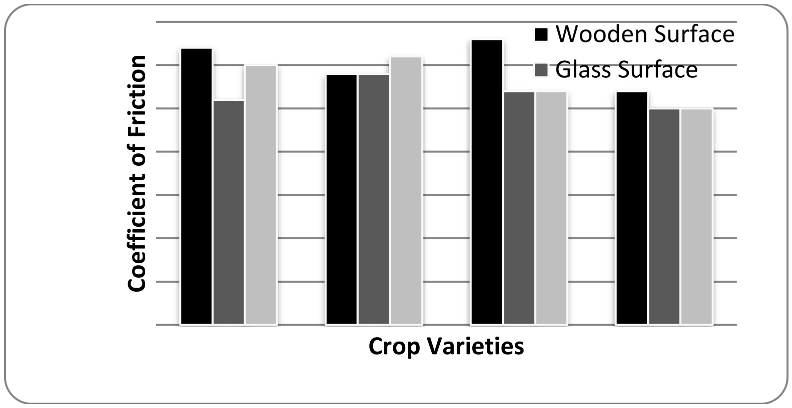

Fig.3.6: Variation of the Coefficient of Friction of the Seeds of Crops Varieties

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AN APPRAISAL OF INFORMATION TECHNOLOGY ON SELECTED AGRICULTURAL OPERATIONS

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ABSTRACT

The use of Information technology in finding a lasting solution to agricultural problems employ the use of mobile phone, use of robotics, networking and programming and applications that range from internet era technologies to the use of sensors, machine vision and autonomous machineries. Information Technology solves problem like dissemination of information, conveyance of processed food, data collection and processing, weather prediction and many others. The use of information of things like big data, robots and other technologies has made a broad approach and more convenient method of solving issues that arise during production or after production in agricultural practices even though this technology make use of intelligent devices, software, hardware and platforms that need to be properly and systematically arranged. The advancement of this technologies is certain to improve the agricultural economy of farmers and the country.

Keywords: Information technology, modern farming, robotics, mobile phones

1. INTRODUCTION

Information technology (ICT) also known as the use of advanced techniques in dissemination of information or raw data. ICT can be defined as a role of unified communications and the integration of Telecommunications (telephone lines and wireless signals), computers as well as necessary enterprise software, middleware, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information.

Ali *et al.*, (2016) define Information and Communication Technologies (ICTs) as devices or tools that permit the exchange or collection of data through interaction or transmission. ICT is an umbrella term that includes radio, television, mobile phone, internet, electronic money transfer, and use of robotics etc. It involves the use of devices, networking, programming, mobiles and services and application that range from internet era technologies to the use of sensors.

Table 1. Shows the statistical use of information technology in the form of internet in all the continents in the world as at year 2012. Fast forward to this present year 2018, it can be noticed that all around the use of the internet is immensely needed as it makes work easy, less stressful and is a very easy means for communication that different people of different works of life, culture and age utilize.

Table 1; Use of Internet in the world and population statistics (June, 2012)

World Regions	Population (billion)	(% of population)	(% of continents)
Africa	1.073.380	15.6	7.0
Asia	3.922.067	27.5	44.8
Europe	820.918	63.2	21.5
Near East	223.608	40.2	3.7
North America	348.280	78.6	11.4
Latin America	593.689	42.9	10.6
Oceania/Australia	35.904	67.6	1.0
Total world	7.017.847	34.3	100.0

Source: - Afërdita (2015)

The necessity of agriculture is to sustain man and its environment as agriculture is the basis of production of healthy food crops which are nutritional to the body for healthy living. It is a complex system, encompassing a wide range of activities and issues: family agriculture (subsistent agriculture) versus large-scale agriculture, commodity production versus value added at origin, productivity versus sustainability. New information has to reach end-users very fast in order to use potential opportunities that will help in achieving beneficial needs. Information on seed, water, nutrients and plant protection is one of the main factors for successful farming. Intensive Information with precise techniques of farming based on knowledge on data gathered will lead factors of sustainable agricultural production.

The use of ICT tools in Nigerian agricultural sector in recent times started with the sharing of Short Message Service with farmers due to the low literacy level and wide use of mobile phones by 75 per cent of the farmers as reported by Vanguard (2013). It was also reported by Vanguard (2013) that the former minister of Agriculture Dr. Akinwumi Adesina once shared mobile phones (e-wallet) to farmers in order to help them predict the weather condition

However, ICT tools such as apps developed by programmers for monitoring of farm activities and management are gradually gaining ground. Other areas where technology is being deployed in the country are crowd funding for investors in agriculture, farm accounting and management, dissemination of market access information, produce pricing and sale and tractor management, among others.

Business day (2017) reported that the co-Founder of Probity Farms, observed that few of these technologies make use of sensors and machine learning. He further stated that the adoption of this technology into the Nigeria agricultural sector came into place in the year 2017 with more technologies advancing in the coming years.

Need for information in the agricultural sector is not only required for the farmers but also for researchers and developers who get themselves involved in improving the agricultural sector. Disseminating of agricultural information arise as a result of problem of distance between a researchers and farmers, cost etc. Weather data of an area, water content in the soil, temperature and results of a research are some necessary agricultural information required on a daily basis. Back when the era of technology had not evolved, information was traditionally disseminated by one on one contact with the receiver and sender. But in the 21st century information can easily be disseminated without one on one contact which has made working in this era effective and efficient.

The main objective of the review was highlighting the development of Internet in the agricultural systems through robotics and food processing.

Advances in ICT Applications

2.1 Robotics in Crop Production

Robotics Technology now-a-days is considered to be an advancing technology. Use of robotics technology in the agriculture field will provide a good and lasting solution to the problems faced by the farmers in the agriculture field. The proposed system (Agricultural robotics) plays a very useful role in the task of seed sowing and many other farm activities. This technology uses various automation techniques in different agriculture fields. Some of the useful operations of these robots include harvesting and picking, weed control, autonomous mowing, pruning, seeding, spraying, thinning, phenotyping, sorting and packaging, utility platforms and many more; some of which will be discussed in this report. Autonomous tractors are equally fast advancing, and are being used for attaching autonomous implement and ground robots.

2.2 Robotics in seeding and plant care

A. Seed mapping and planting

According to Blackmore *et al.* (2005), seed mapping is the concept of passively recording the geospatial position of each seed as it goes into the ground. It is relatively simple in practice as a real time kinematic, GPS is fitted to the seeder and infra-red sensors mounted below the seed chute. As the seed drops, it cuts the infrared beam and triggers a data logger that records the position and orientation of the seeder. A simple kinematic model can then calculate the actual seed position as discussed in Griepentrog *et al.* (2003). The seed coordinates can then be used to target subsequent plant based operations. Autonomous precision seeding combines robotics with geo mapping. The tractor with robotic seeding attachment then places the seeds at precise locations and depths so that each has the best chance of growing adequately and properly

B. Crop scouting and monitoring

Quantified data has tended to be expensive and sampling costs can quickly outweigh the benefits of spatially variable management (Godwin *et al*., 2001). Data collection would be less expensive and timely if an automated system could remain in the crop carrying a range of sensors to assess crop health and status. A high clearance platform is needed to carry instruments above the crop canopy and utilize GPS. Figs 1 and 2 show examples of the machine. Farmers get high level of data using ground robots and drones which make use of sensors and remapping technologies that provide a way to collect the data autonomously. Drone companies provide robotic hardware and analysis software that are used on the field and are initiated via a tablet or smartphone and then view the collected crop data in real time.

C. Weed mapping

Weed mapping is the process of recording the position and preferably the density (biomass) of different weed species using the aspects of machine vision. Pedersen (2001) suggested that one method is to just record the increased leaf area found in weedy areas because weeds are patchy and crops are planted in rows. Another more accurate method raised by Søgaard and Heisel, (2002) is to use active shape recognition, originally developed to recognize human faces, to classify weed species by the shape of their outline. Current research has shown that up to 19 species can be recognized in this method. Color segmentation has also shown to be useful in weed recognition

(Tang *et al.*, 2000). All these methods help in locating the previous location a weed has been sited or could be possibly be seen. Knowing the position and severity of the weeds, there are many methods that can kill, remove or retard these unwanted plants (Nørremark and Griepentrog, 2004). Different physical methods can be used that rely on physical interaction with the weeds while non-contact methods are being developed such as laser treatments (Heisel, 2001) and also micro-spraying which can be used because of likely damage to the interface of the crop and soil. In killing weeds close to the crop plants using a micro spray that delivers very small amounts directly on to the weed leaf is one good method.
Machine vision can be used to identify the position of an individual weed plant and also set series of nozzles mounted close together that can drive and throw an herbicide on to the weed. The computer vision technology can either be solar powered, robot or powered through direct current. In irrigation and fertilization, ground robots can easily access rows of crop and pour water to the crop (Lund and Søgaard, 2005). Other trials have shown that Micro-spraying is an herbicide application system, which is able to reduces the herbicide consumption in row crops by placing only one or a few droplets of herbicide on single weed plants (Graglia, 2004).

The robots don't necessarily need to use chemicals as the computer vision detect the plants and automatically hoes the space between the plants to uproot the weeds, some weed robots make use of lasers to terminate the weed.

Figure 1: Portal crop scouting platform (Madsen and Jakobsen 2001),

Figure 2; Flying robots with Sprayer.
Source: Composition of Agricultural Robotic Technology

2.3 Robotics in selective harvesting

Selective harvesting involves the concept of only harvesting the parts of the crop that meet certain quality efficiency. Some of these crops might not yield because of reduction in quality of the crop during one processing or the other. Selective harvesting can be considered to be a type of presorting and can be based on sensory perception. Examples are to harvest barley below a fixed protein content or combine grain that is dry enough and leave the rest that are not dry to dry out or

to select and harvest fruits and vegetables that meet a size criterion or to separate the broken pods of a crop from the whole grain. As these criteria often attract quality premiums, increased economic returns and could justify the additional sensing.
To be able to carry out selective harvesting effectively, two criteria are needed;

- The ability to sense the quality factor before harvest
- The ability to harvest the desired product of interest without damaging the remaining crop.

Either the crop can be surveyed before harvest so that the information needed about where the crop of interest is located, or that the harvester may have sensors mounted that can ascertain the crop condition. The selective harvester can then harvest that crop that is ready, while leaving the rest to mature, ripe, or dry etc. Alternatively, small autonomous whole crop harvesters could be used to selectively gather the entire crop from a selected area and transport it to a stationary processing system that could clean, sort and maybe pack the produce to where they are stored.

2.4 Food Processing and Robotics

Robots are used for the automation of processes in food manufacturing to save costs and to increase productivity. This industrial robot is currently preferred because of their flexible automation tools used for different processes of different type, e.g. Robotics for packaging, palletizing, de-palletizing, slaughtering, general handling of food and some of the other activities that it does in this industry. Shape, size, color, blemishes and diseases are important aspects, which are needed to be considered when grading fruits and vegetables (Kanali *et al.*, 1998; Chatli *et al.*, 2013 and Mahendran *et al.*, 2011). Color provides valuable information in estimating the maturity and examining the freshness of fruits and vegetables. All these properties of the food product determine the best processing and packaging method that is best for the food product. The automated inspection of produce using machine vision not only results in labor savings, but can also improve quality inspection objective (Kanali *et al.*, 1998). Figure 3 shows a robot used in palletizing and serving. The robots can be used to replace heavy and dangerous manual work especially in harsh environments. They can contribute to an improved hygienic safety of food products, reduce high level of accident and contribute to the improvement of food quality. These robots can be used in the processing industry for packaging semi solid and solid foods.

(a) (b)

Figure 3; Robots in food industry: (a) IRB 660 for palletizing cartons; (b) Serving robot in China (Griffiths, 2014).

According to (Brosnan and Sun, 2004) machine vision is being implemented for the automated inspection and grading of horticulture produce to increase product throughput and to improve objectivity of the industry. (Chen *et al.*, 2002) reported that online poultry inspection with the aid of a multi-camera system can be employed to accurately detect and identify carcasses unfit for human consumption. By doing this it will be easy to identify dead poultry products. Also by automating this process, the level of accuracy in identifying defective eggs increases; and the rate of sorting is higher.

Robots can also be used for picking and placing items such as cookies, hamburgers, chocolate, chicken fillets or pan cakes into primary packing. Additionally, robots are already used in baking lines to handle hot trays. Reducing demands on labor is one of the added advantage of using a robot especially when labor is expensive and is on high demand. Moreover, robots minimize the direct contact of human workers with the products. Also, in beverages industry, bottles are cleaned, counted, filled and arranged on a conveyer belt automatically via robotic machines (Saravacos and Kostaropoulos, 2016).

In the category of Packing and palletizing, the robots and applications have been mostly standardized. The decisions are made based on the payload specifications and the range of speeds available. Palletizing of cookies, beverages, pasta, sweets and other items are now stacked using the robots as shown in figure 3(a). The food serving industry is the newest approach of making use of robots in the food industry (Asif *et al.*, 2015).

2.5 Robotics Technologies

In the last twenty years, specialized sensors (machine vision, global positioning systems (GPS) real-time kinematics (RTK), laser-based equipment, and inertial devices), actuators (hydraulic cylinder, linear, and rotational electrical motors), and electronic equipment (embedded computers, industrial PC, and PLC) have enabled the integration of many autonomous vehicles, particularly agricultural robots. The technology is useful for the fast operations which are performed in the field of agriculture. Sambare *et al.* (2015) stated that the Autonomous Robots now works entirely and automatically under the guidance of computer program. Various sensors are used to collect the data about their surroundings. Manikandan and Screenivasan *(*2014) further stated that they can operate independently and it can be programmed with multiple options, so it has the capability to do all kinds of task around the fields such as crop maintenance etc

Robots used in the Agriculture field are:

a. **Demeter (for harvesting):** It is a robot used for cutting different crops. It drives itself without any human supervision.
b. **Weed controller:** It does the task of weed removing.
c. **Forester Robot:** It is a particular type of robot used for cutting up of wood.
d. **Fruit picking robot:** The fruit picking robots pick ripe fruit without damaging the branches or leaves of the tree. The robot can distinguish between fruit and leaves by using video image capturing and image processing.

Other types of these technologies used for agriculture are:

i. Global Positioning Systems (GPS): (Rains and Thomas, 2000) defined GPS to be a technology used to locate and define spatial features or activities that contributes to the quality of site-specific practices. It produces highly accurate and digitalized map, survey and geo-fencing. A Swedish technology company called Ignitia presently is also providing Nigeria farmers day to day, weekly, monthly weather forecast by using GPS to create localized weather updates that are sent to the rural farmers through SMS. The data sent to the farmers help them to know the weather and time to plant and apply amendments like fertilizer, pesticides, insecticide and also harvesting time.

ii. Geographical Information Systems (GIS**):** A system of creating, storing, analyzing and managing spatial data, mapping and associated attributes. (Rains and Thomas, 2000). It is used for precision farming. The land is mapped digitally and geographical features like topography and contour are obtained. It is helpful in the analysis of soil, where to plant and what to plant.
iii. Remote Sensing (RS): Deals with the detection and measurement of phenomena with devices sensitive to electromagnetic energy.
iv. Variable Rate Technology (VRT): It is a site-specific management practice involving variable rate control (VRC) of seeding, spreading and spraying operations to more accurately target inputs in areas where they are most valuable.
v. Yield Monitoring Technology (YMT): for recording crop productivity as an historical database for crop management.
vi. E-Commerce in Agriculture: A technology of buying and selling of farm produce via the internet (electronic market).
vii. Market Information Technology (MIT): It involves the application of information technology to achieve the marketing functions associated with produce sales and purchase (Rains and Thomas, 2000).

2.6 Weather Forecast

Weather forecasting is the application of current technology and science to predict the state of atmosphere for a future time and given location. Weather forecast is very essential for farmers as its aids good planning for planting crops and its growth. Weather elements that are necessary are temperature, sunlight, humidity and rainfall.

2.6.1 Application in weather forecasting

Data gotten from weather forecast is used in application of irrigation scheduling, rainfall period, aversion of future effect of drought on crops and crop watering. When the field data and weather forecast is gotten on a mobile phone platform it makes the data relevant and very accessible. Irrigation scheduling based on highly accurate weather forecasts and real-time field data will optimize decision making and consequently reduce resource use. A smart watering system and observant which is a wireless irrigation system is used to monitor water level in the soil. It requires precise and real time data to minimize water loss from the soil carry out scheduled irrigation and ensure use of water.

2.6.2 Retrieval and disseminating Methods

According to Qu (2001) and Wang and Chen (2009), it is necessary to set up fluent spread and feedback channels in order that the advanced and useful technology information will be available to farmers. As reported by Yun *et al.* (2016), the rapid development of agriculture information dissemination models is constantly evolving and substantial improvements have been recorded as well. Currently, the agricultural information dissemination models can be classified into the following types:
1. Web Portal - a collection of relevant web sites to form one stop centers for users. Web Portal is a platform hosting a collection of relevant websites.
2. Voice-Based Service - information dissemination through telephone, i.e. call centers, e.g. Mtn, 9mobile.

3. Text Based Service- called Short Message Service is dissemination through text message of phones.
4. Self-Support Online Community - information services provided by a community to its members
5. Interactive Video Conferencing Service - using online multimedia technology to facilitate information service.
6. Mobile Internet Based Service - information dissemination through smart phone service, e.g. Agribusiness price information, E-news etc.
7. Unified Multi-Channel Service Model - utilizing multiple methods to effectively disseminate information through telephones, computers, and mobile phones
8. Social media - Social network data within social network sites such as Facebook, LinkedIn, Instagram and Wiki.

3.0 Conclusion

Information Technology is now advancing in every area sector of the World; it is easy to say that this advancement will bring about development in the agricultural sector. In solving the arising problems in the agricultural sector it can be stated from the report that information technology; improves crop productivity, reduces human power, labour, more efficient, effective, economical and accurate. Although it has few challenges like poor infrastructure, inadequate internet service, lack of knowledge and ignorance on the part of farmers and consumers. If autonomous machines, computer machine vision are left to develop and build up the agricultural sector, it can be concluded that the agricultural industry might overtake other industries in the society and become the source of economic stability and development for every nation in the world if information technology is utilized in agriculture system.

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DETERMINATION OF SOME ENGINEERING PROPERTIES OF TWO GINGERS (*Zingiber Officinale Roscoe*) VARIETIES IN NIGERIA

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ABSTRACT:

Understanding the physical and mechanical properties of agricultural crops is of utmost importance in designing efficient pre-harvest and post-harvest equipment. In this study, some selected engineering properties of two ginger varieties based on the colour; off white name as black (BG) and yellow (YG) ginger grown in Nigeria were determined using standard methods. The properties of BG are; Length (70.91 ± 18.25 mm), width (41.83 ± 12.75 mm), thickness (18.25 ± 2.28 mm), sphericity (0.52 ± 0.08), mass (30.52 ± 12.64 g), volume (24.39 ± 11.71cm^3), density (1.31 ± 0.46 kg m^3), surface area (151.74 ± 1.78 cm^3), angle of repose (48.50 ± 2.38°). The compressive stress, modulus, energy at break of BG are 461.07 ± 15.12 N, 1363.24 ± 15.51 N,197.07 ± 14.55 N. The properties of YG are; Length (37.57 ± 0.56 mm), width (19.40 ± 12.75 mm), thickness (18.95 ± 4.41 mm), sphericity (0.45 ± 0.09), mass (5.04 ± 3.33 g), volume (4.13 ± 3.71cm^3), density (1.67 ± 0.81 kg m^3), angle of repose (48.05 ± 1.26°). The compressive stress, modulus, energy at break of YG are 93.65 ± 13.62 N, 93.55 ± 13.71 N, 92.75 ± 13.65 N. The results will help in the design of post- harvest machines and the processing of the two indigenous gingers in Nigeria.

Keywords*; Mechanical and physical properties, black and yellow ginger*

1.0 INTRODUCTION

Ginger (*Zingiber Officinale Roscoe*) belongs to the plant family of *Zingberraceae*. It is an erect herbaceous plant, which produces underground tuberous stems or rhizomes characterized by strong essence (Erinle,1988; Ajibade and Dauda, 2005). Though a perennial plant, it is cultivated vegetatively as an annual crop in tropical regions for its fleshy underground rhizomes (Ebewele and Jimoh, 1988). It is one of the oldest and most important of all the spices and condiments. Ginger is native to South Eastern Asia; a region whose cuisines still feature this delicious spicy herb.

Ginger is mentioned in ancient Chinese, Indian and middle Eastern literatures, and has long been priced for its aromatic, culinary and medicinal properties. Nigeria on the world map as one of the major producers of ginger has been ranked first in terms of the percentage of total hectares of ginger under cultivation but her contribution to total world output is too low compared to other countries (FAO,2010) which could be due to the poor processing and handling techniques that made it substandard in the International market. The plant is now cultivated in different parts of Nigeria, though the major producing areas include Kaduna, Nassarawa, Sokoto, Zamfara, Akwa-Ibom, Oyo, Abia and Lagos states. Although Southern Kaduna still remains the largest producers of fresh ginger in Nigeria in Kachia, Jabba, Jama'a and Kagarko Local Government Areas (KADP,

2000, KADP, 2004; Bernard, 2008). The average ginger farm size in Kaduna for individual farmers has been reported by Nmadu and Marcus, (2013) as 3.09 hectares of land on the average. The results conform generally to earlier research in Nigeria as reported by; Abu (2009); Emmanuel (2008). In Nigeria, farmers have relied almost exclusively on two major varieties, the yellow ginger "*TafinGiwa*" and the black ginger "*Yatsunbiri*,". The yellow variety is mostly grown in Nigeria because it has the highest demand in the Nigerian market.
Engineering properties are the properties which are useful and necessary in the design and operation of various equipment employed in the field of agricultural processing and also for the design and development of other farm machinery. Masood and Trujillo (2016) reported that Engineering properties of the biological material is important in order to solve problems while designing and selecting the mode of preservation, packaging, processing, and storage.

Eze and Agbo (2011) asserted that processing of ginger in Nigeria has not been standardized consequent upon which low quality ginger which falls short of importer's specifications are produced. In West Africa and Nigeria in particular, this important rhizome is subjected to local processing method which includes cleaning, sorting, peeling, grading, drying, splitting (slicing), size reduction and storage which is labour intensive and generally has low output. Identifying the engineering characteristics of these spices is very important to optimize the design parameters of agricultural equipment used in their production, processing and handling and storage processes. Physical properties describe the unique characteristic way a food material responds to physical treatments (Berk, 2013).

Recent studies on health related effects of ginger which have also stimulated farmers concern on the growth of the plant have shown the efficacy of the plant in some life challenging ailments such as entero toxin induced diarrhea, diabetic nephropathy, nausea, plasma antioxidant, vomiting, high cholesterol, high blood pressure and inflammation (Chen *et al.,* 2007; Ernest and Pittler, 2008; Kim *et al.*, 2008). Due to the health benefits, ginger consumption is at high rate and is consumed by both the young and elderly in the country. This work is therefore aimed at investigating the basic selected engineering properties (physical and mechanical) of (*zingiber officionale*) and also using statistical analysis to investigate the similarities between the two varieties; the Nigerian bold yellow ginger and the black ginger.These properties are needed and can be utilized in the design of various post-harvest systems for ginger.

2.0 MATERIALS AND METHODS

2.1 Materials

Gingers (*Zingiberofficinale*) used for this study were procured from Oja-Oba market in Akure, Nigeria. All analysis for this experiment was carried out at the crop processing Laboratory of Agricultural Engineering Department of the Federal University of Technology, Akure, and the Engineering Material Development Institute (EMDI) Akure, Nigeria.

2.2 Methods

2.2.1 Preparation of samples

The samples were obtained from a local market in Akure, Ondo State. Two varieties of the samples were used in carrying out the experiment, namely the yellow and black ginger. The samples were thoroughly graded to remove stones and bad seeds from all, and were stored at room temperature.

2.2.2 *Moisture content determination*

The moisture content of the samples was determined using American Society of Agricultural Engineers standard method (ASABE, 2007). The moisture content of the samples was determined by using a standard hot air oven method at 105°C until three regular readings were obtained (Gowen *et al*., 2007).

The moisture content (dry basis) of the samples was calculated using the equation below.

$$MC_{db}(\%) = \frac{weight\ of\ moisture\ (w_w)}{weight\ of\ dry\ product(\ w_d)} \times 100 \qquad (1)$$

Where, W_w= Initial weight of material

W_d = bone dry weight of material

2.2.3 Determination of some selected Engineering Properties

a. Geometrical Properties

The average size of the seed was determined by randomly selecting samples of 500g seeds and the three principal dimensions namely, Length (L), width (W) and thickness (T) axes were measured using digital vernier caliper with an accuracy of 0.01 mm (Mammam *et al*.,2005)

b. Geometric mean diameter

Geometric mean diameter *(Dg)* of the samples was calculated using the following relationship given by Shkelqim *et al.* (2010) and (Mohsenin, 1986) in equation (2)

$$D_g = (LWT)^{1/3} \qquad (2)$$

c. Mass

The unit mass of the individual seeds was measured using a top-loading electronic digital balance (Kerro BL30001), with an accuracy of 0.01 g.

d. Sphericity and Surface area

The surface area and sphericity was determined using the equation (3) by Davies and Zibokere, (2011) and Milani (2007), the degree of sphericity,$\emptyset$ can be expressed as follows

$$\emptyset = \frac{(LWT)^{1/3}}{L} \qquad (3)$$

Also, the surface area, S is given by

$$S = \pi {D_g}^2 \qquad (4)$$

e. Volume

The volume of 500g samples of each of the two ginger varieties was determined using the water displacement technique as outlined by Mohsenin (1980). Each sample of a known weight was dropped inside a calibrated beaker with a known volume of water. The displaced water gave the equivalent volume of water and hence the volume of ginger.

f. Density

The density of ginger rhizomes was determined based on the mass to volume ratio, using weight and volume properties determined as stated in e above.

g. Angle of Repose

The angle of repose of 500g ginger rhizomes of each of the two ginger varieties was determined using a special tilting table fabricated in the department of Agricultural Engineering used along with a topless and bottomless box of 150 x100 x20 mm dimension. The method set forth by Kramer (1944) and as reported by Mohsenin (1980) was employed. Individual samples were placed on the table and raised until the ginger rhizomes start to slide. The angle of inclination on the vertical graduation was determined for each sample, and reported as the angle of repose.

h. Coefficient of friction

The coefficient of friction of ginger was determined with respect to three surface which are plywood, galvanized and stainless steel by using inclined plane apparatus as described by Joshi *et al*., (1993). The coefficient of friction was calculated using equation 5

$$\mu_s = \tan\alpha \quad (5)$$

Where, μ_s is coefficient of friction

α is angle of inclination of material surface.

2.2.4 Compression test

A testometric testing machine (Model 1186) equipped with a 5000N compression load was used to carry out the mechanical properties (compression) of the ginger in the Engineering Materials Development Institute (EMDI) at Akure, Ondo. Compression test was performed on the ginger rhizomes using the Monsanto Universal Testing Machine. Testing conditions for the machine were the loading range: 0 – 5000 N; Chart speed 50rpm; and crosshead speed 1.5mm/min. Each seed was placed between the compression plates of the tensonometer. The seed was compressed at a constant deformation rate of 1.25mm/min. The applied forces at bio-yield and oil points and their corresponding deformations for each seed sample were read directly from the force-deformation curve. The mechanical behaviour of the ginger is expressed in terms of force required for maximum strength of the seed, energy required to deform the seed to initial rupture and ginger specific deformation. The rupture is determined as the force on the digital display when the seed under compression makes a clicking sound. Each process is often completed whenever the break point of the positioned seed is reached. All experiments were performed in duplicates.

3.0 RESULTS AND DISCUSSIONS

3.1 Moisture Content of Ginger

The moisture content of yellow and black gingers were 56.87±0.05%, 35.46±0.25% and 19.87±0.05 % db;55.67%±0.51, 34.89±0.30 % and 19.52±0.15 % db respectively.

3.2 Physical properties

A summary of the result of all measured parameters of the physical properties of ginger (*zingiber officionale*) for yellow ginger and black ginger are shown in Tables 1 and 2 respectively.

Table 1: Physical properties of yellow ginger(YG) at moisture content 56.87%, 35.46% and 19.87%db.

Property	**Mean**	**Min**	**Max**	**SD**
Length	69.21	38.55	100.56	18.56
Breath	40.18	22.12	65.06	13.75
Thickness	18.75	15.58	23.16	2.02
Geometric mean	38.28	16.16	68.97	13.81
Mass	32.03	9.7	77.5	18.47
Volume	23.87	5	60	13.30
Density	1.46	0.82	2.58	0.56
Sphericity	0.54	0.41	0.70	0.10

Table 2: Physical properties of black ginger (BG) at moisture content 55.67%, 34.89% and 19.52% dry basis.

Property	Mean	Min	Max	SD
Length	40.37	21.27	93.23	14.86
Breath	13.39	2.73	27.34	3.78
Thickness	14.00	0.02	26.1	4.35
Geometric mean	18.62	1.52	33.33	5.49
Mass	5.77	1.5	21.1	4.21
Volume	6.13	1	33	6.09
Density	1.34	0.37	5.00	0.86
Sphericity	0.48	0.03	0.75	0.12

3.1.1 Axial dimensions

The variation in length, width, thickness and geometric diameter of ginger with moisture content. All dimensions' decrease with decreasing moisture content. Very high correlation was observed between these dimensions and ginger moisture content, which conforms with the findings of Ajav and Ogundale (2014). Figure 1 shows the effect of moisture content on the geometric mean of ginger. The relationship between the geometric mean (Y) and moisture content (x) are expressed:

$$Y = 1.515x + 39.97 \quad R^2 = 0.962 \qquad yellow\ ginger$$
$$Y = 4.545x + 8.713 \quad R^2 = 0.976 \qquad black\ ginger$$

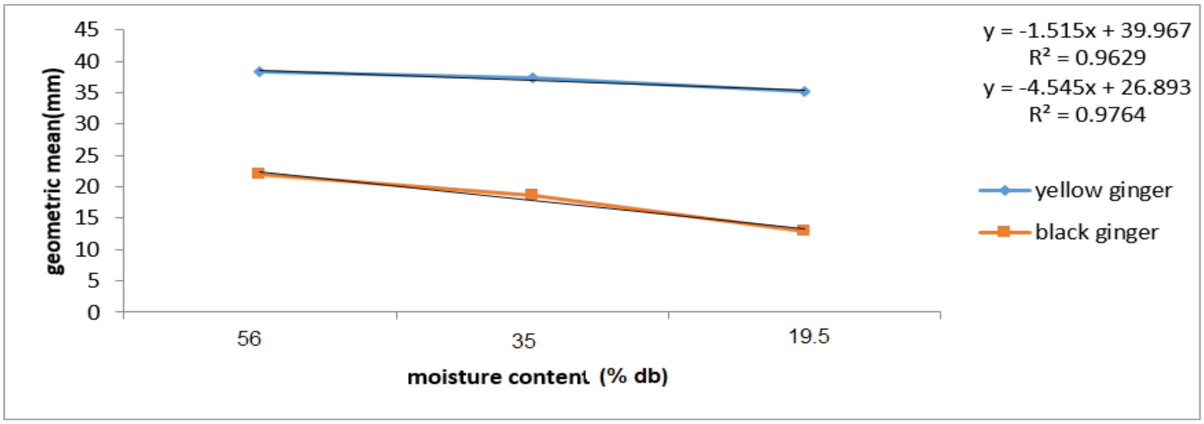

Fig. 1: Effect of moisture content on the geometric mean of ginger

3.1.2 Mass

The mass of the two ginger varieties decreased with decrease in moisture content. The mass decreased from 34.5 to 24.5g for yellow ginger and 9g to 3g for black ginger within the moisture range of 95.67% to 19.87% db as shown in Figure 2. The relationship between the mass (Y) and moisture content (x) are expressed:

$$Y = 2.105x + 0.836 \quad R^2 = 0.918 \qquad yellow\ ginger$$
$$Y = 3.595x + 23.32 \quad R^2 = 0.882 \qquad black\ ginger$$

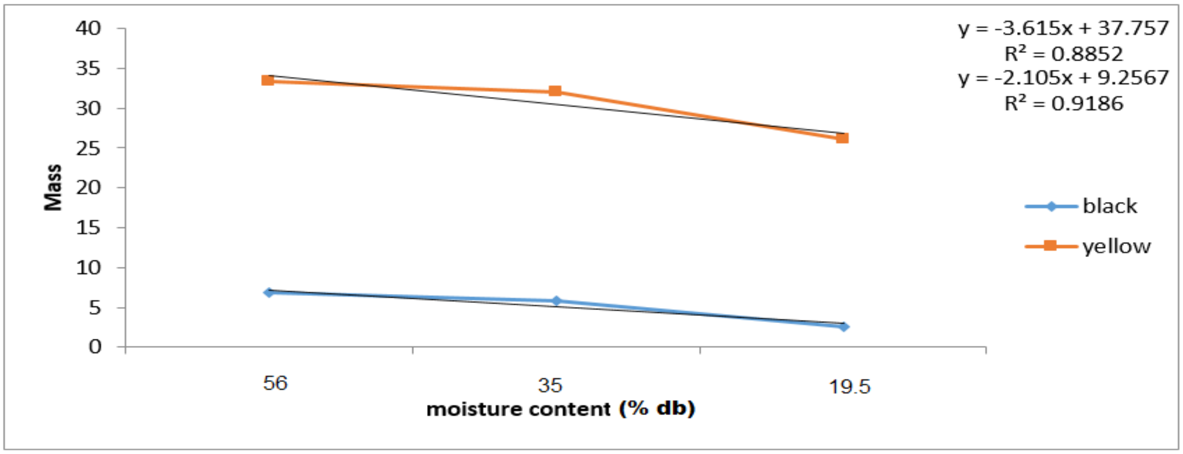

Fig. 2: Effect of moisture content on the geometric mass of ginger

3.1.2 Sphericity

The sphericity of ginger was observed to decrease with decreasing moisture content. Decrease in moisture content from 56% db to 19.5%db led to decrease in the average sphericity of the gingers as shown in Figure 3. Similar observation was reported by Simonyan *et al.* (2009) for Ronghai lablab seeds. The relationship between the sphericity (Y) and moisture content (x) expressed by regression equations for the two varieties of gingers are;

$$Y = 0.1x + 0.743 \quad R^2 = 0.923 \qquad \textit{yellow ginger}$$
$$Y = 0.0095x + 0.67 \quad R^2 = 0.991 \qquad \textit{black ginger}$$

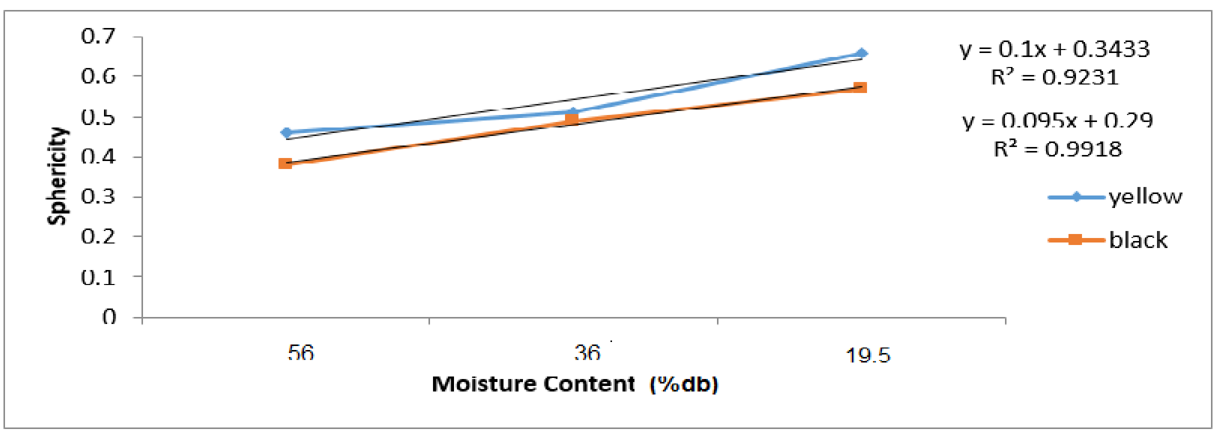

Fig. 3: Effect of moisture content on Sphericity

3.1.3 Angle of Repose

The angle of repose of ginger determined with respect to stainless steel, plywood and galvanized steel surfaces decreased with decreasing moisture content were presented in Figure 4. The variation is similar to that of Aviara *et al.* (1999) for guna seed. The relationship between the angle of repose (Y) and moisture content (x) expressed by regression equations for the two varieties of gingers are;

$$Y = 3.5x + 44.33 \quad R^2 = 0.993 \qquad \textit{yellow ginger}$$
$$Y = 5.5x + 27.66 \quad R^2 = 0.997 \qquad \textit{black ginger}$$

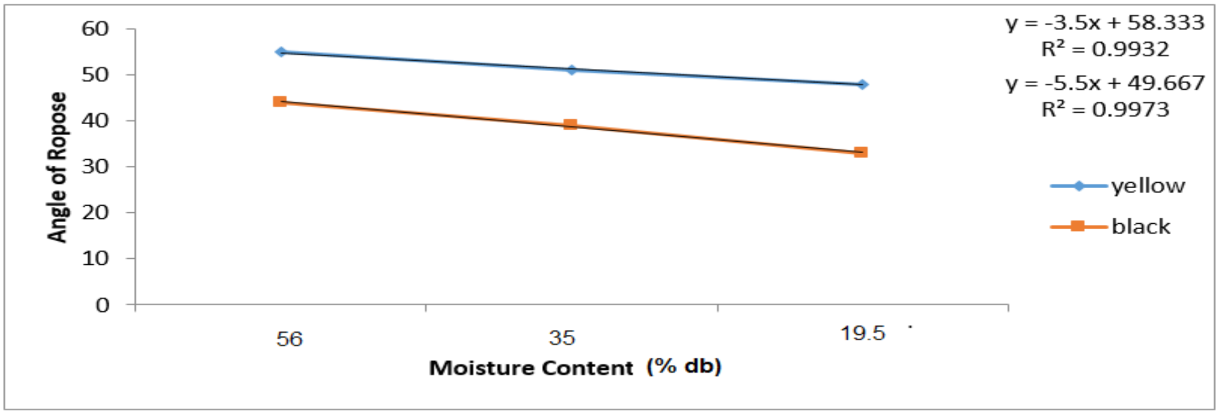

Fig. 4: Effect of moisture content on the angle of repose on yellow and black ginger.

3.1.4 Coefficient of static friction

The coefficient of friction for yellow and black ginger was determined with respect to stainless steel, plywood and glass surfaces and were shown in Figs 5 and 6. It increased with increasing moisture content for both varieties black and yellow ginger. Chandrasekar and Viswanathan (1999) and Gupta and Das (1998) also reported the same for coffee beans and sunflower seed respectively. The relationship between the coefficient of friction (Y) and moisture content (x) expressed by regression equations for the two varieties of gingers are;

$$Y = -0.12x + 0.7667 \quad R^2 = 0.9977 \qquad \textit{yellow ginger}$$

$$Y = -0.03x + 0.4767 \quad R^2 = 0.9643 \qquad \textit{black ginger}$$

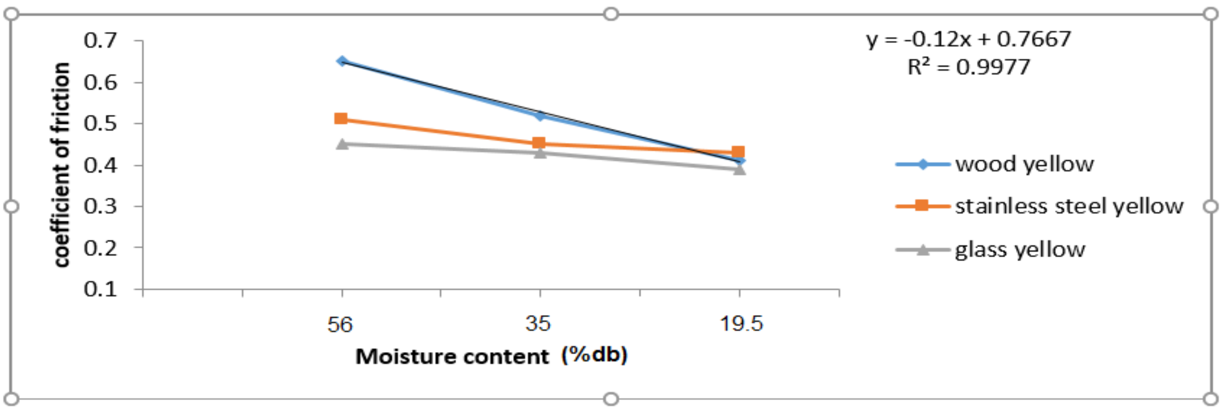

Fig. 5: Effect of moisture content on the coefficient of friction of yellow ginger

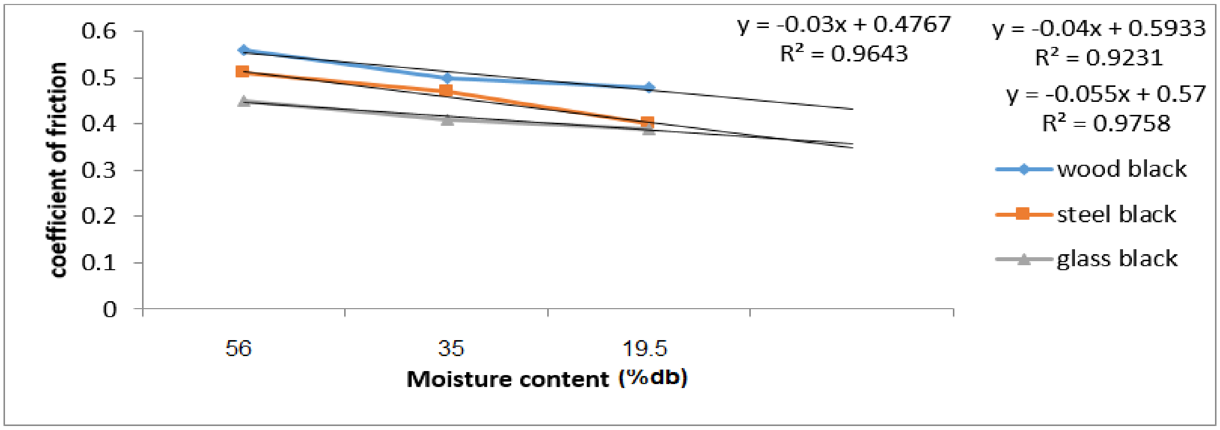

Fig 6: Effect of moisture content on the coefficient of friction on black ginger.

3.2 Mechanical properties

The Ginger rhizome was placed horizontally upon the flat plate of texture analyzer and a probe carrier fixed with a 65 mm diameter flat plate was brought in contact with ginger. A 50 kg load cell was used and compression force was applied at a speed of 0.5 mm/sec to compress the rhizome for 5 mm from the contact point. The firmness was expressed as the force required for compressing the rhizome to a distance of 5 mm.

3.2.1 Compressive stress

The relationship between compressive stress decreased linearly with moisture content. The decrease in compressive stress with moisture content may be due to the fact that as the ginger absorb moisture, they become softer and the forces acting would be minimum leading to reduction in stress. Similar decreasing trend was observed by Seifi and Alimardani, (2010). for Sc 704 corn variety. The relationship between compressive stress (Y) and moisture content (x) expressed by regression equations for the two varieties of gingers are;

$$Y = -0.295x + 4.553 \quad R^2 = 0.054 \qquad yellow\ ginger$$
$$Y = -0.62x + 3.996 \quad R^2 = 0.969 \qquad black\ ginger$$

3.2.2 Young modulus

Young modulus is a measure of the stiffness and rigidity of ginger and it shows how ginger can be deformed. The modulus increased as the moisture content decreases to 65.87%db with value of 1597Mpa and begins to decreases as moisture content decrease to 19.87%db. Figure 7 shows the relationship between young modulus (Y) and moisture content (x) and expressed by the regression equations

$$Y = -418.8x + 1603 \quad R^2 = 0.395 \qquad yellow\ ginger$$
$$Y = -574.5x + 2120 \quad R^2 = 0.552 \qquad black\ ginger$$

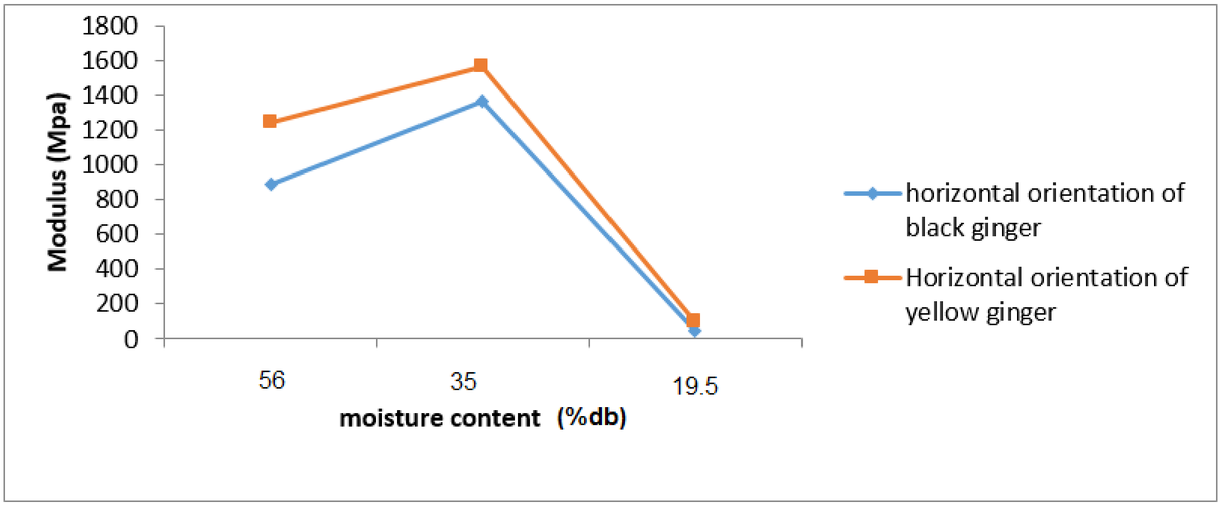

Fig. 7: Effect of moisture content on young's modulus of ginger varieties

3.2.3 Energy at break point

The relationship between the energy at break and moisture content indicated the energy at breaking point. The energy at break increases to 196N for yellow ginger and 106N for black ginger at 65.67% wb and started decreasing as moisture content decreases. This is similar to the work of Bargale *et al.* (1995) who found that the energy required to break barley kernel increase initially and then decreased as the moisture content decrease. It implies that moisture content range is an important consideration in design analysis for post-harvest equipment. The relationship between the energy at break(Y) and moisture content (x) for both horizontal and vertical orientation are expressed by the following equations:

$$Y = -22.57x + 191.2 \quad R^2 = 0.207 \qquad yellow\ ginger\ horizontal$$
$$Y = -23.49x + 128.8 \quad R^2 = 0.635 \qquad black\ ginger\ horizontal$$
$$Y = -0.115x + 1.17 \quad R^2 = 0.02 \qquad yellow\ ginger\ vertical$$
$$Y = 0.05x + 0.256 \quad R^2 = 0.057 \qquad black\ ginger\ vertical$$

The coefficient of friction varies from one material to the other (glass, stainless steel, wood), however glass or steel which has the lowest values of coefficient of friction should be used when constructing seed hoppers in ginger processing machines to allow easy sliding of the ginger rhizome. The mechanical properties of ginger varieties in Nigeria showed high toughness, deformation and young modulus value at vertical position than at the horizontal position. The compressive stress, compressive strain and young's modulus increased as moisture content decreases to a point and begins to decrease. The energy at break point increased with decrease in moisture content.

4.0 CONCLUSIONS

The engineering properties of ginger were investigated for two varieties of ginger. It was observed that the physical properties of the ginger seed determined as a function of moisture content varied significantly with the moisture content. The axial dimensions; geometric mean diameter, angle of repose, surface area, bulk density and coefficient of friction showed an ascending relationship with moisture rise while bulk density and sphericity had a descending relationship on moisture gain.

The engineering properties determined in this study constitute an important baseline data for the scientific design and development of various machines and equipment for the planting, harvesting, post harvesting (processing and handling) operations of ginger (*Zingiber officionale*). The various engineering properties measured will serve as a useful tool in process and equipment design and this will go a long way in assisting to improve yield and quality of ginger.

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MASS AND ENERGY BALANCE ANALYSIS OF PNEUMATIC FLASH DRYERS AND DEVELOPMENT OF OPTIMIZATION MODELS FOR CASSAVA

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ABSTRACT

The use of locally fabricated flash drying system is a major challenge for the production of High Quality Cassava Flour (HQCF). Thus, this study focuses on analysis of pneumatic dryers for cassava processing in relation to its significance to further the understanding of the performance of the existing design models of pneumatic dryers and to identify new way to improve drying performance of the dryers. Four different design models of pneumatic flash dryer for HQCF drying were evaluated at three cassava processing centers. The dryers were subsequently modified based on minimum air required. The dryer models were assessed based on energy efficiency, specific heat consumption, thermal efficiency, heat losses to the ambient and heat losses via air outlet. The highest energy efficiency was recorded for the positive, single cyclone system, dryer model 2 (+1C) which increased from 63.27 to 78.55% while it specific heat consumption was reduced from 3.79 to 3.06 MJ/kg after modification. Furthermore, the modification reduces the fuel consumption in all the dryer models by 22%, 14%, 14% & 16% respectively. Thus, it is established that regardless of some identified drawbacks of all the dryer's models evaluated single cyclone system had the better performance.

Keywords:*Pneumatic flash dryer, High Quality Cassava Flour, Energy efficiency and Specific heat consumption.*

1.0 INTRODUCTION

An increase in cassava processing has been shown to contribute to sustained growth in cassava production in Nigeria (Ugwu and Ukpai, 2002). However, the inherent high moisture content of fresh cassava root promotes microbial deterioration and unfavorable biochemical changes in the commodity (Wenham, 1995). Consequently, cassava roots need to be processed into more shelf stable product like HQCF in order to improve it flavor and reduce post-harvest losses.Current challenges for the cassava industry in Nigeria, is the area of cassava processing in general and drying in particular. This include reducing the drying time, improving throughput and product quality as well as reduction in the production cost per kg of product through appropriate equipment design or modification (Precoppe, et. al., 2015).

Drying is a unit and an essential operation in the production of cassava products such as high quality cassava flour, cassava starch and fufu flour. Mechanical drying ensures improved and consistent product quality. Flash dryers among the different types of dryers (such as rotary dryer, and tunnel dryer) have the shortest residence time. They have several advantages over more complex gas suspension dryers such as fluid bed or rotary types as result of short residence time, hence, most suitable for drying heat-sensitive products like cassava (Oveet and Sardo, 2001). Pneumatic flash dryers have been fabricated and installed in Nigeria Since 2004, however, all these flash dryers are inefficient in terms of energy consumption and or product quality (Kuye, *et al.*, 2010). Hence, the need for innovative cassava processing technologies is enormous. Consequently, the evaluation of the existing flash dryers is required for better improvement and optimization. The objectives of the study are to evaluate the drying performance of some design models of pneumatic flash dryer and modify those dryers base on minimum are.

2.0 MATERIALS AND METHOD

2.1 Identified Existing Processing Centers

The studies were carried out at three cassava processing centers. The processing centers were selected based on the frequency of production of HQCF. These processing centers were Niji Foods Limited located at km 5 Komu road, Ilero in Oyo State, Open Door International Limited, located at Akileye village, Iju Ebiye via Ota, Ogun State and Fadett Cassava Processing Center, located at Ofada via Mowe, Ogun State, which is being managed by Dowog Enterprise under lease. All the three cassava processing centers were located in Southwest region of Nigeria. The features of the pneumatic flash dryers evaluated were presented in table 1.

Table 1: Features of flash dryer models at the processing centers.

Features	**Model 1 (+6C)**	**Model 2 (+1C)**	**Model 3 (-1C)**	**Model 4 (-1C)**
System types	Pressure	Pressure	Vacuum	Vacuum
No. of cyclone	Six	One	One	One
Fuel type	Kerosene	Diesel	Black oil	Diesel
Burner type	Imported	Imported	Locally built	Imported
Drying duct length (m)	7.20	13.50	12.00	12.5
Dry duct diameter (m)	0.76	0.32	0.31	0.31
Outlet diameter (m)	0.25	0.28	0.31	0.27

C stand for cyclone

2.2 HQCF Processing Method and Sample Collection

HQCF samples were produced using the method as described by (IITA Report, 2005), using the four models of flash dryers for the drying. Set of wet and dried product samples were collected per day, after the systems had reached a steady-state condition. Wet samples were collected from the feeder and dried samples collected at the cyclone outlet every 20 minutes.

2.3 Dryers Evaluation and Dryer Modification

The unmodified dryer was evaluated, during three consecutive days. The minimum air flow rate was then calculated and the dryer was subsequently modified. The minimum velocity was used as a basis for the flash dryer modification by selecting a driver pulley which result into speed equivalent to these velocities for the fan blower. Dryers were modified using the minimum air flow determined from sorption parameters (Aviara and Ajibola 2002). The modified dryer was, then evaluated for another three consecutive days, following the same procedure used for the unmodified dryer.

2.4 Tools, Measurements and Experimental Procedure

Measurement were performed using tools, sensors and Data Acquisition System during steady state of the dryers which were being logged directly on to computer system at every 10 seconds.

These tools were: digital industrial balance, thermocouples sensors, temperature-resistant pressure transducer (PAA35X-V-3; Omega Engineering Inc.), OMB-DAQ-54, humidity–temperature probes (HC2-S; Rotronic, Bassersdorf, Switzerland), HygroLab 2; Rotronic, miniature hot-wire anemometers (TVS-1008; Omega Engineering Inc.) and data logger (HC2-S; Rotronic, Bassersdorf, Switzerland).

2.5 Parameters Measured and Calculated

The dryer parameters measured were: temperature & humidity (ambient air, hot air inlet, outlet and exhaust air), pressure (ambient and outlet air), air velocity and weight of feed, product and fuel. The parameters calculated were feed rate and discharge rate, fuel consumption, air density, air enthalpy, minimum air flow rate using standard procedures.

2.6 Dryer Performance Parameters

Dryer performance was determined using methods as described by (Precoppe, 2015). The performance indices were specific energy consumption, energy efficiency, thermal efficiency, heat rate, heat losses via exhaust air and heat losses to the ambient.

2.6 Statistical Analyses

Analysis of variance (ANOVA) was adopted in analyzing the data. SPSS version 17.0 software package was used to statistically analyze the data obtained for all treatments. The significance of treatment means was tested at $P < 0.05$ probability level using Duncan's New Multiple Range Test (DNMRT) (Steel and Torrie, 1980).

2.7 Energy Analysis

Specific energy consumption (q_s) was calculated (Kudra 2009) based on the heat rate added by the dryer's heating unit to the ambient air ($\Delta \dot{Q}_{in}$) and the water evaporation rate ($\dot{m}_\omega$) as shown in Equation 1

$$\textbf{Specific energy consumption } (\mathbf{q_s}) = \frac{\Delta \dot{Q}_{in}}{\dot{m}_\omega} = \frac{\dot{m}_{air}(h_{in} - h_{amb})}{\dot{m}_\omega}$$

(1)

Where $\dot{m}_{air}$ is the air mass flow rate and h_{in} plus h_{amb} are the enthalpy of inlet and ambient air, respectively. The value for $\dot{m}_{air}$ was calculated from the air density, air velocity and cross-sectional area of the exhaust air. While the air density was determined based on the air temperature, relative humidity and pressure, using the equation of state called CIPM-2007 formula (Picard *et al.*, 2008)

Energy efficiency (η_e) was calculated as the quotient of heat used for water evaporation and heat added to the ambient air by the dryer's heating unit (ΔQ) (Kudra, 2009)

$$\textbf{Energy efficiency } (\boldsymbol{\eta_e}) = \frac{Q_w}{\Delta \dot{Q}_{in}} = \frac{m_w \cdot \lambda}{\Delta \dot{Q}_{in}} \qquad (2)$$

Where $\boldsymbol{\lambda}$ is the heat of vaporization the latent heat of the vaporization of water at the inlet temperature of the product (Chapuis *et. al.,* 2017)

Thermal efficiency, (η_T), was defined according to (Strumiłło *et al.,* 2014) based on the inlet air temperature (T_{in}), the outlet air temperature (T_{out}) and the ambient temperature (T_{amb}), as shown in Eq. (3):

$$\text{Thermal efficiency } (\eta_T) = \frac{T_{in} - T_{out}}{T_{in} - T_{amb}}$$

(3)

2.8 Determination of minimum air flow rate

Minimum air flow rate ($\dot{m}^*_{air}$) was determined considering the heat and hydrodynamic demand of the dryer (Kudra, 2012). The highest allowable outlet air relative humidity (ϕ^*_{out}) and the lowest allowable outlet air temperature (T^*_{out}) was determined based on the sorption isotherm of cassava using the modified Halsey model (Iglesias and Chirife 1976) and the parameters for desorption presented by (Aviara and Ajibola, 2002). $\dot{m}^*_{air}$ was determined by dividing water evaporation rate ($\dot{m}_w$) by Y^*_{out} and taking into consideration the absolute humidity of the ambient air as shown in Equation (5):

$$\dot{m}^*{}_{air} = \frac{\dot{m}_\omega}{Y^*{}_{out} - Y_{amb}} = \frac{\dot{m}_{dm}(X_{wp} - X_{dp})}{Y^*{}_{out} - Y_{amb}} \quad (5)$$

Where $\dot{m}_{dm}$ is the dry basis feed rate and X_{wp} and X_{dp} are the moisture content in dry basis of the wet product and of the dried product, respectively. The hydrodynamic demand took into consideration that the minimum air velocity at the drying duct should be higher than the wet product terminal velocity.

3.0 RESULT AND DISCUSSION

3.1 Dryers Performance

The results of the unmodified dryers in the table 2 indicated that significant variation ($p \geq 0.05$) was found in the performance indices for the all the flash dryer models except for the energy efficiency 1(+6C) & 4 (-1C) and specific energy consumption of the dryer models 1(+6C), 3 (-1C) & 4 (-1C). Flash dryer model 2 (+1C) had the highest energy efficiency (63.4 %) while the lowest value of (47.47 %) was recorded for dryer model 3 (-1C) using the mean values over different feed rates. In addition, the lowest value (3.63 MJ/kg) of specific heat consumption was recorded for dryer model 2 (+1C) while the dryer model 3 (-1C) also had the highest value (5.07MJ/kg) using the mean values. According to Kudra, (2012), energy efficiency and specific heat consumption are the most frequently exploited to assess the dryer performance of all the indices from the energy view point. The higher the energy efficiency and the lower the specific heat consumption, the better the dryer performance hence, the pneumatic flash dryer model 2 (+1C) had the best performance.

Furthermore, according to Mujumdar (2014), the specific energy consumption of a pneumatic dryer ranges from 4.5 to 9.0 MJ/kg water while Tolmac *et. al.,* 2005 reported the range of specific consumption of energy to be between 3.50 to 5.04 MJ/kg. Strumiłło *et al.* (2014) reported that the energy efficiency of convective dryers is typically between 20 and 60 %. The specific energy consumption and the energy efficiency of the flash dryer models evaluated fall within these range. In addition, the thermal efficiency of pneumatic dryers ranges from 50 to 75% according to (Rotstein and Crapiste 1997) but the thermal efficiencies obtained for the dryer models 3 (-1C) and 4 (-1C) were within this range however, that of dryer models 1 (+6C) and 2 (+1C) were slightly higher. This might be due to the elevated temperature of the hot air inlet recorded for the two dryer models.

3.2 Performance Comparison between Modified and Unmodified Dryers

There was significant difference between all the performance indices except the specific heat consumption of dryer model 3 (-1C) and thermal efficiency of the dryer model 2 (+1C). There was significant improvement in the performance of modified dryers for all the dryer models, as it could be reflected in table 2 that the energy efficiencies of all the dryers increased while their specific heat consumption reduced with the exception of the dryer model 3 (-1C). Furthermore, the results revealed that 94.1 g/kg, 88.2 g/kg, 89.8 g/kg and 101.2 g/kg (dryer models 1 (+6C), 2 (+1C), 3 (-1C) and 4 (-1C) respectively) of fuel shall be required to dry 1kg of wet product. Whereas in the modified dryers, these values reduced to 73.1g/kg, 75.9g/kg, 77.1g/kg and 85.3 g/kg. This reduction (22%, 14%, 14% & 16%) in fuel consumption is directly proportional to production cost, hence, improvement on investment return.

Table 2: Comparison of performance data of unmodified and modified flash dryer models

Dryer model	Dryer type	Fuel consumption (kg/h)	Heat input rate (kW)	Energy efficiency (%)	Specific energy consumption (MJ/kg)	Thermal efficiency (%)
Dryer model 1 (+6C)	Modified	17.41^{b} ±.01	76.18^{b} ±.02	74.01^{a} ±.06	3.24^{b} ±.04	86.06^{b} ±.09
	Unmodified	22.49^{a} ± .10	106.51^{a} ±.44	52.02^{b} ±.02	4.61^{a} ±.06	87.13^{a} ±.08
Dryer model 2 (+1C)	Modified	18.11^{b} ±.01	82.34^{b} ±.02	78.55^{a} ±.01	3.06^{a} ±.04	80.31^{b} ±.05
	Unmodified	21.09^{a} ±.03	100.60^{a} ±.45	63.27^{b} ±.02	3.79^{a} ±.10	80. 49^{b} ±.03
Dryer model 3 (-1C)	Modified	17.71^{b} ±.10	118.72^{b} ±.02	54.51^{a} ±.10	5.09^{a} ±.10	81.75^{a} ±.05
	Unmodified	20.82^{a} ±.02	127.47^{a} ±.51	47.24^{b} ±.04	5.09^{a} ±.06	54. 40^{b} ±.03
Dryer model 4 (-1 C)	Modified	18.37^{b} ±.08	78.63^{b} ±.05	69.81^{a} ±.11	3.82^{b} ±.10	74.15^{a} ±.07
	Unmodified	21.95^{a} ±.12	102.83^{a} ±.19	50.93^{b} ±.32	5.05^{a} ±.52	65.29^{b} ±.71

*Values are means of 3 replicates and their standard deviation.

*Values with different superscripts along the columns are significantly different ($p \geq 0.05$)

3.3 Temperature Distribution

Figure. 1 presents the temperature distributions along the drying ducts of the flash dryers models. There was high rate of heat transfer between the drying air and the product, thus enhancing the high rate of moisture evaporation during the constant drying period. The temperatures of the drying air which follow the same trend for all the dryer models reduce progressively along the drying duct.

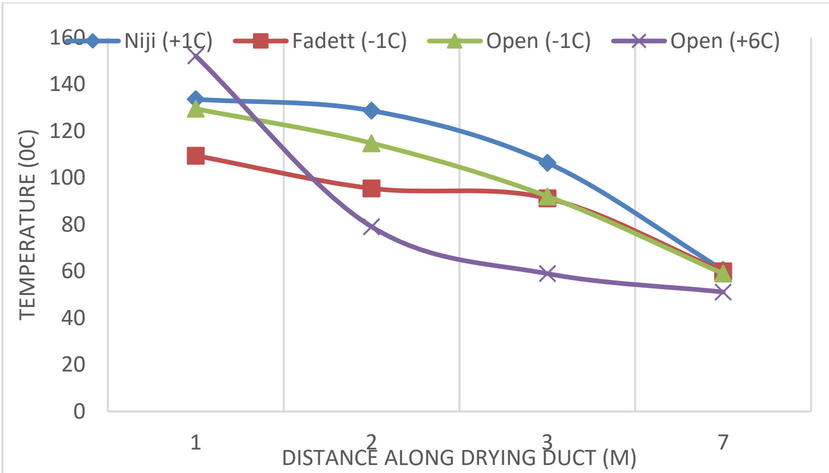


Figure. 1: Temperature Distribution along the Drying Ducts

3.4 Effect of feed rate on the energy efficiency for the different dryer models

The energy efficiency increases with increase in the feed rate for all the dryer models reaching the maximum at the optimum feed rates in both unmodified and modified dryers after modification (Figure. 2). Significant improvement in energy efficiency was observed in all the dryer models after modification. This was as a result of reduction in the air inlet velocity which reduces for all the dryer models. However, dryer model 2 had the highest energy efficiency which increases from 72.3% at velocity of 9.45 m/s and feed rate of 171.70 kg/h to 84.4% at velocity of 7.39 m/s and feed rate of 175.59 kg/h while the lowest values was observed in the dryer model 3 which increases from 56. 0% at velocity of 9.45 m/s and feed rate of 171.70 kg/h to 74.1% at velocity of 7.4 m/s and feed rate of 193.49 kg/h. Hence, dryer model 2 of all dryer models is the best in term of drying performance. Precoppe et. *al.*, (2015) reported similar result of energy efficiency of a pneumatic flash dryer for HQCF drying which increases from 43.1% to 54.0% after modification by reducing the air velocity from 9.5 m/s to 7.2 m/s.

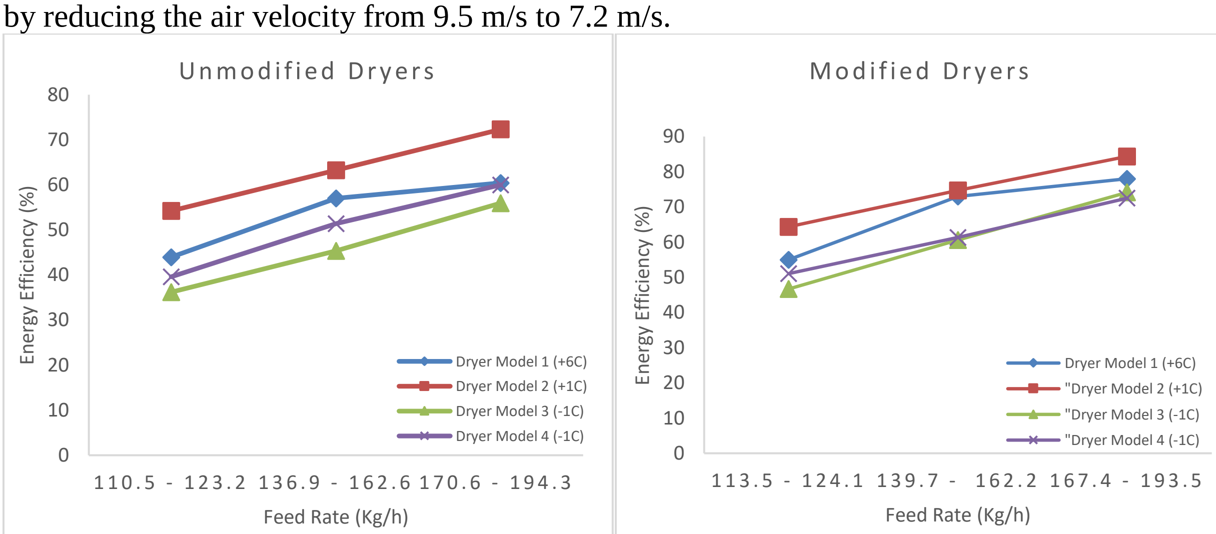
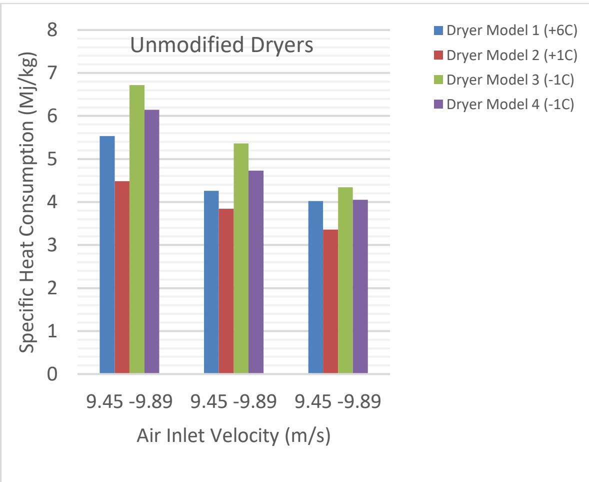


Fig. 2 Effect of feed rate on the energy efficiency

3.5 Effect of inlet air velocity on the specific heat consumption for different dryer models

Figure 3 show the effect of inlet air velocity on the specific heat consumption of all the dryer models for both unmodified and modified dryers at different feed rates. The highest specific heat consumption of 6.72 MJ/kg was recorded at 9.89 m/s velocity and feed rate of 123.48 kg/h for dryer model 3 while the lowest value of 3.36 MJ/kg was obtained at 9.45 m/s and feed rate of 171.70 kg/h for dryer model 2 for unmodified dryers. Also, the highest specific heat consumption of 5.21 MJ/kg was recorded at 7.4 m/s velocity and feed rate of 193.49 kg/h for dryer model 3 while the lowest value of 2.61 MJ/kg was obtained at 7.39 m/s and feed rate of 175.59 kg/h for dryer model 2 for modified dryers. The specific heat consumption of modified dryers of each of the dryer models reduces compared to unmodified dryers. This reduction indicates improvement in the performance of modified dryers for all the dryer models. Furthermore, dryer model 2 also gave the best performance for having the lowest value. This is also similar to report of Precoppe *et. al.*, (2015) of specific heat consumption of a pneumatic flash dryer for HQCF drying which decreases from 5.75 Mj/kg to 4.60 Mj/kg after modification by reducing the air velocity from 9.5 m/s to 7.2 m/s.



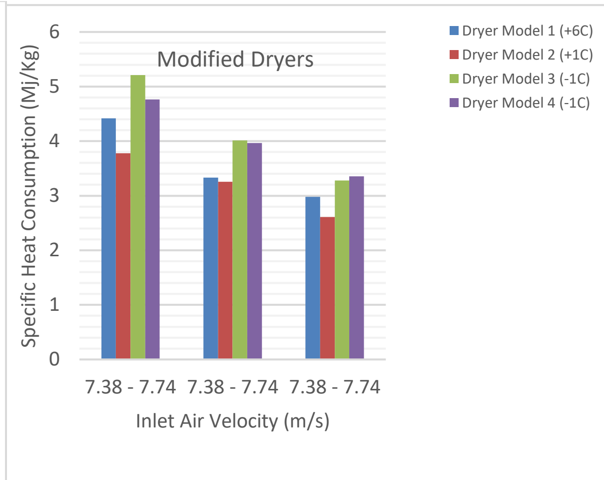
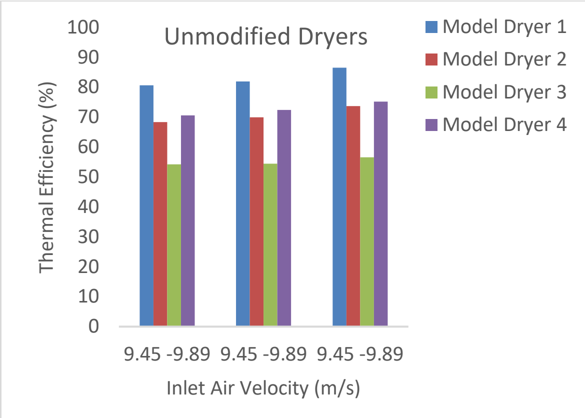


Fig. 3. Effect of inlet air velocity on the specific heat consumption at different feed rates

3.6 Effect of inlet air velocity on the thermal efficiency for different dryer models

Figure 4 shows the effect inlet air velocity on the thermal efficiency of the dryer models before and after modification at different feed rates. The thermal efficiency increases with increase in the feed rate for all the dryer models for both unmodified and modified dryers. It was also observed that the thermal efficiency increased in all the dryer models at the same feed rates after modification. This was also as a result of reduction in the air inlet velocity which reduces for all the dryer models. The maximum thermal efficiency was recorded for dryer model 1 which increases from 86.5% at velocity of 9.45 m/s and feed rate of 192.15 kg/h to 89.8% at velocity of 7.38 m/s and feed rate of 193.09 kg/h after modification while the lowest values was observed in the dryer model 3 which increases from 56. 6% at velocity of 9.89 m/s and feed rate of 194.32 kg/h to 82.2% at velocity of 7.4 m/s and feed rate of 193.49 kg/h after modification.



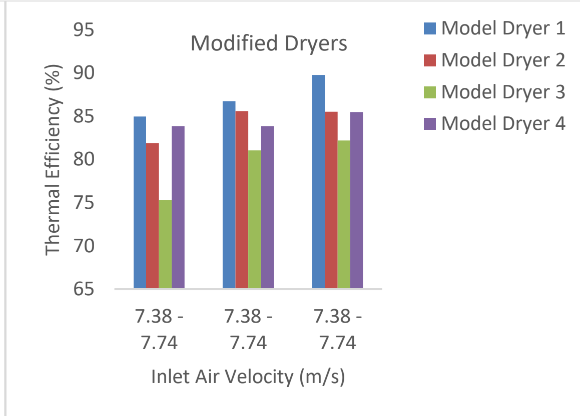


Fig. 4. Effect of inlet air velocity on the thermal efficiency at different feed rates

4.0 CONCLUSION

The four models of pneumatic flash dryers were successfully evaluated. It is established that the positive single cyclone system had the best performance in term of energy efficiency and specific heat consumption. The qualities of the HQCF samples obtained from the model of flash dryers were within the limits set by the relevant Nigerian standards which is an indication that those dryer models are suitable for HQCF production. However, some drawbacks observed in the flash dryers models were absence of insulation on the drying duct which facilitate greater heat loss to the ambient, absence of feeder on some of the flash dryer models, improper design of the multiple cyclone which affect proper separation of product from the exhaust air and absence of heat control system on the burners. These draw backs were militating against the optimum performance of pneumatic flash dryer models. Hence, the need for new engineering design of a functional and well efficient pneumatic flash dryer for HQCF production, because there is a limit to which modification could be carried out on existing flash drying system.

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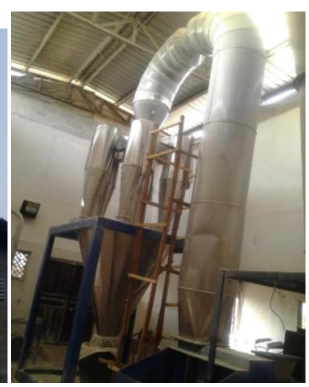
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Figure 1a **Figure 1b** **Figure 1c**

Plate 1a: Negative Single Cyclone System

Plate 1b: Positive Single Cyclone System

Plate 1c: Positive Six Cyclone System

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ENGINEERING PROPERTIES OF WOOD UNDER TWO DRYING METHODS

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ABSTRACT

This project work focuses on the comparison of the engineering properties of *Pyrus communis* under solar and air-drying method. Green samples of the wood were dried simultaneously in both solar kiln and open air for 15 days. The daily moisture content reduction (%MC wet basis) under both drying conditions were observed and recorded. Mechanical tests (shear strength, compressive strength, hardness and tensile strength) were conducted. The results showed that open air-dried woods attained fibre saturation point (FSP) (23.4-30%MC) within three days faster than the solar kiln dried ones, which attained FSP range of 26.4-30.9MC% after the fourth day. Timbers dried in solar kiln attained lower %MC (12.9, 11.0, 14.3, 12.3) when compared to open-air dried samples (22.1, 18.5, 21.1, 17.1) for all the mechanical tests conducted, solar kiln dried timber had higher mechanical properties than the open air-dried woods.

1.0 INTRODUCTION

The high moisture content of freshly milled wood affects its properties, necessitating the reduction of the timber moisture content prior to its use. Moisture reduction from wood improves its mechanical properties such as hardness, shear strength, compressibility strength, tensile strength etc. Over the years, various moisture removal methods have been used, they include uncontrolled (air drying) and controlled (kilns) (Ugwu *et al*., 2015).

Drying is a process of removing moisture involving a simultaneous heat and mass transfer under the influence of air temperature, velocity and relative humidity (Ertekin and Yaldiz, 2004). Drying ensures the attainment of equilibrium moisture content of timber, thereby enhancing shelf life, value addition, volume reduction, workability, strength and quality enhancement (Rajendra, 2007; Bond and Espinoza, 2016). In open-air or natural drying method, which takes a lot of drying time, drying is achieved under direct exposure of woods to ambient air, ambient temperature, relative humidity and natural wind. Solar kiln methods attain faster and more uniform drying in a controlled environment (Ekechukwu, 2010, Belessiotis and Delyannis, 2011; Pirasteh *et al.* 2014).

According to Miri Tari *et al.* (2015), aside moisture removal, drying influences the internal drying strain and stresses and rate of cracks and checks. At high temperatures, mechanical properties are decreased, and defects increased (Thiam *et al.* 2002).Studies in the past have discussed the drying rate of local species, others investigated the effects of different wood drying types on physical and mechanical properties (Oltean *et al.*, 2007; Barański *et al*., 2014; Ugwu *et al*., 2015; Miri Tari *et al*., 2015).No previous study has been reported on the impact of drying methods on the engineering (mechanical and physical) properties of *Pyrus communis.* This paper reports on a study conducted to understand the effect of open air and solar kiln drying on the engineering properties (compressive strength, shear strength, tensile strength, and hardness) of a selected wood species and recommend which is better.

2.0 MATERIALS AND METHODS

Freshly *pyrus communis* was gotten from Edemani in Nsukka, latitude 6.8^{o}N, Nigeria. The timber was cut into 8 sample boards of 0.65m length x 0.24m width each and labelled A-H in duplicates, which represents different sections of the log. A-D was stacked in the solar kiln developed by Ugwu *et al.* (2015) for solar drying while E-H was stacked outside for the air drying. Timber load was stacked between stickers of 25mm thickness and stacked at least 75cm away from both top and bottom of the chamber to enable proper circulation of heated air as shown in Fig 1.

The moisture content and the mechanical tests were carried out using OHAUS Triple Beam Balance (1g accuracy), Fisher Scientific Isotemp Oven Model 655F, Berkel weighing Balance NR139964 (5g accuracy), Vickers's hardness testing machine, Impact strength testing machine, Universal testing machine, Mass cylinder and Pendulum testing machine at the wood workshop section of the Department of Civil Engineering, University of Nigeria.

Fig.1: Wood stacked in the solar kiln (A) and wood stacked in open air environment (B)

2.1. Physical Properties (Moisture content)

These timber boards were representative of the slowest drying part (widest, thickest, highest moisture content and free of knots) (Denig et al., 2000) as reported in Ugwu et al. (2015). Using Eq. (1), the moisture content (MC) of each section was calculated and the average MC of the two sections was computed to obtain the initial MC of the sample board.

$$MC\% = \left(\frac{weight\ of\ wet\ section}{weight\ of\ oven\ dried\ section} - 1\right) * 100 \qquad [1]$$

The wet sample boards were weighed within 5g accuracy and recorded. The average MC from Eq. 1 and 2 were used in estimated the oven-dry weight.

$$\boldsymbol{Estimated\ oven\ drying\ weight\ (g)} = \frac{\boldsymbol{weight\ of\ sample\ board}}{\boldsymbol{100+MC\%}} \qquad \textbf{[2]}$$

The sample boards were reweighed daily and the MC for each day calculated using Eq. 3, the daily weight of each board and the MC (%) were recorded.

$$Current\ MC(\%) = \left(\frac{current\ weight\ of\ sample\ board}{Estimated\ oven\ dry\ weight} - 1\right) * 100 \quad [3]$$

2.2. Mechanical Properties

2.2.1 Shear strength

Shear strength of wood is the measure of its ability to resist internal slipping of one-layer relative to another along the grain, and it is defined by the maximum load per shear plane area. The shear force was determined using universal testing machine and the sheared area was also determined as reported in Uetimane, 2010. The horizontal shear strength (N) was determined using Eq. 4.

$$Shear\ strength = \frac{Shearing\ force\ (F)}{Area\ sheared\ (A)} \quad [4]$$

2.2.2 Tensile strength

A material's static strength is the resistance to permanent deformation This kind of strength tends to prevent bending, twisting or denting of a material permanently in service. Both ultimate load and cross-sectional area was determined as reported in Simpson (1991) and Mujumdar (1995). The tensile strength (TS) was calculated using Eq. (5).

$$Tensile\ strength = \frac{ultimate\ load\ (P)}{cross\ sectional\ area\ (A)} \quad [5]$$

2.2.3 Hardness

Hardness is a characteristic of a material, not a fundamental physical property. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. Indentation hardness was obtained by measuring the depths of indentation using Vickers hardness test method as shown in Eq. (6) and reported in Uetimane, 2010.

$$HBN = \frac{2P}{\frac{2\pi}{D}\left(D^2\sqrt{D^2 - d^2}\right)} \quad [6]$$

where
HBN = Brinnel Hardness no, *D* = Brinnel bulb diameter (indenter), *d* = depth of indentation
P = constant axial load.

2.2.4 Compressive strength

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce its size. Compressive strength resists compression (being pushed together), the compressive strength of wood parallel to the grain is much higher than that perpendicular to the grain. Compressive strength was calculated using Eq. (7), maximum load and cross-sectional area was determined as reported in Uetimane, 2010.

$$\boldsymbol{Compressivestrength} = \frac{\boldsymbol{maximum\ load}(\boldsymbol{kilo\ N})}{\boldsymbol{cross\ sectional\ area}\ (\boldsymbol{M^2})} \quad [7]$$

3.0 Results and Discussion

3.1 Physical properties

Sample Number		Green Weight (kg)	Day														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	**Weight**	**5.8**	**5.8**	**5.7**	**5.2**	**4.4**	**3.9**	**3.85**	**3.8**	**3.7**	**3.6**	**3.5**	**3.4**	**3.3**	**3.2**	**3.1**	**3.0**
B	**Weight**	**5.8**	**5.8**	**5.7**	**5.2**	**4.9**	**4.6**	**4.5**	**4.4**	**3.9**	**3.8**	**3.75**	**3.7**	**3.6**	**3.45**	**3.4**	**3.3**
C	**Weight**	**5.9**	**5.9**	**5.8**	**5.3**	**4.9**	**4.7**	**4.6**	**4.5**	**4.4**	**4.0**	**3.7**	**3.5**	**3.4**	**3.2**	**3.2**	**3.1**
D	**Weig**	**5.6**	**5.**	**5.**	**5.**	**4.**	**4.**	**3.**	**3.**	**3.**	**3.**	**3.4**	**3.**	**3.**	**3.**	**3.**	**3.**

After the oven-drying process and the simultaneous drying of the wood stacks in both open air and in solar kiln for 15 days, weights of all sample boards were obtained daily for calculation of the daily moisture content. Results of daily weight and %MC are shown in Tab.1 and Fig.2.

	ht		6	5	0	4	0	9	85	7	5	0	3	2	15	10	05
E	Weight	4.2	4.2	4.0	3.5	3.0	2.8	2.7	2.6	2.4	2.3	2.25	2.2	2.1	2.05	2.0	2.0
F	Weight	6.4	6.4	6.2	5.6	5.2	4.8	4.7	4.65	4.4	4.3	4.25	4.2	4.0	3.9	3.8	3.7
G	Weight	4.7	4.7	4.3	4.0	3.7	3.4	3.3	3.2	2.9	2.7	2.6	2.5	2.45	2.4	2.3	2.3
H	Weight	5.9	5.9	5.7	5.2	4.6	4.4	4.3	4.2	4.0	3.8	3.7	3.6	3.5	3.45	3.4	3.3

Table 1. Weight of the solar kiln (samples A – D) and air drying (samples E – H) methods

Samples A-D dried in the solar kiln were compared to the open-air dried samples E-H for a period of 15 days as shown in graph in Fig. 2 below. It was seen that the %MC in sample E attained the fibre saturation point before the sample A. The fibre saturation point of sample A was attained on the third day, the drying rate was maintained till it reached the equilibrium moisture content of 12.0% which is remarkable as compared to 22.1% MC attained by air drying. Sample B was compared to sample F, it was seen that the moisture content in sample F attained the fibre saturation point before the sample B, but the fast rate of drying was not maintained unlike in the case of sample B, which attained the fibre saturation point and maintained its drying rate till it reached the equilibrium moisture content of 11.0% which is remarkable as compared to 18.5% MC attained by air drying.

Sample G attained the fibre saturation point before the sample C but could not maintain the fast-drying rate. But in the case of sample C it attained the fibre saturation point and was able to maintain its drying rate till it reached the equilibrium moisture content of 14.3% which is remarkable as compared to 21.1% EMC attained by air drying. Sample H attained the fibre saturation point before the sample D but could not maintain the fast-drying rate. But in the case of sample D it attained the fibre saturation point and was able to maintain its drying rate till it reached the equilibrium moisture content of 12.3% which is remarkable as compared to 17.1% EMC attained by air drying. The results of %MC in Table 1 and Fig. 2 showed similarity when compared Helwa (2004), which reported that timbers were dried for 17days attained 12.0%MC in solar kiln dryer and 20.0% under air drying condition.

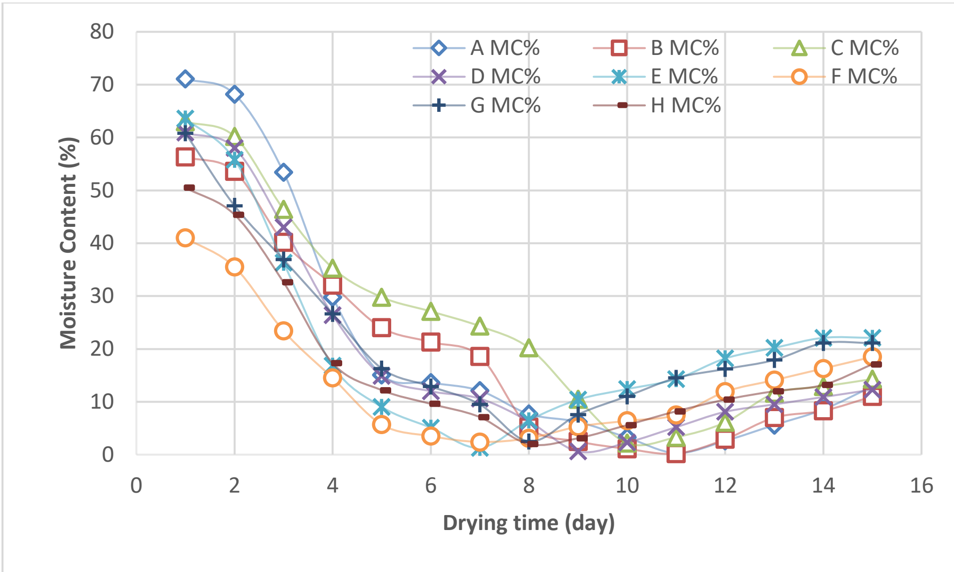

Fig. 2: Graph of %MC samples A-H

3.2 Mechanical Test Results

The mechanical properties of wood are always in relationship with the percent moisture content (Jacek *et al*., 2014). In view of this, sample A (solar dried) and sample E (air dried) to 12.0%MC and 22.1%MC respectively, were compared as shown in Fig. 3a below and it was seen that the mechanical properties of sample A dried under the solar kiln showed more advance in properties with shear strength 137.20 N/mm^2, compressive strength 14.80N/mm^2, hardness 82.9N/mm^2 and tensile strength of 35.96N/mm^2 as compared to sample E dried under air with shear strength 135.84 N/mm^2 compressive strength 14.63N/mm^2 hardness 82.67N/mm^2 and tensile strength of 35.77N/mm^2.Sample C (solar dried) and sample G (Air dried) to 14.3%MC and 21.1%MCrespectively, were compared and showed in Fig. 3athat the mechanical properties of sample C dried under the solar kiln showed more advance in properties with shear strength 137.66 N/mm^2, compressive strength 14.83 N/mm^2, hardness 82.2 N/mm^2 and tensile strength of 36.34 N/mm^{2}as compared to sample G dried under air with shear strength 135.71N/mm^2 compressive strength 14.72 N/mm^2 hardness 81.71 N/mm^2 and tensile strength of 35.76 N/mm^2.

In comparing the mechanical properties of sample B (solar dried) with sample F (air dried) and sample D (solar dried) and sample H (air dried) with a moisture content of 11.0% and 18.5% and 12.3% and 17.1% respectively, as shown in Fig. 3b below, it can be observed that similar trends of higher mechanical properties in solar dried samples exists. This is in line with the reports of Uetimane (2010) and Jacek *et al.* (2014), which revealed that woods dried under controlled environment had higher mechanical properties.

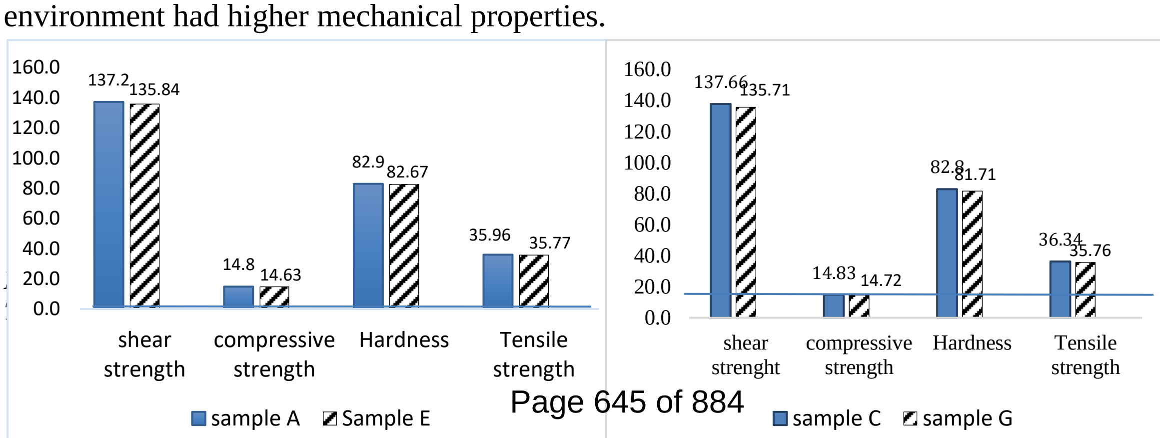

Fig 3a:

Mechanical Properties of Sample A and E; C and G

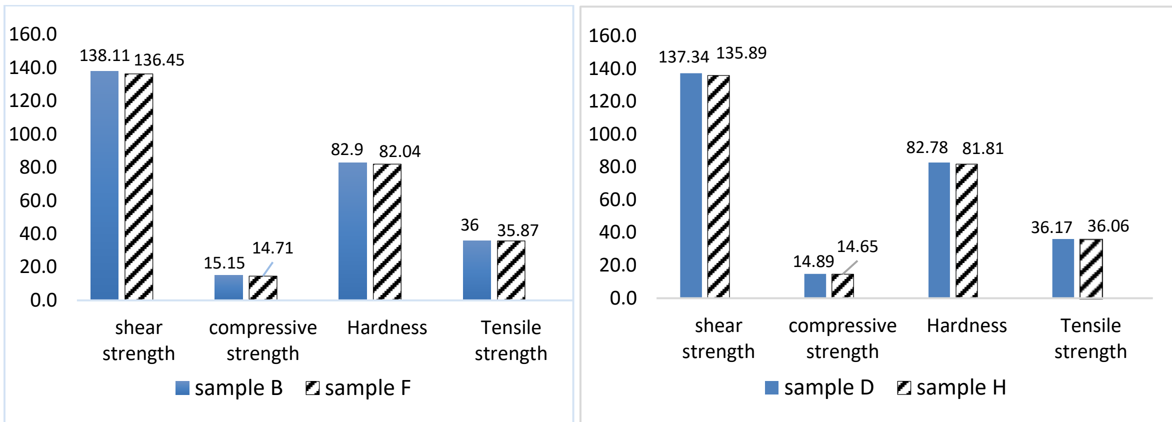

Fig 3b: Mechanical Properties of Sample B and F; D and H

CONCLUSION

This study evaluated the influence of open-air drying and solar kiln drying on the engineering properties of *Pyrus communis*. The open-air drying system attained fibre saturation point (25%-30% MC) faster than the solar kiln drier. Lower %MC was attained by the solar kiln dried timbers. The mechanical properties of the wood showed higher mechanical properties especially in the case of Sample B with the average hardness of 82.9N/mm^2, shear strength of 138.11N/mm^2, compressive strength of 15.15 N/mm^2, and tensile strength of 36.00N/mm^2. Lower mechanical properties were showed by the open-air dried. Better moisture reduction and improved mechanical properties of a woods dried in solar kiln, suggests that solar kiln drier enhanced the engineering properties of timbers when compared to the ones dried in the open air drying.

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Drying Kinetics of Irvingia gabonensis (*Ogbono*)

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***ABSTRACT**:*
This study was aimed at evaluating the thin –layer drying behavior of Irvingia gabonensis in a cabinet dryer at temperature of 70 ^oC meant for drying agricultural materials in order to predict the best equation for drying the process from twelve existing drying Mathematical models. Mathematical models describe the heat and mass transfer phenomena of a product. 500 g samples of freshly harvested Ogbono seeds were loaded into the cabinet dryer for each experiment, removed at regular interval of one hour until three consecutive weights were achieved. Changes in drying weight were measured using a precision weighing balance. Moisture loss and drying rate were determined and the drying data were converted to moisture ratio, these were then fitted to the twelve mathematical models. The best fit model to describe the thin layer drying of Ogbono was achieved based on the model with the highest correlation coefficient (R^2), and lowest reduced chi square (χ^2) , root mean square error (RMSE) and Mean bias error (MBE). Modified Henderson and Pabis model was found to give the overall best fit from all the models examined, it gave the highest R^2 of 0.9940, 3.81×10^{-4}, 1.43×10^{-2} and 5.63E- 04 for (χ^2), RMSE and MBE respectively. Validation of the established model gave good agreement between the experimental and predicted variables, therefore, Modified Henderson and Pabis equation could be used satisfactorily to predict thin layer hot-air drying of Ogbono.

Keyword: *Thin layer , Mathematical model , drying behavior ogbono*

INTRODUCTION

Ogbono is a tropical fruit known as bush mango or wild mango (*Irvingia gabonensis*) (Joseph and Aworh, 1991). It is a seed of the fruit of plant that grows freely in the tropical rain forest, an indigenous forest tree belonging to the group of plant classified as Non timber forest products (NTFP) (Atangana, *et al.*, 2001). It is a major part of people's food in most part of Nigeria, the Niger delta region. The subtly aromatic nut are obtained by collecting the fruit, split to obtain the kernel, the fresh seed is conventionally sun dried for preservation, ground to flour and used in the preparation of the popular *Ogbono* soup or draw soup which impart a unique flavor, draw ability and thickening properties of the soup. It contain high content of mucilage (a thick, gluey substance produce by polar glycol protein) enables it to be used as thickening agents for dishes such as *Ogbono* soup (Gumus and Ketebe, 2013). It is a rich source of protein, iron, calcium, carbohydrate and fat.

A mathematical model is a description of a system using mathematical concepts and languages (Griffths, 2010). A model may be mean to explain a system and to study the effects of different components and to make predictions about behavior (Frigg and Hartmann, 2006). Normally, it is the fastest and the least expensive way, given that it minimizes the number of experiment that need to be conducted to determine the influence of several parameters on the quality and safety of the process.

Simulation models of the drying process are used for improving existing drying systems predicting the airflow over the product or even for the control of the process. It allows design engineers to choose the most suitable operating conditions and then size the drying equipment and drying chamber accordingly to meet desired operating conditions. One of the important unit operation in food industries is dehydration, it is a post-harvest operation that removes water to the minimal level such that microbial activities are drastically reduced therefore spoilage are minimized making agricultural material available throughout the year. It is used in the formation of functional foods products. Dehydration has gone beyond a preservation process but also a method for increasing value-added food (Midilli and Kucuk, 2003). Many undesirable quality changes both physical and chemical changes are associated with drying of food (Vega-Galvez *et al*., 2009, Discala *et al*., 2011) therefore, the current degree of acceptance of dehydrated foods in the market can be further expanded by improving product quality and process applications. Selection of appropriate control variable such as air drying temperature can produce a high-quality final product (Discala *et al.,* 2011).

Fresh *Ogbono* seed is highly perishable because it contains appreciable high moisture content; hence there is need for drying to prolong the shelf- life of the products. Several research studies have reported the influence of air-drying temperature on the relevant quality indices of several agricultural products such as; Vitamin C (Discala and Crapsite, 2008 ; Vega-galvez *et al.,* 2009; Mrad *et al.,* 2012) colour b-carotene (Demirary *et al.,* 2013); viscosity (Burubal and Amber, 2013). Successful prediction using existing mathematical models such as simplified Fick's diffusion (Diamante and Munro, 1993), Modified Henderson and Pabis (Evin 2011, Meziane, 2011), Logarithmic (Shen *et al.,* 2011) and lot more has been made by Sereno and Mederos, (1990);Muthukumarappan and Gunasekara (1994); Ratti and Mujumdar, (1997); Tahmasebi *et al*.(2011); Iguaz *et al*. (2003), Baini and Glangrish, (2007); Famurewa and Adejumo, (2015) but there is little or no literature specifically on the mathematical modeling of *Ogbono* dried at different temperatures.

MATERIALS AND METHODS

Freshly harvested *Ogbono* kernels seeds (*Irivingia gabonensis*) were sourced from Owobamiduro camp in Ilekun, Oda town, Akure local government area of Ondo state, Nigeria, seeds were carefully cleaned splited into two equal halves for uniformity in drying. The dryer was initially heated to achieve desirable steady state temperature of 70 ^{0}C. 500 g sample of freshly harvested *Ogbono* seeds were loaded into the cabinet dryer. The sample was being removed at regular intervals of one hour until three consecutive weight were obtained, indicating equilibrium condition during the experiment, changes in drying weight were measured by using a precision weighing balance (model EK410i) with an accuracy of 0.01g. Drying experiments were conducted in triplicate and average values were recorded. Mathematical models used to describe the drying kinetics of *Ogbono* using a cabinet dryer are presented in Table 1.

Moisture Ratio Determinations

The moisture ratio is the ratio of the moisture content at any giving time to the initial moisture content (both relative to the equilibrium moisture content) it was calculated according to (O'zbek and Dadali, 2007; Shivhare, 1994; Thakor *et al*., 1999, Akanbi *et al*.,2006 and Famurewa and Adejumo 2015) as:

$$MR = {}^{M - Me}\big/_{Mo - Me} \text{……………….(1)}$$

Where M is the moisture content at any drying time, Mo is the initial moisture content and Ma is the equilibrium moisture content (Kg water /Kg dry matter). The values of $M_e$is relatively small compared to those of M or $M_{O,}$ hence, the error involve in the simplification is negligible (Aghbashlo*et al*., 2008; Famurewa and Adejumo 2015), therefore,

$$\text{MR}={}^{M}\big/_{MO}\text{…………………………..(2)}$$

Statistical Analysis

The model constants and the comparison criteria such as correlation coefficient R^2, the reduced chi-square x^2, the root mean square error RMSE and the mean bias error MBE were obtained using Microsoft office Excel 2007 and Sigma Plot 10.0 software.

RESULTS AND DISCUSSION

Table 2 showed the calculated moisture content for *Ogbono* dried at 70 ^{o}C with corresponding drying time (minutes). It was observed that moisture decreases as drying time progresses whereby the overall weight measured decreases indicating the moisture content being disposed through drying process.

It was observed that the sample dried at 70 ^{o}C had drying time between 360 and 420 minutes to achieve the same moisture content of 0.365. The decrease in moisture ratio with increase in drying time for all the samples is due to the fact that the drying time depends on the moisture content of the product to be dried. The more the moisture content, the longer time required for material to be dried to equilibrium moisture content at a constant temperature. For the *Ogbono* sample with initial average moisture content of 37.45%, the difference between the initial weight (water content) and the desired constant weight is high; therefore longer time is required to reduce the weight. This is due to the fact that as drying progresses, the pore spaces are contracting with high concentration of drying matters resulting to low evaporation of moisture with time. This also agreed with the findings of Famurewa and Adejumo, (2015) where it was observed that more drying time is required to dry agricultural material of higher weight.

Table 1.Thin- layer mathematical models used to describe the drying kinetic of *Irvingia gabonensis* using a cabinet dryer at 70 ^oC

Model name	Model equation
Page	$MR=exp(kt^n)$
Modified page	$MR=exp[-(kt)^n]$
Henderson & Pabis	$MR=aexp(-kt)$
Logarithmic	$MR=aexp(-kt)+c$
Two term	$MR=aexp(-k_ot)+bexp(-k_1t)$
Two term exponential	$MR=aexp(-kt)+(1-a)exp(-kat)$
Wang & Singh	$MR=1+at+bt^2$
Approximation and Diffusion	$MR=aexp(-kt)+(1-a)exp(-kbt)$
Verma *et al*	$MR=aexp(-kt)+(1-a)exp(-gt)$
Modified Henderson & Pabis	$MR=aexp(-kt)+bexp(-gt)+cexpt(-ht)$
Midilli & Kucuk	$MR=aexp(-ktn)+bt$

Source: Diamante and Minor, (1993), Tograi and Pehlivan, (2002), Midilli, *et al.*, (2002), Akpinar*et al*., (2003a), Akpinar, (2006) ,Wang, *et al*., (2007a) and Famurewa and Adejumo, (2015)

Table 2: Moisture Ratio (MR) of *Ogbono* seeds at drying time

Drying time (Minute)	(MR) 70 ^oC
0	1.000
60	0.592
120	0.422
180	0.406
240	0.396
300	0.388
360	0.381
420	0.375
480	0.333
540	0.314
600	0.309
660	0.306
720	0.301
800	0.301
860	0.301
920	0.301

The results of the statistical analysis for twelve models for thin layer drying of *Ogbono* at 70 ^oC is shown in Table 3. The modified Herderson and Pabis gave the highest R^2 (0.9940); which is the major parameter for determination of best fit, and lowest RMSE (0.014328428) and thus it was chosen to represent the model that best describe the thin layer drying behavior of *Ogbono* at 70 ^oC.

This is an indication that the modified Herderson and Pabis gave a better correlation between the moisture ratio and drying time.

Table 3: Statistical and model constants of *Ogbono* dried at 70 ^oC

MODEL	CONSTANTS	R^2	χ^2	RMNSE
Modified Henderson & Pabis	a=0.4459;k=5.63E-04 b=5.92E-12;g=0.0272 c=0.5563;h=0.0225	0.9940	0.000381279	0.014328428
Two Term	a=0.4394;k=5.21E-0.4 b=0.5628;t=0.0221	0.9936	0.000317323	0.014821787
Diffusion Approach	a=0.5607;k=0.22; b=0.0237	0.9935	0.000286278	0.014839604
Verma *et al*	a=0.05607;k=0.022; g=5.21E-04	0.9935	0.000286278	0.02461682
Page	k=0.2039;n=0.2711	0.9826	0.000701399	0.024361682
Modified Page	k=2.84E-0.3;n=0.2711 a=0.6575	0.9826	0.000701399	0.024361682
Logarithmic	k=0.014;c0.3366	0.9709	0.001289774	0.02436168
Henderson & Pabis	a=0.7086;k=1.58E-03	0.6344	0.014741735	0.031498156
Wang & Singh	b=2.68E-06	0.5069	0.019899428	0.111686057
Two Term Exponential	a=0.1862;k=0.116	0.5066	0.019899428	0.129761233
Newton	k=0.002689;a=1 n=1205.9083	0.2688	0.27026787	0.157948734
Midili & Kucuk	b=6.17E-04	0.0000	0.081193318	0.237088082

Validation of the model

Validation of the established model was made by plotting the experimental and predicted moisture ratio values with drying time as shown in Figures 1-12. Modified Henderson and Pabis model as shown in Figure 11 shows closest link between the predicted and calculated models. This has validated the earlier established assertion that though there are many models with R^2 greater than 0.9, which is a clear indications that they can also be used to describe the drying kinetics of *ogbono* at 70 ^0C but Modified Henderson and Pabis is the best model.

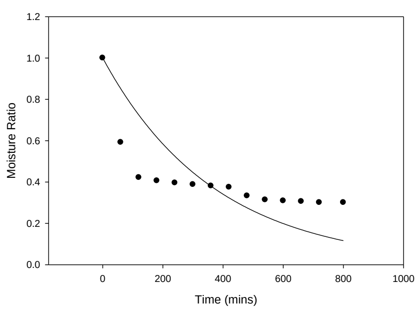

Figure1: Newton Model

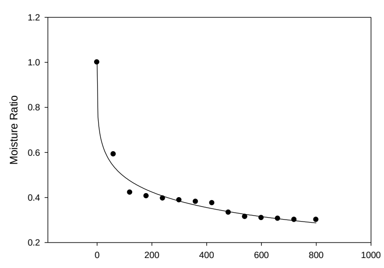

Figure 2: Page Model

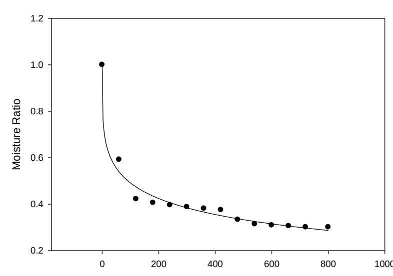

Figure 3: Modified Page Model

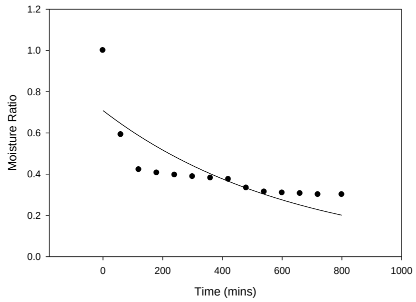

Figure 4: Henderson & Pabis Model

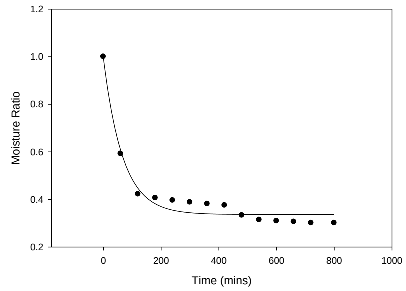

Figure 5: Logarithmic Model

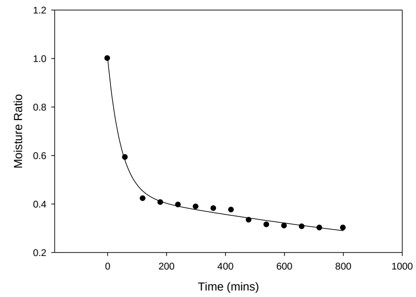

Figure 6: Two-Term Model

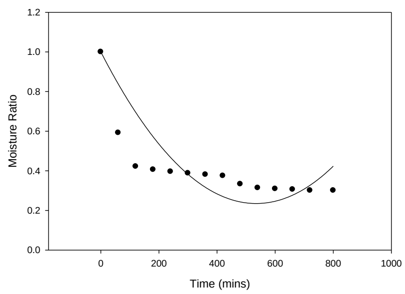

Figure 7: Two-Term Exponential

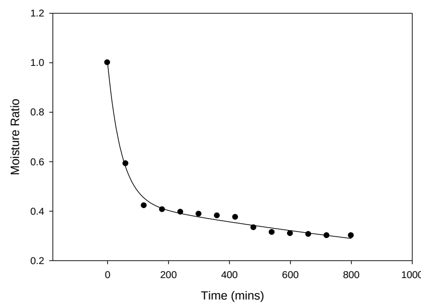

Figure 8: Wang & Singh Model

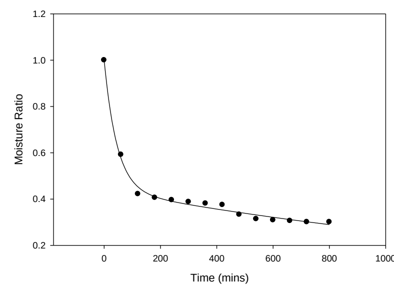

Figure 9: Diffusion Approach Model

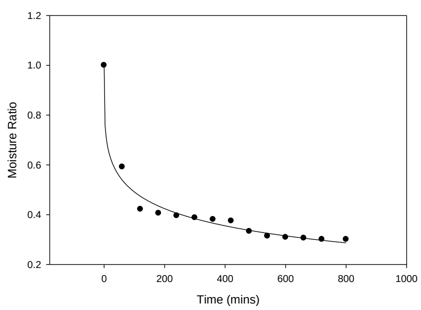

Figure 10: Verma *et al* model

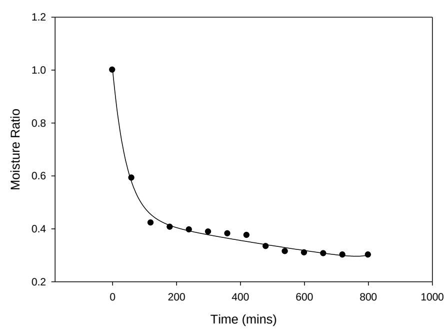

Figure 11:Modified Henderson & Pabis model

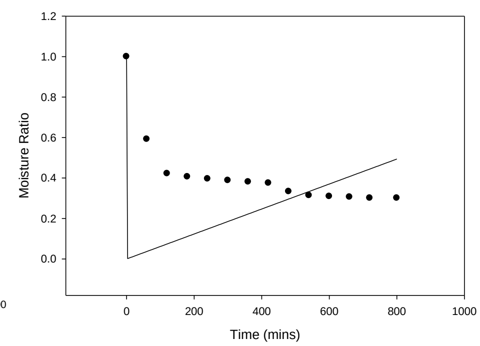

Figure 12: Midilli & Kucuk Model

CONCLUSIONS

Twelve thin-layer model equations were used in testing the drying experiment carried out on the thin-layer drying behavior of *Ogbono* at 70^{o}C.The findings of the study showed that modified Herderson and Pabis model had the highest R^2 and lowest ($\chi 2$) and RMSE of 0.9940,0.0003481 and 0.0143284 respectively , thus, best described the drying behavior of *Ogbono* . Validation of the established models showed that there were good agreements between the experimental data and predicted variables.

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SOIL WATER ENGINEERING

PAPER: NIAE/ EKO/ E003

SIMULATION OF CLIMATE CHANGE IMPACT ON RICE PRODUCTIVITY AT KANO RIVER IRRIGATION PROJECT (KRIP)

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Abstract

Climate change is occurring and its threat to crop productivity is well agreed by scientists all over the world. This work focuses on the impact of climate change on rainfed rice at Kano River Irrigation Project (KRIP), Kano State, Northern part of Nigeria. Historical weather data (2000-2011) for KRIP were obtained and converted to APSIM Met File. Rice yield, management practices, soil and crop data, corresponding to the historical met file were also obtained from secondary sources. These data were used in model validation and sensitivity analysis of APSIM model. The validation result shows that the simulated yield fairly agrees with observed yield with R^2 *and Correlation coefficient values of 0.61 and 0.78 respectively. Analysis of variance shows that yield differences due to temperature rise and atmospheric* CO_2 *level are significant at 5% level of significance. Yield difference due rainfall drop is not significant under the same analysis. The model is therefore, very sensitive to temperature and* CO_2 *changes and less sensitive to rainfall change under rice simulation. Marksim weather generator was used to generate future weather data for the study area from 2018-2030. This data was used to project rice yield assuming management practices remain unchanged. The results showed a decreased rice yield up to 21.7% at KRIP. Climate change according to this work is concluded to have negative impact on rice yield at KRIP, therefore adaptation and amelioration strategies are highly recommended in rice production in KRIP.*

Keywords: *APSIM Model, Temperature, Climate Change, Simulation, and Rice Yield*

INTRODUCTION

According to the Intergovernmental Panel on Climate Change (IPCC), global temperatures are expected to increase between 1.1 and 6.4 °C during the 21st century and precipitation patterns will be altered (Eric, 2013). Climate change threatens to increase the potential for soil erosion, reduce soil quality, lower agricultural productivity and negatively impact food security and global sustainability, making it one of the most severe challenges we will face in the 21st century. The variations in weather and climate will impact crop production as crops are very sensitive to these factors. Climate change affect crop production through changing of main processes in soil and plant namely; crop development, photosynthesis and growth as well as biological and chemical transformations of nutrients in soils. Thus, the climate change is now of great concern to the farmers, scientists, environmental engineers and other stakeholders worldwide.

Mendelsohn *et al* (2000) stated that 'the problem is expected to be most severe in Africa where current information is the poorest, technological change has been the slowest, and the domestic economies depend the most heavily on agriculture as it is the major contributor to the current economy of most African countries, averaging 21% and ranging from 10% to 70% of the GDP.' Moreover, The Intergovernmental Panel on Climate Change (IPCC) predicts that during the next decades, billions of people, particularly those in developing countries, will face changes in rainfall patterns that will contribute to severe water shortages or flooding, and rising temperatures that will cause shifts in crop growing seasons. This will increase food shortages and distribution of disease vectors, putting populations at greater health and life risks (FAO, 2008).

Kano River irrigation project, on another note, is the largest and the most successful irrigation scheme in the country with a development potential of 61,000 ha of irrigable land. Rain-fed agriculture remained the predominant land use, accounting for close to 50 percent of the total land area, irrigated agriculture accounted for only 5 percent of the total land area (Raji, 2003). Therefore, change in temperature and precipitation pattern may likely have a devastating impact on crop productivity in the area. Rice is one of the major crops produced in the area and also one among the crop production selected by the federal government to enhance food sufficiency.

The work will simulate this change in temperature and rainfall pattern and its possible impact on crop productivity, particularly rice yield and biomass and to perform risk assessment for the simulated future rice yield. This will help to plan for adaptation strategies and thus to reduce the severity the climate change may have on the overall irrigation scheme.

METHODOLOGY

Study Location

The Kano River Irrigation Project (KRIP) are divided into Phases I and II, with a total area of about 62,000 ha.The main source of water for irrigation in the region is the Tiga Dam and Ruwan kanya reservoir. Tiga Dam is located on River Kano, which is 70 km south of Kano city, it is the largest irrigation Dam in Nigeria and was designed and built during 1970-1974. The Kano River Irrigation Project Phase I Extension lies about 30 km south of Kano city, on either side of the Kano-Zaria express way. The plan of the federal government of Nigeria was to transform the agriculture from low technology, semi-subsistence farming into modern market oriented sectors which is still in process. However, despite setbacks (KRIP) is one of the most successful irrigation projects in

Nigeria. Kano State of Nigeria locates at 11°59' E and 8°30'N with an average altitude of 486 m ASL and is blessed with abundant fertile land within the Sudan savannah region. According to NPC (2006), Kano has a population of over nine million, out of which 70% are engaged in agricultural activities.

The area is characterized by a mean annual rainfall of about 830 mm all of which falls between June and October. The mean daily temperature ranges from 29 to 38°C (Jibrin et al. 2017). The length of the growing period is 90 to 165 days (for rain-fed crops), with most rains occurring between May and September. Air humidity is high during the wet season and very low during the dry season. Minimum temperatures occur from November to February, and highest temperatures occur in March and April. Daily temperature variation is high during the dry season and low in the wet season (Kebbeh et al. 2003).

Crops grown during the rainy season include rice, wheat, sorghum, groundnuts, cowpea, maize and vegetables. By the onset of the cool dry season, most rain-fed crops have been harvested and the northeastern dry, cool, harmattan winds prevail. This season is favorable for the cultivation of wheat, Irish potatoes, and vegetables such as tomatoes and carrots set in.

Overall, rain-fed agriculture remained the predominant land use, accounting for close to 50 percent of the total land area.

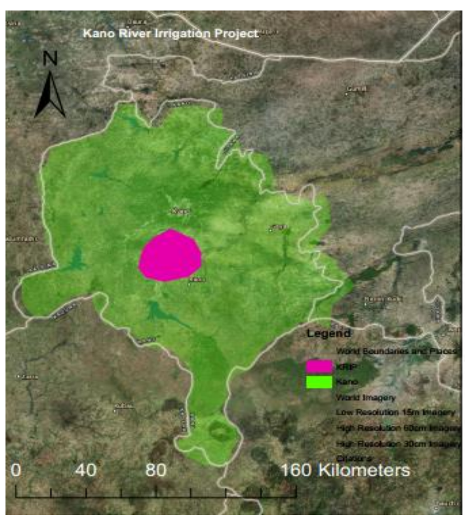

Fig 1. Kano River Irrigation Project (KRIP)

Determination of Rice Yield Response under Rise in Temperature

Since the Intergovernmental Panel on Climate Change (IPCC) projects that global mean temperature may rise up to 5 °C by the end of this century (Natural Resources Institute Finland 2015), response of rice yield to 1°C, 2°C and 5°C rise in temperature were simulated. Results were then subjected to analysis to determine if there will be any significance difference between the yield in the scenarios.

Determination of Rice Yield Response under CO_2 Change

Atmospheric carbon dioxide level may reach up to 685ppm by 2050 if no ambitious policies are implemented (Organisation for Economic Co-operation and Development, 2012). Therefore, effects of 450ppm, 550ppm and 650ppm carbon dioxide concentrations was simulated and outputs were subjected to analysis to ascertain differences.

Determination of Rice Yield Response under Rainfall variability

Rice yield response to change in rainfall patterns of -20%, -15% and -10%, was simulated and outputs were subjected to analyzed to determine impacts.

Determination of Rice Yield Response under Combined Effects CO_2 and Temperature Rise

Combined effects of 1^0C rise in temperature with 450pmm, 550ppm and 650ppm were also simulated. Results were observed and analyzed to study differences.

Simulating Climate Change Impact on Rainfed Yield

The met file created in the above section was then used to run another simulation. Soil parameters, management practices and crop data remain unchanged to make sure that change in simulated yield is as a result in the weather parameters. The same procedure was implemented in configuring and running the model.

Calculating Relative Change in Yield

The relationship below was used to calculate the rate of change in yield between the 12-years baseline yield and projected yield.

Projected Change in Yield (%) = $\frac{Projected\ Yield - Baseline\ Yield}{Projected\ Yield}$

Risk Assessment

Risk assessment was carried out to further aid understanding of the climate change impact. Probability of exceedance for maximum simulated future rice yield was generated, with Percent Probability on Y axis and Simulated Yield on X axis.

RESULT AND DISCUSSIONS

Impact of climate change on rice productivity at KRIP was investigated using APSIM model. APSIM was validated by comparing observed rice yield at KRIP from 2000-2011 and simulated yield of the same period. The results show that APSIM performs fairly well in predicting rice yield with R^2 value of 0.61 and correlation coefficient of 0.78. The following tables 1-3 present the yields to the corresponding temperature, carbon dioxide and rainfall changes.

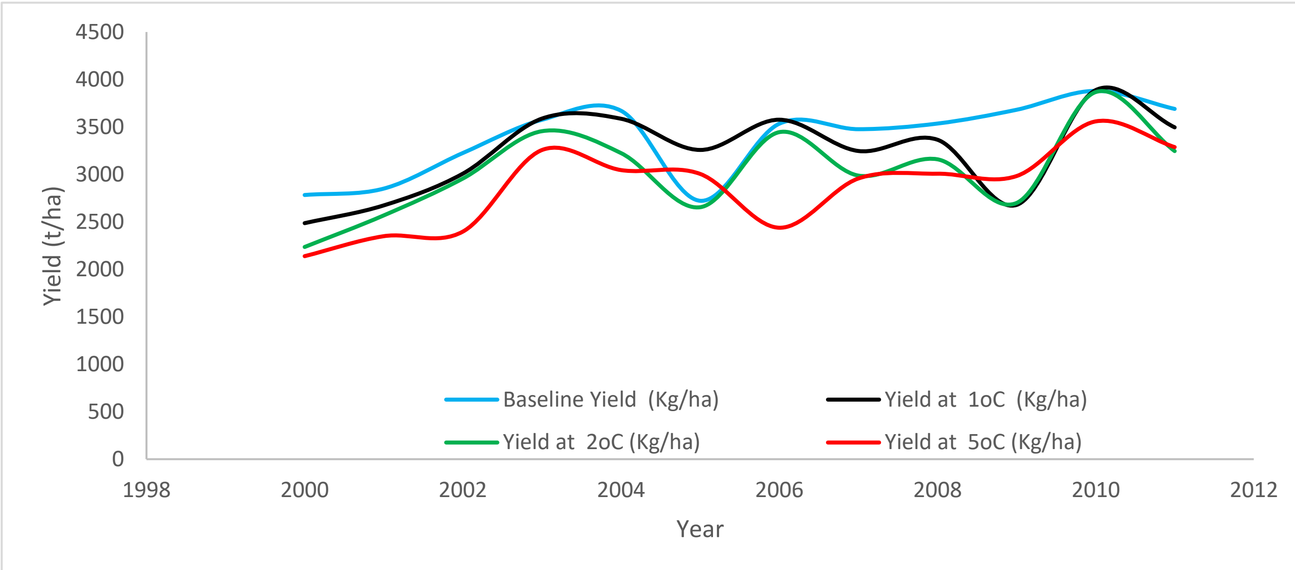

Fig. 2 Yield (t/ha) at increased in temperature

Figure 2 illustrates the reduction in rice yield due to change in temperature. It can be seen that rice yield decreases with increase in atmospheric temperature. Analysis of Variance (ANOVA) also demonstrated that there is highly significant difference in yield under varying temperature levels with P value of 0.029.

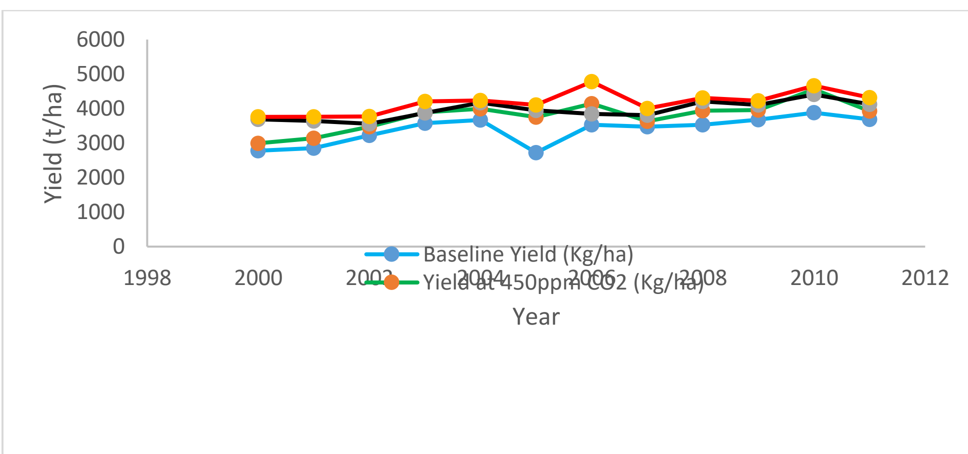

Fig. 3 Yield (t/ha) at increased in Carbon Dioxide

APSIM predicted positive response of rainfed rice yield due elevation of CO_2 concentrations. Figure 3 present the results of increased in yield due to increased CO_2 with 12.2% increase in rice yield at 450ppm CO_2 concentration, 17.7% increase at 550ppm and 24.4% increase at 650ppm respectively. This might be clear since carbon-dioxide is an important component of photosynthesis in plant.

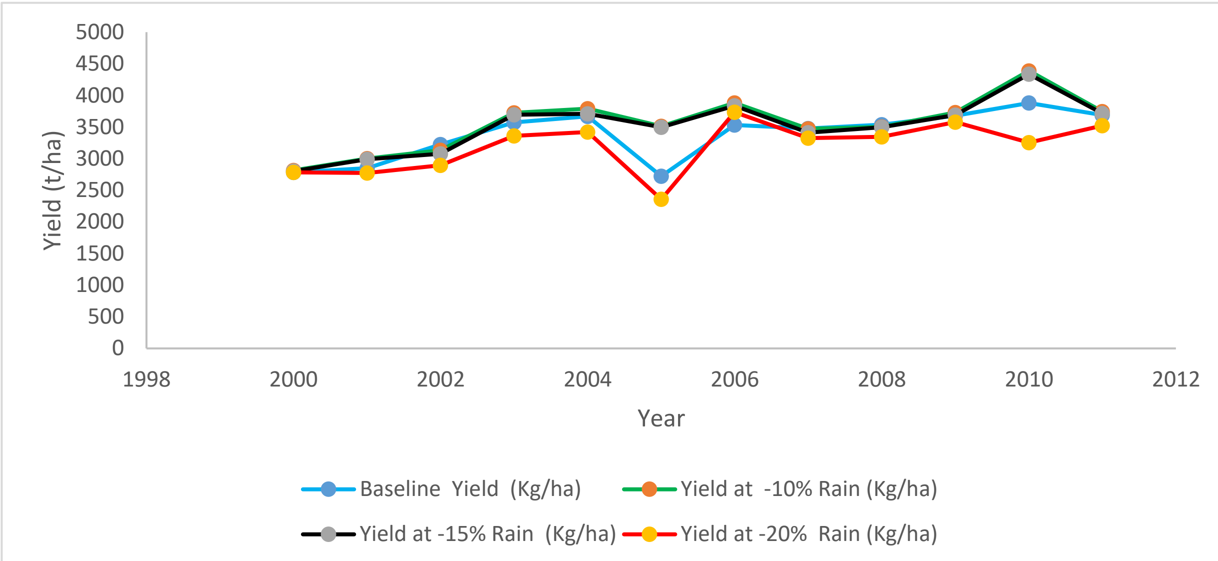

Fig.4 Yield (t/ha) at decreased in Rainfall

Yield decrease was predicated by the model to be only about 0.74% due 10% decrease in rainfall amount from the baseline rainfall amount, 3.65% decrease for 15% decrease in rainfall amount and 5.55% decrease for 20% decrease in rainfall amount respectively. Zhang and Nearing, 2015 and Yahaya and Timothy, 2015 mentioned that rainfall amount may have little effect on the crop yield if decline of rainfall amount occurs out of the crop growing season. Therefore, the slight response of APSIM simulated yield may be due to the fact that the average rainfall amount remains relatively unchanged during the rice growing season.

Relative Change in Yield

Table 1 Relative change in Yield between Historical and Projected Rice Yield

Data	Time Range	Average Yield (kg/ha)	Relative change (%)
Baseline (2000-2011)	12 years	3385.2	
Projected (2018-2029)	12 years	2781.98	-21.7%

The model predicted decrease in average yield of up to 21.7% with the projected weather conditions generated from MARKSIM. This indicates that the projected weather conditions between 2018-2030 will have negative impact on rainfed rice at KRIP. This findings were inline some scholars findings (Wassmann and Dobermann, 2007; Townsend et al., 2009; Xiong 2012; Falaki et al., 2013; Karn 2014; Shakoor et al. 2015; and Kabir, 2015). They all reported that overall impact of climate change will negatively impact rice production around different part of the world.

However, others on contrary reported different impact of climate change on rice yield, for instance Kim et al. (2017) reported positive effect of climate change on rice in Benue State, Nigeria. Kawasaki and Herath (2011) reported fluctuations in rice yield under different climate change scenarios. Nevertheless, these results will not be considered absolute contradiction as the climate change impact is dependent upon other uncontrollable factors and models. Vaghefi et al. (2013) stated that climate change will affect agriculture differently in different part of the world as the case may be.

Risk assessment analysis

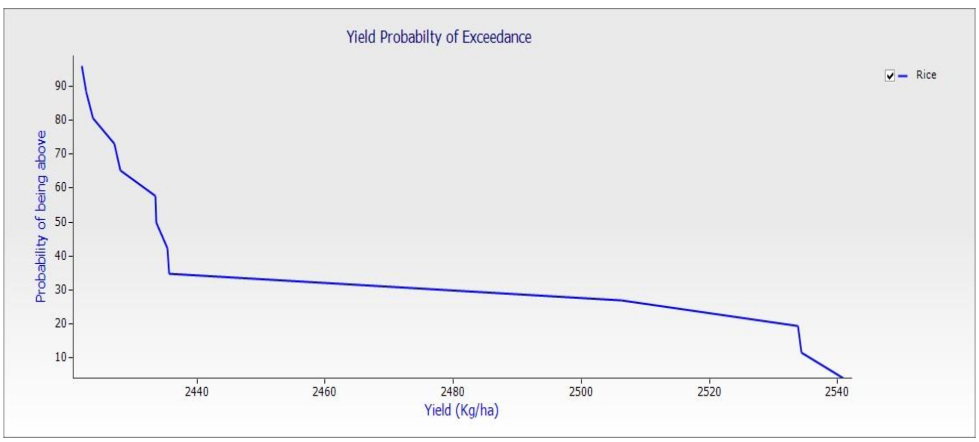

Fig. 5. Yield Probalility of exceedance

The Figure 5 shows probabilities of obtaining various amounts of rice yield in the future seasons. It can be seen that, a yield 2460kg/ha is attainable in only 35% probablity, while the maximum yield of 2540kg/ha is almost unattainable throughout the future seasons.

The model demonstrated high sensitivity to temperature and atmospheric CO_2 levels. It predicted average of 4%, 10%, and 15% decrease in rainfed rice yield for 1^0C, 2^0C and 5^0C rise in temperature respectively For CO_2 levels, it predicted 12.2%, 17.7%, and 24.4% increase in yield at 450ppm, 550ppm and 650ppm. However, the model demonstrated low sensitivity due to change in rainfall amounts respectively. It predicted 0.74%, 3.65% , and 5.5% decrease in rice yield due to 10%, 15%, and 20% decrease in rainfall amount respectively. Combined effect of temperature and CO_2 rises shows that CO_2 elevations cancels out the negative effect of temperature, therefore no significance change.

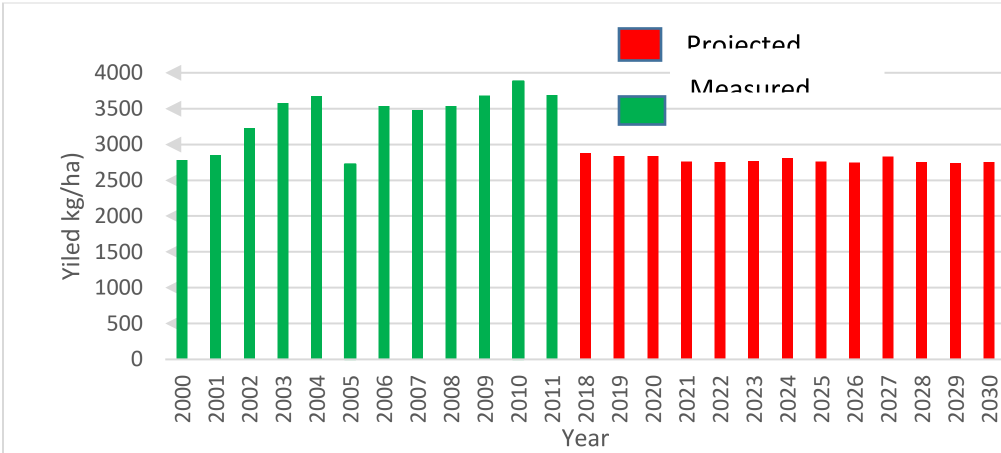

Fig. 6 Simulated future rice yield in (t/ha)

Future weather data for 2018-2030 obtained from Marksim Weather Generator was used then used to simulate rice yield in the corresponding period. The predicted yield showed 21.7% drop in rice yield at the study area. This means climate change will have negative impact on rice production.

CONCLUSIONS

Climate change is most likely to affect rice productivity at KRIP as predicted when production activities maintaned status quo. Since climate is a natural phenomenon and rarely be completely interrupted, adaptation strategies are the best possible options to minimize its impact. APSIM predicted yield agrees fairly well with the observed rice yield from 2000-2011. APSIM demonstrated high sensitivity to temperature change, atmospheric and CO_2 levels, and low sensitivity due to rainfall change under rice module. Therefore, the model will perform fairly well in climate change study under rice production. Rise in temperature has negative impact on rice productivity as it leads to reductions in yields in the area. CO_2 elevations has positive impact on rice productivity as it increases yield in all simulation scenarios investigated. This is perhaps due to increased $C0_2$ availability for enhanced photosynthesis. Effect of drop in rainfall amount on rice productivity triggered little change in rice yield during the simulation. This may be because rainfall amount during the rice growing season remains relatively with the same range. When rise in temperatures is accompanied by elevation in atmospheric $C0_2$, then the negative effect of temperature rise minimizes to even negligible. Which implies that CO_2 elevations cancels the negative effect of Temperature rise. Rice yield at KRIP may drop to up to 21.7% within 2018-2030 due to climate change. Adaptation and amelioration techniques may be adopted to curb the impending threat to food security due to climate chang in order to ensure rice productivity in the region.

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APPLICATION OF RENEWABLE TECHNOLOGY IN REDUCING ENVIRONMENTAL POLLUTION AND GLOBAL WARMING

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ABSTRACT

Disposal and burning of agricultural residues are commonly practiced in some developing countries in which harmful gaseous products released into the atmosphere causes environmental pollution and problem of global warming. Renewable technology can therefore be introduced for the utilization of the residues to produce energy and chemical feedstock. Climate-friendly technology of extraction and pyrolysis of the lignocellulose materials from two agricultural residues (palm fruit fibre and physic nut shell) were carried out. The experiment was conducted at low temperatures (200, 250, 300, 350 and 400 ℃) and pressure 0.1mmHg. The two residues (palm fruit fibre and physic nutshell) contain some chemical compounds that can produce bioenergy and chemical feedstock that will be useful for domestic and industrial purposes. Results showed that aromatics compounds are mainly dominant of the palm fruit fibre which was characterized for bio-fuel production. Amines and organic halogen compounds are highly present in the physic nut shell which can be useful as chemical feedstock for further application. The harmful products being released into the atmosphere may result to depletion of ozone layer and can cause global warming and hence negatively contributing to the problems of climate change.

Keywords: residues, climate change, pollution, global warming, renewable technology

1.0 INTRODUCTION

Global warming refers to as gradual increase in the average temperature of earth's surface and its ocean (Idowu, 2011). Climate change includes global warming and everything else that will be affected by increasing greenhouse gas levels, (UNFCCC, 1994). The global issues of increasing energy prices, dwindling reserves of fossil fuels and impacts of climate change have led to intense global support for bioenergy and chemicals from agricultural crops and residues (Schroeder, 2009). The developing countries are most affected by the climate change as they have low-level response strategies to climate change (Ashraf and Wahaband, 2006; Feiden, 2011). The third world countries are more vulnerable because they live in environments that are more exposed to the ravages of extreme weather patterns (Feiden, 2011). Much of the vulnerability to climate change is a result of poor awareness, limited access to technologies and limited access to capital for investments in mitigation and adaptation initiatives.

Nigeria has numerous agricultural resources and generates large quantities of wastes daily but unfortunately, these residues are unutilized properly as they are left to decompose at the dump site (Jekayinfa and Scholz, 2009) and a large percentage is used as land fill, while some are burnt despite the environmental implications as stated by Jekayinfa and Omisakin (2005). Many countries have plenty biomass that can be processed as an energy resource (Faisal *et al.,* 2011). Various categories of biomass are widely available from agriculture; crop residues, wood residues and dedicated energy crops to municipal solid waste while agricultural residues represent significant potential for developing the bio-energy industry (Elum *et al.,* 2016). The main advantage of using agricultural residues is that they have little or no market value and ready for production in large quantities (Oyedepo, 2011). The residues generated through direct harvest of crops at the growing site (field residues) or as a by-product of processing can be converted to energy (USEPA, 2006). Several researchers have explored the potency of agriculture residues for energy, and the results are encouraging (Elum *et al.,* 2016). So, if these residues are disposed through burning, then bioenergy content and chemical compounds in the residues might be released into the atmosphere. This can cause air pollution and gradually result to depletion of ozone layer, global warming and problem of climate change. It is profitable and highly beneficial if energy and chemicals can be produced from residues rather causing environmental pollution (Onifade *et al.,* 2017).

Pollution is any form of impurity or contaminant released into a natural environment that has the potential to cause harm and destabilize an ecosystem (Dabbs, 1996; Oguduvwe, 2013). Pollution from the activities of oil multinational mostly has to do with air, land and water. Air pollution affects humans and other living organisms. Land pollution affects the land soil and destroys plants and living organisms in the soil while water pollution affects aquatic life. Air, water and land pollution can be caused by oil spillage, gas flaring, above or below ground oil pipeline leakage and oil waste dumping (Elum *et al.,* 2016).

Consequently, the residues dump over a long period have caused land pollution as shown in Fig. 1 and can also cause water pollution if residues are eroded into water bodies (rivers, streams and dams) by runoff water during heavy rain. This may lead to blockage of drainage, canals and water ways which might cause flood and other natural disasters. Sometimes, the residues are burnt which causes air pollution as shown in Fig. 2, consequently the burning activities might release some greenhouse gases from residues into the atmosphere which can attribute to the problem of climate change and global warming. The burning exercise might also kill living organisms in the soil needed for plant growth. Fig. 3 shows effect of improper disposal of wastes on environment, as a result of non-utilization of wastes which leads to natural disaster like flood and water pollution.

Renewable technology is defined as the technology available for the conversion of cellulose in agricultural residues into fuel and chemical feedstock. The possible technologies include incineration, combustion in controlled atmosphere, hydro carbonization, anaerobic digestion and pyrolysis (Ren *et al.,* 2013; Faisal *et al.,* 2011 and Bello *et al*., 2009). Of these renewable technologies, pyrolysis offers the most visible root for the generation of fuel and chemical feedstock. This process implies decomposition of cellulose by heating in the absence of oxygen to produce gases, liquid and char; which has been the source of many basic organic chemicals such as acetone and methanol (Faisal *et al.,* 2011; Goyal *et al.,* 2006). Pyrolytic products can be used as fuels, with or without prior upgrading, or they can be utilized as feedstock for chemical or material industries (Mohammed *et al.,* 2013)

Mitigation and adaptation plans are the only solutions to build resilience to climate change impacts in the nation (Sheppard, 2005; IPCC, 2007; Semenza *et al.,* 2008; OECD, 2010; Sheppard, 2005 & Mathews, 2011). It is observed, at different crop processing sites visited in my community, that the selected agricultural residues (palm fruit fibre and physic nut shell) used in this work are improperly disposed and hence leads to air, land and water pollution. Sometimes, the residues are burnt which causes air pollution by releasing greenhouse gas into the atmosphere which can attribute to the problem of climate change and global warming. This study employs renewable technology for the purpose of converting waste to energy and thereby, it is one of the strategic plans for climate change adaptation and mitigation. The detrimental effects of climate change require that alternative forms of energy such as biogas be utilized to avoid environmental catastrophes. The renewable technology activities not only have better environmental implications on the nation but also improve social and economic development.

Fig. 1: Burning of residue causes air pollution

Fig.2: Improper disposal of residue causes land pollution

Fig. 3: Improper disposal of waste causes flood and water pollution

Fig.4: Heap of Palm fibre

2.0 MATERIALS AND METHODOLOGY

Palm fruit fibre and physic nutshell used for this research were collected from crop processing centres in nearby villages via Ogbomoso town, Nigeria. Heap of this waste is formed at the processing site but the residue is not easily decomposed because it contains oil in it and this has effect on the landscapes as shown in Fig. 1. Water infiltration and percolation are inhibited, resulting to low cultivation of arable crops on the soil of the site.

(a) Purification of the samples

Lignocellulose was prepared from physic nut shell and palm fruit fibre according to the methods reported by (Bello *et al.,* 2009). Fifty (50) grammes of the raw ground sample residues were weighed using an electronic weighing balance Mettla Toledo, with an accuracy of 0.01 g, the sample was put in a 500 ml round bottom flask. Then, 200 ml of ethanol and distilled water was measured (1:1 v/v) using a 100 ml measuring cylinder, and poured into the sample. The flask containing the sample was put on an electric heating mantle set at 70 ℃ and allowed to boil for 30 minutes. Each purification process was maintained for all particle sizes (0.250, 300, 0.425 and 0.550 mm). The purified sample was drained and dried in an oven at 105 ℃ for 48h and cooled in an air tight dessicator with dessicant. Extraction or purification process of the sample was achieved to obtain lignocellulosic contents from the samples.

(b) Pyrolysis

The lignocellulosic (purified) samples were pyrolysed in batch-type reactors in which the reactors are the ampoule and tubular systems. One end-opened narrow cylindrical pyrex tubes of about 3 cm diameter and 15 cm long was used with a tight lid. The pyrex ampoules was made by joining bulbs of 5 cm diameter with the cylindrical tubes. 2 g of lignocellulose was measured in each case and introduced into the reactor by means of narrow plastic funnel. In order to ensure quantitative transfer of the charge, a small Teflon rubber tubing about 2 cm long was used in the joining of the funnel and reactor outlet, and by gently tapping and varying the amount of the charging materials until the exact weight of 2 g as required was introduced into the reactor. Then, 0.2 g of glass wool was placed at the constriction level of the reactor. The wool was held fixed at the constriction point above the reactor so as to prevent discharge of gas during the evacuation period. High vacuum pump was used for the evacuation and the glass was sealed with a hand torch burner when the pressure reaches 0.1 mmHg as was measured with a pirant vacuum gauge. The duration of the evacuation was 5 to 30 minutes for the tubular and ampoule reactors. A thermostat oven furnace was required; the isothermal temperature was allowed to run for ten minutes before introducing reactor and was maintained throughout the run. Each pyrolysis reaction lasted for 120 minutes at each temperature selected ranging from 200 to 400 ℃. To terminate a run, the reactor was removed from the furnace and placed in a dessicator and allowed to cool to ambient temperature level. The gas produced was collected through the tight fitted tap joined to the upper part of the reactor, with a small teflon rubber tubing inserted for easier discharge into an air tight gas bag. The weight of the gas produced was obtained by heating in a furnace. The pyrolysed sample (solid) was collected from the reactor for further process so that liquid extract can be produced using soxhlet extraction as shown in Figure 6; the extraction was carried out for 72 hours.

Two grams of the pyrolysed sample were measured and put into dried thimble container and introduced into soxhlet extractor. Then 100 ml of methanol and dichloromethane solvent, (1:1 v/v) each was poured into a round bottom (250 ml) flask and placed on the electric heating mantle set at 20 ℃ for 24 h. Then, the extracted sample was taken out of the thimble and put into crucible and dried in an oven for 48 hours at a temperature of 105 ℃. The extracted solvent in the round bottom flask was then concentrated using the vaccum pump set. The concentrated extract was cleaned using a glass column (10 cm) filled with sodium sulphate to remove water or impurities. The clean sample filled into 0.2 ml chromatograph vials and then introduced to GC/MS for analysis.

3.0 RESULTS AND DISCUSSIONS

Chemical Characterization of Bio-oil

Fig. 5 presented the results of the spectra obtained from the Fourier Transform Infra-Red spectrometer which was used to characterize the bio-oil produced from palm fruit fibre. The O-H stretching vibrations between 3200 and 3400 cm^{-1}, show the presence of phenols and alcohols. The C-H stretching vibrations between 2800 and 3000 cm $^{-1}$ and C-H deformation vibrations between 1350 and 1450 cm $^{-1}$ show the presence of alkane groups. The C=O stretching vibrations between 1680 and 1750 cm^{-1} are compatible with the presence of ketones, quinones, aldehyde groups. The peaks between 1500 and 1645 cm $^{-1}$ represent C=C stretching vibrations, indicated the presence of alkenes. Besides, mono and polycyclic and substituted aromatic groups can be identified by the absorption peaks between 690-900 and 1350-1450 cm $^{-1}$. Then, Ethers can be identified by a strong C-O stretching band near 1100 cm^{-1} due to the C-O-C linkage in the compound. Aromatic ethers show a strong band near 1250 cm $^{-1}$, while cyclic ethers show a C-O stretching band in the range of 1250-900 cm -^{1}. A broad N-H wagging band appears at 750-650 cm $^{-1}$ represents secondary amides.

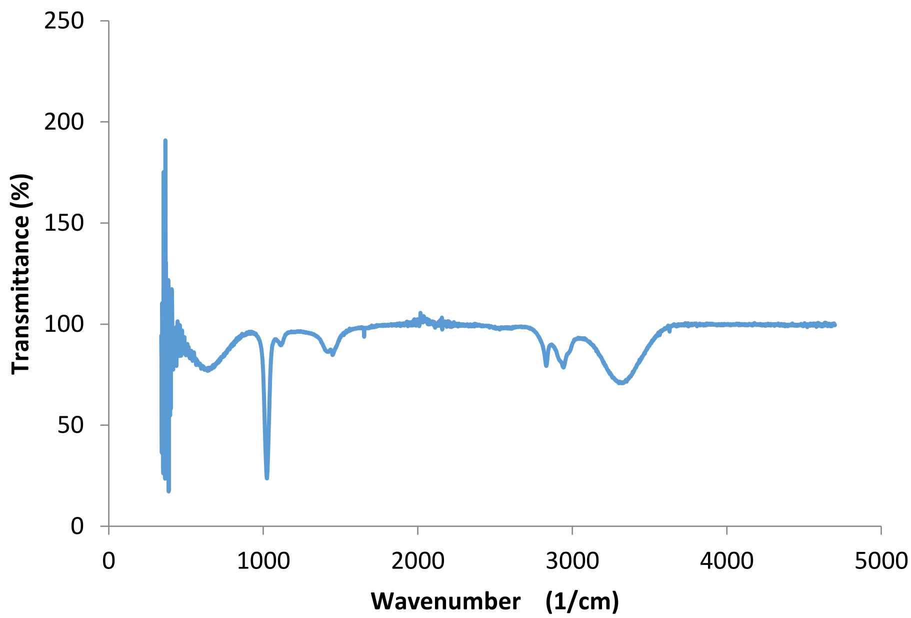

Fig 5: FT-IR spectra bio-oil derived from the residues

GC-MS was used to analyze and identify the chemical components in the liquid. Tables 1 and 2 present the details results of GC-MS analysis. The most abundant products and highest peak area achieved by hexadecanoic (81.3 %). Other prominent products are pentadecanoic acid (1.47-14.5 %), octadecanoic (2.6-70.1 %), eicosanoic (3.5-11.3 %), 2-2-hydroxyethoxy (2.71-12.3 %), Ascorbic 2, 6-dihexadecanoic (7.1-14.3) and Isopropyl palmitate (7.31-41.0). It was observed that different values were obtained at various temperature and particle sizes. This shows effect of experimental parameters (temperature and particles sizes) on the chemical compounds produced from palm fruit fibre. For instance, highest peak of methyl- hexadecanoic, 81.3 % was obtained at 158.8 °C, 0.42 mm, methyl-pentadecanoic acid was high, 14.5 %, at 441.42 ℃, 0.42 mm, eicosanoic had value of 11.3 % at 300 ℃, 0.25 mm. heptadecanoic has highest peak at 200℃, 0.55 mm. Only 300℃ 0.25 mm and 400 ℃ 0.25 mm contained ascorbic 2,6-dihexadecanoic.There are a great number of other compounds but their peak areas are low, so this study did not examine them further. Every compound in Table 2 is classified as aromatic oxygenated and hydrocarbon compounds which are dominant compounds in the palm fruit fibre oil. Oxygenated content is favorable to be used for fuels while other compounds can be useful for chemical productions. The results obtained in this study are different and values are higher than those obtained from palm kernel shell by Faisal *et al.* (2011), it may be due to the hardness of the shell which may not be easily burnt.

Table 1: Identification and analysis of chemical compounds in bio-oil of palm fibre by GC-MS

Chemical compounds	Molecular formula	Molecular weight (g/mol)	Peak Probabilty %
3-methyl Pentadecanoic acid	$C_{16} H_{32}O_2$	256	1.47-2.85
2,16-methyl Hexadecanoic acid	$C_{18} H_{34}O_2$	284	1.30-10.15
Methyl Hexadecanoic acid	$C_{17} H_{34}O_2$	270	81.3
14-methylPentadecanoic acid	$C_{17} H_{34}O_2$	270	9.92-28.7
Tridecanoic acid	$C_{17} H_{34}O_2$	270	2.58
Ethyl Pentadecanoic acid	$C_{17} H_{34}O_2$	270	6.53
EthylEicosanoic acid	$C_{22} H_{44}O_2$	340	3.53-11.3
Ethyl Hexadecanoic acid	$C_{19} H_{38}O_2$	298	2.84
Ethyl Tridecanoate	$C_{15} H_{30}O_2$	242	1.46
MethylOctadecanoic	$C_{19} H_{38}O_2$	298	4.04-66.6
16-methyl heptadecanoate	$C_{19} H_{38}O_2$	298	10.5
Ethyl Octadecanoic acid	$C_{20} H_{40}O_2$	312	60.7
Nonadecanoic acid	$C_{21} H_{42}O_2$	326	0.93
Cyclop1ropanepentanoic	$C_{20} H_{38}O_2$	310	3.73
Tetradecanoic	$C_{16} H_{32}O_2$	256	2.7- 4.63
Ethyl Heptadecanoic	$C_{19} H_{38}O_2$	298	5.48
2-2-hydroxyethoxy	$C_{22} H_{44}O_4$	372	2.71-12.3
Hexadecanoic acid	$C_{18} H_{36}O_2$	284	49.4
Isopropyl palmitate	$C_{19}H_{38}O_2$	298	7.31-41.0
Ascorbic 2,6-dihexadecanoic	$C_{38} H_{68}O_8$	652	7.1-14.3
Ascorbic acid, 6-octadecanoate	$C_{24} H_{42}O_7$	442	2.8

This paper also revealed and identified the bioenergy and biochemical from lignocellulosic materials in physic nutshell as shown in Table 2 which can be used for further processing in small and large scale industries. Aromatic oxygenated and hydrocarbon compounds present in lignocellulose bio-oil of physic nut shell and palm fibre are favorable to be used for fuels. Other compounds found in palm fibre show the potentiality to be used as polymer. Amines and organic halogen compounds are highly present in the physic nut shell oil which can be useful as chemical feedstock for further productions.

Table 2: Identification and analysis of chemical compounds in bio-oil of physic nutshell by GC-MS

Chemical compounds	Molecular formula	Molecular weight (g/mol)	Peak Probabilty %
9-octadecenoic	$C_{21} H_{40}O_2$	356	6.7- 35.3
Hexadecanoic acid	$C_{18} H_{34}O_2$	284	4.0 -82.2
n-propyl 11-octadecenoate	$C_{21}H_{40}O_2$	324	7.27
14-methylPentadecanoic acid	$C_{17} H_{34}O_2$	270	48.9
Linoleic acid	$C_{17} H_{34}O_2$	308	3.72-18.4
Ethyl Oleate	$C_{20} H_{38}O_2$	310	6.53
Eicosanoic acid	$C_{22} H_{44}O_2$	340	1.55-3.53
Butyl 9-octadecanoate	$C_{22} H_{42}O_2$	338	2.53-4.46
Trans -13-octadecanoic	$C_{19} H_{36}O_2$	296	4.16-5.99
Pentadecanoic acid	$C_{17}H_{34}O_2$	289	12-38.5
Methyl10-trans12-cis-octadecadienoate	$C_{19} H_{34}O_2$	294	2.57-8.65
Ethyl 9-cris, 11 trans-octadecadienoate	$C_{20} H_{36}O_2$	308	28.4-33.8
n-propyl 9, 12-octadecenoate	$C_{21} H_{38}O_2$	322	2.91-5.36
EthyneFluoro	C_2HF	44	8.74
2-Aminoheptane	$C_7 H_{17}N$	115	6.69
2-hexanamine	$C_7H_{17}N$	115	15.13
Octanamine	$C_9H_{21}N$	143	2.71-12.3
Benzene thanamine	$C_9H_{11}F_2NO_3$	219	2.56-3.82
Dodecylmethylamine	$C_{13}H_{29}N$	199	2.77-3.0
Octodrine	$C_8H_{19}N$	129	2.36
Cyclopropanebutanoic	$C_{25}H_{42}O_2$	374	2.83
Ethyl iso-allocholate	$C_{26}H_{44}O_5$	436	4.72
14-methyl-hexadecanoate	$C_{19}H_{38}O_2$	298	3.43
3,9-Epoxypregnane	$C_{25}H_{41}NO_2$	435	1.89
Diethylene glycolmonolaurate	$C_{16}H_{32}O_4$	288	1.82
Tridecanoic	$C_{17}H_{34}O_2$	270	0.9-5.41
Docosanoic	$C_{24}H_{48}O_2$	368	0.37-3.7
Undecanoic	$C_{14}H_{28}O_2$	228	2.68
Oleic acid	$C_{18}H_{34}O_2$	282	2.29
Heptadecanoic	$C_{20}H_{40}O_2$	312	1.61-81.3
Bromodecanoic	$C_{12}H_{23}BrO_2$	278	0.73
Octadecadienoyl Chloride	$C_{18}H_{31}ClO$	298	2.80
Cyclopentanetridecanoic	$C_{19}H_{36}O_2$	296	1.07
Octadecanoic	$C_{20}H_{40}O_2$	312	35.3

Conclusion

Chemical compounds from the residues are produced at high temperature. At higher temperature, more harmful gaseous products are released into the atmosphere which resulted to global warming, problem of climate change and environmental hazard. It is more economical to utilize the agricultural residues for energy production than disposing through burning. The work analyses the use of lignocellulosic content of the residues studied as a great opportunity for bioenergy in its efficient forms and such engagement will enhance economic development and improve social wellbeing of the nation.

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Determination of Hydraulic Conductivity of Agricultural Soils for Optimum Food Production

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Abstract

Two sites designated for Agricultural activities were selected for the study which were department of Agricultural & Environmental Engineering (AGE) research farm and University Teaching and Research (SCH) farm both in FUTA. Fifteen physicochemical soil properties determined include, bulk density (BD), total porosity, water holding capacity (WHC) and moisture content (MC). The rest were organic matter (OM), organic carbon (OC), pH, sodium (Na), nitrogen (N), potassium (K), calcium (Ca), Copper (Cu), Electrical Conductivity (EC), Cation exchange Capacity (CEC) and magnesium (Mg). Hydraulic conductivity (K_a) of the two locations was obtained by determining infiltration rate of the soil with a mini disk infiltrometer, measurements taken weekly and results subjected to statistical analysis at $P<0.05$. K_a increased with increased organic matter content and dependent on CEC and pH while soil samples collected and analyzed at T&R farm had the highest mean valves of K, OM, pH, CEC and P to be 4.68$\pm$1.03%, 6.02$\pm$1.15, 14.05$\pm$0.44 and 10.55$\pm$0.46 respectively. Lowest values of the same parameters except P were recorded on AGE farmsite with 4.43$\pm$0.80, 5.22$\pm$1.84 and 12.48$\pm$0.08 respectively. Higher K values were more in soils with higher OM content and high correlation was recorded between K_a at AGE farmsite but low values were recorded at T&R farm. Therefore, K_a was largely affected by factor such as WHC, porosity and MC from the study and K_a values fluctuations in the two farms were as a result of intensive usage of heavy machinery on the soils which largely affect the permeability level of the soils.

Keywords: hydraulic conductivity; permeability; soil; parameters; agricultural activities

INTRODUCTION

Hydraulic conductivity is one of the most important soil properties controlling water infiltration and surface runoff, leaching of pesticides from agricultural lands, and migration of pollutants from contaminated sites to the ground water. This soil property depends strongly on soil texture and structure and therefore can vary widely in space. Hydraulic conductivity also shows a temporal variability that depends on different interrelated factors, including soil physical and chemical characteristics affecting aggregate stability, climate, land use, dynamics of plant canopy and roots, tillage operations and activity of soil organisms (Fuentes *et al.*, 2004). Mc Garry *et al.*, (2000) remarked that results of different tillage treatments and effects on hydraulic properties under well-structured soil conditions are not always consistent across locations, soils and experimental designs. Furthermore, Mc Garry *et al.*, (2000) further observed higher values of hydraulic conductivity (K_a) under no-tillage relative to tilled treatments due to a greater number of macropores, increased fauna activity and the litter of residues formed by accumulated organic matter.

Water dynamics and management require reliable estimates of soil hydraulic properties for effective predictions just as soil properties such as bulk density, texture, porosity and structure are known to affect soil moisture and hydraulic conductivity (Bagarello and Sgroi, 2007). Water flow velocity is also affected by the soils ability to transmit water or the hydraulic conductivity since it passes through small pores, flow is faster when the conductivity is greater. While these properties are necessary for diverse studies on water and solute transport, their measurements often require substantial investment of time and money (Akinbile 2010). However, despite this difficulty, soil hydraulic properties and their values are indispensable in the solution of many soil and water management challenges associated with agriculture, ecology, hydrology, hydrogeology, and other environmental issues (Oshunsanya, 2013).

Saturated hydraulic conductivity (K_s) which is constantly associated with fluid flow through a saturated medium is the most critical soil hydraulic property of the soil matrix (Rawls et al., 1998) and one of the most difficult to obtain (Bagarello *et al.*, 2000). It is influenced by soil texture and structure which in turn is influenced by total porosity and pore size distribution (Oshunsanya, 2013). It is a key parameter that is important for irrigation, drainage, water balance, modelling of water flow and chemical transport through the soil. The knowledge of hydraulic conductivity (K_a) is useful in design specification especially drains, canals and reservoirs, it also shows the relationship between absorption and transmission of water within soils and finally promotes traficability of agricultural machine and equipment. Therefore, the objective of the study is to determine hydraulic conductivity of agricultural soils for optimum food production in Nigeria. Specifically, to determine infiltration and water retention characteristic of soils in the area and its effect on management practices of agricultural production.

MATERIAL AND METHOD

2.1 Description of the Study Area

Two locations were chosen within the southwestern part of Nigeria for the experiment which include the Federal University of Technology (FUTA) Agricultural Engineering research farm (AGE) and FUTA University research farm (SCH) both situated in Akure Ondo state, southwest Nigeria. Located between latitude 7°18’N and longitude 5°7’E, FUTA is within the humid region of Akure, Nigeria which lies in the rain forest zone with a mean annual rainfall of between 1300-1600 mm and with an average temperature of 27°C. The relative humidity ranges between 85 and 100% during rainy season and less than 60% during the dry season period. Akure is about 351m above the sea level. Akure is an area of about 2,303 sq km, situated within the western upland area. The soil is made up of ferruginous tropical soils. Crystalline acid rocks constitute the main parent material of the soils (Akinbile, 2012).

2.2 Sampling Preparation and Analysis

50±0.5g of soil samples were obtained randomly at depths 0-10, 10-20 and 20-30 cm from 6 different locations each using auger from the two locations for preparation before taking to the laboratories for analysis. The samples were air-dried until they reached friability and United States Department of Agriculture (USDA) textural triangle was used in determining soil classification of silt, clay and loam. Fifteen physicochemical properties were determined which include, bulk density (BD), total porosity, water holding capacity (WHC) and moisture content (MC). The rest were organic matter (OM), organic carbon (OC), pH, sodium (Na), nitrogen (N), potassium (K), calcium (Ca), Copper (Cu), Electrical Conductivity (EC), Cation exchange Capacity (CEC) and magnesium (Mg) from the samples. Apart from the pH which was measured by pH meter (model Jenney 3015), OM using H Walkley-Black method, P, Cr, Cu, Fe, Zn and Pb by extraction and Atomic spectrophotometer (AAS), other properties determined was done in the laboratory in accordance with APHA (2005) standard procedures.

2.3 Determination of Hydraulic Conductivity

A mini disc infiltrometer was used in determining the hydraulic conductivity of the two soils *in-situ*. In order to prepare the infiltrometer for measurement, the bubble chamber was filled three quarters full by running water down the suction control tube or removing the upper stopper. Once the upper chamber was full, the suction control tube was slide all the way down and the infiltrometer was inverted to remove the bottom elastomer with the porous disk and the water reservoir was then filled. The position of the end of the mariotte tube with respect to the porous disk was carefully set to ensure a zero suction offset while the tube bubbles. After filling of the water reservoir, the bottom elastomer was replaced; making sure the porous disk was firmly in place ensuring no water leaks out when the infiltrometer is held vertically. Suction rates of 2 cm per seconds were chosen at different points on the field for the infiltration measurement. The lower chamber contained the water that will infiltrate into the soil. The full infiltrometer was placed on the soils and water level was recorded every 30 seconds. It was repeated, the hydraulic conductivity was calculated. The information received was used to determine infiltration rate of the soil. The hydraulic conductivity of soil was calculated using the method of Esteves et al., (2005). The method requires measuring cumulative infiltration vs. time and fitting the results with the infiltration function.

$$I = C_1 t + C_2 \sqrt{t} \qquad 1$$

Where, (m s^{-1}) and (m $s^{-1/2}$) are parameters.

C_1 is related to hydraulic conductivity, and is the soil sorptivity.

The hydraulic conductivity of the soil (k) was then computed using the relationship in equation 2:

$$K = \frac{C_1}{A} \qquad 2$$

Where, C_1 is the slope of the curve of the cumulative infiltration vs. the square root of time, and A is a value relating the van Genuchten parameters for a given soil type to the suction rate and radius of the infiltrometer disk. A is computed from:

$$A = \frac{11.65(n^{0.1}-1)\exp[2.92(n-1.9)ah_o]}{(ar_o)^{0.91}} \qquad n \geq 1.9 \qquad 3$$

$$A = \frac{11.65(n^{0.1}-1)\exp[2.92(n-1.9)ah_o]}{(ar_o)^{0.91}} \qquad n < 1.9 \qquad 4$$

Where n and are the van Genuchten parameters for the soil, r0 is the disk radius, and h0 is the suction at the disk surface.

2.4 Statistical analysis

The slope of the curve of the cumulative infiltration versus the square root of was calculated and analyzed using basic Microsoft Excel spreadsheet macro. Hydraulic conductivity was subjected to ANOVA, linear and non-linear regressions using Statistical package for social sciences (SPSS) software version 16 and least square difference (LSD) all at a significance level of ($p<0.05$).

RESULTS AND DISCUSSION

3.1 Soil Physico-chemical properties of the two locations

Table 1 shows the result of textural class of the soil samples using the USDA textural triangle for classification which is predominantly sandy clay loam in the two locations. Slight variations were observed in the percentage composition of sand, silt and clay of the samples collected from the two locations. SCH has a higher sand content 39.50±3.56% when compared with the AGE farmsite of 31.75±2.10%, lower silt content of 28.88±2.86% as compared with 33.96±2.36 % of AGE farmsite and lower clay content of 32.08±1.20% as compared with AGE clay values of 34.52±1.48%.

Table 1: soil textural classification using the USDA Textural triangle

Location	% Sand	% Silt	% Clay	Soil Classification
AGE farm	31.75±2.10	33.96±2.36	34.52±1.48	Sandy Clay Loam
SCH farm	39.50±3.56	28.88±2.86	32.08±1.20	Sandy Clay Loam

Table 2 shows the nutrient properties of the soils in the two locations and their pH values. The mean percentage organic matter content (OMC) of the two farms of experiment was 4.43±0.80% and 4.68 ±1.03% for AGE and SCH farms respectively. Also, highest pH value of 6.02 was observed in SCH farm while 5.22 was recorded at AGE farm. High OMC and pH were found in the SCH farm is an indication of lesser depletion occasioned by less intensive agricultural practices and agreed with the findings of Doerr *et al.,* (2006) who reported that soil samples with higher values of OMC were found to have high levels of organic matter and pH. High clay content in the SCH farm may also be responsible for the high presence of OMC and this conforms to the statements by Minasny *et al.,* (2004) that as clay contents increases soil organic matter increases. Similarly, CEC at pH 7.0 for all the sites ranged from 14.05 to 12.48 and exception observed in soil samples at AGE farm might have occurred due to the low value of CEC. Soil samples from AGE farm exhibited the least CEC and OMC, least percentage nitrogen (1.08%) with highest exchangeable potassium 15.85±2.41 mg/kg but with lowest extractable phosphorus (8.13±0.21 mg/kg. SCH farm which has the highest soil pH also has the highest extractable phosphorus of (10.55±0.46 mg/kg). This was because Phosphorus availability was strongly influenced by soil pH as reported by Mullen (2009). Availability of Phosphorus is maximized when soil pH is between 5.5 and 7.0

Table 2: Mean of the organic matter, pH and soil mineral properties

Parameters	AGE FARM	SCHOOL FARM
OMC (%)	4.43±0.80	4.68±1.03
OC	2.73±0.51	2.72±0.58
PH	5.22±1.84	6.02±1.15
N (%)	1.08±0.20	1.15±0.19
EC	83.50±5.32	85.75±5.19
P (mg/kg)	8.13±0.21	10.55±0.46
SODIUM (mg/kg)	10.69±0.21	10.99±0.14
POTASSIUM (mg/kg)	15.85±2.41	14.48±0.88
CALCIUM (mg/kg)	20.38±1.89	21.05±2.30
MAGNESIUM (mg/kg)	2.36±0.15	2.30±0.27
COPPER (mg/kg)	1.07±0.20	2.02±0.21
CEC	12.48±0.08	14.05±0.44

Table 3 shows mean values of soil moisture content at different soil depths and the trend showing their variations from one location. Understandably, profile 0 - 10 cm depth had the highest MC while profile 20 – 30cm had the lowest in the two soil locations. This agreed with the findings of Mohanty *et al.,* (1998) but Moustafa (2000) had different views when he reported that soil moisture content decreases with increased depth. The results of bulk density, total porosity, water holding capacity and soil moisture content were also presented in Table 3. The bulk density ranged between 1.7 g cm^{-3} to 1.33 g cm^{-3} and highest bulk density of 1.74±0 g cm^{-3} was recorded at AGE farm at 10 – 20cm, while lowest values of1.50±0.14gcm^{-3} at 0 – 10 on the AGE farm. Continuous usage of the AGE soil for experimental research relating to soil when compared with the SCH farm may be responsible for the higher values of BD as well as successive rainfall observed during experimentation which confirmed the findings of Akinbile (2012) who reported that soils with low antecedent moisture content were more susceptible to compaction under rainfall. Osunbitan *et al.* (2005) also suggested that high rainfall in combination with cycles of wetting and drying of soil may be responsible for the general increase in soil bulk density with time. The high bulk density values at depth of 10 – 20 of AGE farm could also be due to increase in sand and silt contents of their soil texture which according to Oosterbaan and Nijland (1994) generally increase soil bulk density. The total porosity varies from 0.35 cm cm^{-3} to 0.44 cm cm^{-3} with depth 10-20 cm of AGE farm having the lowest while 0-10 of AGE farm have the highest values. This shows an inverse relationship between the bulk density and the total porosity of soils of the various experimental sites. This observation agreed with the works of Doerr *et al.,* (2006).

Table 3: Mean of moisture of content, bulk density and porosity with depth

Parameters	AGE FARM			SCHOOL FARM		
Depths	**0-10cm**	**10-20cm**	**20-30cm**	**0-10cm**	**10-20cm**	**20-30cm**
MC (%)	12.15±2.19	10.25±2.19	9.45±1.20	8.6±2.69	10.65±0.07	7.55±4.73
BD (gcm^{-3})	1.50±0.14	1.74±0	1.65±0.07	1.65±0.09	1.61±0.14	1.6±0.05
P(cm^3cm^{-3})	0.44±0.05	0.35±0	0.38±0.03	0.38±0.04	0.39±0.06	0.40±0.02

3.2 Hydraulic conductivity of soils at both AGE and SCH farms

Figures 1, 2 and 3 present the relationships between the soil's hydraulic conductivity and OM, WHC and OC respectively. From Figure 1, the K_a value ranged from 0.0004 to 0.01 cm/s and from 0.0004 to 0.00065 cm/s on SCH and AGE soils respectively for OM. There is a statistically non-significant relationship between the two parameters in SCH farm with 47% non-linear variance but a statistically significant relationship between them at AGE farm with a non-linear variance of 89% all at $P<0.05$. For figure 2, similar pattern was observed; K_a was statistically non-significant with 35% in SCH but significant with 93% in AGE soil respectively with respect to WHC. While high significant value of 99% was recorded in figure 3 with respect to OC in

SCH farm, a statistically non-significant value of 48% was recorded on the AGE farm at $P<0.05$. This agreed with the findings of Bagarello and Sgroi (2007) and Osunbitan *et al.*, (2005).

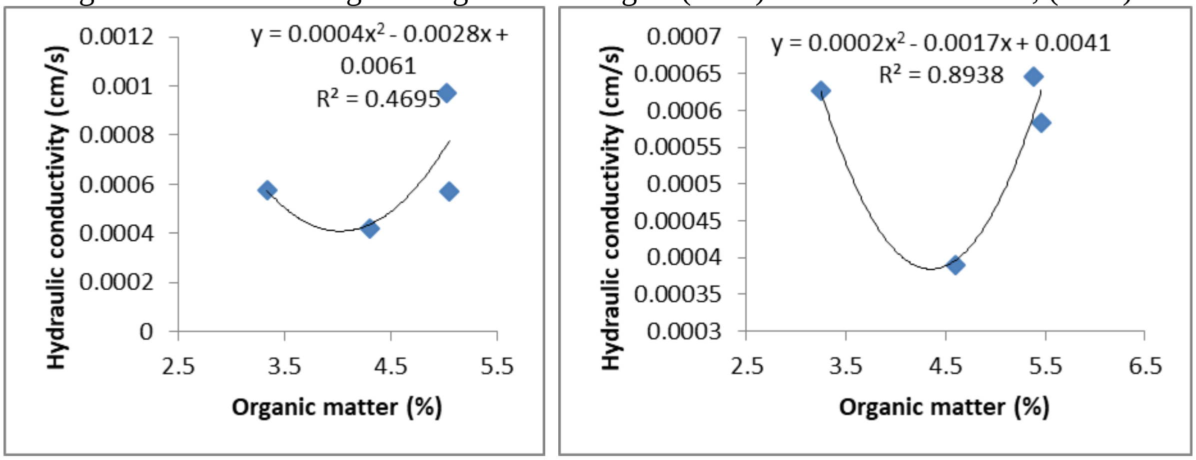

Figure 1: Relationship between hydraulic conductivity and OM at both SCH and AGE farms

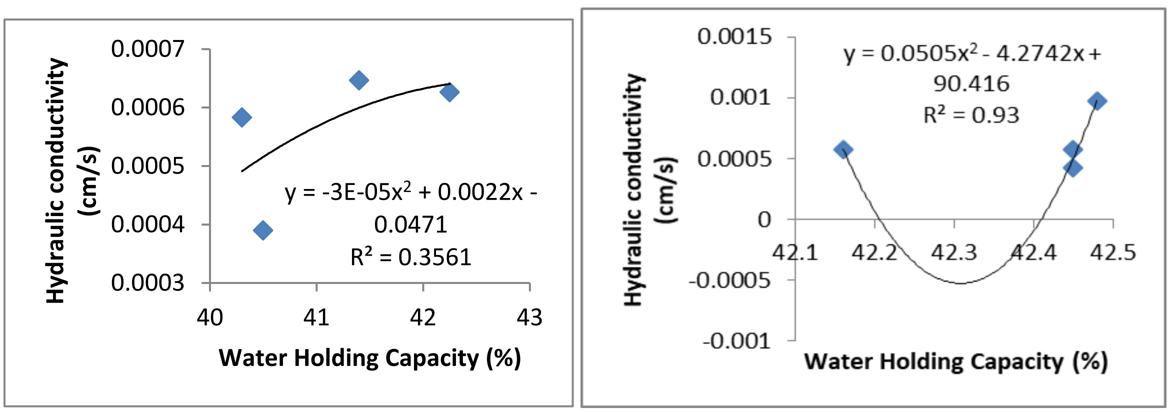

Figure 2: Relationship between hydraulic conductivity and WHC at both SCH and AGE farm

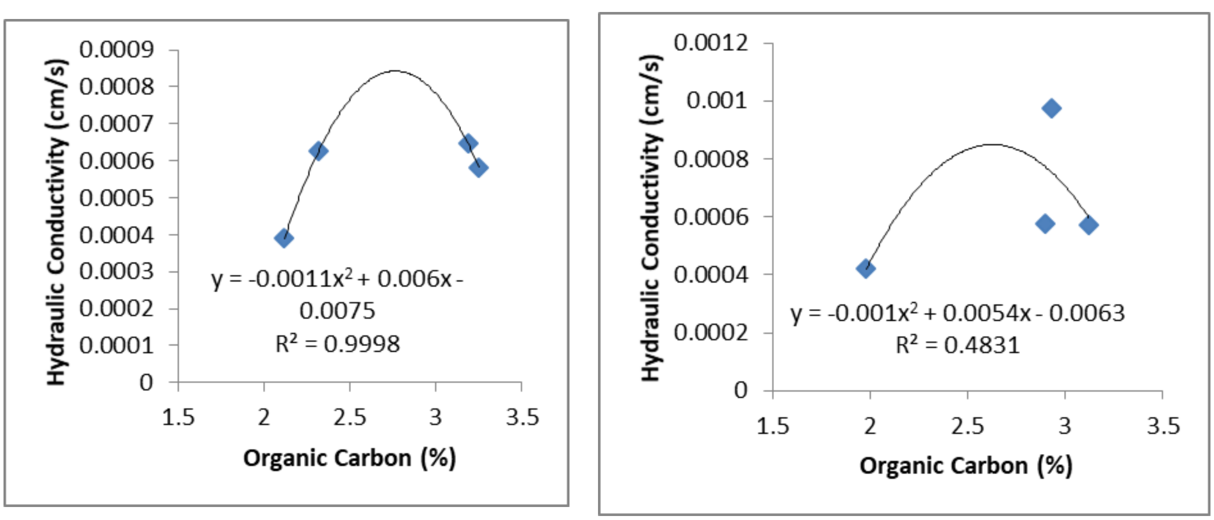

Figure 3: Relationship between hydraulic conductivity and OC at both SCH and AGE farms

CONCLUSION

From the study, K_a is largely dependent on the total porosity of soil, WHC, and MC of soil which also show high correlation with WHC at AGE farm and low correlation with SCH farm. Results from the findings also showed that soil physical and chemical properties such as bulk density, total porosity, WHC, OMC, and aggregation affected water retention characteristics, infiltration, and K_a of soils of the study area. Total porosity and BD showed inverse relationship, K_a increase with increase in OMC depending on CEC and soil pH.

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Physicochemical properties of organo-media buffered lateritic soils

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ABSTRACT

Lateritic soils are found in many farms even though they are not supportive for cultivation. This experiment was designed to assessed physicochemical properties of lateritic soils after buffering to help farmers to produce more crops/ha. There were six treatments namely: laterite soil non-buffered (LNB), laterite soil buffered with organic manure (LSBO), laterite soil buffered with NPK 15-15-15 (LSBN), sandy loam non-buffered (SLNB), sandy loam soil buffered with organic manure (SLBO) and sandy loam soil buffered with NPK 15-15-15 (SLBN). There were three replicates for each treatment arranged in a 2 × 6 × 3 factorial design. The whole arrangements were subjected to the same environmental and climatic conditions. Chemical and physical characteristics of the soil in different treatments were done in the laboratory before and after. The data collected were subjected to descriptive statistics to compare the physicochemical properties of the soils. The results revealed that soil amendments improved availability of P and will be good for plant uptake and also help the soil by reducing sorption and leaching. Also, lateritic soil amended with organic materials optimizes the availability of P and N and improved the CEC, these will be able to lower leaching and improve the root-fertilizer contact.

Keywords*: buffered laterite, organo-media, physicochemical, sandy-loam, soil factors*

INTRODUCTION

Agricultural productivity is affected by soil fertility, the increased population of man and his livestock called for improvement on the soil fertility more than application of chemical fertiliser. Soil differs greatly in texture, chemical composition, colour, depending upon the particles size of mineral component and the amount of organic matter present.

Laterite **is a** soil layer that is rich in iron oxide and derived from a wide variety of rocks weathering under strongly oxidizing and leaching conditions. It forms in tropical and subtropical regions where the climate is humid. Lateritic soils may contain clay minerals; but they tend to be silica-poor, since silica is leached out by waters passing through the soil. Typical laterite is porous and claylike (Anda *et al*., 2008). These conditions include an iron-containing parent rock, a well-drained terrain and abundant moisture for hydrolysis during weathering, relatively high oxidation potential, and persistence of these conditions over thousands of years.

Laterite is not uniquely identified with any particular parent rock, geologic age, single method of formation, climate *per se*, or geographic location. Since it can be found anywhere due to where it is produced from, it is good to be researched upon if it will readily support plant growth. (Anda *et al*., 2008; Stirzaker *et al*.,1996).

In order to produce a certain change of pH, it is usually necessary to add much more acid or alkali than the amount of H^+ and OH^- ions present in the soil suspension. This buffering action is due to the influence of weak acids and their salts (Shareeja, 2000). Soil behaves like a buffered weak acid and that will resist sharp changes in pH. In the case of acidity, it is the ability of the soil to resist change in pH. Thus, aluminum and hydrogen of one pool will replenish the aluminum and hydrogen of another pool as these acid cations are removed. **The importance of buffering of soils is mainly two folds:** (i) the stabilization of soil pH, and (ii) the amounts of amendments necessary to affect a certain change in soil reaction or soil pH (Shareeja, 2000).

Lateritic soils are found in Ejigbo and environs especially in Afaake, Isudurin, Ilawo and its other adjoining villages. These lands may be made available and capable of to yield more per acre when buffered, thus the research was postulated. The research focused on the performances of lateritic soils when fertilized with organic and inorganic manure to be able to make more farmable land available to the farmers in the area and to increase agricultural productivity.

MATERIALS AND METHODS

This study was carried out in the Teaching and Research Farms of Osun State University, Ejigbo Campus, Osun State. The soils used were laterite and sandy loam, both soils were buffered and were also used as control. Buffering materials used were organic manure (OM) made from compost and inorganic fertilizers namely NPK 15-15-15 weighed at the rate of 4kg mixed thoroughly per soil sample in each pot (calculated from 200kg/ha rate for each of the pot as per its soil volume). There were six treatments namely: laterite soil non-buffered (LNB), laterite soil buffered with organic manure (LSBO), laterite soil buffered with NPK 15-15-15 (LSBN), sandy loam non-buffered (SLNB), sandy loam soil buffered with organic manure (SLBO) and sandy loam soil buffered with NPK 15-15-15 (SLBN). There were three replicates for each treatment; the arrangement was $2 \times 6 \times 3$ factorial design.

The soil analysis was conducted at the Agronomy Department Laboratory of Osun State University, College of Agriculture, Ejigbo to determine its mineral/heavy metals analysis of thirty-six (36) soil samples. The data collected were subjected to descriptive statistics.

RESULTS AND DISCUSSION

The soil chemical and physical characteristics are shown in Tables 1 and 2 for before and after the experiment respectively. Table 1 reveals the mean of soil chemical and physical properties for samples taken from the sites before the experiment. The soil pH of the samples before the experiment, Table 1 ranged between 6.91 (laterite, not buffered) and 7.08 (sandy loam, buffered with organic matter), this pH range was between very slightly acid and very slightly alkaline

(Adepetu, *et al.,* 2014). Laterite non- buffered soil had the least organic matter content 0.2 % while sandy loam buffered with organic matter had the highest value, 0.99 %. Organic matter content follows this pattern: Laterite non- buffered < sandy loam buffered with NPK < Laterite buffered with organic matter < sandy loam non buffered < sandy loam buffered with organic matter (Table 1).

Organic matter contentment was generally low and falls below critical value (Adepetu and Adebusuyi, 1985; Adepetu, 1990). It plays a major role in soil physical, chemical and biological properties and acts as a source of nutrients, which increase nutrients at the exchange sites and also affecting the fate of applied pesticides (Alabandan *et al*., 2009); it may also form natural chelates aiding in maintaining iron in a soluble form.

Table 1: Chemical and physical characteristics of different soils before the experiment

Soil Parameter	**Soil types**					
	Laterite non-buffered, LSB	Laterite buffered with OM, LSBO	Laterite buffered with NPK, LSBN	Sandy loam non-buffered, SLNB	Sandy loam buffered with OM, SLBO	Sandy loam buffered with NPK, SLBN
Chemical characteristics						
pH (H_2O)	6.91	6.97	6.92	7.00	7.08	7.00
Organic matter (%)	0.20	0.82	0.40	0.98	0.99	0.70
Available P (ppm)	0.85	2.18	2.58	2.58	1.52	1.50
CEC, (meg/100g)	6.50	5.36	7.50	8.10	8.26	6.30
Nitrogen(ppm)	0.13	0.18	0.37	0.28	0.72	0.52
Cu^{3+} (ppm)	0.88	1.07	2.27	1.37	1.15	1.29
Mn^{2+} (ppm)	9.12	11.23	60.21	29.59	99.37	80.50
Co^{3+} (ppm)	0.75	1.20	1.20	1.38	0.20	4.21
Fe^{2+} (ppm)	43.20	62.00	60.12	42.77	40.20	42.10
Zn^{2+} (ppm)	0.91	1.42	1.20	1.77	3.40	1.92
Physical characteristics						
Sand (g/kg)	881.20	474.20	808.20	700.20	640.30	800.40
Silt (g/kg)	18.80	436.50	98.30	172.50	230.40	49.40
Clay (g/kg)	100.00	89.30	93.50	127.30	129.30	150.20
Textural class	Loamy sand	Loam	Loamy sand	Sandy loam	Sandy loam	Sandy loam

Table 2: Chemical and physical characteristics of different soils after the experiment

Soil Parameter	Soil types					
	Laterite non-buffered, LSB	Laterite buffered with OM, LSBO	Laterite buffered with NPK, LSBN	Sandy loam non-buffered, SLNB	Sandy loam buffered with OM, SLBO	Sandy loam buffered with NPK, SLBN
Chemical characteristics						
pH (H_2O)	7.00	6.98	6.92	7.00	7.10	7.01
Organic matter (%)	0.65	0.92	0.07	1.18	1.24	1.20
Available P (ppm)	1.10	3.18	2.79	3.68	3.41	2.50
CEC, (meg/100g)	4.58	7.36	5.30	7.10	7.16	6.25
Nitrogen (g/kg)	0.09	0.23	0.37	0.33	0.73	0.50
Cu^{3+} (ppm)	1.20	NA	2.27	2.37	2.13	1.12
Mn^{2+} (ppm)	20.50	12.7	90.87	29.57	109.97	85.20
Co^{3+} (ppm)	1.50	NA	NA	1.40	0.20	0.20
Fe^{2+} (ppm)	60.2	81.53	80.20	72.07	80.20	70.20
Zn^{2+} (ppm)	1.20	2.30	2.93	2.77	4.43	2.80

Phosphorus and cation exchange capacity was also low (Sobulo and Adepetu, 1987). Numerous factors limit yields (Mulatu and Lakew, 2011), the most important abiotic stresses include low soil fertility and poor agronomic practices. However, Nitrogen content ranged between 0.13 % to 0.72 %. This value was between medium to high value (Obigbesan, 2000). The particle size analysis revealed that the soil ranged from loam to sandy loam.

Table 2 reveals the mean of soil chemical and physical properties for samples taken from the sites after the experiment. There were increase in organic matter content and available phosphorus after planting for all the treatments; this might be as a result of soil amendments. Soil amendments appear promising as a strategy to address the nutrient deficiencies of laterite, which is in conformity with the results of Gatachew *et al*, 2016

In Table 2, soil amendments had improved availability of P, this will be good for plant uptake by reducing sorption and leaching, this supports the results of other studies (Lehmann *et al*., 2003; Inal *et al*., 2015). Laterite amended with organic materials and inorganic fertilizer optimizes the availability of P, this could lower leaching, improves the root-fertilizer contact and thus CEC and N (Agegnehu *et al*., 2015; Van Zwieten *et al*., 2015). It would also improve apparent low values of exchangeable cations, percent organic carbon (%OC) and OM (Table 2). As shown, there were slight changes in all these parameters after the buffering in either case, Table 2.

As crop production in this country is entirely rain-fed and terminal moisture stress is a critical problem at flowering stage, the positive effects of organic matter incorporation on lateritic soil to enhance moisture retention is likely to be a critical factor. The addition of organic matter and NPK fertilizer mixes to lateritic soils may have stabilizing effects especially on easily degradable components of the organic matter.

CONCLUSION

The use of organic amendments in a farming system can improve soil biophysical and chemical properties, maintain satisfactory crop yield, reduce the costs of production and therefore increase profitability and enhance long-term sustainability of the production system.

The interaction between organic amendment and NPK fertilizer of lateritic soils should be tested over longer periods involving representative locations across major crop producing areas of the country.

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Effect of Soil Organic Amendments and Irrigation Interval on Yield of Cucumber *(Cucumis sativus L.)*

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ABSTRACT

This study evaluated the effect of organic amendments and irrigation interval on crop yield of cucumber (Cucumis sativus L.) at Agricultural and Environmental Engineering Departmental Demonstration farm Bayero University Kano, Nigeria. The experiment comprised of three levels of organic amendments: No-Amendment (A_0), poultry manure amendment (A_1), and millet chaff amendments (A_2) and also three levels of irrigation interval: 3-days irrigation interval (S_1), 5-days irrigation interval (S_2) and 7-days irrigation interval (S_3), thus constituting a 3^2 factorial experiment. The 9 treatments were replicated 3 times, making a total of 27 experimental runs and the treatments were laid on the field in Randomized Complete Block design (RCBD) with blocks lying across the field. Water application was done based on daily evapotranspiration of the study area. The results obtained was subjected to analysis of variance (ANOVA): amendments and irrigation interval being the independable while yield as the dependable parameters. The analysis of variance shows that the effect of irrigation interval and amendments on yield were found to be highly significant at 1% level of significance. Though, there is no significant difference between no amendments (control) and millet chaff amendments treatments but highly significant difference was observed between poultry manure and earlier amendments (no-amendment and millet chaff amendment). However, despite the highest yield obtained with poultry manure with 3-days irrigation interval (A_1S_1) it can be conclude that 5-days irrigation interval alongside with poultry manure (i.e.A_2S_2 treatments) should be adopted as it is expected that the 20% yield reduction by A_2S_2 (20.3t/ha) from A_2S_1 (25.7ton/ha) can be compensated by reducing cost of pumping operation, pump wear, time consumption and drudgery involved in the irrigation operation.

Keywords: *Organic amendment, Irrigation interval, Yield, Cucumber*

1.0 INTRODUCTION

Soil is one the most precious natural resources. Proper soil management is the key to sustainable agricultural production. Soil management involved six essential practices: maintenance of soil organic matter, proper amount and type of tillage, maintenance of a proper nutrient supply for plants, avoidance of soil contamination, maintenance of correct soil acidity, and control of soil loss (Hiscox, 2006).Soil quality is another key factor to be considered in crop production and it is however defined as the capacity of the soil to function within ecosystem and land use boundaries, to sustain biological productivity, maintain environmental quality and promote plant, animal and human health(Doran and Jones, 1996).

Water scarcity on the other hand, is one of the global issues which can cause a serious threat to the global food security by lowering agricultural productivity. Competition for water among agricultural activities, industrial, and domestic uses creates the need of continuous improvement of irrigation practices in agricultural production in the world (Hexi *et al.,*2011). A portion of 70-80% of the diverted total water in the arid and semi-arid regions is used in agriculture (Fereres and Soriano, 2007). Recently, the available amount of water to agriculture is declining worldwide because of the rapid population growth and the greater incidence of drought caused by climate change and different human activities (World Bank, 2006). In irrigated land, farmers are seeking methods to save the limited available resources (soil and water) and at the same time increasing in food production. Soil amendment could be one of the ways in which soil water retention capacity can be increased thereby saving the limited available water and improving the fertility of the soil.

Agricultural soil fertility has been reported to rapidly loss due to degradation of soil's physical, chemical and biological properties which commonly arise as a result of imprudent water application and lack of incorporating proper amendments during tillage operation (Ojeniyi, 1995).

Preliminary studies revealed that the use of chemicals as amendments to the soil have negative consequences and sometimes unaffordable to many farmers which may lead them to abandon their plot especially during the dry season (Kasim, 2017). Therefore, in order to boost agricultural production with limited available water and improve soil water holding capacity to meet up with high food demand in areas with similar water problem to the study area, there is need to come up with affordable and adaptive strategies to conserve the limited soil and water for high food production. The farmers in the study area highly depend on wash bore as a source of irrigation water and no saving technique adopted. This results into high cost of pumping, the frequent level of irrigation and technical know-how on water saving techniques are some of the problems faced by the farmers in the study area. There are number of amendments that can be used in soil amendment in terms of soil nutrients and improving soil water holding capacity. Among others, poultry manure and millet chaff were used as amendment materials in this study. Millet chaff was chosen because of its availability in the study area.

Cucumber (*Cucumissativus*L.) is an important vegetable and one of the most popular members of the Cucurbitaceae family (Lower and Edwards, 1986). It is thought to be one of the oldest vegetables cultivated by man with historical records dating back 5,000 years (Wehner and Guner, 2004). In spite of the increasing relevance of cucumber in Nigeria, low yields are obtained in farmers' fields because of declining soil fertility due to continuous cropping and disregard for soil amendment materials. Therefore, in order to boost productivity of cucumber and sustain agricultural production through utilizing the limited available natural resources such as land and water in the face of rapid population growth, climate variability, agricultural and other infrastructural development. Investigation on land and soil water management strategies (water use efficiencies and soil organic amendment) is very essential. From this background, this research is coming up with appropriate soil and water management strategies and usage of available and affordable organic materials (Poultry manure and millet chaff) as amendments to the soil and also determining the effect of amendments and irrigation interval on yield of cucumber.

2.0 MATERIALS AND METHODS

2.1 Description of the Study Area

The study was conducted at Agricultural and Environmental Engineering Departmental farm of Bayero University Kano which is located along Gwarzo road between the following coordinates: 11.9770°, 8.4172° and 11.9771°, 8.4211° northward and 11.9697°, 8.4203° and 11.9668°, 8.4116° southward. The area has an altitude of 454m above sea level. Some of the climatic conditions of the area are; annual minimum and maximum temperatures of 20.5°C and 33.9°C, maximum relative humidity of 82% and minimum relative humidity of 23% and an annual rainfall of 890.40mm (Muhammad, 2014 and Shanono *et al.,* 2014).

2.2 Field /Laboratory Experiment

2.2.1 Soil Moisture content: The moisture content was determined by using gravimetric method as described by Michael and Ojha (2005) in Equation 1

$$MC = \frac{M_W - M_d}{M_d} \times 100 \quad (1)$$

where: MC = moisture content (%), M_w = mass of wet soil (kg), and M_d = mass of dry soil (kg)

2.2.2 Bulk density: Bulk density of the soil was determined using core sampler method (Grossman and Reinch, 2002) as described by Equation 2

$$\rho_b = \frac{M_S}{V_C} \quad (2)$$

where $\rho_b =$ bulk density (in g/cm^3), M_S = mass of oven dried soil (g), and V_C= volume of core sampler in (cm^3)

2.2.3 Soil classification: Particle size analysis was performed by using Bouyoucos hydrometer method (Gee and Dr., 2002). The percentage of sand, silt and clay particles in the samples were determined from Equations 3 to 6

$$\%(Si + C) = \frac{CHR_1}{W_S} \times 100 \quad (3)$$

$$\%C = \frac{CHR_2}{W_S} \times 100 \quad (4)$$

$$\%Si = \%(Si + C) - \%C \quad (5)$$

$$\%S = 100 - \%(Si + C) \quad (6)$$

where: $Si =$ silt, $C =$ clay, $S =$ sand, $CHR_1 =$ first corrected hydrometer reading, $CHR_2 =$ is second corrected hydrometer reading, $W_S =$ weight of sample

2.2.4 Organic matter content (OC)

Walkey Black wet oxidation method (Udo *et al.,* 2009) was used to determine the percentage of organic matter content present in the soil as shown in Equations 7 and 8

$$\%Org.C = \frac{N(V_1 - V_2)}{W} \times 0.3f \quad (7)$$

$$\%Org \bullet Matter = Org.C \times 1.724 \quad (8)$$

where; N= normality of ferrous sulphate solution, V_1= ferrous ammonium sulphate requires for the blank, V_2= ferrous ammonium sulphate required for the sample, W= mass of sample (g)

2.2.5 Electrical conductivity (EC)

Soil salinity of the study area was determined by obtaining electrical conductivity of the soil of using saturation extraction method described in (Udo *et al.,* 2009).

2.3 Experimental Procedure

An experiment was conducted to test the effect of the amendments and irrigation interval on the yield of cucumber (*Market more79*) at Agricultural and Environmental Engineering demonstration farm. The field experiments consisted of 9 treatments. The treatments comprised of three level of organic amendments and three levels of irrigation intervals, thus constituting a 3^2 factorial experiment. The three amendments are (A_0= No amendment, A_1= poultry manure and A_2= millet chaff) and the three levels of irrigation intervals are (S_1= 3days, S_2= 5days and S_3= 7days). The 9 treatments were replicated three times, making a total of 27 experimental runs. The treatments were laid on the field in Randomized Complete Block Design (RCBD), with the blocks lying across the field. The buffer zones were 1.5m and 0.5m for main plot and sub-plot respectively.

2.4 Land Preparation

A land of area of 54 m x 10 m was prepared into leveled basins of 2 m x 1.5 m. The field was irrigated before planting and the planting was done after an incubation period of one week for the application of the amendments. Cucumber (*Market more79*) was planted in a row at plant spacing of 50 cm between plant and 65 cm between rows and the plant population per unit plot was approximately nine (9) cucumber and consequently two hundred and forty-three (243) cucumber stands for the entire twenty-seven (27) experimental plots. The average weight of poultry manure and millet chaff amendments spread in each plot was 0.56 kg/m^2 and 0.93 kg/m^2 respectively. This amount was sufficiently enough to cover the plot area. Weeding was done five times on plots with millet chaff amendments and two times on plots with poultry amendments and without amendments. Systemic insecticide was applied twice on a weekly basis at early flowering stage and then at 3-days interval during mid to maturity stage.

2.5 Irrigation Water Application

Surface irrigation method was adopted. Water was pump from the source (tube well) and convey into the field reservoir through a pipe system and eventually serve the basins manually using calibrated container. Irrigation water application was based on actual evapotranspiration (ET_C) and crop coefficient (Kc) value of cucumber at different growing stage. The volume of water applied to the plot was estimated using the Equation (9).

$$V = ET_C \times A \times Nd \qquad (9)$$

where; V= Volume (m^3), ET_C= Actual crop evapotranspiration (mm/day), A= area of plot *= 2 x 1.5= 3m^2 and Nd. = Number of day.*

Actual crop evapotranspiration was estimated using Equation 10.

$$ET_C = ETo \times K_C \qquad (10)$$

where:ET_C = actual evapotranspiration (mm/day), ET_O = is reference evapotranspiration (mm/day) and kc = is crop coefficient of cucumber was obtained from literature.(Makinde *et al.,* 2016).

2.6 Cucumber Yield Harvesting

The cucumber yield was harvested three times depending on the matured fruits. The harvesting started at 5 weeks after planting. The maturity of fruits was indicated based on size and colour of

Plate 1: Experimental field showing cucumber

Plate 2: Experimental field fruits at maturity stage

Plate 1 show how cucumber crop the fruits began to show the signs of maturity by displaying long cylindrical fruit at 5 weeks after planting. Plate 2 shows how cucumber was harvested before fully matured by removing ripped cucumber fruit manually and labelled according to the treatment applied to the plots and then weighed.

The crop yield was computed for each of the experimental plot in accordance with (Igbadun *et al.,*2012) using Equation 11.

$$Y = \frac{W}{A}\left(Kg / m^2\right) \tag{11}$$

where Y is the crop yield $\left(Kg / m^2\right)$, W is the weight of harvested cucumber (Kg) and A is the area of the plot harvested (m^2)

2.7 Statistical Analysis

The result obtained was subjected to statistical analysis using Analysis of Variance (ANOVA).

3.0 RESULTS AND DISCUSSION

3.1 Soil of the experimental site

The soil of the site was found to have an average moisture content of 13.4% and average bulk density of 1.5g/cm^3 as reported by Zakari *et al.,* (2012) where other physiochemical properties of the soil at various layers is presented in Table 1.

Table 1: Moisture content and Bulk density of the experimental site.

Depth (cm)	Moisture Content (% dwb)	Bulk density (g/cm^3)	Organic matter (%)	EC (dS/m)	Clay (%)	Silt (%)	Sand (%)	Textural Class
0 - 20	10.3	1.6	1.12	0.32	13.31	22	64.7	Sandy loam
20 - 40	14.0	1.4	0.96	0.26	13.97	32	54.03	Loam
40 - 60	15.9	1.6	0.94	0.39	13.95	40.02	46.03	Loam
Average	**13.4**	**1.5**	**1.01**	**0.32**	**13.74**	**31.34**	**54.92**	**Loam**

dwb= Dry weight basis

3.2 Crop Yield

Table 2 shows the total mean yields of cucumber harvested in the experimental field. The total yield ranged from 2.3 to 25.7 t/ha. The least yield (2.3t/ha) was obtained from the A_2S_3 treatments, while the highest yield (25.7t/ha) was obtained from A_1S_1 treatments (Figure 1). It was expected that the least irrigation interval with no amendment (i.e.A_1S_3) will produce the least yield since cucumber crop is known to be responsive to water, but the least yield was from A_2S_3 treatments, this might be because incomplete decomposition of millet chaff amendments as well as effect of weed caused by the millet chaff which was observed during the experiments, couple with the least irrigation interval (7 days interval) compared to the other treatments. The yield obtained from all treatments of this research disagree with Simseka *et al.,* (2005), who worked with cucumber crop and gave the range of yield to be 40 -70tons/ha. Hence, the disagreement may be due to climatic condition, crop variety and period of the experiment.

Table 2: Total and mean Yield of cucumber (ton/ha)

Treatments	Mean Yield (ton/ ha)
A_0S_1	8.7
A_0S_2	9.0
A_0S_3	3.4
A_1S_1	25.7
A_1S_2	20.3
A_1S_3	10.1
A_2S_1	12.3
A_2S_2	11.7
A_2S_3	2.3

However, the yield from poultry manure amendment with irrigation interval of 3-days and 5-days which are 25.7 and 20.3 tons/ha respectively are in agreement with Enujeke, (2013), who carried out an experiment in Asaba Area of Delta state on growth and yield of cucumber as influenced by poultry manure and found the mean yield to be 21.3tons/ha while the other treatments disagree with it. Moreover, Remison, (2005) gave approximate ranged of cucumber yield to be between 5-7tons/ha, however, this research is in disagreement with that because No-amendment and millet chaff amendments corresponding to 3 and 5 days irrigation interval gave 8.7, 9, 12.3 and 11.7tons/ha.

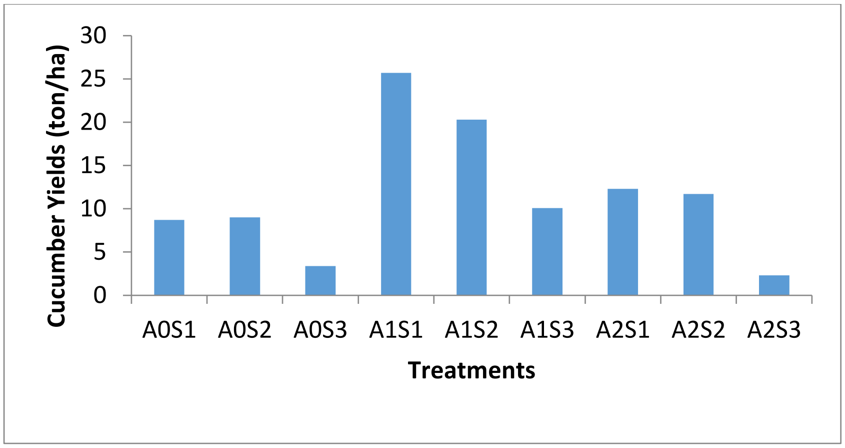

Figure 4: Cucumber Yield as influence by both soil amendments and irrigation interval

Key: ***A_oS_1= No amendment vs 3days irrigation interval, A_oS_2= No amendment vs 5days irrigation interval, A_oS_3= No amendment vs 7days irrigation interval, A_1S_1= Poultry manure vs 3days irrigation interval, A_1S_2= Poultry manure vs 5days irrigation interval, A_1S_3= Poultry manure vs 7days irrigation interval, A_2S_1= Millet chaff vs 3days irrigation interval, A_2S_2= Millet chaff vs 5days irrigation interval, and A_2S_3= Millet chaff vs 7days irrigation interval***

Yield from poultry manure amendment is significantly ranked highest corresponding to irrigation interval of 3-days interval. The interaction between amendments and irrigation interval was also highly significant at 1% level of significance. This result revealed that organic amendments and irrigation interval significantly influences the yield of cucumber crop.

3.3 Effect of Organic Amendments and Irrigation Interval on Yield of Cucumber

The result of the experiment was subjected to statistical analysis using Analysis of Variance (ANOVA). Table 2 present the result of the statistical analysis using Statistical Analysis Software (SAS) with independent variables as organic amendments and irrigation interval and yield of cucumber as dependent variables. The analysis shows that the effect of various irrigation interval and organic amendments used were found to be highly significant at 1% level of significance. Though, there is statistical difference within the organic amendments of poultry manure to that of No-amendment and millet chaff. The insignificant difference between No-amendment and millet chaff may result from incomplete decomposition of the millet chaff amendment. It is expected that if the millet chaff completely decomposes, there will be statistically differences within the yields of the amendments and thereby improving the water holding capacity of the soil. This means that both organic amendments and irrigation interval have significant effect on the yield of cucumber crop. The table also presented the result of the analysis that compared the various irrigation interval and different organic amendments used and found to be highly significant at 5% level of significance. This implies that irrigation interval and organic amendments used, has significant effect on the yield of cucumber grown in the study area. The interaction between the amendments (A) and irrigation interval (S): (A*M) was also found to be significance.

However, the result further reveals that the best organic amendment to cucumber at experimental site is poultry manure corresponding to 3 days irrigation interval giving mean yield of 25.7 ton/ha. Despite the high yield that was observed from the plot of poultry manure amendment with 3-days irrigation interval, it was analyzed that the 5-days irrigation interval alongside with poultry manure amendment resulted in yield reduction of approximately 20% from the earlier treatment (A_2S_1). However, water can be saved and the soil been conserved by the 5-days irrigation interval and this could compensate the yield reduction by putting more land into use and thereby reducing the cost of pumping water operation, pump wear, time consumption and drudgery involved in the irrigation operation.

Table 2: Statistical Analysis of the Effect of Organic Amendments, Irrigation Interval and their interaction on Yield of Cucumber

Treatments	Yield (kg/m^2)
<u>**Amendments (A)**</u>	
A_0	1.8074b
A_1	4.0556a
A_2	1.9259b
Significance	**
LSD @ 1%	0.2758
<u>**Irrigation Sch.(S)**</u>	
S_1	3.4741a
S_2	2.889b
S_3	1.4259c
Significance	**
LSD @ 1%	0.2758
<u>Interaction</u>	
A x S	**

**= Highly significance at 1%, A = Organic amendment, S = Irrigation interval, Means with same letter are not significantly different

4.0 CONCLUSION

This research focused on the effect of soil organic amendments and irrigation interval on the yield of cucumber. Based on the e result obtained, it can be concluded that irrigation interval and organic amendments could individually or combine significantly improve the cucumber yield. Management of cucumber for maximum yield requires optimizing irrigation water supply in combination with proper application of soil organic amendment. Hence, despite the fact that high yield resulted from poultry manure amendment corresponding to 3-days irrigation intervals but based on the analysis of the result, it can be concluded that 5-days irrigation interval alongside with poultry manure (i.e. A_2S_2 treatments) should be adopted as it is expected that the 20% yield reduction by A_2S_2 (20.3 tons/ha) from A_2S_1 (25.7 tons/ha) can be compensated by reducing the cost of pumping operation, pump wear, time consumption and drudgery involved in the irrigation operation.

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Cone Index Properties of Soil and Some Growth Parameters of Cassava (*Manihot esculenta* crantsz) under Different Tillage Management

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ABSTRACT

The study was conducted to investigate the effects of different tillage operations on soil strength properties and yield of cassava (Manihot esculentaI crantz). Randomized complete block design with three treatments replicated three times on a sandy clay loam soil in Akure, Nigeria. Field experiments were conducted during two seasons. Soil bulk density and cone index of penetrometer were determined for each of the treatments. The cone penetration resistance was determined at depths of 7.5, 15, 22.5, 30, 37.5 and 45 cm. All the tillage operations were significantly different (P = 0.001) in their effects on soil penetration resistance. The results indicated zero/no tillage has the highest penetration resistance compared to other tillage methods. Primary tillage produced the plant having the highest height, leaf count and leaf area, while zero/no tillage produced the plant with the highest stem diameter and leaf area index. All plant growth parameters (plant height, stem diameter, leaf area and leaf area index) were statistically not significantly different except leaf count in all soil tillage treatments. Output of this research is useful for cassava and other tuber crop growers in the study area and other regions of similar climate especially in the selection of appropriate tillage management considering the economics and productivity involved in all the systems.

Keywords: *Tillage; Cassava; Penetration Resistance; Leaf area index; Akure.*

1 INTRODUCTION

Soil tillage operations and related changes of soil physical parameters are of growing importance in agricultural production. Tillage is a management input that affects soil physical characteristics (Katsvairo *et al*., 2002). Physical, mechanical, chemical and biological properties of soil are altered by tillage management. Soil tillage practice and its consequences on agricultural sustainability through its effects on soil processes, soil properties, and crop growth is of high interest in many parts of the world (Aina, 2011). Some of the soil properties affected by tillage include soil bulk density, total porosity, hydraulic conductivity, penetration resistance etc which are important for favourable conditions for crop growth and maintaining soil quality (Rachman *et al*., 2003). Since soil physical properties play a central role in transport and reaction of water, solutes and gases in soils, their knowledge is very important in understanding soil behaviour to applied stresses, transport phenomena in soils, hence for soil conservation and planning of appropriate agricultural practices for optimum crop yield.

Physical, mechanical, chemical and biological properties of soil are altered by soil tillage management. A wide range of special tillage operations involving soil inversion, chiseling, subsoiling or deep tillage have been found to be beneficial by minimizing soil hardening or bulk density, improving soil porosity, infiltration, soil water storage, and root development (Lal, 1984; Ogunremi *et al*., 1986, Adeyemo and Agele, 2010). Ojeniyi and Agboola, (1995) and Adeyemo and Agele, (2010) reported that these practices influence soil physical conditions, nutrient availability, growth and yield of crops. They also enhance rapid root elongation with depth; induce a high root density in the subsoil and increases final yield.

Yield has always been a major yard stick for measuring successful agricultural method and economic indices (Bello, 2014). The demand for Cassava has globally increased and it overshoot supply, the occurrence of drop in yield has also put a lot of pressure on production of Cassava and the present increase in cultivation is not enough to curb demand (FAO/IFAD, 2005). This research seeks to achieve optimum yield of cassava using statistical tools by employing nutrient availability, soil strength and physical conditions and hydraulic properties based on the key role in cassava production. Through proper tillage operations, these properties enhance rapid root elongation with depth; induce a high root density in the subsoil and increases final yield (Adeyemo and Agele, 2010). The importance of the soil strength assessment on the ever growing needs of cassava cannot be over emphasized. Therefore, this study was aimed at examining the impact of different tillage management on soil penetration resistance, bulk density, hydraulic conductivity and growth and yield of cassava in an Alfisol in Southwestern part of Nigeria.

2 MATERIALS AND METHODS

2.1 Study Area

The research was conducted at the Research and Training Farm of the Department of Agricultural Engineering, Federal University of Technology, Akure, Ondo State, Nigeria. The site lies within the humid region of Nigeria between latitudes $7^0$14'N and $7^0$17´N and within longitudes $5^0$08´E and $5^0$13´E. Akure has a land area of about 2,303 sq km and is situated within the Western upland area. Akure lies in the rain forest zone of Nigeria with a mean annual rainfall of between 1300 – 1600 mm and with an average temperature of 27°C (Fasinmirin *et al.*, 2018).

The relative humidity ranges between 85 and 100% during the rainy season and less than 60% during the dry season period. Akure is about 351 m above the sea level.

2.2 Treatments and Experimental Procedure

An experimental plot consisting of three (3) treatments and four (4) replicates was laid out in randomized complete block design to make a total of twelve (12) plots. There three soil treatments are: Secondary Tillage (ST); Primary Tillage (PT); and Zero or No – Tillage (NT). The PT was done using disc plough mounted on a tractor to plough the soil. The first ploughing was followed three (3) days after, by another round of ploughing; while the secondary tillage involves harrowing of the soil after an initial ploughing operation in the same manner as the primary tillage. Zero or No-tillage (NT) involves the use of herbicides to control the vegetation and weeds on the plots. Each plot was 12 m by 10 m. Tillage treatments were carried out in the month of August each year. The same location was used for the 2 years of the experiment.

2.3 Measurement

2.3.1 Penetration resistance (PR)

Soil penetration resistance (PR) was determined using cone penetrometer, HYPEN1 model, with 30° cone angle and 2 threaded extension rods 450 mm long graduated every 75 mm. Penetration resistance data were determined at two weeks interval and cone index values were recorded at an interval of 75 mm down the soil profile to a depth of 450 mm.

2.3.2 Agronomic parameters

Plant population was carried out once and measurement of plant height, number of leaves and stem girth were carried out throughout the growth period of cassava. A representative of the plants was selected in each of the replicates from which numbers of leaves were obtained. These were carried out by counting manually during the period of planting on a weekly basis. The stem diameter of cassava was measured at some the 3 – 4 cm length of stem just above the soil surface using venier caliper. Likewise, the heights of the plant were measured from the soil surface to the tip of the plant using a meter rule. Three representative plant samples were used for height measurement and same plant samples were used for leaf area measurement in the different tillage treatments. The leaf area measurement was done using "Compu Eye, Leaf & Symptom Area" software by Bakr, (2005). The software was calibrated and a coefficient of multiplication of 0.96 was gotten from the calibration having compared the results with that traced on a graph paper to measure its area. The results were also validated with another image analyser, Digimizer 4.2.2.0 by MedCalc software to ascertain its accuracy.

From these measurements, leaf area index (LAI) was estimated by the formula

$$LAI = \frac{\text{LA} \times \text{LC} \times \text{no of plants}}{\text{land area covered}} \qquad 1$$

where LA is the leaf area and LC is the leaf count.

2.4 Statistics

The cone index values and plant growth parameters were subjected to statistical analysis to determine the mean, standard deviation and Analysis of variance (ANOVA), linear and non-linear regressions were used to separate means of soil and plant parameters obtained from the different tillage treatment using Microsoft excel and Minitab 17.

3. RESULTS AND DISCUSSION

3.1 Cone index from tillage treatments (kPa)

Tables 1 to 6 show the effects of the different tillage methods on the soil penetration resistance at various growth stages of cassava. During the flowering stage of the 1st Season (i.e 2012/2013), zero/no tillage has the highest penetration resistance compared to other tillage methods. There were significant differences in the penetration resistance between the tillage methods at soil depths 7.5, 30 and 37.5 cm. The increase in penetration resistance at the no tillage plots was due to the absence of soil manipulation, while secondary tillage which was more intensely manipulated has the least value. Penetration resistance is an indirect measure of soil shear strength (Osunbitan *et al.,* 2005). During the developmental stage/canopy establishment, ST has higher penetration resistance values compare to other treatments, which might be due to the presence of hard pan in the lower layers. The penetration resistance of the soil varied significantly ($p < 0.05$) with the method of tillage operations at 45 cm depth only. However, while the penetration resistance increased with time after tillage under ST and PT treatments, it decreased slightly under NT at the six depths sampled.

Osunbitan *et al*. (2005) reported similar observation in their study of the effects of different tillage operations on bulk density, and the hydraulic properties of a loamy sand soil of Southwestern Nigeria. Similar findings were observed during the dormancy/maturity stage of the 2012/2013 cropping season. There was significant difference in the values of the penetration resistance among the three tillage treatments at 7.5, 30, 37.5 and 45 cm respectively. The penetration resistance was significantly and consistently higher under NT throughout the developmental stage/canopy establishment and dormancy/maturity stage of the study. The soils' penetration resistance generally increased with increase in depth for all treatments.

Table 1. Mean Significant differences in penetration resistance between tillage systems during the flowering stage of the 1st Season

	Penetration Resistance (kPa)		
DEPTHS	Secondary tillage	Primary tillage	No tillage
7.5 cm	499.5^{B}	525.4^{B}	740.7^{A}
15 cm	1050.7^{B}	844.0^{B}	1137^{B}
22.5 cm	1429.7^{B}	1257.4^{B}	1516^{B}
30 cm	1912.0^{AB}	1601.9^{B}	2049.8^{A}
37.5 cm	2205^{B}	2032.6^{B}	2618.2^{A}

45 cm	2601^{B}	2290.9^{B}	2739^{B}

Values followed by similar letters under the same row are not significantly different at p=0.05

Table 2. Mean Significant differences in penetration resistance between tillage systems during the developmental stage/canopy establishment of the 1st Season

	Penetration Resistance (kPa)		
DEPTHS	Secondary tillage	Primary tillage	No tillage
7.5 cm	655^{B}	379^{B}	465^{B}
15 cm	1515.8^{A}	1085^{A}	1326^{A}
22.5 cm	1791^{A}	2153^{A}	1102^{A}
30 cm	2360^{A}	2084^{A}	1309^{A}
37.5 cm	2911^{A}	2498^{A}	1860^{A}
45 cm	3669^{A}	3049^{AB}	2050^{B}

Values followed by similar letters under the same row are not significantly different at p=0.05

Table 3. Mean Significant differences in penetration resistance between tillage systems during the dormancy/maturity stage of the 1st Season

	Penetration Resistance (kPa)		
DEPTHS	Secondary tillage	Primary tillage	No tillage
7.5 cm	1808.6^{A}	878^{B}	878.5^{B}
15 cm	2756^{A}	1791^{A}	1447^{A}
22.5 cm	3324^{A}	2136^{A}	1980.9^{A}
30 cm	3703^{A}	2274^{B}	2291^{B}
37.5 cm	4117^{A}	2696^{B}	2687^{B}
45 cm	4530^{A}	3290^{B}	2928.3^{B}

Values followed by similar letters under the same row are not significantly different at p=0.05

During the 2013/2014 cropping season, means significant differences in penetration resistance between tillage systems during the flowering stage shows that NT treatment have the highest penetration resistance in all the depths in comparison to the other treatments (ST and PT) (Table 4 – 6). A similar finding was observed in the first cropping season. There was statistically significant difference among the treatments at depths 7.5, 15, and 45 cm respectively. Penetration resistance between tillage systems during the developmental stage/canopy establishment and the harvest stage during the second cropping season shows that ST has the overall highest PR values down the depths.

Table 4. Mean significant differences in penetration resistance between tillage systems during the flowering stage of the 2nd Season

	Penetration Resistance (kPa)		
DEPTHS	Secondary tillage	Primary tillage	No tillage
7.5 cm	602.9^{C}	775.1^{C}	2015.33^{A}
15 cm	1326.33^{C}	1516^{C}	2549^{A}
22.5 cm	2274^{B}	1998^{B}	3083^{B}
30 cm	2997^{B}	2446^{B}	3411^{B}
37.5 cm	3738^{B}	3307^{B}	3945^{B}
45 cm	4427^{A}	4031^{B}	4444^{A}

Values followed by similar letters under the same row are not significantly different at p=0.05

Table 5. Mean significant differences in penetration resistance between tillage systems during the developmental stage/canopy establishment of the 2nd Season

	Penetration Resistance (kPa)		
DEPTHS	Secondary tillage	Primary tillage	No tillage
7.5 cm	1120^{B}	671.8^{B}	810^{B}
15 cm	2618^{B}	1223^{C}	1378^{C}
22.5 cm	3376^{AB}	2567^{B}	2584^{B}
30 cm	4203^{A}	3462^{A}	3479^{A}
37.5 cm	4857^{AB}	3841^{B}	4134^{B}
45 cm	5030^{AB}	4237^{B}	4513^{B}

Values followed by similar letters under the same row are not significantly different at p=0.05

Table 6. Mean significant differences in penetration resistance between tillage systems during the dormancy/maturity stage of the 2nd Season

	Penetration Resistance (kPa)		
DEPTHS	Secondary tillage	Primary tillage	No tillage
7.5 cm	930^{A}	551^{A}	723.4^{A}
15 cm	1240^{A}	1050.7^{A}	1120^{A}
22.5 cm	2119^{A}	1395.2^{B}	1567^{AB}
30 cm	2877^{A}	1843.1^{B}	2033^{AB}
37.5 cm	3445^{A}	2308^{B}	2412^{B}

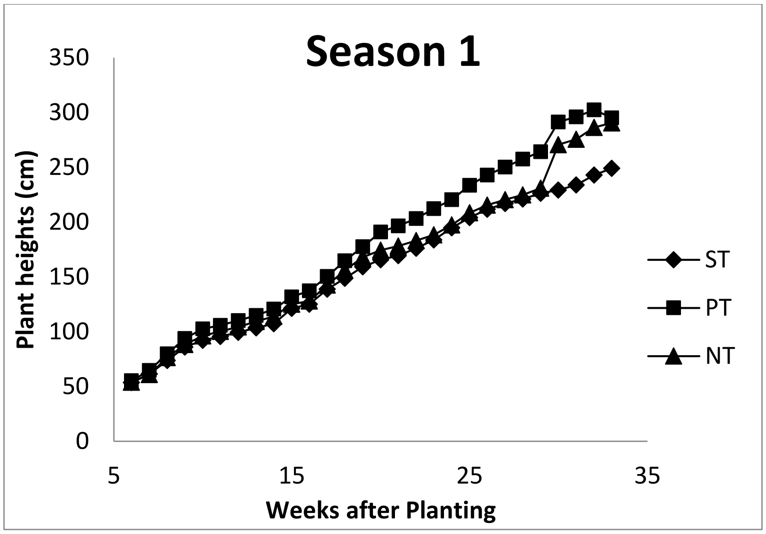
45 cm	3738^{A}	2928^{A}	2911^{A}

Values followed by similar letters under the same row are not significantly different at p=0.05

3.3 Agronomic parameters of cassava from the tillage treatments

The pattern of the plants height of cassava on function of weeks after planting (WAP) in 2012/13 and 2013/2014 planting seasons were similar. In both cases, cassava showed an increasing trend with increasing WAP (Figure 1). At 25 WAP (roots formation stage) for the cropping season 1, PT had the highest average plant height, while for cropping season 2; ST had the highest value with NT having the least average plant height for the two cropping seasons.

The maximum values of the average plant height for the two cropping seasons were recorded until the 33 WAP (i.e. maturity/senescence stage for all the treatments (Figure 1). The average plant height increased rapidly from 25 to 33 WAP referred to as the maturity stage, hence, at the end of the two cropping seasons, the highest average plant heights measured were 302.38, 249.13 and 290.5 cm for cropping season 1 and 312.5, 279.75 and 250.75 for cropping season 2 for the treatments ST, PT and NT, respectively. Figure 2 shows the changes of the stem diameter (cm) of cassava with time (WAP). The largest average stem diameters on 15 WAP (developmental stage/canopy establishment) for ST, PT and NT were 1.86 and 2.03, 2.15 and 2.3 and 2.02 and 1.90 cm for season1 and season 2, respectively. During the flowering stage (5 to 10 WAP), there were sudden increase in the average stem diameter in all the treatments. The increases in the average stem diameter were smaller towards the late-season (i.e. 26 to 33 WAP) as compared with the flowering stage as shown in Figure 2. In all the treatments, PT had the highest value of average stem diameter in both seasons, while ST had the least value in the first cropping season and NT had the least value in the second cropping season. Figure 3 shows the changes of the leaf count of cassava with time (WAP). The figure shows that the average leaf count increased with age (i.e. cassava growth stages) for all the treatments in the two cropping seasons. The highest average leaf count of 153 was obtained for NT and the least value of 122 was recorded for PT during cropping season 1, while for cropping season 2, ST had the highest leaf count of 144 with NT having the least value of 105. The average changes in the leaf area of cassava with time (WAP) in 2012/13 and 2013/14 cropping seasons is presented in Figure 4. At 18 WAP (developmental stage/canopy establishment) for cropping seasons 2, PT had the highest average leaf area (398.11 cm^2), with NT having the least value (330.76 cm^2). The maximum value of the average leaf area for cropping season 1 was recorded on 33 WAP (late-season stage) with PT having leaf area of 364.07 cm^2 and ST plot having the least of 307.80 cm^2. The average leaf area indexes for the two cropping seasons were shown in Figure 5 with the values 4.44, 5.52 and 5.37 for ST, PT and NT for cropping season 1 and values 3.76, 4.31 and 3.86 for ST, PT and NT for cropping season 2 respectively at the maturity/dormancy stage (33 WAP). The peak of LAI is between 4-6 months after planting at which point plant senescence is reached. LAI was directly proportional to crop growth rate until the LAI of 4 and above was attained.



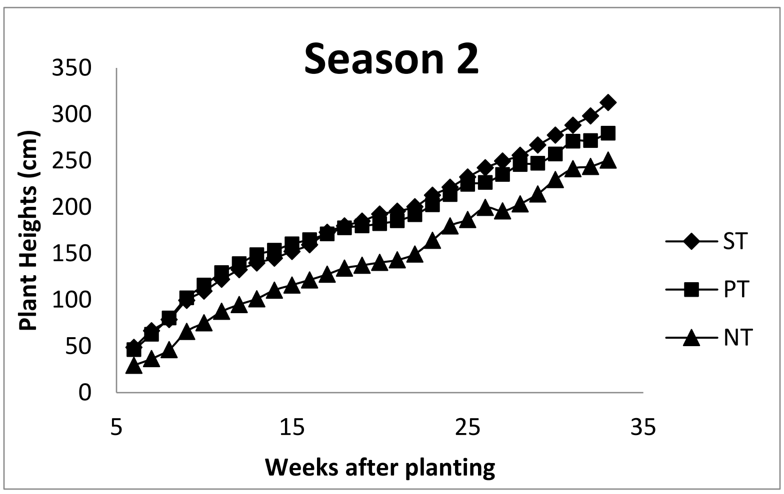
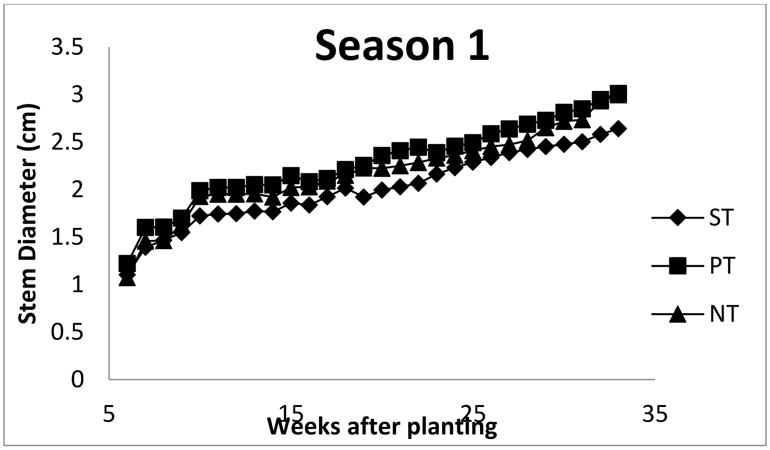


Figure 1. Plant height (cm) of cassava with time (WAP) in season 1 (2012/13) and season 2 (2013/14) planting seasons



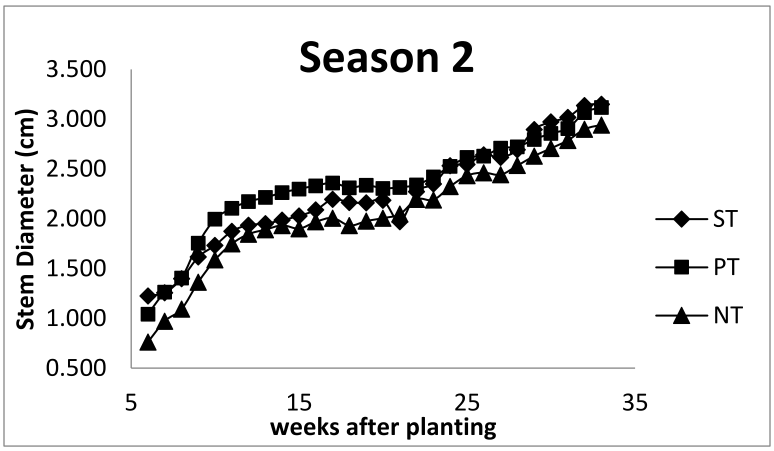
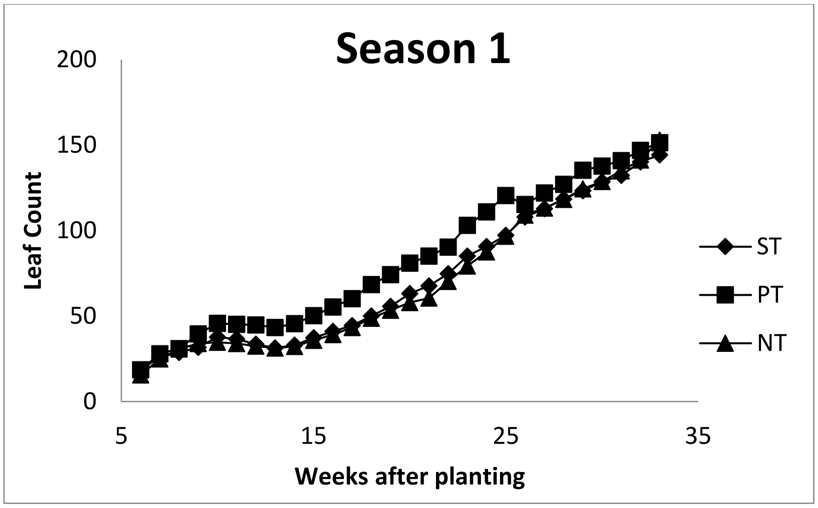


Figure 2 Stem diameter (cm) of cassava with time (WAP) in season 1 (2012/13) and season 2 (2013/14) planting seasons



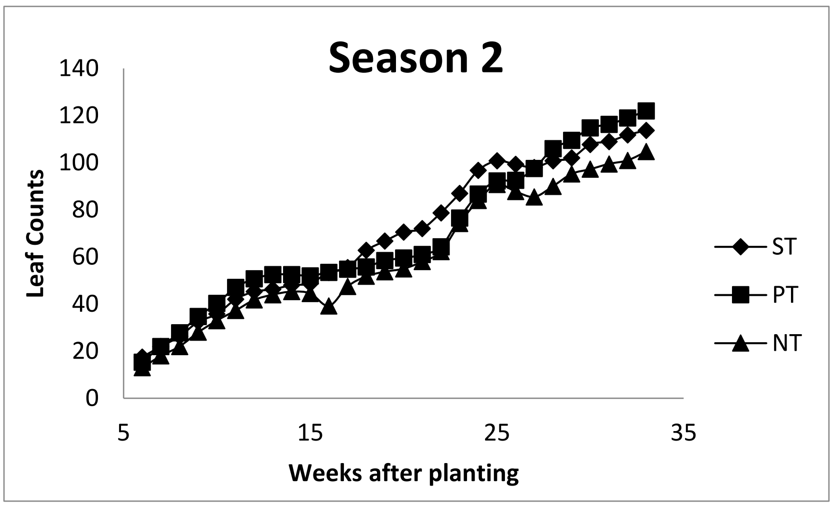
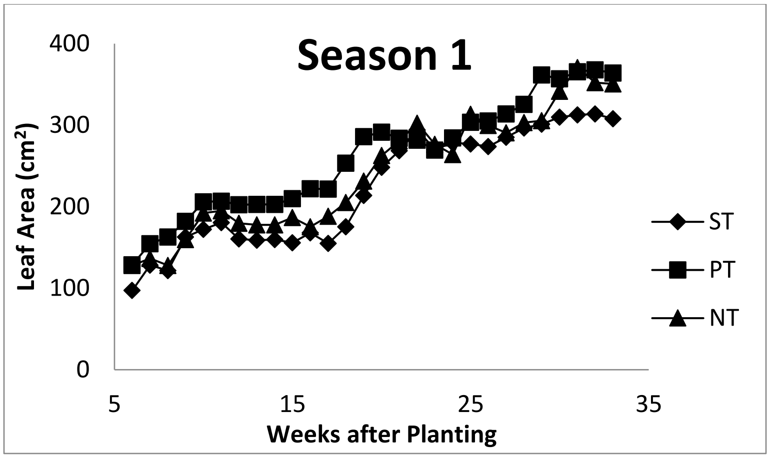


Figure 3 Leaf counts of cassava with time (WAP) in season 1 (2012/13) and season 2 (2013/14) planting seasons



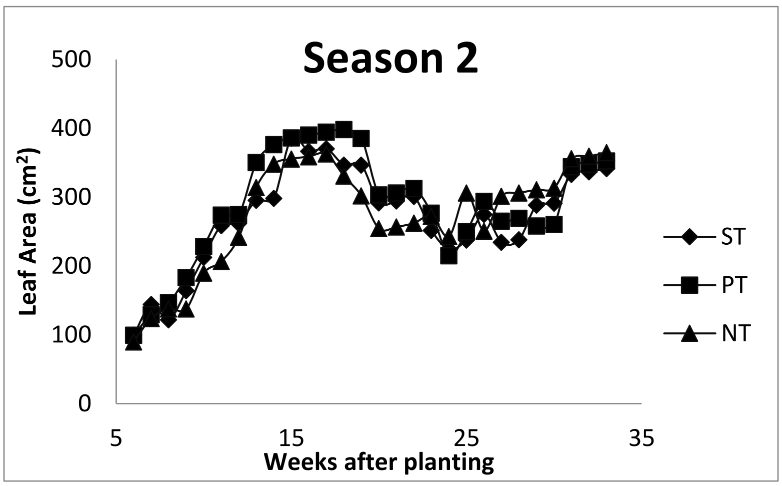
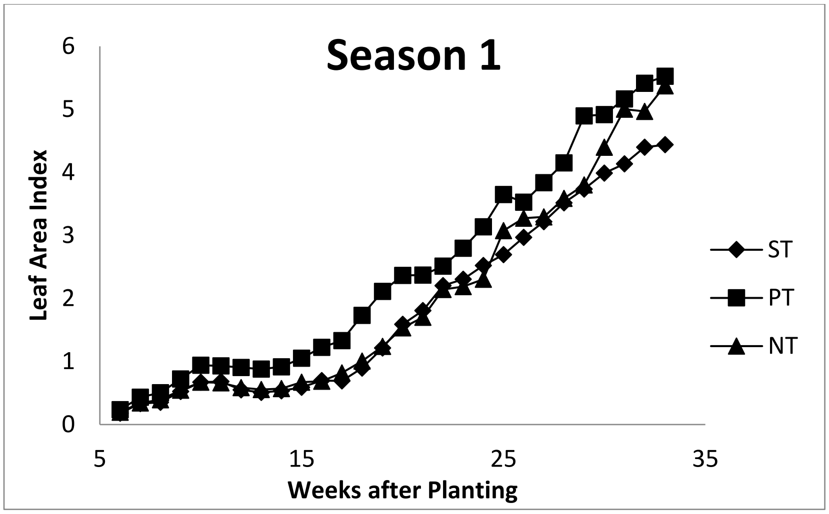


Figure 4 leaf area (cm) of cassava with time (WAP) in season 1 (2012/13) and season 2 (2013/14) planting seasons



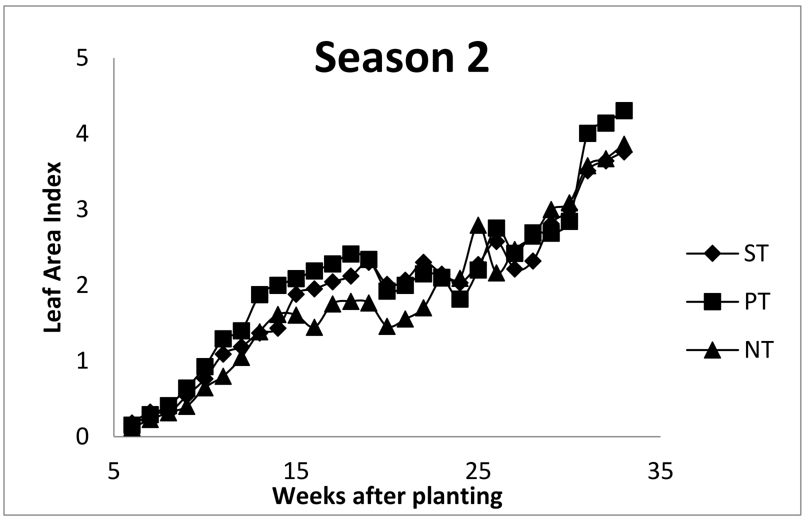


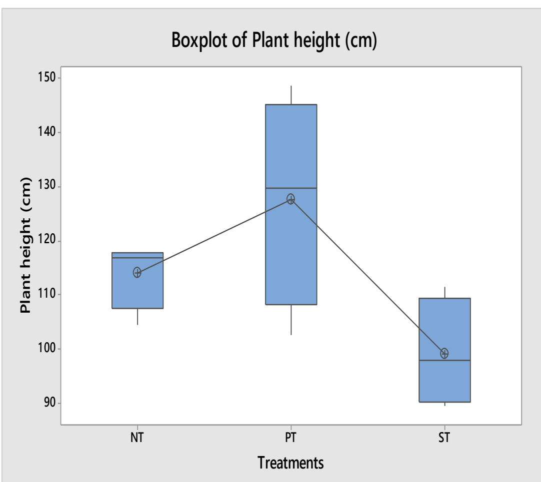
Figure 5. Leaf area index of cassava with time (WAP) in season 1 (2012/13) and season 2 (2013/14) planting seasons

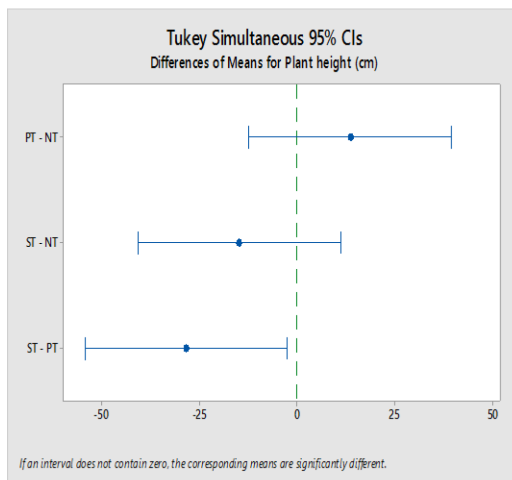
Table 7 and 8 showed data on the effect of the different tillage methods on growth of cassava during the 2012/2013 and 2013/2014 cropping seasons, respectively. In the first cropping season (2012/2013), primary tillage produced the plant having the highest plant height, leaf count and leaf area while zero/no tillage produced the plant with the highest stem diameter and leaf area index (Figure 6 and 7). There was statistically significant difference ($p = 0.05$) in all the plant parameters (except leaf count) among the different tillage systems. However, in the second cropping season (2013/2014), most values of plant parameters were not significantly difference ($p = 0.05$) except for plant height between primary tillage and the no tillage treatments. NT treatment had the highest stem diameter, leaf area and leaf area index respectively during the 2012/2013 growing season. The mean plant height though highest in treatment under ST during the 2013/2014 growing season, there were no significant difference ($p = 0.05$) when compared with the plant height under the PT treatment plot (Figure 6).

Table 7. Effect of tillage methods on the growth of cassava in 2012/2013 cropping season

Tillage system/plant parameters	Tillage Treatments		
	Secondary tillage	Primary tillage	No tillage
Plant height (cm)	99.2^{B}	127.6^{A}	114^{AB}
Stem diameter (cm)	1.54^{B}	1.76^{AB}	1.84^{A}
Leaf count	40.87^{A}	45.71^{A}	41.37^{A}
Leaf area (cm^2)	187.9^{B}	212.8^{AB}	236^{A}
Leaf area index	0.97^{B}	1.17^{A}	1.2^{A}

Values followed by similar letters under the same row are not significantly different at p=0.05





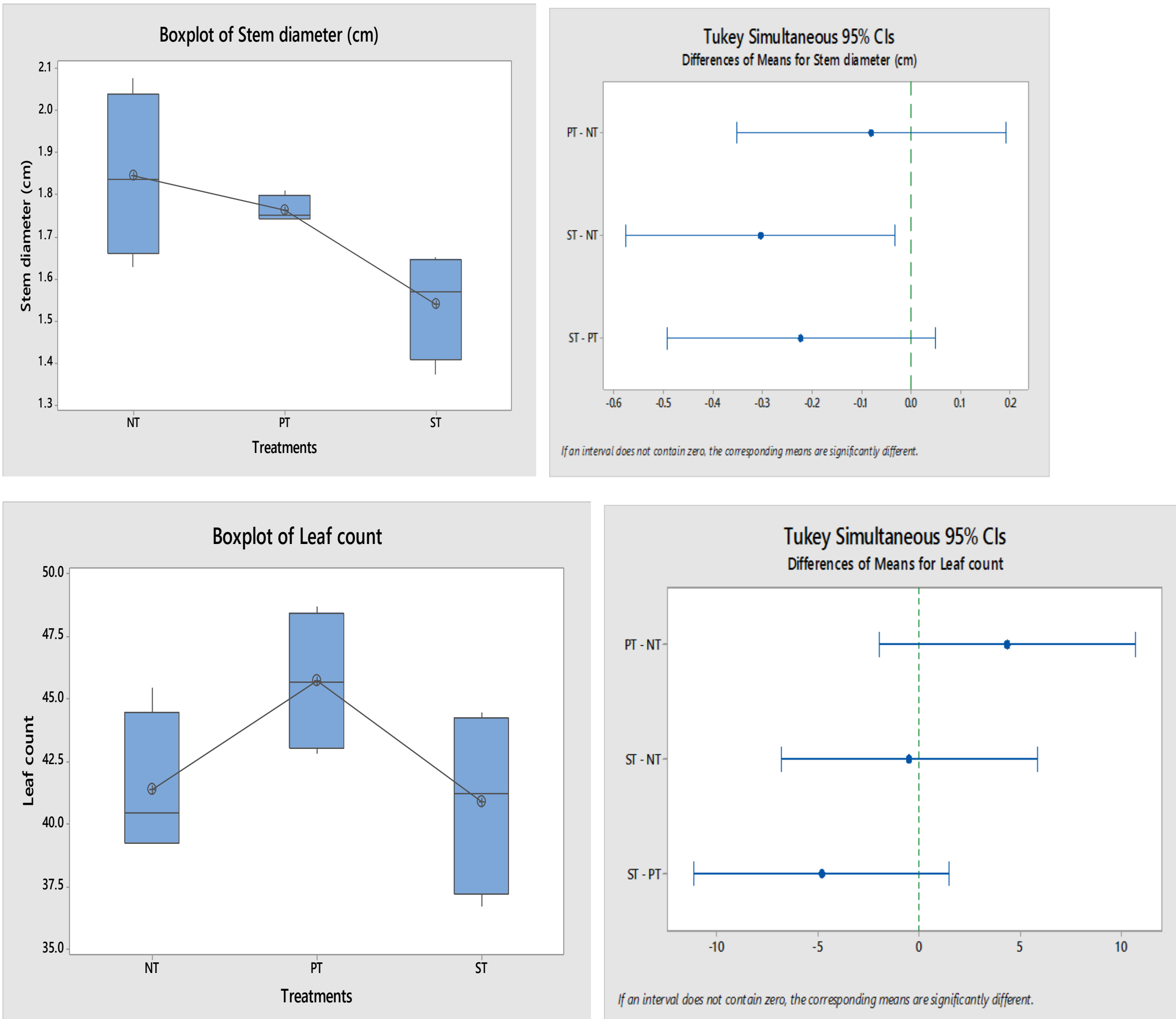
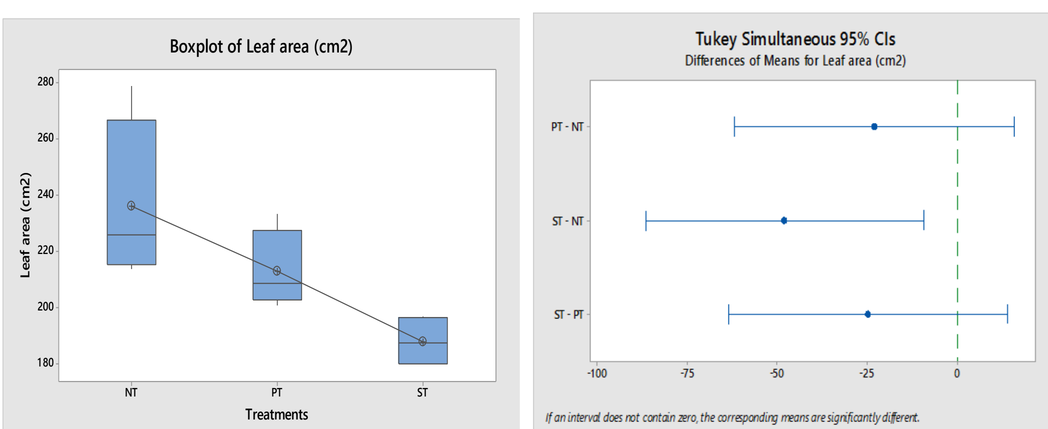


Figure 6. Plant height, stem diameter and leaf count under different tillage systems in 2012/2013 cropping season



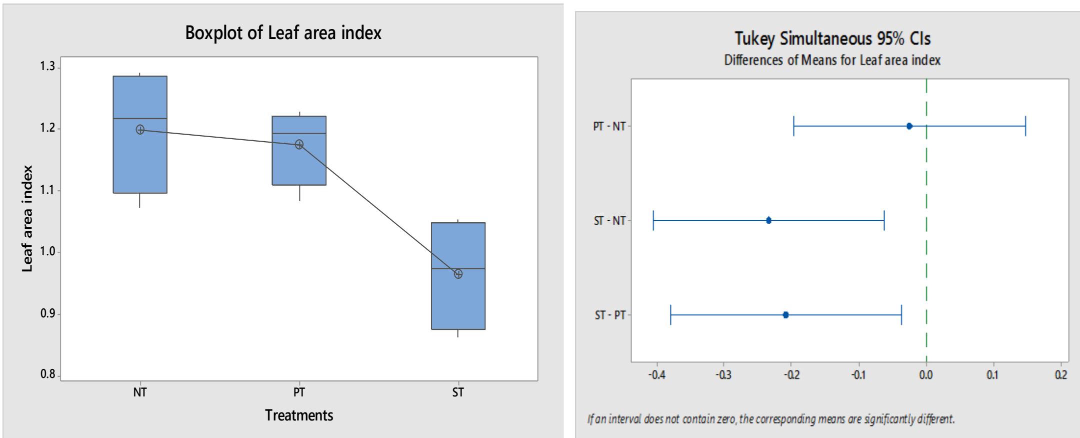


Figure 7. Leaf area and leaf area index under different tillage systems in 2013/2014 cropping season

Table 8. Effect of tillage methods on the growth of cassava in 2013/2014 cropping season

Tillage system/plant parameters	Tillage Treatments		
	Secondary tillage	Primary tillage	No tillage
Plant height (cm)	187^{A}	180.9^{A}	143.8^{B}
Stem diameter (cm)	2.24^{A}	2.33^{A}	2.06^{A}
Leaf count	69.7^{A}	69.1^{A}	61.1^{A}
Leaf area (cm^2)	271.9^{A}	288.3^{A}	273.4^{A}
Leaf area index	1.94^{A}	2.08^{A}	1.83^{A}

Values followed by similar letters under the same row are not significantly different at p=0.05

4 CONCLUSION

The study was conducted to investigate the effects of different tillage operations on penetration resistance and growth parameters of cassava in a Sandyclayloam soil of Akure, Southwestern Nigeria. Penetration resistance was significantly and consistently higher under NT throughout the two crop growing seasons Penetration resistance increased with increase in week after planting. The primary tillage treatment plot produced the plants with the optimal agronomic parameters at both the first and second cropping seasons as it gave the highest height, leaf area and leaf area index, though leaf counts were not significantly different among treatments. The adoption of PT for soil preparation in the cultivation of cassava will ensure minimum soil disturbance and retention of soil aggregates for optimum yield of the crop.

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Optimization of Cassava (*Manihot esculenta crantz*) Yield from Some Physical and Mechanical Properties of Soil

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ABSTRACT

Cassava Manihot esculenta crantz is one of the most common staple food widely consumed in the sub-Saharan Africa and other tropical countries of the world. The demand for the crop far exceeds its supply and this often force the price of the commodity up especially during off-seasons. This research therefore was conducted to determine the influence of different soil tillage management (Primary tillage, PT; Secondary tillage, ST; No tillage, NT) on cassava productivity and optimize the yield of the crop on function of some important soil physico-chemical characteristics. Soil samples were collected at the 0 – 10, 10 – 20 and 20 – 30 cm depth in a Sandyclayloam soil of Akure, Nigeria and analyzed for soil macro nutrients. Soil physical parameters such as moisture content (MC), hydraulic conductivity (K) and penetration resistance (PR) were measured using standard methods. Cassava variety TMS 419 was planted and yield parameters were measured during the growing and maturity stages of the crop. Response Surface Methodology (RSM) was applied using Minitab version 17.1.0 to determine the optimum levels of five important parameters of soil which include organic matter content (OMC), Nitrogen (N), PR, MC and K for cassava yield prediction. PT produced the highest yield of cassava (25.25 tons/ha) followed by zero/ no tillage (19.33 tons/ha) and the least was in ST (17.17 tons/ha) during the 2012/2013 season. In the second year (2013/2014) cropping season), NT produced the lowest mean yield of cassava (10.58 tons/ha) followed by ST (14.5 tons/ha), whereas the PT was highest in terms of cassava tuber yield (21.42 tons/ha). The optimal values of OMC, N, PR, MC and K were found to be 1.49 %, 0.28 %, 1446.9 kPa, and 10.67 % and 3.53 cmh^{-1}, respectively, to achieve a maximum of 46.06 tons per hectare of cassava yield in 2012/2013 cropping season, while the best soil condition to obtaining a maximum value of 42.97 tons per hectare of cassava yield in the 2013/2014 season are 1.47 %, 0.08 %, 2357.12 kPa, 10.06 % and 2.77 cmh^{-1} for OMC, N, PR, MC and K, respectively. The output of this research can be employed in the practice of soil pre-conditioning to obtain good yield of cassava in the study area and other regions of similar climate and soil condition.

Keywords: Cassava; Hydraulic conductivity; Organic matter; Penetration resistance, Soil

1 INTRODUCTION

THe expanding population in many countries has required and will continue to demand an ever-increasing agricultural production of feeds and fibres through soil tillage operations (Osunbitan *et al,* 2005). Different management practices to improve the growth and yield parameters of cassava have been studied with the aim of significantly improve the overall cassava yield and meet the ever increasing demands of the populace. Farm production planning itself is a complex process, wherein the input-output relations, the input-output cost price ratios, the available farm natural resources, as well as the farmer's preferences should be taken into consideration (Zgajnar, 2011). In tropical regions, soil ecosystems are often constrained beyond their natural capacity. Consequently, the soils are reduced in productivity and sustainability (Jongruaysup *et al.*, 2003). Thus, soil management will be responsible for important changes in soil quality parameters, particularly those related to soil structure and water movement.

Soil hydraulic property is the major soil property that determines the water retention and movement in soils. The soil-moisture characteristic curve or soil water retention curve SWRC θ (*h*) and hydraulic conductivity *K* (*h*) function are two basic hydraulic properties of soils. They are of fundamental importance in the fields of crop production and agronomy. However, soil hydraulic properties and soil strength are subject to temporal changes particularly in the near-saturated range where soil structure essentially influences water flow characteristics (Strudley *et al.,* 2008). Physical, mechanical, chemical and biological properties of soil are altered by Soil tillage management and compaction. The structure of soil top layers is subject to temporal changes, caused by agricultural operations (soil tillage and compaction) and biological activities.

Since soil physico-chemical, mechanical and hydraulic properties play a central role in transport and reaction of water, solutes and gases in soils, their knowledge is very important in understanding soil–plant–water interaction, hence for soil conservation and planning of appropriate agricultural practices. Therefore, the objective of this study was to assess the yield of cassava on function of the interaction of some soil physical properties under different tillage management in the humid rainforest climate of Akure, Southwestern Nigeria.

2 MATERIALS AND METHODS

2.1 Site description

The research was conducted at the experimental Farm Site of the Department of Agricultural and Environmental Engineering, Federal University of Technology, Akure, Nigeria, which covers a total land area of approximately 2ha. The site lies within the humid region of Nigeria between latitudes $7^{0}14'$N and $7^{0}17'$N and within longitude $5^{0}08'$E and $5^{0}13'$E

(Fasinmirin and Adesigbin, 2012). Akure has a land area of about 2303 sq km. Akure lies in the rain forest zone of Nigeria with a mean annual rainfall of between 1300–1600 mm and with an average temperature of 27°C (Fasinmirin *et al.,* 2018). The relative humidity ranges between 85 and 100% during the rainy season and less than 60% during the dry season period. The soil of the site is predominantly sandy clay loam and belongs to the Alfisol (Soil Survey Staff, 1999) or Ferric Luvisol (FAO, 2006). Akure is about 351 m above the sea level. The map showing Akure south in Ondo State is presented in Figure 1.

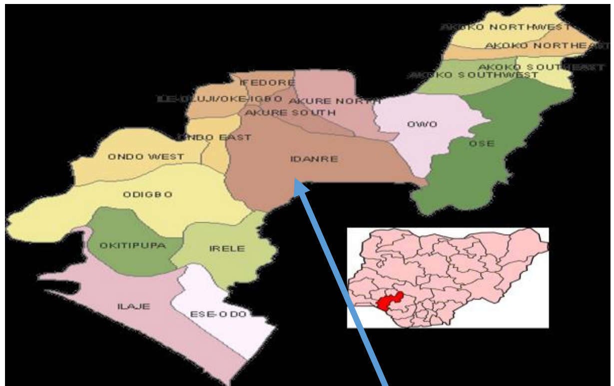


Figure 1: Map of Nigeria showing Ondo State and Map of Ondo State showing Akure South Local Government Area

2.2 Treatments and experimental procedures

Two years' experiment (20112012 and 2012/2013 planting seasons) was conducted. The experiment which consisted of three treatments with four replicates was laid out in randomized complete block design to make a total of twelve (12) plots. The three soil tillage treatments are: Secondary tillage (ST); Primary tillage (PT); and No – tillage (NT). Primary tillage was done using disc plough mounted on a tractor to plough the soil. The first ploughing was followed three (3) days after, by another round of ploughing; while the secondary tillage involves harrowing of the soil after an initial ploughing operation in the same manner as the primary tillage. Zero or No-tillage (NT) involves the use of herbicides to control the vegetation and weeds on the plots. Each plot was 12 m by 10 m. Tillage treatments were carried out in the month of August each year. The same location was used for the 2 years of experiment. The soil parameters tested to determine the influences of tillage treatments on the yield of cassava include soil nitrogen, organic matter content, moisture content, the bulk density, total porosity, the soil penetration resistance (measured on weekly basis) and hydraulic conductivity (on monthly basis) of the experimental plots.

2.3 Soil sampling and measurement

Soil samples were collected in soil profiles at depth up to 100 cm; from the 4 different locations in Akure mainly from soil superficial series. (0 – 15 cm) Samples were collected from horizon A in each location, packed in plastic bags, and transferred to the laboratory. The samples were allowed to dry in the open air until reaching friability and was analyzed for particle size determination, and macro nutrients such Nitrogen, Phosphorus, Potassium, Calcium, Organic matter, pH and Cation exchange capacity at the soil laboratory of the Federal University of Technology, Akure.

2.3.1 Soil moisture content

Soil samples were collected in cylindrical metal cores of height 4.8 cm and diameter 5.0 cm at depth 0 – 10, 10 – 20 and 20 – 30 cm from the three tillage treatments and replicates. The cylinders were carefully driven into the soil with the aid of mallet, while ensuring undisturbed sampling. The core samplers were driven down to ensure both open sides of cylinder were filled in order to ensure that the soil volume is equal the volume of the cylinder. Samples were carefully removed with the aid of hand trowel and weighed insitu to obtain the volume of wet soil. The samples were carefully arranged in box container and transferred into the oven in the soil laboratory. The samples were arranged in the oven and dried to a constant weight at 105^0C. The samples were later off loaded from oven, allowed to cool and weighed to determine the dry weight. Soil moisture content for the samples from the tillage treatments were then calculated using gravimetric method as described in Fasinmirin and Oguntunde (2016) and Olorunfemi and Fasinmirin (2017).

2.3.2 Hydraulic conductivity

The minidisk infiltrometer, a hand-held field instrument was used to rapidly assess soil infiltration capacity as described by Olorunfemi and Fasinmirin (2017). Unsaturated hydraulic conductivity and water sorptivity were calculated from the infiltration data obtained during field measurement. The suction rate of 2 cm per seconds was chosen at different points on the field for the infiltration measurement. The 2 cm setting is adequate for most soils and is the optimal suction rate for infiltration measurement from our past field test and measurements. The data collected were then used to calculate the water infiltration rates of the soil and subsequently the hydraulic conductivity of soils under the different tillage treatments were determined following the method described in Fasinmirin *et al.* (2018)

2.3.3 Penetration resistance

Penetration resistance describes the amount of pressure, in kilopascals (kPa), applied to push the penetrometer through a soil profile (Tokunaga, 2006). Soil penetrability is a measure of the ease with which an object can be pushed or driven into the soil. Soil penetration resistance (PR) was determined using cone penetrometer, HYPEN1 model supplied by Pike Agri – Lab Supplies, Inc [(207) 897-9267]. with 30° cone angle and 2 threaded extension rods 450 mm long graduated every 75 mm. Penetration resistance data were determined at two weeks interval and cone index values were recorded at an interval of 75 mm down the soil profile to a depth of 450 mm.

2.3.4 Cassava yield measurement

Cassava tubers were harvested to determine the tuber length, weight of the tubers, number of tubers per plant, and tuber circumference were measured for the estimation of tuber sphericity/roundness. Random collection of six (6) cassava tubers per plot was carried out by manual uprooting method. The cassava stems were carefully shaken to agitate the soil to ensure all tubers were uprooted during harvest. The uprooted tubers were weighed fresh on electronic weighing balance which measures to 0.01 measuring sensitivity. The mean yields were determined from the simple average of the six (6) sampled tubers. Tuber length was measured using steel rule and the diameter estimated using Vernier Caliper. Tuber area and sphericity were estimated using the following equations:

$$Area\ (A) = \frac{\pi\, d^2}{4} \qquad 1$$

$$Sphericity\ (S) = \frac{4\, \pi\, A}{P^2} \qquad 2$$

where p = perimeter of the tuber($P = 2\pi r$).

The sphericity was measured by the cutting of each tuber length into three (3) sections: the big, the middle and the smallest diameter segments. The circumferences of each of the segments were measured for sphericity analysis.

2.3.5 Optimization

Many designed experiments involve determining optimal conditions that will produce the “best” value for the response. Using the final model, factor settings that optimize the response (maximize Cassava yield) were identified (optimization). Optimal factor values depend on the process objective. Response Optimizer provides you with an optimal solution for the input variable combinations and an optimization plot. Response Optimizer searches for a combination of input variable levels that jointly optimize a set of responses by satisfying the requirements for each response in the set. The optimization is accomplished by obtaining the individual desirability (d) for each response. Since we have only one response, the overall desirability is equal to the individual desirability. The individual desirability (d) for the response was obtained using the goals and boundaries provided (maximize the response).

Response Surface Methodology (RSM) is an important tool in analyzing the experimental data, resulting in the optimization of conditions for product development. This method was applied using Minitab version 17.1.0 to identify the optimum levels of the five factors, i.e. OMC, N, PR, MC and K regarding one response: yield. A five-factor and three-level Box–Behnken design consisting of a base design of 16 runs including four replicates at center point was employed for this purpose. A total number of 89 experimental runs were carried out. The order of experiments was fully randomized. These data were analyzed by multiple regressions using the least squares method. The goal of this optimization procedure was to obtain optimum conditions which give higher cassava yield. A second-order polynomial equation was used to relate the response variable (Y_i) with independent variables (Xi).

$$Y_k = \beta_{k0} + \sum_{i=1}^{n} \beta_{ki} x_i + \sum_{i=1}^{n} \beta_{kii} x_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \beta_{kij} x_i x_j \qquad 3$$

where Y_k is the response variable, Y_1 is the cassava yield (tons per ha). xi represents the coded independent variable (X_1 is the OMC, X_2 is the TN, X_3 is the PR, X_4 is the MC and X_5 is the K); where β_{k0} was the value of the fitted response at the center point of the design, i.e. point (0,0,0). β_{ki}, β_{kii}, and β_{kij} were the linear, quadratic, and cross-product regression coefficients, respectively.

2.4 Statistical Analysis

Hydraulic conductivity, soil water sorptivity, bulk density and soil resistance values were subjected to statistical analysis to determine the mean, standard deviation, coefficient of variation, linear and nonlinear regressions. The significance tests of the soil physical, chemical and mechanical properties on function of treatments and their interactions were performed using the Analysis of Variance (ANOVA) within the General Linear Model (GLM) procedure using Minitab 17 statistical software. RSM was used to determine the optimum levels of the five factors, i.e. OMC, N, PR, MC and K on one response i.e. yield.

3 RESULTS AND DISCUSSION

3.1 Soil physical properties

Table 1 shows the result of particle size composition and chemical properties of soil samples during planting seasons 1 and 2. The soils of the experimental site were predominantly sandy clay loam according to USDA soil textural classification (Soil Survey Staff, 1999). Tillage managements have no significant effect on the sand, silt and clay fractions (Table2) as soil textural class is a permanent and natural attribute of the soil (Hillel, 1998). Are *et al.* (2009) and Fasinmirin *et al.* (2018) reported that the textural class of a particular soil may not necessarily change even if the soil management changed.

There were reductions in some nutrients composition of the soil samples of the primary and secondary tillage treatments in the second planting season. Soil generally depletes its nutrients after harvest after the harvest of cassava tubers. Cassava like any other crop absorbs nutrients from the soil and at harvests all or parts of these are removed from the field, resulting in nutrient depletion and fertility decline (Sumithra *et al.* 2013). No tillage plots however shows increase soil organic matter contents in the second cropping season.

3.2 Effects of Tillage Methods on Soil Hydraulic Properties

Tables 2 and 3 show the means significant difference in hydraulic conductivity (K) between the different tillage systems during flowering, canopy establishment and maturity/dormancy stages for the two cropping seasons (2012/2013 and 2013/2014 cropping seasons). The hydraulic conductivity of the soils did not vary significantly with the method of tillage operations in the two cropping seasons. However, in the 2012/2013 cropping season i.e first season, ST had the highest mean hydraulic conductivity value during the flowering and maturity stages while PT had the highest during the developmental/canopy establishment stage, whereas NT had the lowest unsaturated hydraulic conductivity in developmental/canopy establishment and maturity/dormancy stage. In the 2013/2014 cropping season, ST had the highest K in the establishment /development and maturity/senescence stages of plant, while PT had the highest K in the developmental/canopy establishment stage. In both seasons (2012/2013 and 2013/2104 seasons), there were decreasing trend in the values of unsaturated hydraulic conductivity as the crop growth progresses during the second cropping season (Table 3).

Table 1 Mean (Standard Deviation) of Soil Physico-Chemical Properties during the Two Planting Seasons

	ST		PT		NT	
Parameters	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Sand (%)	52.80(±0.17)	60.8(±2.34)	48.00(±3.71)	52.80(±1.57)	48.80(±3.04)	52.80(±2.42)
Clay (%)	27.20(±3.21)	27.2(±1.78)	29.20(±2.53)	26.20(±4.83)	31.20(±1.68)	35.20(±1.07)
Silt (%)	20.00(±2.81)	12.00(±3.67)	22.80(±2.51)	21.00(±1.07)	20.00(±6.24)	12.00(±2.59)
Organic Carbon (%)	0.77(±0.17)	0.75(±0.34)	0.79(±0.08)	0.77(±0.13)	0.80(±0/42)	0.84(±1.02)
Organic matter (%)	1.32(±3.10)	1.29(±2.07)	1.32(±1.89)	1.22(±0.21)	1.38(±1.09)	1.44(±0.89)
pH	5.90(±1.57)	5.42(±0.78)	5.48(±2.77)	5.45(±3.07)	5.80(±1.06)	5.78(±0.46)
Nitrogen (%)	0.18(±0.43)	0.06(±0.01)	0.20(±0.03)	0.06(±0.29)	0.26(±0.17)	0.08(±0.03)
Sodium (cmol/kg)	0.18(±0.08)	0.06(0.04)	0.20(±0.15)	0.07(±0.04)	0.26(±0.09)	0.08(±0.03)
Potassium (cmol/kg)	0.20(±0.07)	0.14(±0.12)	0.34(±0.17)	0.17(±0.12)	0.29(0.16)	0.13(0.07)
Magnesium (cmol/kg)	1.10(±0.58)	0.60(±0.13)	1.30(±0.57)	0.50(±0.07)	1.10(±0.07)	0.50(±0.06)
Calcuim (cmol/kg)	2.50(±0.17)	1.10(±008)	3.00(±1.04)	1.00(±0.06)	2.50(±1.05	1.40(±0.56

Table 2 Means Significant differences in hydraulic conductivity between tillage systems during the different phenological stages of the 1st Season

	Tillage Treatments		
STAGES	**Secondary tillage**	**Primary tillage**	**No tillage**
establishment/developmental	3.33^{A}	3.17^{A}	3.02^{A}
developmental /canopy establishment	2.05^{A}	3.22^{A}	3.30^{A}
maturity/senescence	2.53^{A}	2.49^{A}	2.25^{A}

Values followed by similar letters under the same row are not significantly different at p=0.05

Table 3 Means Significant differences in hydraulic conductivity between tillage systems during the different phenological stages of the 2nd Season

STAGES	Tillage Treatments		
	Secondary tillage	**Primary tillage**	**No tillage**
establishment/developmental	2.35^{A}	2.33^{A}	2.33^{A}
developmental /canopy establishment	2.32^{A}	2.45^{A}	1.71^{A}
maturity/senescence	0.60^{B}	0.44^{B}	0.52^{B}

Values followed by similar letters under the same row are not significantly different at p=0.05

Green *et al*. (2003) reported that results for the different tillage treatments are not always consistent across locations, soils and experiment designs with regard to the effects of tillage on the soil hydraulic properties under well-structured soil conditions. Results from studies on the short-term tillage-induced effects on the hydro-physical properties of agricultural soils and their dynamics over the fallow period have shown that the loosening of surface soil by tillage operations increases the total soil porosity (Logsdon *et al.*, 1999; Miller *et al*., 1998; Green *et al*., 2003). This may have accounted for the high values of K observed in ST plots during the early stage of crop development as an increase in K has commonly been observed in recently tilled soils (Messing and Jarvis, 1993), probably as a consequence of an increase in the number of active mesopores. However, on the long run, there is tendency of reduced porosity in the tilled plots. Hydraulic conductivity depends upon soil texture and structure, which varies in both space and time (Fuentes et al., 2004).

Osunbitan *et al.* (2005) in their research to investigate the effects of different tillage operations on bulk density, and the hydraulic properties of a loamy sand soil of Southwestern Nigeria reported that the saturated hydraulic conductivity of the plots generally decreased with weeks after cultivation apparently due to soil resettlement and compacting effects of rainfall and runoff over the soil. This agrees with the findings of Kribaa *et al*. (2001) who similarly observed a decrease in soil conductivity with time after cultivation in an Algerian soil.

Nonetheless, a soil that is coarser and well-aggregated will have a higher infiltration rate than that of a soil with a finer texture that is not as well-aggregated (Troeh *et al.,* 2004). The initial water content of the soil will affect infiltration. A dry soil will have a higher initial infiltration rate than a wet soil. Also, if soil moisture increases, soil pores may expand in soils with high organic matter content (Tsuboyama et al., 1994). Pore size and continuity are also important to the hydraulic conductivity of soils. Macropores and earthworm and decaying root channels vastly increase the amount of water that will infiltrate the soil (Fuentes *et al.,* 2004).

3.3 Effects of Tillage Methods on Cassava Yield

The yield (tons/ha) of cassava on function of different tillage systems during the 2012/2013 and 2013/2014 cropping seasons is presented in Figure 2 and 3. Tillage had significant effect on cassava yield at both cropping seasons. In the first cropping season (2012/2013), the mean tuber yield of cassava (17.17 tons/ha) recorded in the treatment under secondary tillage (ST) was significantly lower than tuber yield under primary tillage (PT), which produced the highest yield of cassava (25.25 tons/ha). The tuber yield of ST is significantly lower ($p = 0.05$) when compared to zero/ no tillage (19.33 tons/ha) (Figure 2). Similar trend was also observed in the second year (2013/2014 cropping season), zero/no tillage (NT) produced the lowest mean yield of cassava (10.58 tons/ha) followed by secondary tillage (ST) (14.5 tons/ha) and these yields were greatly different from primary tillage (PT) (21.42 tons/ha) (Figure 4.36). In the two trials, tillage methods significantly ($p = 0.05$) affected the cassava yield during the 2012/13 and 2013/14 cropping seasons in the study location.

Similar trend was observed for the average cassava tuber diameter (cm) and tuber length (cm) for all the treatments (ST, PT and NT) in the first cropping season (2012/2013) and second cropping season (2013/2014) respectively (Figure 2 and 3). There were no statistically significant differences in the tuber diameter and length among the means of the treatments. Average cassava tuber diameter during the 1st cropping season was highest in treatment plots under Primary tillage with mean value of 7.10 (±1.61) cm. Mean tuber diameter value of 6.53 (±1.30) cm obtained in treatment plots under secondary tillage is comparable with treatment plots under No tillage, where the average tuber diameter of cassava was 6.35 (±1.32) cm. In the second year, PT plots have the highest mean average diameter of 7.87(±1.64) cm which is comparable to that of secondary tillage plots with mean value of 7.48(±1.48) cm. Zero/No tillage plots have the least mean average diameter value of 5.87(±0.75) cm.

When considering the length of cassava tubers in the treatment plots for the two cropping seasons, PT plots has the highest length of cassava tubers with mean value of 63.67 (±15.98) cm while ST and NT plots have mean values of 46.2 (±16.35) cm and 48 (±17.69) cm respectively in the first cropping season. In the second cropping season, PT, ST and NT have mean values of 47.83 (±9.54) cm, 41.83 (±12.61) cm and 42 (±9.63) cm respectively.

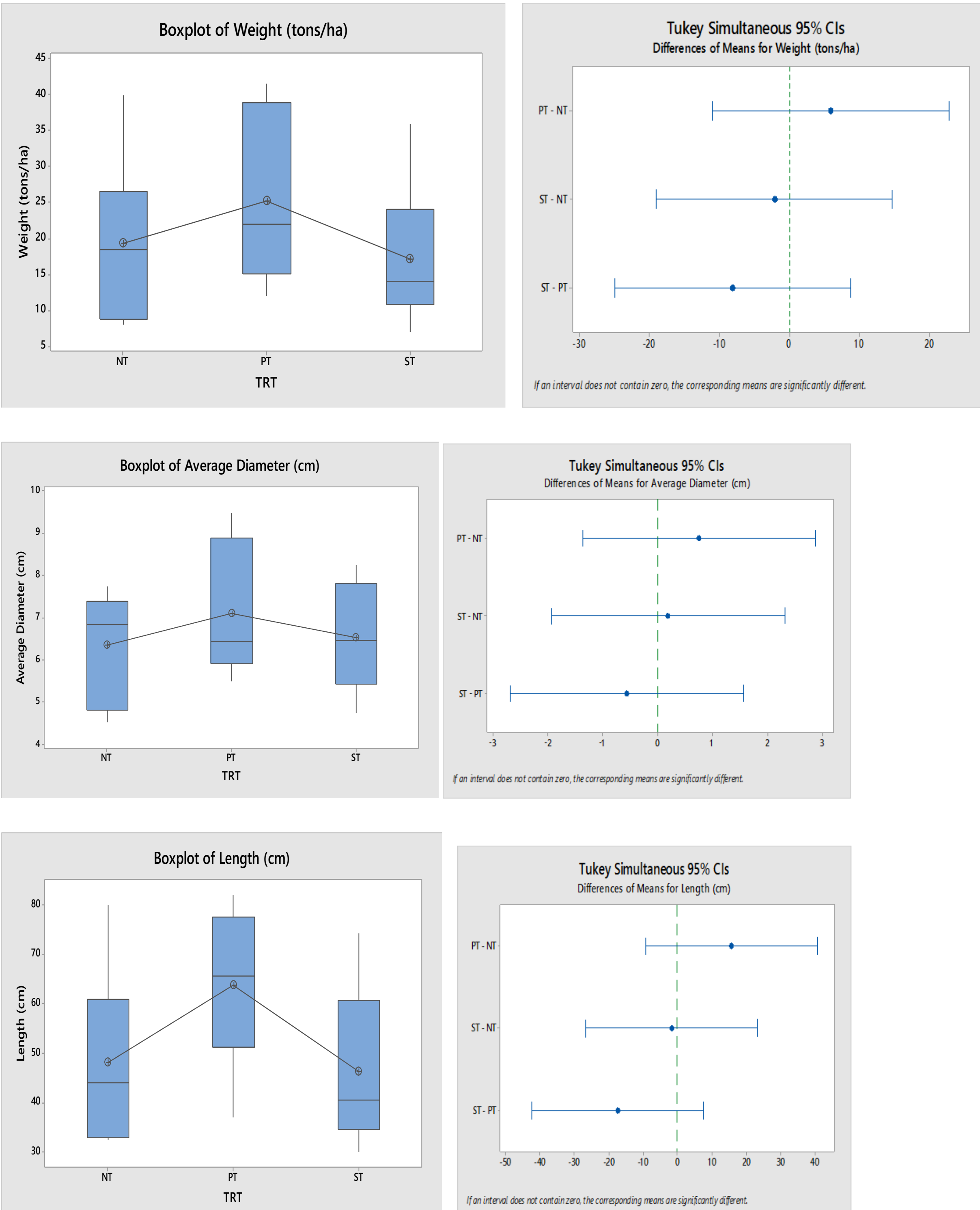
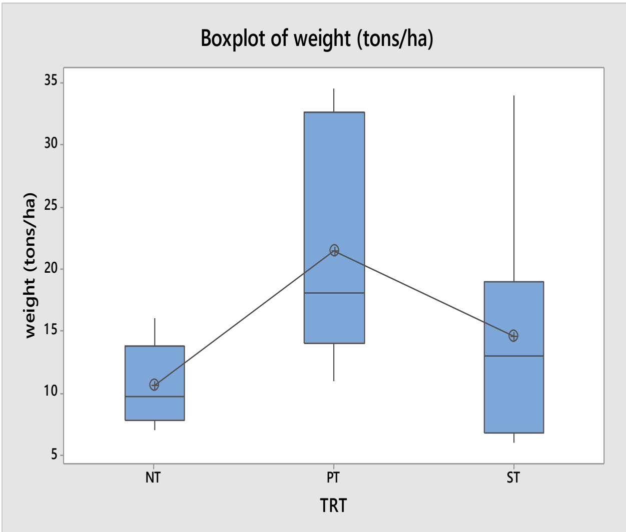


Figure 2. Weight (tons/ha), average diameter (cm) and length (cm) of the cassava yield of 2012/2013 cropping season against different tillage treatments


Boxplot of weight (tons/ha)
weight (tons/ha)
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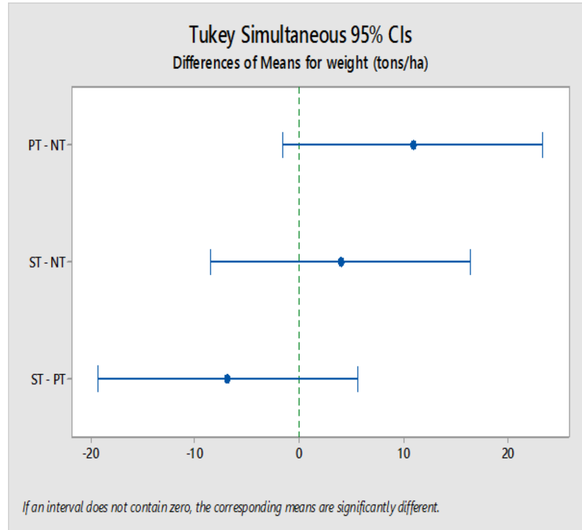
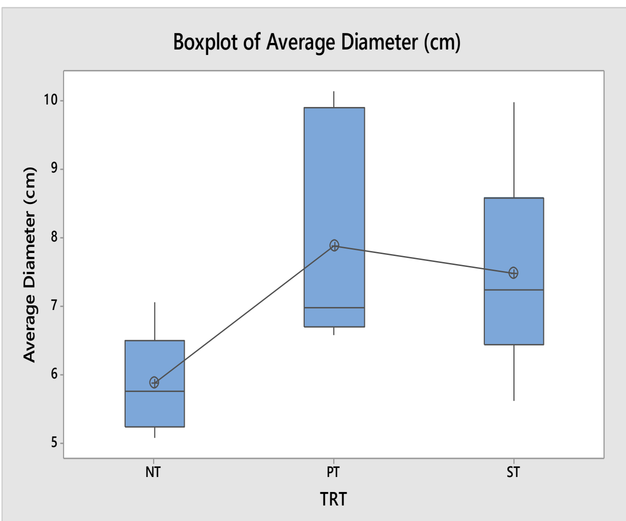
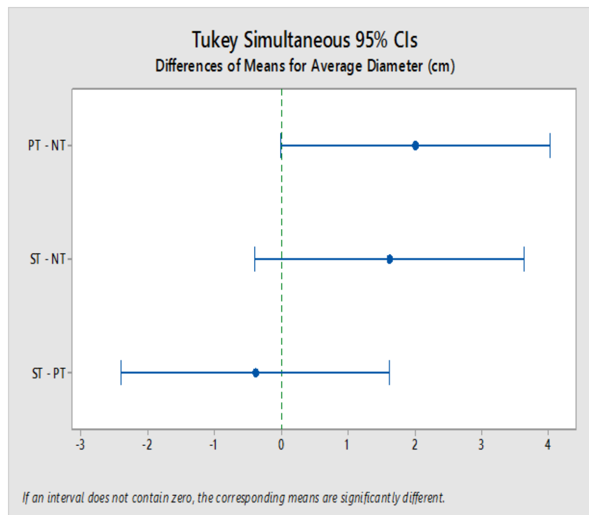
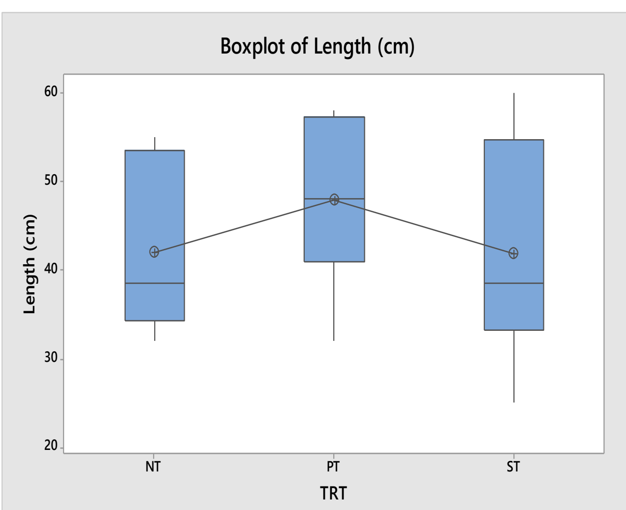
5
NT
PT
ST
TRT


Tukey Simultaneous 95% CIs
Differences of Means for weight (tons/ha)
PT - NT
ST - NT
ST - PT
-20
-10
0
10
20
If an interval does not contain zero, the corresponding means are significantly different.


Boxplot of Average Diameter (cm)
Average Diameter (cm)
10
9
8
7
6
5
NT
PT
ST
TRT


Tukey Simultaneous 95% CIs
Differences of Means for Average Diameter (cm)
PT - NT
ST - NT
ST - PT
-3
-2
-1
0
1
2
3
4
If an interval does not contain zero, the corresponding means are significantly different.


Boxplot of Length (cm)
Length (cm)
60
50
40
30
20
NT
PT
ST
TRT

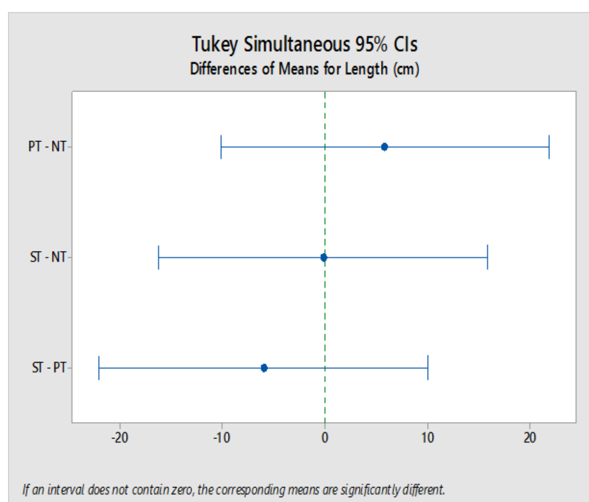

Tukey Simultaneous 95% CIs
Differences of Means for Length (cm)
PT - NT
ST - NT
ST - PT
-20
-10
0
10
20
If an interval does not contain zero, the corresponding means are significantly different.

Figure 3 Weight (tons/ha), average diameter (cm) and length (cm) of the cassava yield of 2013/2014 cropping season against different tillage treatments

Roundness of cassava during the 2012/2013 cropping season was highest in treatment plots under Primary tillage with mean value of 1.46 (±0.12) (Table 4). Treatment plots under No tillage and Secondary tillage, have roundness of cassava of 1.30(±0.12) and 1.36(±1.36), respectively. Similar trends of cassava roundness were observed during the 2013/2014 cropping season (Table 5). Highest mean roundness was recorded in treatment plot under Primary tillage with value 1.47(±0.20). Roundness was lowest in treatment plot under No tillage with mean value of 1.28 (±0.12).

The highest roundness of cassava in plots under Primary tillage may have been influenced by the soil loosening and tilt, which enhanced tuber penetration without appreciable hindrances. The lowest roundness in No tillage plots could have resulted from plant stumps and stones that remained in the superficial and subsoil layers since no tilting or turning of the soil was performed before planting operation. The roundness of cassava could be an important factor in the postharvest processing of the cassava especially the peeling operation which may be well enhanced if cassava roundness is near perfect.

Table 4. Roundness of Cassava from the different Tillage Treatment Plots during the 2012/2013 Season

Replicates	No Tillage	Secondary Tillage	Primary Tillage
1	1.51	1.45	1.29
2	1.35	1.43	1.41
3	1.26	1.34	1.61
4	1.29	1.29	1.46
5	1.23	1.31	1.60
6	1.15	1.32	1.40
Mean	1.30	1.36	1.46
Standard Dev.	±0.12	±0.07	±0.12

Table 5. Roundness of Cassava from the different Tillage Treatment Plots during the 2013/2014 Season

Replicates	No Tillage	Secondary Tillage	Primary Tillage
1	1.41	1.38	1.85
2	1.23	1.42	1.40
3	1.19	1.28	1.33
4	1.43	1.38	1.52
5	1.14	1.40	1.34
6	1.25	1.32	1.36
Mean	1.28	1.36	1.47

Standard Dev.	±0.12	±0.05	±0.20

3.3.1 Cassava yield model

Models predicting the yield function of cassava for the two cropping seasons were developed using the 5 important soil factor: OMC, N, PR, MC, and K. Minitab uses standardized X variables because standardization removes most of the correlation between linear and higher-order terms, which reduces the chance of adding these terms unnecessarily, when it builds the regression model. The final model is displayed in unstandardized (natural) units. Equation 4 and 5 predicted statistically and practically significant cassava yield. In the 2012/2013 cropping season, total nitrogen contributes the most to this model, while hydraulic conductivity and total nitrogen are higher in their coefficients and significantly contributed to the model output for the 2013/2014 cropping season.

Cassava yield model for 2012/2013 cropping season

Yield (tons/ha) = -46.01 + 17.027 OMC + 107.68 N + 0.000525 PR + 2.875 MW + 1.879 K 4

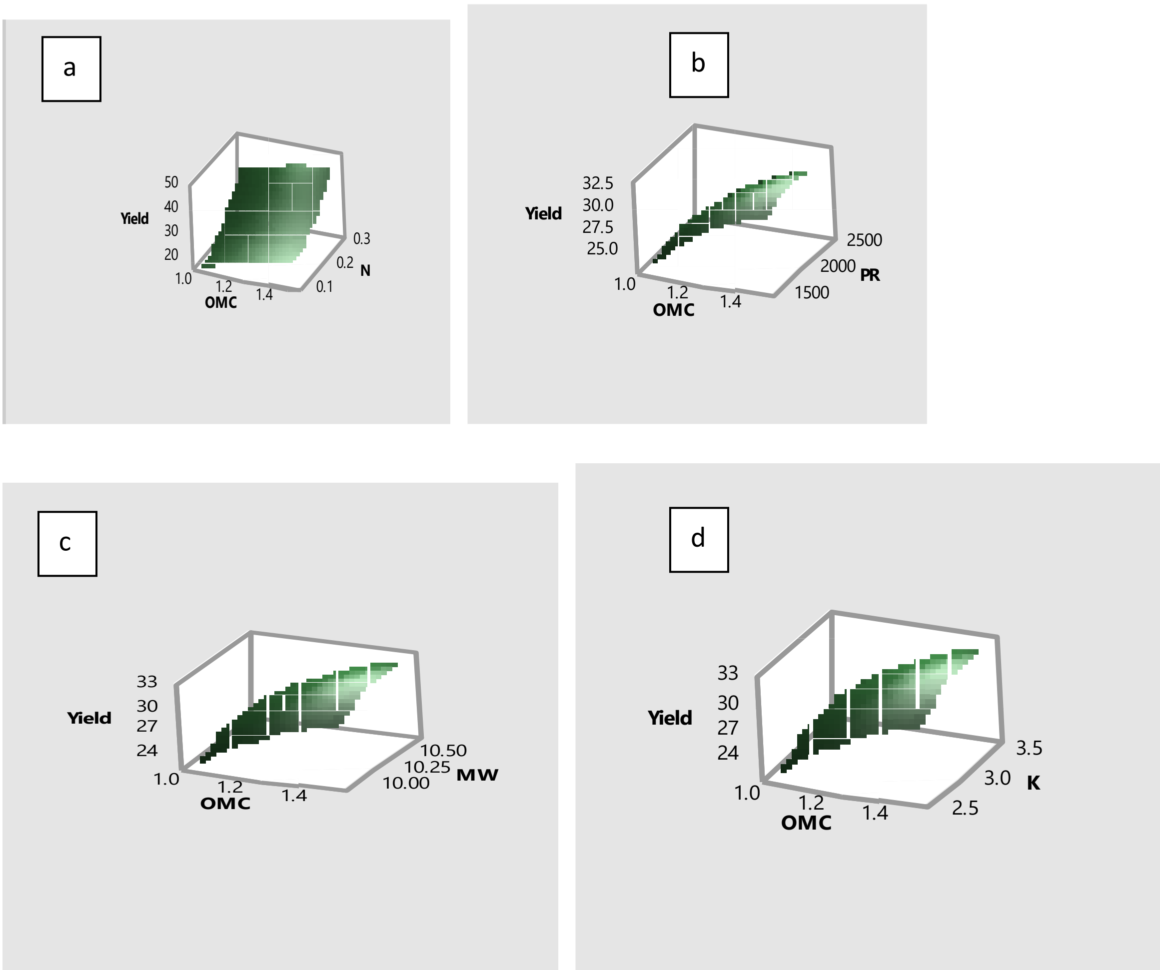
Cassava yield model for 2013/2014 cropping season

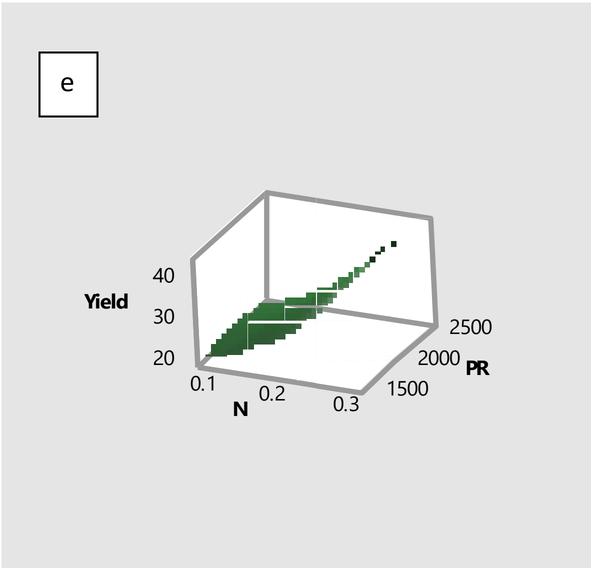
Yield (tons/ha) = 14.58 + 27.9 OMC + 331.73 N + 0.003574 PR + 4.2109 MW + 10.7822 K – 8.47 OMC^2 5

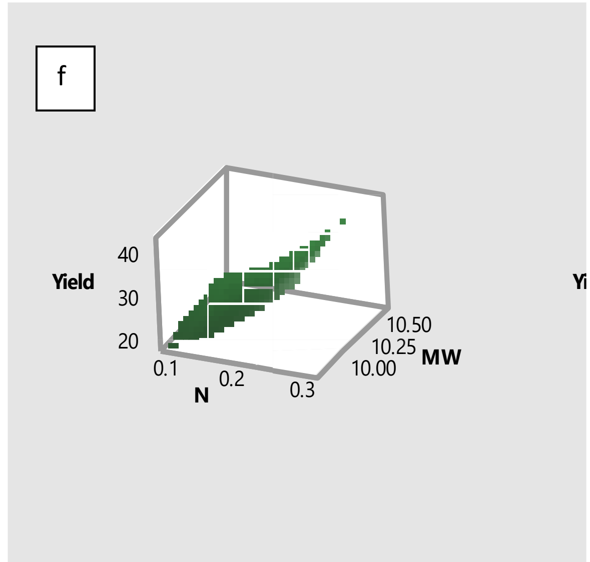
3.3.2 Cassava yield optimization

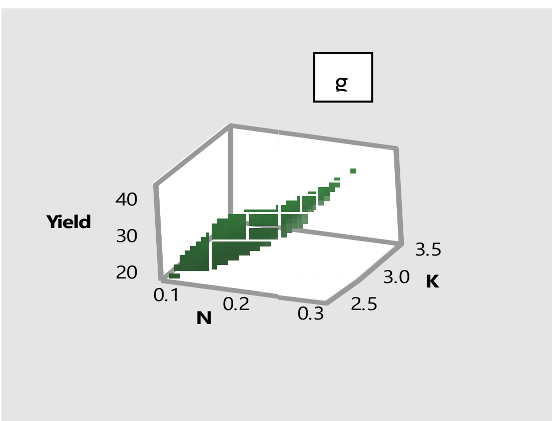
Cassava yield optimization for 2012/2013 cropping season

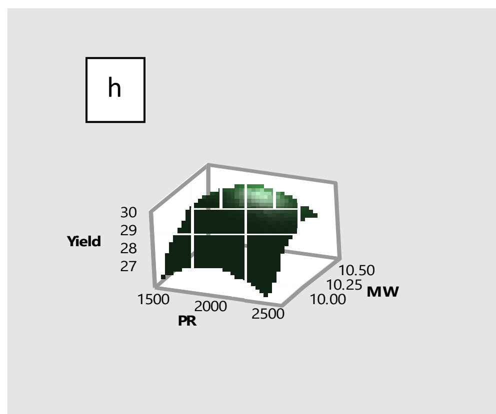
For the 2012/2013 cropping season, the optimal values of organic matter content, total nitrogen, penetration resistance, soil moisture content and hydraulic conductivity were found to be 1.49 %, 0.28 %, 1446.9 kPa, and 10.67 % and 3.53 cmh^{-1}, respectively, to achieve a maximum 46.06 tons per hectare of cassava yield. Figure 4. shows the summary report of quadratic model for yield for 2012/2013 cropping season. The summary report comprises of the Pareto chart, design information, optimal factor settings and % of variation of the yield. Based on the models for cassava yield, we can conclude there is a relationship between the factors A, B, C, D and E in the models and yield of cassava at 0.10 levels of significance for the 2012/2013 cropping seasons. The models explained 98.97 % of the variation in cassava yield for 2012/2013 cropping season. The Prediction and Optimization Report (Figure 4.) for 2012/2013 cropping season shows the solution for obtaining a targeted value of 46.06 tons per hectare of cassava yield. For the optimal settings, the models predict a yield of 46.06 tons per hectare with a prediction interval of 43.89 to 48.24 tons per hectare. Top five design points with predicted cassava yield values closest to the optimal solution is also shown for evaluation and consideration. The Effects Report (Figure 4.) graphically illustrates all of the interaction and main effects that are in the quadratic model for yield. Each soil parameter has significant effect on the yield. For instance, increase in OMC and N leads to increase in the yield of cassava. The interactions of the soil parameters have no significant effect on the yield of cassava, which indicates that the effect one variable has on cassava yield is independent of the setting of the other variable. The three dimensional response surface graphs that reveal the relation between yield and some important factors in the 2012/2013 cropping seasons were generated by Minitab software and are shown in Figure 4. The surface plot also shows quadratic effects in all the parameters interaction. That is, the response surface exhibits curvature as you change either variable while holding the other constant.




e
Yield
40
30
20
0.1
0.2
0.3
N
1500
2000
2500
PR


f
Yield
40
30
20
0.1
0.2
0.3
N
10.00
10.25
10.50
MW


g
Yield
40
30
20
0.1
0.2
0.3
N
2.5
3.0
3.5
K


h
Yield
30
29
28
27
1500
2000
2500
PR
10.00
10.25
10.50
MW

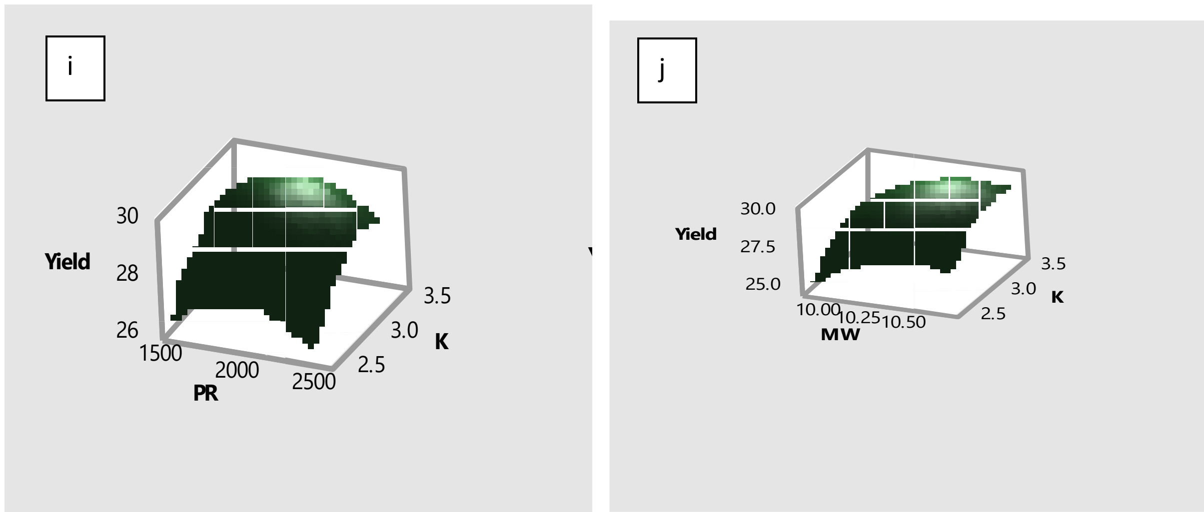
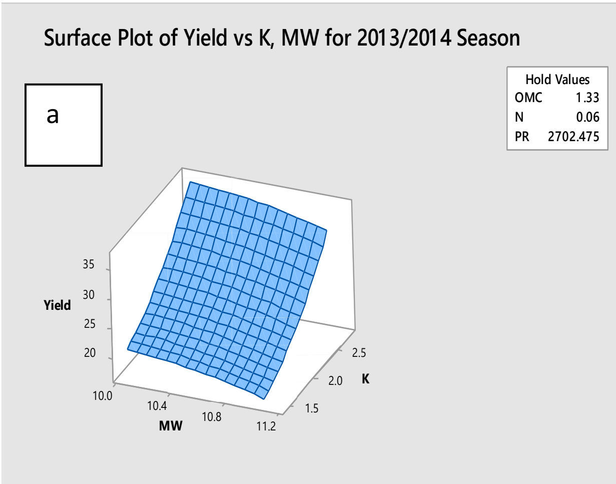
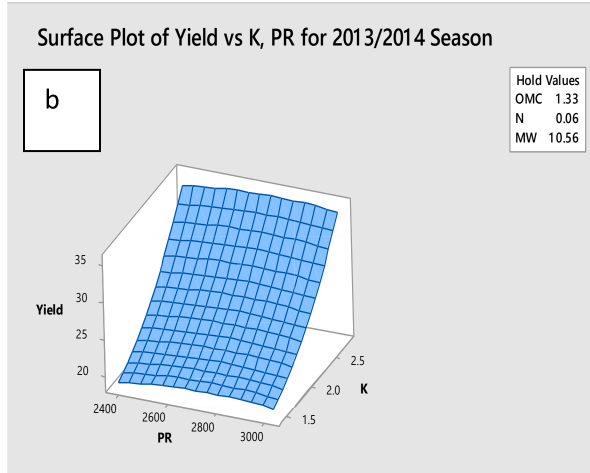


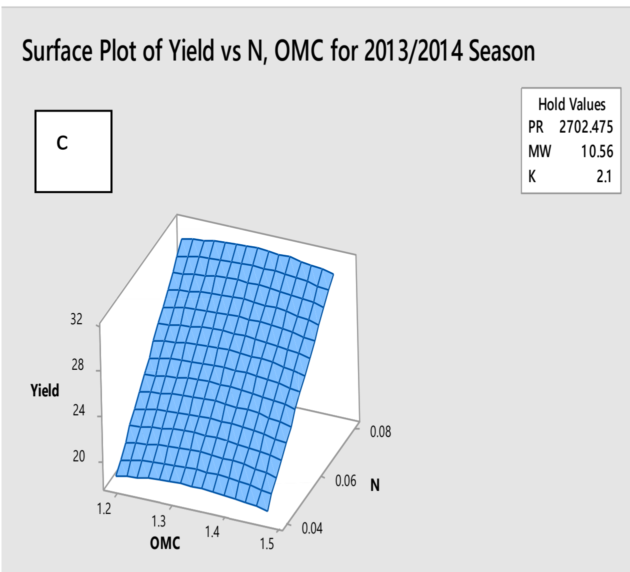
Figure 4(a – j). Cassava yield response to the interaction of soil parameters during the 2012/2013 cropping season, while other soil parameters are kept constant

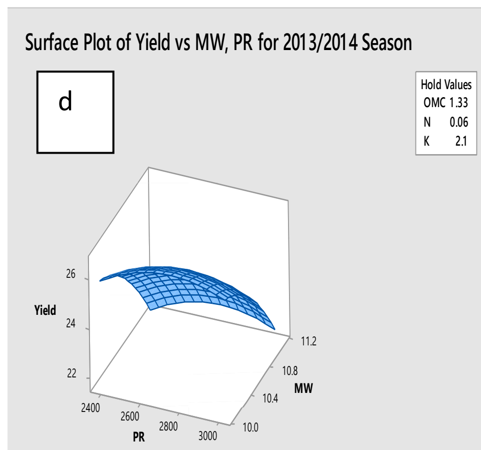
Cassava yield optimization for 2013/2014 cropping season

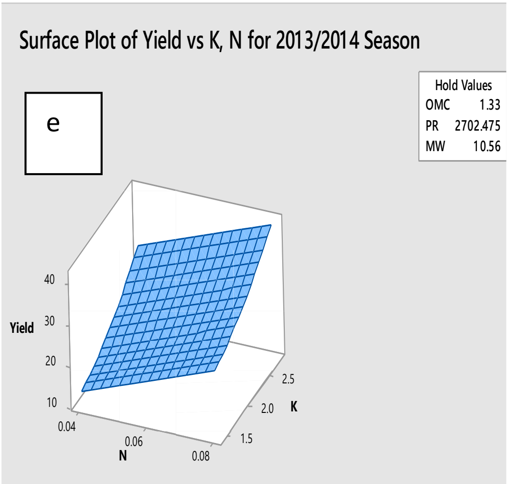
The summary report (Figure 4(a - j) of quadratic model showed the optimal factor settings that achieved a maximum cassava yield of 42.97 tons per hectare in the 2013/2014 cropping season comprises of the Pareto chart, design information, optimal factor settings and % of variation of the yield. According to the Pareto chart of standardized effects, factors A, B, C, D and E have significant (0.1 level of significance) effect on the response (Yield) and these are the factors selected in the model. The factors (OMC, N, PR, MC and K) in the model explained 98.88% variation in the yield response of Cassava. The Prediction and Optimization Report (Figure 4.45) for 2013/2014 cropping season showed that the solution for obtaining a maximum value of 42.97 tons ha^{-1} of cassava yield should have optimal settings of soil parameters as 1.47 %, 0.08 %, 2357.12 kPa, 10.06 % and 2.77 cmh^{-1} for organic matter content, total nitrogen, penetration resistance, soil moisture content and hydraulic conductivity, respectively. For the optimal settings, the models predict a yield of 42.97 tons ha^{-1} with a prediction interval of 42.32 to 43.63 tons ha^{-1}. Top five design points with predicted cassava yield values closest to the optimal solution is also shown for evaluation and consideration. The Effects Report (Figure 5) graphically illustrates all of the interaction and main effects that are in the quadratic model for yield. Each soil parameter has significant effect on the yield. The interactions of the soil parameters have no significant effect on the yield of cassava, which indicates that the effect one variable has on cassava yield does not depends on the setting of the other variable. Figure 5 shows the three-dimensional response surface graphs that reveal the relation between yield and some important factors in the 2013/2014 cropping seasons

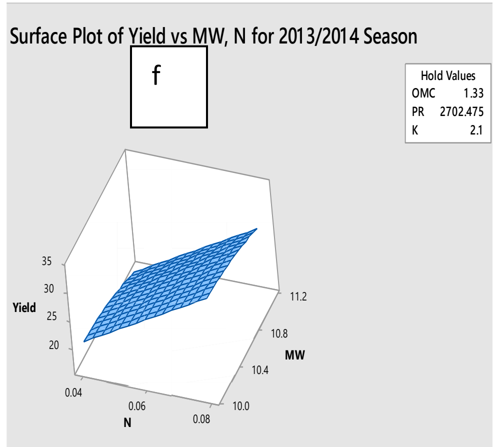

Surface Plot of Yield vs K, MW for 2013/2014 Season
a
Hold Values
OMC 1.33
N 0.06
PR 2702.475
Yield
35
30
25
20
10.0
10.4
10.8
11.2
MW
1.5
2.0
2.5
K

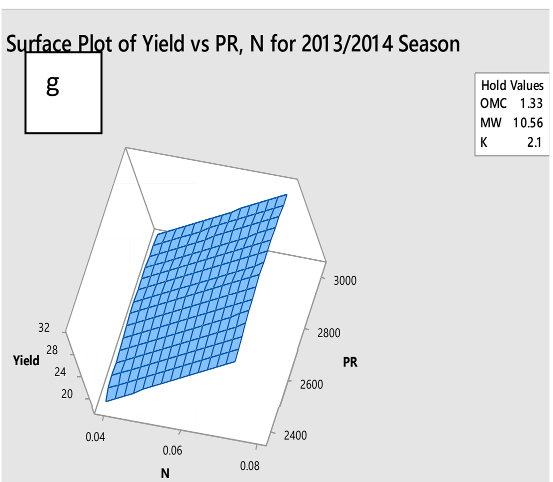

Surface Plot of Yield vs K, PR for 2013/2014 Season
b
Hold Values
OMC 1.33
N 0.06
MW 10.56
Yield
35
30
25
20
2400
2600
2800
3000
PR
1.5
2.0
2.5
K

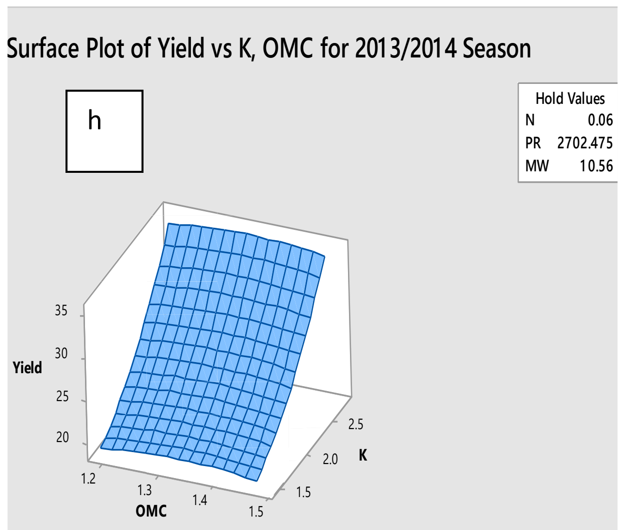

Surface Plot of Yield vs N, OMC for 2013/2014 Season
c
Hold Values
PR 2702.475
MW 10.56
K 2.1
Yield
32
28
24
20
1.2
1.3
1.4
1.5
OMC
0.04
0.06
0.08
N


Surface Plot of Yield vs MW, PR for 2013/2014 Season
d
Hold Values
OMC 1.33
N 0.06
K 2.1
Yield
26
24
22
2400
2600
2800
3000
PR
10.0
10.4
10.8
11.2
MW


Surface Plot of Yield vs K, N for 2013/2014 Season
e
Hold Values
OMC 1.33
PR 2702.475
MW 10.56
Yield
40
30
20
10
0.04
0.06
0.08
N
1.5
2.0
2.5
K


Surface Plot of Yield vs MW, N for 2013/2014 Season
f
Hold Values
OMC 1.33
PR 2702.475
K 2.1
Yield
35
30
25
20
0.04
0.06
0.08
N
10.0
10.4
10.8
11.2
MW


Surface Plot of Yield vs PR, N for 2013/2014 Season
g
Hold Values
OMC 1.33
MW 10.56
K 2.1
Yield
32
28
24
20
0.04
0.06
0.08
N
2400
2600
2800
3000
PR


Surface Plot of Yield vs K, OMC for 2013/2014 Season
h
Hold Values
N 0.06
PR 2702.475
MW 10.56
Yield
35
30
25
20
1.2
1.3
1.4
1.5
OMC
1.5
2.0
2.5
K

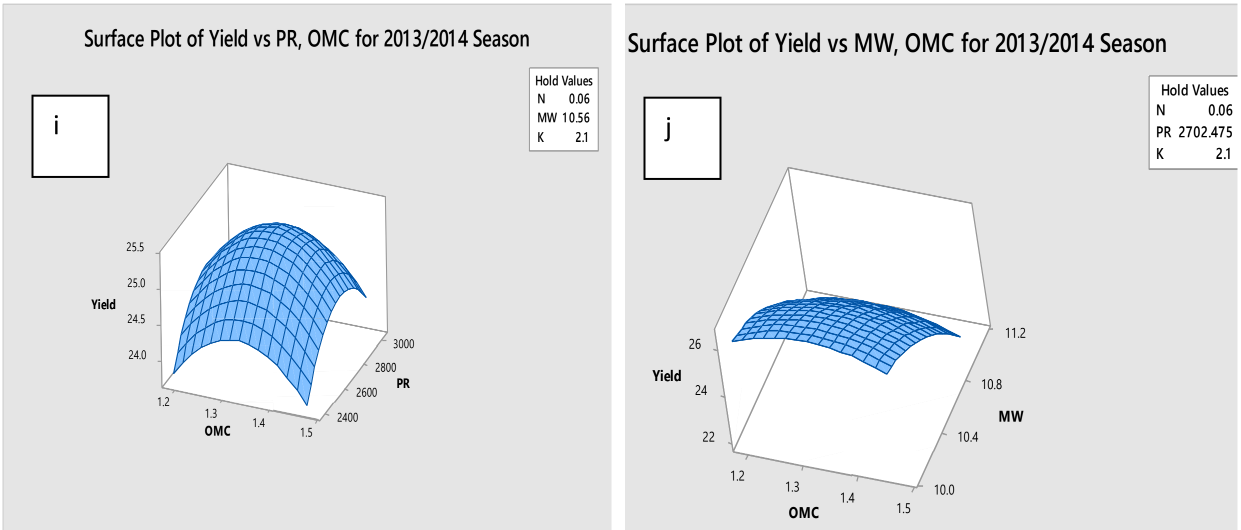


Figure 4(a – j). Cassava yield response to the interaction of soil parameters during the 2013/2014 cropping season, while other soil parameters are kept constant

CONCLUSION

Cassava yield optimization was conducted from combination basic soil parameters such as N, MC, K, OMC and K using Response Surface Methodology. The optimal values of OMC, N, PR, MW and K were found to be 1.49 %, 0.28 %, 1446.9 kPa, and 10.67 % and 3.53 cmh^{-1}, respectively, to obtain a highest yield value of 46.06 tons per hectare of cassava in 2012/2013 cropping season, while the best operating conditions to obtain highest yield value of 42.97 tons per hectare of cassava during the 2013/2014 season are 1.47 %, 0.08 %, 2357.12 kPa, 10.06 % and 2.77 cmh^{-1} for OMC, N, PR, MW and K, respectively.

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QUALITY ASSESSMENT OF RAW WASTE WATER FOR IRRIGATION: CASE OF THE INTEGRATED FARM PROJECT OF NCAM ILORIN, NIGERIA

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ABSTRACT

This study aimed at examining some physico-chemical Properties of the raw wastewater from pond of the National Centre for Agricultural Mechanization. With a view to determining its suitability for irrigation farming of vegetables crops cultivated at the Centre. Five sampling point were located at the study area, the samples were taken six week after the stocking of fish at a regular interval over a period of time. (In the month of May, June, July and August) in plastic containers of 150cl capacity after being properly washed, cleaned and sterilized. The laboratory analysis were conducted to determine the experimental physico-chemical parameters such as p^H, Alkalinity, Acidity, Electrical conductivity, TDS, Chloride, Sulphate, Sodium, Magnesium, Nitrate, Calcium, SAR and Potassium. Out of these parameters tested. Two of them constitute major cause for concern. p^H of water sample at July and August (3&4 month of sampling) as well as potassium ion concentration of water samples exceeded the irrigation guidelines at all the five sampling point. All other listed parameters are within the irrigation guidelines. Hence the need for restriction in the use of the water for irrigation. This study, therefore showed the need for wastewater to be subjected to some level of treatment especially during the dry season when the water will be required for irrigation

Keywords. Irrigation, physico-chemical, Water quality, Wastewater, NIFAP

1.0 INTRODUCTION

The demand for water has been on the increase because its uses have become more varied. Water is indispensable in Man's activities. The sources of water for usage include river, stream, lakes, ponds, rain water and groundwater such as spring water, well water, and boreholes etc. in the Northern part of Nigeria, subject to arid conditions, there has been tremendous progress in irrigation development programmes (Ahmed and Tanko,2000). Today due to the constraint in availability of the freshwater for irrigation, wastewater especially sewage water is being used for irrigation of agriculture fields (Singh et al. 2012). Specially, in arid and semi-arid regions, irrigation water shortage turns treated wastewater into an attractive source of water for irrigated agriculture (Pescod 1992). Hamilton et al. (2007) reported that globally around 20 million ha of land were irrigated with reclaimed wastewater, and amount would increase markedly during the next few decades as water stress intensifies. However, Chen et al 2015 reported in spite of poor general public's knowledge on water resources, their awareness on reclaimed water reuse was high. Moreover, some of the stakeholders had concerns about the potential risks from reclaimed wastewater reuse.

Several studies have been done to investigate the possibility of using treated wastewater for irrigation. For example, Torabian and Motallebi (2003) in addition to evaluating the wastewater quality of EKBATAN treatment plant presented the plan of wastewater reuse management. Ghasemi and Danesh (2012) studied the wastewater samples from Mashhad treatment plant and stated that according to Ayers and Westcot Guide (1985), wastewater can be used for irrigation of agricultural land. Results of Hassanli and Javan (2006) and Salehi et al. (2008) showed that the application of treated wastewater for irrigation of green and afforestation species is possible. To alleviate the problem of moisture stress during the prolonged gaps between rains as well as in dry season, supplementary irrigation is provided. This is done by lifting the water from perennial surface water bodies and or shallow wells. Although irrigation is useful for sustaining agricultural production in any locality. It is imperative that only good quality water be used. Poor quality water affect both soil quality and crop production adversely (Bello, 2001; USDA, 2001; FAO, 1994).

Generally, irrigation water must have low concentration of salts. A high concentration of dissolved salts affects the water intake of the plant. The plant may result in dehydration or wilting due to high osmotic pressure. As such, water with high concentration of salt should not be used. However, the tolerable concentration of salts in water will also depend upon type of soil. The water with salts may however be tolerable or even useful for irrigation in some types of soil. For example, heavy clayey soil with a low permeability and plenty of soluble salts will not tolerate the water with a concentration of salts but light sandy soil may tolerate such water. (Arora, 2007, Beecroft *et al* 1987, Egboka et al 1989).

The world over is tending towards organic agricultural production, recycling of wastes and zero waste concept; there is therefore the need to proffer alternatives, more especially as The world is tending towards biotechnology, organic farming and other natural concepts of solving human challenges. It is of immense importance that the wastes from the pond, meant to be used for irrigation to actualize the zero waste concepts, be properly analyzed in order to avoid danger to crops. This project will also assist farmers in no small measure to convert their wastes to wealth.

The purpose of the study is to examine some physico-chemical properties of the water samples taken from integrated farm project NCAM pond (Treatments) and hence its suitability as source of water for irrigation of vegetables crops cultivated at the center

2.0 MATERIALS AND METHOD

2.1 Site Location

The proposed research was carried out at the National Centre for Agricultural Mechanization (NCAM), Ilorin. NCAM situated on longitude 4.6122^{O} East and Latitude 8.4161^{0} North.

2.1.1. NIFAP Fish Pond and the Available Treatments

The NCAM integrated farm project (NIFAP) was established in 2014 and consist of aquaculture, poultry farming and irrigation pilot project. Effluent from the fish ponds are subjected to three treatments namely water hyacinth, charcoal and Chinese weed, before being used for irrigation.

2.2 METHODOLOGY

Two water samples were collected at five different points on the treatment line monthly; first at the pond (A), at the basement (B), i.e. before the treatment point, at the water hyacinth treatment point (C), at the Chinese weed (D) and lastly at the charcoal treatment points (E). This is to investigate variation, if any, in the quality of the water as it is conveyed from the concrete pond to the earthen pond. The water samples were collected in 150cl transparent plastic containers after being properly washed, cleaned and sterilized and subjected to standard analysis to conduct its quality for irrigation of vegetables crops at the center. The results were compared with the Established Irrigation guidelines, i.e. FAO, 1994.

3.0 RESULT AND DISCUSSIONS

The values of different physico-chemical parameters recorded from the integrated farm project NCAM, Ilorin for the period of four months are summarized below.

Fig.1 Sampling at pond

Fig. 2 sampling at basement

Fig. 3 sampling at water hyacinth

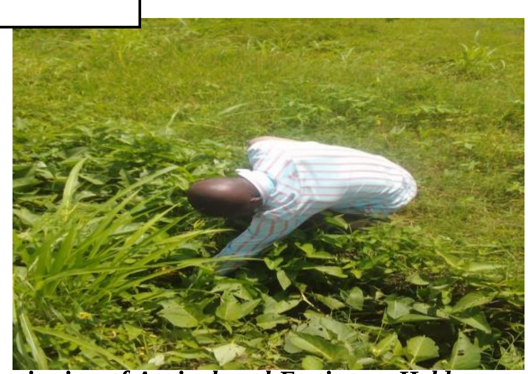

Fig. 4 Sampling at Chinese weed

Fig. 5 sampling at charcoal

SAMPLES 1

Physico-chemical parameters recorded for the month of May

Parameters	A	B	C	D	E	FAO Standard
P^H	7.23	7.19	7.06	7.06	7.13	6.0-8.5
TDS	104.67	96.33	103.67	103.67	103.45	0-2000
Electrical cond.(dS/m)	0.14	0.10	0.13	0.13	0.40	0-3
Acidity (mg/l)	2.80	3.00	3.60	3.60	3.20	0-10
Alkalinity (mg/l)	98.00	84.00	79.00	79.00	82.00	0-200
Chloride (mg/l)	0.19	0.11	0.14	0.06	0.06	0-1065
Total Hard. (mg/l)	68.00	67.70	56.00	46.22	46.22	
Mg (mg/l)	15.20	15.10	6.00	5.80	5.80	0-120
NO^-_3 (mg/l)	4.80	4.40	1.20	1.05	1.05	0-10
Na^+ (mg/l)	10.00	8.00	9.00	9.00	6.00	0-920
K^+ (mg/l)	6.00	5.00	5.00	4.00	5.00	0-2
Ca^{2+} (mg/l)	14.00	13.00	12.00	12.00	11.00	0-80
SO_4^{2-} (mg/l)	23.36	24.90	17.46	17.71	17.44	0-1920
SAR(me/l)	0.26	2.13	3.00	3.02	2.07	0-15

Note: Samples designation as stated in 2.2 above

Sources: FAO (1994) Irrigation and drainage maximum permissible limits of water Sources: [8, 11]

SAMPLES 2

Physico-chemical parameters recorded for the month of June

Parameters	A	B	C	D	E	W.H.O Standard
P^H	8.30	7.55	7.40	7.50	7.42	6.0-8.5
TDS	80.50	72.50	76.72	76.00	78.50	0-2000

Electrical cond. (dS/m)	0.12	0.09	0.10	0.10	0.11	0-3
Acidity (mg/l)	2.60	2.80	3.00	2.80	3.10	0-10
Alkalinity (mg/l)	114.00	110.00	106.00	110.00	106.00	0-200
Chloride (mg/l)	0.12	0.11	0.07	0.09	0.08	0-1065
Total Hard (mg/l)	170.0	130.00	117.60	95.78	110.90	
Mg (mg/l)	52.00	48.50	45.60	20.18	40.30	0-120
NO_3^- (mg/l)	5.00	4.60	1.05	1.06	1.15	0-10
Na^+ (mg/l)	12.00	9.00	11.00	11.00	10.00	0-920
K^+ (mg/l)	6.00	4.00	4.00	5.00	5.00	0-2
Ca^{2+} (mg/l)	16.00	15.00	15.00	15.00	15.00	0-80
SO_4^{2-} (mg/l)	4.84	4.65	2.28	2.28	3.22	0-1920
SAR (me/l)	2.06	1.59	2.00	2.63	1.90	0-15

Note: Samples designation as stated in 2.2 above
Sources: FAO (1994) Irrigation and drainage maximum permissible limits of water sources: [8, 11]

SAMPLES 3
Physico-chemical parameters recorded for the month of July

Parameter	A	B	C	D	E	FAO Standard
P^H	10.0	10.0	9.50	9.80	9.70	6.0-8.5
TDS	106	84	102	105	102	0-2000
Electrical cond. (dS/m)	0.32	0.13	0.26	0.27	0.25	0-3
Acidity (mg/l)	0	0	0	0	0	0-10
Alkalinity (mg/l)	212	202	146	195	188	0-200
Chloride (mg/l)	0.09	0.07	0.04	0.06	0.05	0-1065
Total Hard (mg/l)	100	62	25	49	22	
Mg (mg/l)	69.6	6	9	20.2	7.6	0-120
NO^{3-} (mg/l)	7.2	5.4	4.5	4.7	4.3	0-10
Na^+ (mg/l)	16	14	15	14	15	0-920
K^+ (mg/l)	8	6	8	6	6	0-2
Ca^{2+} (mg/l)	12	12	12	12	13	0-800
SO_4^{2-} (mg/l)	33.52	25.32	18.20	24.69	20.04	0-1920

SAR (me/l)	2.50	4.67	4.67	3.49	4.67	0-15

Note: Samples designation as stated in 2.2 above

Source: FAO (1994) Irrigation and drainage maximum permissible limits of water sources: [8,11]

SAMPLES 4

Physico-chemical parameters recorded for the month of August

Parameter	A	B	C	D	E	FAO Standard
P^H	9.60	9.50	9.30	9.30	9.0	6.0-8.5
TDS	156	117	147	141	146	0-2000
Electrical cond. (dS/m)	0.48	0.36	0.39	0.37	0.37	0-3
Acidity (mg/l)	0	0	0	0	0	0-10
Alkalinity(mg/l)	188	174	140	135	124	0-200
Chloride (mg/l)	0.10	0.08	0.07	0.08	0.07	0-1065
Total Hard (mg/l)	35	33	21.5	21.5	18	
Mg (mg/l)	5.4	6	9.5	4.7	3.6	0-120
NO^{3-} (mg/l)	4.9	4.2	1.5	1.32	1.25	0-10
Na^{2+} (mg/l)	20	21	21	20	20	0-920
K^+ (mg/l)	5	6	7	9	8	0-2
Ca^{2+} (mg/l)	11	12	12	12	11	0-800
SO_4^{2-} (mg/l)	11.99	9.97	7.55	7.38	8.55	0-1920
SAR (me/l)	6.99	7.00	6.42	6.94	7.41	0-15

Note: Samples designations as stated in 2.2 above

Source: FAO (1994) Irrigation and drainage maximum permissible limits of water sources: [8s, 11]

3.1 P^H & Alkalinity

The P^H value of a solution is the negative logarithm of the concentration of hydrogen ion in mole per litre. The P^H values of water sample range from 7.23-10.00 (Pond), 7.19-10.00 (Basement), 7.06-9.50 (Water hyacinth), 7.06-9.80 (Chinese weed) &7.13-9.70 (Charcoal). When compared with FAO Irrigation water guideline, the PH values are all within permissible limit for the first-two month of sampling, which indicates a slightly alkaline condition, but exceed the limit for the third-fourth month, showing a more strongly alkaline condition. Alkalinity of water samples in the study area range from 98-212mg/l (Pond), 84-202mg/l (Basement), 78-140mg/l (Water hyacinth), 79-195mg/l (Chinese weed) & 82-188mg/l (Charcoal).

3.2 Electrical conductivity EC& TDS

Electrical conductivity is the measurement of the ability of a solution to conduct electric current. It is measured in mhos/cm at 20-25^{0}C. The values obtained range from 0.12-0.48 (Pond), 0.08-0.36 (Basement), 0.10-0.39 (Water hyacinth), 0.10-0.37 (Chinese weed) & 0.11-0.37 (Charcoal) which fall within permissible limit for all treatment. Electrical conductivity correlates with the estimation of TDS. The TDS in the study area range from 80.50-156 (Pond), 70.50-117 (Basement), 70.20-147 (Water hyacinth), 69.08-141 (Chinese weed) & 70.50-146 (Charcoal). The maximum permissible limit for irrigation is 2000 which is far less than the value from samples analyzed.

3.3 Chloride

Chloride is highly soluble and free from chemical reactions with soil rock minerals, and so remains stable once they enter into solution. The values obtained from sample range from 0.09-0.19mg/l (Pond), 0.07-0.11mg/l (Basement), 0.04-0.11mg/l (Water hyacinth), 0.06-0.14 mg/l (Chinese weed) & 0.05-0.08mg/l (Charcoal) and are all within the maximum allowable range of 1065mg/l for irrigation water.

3.4 Magnesium

Magnesium is an important component of most rocks and it occurs in the form of insoluble silicates which become more soluble carbonates as they are weathered. The magnesium ion level in water (treatment) range between 5.4-69.6mg/l (Pond), 6.0-48.50mg/l (Basement), 6.0-45.60mg/l (Water hyacinth),4.7-20.20mg/l (Chinese weed) & 3.6-40.30mg/l (Charcoal) and all within the permissible allowable range of 120mg/l for irrigation water.

3.5 Nitrate

The nitrate concentration varied within the study area. The nitrate values varied from 4.8-7.2mg/l (Pond), 4.40-5.40mg/l (Basement), 1.05-4.5 (Water hyacinth), 1.06-4.7mg/l (Chinese weed), &1.05-4.30mg/l (Charcoal). The maximum was observed for pond (treatment) and the minimum for water hyacinth and charcoal. All the samples in the study area are within the FAO (1985) limit.

3.5 Sodium

Sodium is the most abundant cation in the hydrosphere by virtue of its abundance in the ocean. It is derived in rivers and streams through weathering action in the form of sodium carbonate which is soluble. The sodium ion level in the water samples (treatment) range between 10-

20mg/l (Pond), 8-21mg/l (Basement), 9-21mg/l (Water hyacinth), 9-20mg/l (Chinese weed) & 9-20mg/l (Charcoal). All the samples are within the maximum allowable range of 920mg/l for irrigation water.

3.6 Potassium

Potassium are less abundant in water because of its tendency to either absorbed or fixed in clays and are more resistant to chemical weathering than sodium minerals. The maximum irrigation water is 2.0mg/l and the value obtained from this investigation range between 5-8mg/l(Pond), 4-6mg/l (Basement), 4-8mg/l (Water hyacinth),4-9mg/l (Chinese weed) & 5-8mg/l (Charcoal). These values are grossly excessive at all sampling points. The water therefore, not suitable for irrigation purpose in its present form because it is injurious to plant and is capable of creating high osmotic pressure, promoting early wilting in plants, especially in vegetables, fruits and potatoes.

3.7 Calcium

Calcium is a major constituent of most igneous, sedimentary and metamorphic rock. The guidelines for calcium in irrigation water is 800mg/l, whereas the highest value encountered from samples is 16mg/l at sample point A (Pond) which shows that the calcium ion content of all the treatment is within acceptance level.

3.8 Sulphate

Sulphates may originate from sulphides of other metals introduced into the water. The value obtained from the samples range from 4.84-33.52mg/l (Pond), 4.64-25.32mg/l (Basement), 2.28-18.20mg/l (Water hyacinth), 2.28-24.69mg/l (Chinese weed) & 3.22-20.04 (Charcoal) while the irrigation water limit is 1920mg/l, which shows that there is no excessive sulphate concentration in the water.

4.0 CONCLUSION

Raw wastewater from integrated farm project NCAM, Ilorin Nigeria was assessed for their quality in terms of their potential for irrigation. The result shows that the P^H of water sample at July and August (3 & 4) months of sampling as well as potassium ion concentration of the water sample at all the sampling point were above the irrigation water guidelines, while other parameters are within the standard. This result showed that the wastewater (treatments) to be subjected to some level of treatment especially during the dry season when the level of dilution by rain water will be absent, and the water will be required for irrigation.

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PROBLEMS OF SOIL EROSION IN URBAN AREAS: A CASE STUDY OF AUCHI IN EDO STATE, NIGERIA

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ABSTRACT

Soil erosion has become a great ecological treat to lives, properties and particularly the washing away of agricultural soils. It has a social and psychological impact which makes it very difficult to access when extreme events occur. In order to enhance a suitable environment devoid of soil erosion menace, the study examines the factors that cause erosion, socio-economic impacts and control measures to erosion in Auchi, Etsako West Local Government Area of Edo State, Nigeria. The study involves oral interview during field visits and the use of structured questionnaires to elicit information. In carrying out the survey, Auchi was divided into five quarters for easy administration of the questionnaires to the respondents. A total number of 250 questionnaires were served, out of which 215 questionnaires were retrieved at the end of the study which indicates 86% success rate. The questionnaires were compiled and analyzed using descriptive statistics, which include frequency and percentages. The study revealed that soil erosion has a very severe impact on the socio-economic life and activities of the residents in Auchi particularly with respect to destruction of properties, farmlands, roads, displacement of peoples as well as the resultant psychological effect. Different factors were attributed to the cause of soil erosion in the study area amongst them are lack of or poorly constructed drainages, poor physical planning such as building houses and other structures contrary to urban and regional planning rules and regulations, poor handling of erosion control projects in the pasts, bad soil characteristics and topography of the town were identified. Also individual and community efforts at reducing erosion problem yielded no results as suggested measures to be adopted by government in controlling soil erosion include design and construction of drainage systems during execution of roads, continuous studying of the erodibility properties of soils in the study area, rain harvesting to reduce overland flow as well ensure storage for other purposes and award of erosion control contracts to qualified contractors for execution. In addition, areas prone to erosion should be marked as waterways or water paths where erection of buildings or other structures should not be allowed.

Keywords: *Soil, Erosion, Auchi, Study area*

1.0 INTRODUCTION

Erosion is the gradual removal of the top soil from its position to another place by agents of erosion like rain, wind, etc. The action of erosion is very destructive and causes environmental hazards by rendering land useless for crop cultivation and construction work like buildings, roads, dams, culvert, etc. Erosion occurs in all parts of the world and if left uncontrolled, it can bring about the ruin of a nation's economy (Toy *et al.,* 2002). In addition, the level of soil destruction differs in different parts of the country depending on the cause of the erosion (Onwueme and Asiabaka, 1992; Idah *et al.,* 2008; Onu, 2011).

In addition, erosion leads to loss of agricultural lands, resulting to reduction in both annual and perennial crops yield. In the tropics, for example, as long as the land remains covered with natural vegetation, the danger of erosion is minimal. But as soon as the forest is cut down for agricultural purpose, erosion can set in. In the deserts, for instance, erosion is almost a continuous process owing to lack of vegetation as the soil never has time to settle down and be bound together by rotten organic matters (Whisenant, 2008). Erosion has caused environmental problems by affecting the earth's landscape and the effect of soil erosion has been observed through the process of land degradation (El-Swaify, 1982). However, different types of environmental problems like indiscriminate dumping of refuse, flooding, etc occur in Auchi, Etsako West Local Government Area of Edo State, Nigeria as soil erosion is more pronounced and has metamorphosed into serious environmental disaster in the area. Soil erosion also appears to be one of the major environmental hazards in Auchi, manifesting itself through incidences of water and wind erosion, accumulation of dunes and exposure of lateritic iron stones on the landscapes.

Moreso, soil erosion has further posed a great problem of different dimensions and magnitude in Auchi, as the inhabitants live in perpetual fear of losing their crops, livestock, land resources, houses and even their lives to this "ugly" phenomenon called erosion. This problem is so devastating that it calls for public, private and non-governmental organizations' attention. It is now a head-line in the media and the problem of this magnitude needs qualitative and in-depth study into the origin, causes and effects of this problem on man's environment. This will also enable researchers' to be able to come up with measures that will ensure sustainability of urban environment. Although much has been invested on its control by government, communities, individuals and non-governmental organization, soil erosion is still a recurring phenomenon in the study area and it is gradual extending to areas that were not formally affected.

In order to enhance a sustainable urban area like Auchi in Edo State, Nigeria to be free from the scourge and menace of soil erosion, this study therefore examine the problems of soil erosion and their socio-economic impacts in Auchi, Edo State, Nigeria. It also investigates the different control measures that have been adopted to check soil erosion in the study area.

2.0 MATERIALS AND METHODS

2.1 Description of the Study Area

Auchi is located between latitude 6^0 70 ”00” to 7^0 18 ”00” North of the Equator and longitude 6^0 49 ”00” East of the Greenwich Meridian. Auchi is the headquarters of Etsako-West Local Government Area of Edo State, Nigeria (Figures 1 & 2). The area covers a total land area of 94,562 km^2. Auchi is underlain by sedimentary formation of the Miocene-Pleistocene age (Odemerho and Onokherhoraye, 1985). The area is found in the South Central (lower Niger sedimentary rock areas). The sedimentary rocks in the area are easily broken down by the incidence of water which results in the removal of particles of the rock. Auchi area is generally sloppy and as a result, the topography allows the easy movement of soil particles such that with little rainfall, rapid movement of materials is encouraged. Auchi area is referred to as the “Oshibujie” plain and it is surrounded by the Kuruku hills up North and Samorika hills with a height of about 672 meters above mean sea level.

Auchi has a sub-humid climate with annual rainfall which ranges between 1000mm-1500mm. It has a two distinct seasons in a year: the rainy season and the dry season. The rainy season occurs between April and October with a short break in August and the dry season lasts from November to April with cold harmattan dust in December. The annual average temperature ranges from 20^0C to 35^0C and its diurnal range of temperature is about 12.4^{o}C. Auchi soil is mainly lateritic and it is a product of tropical weathering. It is red or at times reddish brown in colour with or without concentration and is generally found below hardened ferruginous crusts or hard pan (Odemerho and Onokherhoraye, 1985). The soil also contains abundant clay particles. Since clay particles contain little air, they readily hold water which forms a tenacious, sticky mass. Since percolation of surface water is reduced to the bearest minimum by the considerable low absorptive capacity of the sandy-clay particles, the heavy rainfall in the study area on a relatively undulating sloppy terrain acts therefore as a catalyst by making the soil easily saturated and erodible.

The natural vegetation of Auchi is of guinea savannah type with traces of rainforest which is characterized by tall grasses, shrubs and trees. These trees range from locust-beans, obeche, Mahogany, Gmelina, etc (Odemerho and Onokherhoraye, 1985). The guinea savannah is gradually transiting into a secondary type and this is as a result of the activities of man such as bush burning, indiscriminate felling of trees and construction of roads amongst others. These activities have greatly affected the natural environment of the area thus leading to the removal of vegetation cover which reduces infiltration and increases run-off thereby leading to gully formation. Auchi has a population of 197, 609 and 23, 588 households with a density of 209 per square kilometer (NPC, 2006) which is unevenly distributed due to topography, cultural and socio-economic factors. Auchi is divided into five neighborhoods which naturally correspond with the socio-cultural division of the town. These are Utsogun, Akpekpe, Aibotse, Igbe and Iyehkei. The people of Auchi are generally referred to as part of the “Afemai”. In the past, Auchi was mainly an agrarian society, but attention has gradually shifted from agriculture to trade and commerce ranging from small to medium scale ventures due to the location of the administrative headquarters of Etsako West Local Government and the Federal polytechnic in the town.

2.2 Data Collection and Analysis

This study was carried out to determine causes of erosion problems in Auchi, the headquarters of Etsako-West Local Government Area of Edo State in Nigeria. In carrying out this study, an in-depth reconnaissance survey was carried out in the study area to determine the existing land uses in Auchi and to know the exact area that have been greatly affected by soil erosion (Figure 2**.** The data for this study were collected through a structured questionnaire and oral interview as well as personal observation. Observation and photographic recordings were also made during the survey. Information sought included factors attributed to the cause of soil erosion in the study area; determining the effects of soil erosion on the inhabitants, physical infrastructure and on the entire town including measures put in place on how to reduce soil erosion.

A total number of 250 questionnaires were served out of which 215 questionnaires were retrieved at the end of the study which indicates 86% success rate. Due to the large size of Auchi, stratified random sampling techniques was adopted as a method of data collection. This method involves dividing the entire study area into number of quarters after which random selection was made from each quarter (Abdulazeez *et al.,* 2002). The chosen sample method is expected to cover a reasonable sample size of the population of Auchi. Therefore, the study area was stratified into five neighborhoods' based on the original five existing quarters in the area as follows: Usotgun, Iyekhei, Akpekpe, Igbe and Aibotse. Of all the two hundred and fifty (250) questionnaires that were administered, two hundred and fifteen (215) questionnaires were retrieved at the end of the study with fifty-four (54) administered in Usogun quarter, forty-eight (48) in Iyekhei, thirty-eight (38) in Akpekpe, forty –nine (49) in Aibotse and twenty-six (26) in Igbe quarter. The questionnaires administration was also based on the population density for each quarter.

The information obtained from the completed questionnaires was compiled and analyzed using descriptive statistics, which include frequency and percentages. Although the usual survey bottlenecks of respondents' reluctance to provide information were experienced, this was considered inconsequential as there were many respondents to interview and obtain similar information. In addition, reluctant respondents in areas considered erosion prone were further persuaded with extensive explanation on the aim of the study and most especially on the part of the questionnaire requesting information on the causes of erosion and suggested measures adopted in their areas.

3.0 RESULTS AND DISCUSSION

The result of the erosion problems in the study area and the suggested measures proffered by the respondents to mitigate the problems including socio- demographic characteristics of respondents are presented in Tables 3.1 to 3.16 below:

Table 3.1: Sex of respondents

Sex	No of respondents	Percentage (%)
Male	100	54
Female	115	46
Total	215	100

As shown in Table 3.1 above, 54% represent male and 46% represent female. Therefore, male were more in number than female while responding to the questionnaires during the survey.

Table 3.2: Age of respondents

Age of respondents	No of respondents	Percentage (%)
15-25	93	43
26-35	64	30
36-45	35	16
46-55	13	6
56 and above	10	5
Total	215	100

From Table 3.2 above, 15-25 years represent 43% age of respondents; 26-35 years represent 30% age of respondents; 36-45 years represent 16% age of respondents; 46-55 years represent 6% age of respondents; and 56 and above represent 5% age of respondents. It can therefore be concluded that the age of the respondent's ranges between 15 to 56 years and above.

Table 3.3: Level of education of respondents

Level	No of respondents	Percentage (%)
No formal education	9	4
Primary(First School Leaving Certificate)	38	18
Secondary (WASC)	81	38
Diplomas, Higher Diplomas/Degrees (ND/HND/B.Sc/M.Sc)	87	40
Total	215	100

From Table 3.3 above, 4% of the respondents had no formal education, 18% of the respondents had First School Leaving Certificate, 38% of the respondents had West African School Certificate while 40% of the respondents had qualifications from higher institutions like ND, HND, B.Sc and M.Sc. It can therefore be concluded that majority of the respondents were educated while responding to the questionnaires.

Table 3.4: **How long have you been living in the area**

No of years	No of respondents	Percentage (%)
Less than one year	Nil	Nil
1-10	80	37
11-20	31	14
21-30	14	7
31 and above	90	42
Total	215	100

From Table 3.4 above, 37% of the respondents have been residing in the study area between 1 to 10 years, 14% of the respondents have been living in the area between 11 to 20 years, 7% of the respondents have been living in the area between 21 to 30years, 42% of the respondents have been living in the area between 31 years and above while none of the respondents had lived in the study area for less than one year.

Table 3.5: Occupation of the respondents

Occupation	No of respondents	Percentage (%)
Farming	82	38
Civil servants	80	37
Self employed	35	16
Others (unemployed)	18	9
Total	215	100

From Table 3.5 above, 38% of the respondents were farmers, 37% of the respondents were civil servants, 16% of the respondents were self-employed and 9% of the respondents were unemployed. It can therefore be concluded that majority of the respondents in this study area were farmers or civil servants.

Table 3.6: Has soil erosion been a problem

Response	No of respondents	Percentage (%)
Yes	190	88
No	25	12
Total	215	100

As shown in Table 3.6 above, 88% of the respondents identified erosion as a problem in the study area while 12% of the respondents identified soil erosion as a non- problem in their areas. From the above analysis, it can therefore be concluded that soil erosion is a major problem threatening the inhabitants of the study area.

Table 3.7: **Duration of the soil erosion problem**

Variables	No of respondents	Percentage (%)
10 years	54	25
10-20 years	71	33
20-30 years	30	14
30-40 years	60	28
40 and above	Nil	Nil
Total	215	100

A shown in Table 3.7 above, 25% of the respondents stated that erosion started about 10 years ago, 33% of the respondents stated that erosion started about 10 to 20 years ago, 14% of the respondents stated that erosion started about 20 to 30 years ago, 28% of the respondents stated that erosion started about 30 to 40 years ago and no respondents stated there was no incidence of erosion 40 years ago and above. It can be inferred from the analysis that soil erosion actually started about 30 to 40 years ago in Auchi.

Table 3.8: Ranking of the severity of soil erosion

Variables	No of respondents	Percentage (%)
Severe	50	23
Moderate	30	14
Very severe	92	43
Not severe	43	20
Total	215	100

From Table 3.8 above, 23% of the respondents reported severe case of erosion problem in their area, 14% of the respondents reported moderate case of erosion problem in their area, 43% of the respondents reported very severe case of erosion problem in their area while 20% of the respondents reported not severe case of erosion problem in their area. It can therefore be concluded from the analysis above that soil erosion is very severe in the study area as 43% of the respondents made this remark.

Table 3.9: Individual effort at reducing erosion problem

Variables	No of respondents	Percentage (%)
Yes	136	63
No	79	37
Total	215	100

From Table 3.9 above, 63% of the respondents have not adopted any control measures to reduce erosion while only 37% of the respondents have adopted some control measures like the use of sandbags as shown in plate 5. It can be observed from the analysis that majority of the respondents have not adopted any control measures to mitigate this problem in their areas.

Table 3.10: Community efforts at reducing erosion problem

Variables	No of respondents	Percentage (%)
Yes	113	53
No	102	47
Total	215	100

From Table 3.10 above, 53% of the respondents stated that their communities has made some effort to control soil erosion in their area while 47% of the respondents stated that their communities has not made any effort to control soil erosion in their area. It can therefore be deduced that most communities has made some form of efforts to control soil erosion in Auchi.

Table 3.11: Government efforts at reducing erosion problem

Variables	No of respondents	Percentage (%)
Yes	90	42
No	125	58
Total	215	100

From Table 3.11 above, 42% of the respondents stated that government had made no concerted effort to control soil erosion problem in their area while 42% of the respondents stated that government had made appreciable effort to control soil erosion problem in their area. From the above analysis, it can be deduced that government had made some concerted efforts to control soil erosion problem in Auchi. One of the government efforts aimed at controlling erosion in one of the study area is the design and construction of drainage systems in the affected area as shown in plate 6.

Table 3.12: **Causes of erosion in Auchi**

Variables	No of respondents	Percentage (%)
Bad soil characteristics and topography	116	54
Poor physical planning	37	17
Unskilled contractors handling erosion control projects	12	6
Poorly constructed drainages during execution of roads project	50	23
Total	215	100

From Table 3.12 above, 54% of the respondents stated that bad soil characteristics and topography of their area is a cause of erosion, 23% of the respondents stated that poorly constructed drainages during execution of road project in their area is a cause of erosion, 17% of the respondents stated that poor physical planning such as building houses and other structures contrary to urban and regional planning rules and regulations is a cause of soil erosion in their area while 6% of the respondents stated that past attempt to control erosion in the area failed due to the award of contract to unskilled contractors to control soil erosion. It can concluded that bad soil characteristics and topography; and poorly constructed drainages during execution of roads project in the study areas are major soil erosion problems in Auchi.

Table 3.13: Does soil erosion has effects on lives and properties

Variables	No of respondents	Percentage (%)
Yes	170	79
No	45	21
Total	215	100

From the Table 3.13 above, 79% of the respondents stated that soil erosion has resultant effect on lives and properties while 21% of the respondents stated that soil erosion has no effect on lives and properties. It can therefore be concluded that soil erosion has adverse effect on lives and properties from the above analysis as shown in plates 1 to 4.

Table 3.14: **Has government made any compensation to victims of soil erosion**

Variables	No of respondents	Percentage (%)
Yes	70	33
No	145	67
Total	215	100

From the Table 3.14 above, 67% of the respondents stated that no compensation has been given to victims of soil erosion problems in their area while 33% of the respondents stated government has made some compensation in form of cash gifts to victims of very severe cases of soil erosion problems in their area. It can therefore be concluded from the analysis that despite damage done to lives and properties in the study area, some form of compensation had been made to victims of soil erosion in the study area, which may not be enough to cover inhabitants that suffered under such erosion problem.

Table 3.15: Types of soil erosion prevalence in Auchi

Types of Soil Erosion	No of respondents	Percentage (%)
Splash Erosion	30	14
Sheet Erosion	20	9
Rill Erosion	49	23
Gully Erosion	116	54
Total	215	100

From the Table 3.15 above, 54 % of the respondents stated that gully erosion is more pronounced in their area, 23% of the respondents stated that rill erosion is more pronounced in their area, 14 % of the respondents stated that splash erosion is more pronounced in their area while 9% of the respondents stated that sheet erosion is more pronounced in their area. It can therefore be concluded that gully erosion is more pronounced in the study area and also has adverse effect on lives and properties from the above analysis as shown in plates 1 to 4.

Table 3.16: Suggested measures to be adopted by government in controlling soil erosion in Auchi

Measures	No of respondents	Percentage (%)
Channelization of water-ways and construction of drainages on roads sides	90	42
Planting of grasses and trees	18	8
Public enlightenement	22	10
Erection of embankment & rehabilitation of some major roads	13	7
Rain harvesting	20	9
Award of contract to qualified contractors for erosion control execution	52	24
Total	215	100

From Table 3.16 above, 42% of the respondents suggested channelization of water-ways and construction of drainages on roads sides, 8% suggested the planting of grasses and trees, 10% suggested that public enlightenment of the peoples on the devastating effects of erosion, 7% suggested erection of embankment and rehabilitation of some major roads, 9% suggested rain harvesting to reduce overland flow as well as ensure storage for other purposes and 24% suggested award of contracts to qualified contractors for erosion control execution. It can therefore be concluded that erosion control contracts should be awarded to skilled and qualified contractors for execution.

It must however be noted that from the field survey, the study area (Auchi) is seen to be in a state of deplorable condition due to the scourge of soil erosion ravaging the area particularly in areas like Inu-Umoru street and Zongo area in Usotgun quarters in Auchi. Damage ranging from the loss of lives, livestock, properties, loss of land resources, damage to roads and infrastructure, etc has been recorded as shown in plates 1 to 4. Despite the extent of damage, little compensation has been made to victims of soil erosion and majority of the population need to be enlighten well about the scourge and consequences of soil erosion, hence they build houses and other structures contrary to urban and regional planning rules and regulations. In addition, the contract to control soil erosion projects in Auchi has been awarded several times but not much had been achieved.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Soil erosion has reduced the rate of physical development in the study area, loss of lives and properties and creates land scarcity, impaired the aesthetics quality of the environment and disrupts the socio-economic life of the peoples. However, when the recommendations on control measures such as planting of grasses, use of sand fill-bags and rain harvesting are combined effectively, temporary measures will be achieved. Also, if the permanent control measures recommended are well implemented, then the identified soil erosion problems in the study area will be a mirage and this will go a long way in improving not only the environmental quality but also, it will enhance a sustainable urban-area free from the scourge and menace of soil erosion. Neglect of devastated areas could result in a further greater loss. So, the local, state and federal government as well as non-governmental organizations and international bodies concerned on environmental issues should work together to save Auchi town in Edo State, Nigeria from impending environmental doom.

4.2 Recommendations

The following recommended measures will help to control, reduce and possibly to protect the soil against erosion caused by water. Temporary measures aimed at controlling erosion in Auchi include planting of grasses, use of sand fill bags and rain harvesting. Some permanent control measures aimed at controlling erosion in Auchi include:

- ✓ Resident of the affected areas prone to erosion should vacate immediately and relocate to another area.
- ✓ Proper town planning and development should be carried on Auchi metropolis as this will help to solve erosion problems in the study area.
- ✓ The three tiers of government should construct appropriate drainages of reasonable sizes and depths in all streets in the five quarters.
- ✓ There should massive engagement of peoples in planting of trees to reduce the effects of erosion in the area.
- ✓ The need to control the degree of environmental abuse by house builders and construction firms in the area should be ensured. This can be monitored by town planning

and environmental control agencies in the area and the erosion prone areas should be zoned as protected areas.

- ✓ Design and construction of engineering erosion and control structures should be properly adopted.
- ✓ Continuous studying of the erodibility properties of soils in the study area should be carried out from time to time.

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Figure 1. Map of Edo State Showing Etsako-West

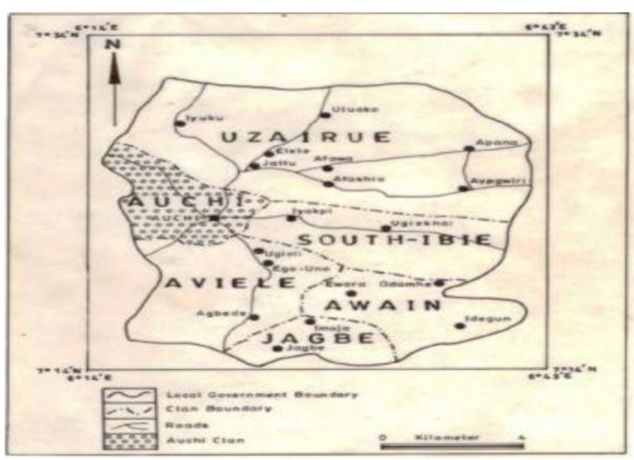

Figure 2. Map of Etsako-West Local Government Council showing Auchi

Plate 1: Shows a house affected by the gully erosion at Old Zongo area, Usogun, Auchi.

Plate 2: Shows an erosion site at chairman street Iyekhei, Auchi.

Plate 3: Picture showing a road affected by gully erosion at Aibotse.

Plate 4: Picture showing the dilapidated building at Abu Inumoru street, Aibotse.

Plate 5: Shows a site at Iyeheki, Auchi where sand bags are used to control erosion

Plate 6: Shows a drainage constructed by SETRACO Company at back of Union Bank Usogun.

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The fate of N, P and K during digestion and co-digestion of animal manures under mesophilic condition

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ABSTRACT
The study was carried out to determine the organic fertilizer quality of digested and co-digested animal manures during and after anaerobic digestion. Chicken manure (CM), cow dung (CD) and swine (SD) dung were digested separately and co-digested (1:1 w/w dry basis) in batch type digesters to compare variations in the biogas yield and nitrogen (N), phosphorus (P) and potassium (K) concentrations of the manures. The results showed that manure type had significant ($p \leq 0.05$) effect on the parameters monitored during the 84-day experiment. Among the separately digested manures, CM had highest biogas yield and K gain, while CD had least N loss and highest P gain. Among the co-digested manures, CM:SD had highest biogas yield and P gain, CD:CM had highest K gain, while there was no significant ($p > 0.05$) difference in N loss. Based on the recorded gains and losses, the study concluded that after the extraction of biogas, digested CD and co-digested CM:SD had highest N and P concentrations while CM and CD:CM had highest K concentration.

Keywords: Anaerobic digestion; Animal manures; Organic fertilizer; Plant nutrients; Biogas

1. INTRODUCTION

In anaerobic digestion both renewable energy and biofertiliser are produced. Anaerobic digestion for biogas production leads to several changes in the composition of the resulting digestates compared to the original feedstock (ammonia content, pH, carbon to nitrogen ratio, phosphorus, potassium, etc.), which are relevant for the plant availability of macro and micronutrients after field application. Nitrogen (N), phosphorus (P), and potassium (K) are transformed by the microbial processes, but these nutrients are not destroyed (Topper *et al.*, 2017). Some nutrients, like sulphur are converted into different compounds during the digestion process; in this case, hydrogen sulfide gas is produced. During anaerobic digestion, about 20 – 95% of the feedstock organic matter (OM) is degraded, depending on feedstock composition. Previous studies (Moller and Muller, 2012; Mitchell *et al.*, 2015; Risberg, 2015; Topper *et al.*, 2017) on the quality of effluent (or digestate) from anaerobia digestion have yielded contradictory results, hence further studies are needed to examine the quality especially in terms of the major plant nutrients (N, P and K). The objectives of the study were therefore to assess biogas yields from separately and co-digested animal manures and to determine the effect of anaerobic digestion on the N, P and K of animal manures.

2. MATERIALS AND METHODS

The anaerobic digestion experiment was conducted in a laboratory under mesophilic conditions (20 – 45 ^{o}C) at the Department of Agricultural and Environmental Engineering of the Obafemi Awolowo University, Nigeria. Fresh cow dung (CD), chicken manure (CM) and swine dung (SD) were collected from the University Teaching and Research Farm.

2.1. Analytical procedure

The manure samples were analysed for moisture content using the gravimetric method (oven drying at 105 ^{o}C for 24 h); volatile solids (VS) content (ashing of TS at 550 ^{o}C for 5 h); total N (regular-Kjeldahl method; Bremner, 1996); total P (after acid digestion) using ultra-violet visible
spectrophotometer (UNICAM UV1 model) of wavelength 660 nm; total K (after acid digestion) using atomic absorption spectrophotometer (Alpha 4 model);pH (using a digital pH meter). The total carbon (TC) content was estimated from the ash content according to the formula (Mercer and Rose, 1968):

$$TC\,(\%) = [100 - Ash\,(\%)]/1.8 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

2.2. Experimental set up

The batch digestion experimental set up was adapted from Ogunwande *et al.* (2015). The components were: digesters, water tanks and water collectors. The digesters were adapted using cube-shaped 25 dm^3 plastic containers. The containers were positioned to give surface area (dm^2) and height (dm) dimensions of 2.50 × 4.65 and 2.15, respectively. A drain plug was fitted at the base of each digester for collection of samples for pH analysis. Each digester had a digital thermometer probe fitted to it for temperature measurement. Similarly, the water tanks and water collectors were adapted using 10 dm^3 and 5 dm^3 rectangular plastic containers, respectively. Rubber hose was used to connect each digester to the water tank and the water tank to the water collector.

2.3. Manure preparation and anaerobic digestion

The individual manures and mixed manures (at 1:1 w/w dry basis) were set up for digestion and co-digestion, respectively. Based on the initial MC, each treatment was diluted to 8% TS with potable water, as recommended by Zennaki *et al.* (1996), agitated vigorously and screened using a 6 mm plastic mesh to remove gross solids. The digesters were loaded once during the experiment to 70% of the capacity with the substrates. The daily biogas production was measured by water displacement method. Each treatment was replicated thrice. The digesters were manually agitated twice daily to ensure intimate contact between micro-organisms and the substrates and for uniform heat distribution. The manure types were digested and co-digested for 84 days during which ambient and substrates temperatures and biogas yield were measured daily, pH was measured weekly and N, P and K were measured third, sixth and twelfth weeks.

2.4. Statistical analysis

The data collected was subjected to one-way analysis of variance (ANOVA) to determine the effect of manure type on the measured properties. Where the effect was significant at $p \leq 0.05$, Duncan's Multiple Range Test was used to separate the means. Analysis was performed using the Statistical Analysis System (SAS, 2002) software.

3. RESULTS AND DISCUSSION

The initial properties of the manures were presented in Table 1. The pH fell within the range of 6-8 considered suitable for bacteria involved in anaerobic digestion (Rynk *et al.*, 1992; Metcalf and Eddy Inc., 2003). The C: N ratio of the manures (except for CM) (Table 1) ranged within 20:1-30:1 recommended for effective biodegradation (Rynk *et al.*, 1992). The substrate temperatures during digestion ranged between 28 and 36 ^{o}C, an indication that the anaerobes that caused the decomposition operated within the mesophilic temperature range of 25-35 ^{o}C considered optimal for the support of biological-reaction rates (Tchobanoglous *et al.*, 2003).

3.1 Biogas

The results of the ANOVA showed that manure type had significant ($p \leq 0.05$) effect on the biogas yield. The cumulative biogas yield (Fig. 1) showed that from the separately digested manures, CM had the highest biogas yield while CM:SD had the highest from the co-digested manures. The highest yield from CM was in conformity with previous anaerobic digestion studies (Itodo and Awulu, 1999; Ojolo *et al.*, 2007) and was attributed to high biodigestibility of poultry manure (Odeyemi and Adewumi, 1982). The highest yield from CM:SD was attributed to the biodigestibility of the CM and a synergetic effect due to complementary characteristics of the CM and SD mixed (Comino *et al.*, 2010).

3.2 Nitrogen

The results of the ANOVA showed that manure type affected ($p \leq 0.05$) N concentration during the experiment. The average N concentrations during digestion (Table 2) showed that the separately digested manures had higher concentrations, with CM having the highest due to its low C: N ratio. On the other hand, the co-digested manures had lower and significantly the same ($p > 0.05$) concentrations. The total N concentrations in the manures decreased with digestion time in all the treatments. The major loss occurred within the first three weeks (Fig. 2) and may have been in form of the ammonia nitrogen. It has been reported that some amount of ammonia gas escapes with biogas during digestion (Topper *et al.*, 2017). The final loss in N ranged from 75.4-81.8% in separately digested manure with CM and CD having the highest and least, respectively. Similarly, from the co-digested manures, the final loss ranged from 79.5-80.9% with CD:CM and CD:SD having the highest and least, respectively. It was observed that higher N loss was associated with the CM and this may have been as a result of its low C: N ratio.

3.3 Phosphorus

Manure type had significant ($p \leq 0.05$) effect on the P concentration in the manures. CD had the highest average concentration among the separately digested manures while CM:SD had the highest among the co-digested manures (Table 2). Generally, the P concentration in the manures increased with digestion time after the temporary decrease within the first three weeks (Fig. 3). The gain in P concentration was attributed to the net loss of dry mass as a result of decrease in the OM content (Charest and Beauchamp, 2002). The final gain was higher (670.5 – 1136.7%) in the separately digested manures and lower (156.6 – 226.4%) in the co-digested manures.

3.4 Potassium

The ANOVA results revealed that manure type had significant ($p \leq 0.05$) effect on the K concentration in the manures. Unlike P, the separately digested manures had lower average concentration of K while the co-digested manures had higher and significantly the same ($p > 0.05$) concentration (Table 2). P concentration was observed to fluctuate during digestion (Fig. 4). It increased from the lowest value to the highest value within the first three weeks of digestion in all the treatments. Generally, the K concentration experienced gain in all the treatments. Similarly to P, the gain in concentration was attributed to the net loss of dry mass as a result of decrease in the OM content (Charest and Beauchamp, 2002). The final gain was higher in the co-digested manures (1817.8-2117.6%) and lower in the separately digested manures (1303.5-1497.4%).

4. CONCLUSIONS

The study showed the variation and status of major plant nutrients, N, P and K, in the manures during digestion and co-digestion. Among the separately digested manures, CM had highest biogas yield and K gain while CD had least N loss and highest P gain. Among the co-digested manures, CM:SD had highest biogas yield and P gain, CD:CM had highest K gain while there was no significant ($p > 0.05$) difference in N loss. Based on the gain/loss experienced, the study concluded that after the extraction of biogas, digested CD and CM:SD had highest N and P concentrations while CM and CD:CM had highest K concentration.

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Table 1. The initial concentration of the manure.

Parameter	Manure type					
	CD	CM	SD	CD:CM	CD:SD	CM:SD
Moisture content* (%)	79.9	80.5	63.9	80.2	74.0	74.4
VS (%)	95.7	61.1	92.1	78.6	93.9	76.9
Total C (%)	53.2	33.9	51.2	43.7	52.1	42.7
Total N (%)	1.81	2.23	1.88	2.01	1.85	2.05
Total P (mg L^{-1})	27.5	19.5	22	25.1	21.8	25.1
Total K (mg L^{-1})	32.5	46.5	25.5	34.5	38.6	35.8
C:N ratio	29.4	15.3	27.2	21.7	28.2	20.8
pH	7.42	7.01	6.80	7.28	7.11	7.47

* Moisture content was measured on wet weight basis.

Table 2. Duncan's multiple range tests showing the effects of manure composition on measured parameters.

Manure type	Properties			
	Biogas	N (%)	P (mg L^{-1})	K (mg L^{-1})

	(cm^3 kg^{-1} VS fed day^{-1})			
CD	135.8^{b}	0.749^{b}	115^{a}	446.1^{b}
CM	159.6^{a}	0.821^{a}	66.4^{b}	704.9^{a}
SD	142.9^{b}	0.689^{c}	69.2^{b}	345.3^{b}
CD:CM	62.52^{c}	0.323^{d}	33.9^{d}	860.8^{a}
CD:SD	65.93^{c}	0.335^{d}	44.7^{d}	728.9^{a}
CM:SD	152.0^{a}	0.320^{d}	51.7^{c}	765.4^{a}

Superscripts with the same letter are not significantly different at $p \leq 0.05$.

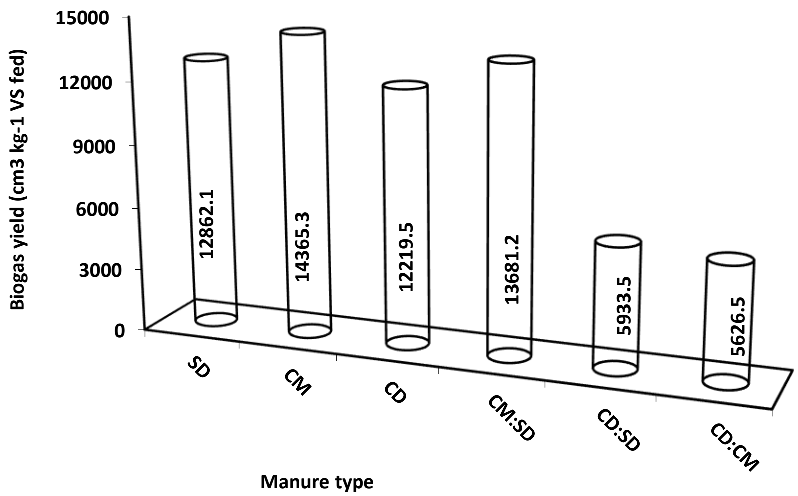
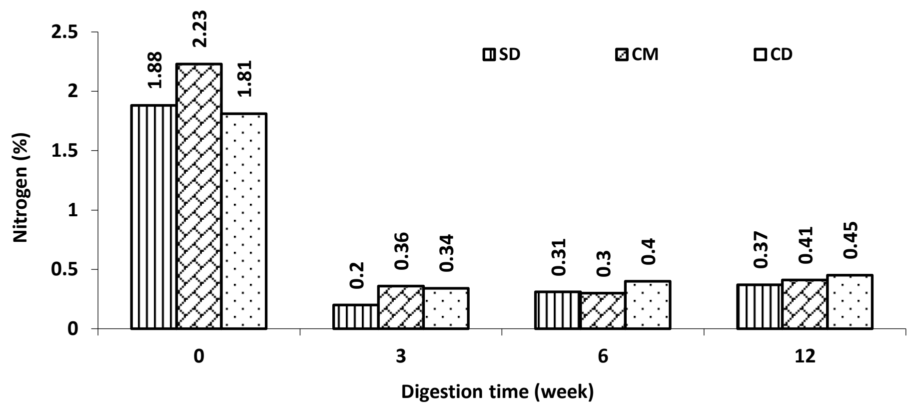


Fig. 1. Cumulative biogas yield during digestion and co-digestion of animal manures.

a)



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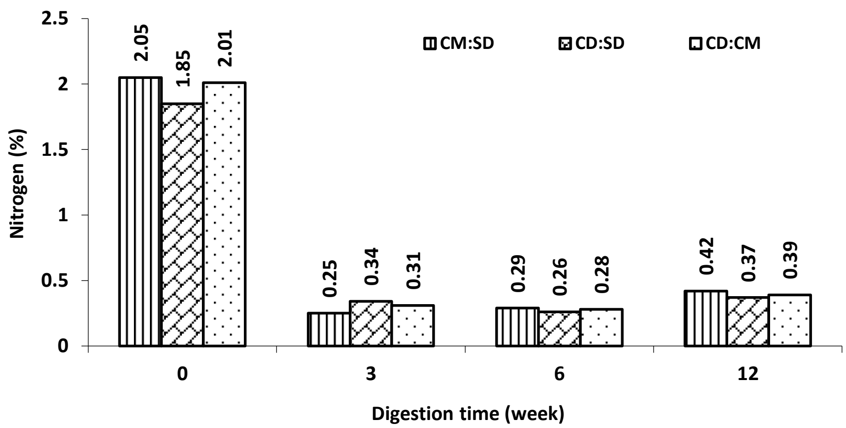
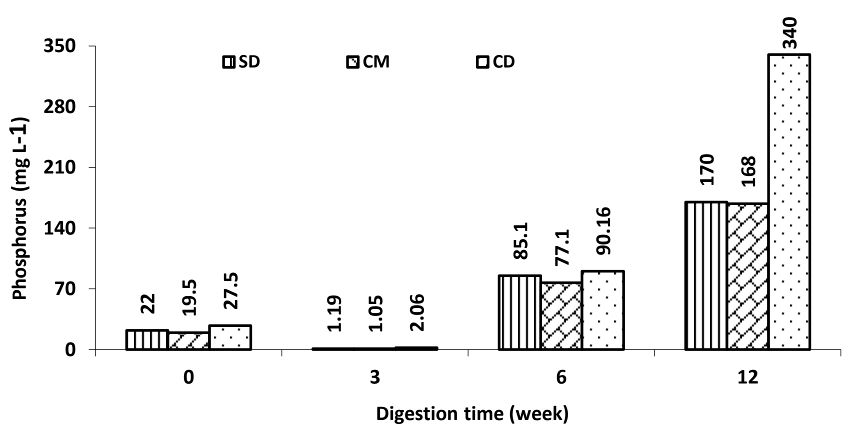


Fig. 2. Changes in nitrogen concentration during: a) digestion and b) co-digestion of animal manures.

a)



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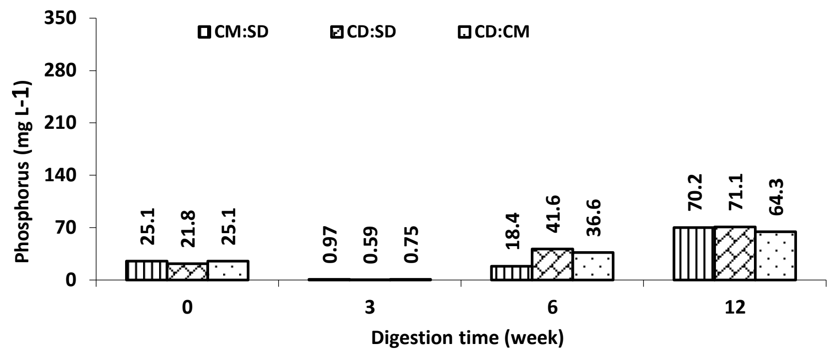
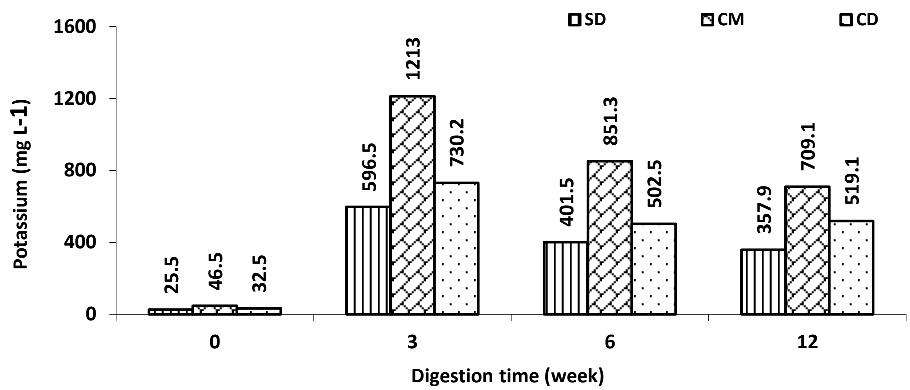


Fig. 3. Changes in phosphorus concentration during: a) digestion and b) co-digestion of animal manures.

a)



b)

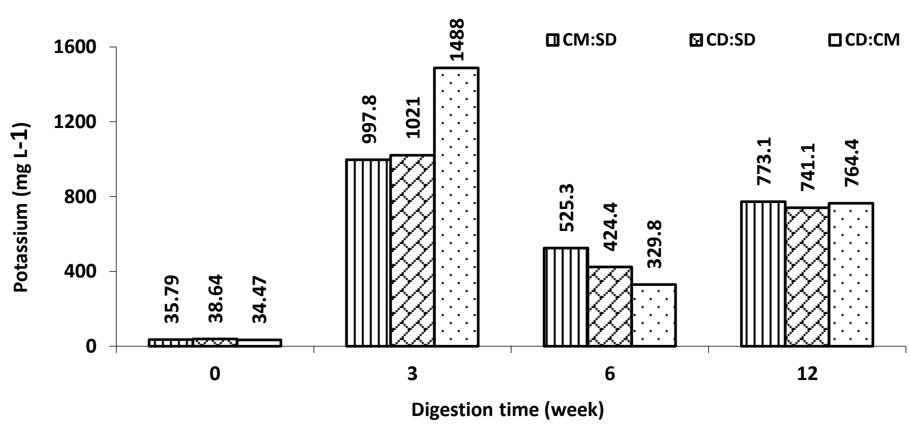


Fig. 4. Changes in potassium concentration during: a) digestion and b) co-digestion of animal manures.

VALIDATING WATER PRODUCTIVITY AND ECONOMICS OF CASSAVA PROPAGATION IN IBADAN, SOUTH WESTERN NIGERIA

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ABSTRACT

Cassava, a typical tropical plant is one of the most important staple foods in developing countries. In the tropics, cassava water requirement is majorly met through rainfall. The response of yields to effective rainfall used by cassava in Ibadan, was investigated in this study. A twenty-year daily rainfall weather data for Ibadan was obtained from NIMET (Nigeria Meteorological Agency) spanning 1994 to 2013 and was processed using CROPWAT 8.0 model through the fixed percentage (80%) method, the model was used to run the 20 years daily rainfall data while the cassava field yield data was obtained from FAOSTAT website for the same period.

Results of the annual water productivity values showed that there was a very low water productivity of 0.9kg/m^3 in 2012 while 2013 recorded the highest water productivity of 2.2 kg/m^3. Variations in yield and effective rainfall for the years under consideration are not linearly related. The trend of the yield against effective rainfall was used to determine the alternative cost of water, if crop production was strictly through irrigation. Supplying 7,000 litres of water to any farthest location would cost ₦12,000 per hectare. The maximum and minimum cost of water used was recorded in 2010 and 2001 with price ₦17,775,894 and ₦9,903,492 respectively. This shows that, if cassava production was solely dependent on irrigation, then ₦17,775,894 would have be spent to produce 12,215 kg/ha in year 2010. There is need to ensure these costs of withdrawal, transportation and application are valued along with the main cost of cassava to reflect the virtual water concept.

***Keywords**: Water productivity, Cassava (Manihot esculenta), Effective rainfall, Cropwat 8.0 model, Rainfall data.*

1. INTRODUCTION

Cassava (*Manihot esculenta)* is a major staple food in the developing world, providing a basic diet for over half a billion people. Once regarded as the food of the poor, cassava now brands itself as a crop that is responding to trends in global economy and challenges of climate change (FAO, 2013). Cassava is the third largest source of food carbohydrates in the tropics, after rice and maize, (FAO, 1995) and is an important source of food in the tropics. Cassava is a major source of starch and is second only to maize (FAO, 2013) and global harvest of cassava in 2012 was about 280 million, showing about 60 percent increase since 2000. Africa produces about 62 per cent of the total world cassava production and Nigeria is the world largest producer of the crop, producing about 54 million tonnes in 2013 (Oni, 2016; FAOSTAT, 2015). Reasons for the increasing demand for cassava is not far fetch. Apart from being in high demand for food manufacturing industries, some renewable energy industries demand cassava in high quantities for bio-ethanol production. Some countries cultivate cassava for its leaves which contain about 25 percent of protein (FAO, 2013).

Water is essential in the cultivation of cassava. In the tropics where cassava is mostly grown, rain is the primary source of water used in its cultivation. Cassava is known for its resistance to extreme climatic conditions. It can tolerate drought and grow in low-nutrient soil (Odubanjo et al., 2011). Even though cassava can withstand drought conditions, there has been concerns about the effect such condition has on its yield. Cassava can grow in areas that receive just 400mm of average annual rainfall (FAO, 2013). Water availability therefore affects the yield of cassava. The first three months after planting cassava is very sensitive to soil water deficit and water stress at any time during this period will reduce the growth of roots and shoots significantly (GreenWater, 2014; FAO, 2013). In most parts of the world, cassava is almost exclusively a rainfed crop. More peculiarity is given to developing countries that seldomly invest in irrigation to supplement rainfall in cassava production.

Virtual water is a concept introduced by Allan in 1993 to explain the essentiality of water in the value of a crop. It entails the total amount of water involved in the production of any agricultural commodity from start to finish (Hoekstra, 2003; Lillywhite, 2010). There are basically three classifications of virtual water; Blue water (regarded as water contained in surface and subsurface water bodies, Green water (rainfall), and Grey water (wastewater). Siebert and Döll (2010) reported that between 1998 and 2002, the world total crop water use was 6685 km^3/yr, where green water use of rainfed crops was 4586 km^3/yr. Only 1180 km^3/yr was reported for blue water use between this period. Blue water use as percentage of total crop water use was highest for date palms (85%), cotton (39%), citrus fruits (33%), rice (33%) and sugar beets (32%), while for cassava, oil palm and cocoa, almost no blue water was used (Siebert and Döll, 2010). This affirms that cassava is almost solely dependent on rainfall. The concept of virtual water crop production is usually disregarded as most farmers places less emphasis on the cost of water used during cultivation. In Africa where most of the water used for crop production is through rainfed, costs of water used in cultivation are rarely discussed. Economics of water contributes towards improved allocations of water resources alongside the full social benefits of the goods and services that water provides. Even though rain is freely given by nature, there is need to quantify its contribution to crop water use and its relevance to the virtual water concept. The study was therefore designed to examine the relationship between effective rainfall and cassava yield in Ibadan within a 20-year period. Also, the cost of alternative water source for cassava cultivation was considered.

2. MATERIALS AND METHODS

The study was carried out in Ibadan, southwestern Nigeria and located approximately on latitude 7°23’ to 7°55’ North of the Equator and longitude 3°5’ to 4°36’ East of the Greenwich

Meridian (Oladele and Oladimeji, 2011). Average length of dry season for Ibadan is about 121-151 days (October to March) during which little or no precipitation occurs. Mean daily air temperatures (minimum and maximum) range between 23.6°C and 33.2°C. Wind speed ranges from 50.3 km/day in December to 735 km/day in April, with a north eastern to south western wind direction dominating from November through April. Soil is a medium loam, on deeply weathered Pre-Cambrian Basement Complex rocks but overlain by Aeolian drift of varying thickness (Ogunwole, 2000).

2.1 Climatic Data

The climatic data of Ibadan were obtained over a 20-year period (1994-2013) from Nigerian Meteorological Agency (NIMET) and was imputed into CROPWAT8.0 for windows.

2.2 Cassava Yield Data:

The cassava yield data for 20 years (1994-2013) was obtained from Food and Agriculture Organization Statistics (FAOSTAT, 2015) and calculated per hectare on annual basis.

2.3 Determination of Reference Crop Evapotranspiration (ET_O)

Water needs of other crops are directly linked to this climate parameter (Mohammed, 2009). To calculate ET_o, the respective climate data was collected from the nearest and the most representative meteorological stations. Although several methods exist to determine $ET_{o,}$ the Penman-Monteith Method has been recommended as the appropriate (Allen *et al*., 1998; FAO, 1998; Siebert and Döll, 2010; Ewemoje and Okalawon, 2011).

$$ETo = \frac{0.408\Delta\,(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1+0.34u_2)} \quad (1)$$

where: ET_O = Reference evapotranspiration (mm day^{-1})
R_n = Net radiation at the crop surface (MJ m^{-2} day^{-1})
G = Soil heat flux density (MJ m^{-2} day^{-1})
T = Mean daily air temperature at 2 m height (°C)
μ2 = Wind speed at 2 m height (ms^{-1})
e_s = Saturation vapour pressure (kPa)
e_a = Actual vapour pressure (kPa)
Δ = Slope vapour pressure curve (kPa $^oC^{-1}$)
The United States Department of Agriculture Soil Conservation Service (USDA-SCS) method was used in determining effective rainfall on monthly basis which accumulated to annual effective rainfall. The method is implemented in models for planning and management of irrigation as the CROPWAT model where the USDA-SCS method is the default method for calculation of effective rainfall among other four methods (Marica, 2013).

2.4 Determination of Cassava Crop Water Productivity

Water Productivity (WP) is more directly linked to overall ambitions in water-scarce or water-costly situations than in systems which are supplied with plentiful, low value water. WP is most meaningful as an indicator as water resources become increasingly scarce. Assessment may be required for the whole system or parts of it, defined in time and space with the formula below,

$$WP = \frac{yield}{Volume\ of\ water\ used} \quad (2)$$

The annual agricultural yield or benefit of cassava was obtained from the FAOSTAT for the period of twenty years (1994-2013) on yearly basis and the rainfall data obtained from NIMET was processed to determine the amount of water required by the plant during the period under consideration. With the equation 2, the annual water productivity was calculated for the specified period. From the water productivity calculated, it was easy to predict the amount of water that would be needed in the cassava production annually.

2.5 Cost of Water Applied

In this study, the cost of the quantity of water used was determined by considering the cost of water supply by the water tankers from the Oyo State Water Corporation, Eleyele, Ibadan. The price for which the water is delivered depended on the distance travelled for delivery. Therefore, for the farthest location supply of 7,000 litres of water, the corporation charge ₦12,000. On this basis, the quantity and a possible cost of water used annually from 1994 to 2013 was calculated. It was assumed that the water equivalent of the amount of effective rainfall used in cassava production was supplied by the local water vendors in Ibadan.

3. RESULTS AND DISCUSSION

Table 1 shows the rainfall pattern based on the planting and harvesting dates of cassava for the period of 20 years. From the rainfall pattern it was observed that Cassava growth to maturity took approximately 9 months. The highest total rainfall (1485.4mm) was recorded in 2010. This was expected as 2010 through 2012 were regarded as wet years (Ewemoje and Eyeowa 2014).

Figures 1a and 1b show the effective rainfall and cassava yield for the years under consideration. The minimum value for effective rainfall (577.8 mm) was observed in the 2001 with cassava yield of 9,601.20 Kg/ha. However, the minimum effective rainfall did not translate to the minimum cassava yield. The maximum value for cassava yield (13,947.40 Kg/ha) was observed in 2013 with a corresponding effective rainfall value of 644.8 mm. Planting early in the rainy season will generally produce the highest yields as shown in Table 2. All the cassava planted early in the month of march in the 1995, 2010, 2011 and 2013 had a better yield compared to others except in some few occasions and this may be due to plants having adequate soil moisture during the most critical part of their growth cycle.

Table 1: Rainfall Pattern during Cassava Cultivation Period

TOTAL YEAR RAINFALL		MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
1994	-	88.9	301.2	63.6	164.0	67.0	211.5	246.6	19.5	0.0	-	
	1,162.3											
1995	127.8	81.3	146.7	129.9	220.7	260.1	139.3	213.1	20.2	-		-
	1,339.1											
1996	-	122.1		188.3	231.4	116.9	161.4	226.5	84.9	0.0	0.4	-
	1,131.9											
1997	-	141.9		104.7	154.1	63.6	98.8	151.7	170.5	1.6	9.0	-
895.9												
1998	-	126.9		198.5	259.5	114.2	177.3	80.3	263.4	0.0	0.0	-
	1,220.1											
1999	-	-	189.8	226.9	230.3	162.7	149.5	154.9	24.4	0.0	19.0	
	1,157.5											
2000	-	-	112.6	104.0	149.8	183.6	241.0	144.2	19.6	0.0	18.8	973.6
2001	-	-	145.9	194.2	93.5	52.1	229.1	63.0	1.9	0.2	1.0	780.9
2002	-	79.4		116.6	189.3	180.3	168.9	62.6	254.4	74.1	0.0	-
	1,125.6											
2003	-	101.0	129.4	203.7	205.7	107.6	283.8	153.8	39.9	0.0	-	
	1,224.9											
2004	-	55.0	181.4	223.6	100.6	136.5	142.0	228.5	0.7	0.0	-	
	1,068.3											
2005	-	123.0	111.1	165.2	152.4	92.5	352.7	160.6	3.7	0.0	-	
	1,161.2											
2006	-	67.1	107.6	167.1	98.8	104.9	148.8	188.0	256.1		4.9	-
	1,143.3											
2007	-	65.9	176.6	229.4	133.3	356.6	178.4	168.8	71.5	10.8	-	
	1,391.3											
2008	-	98.7	64.9	204.3	283.5	161.9	199.7	92.9	0.0	24.7	-	
	1,130.6											
2009	-	104.4	130.8	146.7	229.4	74.3	111.5	117.8	2.1	0.0	-	917.0
2010	131.6	70.8	204.4	167.4	107.1	205.7	256.5	240.5	101.4		-	-
	1,485.4											

2011	38.6	36.2	68.6	143.3	140.5	308.1	244.6	163.6	0.6	-	-	1,144.1
2012	38.4	214.6	221.1	145.5	87.7	104.4	190.3	182.5	15.7	-	-	1,200.2
2013	37.3	67.2	105.2	124.5	126.4	10.6	128.5	163.7	29.8	-	-	793.2

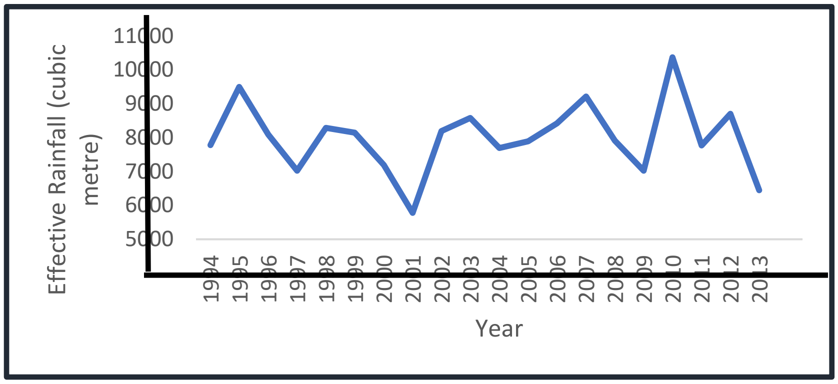

Fig 1a: Effective rainfall for the years under consideration

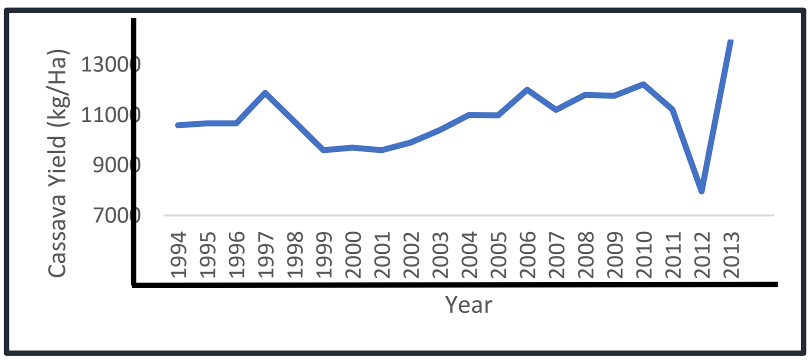

Fig 1b: Cassava yield for the years under consideration

3.1 Water Productivity

Table 2: Water Productivity Table between 1994-2013 (20 Years)

Year	Planting Date	Harvesting Date	Total Rainfall (mm)	Effective Rainfall (mm)	Cassava Yield (Kg/Ha)	Effective Rainfall (mm^3/Ha)	Effective Rainfall (m^3)	Water Prod. (Kg/m^3)
1994	April 20th	Dec. 23rd	1162.3	777.4	10592.8	7774000	7774	1.362593
1995	Mar. 15th	Nov. 17th	1339.1	949.6	10667.1	9496000	9496	1.123326
1996	April 20th	Dec. 22nd	1131.9	808.5	10664.6	8085000	8085	1.31906

1997	April 5th	Dec. 10th	895.9	702.6	11881.8	7026000	7026	1.691119
1998	April 15th	Dec. 20th	1220.1	829.2	10746.1	8292000	8292	1.29596
1999	May 5th	Jan. 10th	1157.5	814.6	9599.8	8146000	8146	1.178468
2000	May 10th	Jan. 17th	973.6	718.8	9700	7188000	7188	1.349471
2001	May 9th	Jan. 10th	780.9	577.8	9601.2	5778000	5778	1.661682
2002	April 25th	Dec. 27th	1125.6	819.8	9901.3	8198000	8198	1.20777
2003	April 15th	Dec. 20th	1224.9	858.4	10402.3	8584000	8584	1.211824
2004	April 22th	Dec. 28th	1068.3	769	11001.1	7690000	7690	1.430572
2005	April 16th	Dec. 21th	1161.2	789	10990.2	7890000	7890	1.392928
2006	April 18th	Dec. 27th	1143.3	842.2	12000.3	8422000	8422	1.424875
2007	April 16th	Dec. 17th	1391.3	921	11202.6	9210000	9210	1.216352
2008	April 15th	Dec. 20th	1130.6	790.8	11800.4	7908000	7908	1.49221
2009	April 19th	Dec. 11th	917	702.6	11767.9	7026000	7026	1.674907
2010	March 7th	Nov. 12th	1485.4	1037.1	12215.5	10371000	10371	1.177852
2011	March 27th	Nov. 30th	1144.1	776.8	11210.8	7768000	7768	1.443203
2012	March 30th	Nov. 27th	1200.2	870.7	7958.5	8707000	8707	0.914035
2013	March 26th	Nov. 30th	793.2	644.8	13947.4	6448000	6448	2.163058

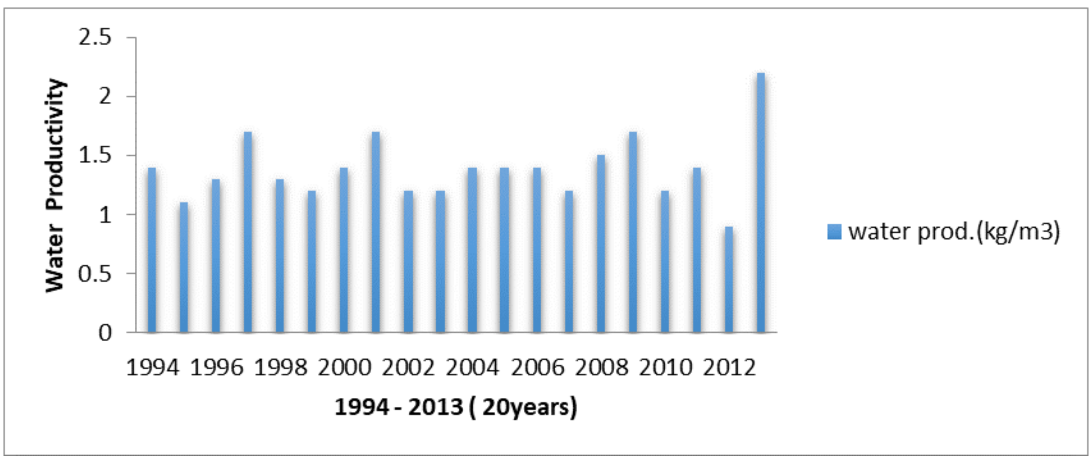

Figure 2: Water productivity

3.2 Cost of Alternative Water

Table 3: ANNUAL WATER COST

Year	Cassava Yield (Kg/Ha)	Effective Rainfall (m^3)	Effective Rainfall (litre)	Cost of water Used (₦)

1994	10592.8	7774	7774000	13324636
1995	10667.1	9496	9496000	16276144
1996	10664.6	8085	8085000	13857690
1997	11881.8	7026	7026000	12042564
1998	10746.1	8292	8292000	14212488
1999	9599.8	8146	8146000	13962244
2000	9700.0	7188	7188000	12320232
2001	9601.2	5778	5778000	9903492
2002	9901.3	8198	8198000	14051372
2003	10402.3	8584	8584000	14712976
2004	11001.1	7690	7690000	13180660
2005	10990.2	7890	7890000	13523460
2006	12000.3	8422	8422000	14435308
2007	11202.6	9210	9210000	15785940
2008	11800.4	7908	7908000	13554312
2009	11767.9	7026	7026000	12042564
2010	12215.5	10371	10371000	17775894
2011	11210.8	7768	7768000	13314352
2012	7958.5	8707	8707000	14923798
2013	13947.4	6448	6448000	11051872

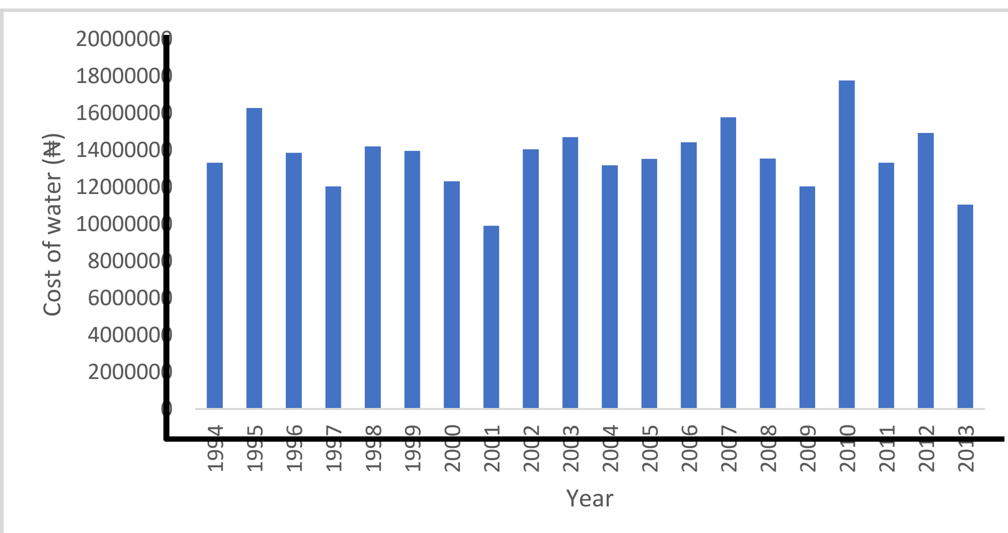

Figure 3: Cost of Water

Maximum rainfall was recorded in the 17th year (2010) (March 7 – November 12) with a value of 1485.4mm, while the minimum value was recorded in the 8th year (2001) (May 10 – January 10) with a value of 780.9 mm. Effective rainfall was computed to know the amount of water in terms of rainfall that is available for the crop (cassava). The maximum and minimum values for effective rainfall were 1037.1mm and 577.8mm respectively.
The maximum yield of cassava in kg/ha was recorded to be 13,947.40 as at the 20th year (2013) which was planted on the 26th of March and harvested on the 30th of November, with an effective rainfall of 644.8mm. Based on the trend of data collected, it showed that the maximum yield was recorded when low rainfall was observed which can be linked to the cost of water that can be used in replacement for effective rainfall (irrigation).
Figure 3 shows the cost of water that could be used to replace water obtained from rainfall on yearly basis (i.e. 1994 – 2013). The highest cost of water was observed in year 17(2010) with the maximum price of ₦17,775,894. The lowest cost of water used was observed in year 8(2001) with the minimum price of ₦9,903,492.

These costs are important to determine so that it could be valued along with the main cost of cassava like in the determination of virtual water. This is applicable mostly in countries like Israel where water is very scarce. When cassava is produced, they value the cost of water used for the production and add it to the selling price in case of exportation.

CONCLUSION The cost of water was highest in year 2010 and the highest yield was recorded in 2013. The lowest cost of water was recorded in 2001. If the cost of water supplied through rainfall is included in the cost of cassava, especially the cassava exported, this amount can be used to provide water used in cassava cultivation during periods of drought, thus leading to higher annual yield. The virtual water concept is a very useful tool in crop production.

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A REVIEW OF THE MANAGEMENT OF SALT AFFECTED SOIL IN ARID AND SEMI-ARID REGIONS

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ABSTRACT

A study was conducted to review various irrigation management and techniques employed in reclamation of salt affected soil in regions where rainfall is less to supplement the loss of moist due to high temperature and crop water use (Evapotranspiration). It was evaluated that about 20% of cultivated lands and 33% of irrigated agricultural lands in the world were salt affected and the amount of land now at risk of salinity is four times of current affected areas, An over estimation of the leaching requirement usually result to the application of excessive amounts of irrigation water and increased salt loads in drainage systems, which can detrimentally impact the environment and reduce water supplies. Results obtained shows positive outcomes but slight significance in some approaches due to irrigation frequency.

Keywords: *Leaching; Evapotranspiration; Salinity; Irrigation*

1.1 OVERVIEW

Soil salinization enhanced by high rates of evapotranspiration is a prominent challenge in arid and semi-arid regions (Jayawardane et al., 2001; Freedman et al., 2014). Currently, an average of over 20% of the world's cultivated land are threatened by salinity (Li et al., 2014; Zhang et al., 2015). Salt affected soils, mostly saline and sodic soils contain excessive salts and constitute a serious land degradation problem, which affects over 6% of the world land area (FAO-AGL, 2000). They lead to poor plant growth through osmotic stress, poor soil structure, and inadequate nutrient uptake (Grattan and Grieve, 1999; Mengel et al., 2001). Soil salinity is one of the most severe physical and chemical stresses, which negatively influence growth and yield of non-halophyte and even halophyte crops and threatens both the food security and sustainability of agricultural production worldwide (Debez et al., 2008; Yang et al., 2016). It is evaluated that the amount of land at risk of salinity is four times of currently affected areas (Foolad, 2004; FAO, 2008; Pitman and Lauchli, 2002). An estimated stressed area will expand to 50% of irrigated land by 2050 (Wang *et al*. 2003).

Irrigation with saline waters requires application of extra water for leaching of salts from the root zone to prevent excessive accumulation of salts that would limit the yield potential of crops (Letey et al., 2011). Thus, a debate exists between applying more water for soil salinity control and applying less water to protect groundwater from being polted and making more water available for other purposes (Letey et al., 2011). In recent years, leaching method of regulating salt affected soils using drip irrigation with saline water has been successfully applied in reclamation of saline soils on crop and some landscape plants (Kang et al., 2010; Sun et al., 2013; Chen et al., 2015; Li et al., 2016).

Soil salinity is now a major obstacle for the utilization of saline land resources (katerji et al., 2005; Oo et al., 2015). Several hectares of land worldwide are too saline to sustain production of economic crops and more lands are at risk to become non-productive each year because of salt accumulation, and salinity problem. These problems are severe especially in the arid and semiarid regions where temperature is high with insufficient rainfall to supplement water loss and leach salts from the plant root zone, (Carter, 1975; Rhoades, 1986).

Kadawa is one the sector of the Kano River Irrigation Project (KRIP) which is a major irrigation scheme in Nigeria. It has been reported that this sector of the KRIP is affected by salinity (Maina et al., 2012). This problem needs to be addressed to protect the soils for sustainable crop production and ensure food security to Kano, Nigeria.

This paper reviews (i) the effect of leaching requirement on irrigation frequency, (ii) most appropriate method to salt affected soil reclamation.

2.1 Soil

According to Dhameja, (2004) soil is a shallow body of materials found on the surface of the land. It is the habitat of micro-organisms and burrowing animal. Soil formation result from three different types of rocks, (igneous, sedimentary and metamorphic rocks) which disintegrate by physical, chemical or biological agents, and regoliths are formed which later on turned to mature soil under the influence of pedogenic process. Many researchers point out that most salt affected soil are likely to have their salt origin from parent materials

2.1.1 Soil Salinity

Soil salinization is a common problem in arid and semiarid areas where the evaporation rate is higher than the precipitation rate. Naturally, soil may contain ample amount of salts due to the presence of salts in the parent rock forming soil. Seawater and shallow saline groundwater are other sources of salt in soils. A very common source of salt in irrigated land is the irrigation water itself. After irrigation, the water added to the soil is extracted by the crop or evaporates directly from the soil. The salts, however, is left behind in the soil. If not removed it accumulates in the soil and this process is called salinization (Brouwer et al., 1985). Soil salinization has two types primary and secondary. The primary salinization is caused by the soil characteristics. However, secondary salinization is caused by irrigation. Soil salinity is defined as the salt concentration in the water extracted from a saturated soil (called saturation extract). Rhoades et al. (1992) stated that soils with a soil water salinity less than 0.70 dSm^{-1} is considered to be non-saline. Studies were made to examine salinity threshold of various crops to be able to know at which level of salinity usually affects the production and response by halophytes and non-halophytes crops. Ayers and Westcott, (1985) reported (Table 1) salts tolerance of some crops which tends to affect the quality and quantity of yield.

2.1.2 Irrigation Water Salinity

Irrigation water salinity is the concentration of the dissolved salts present in irrigation water ($g\ l^{-1}$), or in parts per million (ppm). The major cations of the dissolved salts are sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^+) but K^+ concentration is usually low due to interactions with soil particles especially in clay soil, while the major anions are chloride (Cl^-), bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), sulfate (SO_4^{2-}) and nitrate (NO_3^-). CO_3^{2-} is generally not a major constituent unless the pH value of the water exceeds 8.0 (above neutral, alkalinity) (Hanson et al., 2006). Table 2 shows the classification and uses of water according to its salinity and ranges of total dissolve salt (TDS) present.

Table 1: Soil salinity thresholds determined for saturated soil paste extracts (ECe) for some crops.

Crop	ECe (dS/m)	Slope (%)	Salt tolerance
Agronomic crops			
alfalfa	2.0	7.3	moderately sensitive
barley	8.0	5.0	tolerant
corn	1.7	12.0	sensitive
cotton	7.7	5.2	tolerant
dry bean	1.0	19.0	sensitive
rice	3.0	9.1	moderately sensitive
sorghum	6.8	16.0	tolerant
wheat	6.0	7.1	tolerant
Vegetable crops			
broccoli	2.8	9.2	moderately sensitive
cabbage	1.8	9.7	moderately sensitive
carrot	1.0	14.0	sensitive
celery	1.8	6.2	moderately sensitive
garlic	3.0	14.3	sensitive
lettuce	1.3	13.0	moderately sensitive
onion	1.2	16.0	sensitive
pepper	1.7	14.0	moderately sensitive
potato	1.5	12.0	moderately sensitive
spinach	2.0	7.6	moderately sensitive

squash	4.7	10.5	moderately tolerant
tomato	2.5	9.9	moderately sensitive
Perennial crops			
almond	1.5	19.0	sensitive
apricot	1.6	24.0	sensitive
blackberry	1.5	22.0	sensitive
grape	1.5	9.6	tolerant
orange	1.7	13.1	tolerant
peach	1.7	21.0	tolerant
plum (prune)	1.5	31.0	moderately sensitive
strawberry	1.0	33.0	sensitive

Ayers and Westcott 1985.

Crops such as barley, sorghum and wheat are highly salt tolerant unlike strawberry, dry bean and carrot that are highly affected by level of salinity. Any slight change in salt level affects crop yield.

Table 2, Classification of Saline Waters

Water Class	Electrical Conductivity dSm^{-1}	Salt Concentration mg/l	Type of Water
Non Saline	< 0.7	< 500	Drinking and Irrigation Water
Slightly Saline	0.7 – 2.0	500 – 1500	Irrigation Water
Moderately Saline	2.0 – 10	1500 – 7000	Primary Drainage Water and Groundwater
Highly Saline	10 – 25	7000 – 15000	Secondary Drainage Water and Groundwater
Very High Saline	25 – 45	15000 – 35000	Very Saline Groundwater
Brine	>45	>35000	Sea Water

Rhoades, 1996

2.2 Salinity and Crop

Katerji et al. (2003) studied the effects of salinity on yield and development of crops. They concluded that salinity causes reduction in crop yield by affecting the number and weight of grains, tubers, and fruits. Salinity effect also depends on other factors such as soil properties, climate conditions, irrigation practices, and water management.

Salinity affects the water stress of the plant through its effect on the osmotic potential of the soil water. With increasing salinity, the osmotic potential decreases as well as the water availability for the plant, resulting in rising water stress which in turn affects stomata conductance, leaf growth and photosynthesis (Parida and Das, 2005).

There are several approaches for predicting the decrease in crop yield due to salinity. The FAO approach assumes that crops can tolerate salinity up to a certain level without a considerable loss in yield (electrical conductivity threshold). When salinity increases beyond this threshold, crop yield decreases linearly in proportion to the increase in salinity (Allen et al., 1998).

It is well know that most crops cannot grow on soils that contain considerable amount of salts. One reason for this is that salt causes a reduction in the rate and amount of water uptake by the plant roots and salinity always affects yield, evapotranspiration, stomata conductance, and leaf area (Hanson et al., 2009; Malash et al., 2008; Parida and Das, 2005).

2.3 Salt Balance

The relationship between the quantity of soluble salt brought into an area by the irrigation water and the quantity removed from the area by the drainage water is known as salt balance of the area (Michael, 1978). Bauder et al., 2014 studied the common salt found in salt affected soil or irrigation water and how they influence the osmotic water uptake of non-halophyte crops.

Table 3. Common salt compounds.

Salt compound	Cation (+)	Anion (-)	Common name
NaCl	Sodium	Chloride	halite (table salt)
Na_2SO_4	Sodium	Sulphate	Glauber's salt
$MgSO_4$	Magnesium	Sulphate	Epsom salts
$NaHCO_3$	Sodium	Bicarbonate	Baking soda
Na_2CO_3	Sodium	Carbonate	Sal soda
$CaSO_4$	Calcium	Sulphate	Gypsum
$CaCO_3$	Calcium	Carbonate	Calcite (lime)

Bauder et al., 2014

2.3.1 Salt Stress

According to FAO report, soils affected by salt have a high soluble salt like sodium (Na^+), chloride (Cl^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), and sulphate (SO_4^{2-}) (Bohn et al. 1985; (FAO 2009; Manchanda and Garg 2008). Normal soil has pH = 4.5 – 7.5, electrical conductivity (EC) < 4 dS m^{-1}, exchangeable sodium percentage (ESP) <15, and sodium absorption ration (SAR) < 15, make most favourable environment for nutrient availability and plant growth (Bohn et al., 1985). However, salt stressed soil is that with high concentration of soluble salts that negatively affects plant growth.

2.4 Leaching and Drainage Requirement

Leaching is the processes of percolating water through the soil profile to move salt beneath the root zone were crop roots normally extract water for growth. However, when crops are already planted on the salt affected soils on a field, excess water are to be applied to cover the crop water use, evapotranspiration and leaching. Leaching process will be efficient if an adequate drainage system is designed, (Cahn and Bali, 2015).

Recently, many studies have been conducted to evaluate the use of different levels of water application and irrigation amount of micro sprinkler irrigation (Leaching) in coastal region with very strongly saline silt soil (Chu et al., 2015). According to Cahn and Bali (2015), an efficient method for accessing whether leaching was effective in treating the salt problem in the crop root zone is to measure the soil salinity at various vertical distances within the soil profile. The method can be achieved under the following steps:

- Soil samples should be collected from three equal depth intervals in the root zone. Each depth should be a composite of soil sampled within a location of the field.
- Electrical Conductivity analysis of saturated extract should be conducted for the soil sample collected each layer.
- Salinity values should be compared among different depth. It is expected that salt concentration should be increasing down the depth of the soil if leaching is effective. But if salinity is higher at the top soil than beneath the soil surface, the leaching is not effective for reducing the soil.
- Effectiveness of a leaching strategy can be assessed by comparing the average of the average EC of the root zone with the EC of applied irrigation water using equation (1)
$$LR = (EC_{iw} \times 100)/[(EC_e \times 5) - EC_{iw}] \qquad (1)$$

According to Michael (1978), leaching requirement can also be determined using equation (2)

$$LR = \frac{D_d}{D_i} = \frac{EC_{iw}}{EC_d} \qquad (2)$$

Where LR is the leaching requirement (ratio or %); EC_{iw} is the electrical conductivity of irrigation water; EC_e is the electrical conductivity of saturation extract of the soil, EC_d is the electrical conductivity of drainage water (in mmhos/cm); D_{iw} and D_d are depths of irrigation water and soil (cm).

Kern, 1990; Devrajani, 1993; Jamali et al., 2012; Tony and Pitt, 1975, agreed that leaching of salt affected soil by irrigation applications produced significant results of EC reduction in the soil root zone. They reported that frequent application of increased irrigation water leached down salt beneath the root zone reclaiming 85% of the soil. According to Li, (2017) the variation in hydraulic conductivity of sandy loam soil compared to that of the silt soil resulted to a more efficient salt leaching in sandy loam soil than in silt soil. Considering all factors, leaching process under micro sprinkler irrigation improved water movement in soils under unsaturated flow conditions (Chu, 2016). Micro sprinkler irrigation was found to be an effective method for reclaiming the highly saline soils (Chu, 2016).

Table 4: Average salt balance for different levels of leaching

Irrigation water salinity EC_{iw} (dS/m)	Leaching level LF (%)	Average salt in per irrigation (g)	Average salt out per irrigation (g)	Average salt accumulation per irrigation (g)	Average soil solution salinity ECe (dS/m)
4	3	53.1	23.3	29.9	15.6
	20	70.2	95.9	−25.6	8.5
	29	93.6	141.8	−48.1	5.5
	37	121.2	195.7	−74.5	3.7
9	3	135.0	36.1	98.9	22.3
	20	171.5	118.5	53.0	17.1
	29	202.2	166.8	35.4	14.9
	37	265.9	270.8	−4.9	10.2
12	3	169.1	38.1	131	30.4
	20	213.3	125.5	87.8	23.5
	29	257.1	194.8	62.3	17.7
	37	315.8	282.9	32.9	15.4

Heidarpour, 2008

3.0 CONCLUSION

This paper reviewed the Effect of leaching requirement on irrigation frequency appropriate leaching methods of salt affected soil reclamation. Researchers have made serious input on leaching requirement and various achievements were made in respect to reclamation of soil-affected areas. Results obtained revealed positive outcomes but slight significance in some approaches due to irrigation frequency.

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Removal of Excessive Fluoride Ions from Groundwater in Ibadan, Oyo State Using Low Cost Bio-Adsorbents Materials

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ABSTRACT

Fluoride is frequently depicted as a 'double-edged sword' as an insufficient intake is related to dental disorder while much ingestion leads to dental and skeletal fluorosis which has no treatment. Prevention is only through the supply of fluoride safe water by using de-fluoridation techniques. The research is aimed at putting to test, non-conventional methods of excessive fluoride removal from underground waters in Ibadan, Oyo state using various bio-adsorbents such as egg shell powder and neem leaf powder for the removal of excess fluoride from drinking water was studied. The study employed a batch method to investigate the efficiency of the adsorbents. The effects of various physico-chemical parameters such as pH, adsorbent dose, initial fluoride concentration and contact time on adsorption of fluoride were studied. It was observed that the uptake of fluoride was maximum at original pH 6 for both adsorbents. The equilibrium adsorption data were fitted reasonably well for Freundlich isotherm, Langmuir isotherm and Temkin isotherm model. The rate of adsorption was rapid and maximum fluoride uptake was attained within 90 minutes for egg shell powder and 120 minutes for neem leaf powder. The results of kinetic models showed that the pseudo-second-order kinetic model was found to correlate well to the experimental data. The results of thermodynamic parameters showed that the adsorption process is feasible. The positive values of the entropy change suggest increased randomness at solid-liquid interfaces during the adsorption. . The efficiencies of the adsorbents towards the removal of excessive fluoride ions from samples were also examined and were found to remove fluoride ions from groundwater.

***Keywords**: De-fluoridation; Egg shell powder, Neem leaf powder; Physico-chemical parameters; Isotherm model; Kinetic modelling.*

1.0 INTRODUCTION

Water is a colourless, transparent, odourless, tasteless liquid that forms the seas, lakes, rivers, and rainfall as well as the basis of the fluids to living organisms (Michael, 2000; Okhakhu, 2017). Water is a combination of hydrogen and oxygen atoms, with a chemical formula H_2O and known to be the most abundant compound (70%) on earth's surface (Osei, 2005; Brini *et al*., 2017). However, for water to be potable it must be microbiologically free and in order to achieve this, an approach that will eliminate pathogenic organisms from the source of water supply must be ensured. Retra (2002) and Unamba (2016) described water in its pure form as a substance that has a pH value of 7.0, freezing point of 0˚C and boiling point of 100˚C at 760mmHg. Water is capable of dissolving other substances more than any other known solvent and therefore, it is called a universal solvent. Water has been recognized as a potential carrier of germs and diseases (Retra, 2002; Unamba, 2016)). Ground water often contains high inorganic minerals under favourable conditions. The conditions mainly are dissolution or weathering of rocks and soils, dissolving of lime, gypsum and other salt sources, mining activities, industrial and agricultural activities and geological formations of area etc. The runoff carries available minerals due to above activities and percolates with rainwater and joins the ground water. Some of the commonly occurring constituents are calcium, magnesium, sodium, potassium, iron, manganese, arsenic, nitrate, chlorides, fluoride bicarbonate etc. Presence of these ions in excess of permissible limits as prescribed by WHO and others as indicated in Table 1.2 results in undesirable health effect. Among various ions present “Fluoride” has physiological properties of the great interest and importance for human health and well beings. Fluoride is a salt of an element called fluorine. Fluorine is the most highly reactive element of halogen family. It has been estimated that fluorine is the seventeenth most abundant element constituting about 0.065% of the earth’s crust. It does not exist as a free element. Small amounts are found in seawater, bones and teeth. It exists in water mainly as fluoride associated with monovalent cations such as NaF and KF are water soluble, while those forms with divalent cations such as CaF_2 and PbF_2 are generally insoluble. The fluoride forms many stable complexes with ammonium and iron. Other compounds, which exist in acid solution, are mono and hexa-fluoroaluminate; and mono and hexa-fluoroferrate. The simple free fluoride ion exists in alkaline solution (Choudhary *et al.*, 2014; Singh, 2016). Fluoride commonly occurs in earth’s crust as fluorspare (CaF_2), Appatite and rock phosphate and phosphorites. Fluorine is a naturally occurring element found in various minerals. Fluoride is normally present in the form of fluoride ions in minerals, found in sedimentary (limestone and sandstone) and igneous (granite) rocks, and leached out to contaminate water through geological processes (Table 1.1). Higher fluoride levels in the groundwater get through these minerals by volcanic and fumarolic processes. Fluoride, although beneficial for the mineralization of hard tissues in the human body, can be toxic to humans with chronic exposure to elevated concentrations (Khichar *et al*., 2015). While nitrates pollution is caused by the intensive use of nitrogen fertilizers, crop irrigation with waste water and the use of manure. The principal sources of fluorine were drinking water and food such as sea fish, cheese and tea. Small quantity of fluoride is an essential component for normal mineralization of bones and formation of dental enamel. More recently, excess fluoride in drinking water wreaks havoc in more than 35 nations across the globe; forcing hundreds of million people live under the threat of diseases, Fluoride ions excess presence in water is prioritized as a major impediment to the sustainable drinking water supply. In many cases, the water sources have been rendered unsafe not only for human consumption but also for other activities such as irrigation and industrial needs. Although concentration of fluoride in drinking water less than 1.0 mg/1 is said to be beneficial for the formation and calcification of dental resistant enamel and for the stabilization of the skeleton structure but at level slightly above 1.0 mg/1, mottling of teeth has occasionally been reported. Dental fluorosis, also called “mottled enamel”, occurs when the fluoride level in drinking water is marginally above 1.0 mg/l. Crippling skeletal fluorosis, which is associated with the higher levels of exposure, can result from osteosclerosis, ligamentous and tendinous calcification and extreme bone deformity. Skeletal fluorosis is tingling sensation in legs and feet followed by pain and stiffness of the back as shown in Table 1.3 (Nemade *et al.*, 2002; Panchore, 2016). Nitrate is a colorless, odorless, and tasteless compound that is present in some groundwater. Therefore, there is a need to proffer methods and techniques to remove excessive fluoride ions and nitrate ions from water to make them fit for human consumption. The present investigation deals with adsorption of fluoride and nitrate ions on low cost adsorbents (egg shell powder and neem leaf powder). This method is also called Bioremediation. The effects of various physico-chemical parameters such as pH, Adsorbent dose, initial fluoride concentration, contact time and temperature were investigated. Groundwater samples collected randomly within Ibadan metropolitan city, Oyo state were used for fluoride removal studies.

Table 1.1: Fluoride Content of Mineral Soils.

Minerals	Fluoride (Mg/L)
Meteorites	28-30
Dunite	12
Basalt	100
High calcium	520
Granite	---
Alkali rocks	1200 – 8500
Shale	740
Sand stone	270
Deep sea clays	1300
Deep sea carbonates	540

Sources: Dinesh, (2012).

Table 1.2: Permissible limit of fluoride in drinking water prescribed by various Organizations

S. No.	Name of organization	Permissible limit of fluoride ion (mg/lit)
1	World Health Organization (International standard for drinking water)	0.6-1.0
2	US Public Health Standards	0.8
3	The committee on public health engineering manual and Code of practice,Government of India	1.0
4	Bureau of Indian Standards	1.0

Source: WHO (2004).

Table 1.3:Effects of fluoride in water on human health

Fluoride concentration (mg/l)	Effects
< 1.0	Safe limit
1.0 - 3.0	Dental fluorosis (discoloration, mottling and pitting of teeth)

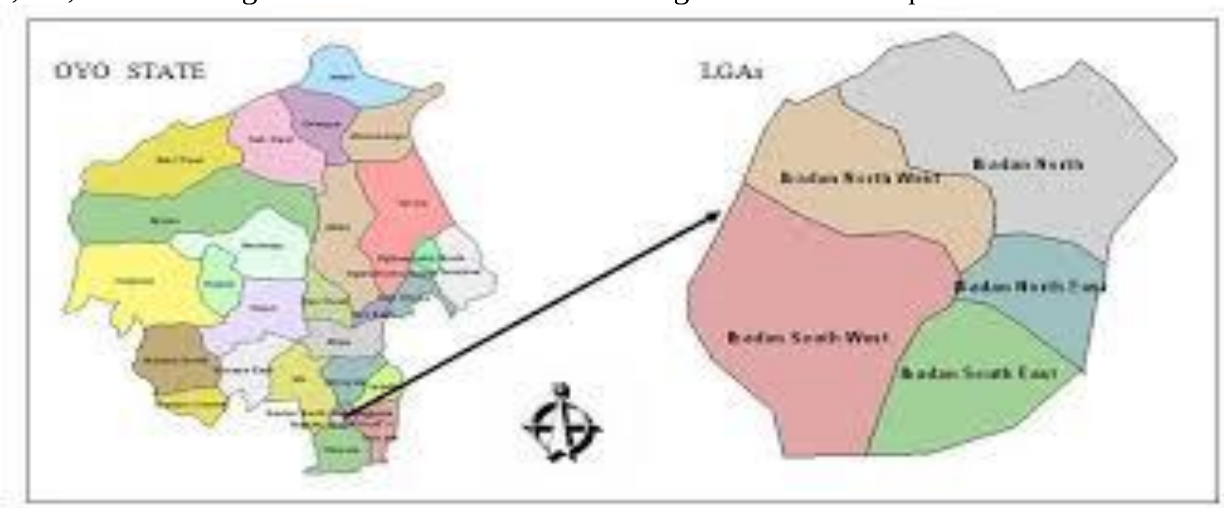
3.0 - 4.0	Stiffened and brittle bones and Joints
4.0 - 6.0	Deformities in knee and hip bones and finally paralysis making the person unable to walk or stand in straight posture, crippling fluorosis.

Source: Dissanayake, (1991).

2.0 MATERIALS AND METHODS

2.1 Study Area

This study covers Ibadan metropolitan city, which is the largest indigenous city in Africa. Ibadan is the capital of Oyo state. It is made up of eleven local government areas. They are: Ibadan North-West, Ibadan North-East, Ibadan South-East, North Ibadan and Ibadan South-West as shown in figure 2.1. Other six local government areas are: Akinyele, Lagelu, Egbeda, Ona-Ara, Oluyole and Iddo local government areas. Ibadan lies at latitude 7 ˚23' N and Longitude 3˚ 56'E. It is located at the transition zone between the forest and grassland areas of the Nigeria. The population of central Ibadan which is made of by the five Local Government Areas is 1,338,659 according to census result of 2006 covering an area of 128 square kilometer



.**Figure 2.1: Map showing location of Ibadan, Oyo State**

2.2 Egg Shells

The chicken egg shells, (*Gallus gallus domesticus, L.*) were collected from a local eatery, cakes and pastries restaurant, Stateline road, off FUTA road, Akure, Ondo state, Nigeria. The egg shells were washed with distilled water until the egg white was completely removed and dried at room temperature. They were pulverized into smooth, fine particle "dust-like" form using Ceramic (porcelain) pestle and mortar and kept in an air tight container. All reagents used were of analytical grade, obtained from Sigma Aldrich and were used without further purification.

2.3 Neem Leaves

Neem leaves was obtained from a neem tree at opposite lecture theatre, ETF, Obanla, FUTA campus, Ondo state, Nigeria. The neem leaves were washed with distilled water to remove free acids and dirt then oven dried at 40ºC for 48 hrs to remove its moisture content. The oven dried neem leaves were crushed in Ceramic porcelain pestle and mortal, and then kept in an air tight container. All reagents used were of analytical grade, obtained from Sigma Aldrich and were used without further purification.

2.4 Preparation of Sample Collecting Bottles

Plastic wares and viols were used for collecting and handling fluoride solution and for analysis. No glass containers were used throughout the period of the study. All plastic ware was washed in dilute HNO_3 acid and rinsed thoroughly with deionized water prior to its use for collecting and handling.

2.5 Batch Adsorption Studies

100 ml of the fluoride solution was taken in a PVC conical flask and known weight (0.1g) of adsorbent material. The pH of the solution was adjusted using 0.1 M HCl and 0.1 M NaOH solutions was added into it and then kept on a rotary shaker for 6 h in order to attain the equilibrium. The solution was then filtered through Whatman filter paper no. 42 and the filtrate was analysed for residual fluoride concentration by ion selective electrode method using Orion ion electrode instrument at Sustainables laboratory, Akure and FATLAB, Ibadan. All adsorption experiments were conducted at room temperature of 30±2^{0}C. The specific amount of fluoride adsorbed was calculated from:

$$q_e = \frac{(C_o - C_e)V}{M} \qquad (1)$$

Where:
qe is the adsorption capacity (mgg−1) in the solid at equilibrium;
C_0, Ce is the initial and equilibrium concentrations of fluoride (mgL−1), respectively;
V is the volume of the aqueous solution (groundwater);
Wisthemass(g) of adsorbent used in the experiments.

2.6 Method of Analysis

After the fluoride adsorption equilibrium studies, the experimental samples were filtered through Whatman filter paper no. 42 and the filtrate was analyzed for residual fluoride concentration by ion selective electrode method using Orion ion electrode instrument supplied by Thermo Electron Corporation.

Table 2.1:Physicochemical parameters of water sample analysed with WHO and FAO Standards

Parameters	WHO	FAO	Well Water (Dry Season)	Well Water (Rainy Season)
Colour	Colourless	Colourless	Clear	Brownish
Odour	Odourless	Odourless	Mild	Mild

Taste	Tasteless	Tasteless	Tasteless	Tasteless
Temp(ºC)	25	25	25	23
pH	6-8.5	6.5-8.5	6.82	6.78
F^-	<1.0	<1.5	1.16	3.16
Turbidity	0.5-5	5.0	4.5	5.01
Alkalinity	100	200	248.00	252
Salinity	183	155	147	144.24
Zn	3.0	3.0	0.24	0.34
Al	0.1	-	0.03	0.005
CL^{-1}	200	2000	20.40	23.68
NO_3	50	30	0.34	0.26
SO_4	150	0.05	1592.30	1589.46
Fe	0.5-50	0.5-50	0.18	0.14
Pb	0.01	0.01	ND	BDL
Cu	1.0	1.0	0.05	0.12
Mn	0.5	0.5	0.02	BDL
Cr^{3-}	0.05	0.05	ND	BDL

Unless otherwise stated all units are in mg/L; pH is dimensionless; Turbidity *in NTU – Nephelometric Turbidity Unit*

Source: *FAO (2007); WHO, (2004)*

pH is an important parameter for adsorption of contaminants (fluoride ions) from aqueous solution(groundwater) because it affects the solubility of fluoride ions, concentration of counter ions on the functional groups of the adsorbent, the surface charge of the adsorbent and the degree of ionization of the adsorbate during reaction (Hema, 2014). Adsorption of fluoride ions was studied in the pH range of 4-9 To determine the optimum time for fluoride ions removal, contact time studies were conducted. Percentage removal of Fluoride ions was measured as a function of contact time ranging from 5 to 360 minutes The effect of concentration on uptake of fluoride on the adsorbents was studied at optimal pH values, the adsorbent dose of 0.10 g (in 100ml solution), optimum contact times and at room temperature. The initial fluoride concentrations studied were (1.5, 2, 2.5, 3.0 and 3.16 ppm)

Adsorbent dose variation experiment is one of the significant parts of the study that determines the capacity of adsorbents for a given initial concentration of fluoride ion at the operating circumstances. Thus the experiments were carried out by varying adsorbent doses only in the range 0.1–1.0 g at room temperature. Adsorption is generally described through adsorption isotherms, which is the relationship between the amounts of a substance adsorbed at constant temperature (Abuzer *et al*., 2011). Adsorption isotherm represents the equilibrium relationship between the adsorbate (fluoride ions) concentration in the liquid phase and that on the adsorbents (egg shell powder and neem leaf powder) surface at a given condition. In the present study, Langmuir, Freundlich and Temkin models were used to describe the equilibrium experimental data for sorption of fluoride ions onto egg shell powder and neem leaf powder by varying initial fluoride ion concentrations from 1.5 ppm to 3.16 ppm room temperature (30˚C). Temperature is an important parameter that determines the thermodynamics of adsorption process. The effect of temperature on the removal of fluoride ions was investigated in the temperature range of 298−338 k.

In any adsorption process, both energy and entropy considerations must be taken into account in order to determine what process will occur spontaneously. Values of thermodynamic parameters are the actual indicators for practical application of a process. The Gibbs free energy change, $\Delta G°$, is an indication of spontaneity of a chemical reaction and therefore is an important criterion for spontaneity. Also, enthalpy, $\Delta H°$ and entropy, $\Delta S°$ factors must be considered in order to determine the Gibbs free energy of the process. The thermodynamic parameters of Gibb's free energy change, ΔG^o, enthalpy change, ΔH^o, and entropy change, ΔS^o, for the adsorption processes are calculated using Equations.

$$\Delta G = -RTInK_L \quad (2)$$

And

$$InK_L = \Delta S^{\circ}/R - \Delta H^{\circ}/RT \quad (3)$$

3.0 Results and discussions

3.1 Effect of pH on fluoride removal

The effect of pH on fluoride ions removal using egg shell powder and neem leaf powder showed various change in the percent removal over the entire pH range as shown in figure 3.1. The experimental results reveal that fluoride removal efficiency increases with the increase in pH and reached up to 97.5% at pH 6 for egg shell powder and 79.4% at pH 6 for neem leaf powder. Maximum adsorption was observed at pH 6 while in acidic and alkaline pH the fluoride removal was observed to decrease. The progressive decrease of fluoride uptake at alkaline pH could be mainly due to two factors: the electrostatic repulsion of fluoride ion to the negatively charged surface of the Egg shell powder and the competition for active sites by excessive amount of hydroxyl ions. The effect of pH on adsorption of fluoride in highly acidic pH (below pH 4) was not investigated because egg shell powder is not stable.

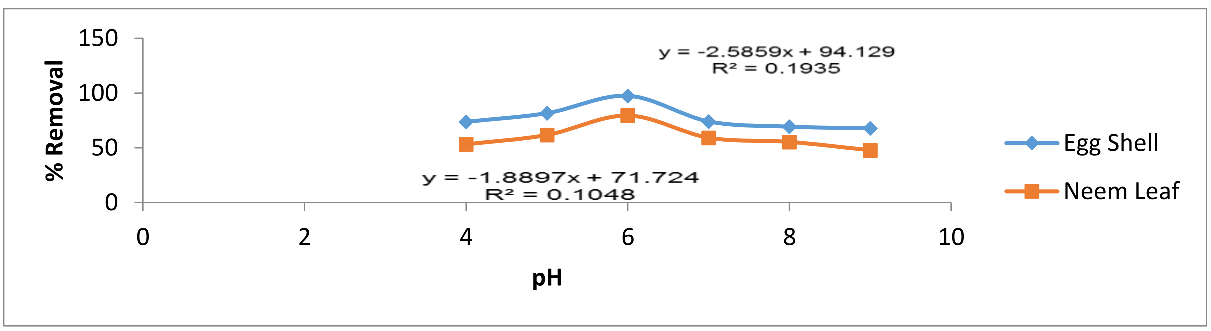


Figure 3.1:Effect of pH on the removal of fluoride ions (C_o= 3.16 ppm, C_{dosage}= 0.10 g, at room temp°C, time= 6 h)

The increase in adsorption as the pH increases may be due to availability of the adsorption sites on the surface of the adsorbent and its functional group that attract ions upon it for adhesion when pH approaches neutrality. Similar results were obtained with some selected local adsorbents (Elsay *et al*., 2015). Thus it was found that removal of fluoride ions from solution was pH dependent and in view of these observations, the value of pH 6 was taken as the optimum pH for further adsorption studies.

3.2 Effect of Contact Time on Fluoride Ions Removal

The results are presented in figure 3.2. The rate of sorption of Fluoride ions on egg shell powder and neem leaf powder was rapid during the first 60 min reaching a value of 56.33% and 66% for both adsorbents; later on adsorption rate becomes slower and attained an optimum with percentage uptake of 93.4% at 90 minutes for egg shell powder and 79.4% at 120 minutes for neem leaf powder. The time required to attain this state of equilibrium is termed the equilibrium time.The amount of fluoride ion adsorbed at the equilibrium time reflects the maximum adsorption capacity of the adsorbent under these particular conditions(Ushakumary *et al*., 2011). Further increase in contact time has a negligible effect on the percentage removal of fluoride ions. The fast initial uptake may be due to the accumulation of fluoride ions on the surface of adsorbent which is a rapid step. This is due to the fact that a large number of unoccupied surface sites are available for adsorption during the initial stage and after some time the remaining unoccupied surface sites are difficult to be occupied due to repulsive forces between the solute molecules on the solid and bulk phases (Danish *et al*., 2011).

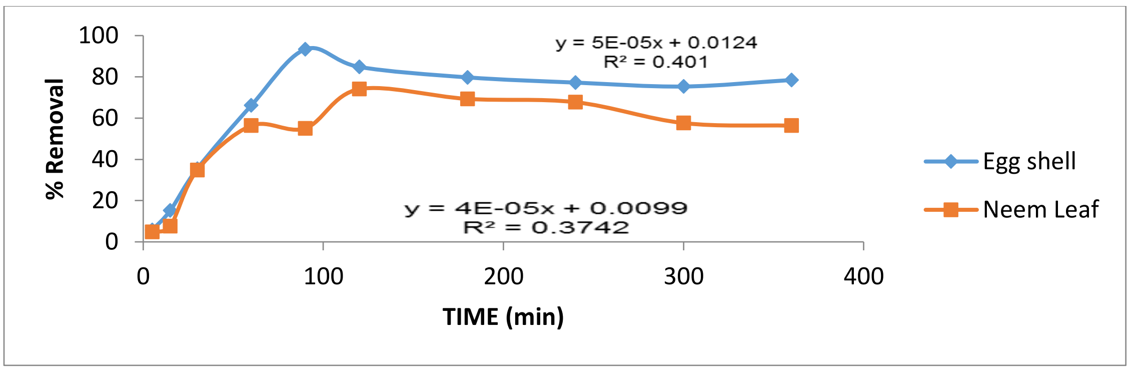


Figure 3.2: Effect of contact time on the removal of fluoride ions (C_o= 3.16 ppm, C_{dosage}= 0.10 g, T= 298k, pH=6, contact time 5-360minutes).

As the contact time increases, intra-particle diffusion becomes predominant. Hence, more time is required in the transfer of fluoride ions from solid surface to internal adsorption sites through the pores. As a result, the driving force of mass transfer between liquid and solid phase in an aqueous adsorption system decreases as time elapsed. Further, the ions have to pass through the deeper surface of the pores for binding and encounter much larger resistance which slows down the adsorption during the later phase of adsorption (Srivastava *et al.*, 2008). It can be concluded that the rate of fluoride binding with adsorbent mass is more predominant during initial stages, which gradually decreases since the functional groups present in the surface of the sorbent gets exhausted and remains almost constant after 90 minutes and 120 minutes for egg shell powder and neem leaf powder respectively. The results obtained were in agreement with Goswami *et al*. (2015) where maximum removal of Fluoride ions was described at a contact time of 60 minutes for neem leaf powder and Bhaumika *et al*. (2012) for egg shell powder at 120 minutes of time. Thus equilibrium time of 90 minutes and 120 minutes respectively were selected for further studies.

3.3 Adsorption Kinetics

The adsorption data obtained were tested with pseudo first order kinetic model as shown in figure 3.3. The result from Table 3.1 shows that there was a large difference between the values of $q_{e,cal}$ and $q_{e,exp}$ and also theR^2values were not close to unity for the two adsorbents. The Lagergren pseudo first order mechanism shows poor linear plots. It has been reported that in most cases, the first–order equation of Largergren does not fit well for the whole range of the contact time; it is generally applicable to the initial 20 to 30 minutes of the sorption process (Guo *et al*., 2002).The same data were tested with pseudo second order kinetic mechanism as shown in figure 3.4. The results from table 3.1in the case of pseudo-second-order model showed that the calculated q_e value is close to the experimental q_e values suggesting that the sorption process obeys of pseudo-second order kinetic model which is in consonance with the reports of the previous investigators (Fazal *et al*., 2012) and (Olasunkanmi *et al*., 2014). The plots have better linearity and the adsorption of fluoride by using concrete follows pseudo second order kinetic model. Furthermore, the correlation coefficient R^2 for pseudo-second-order model was much closer to unity than the correlation coefficient for pseudo-first order model. These plots showed different distinct linear regions within individual sets of data and follows pseudo second order kinetics. The intra-particle diffusion model gave a straight line plots as shown figure 3.5 and did not pass through the origin, suggesting that adsorption proceeds from boundary layer mass transfer across the interface to the intra particle diffusion within the pores of adsorbent. The correlation coefficient R^2 for intra-particle diffusion model was averagely close to unity. Given the multilinearity of this plot for adsorption of fluoride ions, this suggested that adsorption occurred in 3 phases. However, if the data exhibit multi-linear plots, two or more steps influence the absorption processes (El-Said, 2010).

The rate constant of adsorption was determined from pseudo-first-order rate expression as $\frac{dq_e}{dt} = k_1(q_e - q_t)$ (4)

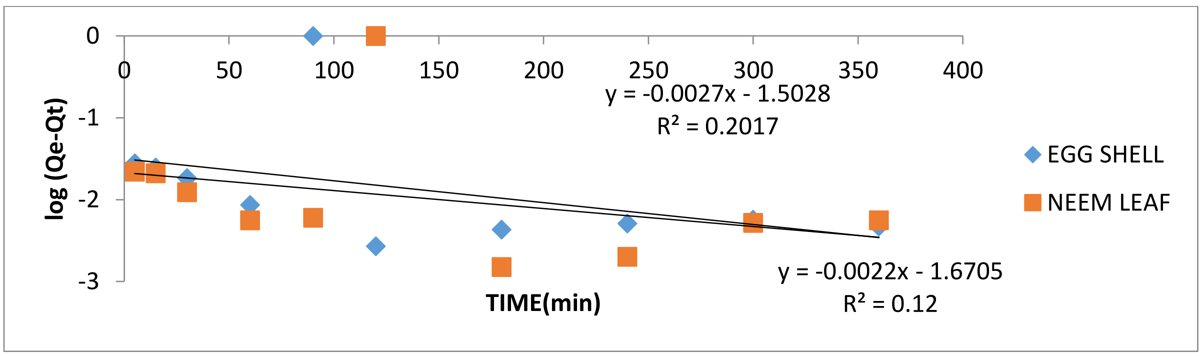


Figure 3.3: Pseudo-first-order plot (C_o= 3.16 ppm, C_{dosage}= 0.10g, T=Room Temp. pH= 6)

The pseudo-second order linearized equation is expressed as $dq_t/_{dt} = k_2(q_e - q_t)^2$ (5)

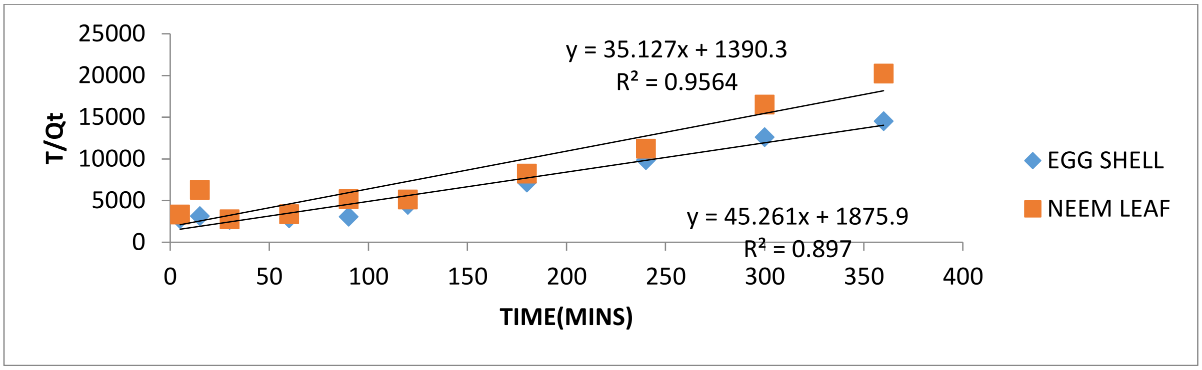


Figure 3.4: Pseudo second order plot (C_o= 20 ppm, C_{dosage}= 0.10g, T= Room Temp., pH= 6)

The intra-particle diffusion model is given as $q_t = k_{id}t^{1/2} + C$ (6)

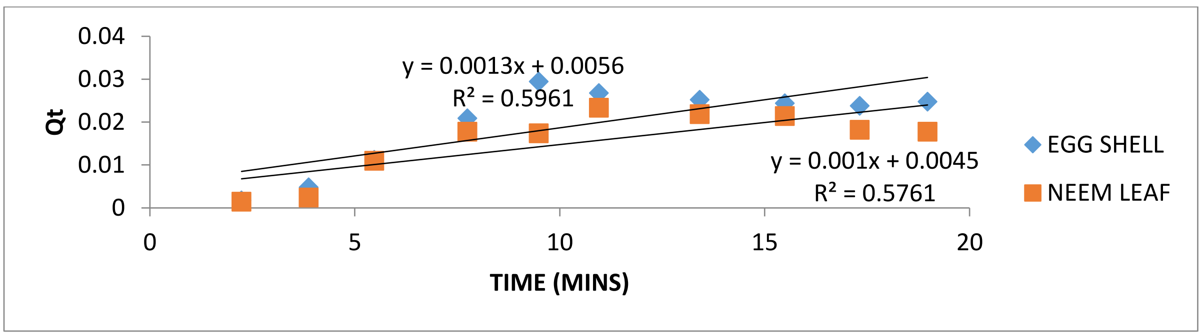


Figure 3.5: Intra particle diffusion model (C_o= 3.16 ppm, C_{dosage}= 0.10 g, T= Room Temp., pH= 6)

Table 3.1: Kinetic parameters for adsorption of Fluoride ions onto egg shell powder and Neem leaf powder

Parameters	**Egg shell powder**	**Neem leaf powder**
Pseudo-first-order		
$q_{e,exp}$ (mg g^{-1})	**0.0295**	**0.0234**
$q_{e,cal}$ (mg g^{-1})	0.031	0.021
k_1 (min^{-1})	0.0046	0.0046
R^2	0.201	0.120
Pseudo-second-order		
$q_{e,cal}$ (mg g^{-1})	0.028	0.022
k_2 (g mg^{-1}min^{-1})	0.887	1.093

R^2	0.956	0.897
Intra-particle diffusion		
k_{id} (mg $g^{-1}min^{-1/2}$)	0.001	0.001
C (mg g^{-1})	0.005	0.004
R^2	0.596	0.576

3.4 Effect of Initial Concentration on Fluoride Ions Removal

The percentage of sorption is given in figure 3.6. According to the plot, the percentage removal of fluoride ions decreases with the increase in initial fluoride ions concentration as a maximum adsorption of 100 % decreased gradually to 92 % from 1.5ppm to 3.16 ppm for egg shell powder and 98% at 1.5 ppm to 75% at 3.16 ppm for neem leaf powder. This can be explained as follows: at low fluoride ion/adsorbent ratios, fluoride ion adsorption involves higher energy sites. As the fluoride ion/adsorbent ratio increases, the higher energy sites are saturated and adsorption begins on lower energy sites, resulting in decrease in the adsorption efficiency. According to SenthilKumar *et al*. (2010), at lower fluoride ions concentration, the percentage uptake was higher due to larger surface area of adsorbent available for adsorption. When the concentration of fluoride ions became higher, the percentage removal decreased since the available sites for adsorption became less due to saturation of adsorption sites. At a higher concentration of fluoride ions, the ratio of initial number of moles of fluoride ions to the adsorption sites available was higher, resulting in lower adsorption percentage. However, different from the percentage uptake, increasing initial fluoride ions concentration from 1.5 ppm to 3.16 ppm, the amount of fluoride ions adsorbed at equilibrium increased. This occurred due to increase in driving force of the concentration gradient to overcome all mass transfer resistance of fluoride ions between aqueous and solid phases and accelerate the probable collision between fluoride ions and sorbents, thus resulting in higher uptake of fluoride ions (Chen *et al*., 2005).

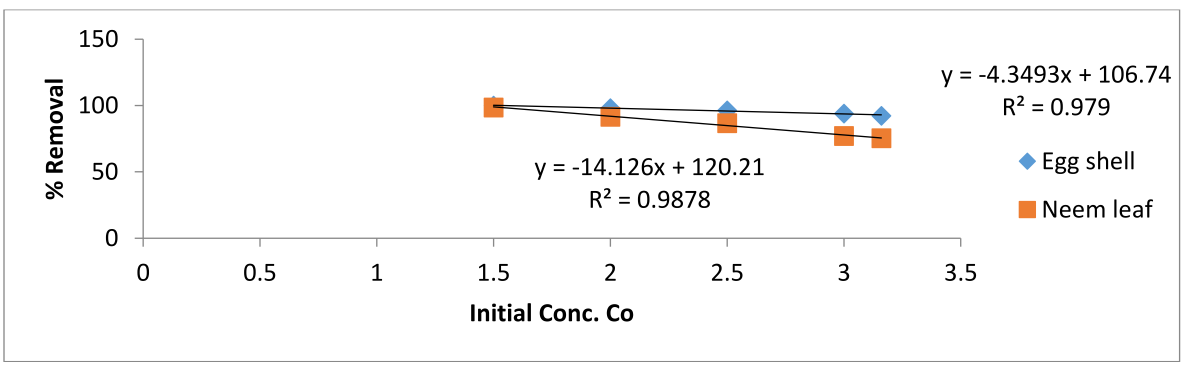


Figure 3.6: Effect of initial fluoride concentration for Egg Shell Powder and Neem Leaf Powder (C_o= 1.5, 2.0, 2.5,3.0,3.16 ppm, C_{dosage}= 0.10g, pH=6)

3.5 Effect of Adsorbent Dosage on Fluoride Ions Removal

The effect of adsorbent dose on the adsorption of fluoride by those adsorbents is shown in Figure 3.7. The fluoride ions removal efficiencies increase with increase in adsorbent dose for both adsorbents and reach a saturation level at higher doses (i.e. starting from 0.5 g of the adsorbents) for both adsorbents that can be related to an increase in contact surface area of adsorbent particles as illustrated in figure 3.7. Adsorbent doses beyond the steady state or saturated state do not improve adsorption due to availability of excess adsorption sites than that of sorbents, assuming that the number of adsorption sites per unit mass of adsorbents remains constant. At lower dosage of adsorbents, there are insufficient active sites that the adsorbate can easily occupy. However, at higher dosage, active sorption sites are sufficiently available for the adsorbates to occupy. Similar results have been reported in the study on adsorption of Cr (VI) and Ni (II) by Attia *et al*. (2010) and Gupta *et al*. (2006) respectively.

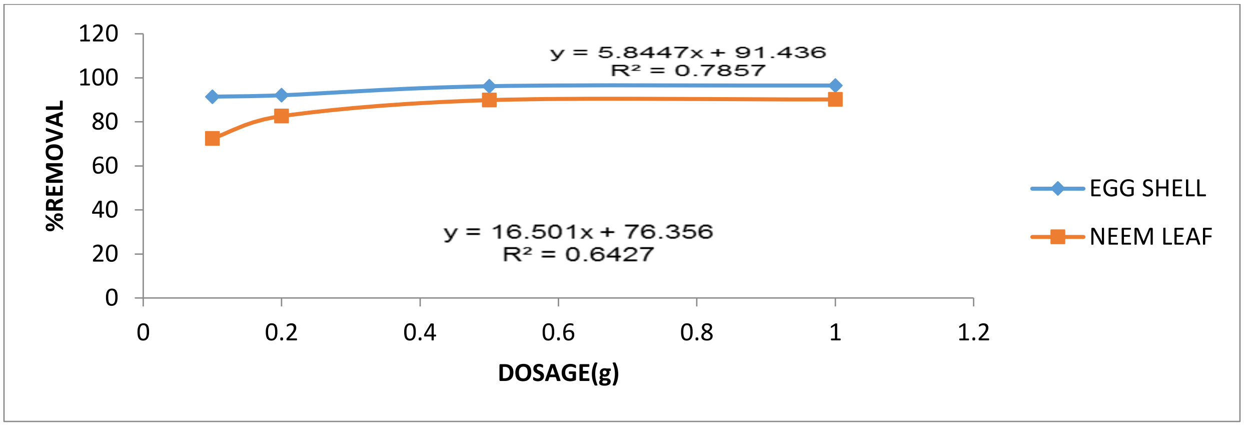


Figure 3.7: Effect of Adsorbent Dosage on fluoride ions removal (C_o= 3.16 ppm, C_{dosage}= 0.10g, pH=6)

3.6 Adsorption Isotherm

The results of the isotherms are shown in table 3.2. It can be inferred that the isotherm data obtained for the adsorption of fluoride ion onto egg shell powder and neem leaf powder was model with Langmuir, Freundlich and Temkin models as shown in Table 3.2. The Langmuir isotherm fits quite well with both adsorbent experimental data (correlation coefficient in the range 0.990-0.997) (Figure 3.8) In the case of Freundlich, only the neem leaf powder experimental data fits properly with correlation coefficient of 0.973 (Figure 3.9). For Temkim, also only the neem leaf powder experimental data fits properly with correlation coefficient (R^2 = 0.958) as compared with egg shell powder with the low correlation coefficients (Figure 3.10). Based on this, the experimental data for the adsorption of fluoride on the different adsorbents shows that the Langmuir isotherm gives a good fit to the adsorption process. This may be due to homogeneous distribution of active sites onto adsorbents surface, since the Langmuir, equation assumes that the adsorbent surface is homogenous.

The Langmuir adsorption isotherm can be represented as given,$q_e = \frac{q_{max} b C_e}{1+bC_e}$ (7)

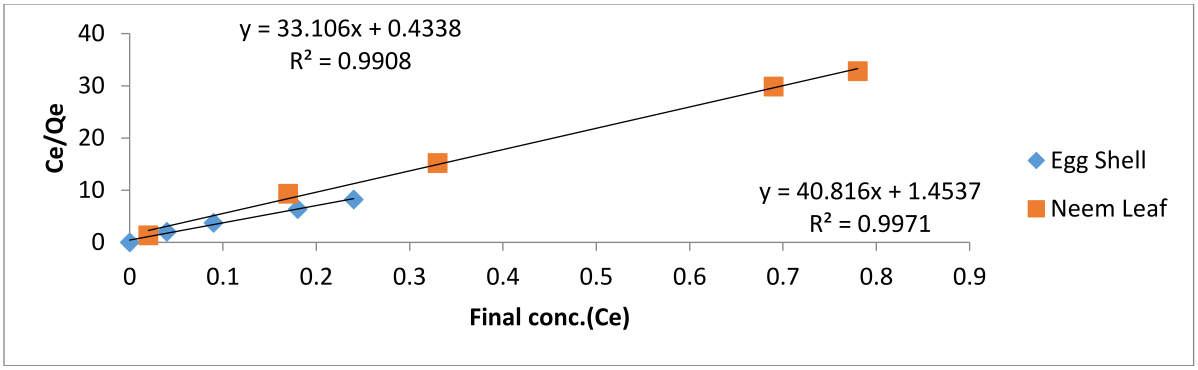


Figure 3.8: Langmuir isotherm plot for egg shell powder and neem leaf powder (C_o= 1.5-3.16 ppm, C_{dosage}= 0.10g, T= room temp., pH= 6, t= 90 minutes and 120 minutes

The Freundlich equation is expressed as given, $\log q_e = \log K_F + {}^{1}/_{n} \log C_e$ (8)

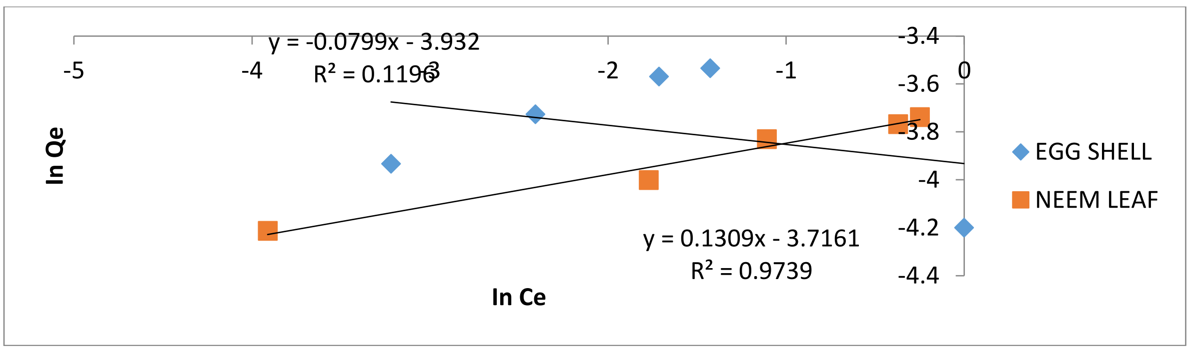


Figure 3.9: Freundlich isotherm plot for Egg shell powder and Neem leaf powder(C_o= 1.5-3.16ppm, C_{dosage}= 0.10g, T= room temp., pH= 6, t= 90 mins and 120mins

The Temkim isotherm model equation is given as$q_e = B \ln A_T + B \ln C_e$ (9)

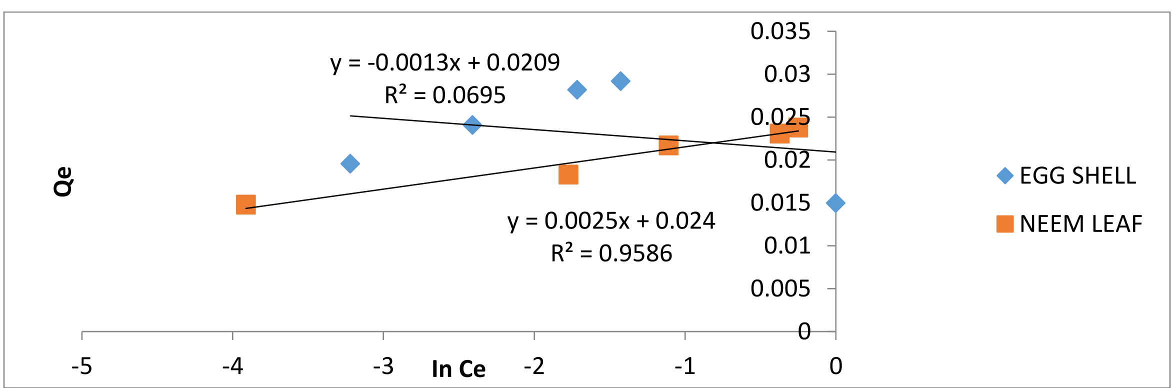


Figure 3.10: Temkin isotherm plot for egg shell powder and neem leaf powder(C_o= 1.5-3.16 mg/L, C_{dosage}= 0.10g, T= room temperature, pH= 6, t= 90 mins and 120 mins)

Table 3.2: Isotherm Constants of Different Isotherm Model

	Parameters	**Egg Shell Powder Room T°C**	**Neem Leaf Powder Room T°C**
Langmuir	q_{max} *(mg/g)*	0.030	0.025
	k_L *(L/mg)*	76.982	28.087
	R_L	0.00409	0.011
	R^2	0.990	0.997
Freundlich	k_F*(mg/g)L/mg*	0.020	0.024
	N	-12.658	7.692
	1/n	-0.079	0.130
	R^2	0.119	0.973
Temkin	*B(mg/L)*	-0.001	0.002
	b_T	-2477572	1238786
	A_T *(L/mg)*	485165195	162754.8
	R^2	0.069	0.958

3.7 Effect of Temperature on Fluoride Removal

The results obtained are shown in figures 3.11.The result shows that increase in temperature has a negative effect on the bio sorption capacity of both adsorbents. The percentage of fluoride ions adsorbed decreased slightly from 95.25% at 298 K to 61.07% at 338 K for 3.16 ppm of adsorbate solution. This is expected because an increase of the thermal energy may induce higher mobility of the adsorbate causing desorption. Previous investigators have shown that temperature adsorption relationship could be explained as being exothermic which implies that an increase in the temperature leads to an increase in desorption of the sorbed ions, thus deactivation of the binding sites resulting in decline of removal efficacy (Sarkar and Acharya, 2006; Sarý *et al.*, 2007). Also the slight difference in the percentage fluoride ion adsorbed may be due to the chemical interaction between adsorbate and adsorbents, creation of some new adsorption sites or the increased rate of intra-particle diffusion of Fluoride ions into the pores of the adsorbents (Wanees *et al.*, 2012).

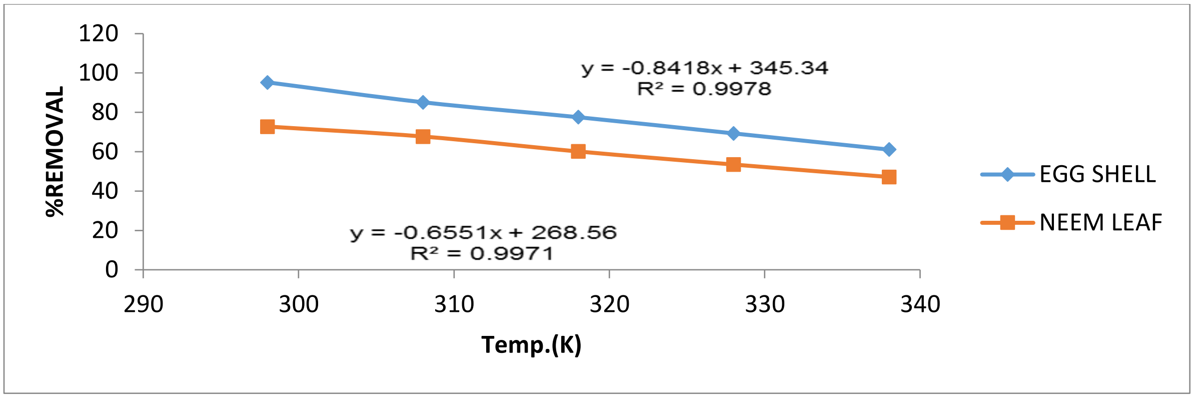


Figure3.11: Effect of temperature on removal of fluoride by both adsorbents (C_o= 3.16 ppm, C_{dosage}= 0.10g, pH=6)

3.8. Thermodynamic Studies

The values of ΔH (-50.93), ΔS (-0.186) kJ/mol and ΔH (-23.412), ΔS (-0.108) kJ/mol) for egg shell powder and neem leaf powder respectively were determined from the slope and intercept of the plot of ln K_L versus 1/T as shown in figure 3.12 and table 3.3. The negative value of ΔH reveals the exothermic nature of the reaction. Also, the values of entropy change (ΔS) was negative, reflecting good affinity of fluoride ions towards the sorbent and suggest a decrease in randomness at the solid-solution interface during the adsorption process. The ΔS values (-0.186 and -0.108) for both adsorbents are very small indicating that the entropic change occurring during adsorption process is negligible (Hao *et al.*, 2010).The result of the change in the Gibbs free energy in the temperature range studied as presented in table 3.3 reveals that Δ*G* values ranged from 4.690 kJ/mol at 298 K to 12.155 kJ/mol at 338 K for egg shell powder while for neem leaf powder the values ranged from 8.90 kJ/mol at 298 K to 13.232 kJ/mol at 338 K. The positive values of the Gibbs free energy change (ΔG) for both egg shell powder and neem leaf powder indicated that the adsorption process was not spontaneous but feasible. In the same vein, the positive values of $\Delta G°$ increased with an increase in temperature suggesting that a better adsorption is actually obtained at lower temperature (confirming the exothermic process). This is because the increase in Δ*G* with increase in the temperature shows a decrease in feasibility of the reaction process. This is expected because increase in temperature results into increase in desorption of the sorbed ions which will ultimately reduce the removal efficiency of the bio sorbent.

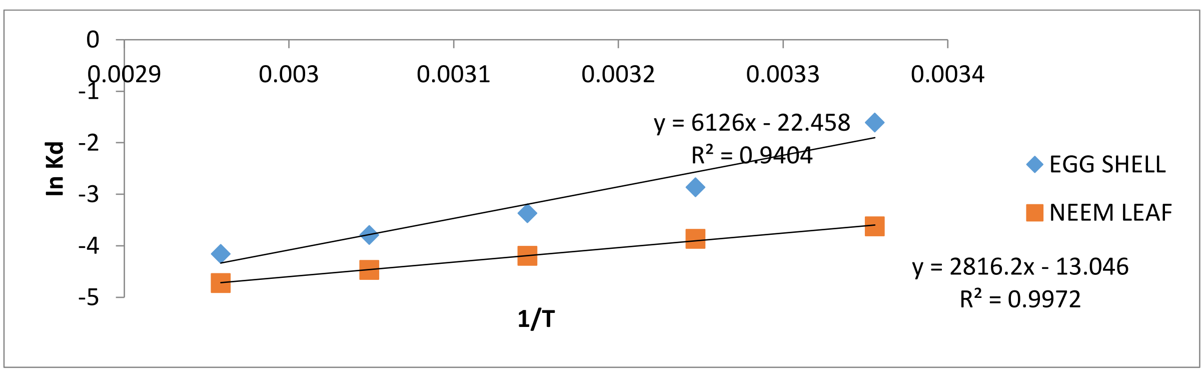


Fig.3.12:Van't Hoff plot for both Adsorbent(C_o= 3.16 ppm, C_{dosage}= 0.10g, T= 28-65°C,

pH= 6, t= 90 min & 120 mins

Table 3.3: Thermodynamic Parameters for Adsorption of Fluoride Ions onto Egg shell powder and Neem leaf powder

	ΔG°(kJ/mol)					**ΔH°(kJ/mol)**	**ΔS°(J/mol/K)**
	298 K	**308 K**	**318 K**	**328 K**	**338 K**		
Egg shell Powder	4.68	6.56	8.422	10.289	12.155	-50.931	-186.649
Neem leaf Powder	8.895	9.979	11.063	12.147	13.232	-23.412	-108.415

Conclusion

The adsorption of fluoride on the surface of the adsorbent is found to depend mainly on the pH of the solution as well as the concentration, dosage and contact time.The adsorption of fluoride on the surface of the adsorbent was optimum at a contact time of 120 minutes for neem leaf powder and contact time of 90 minutes for egg shell powder. The obtained results showed that the maximum adsorption capacity occurred at pH 6. The kinetic studies revealed that the adsorption process best fit the pseudo-second-order kinetic model for both adsorbents. The adsorption isotherms (Langmuir, Freundlich, Temkin isotherms) at different concentration showed that Langmuir model best fitted both egg shell and neem leaf powder. Egg shell powder adsorbents showed excellent removal of fluoride from water than neem leaf powder considering the contact time.

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EFFECT OF DRIP IRRIGATION FREQUENCY AND WATER REGIME ON THE YIELD OF TOMATO (*Lycopersicon esculentum)* Mill..

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ABSTRACT

Tomato is an important fruit vegetable in Nigeria. However, there is limitation to its production during the dry season, due to water shortage. This work studied the effects of deficit irrigation on yield of tomato under drip irrigation system in Ogbomoso, Southwestern Nigeria. A Randomized Complete Block Design (RCBD) experiment was set up with irrigation frequency and depth as the main and sub-plot respectively in three replicates. Three frequencies (7, 5 and 3 days; designated as F1, F2 and F3, respectively) and three depths (100, 75 and 50% of crop Evapotranspiration; designated as D1, D2 and D3, respectively) were used. Number of Flowers (NoF) was recorded weekly. The yield was determined by summation of the weights of the fruits harvested in each sub-plot at intervals of 3 days for 33 days. Analysis of Variance was done to determine the relationship between irrigation interval, depth and yield. The mean was separated using Fisher's Least Significant Difference (LSD) at 95% confidence level ($P<0.05$). The results obtained for number of flowers from the irrigation frequencies F_1, F_2 and F_3 were similar. However, D_2 (75% ET_C) had the highest number of flowers across the treatments. F_1 had the highest number of fruits and was significantly different from F_2 and F_3 though, not significantly different from F_2 at probability level of 5%. F3 with irrigation depth of 50% ETc had the highest yield (92.3 ton/ha).The results obtained indicated that irrigation frequency of 3days is better for optimum yield of tomato.

Keywords: irrigation depth, irrigation frequency, tomato, evapotranspiration,

I INTRODUCTION

Tomatoes are in high demand because the world population consumes them daily. It is one of the popular vegetables and also an important source of antioxidants such as lycopene, phenolic, and vitamin C which play important roles in the prevention of certain forms of cancer (Agarwal and Rao, 2000). Tomatoes can be consumed fresh, cooked or processed into various products and is composed mainly of water (approximately 90%), soluble and insoluble solids (5-7%), citric and other organic acids, vitamins and minerals (Pedro and Ferreira, 2007). The present world tomato fruit production stands at 100 million metric tons. It has been reported that Africa produces about 79% of the total world production of tomato, and that in Africa, Egypt is the leading producer of the crop with an annual production of 1.51 million metric tons which amount to about 65% of the total world production while Nigeria features second to Egypt in terms of production with 0.25 million metric tons per annum (Okunoya, 1996 and FAO, 2008). Nigeria ranked 13th amongst the world 15th top producers of tomatoes with about 1.7% of the world index (FAO, 2010). In Nigeria, almost all the parts of the country produce tomato but it is predominantly produced in the North, particularly during the dry season via irrigation (Rahman, 1999).

Tomato is grown in different parts of the world where annual rainfall ranges between 300- 600 mm Snyder (1992). However, current global concerns on attainment of food security and poverty alleviation require new strategies with marked potential for water conservation and yield increase. It is in this light that drip irrigation system, whose efficiency has been estimated at about 95% has been viewed as the most practical solution in vegetable production. Observably, during the months of November to March, tomato is very scarce in the Southwestern parts of Nigeria and the product has to be transported from the North. However, due to long distance and its high perishability, the products becomes very scarce and expensive (Okunoya, 1996). There is therefore a need to encourage tomato production in the Southern parts of Nigeria, particularly during the dry season to bridge the production deficit gap.

Tomato being a popular crop among other vegetable crops in the world has inadequate production level in Southwest Nigeria particularly during the dry season as a result of water shortage. It is therefore expedient to look for a way of producing tomato with less water usage and study the influence of irrigation on the development of the plant leaves and branches before fruiting begins. Thus, the main objective of this work was to determine the influence of drip irrigation frequencies and depths of water application on the yield of tomato as well as the number of flowers.

2 MATERIALS AND METHODS

2.1 Description of the Study Area

The researches were carried out at Ladoke Akintola University of Technology, Ogbomoso in the Department of Agricultural Engineering Research Field. Ogbomoso lies between Latitudes 8^{o} 08^{1} and 8^{o} 10^{1}N of the Equator and Longitudes 4^{o} 10^{1} and 4^{o}14^{1} E of the Greenwich Meridian. The climatic condition of Ogbomoso is mostly influenced by the Northeast and Southwest trade winds with a maximum temperature of 33^{o}C and a minimum temperature of 28^{o}C (Olaniyi *et al.*, 2010). The relative humidity of this area is high all year round (about 74%) except in the month of December to February where relative humidity is low when the dry wind blows from the North (Olaniyi, 2006). The average annual rainfall is about 1000 mm. The soil type is sandy loam. The soil on the field used for the research is sandy loam and had been fallowing for three years before the experiment.

2.2 Irrigation Scheduling

According to Oke and Ojediran (2015), the irrigation scheduling was determined as a function of ETc. Three depths of application (D1, D2 and D3) were used as 100% ETc, 75% ETc and 50% ETc (ETc, 0.75 ETc and 0.5ETc). Three frequencies (F1, F2 and F3) were used at every 7, 5, and 3 days respectively. The depths of application and frequencies were arranged according to 3 x 3 x 3 RCBD. The volume of application for the desired depth was determined by multiplying the depth by the crop area as

$$a_v = d_i \times a_c \quad (1)$$

Where: a_v is the volume of application (m^3 or L), d_i is the irrigation depth (m) and a_c is the crop area (m^2). The drippers were calibrated to have a discharge $4\ l/h$. The time required for applying the desired volume was calculated using the relation

$$t = \frac{a_v}{d} \quad (2)$$

Where: t is the time required (hr), d is the discharge (L/hr)

2.3 Determination of Agronomic Parameters

The growth parameters (height, number of leaves, and number of flowers) were monitored on weekly basis. The plant height was measured with the aid of a flexible tape; number of leaves, number of flowers and number of branches were determined by visual counting (Oke *et al.*, 2016).

2.4 Determination of crop yield

The crop yield was determined by weighing the fruit harvested under each treatment at different times until no tomato was found on the field. A digital weighing balance (model MP 10001, Gallenhamp) was used for the weighing.

2.5 Statistical Analysis

The data collected on various parameters were subjected to analysis of variance (ANOVA). All the statistical analyses were done using SPSS (*SPSS IBM Statistics v. 20)*. The means were separated using Least Significant Difference (LSD) at 5 % probability level (Oke *et al.,* 2016).

3 RESULTS

3.1 Number of flowers

Figures 1 – 3 indicates the number of flowers and it was observed that the results obtained from the irrigation frequencies F_1, F_2 and F_3 were similar. Highest number of flowers was recorded with depth of water application D_2 of 75% ET_C across the treatments at week seven with the mean values of 292, 299 and 256 respectively. The least number of flowers was obtained at depth of water application with 100% ET_C, D_1 in the frequencies F_1 and F_3 except at treatment F_2 where the least values was recorded at depth of water application with 50% ET_C, D_3 between week six and eight. However, it was observed that flower number increases as irrigation interval decreases. The results for flower number for all the treatments generally show that, 75% ET_C of tomato has no significant differences among the irrigation intervals. However, the results of the growing season for the number of flowers are presented in Table 1 – 3.

Table 1: Effects of drip irrigation frequency and depths on number of flowers for 7-days interval in tomato

Date	F1D1	F1D2	F1D3	F	D	FxD
18/03/14	3	2.333333	0	0.10ns	2.60ns	0.31ns
25/03/14	N	14	1.666667	3.50*	1.66ns	1.74ns
1/4/2014	9.333333	8.666667	10.66667	0.60ns	1.78ns	0.76ns
8/4/2014	46.66667	42	39.33333	0.36ns	3.04ns	0.40ns
15/04/14	172.3333	129.3333	127	3.68*	3.75*	0.22ns
22/04/14	31	47.33333	52.33333	4.99*	0.76ns	1.19ns
28/04/14	129.6667	114.3333	102.3333	5.16*	2.78ns	1.60ns
5/5/2014	19.33333	26.66667	24.66667	7.63*	0.12ns	0.73ns
13/05/14	17.33333	23.33333	21.33333	12.64*	0.17ns	1.08ns
20/05/14	50	42	45	9.17*	0.99ns	0.83ns
27/05/14	4.666667	4.666667	2.666667	0.11ns	0.78ns	3.28*
4/6/2014	3.333333	3.7E-17	0.333333	1.72ns	9.39*	3.47*

Table 2: Effects of drip irrigation frequency and depths on number of flowers for 5-days interval in tomato

Date	F2D1	F2D2	F2D3	F	D	FxD
18/03/14	3.666667	-2.5E-16	1.94E-16	0.10ns	2.60ns	0.31ns
25/03/14	3.666667	3.666667	3.333333	3.50*	1.66ns	1.74ns
1/4/2014	12.66667	1	5	0.60ns	1.78ns	0.76ns
8/4/2014	54.66667	26	22.66667	0.36ns	3.04ns	0.40ns
15/04/14	138.3333	59.66667	46	3.68*	3.75*	0.22ns
22/04/14	79	42	34.66667	4.99*	0.76ns	1.19ns
28/04/14	156	155.3333	100.3333	5.16*	2.78ns	1.60ns
5/5/2014	47.66667	29.66667	26	7.63*	0.12ns	0.73ns
13/05/14	41	27	25.33333	12.64*	0.17ns	1.08ns
20/05/14	141.6667	138	93	9.17*	0.99ns	0.83ns
27/05/14	3	3.333333	5	0.11ns	0.78ns	3.28*
4/6/2014	1	0.333333	0.333333	1.72ns	9.39*	3.47*

Table 3: Effects of drip irrigation frequency and depths on number of flowers for 3-days interval in tomato

Date	F3D1	F3D2	F3D3	F	D	FxD
18/03/14	2.333333	1.666667	-5E-16	0.10ns	2.60ns	0.31ns
25/03/14	3.333333	0.666667	1	3.50*	1.66ns	1.74ns

1/4/2014	11	6.666667	4.666667	0.60ns	1.78ns	0.76ns
8/4/2014	55.33333	30.33333	30	0.36ns	3.04ns	0.40ns
15/04/14	119.3333	59.33333	74.33333	3.68*	3.75*	0.22ns
22/04/14	101	65.66667	99.33333	4.99*	0.76ns	1.19ns
28/04/14	113	65	97	5.16*	2.78ns	1.60ns
5/5/2014	52.66667	54	57.66667	7.63*	0.12ns	0.73ns
13/05/14	49.33333	50.66667	66.66667	12.64*	0.17ns	1.08ns
20/05/14	101.6667	53	82.33333	9.17*	0.99ns	0.83ns
27/05/14	4.333333	4.666667	3	0.11ns	0.78ns	3.28*
4/6/2014	1	0.666667	0.333333	1.72ns	9.39*	3.47*

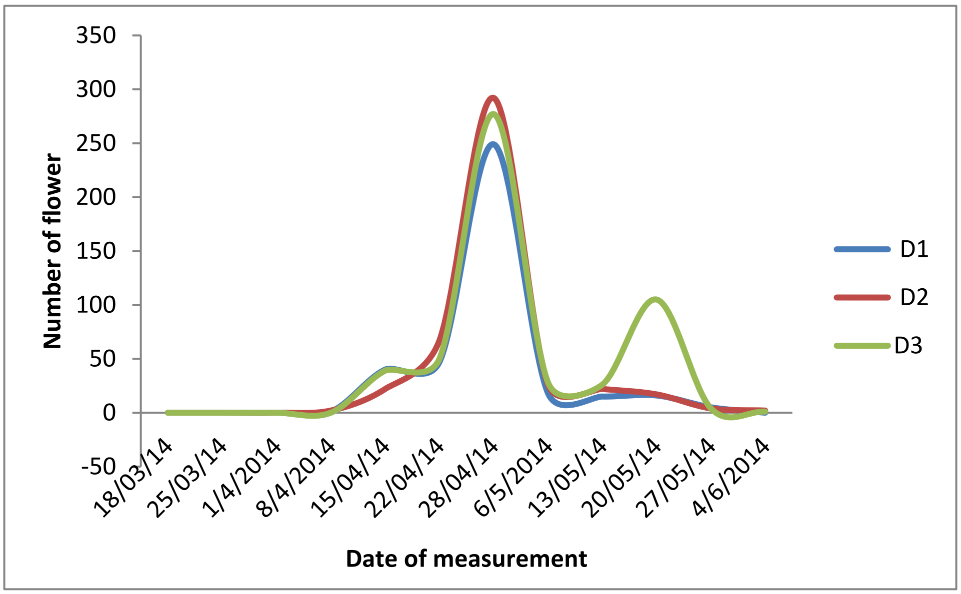

Figure 1: Effect of 7-day irrigation frequency on number of flowers

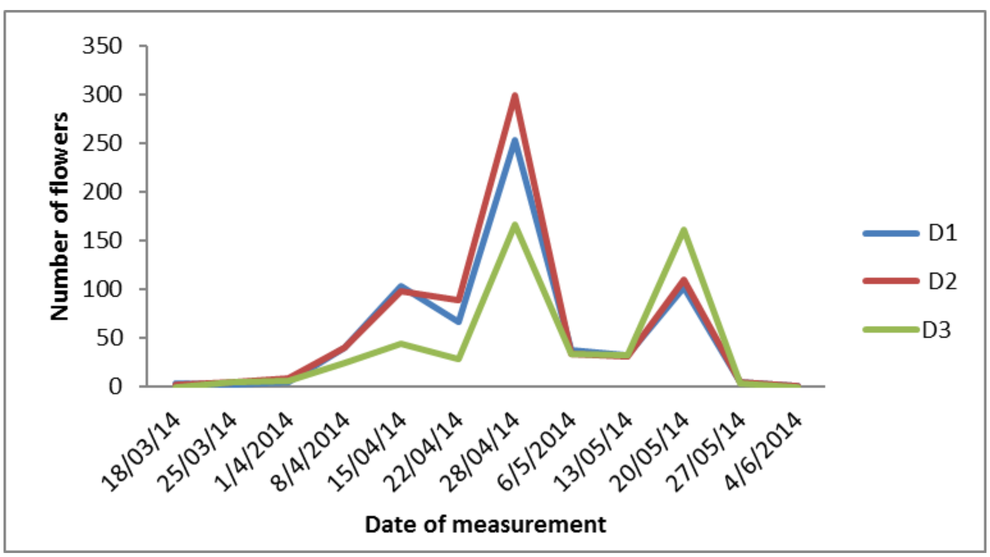

Figure 2: Effects of 5-days irrigation frequency on number of flowers

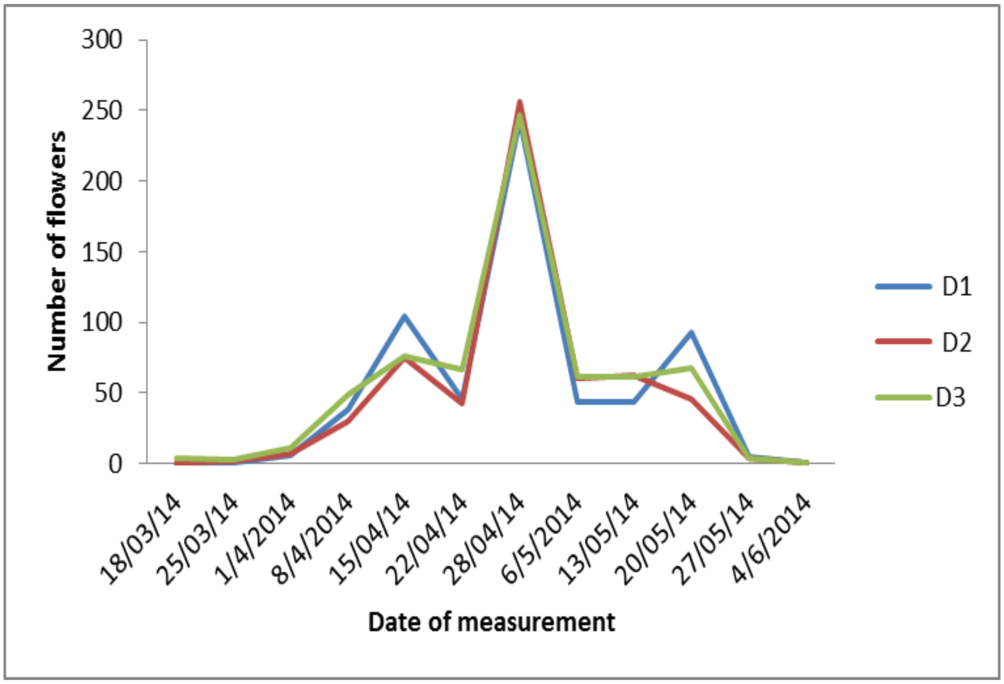

Figure 3: Effects of 3-days irrigation frequency on number of flowers

3.2 Number of fruits

From Figures: 4 – 6, it is clearly shown that similar trend was observed in all the treatments and that there was a significant fluctuation in the number of fruits produced. The highest values were obtained from depth of water application with 75% ET_C (D_2). It was reported according to Ponce *et al.* (1996) that plants under any kind of stressed conditions tends to shorten their life span and try to complete life cycle in haste which causes the minimum flowering and fruiting of plants. Candido *et al.* (1999) also reported that, drought reduces fruit growth, size and excessive fluctuations in soil moisture content which may induce physiological disorders such as blossom and rot. This report is in agreement with this study. Irrigation frequency and water regime has a lot of impact on the number of flowers as this will in turn increase fruit yield and the quality of tomato. It was observed also, in the cause of this study, that fruit growth and size reduces due to the fluctuations in the soil moisture content and the variation in number of fruits was due to irrigation frequency which was very small.

For the mean number of fruits, frequency F_1 had the highest and it was significantly different from F_2 and F_3 though, not significantly different from F_2 at probability level of 5% ($P < 0.05$). Owusu-Sekyere *et al.* (2012) in their research suggested that, a slight reduction of water requirement of tomato does not significantly affect the number of fruits formed. It was stated that above 10% water stress affects number of fruit. And according to Norman *et al.* (1995), the number of fruits decreases under water stress. However, 75% ET_C of tomato is the best depth of water application required to grow quality fruits of tomato as the number of flowers will determine total fruits number that will be produced. The results of the growing season for the number of fruits are presented in Table 4 – 6 respectively.

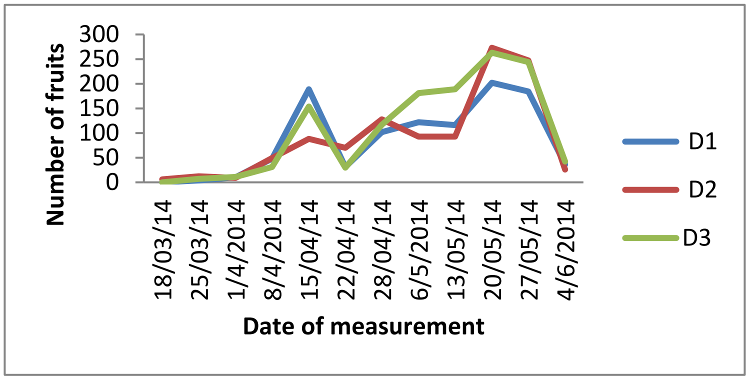

Figure 4: Effects of 7 – days irrigation frequency on number of fruits

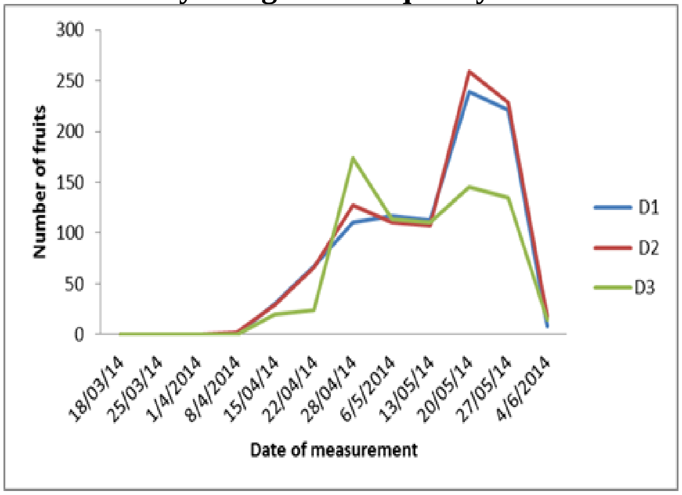

Figure 5: Effects of 5 – days irrigation frequency on number of fruits

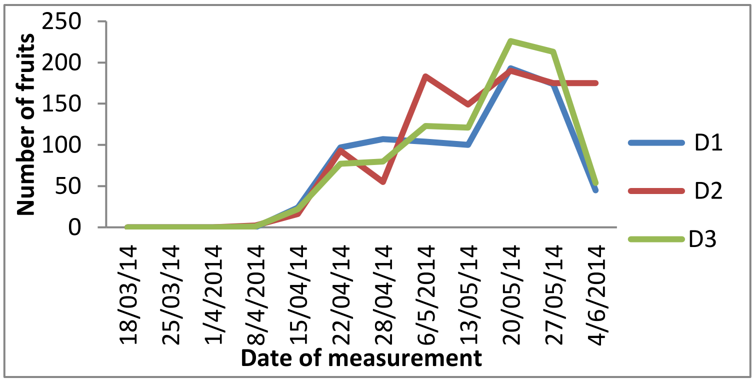

Figure 6: Effect of 3-day irrigation frequency on number of fruits

Table 4: Effects of drip irrigation frequency and depths on number of fruits for 7-days interval in tomato

Date	F1D1	F1D2	F1D3	F	D	FxD
18/03/14	0	0	0	*	*	*
25/03/14	0	0	0	*	*	*
1/4/2014	0	0	0	*	*	Ns
8/4/2014	2.333333	-2E-17	4.63E-18	0.17ns	6.10*	0.17ns
15/04/14	12	29.66667	59	2.03ns	9.25ns	2.21ns
22/04/14	46.66667	61.66667	55.33333	0.20ns	0.29*	0.96ns
28/04/14	287	285.6667	244	0.62ns	3.70ns	1.64ns
5/5/2014	108.3333	136.6667	150.3333	0.41ns	0.53ns	0.96ns
13/05/14	106.3333	135.6667	155.3333	0.40ns	0.56ns	1.08ns
20/05/14	250.6667	263.6667	223	1.24ns	2.91ns	1.00ns
27/05/14	233.3333	240.6667	200.3333	1.18ns	2.88ns	0.88ns
4/6/2014	31.66667	38.66667	33	6.58*	0.16*	0.19ns

Table 5: Effects of drip irrigation frequency and depths on number of fruits for 5-days interval in tomato

Date	F2D1	F2D2	F2D3	F	D	FxD
18/03/14	0	0	0	*	*	*
25/03/14	0	0	0	*	*	*
1/4/2014	0	0	0	*	*	Ns
8/4/2014	1.333333	3.93E-17	2.7E-17	0.17ns	6.10*	0.17ns
15/04/14	11.33333	21.33333	45.66667	2.03ns	9.25ns	2.21ns
22/04/14	76.33333	54	53.33333	0.20ns	0.29*	0.96ns
28/04/14	322.3333	190.6667	205.3333	0.62ns	3.70ns	1.64ns
5/5/2014	158.3333	94.66667	86.66667	0.41ns	0.53ns	0.96ns
13/05/14	155	91	83.33333	0.40ns	0.56ns	1.08ns
20/05/14	280.3333	174.6667	187	1.24ns	2.91ns	1.00ns
27/05/14	251	158.3333	174	1.18ns	2.88ns	0.88ns
4/6/2014	17.33333	10.33333	12	6.58*	0.16*	0.19ns

Table 6: Effects of drip irrigation frequency and depths on number of fruits for 3-days interval in tomato

Date	F3D1	F3D2	F3D3	F	D	FxD
18/03/14	0	0	0	*	*	*
25/03/14	0	0	0	*	*	*
1/4/2014	0	0	0	*	*	Ns
8/4/2014	1.666667	1.8E-16	-4.2E-16	0.17ns	6.10*	0.17ns
15/04/14	22	16.33333	22.66667	2.03ns	9.25ns	2.21ns

22/04/14	35	40.33333	79.33333	0.20ns	0.29*	0.96ns
28/04/14	287	176	282.3333	0.62ns	3.70ns	1.64ns
5/5/2014	154	106.6667	148	0.41ns	0.53ns	0.96ns
13/05/14	149	104	116.6667	0.40ns	0.56ns	1.08ns
20/05/14	249.6667	156	201.6667	1.24ns	2.91ns	1.00ns
27/05/14	229.6667	145	186.3333	1.18ns	2.88ns	0.88ns
4/6/2014	106.6667	69	97.33333	6.58*	0.16*	0.19ns

3.3 Yield of tomato

The effects of irrigation frequency and depth of application had an influence on fruit yield as shown in Figure (7). This is in agreement with Byari and Al-sayed, (1999) who found a reduction in fruit mean mass due to increased irrigation intervals (1, 2, 3, 5) and their findings were explained to establish that plants were under water stress because, irrigation regime has a major influence on the soil moisture profile. Irrigation frequency in this work had a significant effect on yield of tomato. Pulupol *et al.,* (1996) and Byari and Al-sayed, (1999) in their research findings ascribed poor plant yield to plants grown under water stress or increased time of irrigation intervals between successive irrigations. The average fruit yield obtained for 7, 5 and 3 day frequencies of irrigation were 54.5, 62.4 and 92.3 tones/ha, irrigation frequency and regimes have significant effects on number of leaves, fruits and flowers, plant height, yield and overall growth performance of the tomato fruit as reported in Table 1.

The differences in irrigation frequencies may be enough to cause water to be limiting factor for yield of tomatoes. Several researchers have reported that frequency of irrigation and quantity of nutrient in solution applied to plants affect yield (May and Gouzale (1994); Peet and Willits (1995); Singandhupe *et al;* 2002). Figure 4.19 shows the yield for 3, 5 and 7 days irrigation frequencies and for the three depth of application (100, 75 and 50% ETc). The results indicated that 3-days irrigation frequency increased the average yield by 30% over the highest yield of 5-days and 45% over that of 7-days irrigation frequencies. The average yield of 3-days irrigation frequency was 92.3 ton/ha while 62.4 ton/ha for 5-days and 54.5 ton/ha for 7-days frequencies. The results of 5 and 7-days irrigation frequencies indicated that irrigation at 3-days frequency with 50% ETc was the best as it produces 92.5 ton/ha over the others Table 7.

The average fruit yield obtained for 7, 5 and 3 days frequencies of irrigation and at the depth of water applications of 100, 75 and 50% ET was 54.5, 62.4 and 92.3 tones/ha respectively in this study. The fruit yield obtained were higher than values reported by Zotarelli *et al.* (2009) for tomato yield of 28, 56 and 79 mg/ha for three years (2005, 2006 and 2007) for tomato variety Florida 47. This is due to poor fruit set resulting from temperature that is generally above optimum range for good fruit set (Simon and Sobulo, 1974). Moreover, the fruit yield obtained were comparable with the values reported by Saleh *et al.* (2008) for tomato yields of 66, 63, 61, 58 and 56 tones/ha at irrigation period of day time (DT), evening time (ET), day night time (DNT), night time (NT) and morning time (MT) respectively, this results is due to poor tomato yield to non-development of flowers into fruits (Adelana, 1975) and multiple water application due to type of soil used. The values are in similar trend with the values reported by Badr and El-Yazied, (2007) for highest tomato average total fruit yields of 67.75, 65.13 and 63.29 tones/ha with frequencies of 1, 3 and 7 days respectively.

The values obtained also from the field are similar to fruit yields reported by Zhai *et al.*, (2010) for tomato yields of 76, 52.84 and 38.12 tones/ha at 3, 4 and 2 days frequency of irrigation, the results obtained is due to long internal or low frequency of irrigation which could not result in a good fruit yield especially when the water is applied in low amount at each irrigation period. It was estimated that national average yield of tomato is 114 tones/ha while the world production in terms of total fruit yield in 2007 – 2008 were estimated at 746.4 tones/ha. Also, U.S.A and Taiwan yields obtained were 175 and 178 tones/ha (Bowen and Kraktu, 1982), Nigeria obtained 5 tones/ha in Western part and 20 tones/ha in Northern part of the country (Quinn, 1980; Adelana, 1978). In total, the fruit yields obtained in my research field were 209.2 tones/ha which falls within the range of the yield obtained according to Badr and El-Yazied, (2007), Saleh *et al.*, (2008) and Zhai *et al.*, (2010) with the total yield of 196.2, 304 and 167 tones/ha respectively. The yields obtained is significantly different at ($P<0.05$). However, the average yield of tomato and the statistical results of the growing season of tomato field experiments in 2014 are presented in Table 4.10.

Table 7: Average yield of tomato (ton/ha) during growing season

Treatments	Tomato yield (ton/ha) March-June, growing season
F1	54.5
F2	62.4
F3	92.3
LSD (*P>0.05*)	
F	6.27*
D	2.28*
F x D	1.65*

F1: Weekly irrigation interval; F2: 5 days irrigation interval; F3: 3 days irrigation interval; F: irrigation frequency; D: irrigation depth of application; F x D: frequency and depth interaction; * significant at 5% level of probability by Fisher's Least square difference (LSD).

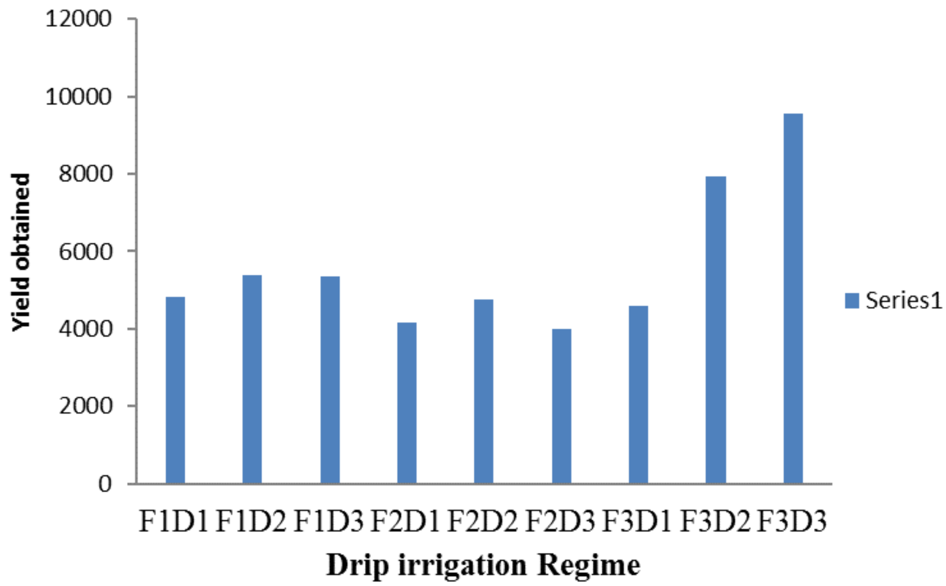

Figure 7: Effect of irrigation Frequency and Water Applied on Yield Obtained

4. CONCLUSION

A two factor Randomized Complete Block Design (RCBD) for frequency of water application and depth of water application on tomato (*lycopersicon esculentum* M.) was carried out and evaluated at the Department of Agricultural Engineering Experimental Field, Ladoke Akintola University of Technology, Ogbomoso, using drip irrigation method.

The is made up of three treatments and three replicates giving rise to 27 plots each of which was 2 m by 2 m with a spacing 0.5 m within row and 1 m in between row. Soil physical properties were determined as well as the frequency of water application and depth of water application were considered to calculate or estimate the growth parameters and yield of tomato.

It was observed that drip irrigation frequencies with different water regimes have significant effects on the yield of tomato. Therefore, it can be concluded that drip irrigation is the best method of irrigation for the production of tomato in the area of study.

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PAPER: NIAE/ EKO/ E023

PREDICTABILITY EFFECTS OF SEA SURFACE TEMPERATURE (SST) OF GULF OF GUINEA (GOG) ON LENGTH OF GROWING SEASON (LGS) IN BENIN-OWENA RIVER BASIN NIGERIA

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ABSTRACTS

The direct interface that exists between Atlantic Ocean and Benin-Owena River Basin calls for this study. Data used for this study were annual NOAA extended reconstructed sea surface temperature (SST) for 55 years (1951- 2005) and daily rainfall data for 55 years (1951- 2005) for 80 locations over Benin- Owena River Basin Nigeria, obtained from the archives of Northern Oceanic and Atmospheric Administration (NOAA_ GDFL_SRCA4), U.S Department of Commerce. The objective of this study is to develop regression model and establish the coefficient of determination (R^2) for SST and LGS using SPSS. The results showed that the mean of SST was 27.43^{0}C. The longest and shortest LGS means are 177 days and 163 days LGS at Longitudes 7.92 E and 3.96 E respectively. The values of coefficient of determination (R^2) and predictability (P) for all the locations ranged from 0.00 to 0.5 revealing that SST is not a good predictor of LGS.

Keywords: Length of Growing season, good predictor, coefficient of determination, sea surface temperature and Gulf of Guinea

1.0 INTRODUCTION

It is obvious from numerous studies that sea surface temperature generated numerous by products such as El Nino Southern Oscillation (ENSO), EL Nino, La Nina, teleconnections and so on, that influence the rainfall pattern and climate conditions beyond the tropics which invariably takes tolls on the socio-economic and ecosystem of many places including the study area (Cane.,2000).

El Nino Southern Oscillation (ENSO) is part of teleconnections, as resulted from amongst other factors the inter-annual warming and cooling of equatorial pacific sea surface temperature (SST). The term teleconnections is usually defined as a coherent atmospheric response resulted from sea surface temperature or atmospheric pressure patterns, or it can simply refer to climate anomalies being related to each other at typically large distance of thousand Kilometres (Glantz et al., 1991). .

El Nino and La Nina are opposite phases of what is known as ENSO. ENSO is described scientifically as the fluctuations in temperatures between the ocean and atmosphere in the east-central Equatorial while La Nina and El Nino are complex weather patterns emerged due to variations in Ocean temperatures in Pacific and sometimes referred to as the cold and warm phases of ENSO respectively. El Nino also tends to cause warmer than average conditions over parts of the tropics and in the extra-tropics (Halpert and Ropelewski, 1992). For instance, 1998, a year of a very large El-Nino event, is the warmest year of the satellite record in the global average (Chase *et al*.,2004).

The strategic location of Benin-owena River Basin informed this study as it has direct interface with the Atlantic Ocean both in terms of Ocean-Atmosphere interaction and runoff discharge. Benin-Owena River Basin falls within West Littoral Atlantic drainage system of 100, 500 Km^2 which extended over states of Ekiti, Ondo, Edo and Delta (Bashr and Garba, 2003).

Hydrological, ecological and human systems of this Basin have experienced amongst other deforestation, change in land use patterns, obliteration of natural water courses and urbanization which ostensibly altered some vital decisions as regard to agricultural planning, adaptation strategies, food security and sustainable management of ecosystem; and to address such developments, Ogutunde *et al* (2012) opined that proper understanding of patterns, distribution and change in rainfall onset dates (ROD), rainfall cessation dates (RCD) and length of growing season (LGS) is crucial.

Various studies have come out with results showing factors that may influence the climate of Nigeria which amongst others include sea surface temperatures, wind, shear, tropospheric jets, potential equivalent temperature gradient, the position and strength of the Saharan heat low and the migration of inter-tropical Discontinuity (ITD) with associated vegetation, soil moisture, topography and air masses (Amassah-Authur and Jagtap, 1999; Abiodun *et al.,*2002; Omotosho and Abiodun, 2007 & Oguntunde *et al.,* 2014). Sea surface temperature model is one of the methods used to estimate annual rainfall (Lamb and Peppler, 1992; Janicot *et al.,* 1998). Shang-Ping & James A. Carton (2004) studied Tropical Atlantic variability as regards its patterns, mechanism and impacts and the result showed that when equatorial Atlantic is uniformly warm, anomalies of cross-Equatorial SST gradient and the Inter-tropical convergence zone (ITCZ) are closely coupled, resulting in anomalous rainfall over north-east trades and SST over the northern tropical Atlantic.

Allison Rogers (2011) reported that growing season widens due to global warming. Kunkel (2016) reported that the length of the growing season has increased more rapidly in the West than in the East of United States of America. Also in Nigeria, length of growing season varies along agro-ecological zones thus; savanna and Guinea regions are currently experiencing reduction in length of growing seasons and Sahel zone was showing increasing length of growing seasons (Oguntunde *et al.,* 2014); and short-falls in the length of growing season reduces in the frost zone (Bello, 1996).

Previous studies have adequately addressed length of growing seasons showing analysis of spatial and temporal patterns in onset, cessation and length of growing season (Oguntunde, 2014); evidence of changes in pattern and trends in the monthly, season and annual rainfall amount over time and space in Nigeria (IITA, 1992; Jagtap, 1995 & Oguntunde *et al*., 2012); differences in rainfall characteristics for different regions of Nigeria (Olaniran and Summer, 1989, and Edoga, 2007). This study is to develop model and establish the coefficient of determination (R^2) for SST and LGS, and as well as to ascertain if sea surface temperature is a good predictor of length of growing season.

2.**0 DATASETS AND METHODS**

2.1 Description of research Location

The research location, which is Benin-Owena River Basin (figure 1) lies between longitude of $5^{0}.36^{1}00^{11}$N and $8^{0}12^{i}13^{ii}$N and latitude of $4^{o}14^{i}30^{ii}$ E and $6^{0}31^{1}35^{11}$E. Benin-Owena River Basin, covering littoral states of Ondo, Edo and Delta in Southern Nigeria and Ekiti state, falls within West Littoral Atlantic drainage system. West littoral has drainage areas of 100, 500 Km^2 and contained 10 Smaller sub-hydrological areas and 18 Sub-sub hydrological areas (Bashr and Garba, 2003). The study area experiences frequent rainfalls between April and July with a short break in August and continues between September and November, with the heaviest rainfall in July. The average daily temperature is ranging from 22ºC during Harmattan season (December-February) to 32ºC in March (the peak temperature) and the annual rainfall is ranging between 1800 mm to 3000 mm. The vegetation is tropical rainforest (Uluocha and Ekop, 2002).

Gulf of Guinea is the northeastern most part of the tropical Atlantic Ocean between cape Lopez in Gabon and cape Palmas in Liberia with total area of 2. 35 Million Km^2 and it has Atlantic and Niger River as the sea and river sources which cut across Basin Countries of Ghana, Togo, Benin and Nigeria.

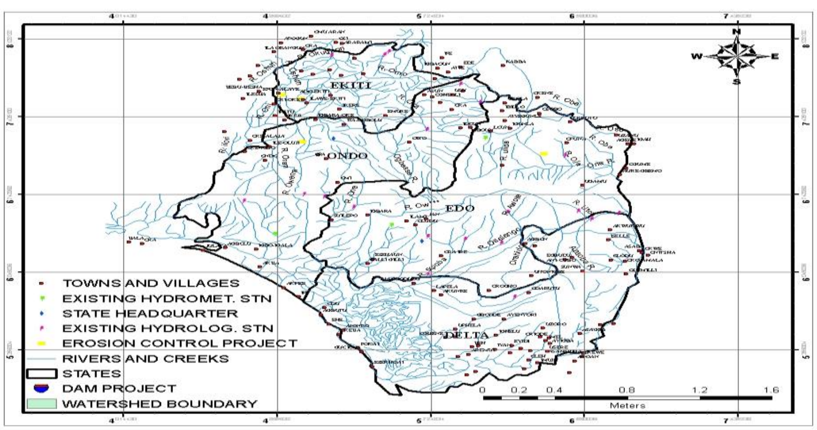

Figure 1: GIS Map of Benin-Owena River Basin

2.2 DATASET

Data used for this study were annual NOAA extended reconstructed sea surface temperature (SST) for 55 years (1951- 2005) and daily rainfall data for 55 years (1951- 2005) for 80 locations over Benin- Owena River Basin Nigeria, obtained from the archives of Northern Oceanic and

Atmospheric Administration (NOAA_ GDFL_SRCA4), U.S Department of Commerce. Daily rainfall data covered latitudes 7.92 N, 7.48 N, 7.04 N, 6.6 N, 6.16 N, 7.72 N, 5.28 N and 4.84 N and each latitude, has longitudes 3.96 E, 4.4 E, 4.84 E, 5.28 E, 5.72 E, 6.16 E, 6.6 E, 7.04 E, 7.48 E and 7.92 E respectively to make it 80 locations. Annual SST data, covered down westward of Atlantic Ocean were sourced from the archives of Northern Oceanic and Atmospheric Administration, U.S department of Commerce on longitude 3W(-3) to 2E (XT Ave), latitude 3N to 5N (XY Ave).

2.2.1 Estimation of Onset, Cessation and Length of Growing Season

Rain onset and cessation were calculated based on Odekunle (2004) which defined onset as the date when an accumulated 7-8 % of the annual rainfall total is obtained and cessation as the date when an accumulated 90 % of the annual rainfall total is obtained for a given station.

Meanwhile, length of growing season was calculated based on Oguntunde *et al* (2014) which defined length of growing season (LGS) as the number of days between the onset and cessation and it is simply determined by finding the differences between the rain cessation dates and rain onset dates (i.e LGS= RCD- ROD).

The onset of rains or the start of the growing season was defined as the receipt of adequate amount of rainfall for the survival of seedling after sowing (Ati *et al*., 2002). It is considered as one of the most important characteristics to which other seasonal rainfall attributes are related (Oguntunde *et al.,*2014).

Cessation has been defined as 'the last useful rain' or last precipitation that contributes to available water to a crop sown after onset date (Omotosho *et al.,* 2000). Similarly, Odekunle (2004) defined ' growing season' as the period of the year during which rainfall is sufficiently suitable for sowing, germination, establishment and full development of crops.

2.2.2 **Measurement and Estimation of Sea Surface Temperature**

Sea surface temperature is measured by various instruments at various depths. SST is majorly measured by Satellite microwave, Radiometer, Infrared Radiometers, Instu moored, drifting and buoys. These instruments have various degrees of accuracy and they are being improved upon over time.

For examples, most buoys have sensors located at about 1 meter depth, or at regular interval along a tether line; Infrared radiometer measure a depth of about 20 micrometers an micro wave radiometers measure a depth of a few millimeters in the space. Gentemann *et al.,* (2010) reported that microwave instruments TIMI, AMSR-E, AMSR2, WindSat, and GMI all measure multiple frequencies that are more than sufficient to remove the surface roughness and atmospheric effects, and prior to 1997, SST were only available globally from IR Satellite retrievals but with the launch of TIMI, micro wave retrieval became possible. As regards the annual SST was calculated by finding the average of daily monthly values i.e values for month of January to December were divided by twelve to have annual SST, and this was achieved through excel package.

3.0 RESULTS AND DISCUSSIONS

3.1 Means and standard deviations of SST and LGS at different locations

Table 1 showed the means and standard deviations (SD) of SST and LGS at different locations of the study. It showed that while the mean of SST was 27.43°C with a standard deviation of 0.50, the LGS has the highest mean at Long. 7.92 E with mean length of 177 days (SD = 11.21 days) and the least mean at Long. 3.96 E with mean 163.23 days (SD = 10.95 days).

Table 1: Means and standard deviations of SST and LGS at different locations

Variable	Mean	Standard Deviation
SST	27.43	0.50
LGS at Long. 3.96E	163	10.95
LGS at Long. 4.4E	164	11.16
LGS at Long. 4.84E	166	10.73
LGS at Long. 5.28E	170	13.29
LGS at Long. 5.72E	173	11.05
LGS at Long. 6.16E	175	10.88
LGS at Long. 6.6E	171	11.58
LGS at Long. 7.04E	173	10.39
LGS at Long. 7.48E	175	9.46
LGS at Long. 7.92E	177	11.21

3.2 Regression Coefficients between SST and LGS at various locations

The results of regression coefficients and models generated between SST and LGS for various locations are illustrated in tables 2 to 11.

Table 2: Regression coefficients between SST and LGS at Longitude 3.96 E

Model	B	Se	T	P
(Constant)	27.432	1.030	26.621	.000
LGS at Long. 3.96E	-0.00002	.006	-.004	.997

R^2=0.00; $F_{I.53}$=0.000; p=0.997

The model of SST on LGS (Long. 3.96 E) is: **SST = 27.432 - 0.00002 LGS (Long. 3.96 E)**

All the parameters measured reveals that the relationship is not significant (P > 0.05) and the coefficient of determination (R^2) is zero revealing that LGS is not a good predictor of SST as it accounted for zero percent of the variability in the SST.

Table 3: Regression coefficients between SST and LGS at Longitude 4.4 E

Model	B	Se	T	P
(Constant)	27.595	1.017	27.134	.000
LGS at Lat. 4.4E	-.001	.006	-.165	.870

R^2=0.00; $F_{I.52}$=0.027; p=0.870

The model of SST on LGS (Long. 4.4 E) is: **SST = 27.595 + 0.001 LGS (Long. 4.4 E)**

All the parameters measured reveals that the relationship is not significant (P > 0.05) and the coefficient of determination (R^2) is zero revealing that LGS is not a good predictor of SST as it accounted for zero percent of the variability in the SST.

Table 4: Regression Coefficients between SST and LGS at Longitude 4.84 E

Model	B	Se	T	P
(Constant)	27.196	1.070	25.429	.000
LGS at Lat. 4.84E	.001	.006	.217	.829

R^2=0.00; $F_{I.53}$=0.047; p=0.829

The model of SST on LGS (Lat. 4.84 E) is: **SST = 27.196+ 0.001 LGS (Long. 4.84 E)**

All the parameters measured reveals that the relationship is not significant (P > 0.05) and the coefficient of determination (R^2) is zero revealing that LGS is not a good predictor of SST as it accounted for zero percent of the variability in the SST.

Table 5: Regression Coefficients between SST and LGS at Longitude 5.28 E

Model	B	Se	T	P
(Constant)	27.450	.884	31.053	.000
LGS at Long. 5.28E	.000	.005	-.025	.980

R^2=0.00; $I._{L53}$=0.001; p=0.980

The model of SST on LGS (Long. 5.28 E) is: **SST = 27.450+ 0.0001 LGS (Long. 5.28 E)**

All the parameters measured reveals that the relationship is not significant (P > 0.05) and the coefficient of determination (R^2) is zero revealing that LGS is not a good predictor of SST as it accounted for zero percent of the variability in the SST.

Table 6: Regression Coefficients between SST and LGS at Longitude 5.72 E

Model	B	Se	T	P
(Constant)	26.382	1.069	24.670	.000
LGS at Long. 5.72E	.006	.006	.980	.331

R^2=0.02; $F_{I.53}$=0.961; p=0.331

The model of SST on LGS (Long. 5.72 E) is: **SST = 26.382+ 0.006 LGS (Long. 5.72 E)**

All the parameters measured reveals that the relationship is not significant (P > 0.05) and the coefficient of determination (R^2) is 0.02 revealing that LGS is not a good predictor of SST as it accounted for 2% of the variability in the SST.

Table 7: Regression Coefficients between SST and LGS at Longitude 6.16 E

Model	B	Se	T	P
(Constant)	25.947	1.091	23.786	.000
LGS at Long. 6.16E	.008	.006	1.360	.180

R^2=0.03; $F_{l.53}$=1.850; p=0.180

The model of SST on LGS (Long. 6.16 E) is: **SST = 25.947+ 0.008 LGS (Long. 6.16 E)**

All the parameters measured reveals that the relationship is not significant (P > 0.05) and the coefficient of determination (R^2) is 0.03 revealing that LGS is not a good predictor of SST as it accounted for 3% of the variability in the SST.

Table 8: Regression Coefficients between SST and LGS at Longitude 6.6 E

Model	**B**	**Se**	**T**	**P**
(Constant)	25.792	.995	25.922	.000
LGS at Long. 6.6E	.010	.006	1.647	.105

R^2=0.05; $F_{l.53}$=2.714; p=0.105

The model of SST on LGS (Long. 6.6 E) is: **SST = 25.792+ 0.010 LGS (Long. 6.6 E)**

All the parameters measured reveals that the relationship is not significant (P > 0.05) and the coefficient of determination (R^2) is 0.05 revealing that LGS is not a good predictor of SST as it accounted for 5% of the variability in the SST.

Table 9: Regression coefficients between SST and LGS at Longitude 7.04 E

Model	**B**	**Se**	**T**	**P**
(Constant)	26.008	1.134	22.932	.000
LGS at Long. 7.04E	.008	.007	1.255	.215

R^2=0.03; $F_{l.53}$=1.574; p=0.215

The model of SST on LGS (Long.7.04 E) is: **SST = 27.432 – 0.00002 LGS (Long. 7.04 E)**

All the parameters measured reveals that the relationship is not significant (P > 0.05) and the coefficient of determination (R^2) is 0.03 revealing that LGS is not a good predictor of SST as it accounted for 3% of the variability in the SST.

Table 10: Regression Coefficients between SST and LGS at Longitude 7.48 E

Model	B	Se	T	P
(Constant)	26.397	1.272	20.751	.000
LGS at Long. 7.48E	.006	.007	.812	.420

R^2=0.01; $F_{l.53}$=0.659; p=0.420

The model of SST on LGS (Long. 7.48 E) is: **SST = 26.397+ 0.006 LGS (Long. 7.48 E)**

All the parameters measured reveals that the relationship is not significant ($P > 0.05$) and the coefficient of determination (R^2) is 0.01 revealing that LGS is not a good predictor of SST as it accounted for 1% of the variability in the SST.

Table 11: Regression coefficients between SST and LGS at Longitude 7.92 E

Model	B	Se	T	P
(Constant)	26.841	1.086	24.720	.000
LGS at Long. 7.92E	.003	.006	.541	.591

R^2=0.01; $F_{l.53}$=0.293; p=0.591

The model of SST on LGS (Long. 7.92 E) is: **SST = 26.841+ 0.003 LGS (Long. 7.92 E)**

All the parameters measured reveals that the relationship is not significant ($P > 0.05$) and the coefficient of determination (R^2) is 0.01 revealing that LGS is not a good predictor of SST as it accounted for 1% of the variability in the SST.

4.0 CONCLUSION

The connection that exists between the ocean and atmosphere makes sea surface temperature to influence rainfall patterns throughout the World. For example, when El-Nino is warm over equatorial Pacific Ocean off South America, it will result into more humid in the Southwestern

United States of America but when El Nino cools western pacific, it will lead to less rain over Australia and Indonesia (https://earthobservatory.nasa.gov/globalmaps/TRMM_3B43M/AMSRE_SSTAn_M).

In this study, ten locations were considered for the determination of the predictability effects of SST on LGS, and the results showing coefficient of determination (R^2) ranging 001 to 0.5 which reveals that LGS is not a good predictor of SST.

5.0 RECOMMENDATION

It is recommended that further studies be conducted to determine the influence of SST on the rain intensity and frequency instead of rain onset and rain cessation which dictates length of growing season.

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AD001

DEVELOPMENT OF A PRECONDITIONING SYSTEM FOR FUTA FLOATING FISH FEED EXTRUDER

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ABSTRACT

The need to enhance the quality of fish feed produced in Nigeria was the major consideration in the design and development of a preconditioning system. The machine consists of two insulated cylindrical barrel, set of arranged paddles on a shaft, frame, hot water and feed mash inlet, discharge chute, chain and sprocket.It was powered by a three-phase 15hp electric motor which transmits power to the machines shaft and set of paddles via chain and sprocket. The performance characteristics of the machine; mixing efficiency and throughput capacity were evaluatedusing NIOMR feed formulation at feed mash particle sizes of 900 µm, 550 µm, 520 µm and paired paddle rotating speed of the lower and upper chamber at (96.8; 145.2), (122.6; 183.2) and (174.5; 260.8) rpm respectively.The throughput capacity of the preconditioner is 650 kg/hr. The results showed increase in temperature and moisture content level of the particles as the machine speed decreases.The optimum mixing efficiency that gave best uniformity of mix was attained when Paired paddle speeds were (96.8; 145.2), (122.6; 183.2) with an average Biot numbers of 0.1.

KEYWORDS: Design, preconditioner, mixing efficiency, throughput capacity, Biot number.

1. INTRODUCTION

Fish feed is a nutritional formulation which consists of different classes of food in the right proportion that aids fish growth.Fish feed can be classified into natural and artificial diet (Craig and Helfrich, 2002). Natural fish feeds are sourced from natural waters or well-fertilized ponds which are balanced diet that help fishes grow strong and healthy. Examples of this food source are microscopic plants (phytoplankton), microscopic animals (zooplankton), insects, crustaceans,copepodsandmolluscs (Bolorunduro, 2002). Artificial feeds can be complete or supplementary diets. Complete diets supply all the ingredients (protein, carbohydrates, fats, vitamins, and minerals) necessary for optimal growth and health of the fishin the right proportion. Most of this complete dietare formulated with protein (18-50%), lipid (10-25%), carbohydrate (15-20%), ash (< 8.5%), phosphorus (< 1.5%), water (< 10%), and trace amounts of vitamins, and minerals. While supplementary diet is used only to support the natural feeds with energy-based food in form of carbohydrate, proteins and fats & oil, but does not contain minerals and vitamin (Craig and Helfrich, 2002). They can be used in all fish culture system.Artificial feeds also known as commercial fish diets can be manufactured using well-compoundedmixtureoffeedstuffsandcanbe extruded (floating or buoyant) orpelleted (sinking) feeds (Craig and Helfrich, 2002).The estimated quantity of imported fish feed from European countries into Nigeria annually stand at 4000 tons (AIFP, 2004),this reducesthe country's foreign exchange earnings as few manufacturers that have ventured into production of fish feed in the country produce low quality feeds, import most of the key equipment used, which are very expensive and costly to maintain. This was evident inthe submission of FAO (2005), that the fishery industry has not achieved its goal of employment and social peace because the system is not operating in a sustainable and efficient manner. In commercial fish feed production, certain steps are taken to achieve extruded or pelleted feeds. They are selection of ingredients, grinding, mixing, preconditioning and extrusion, cooling and drying (Woynarovich*et al.*, 2011).Preconditioning which is one of the unit operationsin fish feed production is neglected by most manufacturers in Nigeria in order to reduce cost of production. The goal for preconditioning is to hydrate, pre-heat and mix powdery raw materials with injected fluids (steam, water and potentially oil or slurries) to obtain a homogeneous pre-cooked product that is best adapted to the next stage in fish feed production line. This operation improves extruder efficiency and reduces energy consumption, equipment wear and maintenance cost (Bailey *et al.*, 1995).Preconditioning systems allow greater flexibility in controlling process parameterslike temperature and moisture which extruders lackthat affects the quality of the feed (Vijayagopal, 2004).With no known report on any existing preconditioning system for fish feed production developed in Nigeria, this research to develop a preconditioning system for fish feed production was conceptualized with the aim of improving the feed quality produced by the newly developed FUTA fish feed extruder which canbe adopted to suit other extruders in Nigeria.

2. METHODOLOGY

2.1 Design considerations

The preconditioner was designed based on the following considerations:

i. The choice of materials used was based on their quality, availability, durability, efficiency, workability, desired goal and their suitability for construction.
ii. Preconditioner technology requires injection of heat and moisture in a closed system, so proper insulation material was used on the body frame of the equipment to retain heat inside the mixing chamber which reduces heat loss and burns to the user.
iii. Aesthetics was considered for the equipment to be appealing to consumers.
iv. The paddles were designed to achieve uniform mixing efficiency.
v. The assembly of the machine was made simple for easier maintenance.

2.2 Description of machine

The preconditioner as shown in Figures 1 and 2, consists of the paddles and shaft arrangement made of stainless steel for mixing and conveying the preconditioned feed mash. The internal cylindrical barrels (upper and lower chambers) are made of stainless steel and insulated with a Polyurethane foamto retain heat during mixing and held in place by a removable cover. They are supported by a frame made of 75 × 75 mm mild steel angle iron to withstand tensional and vibrational stress. The machine is powered by 15hpelectric motor operating at speed of 1460rpm. A reduction gear of ratio 5:1 which transmits power to the chain and sprockets that rotates the two shafts carrying the well-arranged sets of paddles. Thedifferent components of the preconditioner were designed and selected using standard engineering principle.

2.3 Operational principle of the fish feed preconditioner

The feed mash and hot water were introduced into the upper chamber of the machine through the feed mash and hot water inlet pipes simultaneously. The feed mash was hydrated, heated and conveyed radially into the lower chamber at high speed before being transferred to the discharge chute at reduced speed to increase retention time for adequate mixing of feed. The paddle angle between the two rotating shafts were configured such that though the shafts moved in the same direction, the feed mash were conveyed in the opposite direction.

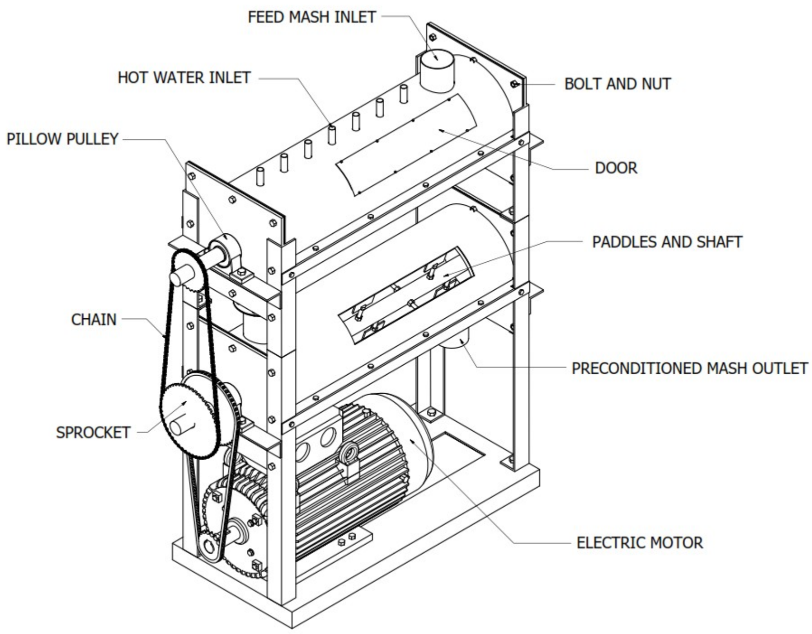

Figure 1: Isometric view of the fish feed preconditioner

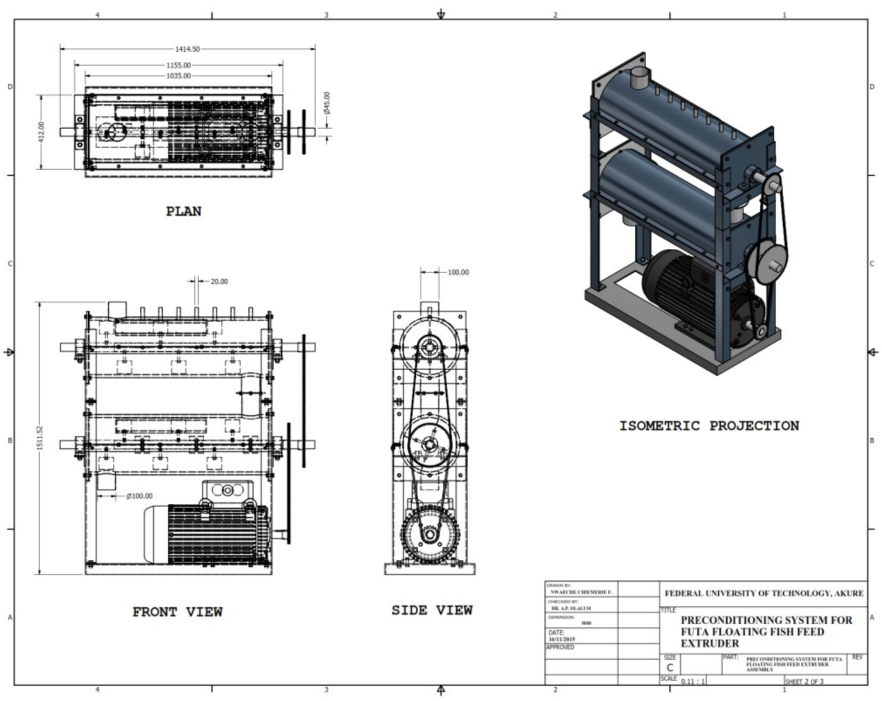

Figure 2: Orthographic projection of the machine

2.4 Design calculation

Determination of the upper chambers internal surface area

The chamber is made up of stainless steel. The chamber and other parts welded on it, is cylindrical in shape.

Let the surface area of the cylindrical parts is given by

$$C_A = 2\pi r(r+h) \tag{1}$$

Surface area of the inlet and outlet unit on the upper chamber

$$C_B = 2\pi r(r+h) \times 2 \tag{2}$$

Surface area of the hot water inlets (7 in number) on the upper chamber

$$C_c = 2\pi r(r+h) \times 7 \tag{3}$$

Total area, $T_A = C_A + C_B + C_C$ (4)

Determination of the lower chambers internal surface area

The chamber is made up of stainless steel. The chamber and other parts welded on it, is cylindrical in shape. The dimension used in the upper chamber for C_A and C_B was also used for the lower chamber.

Total area, $T_A = C_A + C_B$ (5)

Determination of the volume and mass of the upper internal chamber

$$Density = \frac{Mass}{Volume} \tag{6}$$

Density of stainless steel = 7930kg/m^3

$$C$$
$$Area \times Thicknes(¿¿A + C_B + C_C)$$
$$\therefore Volume = ¿ \tag{7}$$

$$\therefore Mass = Volume \times Density \tag{8}$$

Determination of the volume and mass of the lower internal chamber

$$Density = \frac{Mass}{Volume}$$

Density of stainless steel = 7930kg/m^3

$$\therefore Volume = ¿ Area \times Thicknes(¿¿ A + C_B) C \quad (9)$$

Design of Chain and sprockets

The chain drive system of this machine is made up of two chain and sprocket assemblies. One connecting the drive and lower chamber and the other connecting the lower and upper chamber of the machine. Based on investigation of existing preconditioners a rotational speed ranging from 150 – 400 rpm was selected for both chambers.

A moderate shock service condition with service factors (K_s) was selected from the manufacturer's catalogue.

$$K_s = K_1 \times K_2 \times K_3$$ (Khurmi and Gupta, 2005)

where $, K_1$ is load factor = 1.25, for mild shock

K_2 is lubrication factor = 1.5, for periodic lubrication

K_3 is rating factor = 1, for 8 hours per day

Lower and upper chamber chain drive system

Velocity ratio of a chain drive is given by

$$V.R \; ¿ \frac{N_1}{N_2} = \frac{T_2}{T_1}$$ (Khurmi and Gupta, 2005)

Where N_1 *is* speed of rotation of driving sprocket

N_2 *is* speed of rotation of driven sprocket

T_1 *is* number of teeth on the larger sprocket

T_2 *is* number of teeth on the smaller sprocket

Design power = rated power × service factors

Determination of pitch circle diameter of the driving and driven sprockets

$$d_1=\frac{P}{\sin\left(\frac{180}{T_1}\right)} \wedge d_2=\frac{P}{\sin\left(\frac{180}{T_2}\right)}$$ (Khurmi and Gupta, 2005)

Where d_1 and d_2 is pitch circle diameter of driving and driven sprocket respectively

P is chain pitch

T_1 and T_2 is number of teeth of the driving and driven sprocket respectively.

Pitch line velocity of the driving sprocket

$$V_1=\frac{\pi d_1 N_1}{60}$$ (Khurmi and Gupta, 2005)

Where d_1 is pitch circle diameter of driving sprocket

V_1 is pitch line velocity

N_1 is speed of rotation of driving sprocket

Total load on the driving side of the chain, W

$$W=\frac{rated\ power}{pitch\ line\ velocity}$$ (Khurmi and Gupta, 2005)

Design of power transmitted on the basis of breaking load, W_B

Breaking load W_B= 106p^2 (in Newton) for roller chains. (Khurmi and Gupta, 2005)

Where p is chain pitch

Safety factor, n = $\frac{W_B}{W}$ (Khurmi and Gupta, 2005)

Power transmitted, $P=\frac{W_B \times V_1}{n \times K_s}$ (Khurmi and Gupta, 2005)

Chain velocity, $V = \frac{T_1 P N_2}{60}$ (Khurmi and Gupta, 2005)

Where T_1 is number of teeth in the driving sprocket

N_2 is speed of rotation of the driven sprocket

P ischain pitch

Tangential driving force,

$$F_T = \frac{power\ transmitted\,(¿watts)}{speed\ of\ chain \in m/s}$$ (Khurmi and Gupta, 2005)

Centrifugal tension in the chain, $F_C = mv^2$ (Khurmi and Gupta, 2005)

Tension in the chain due to sagging, $F_S = Kmgx$

Where m *is* mass of the chain per metre

x is centre distance

g is acceleration due to gravity

K is constant (Khurmi and Gupta, 2005)

Total tension on the driving side of the chain, $T_T = F_T + F_C + F_S$

To calculate the centre distance between the sprockets

The minimum allowable centre distance between the driving and driven sprocket should be 30 to 50 times the pitch. Thus, for this model 30 times the pitch is selected.

30p = 30 × 25.4

In order to accommodate initial, say in the chain, the value of centre distance is reduced by 2 to 5mm

Correct centre distance, x = 762 – 4

(Khurmi and Gupta, 2005)

To calculate number of chain links

$$K = \frac{T_1 + T_2}{2} + \frac{2x}{P} + \left[\frac{T_2 + T_1}{2\pi}\right]^2 \frac{P}{x}$$ (Khurmi and Gupta, 2005)

To calculate chain length

$L = K * P$ (Khurmi and Gupta, 2005)

Design of shaft

Lower and upper chamber shaft design

Maximum bending moment

$M_b = \sqrt{M_v^2 + M_H^2}$ (Khurmi and Gupta, 2005)

Torsional moment M_t for the shaft

$M_t = \frac{P \times 60}{2\pi n}$ (Khurmi and Gupta, 2005)

Where P is the design power in watts and n is the speed of rotation in rpm for the driven sprocket.

Diameter of the shaft

The diameter of the shaft is given by

$$d^3 = \frac{16}{\pi S_s} \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$ (Khurmi and Gupta, 2005)

Where K_b and K_t are combined shock and fatigue factors applied to bending moment and torsional moment.

S_s is allowable stress for shaft with key way = 42MN/m^2

K_b and K_t are 1.5 and 1.0 respectively for rotating shaft.

Shaft is usually subjected to axial bending and torsional loads

For solid shaft

$$Tensile\ stress = \frac{4 f_a}{\pi d^2}$$

f_a is the reaction at bearings close to the chain and sprocket on the shaft of the upper and lower chambers

Bending load for lower and upper chamber shaft

$$Bending\ stress = \frac{32 M_b}{\pi d^3}$$

2.3 Preliminary test

The composition of the feed mash ingredient used and volume of water added in the mixture during preliminary test were according to suggestionproposed by Nigerian Institute for Oceanography and Marine Research (NIOMR). The Table 1 below shows the percentage composition by mass of the different ingredients used.

Table 1. Fish feed mass formulation used

S/N	Ingredient	Percentage composition by mass (%)
1.	Cassava flour	39
2.	Soymeal	20
3.	Groundnut Cake	20
4.	Fish meal	20
5.	Fish premix	0.5
6.	Nitox Antimould	0.5

Source: Nigerian Institute for Oceanography and Marine Research (NIOMR)

The machine was tested by varying feed mash particle sizes of 900, 550and 520 µm. The machine paddle speed were in pairs of (96.8; 145.2), (122.6; 183.2) and (174.5; 260.8) rpm. The first and second values in the bracket represents the paddle speed of the lower and upper chamber respectively. The initial moisture content and temperature of the formulated fish feed were taken before each run.Hot water at 100 °Cand feed mash were introduced into the preconditioner simultaneously at rate of 2 litres per 13kg batch. At the discharge, the weight of the final temperature and moisture content of the preconditioned feed were all determined. The thermal conductivity and volumetric heat capacity was determined using a single instrument called KD2 Pro which has 30 mm dual-needle sensor that was inserted into the feed mash which measures and displays its reading. Each run was repeated three times and their average was used for analysis. The throughput capacity and mixing efficiency were determined to calculate the performance indices of the machine.

Throughput capacity $T_{p,}$ was determined using equation (6) below.

$$T_p = \frac{W}{t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where, T_p is throughput capacity (kg/h)

W is weight of the feed mash collected (kg)

t is time taken for preconditioning (min)

Determination of mixing efficiency of the preconditioner

The mixing efficiency of the preconditioner was determined using the dimensionless Biot number *Bi*that is generated after mixing; when the Biot number (Bi) is less than 0.1 it means the preconditioner mixes poorly, intermediate when is approximately 1 and good mixing when the Biot number is greater than 10. Biot number is given by

$$Bi = \frac{\lambda r}{\alpha} \qquad \text{...} \ (10)$$

where λ = h_{fp} whichis heat transfer coefficient ($W/m^2/°C$)

α is thermal conductivity (W/°C/m)

r is radius sphere of the feed mash particle (m) (Urmas *et al.*, 2015)

$$\therefore h_{fp} = \frac{Q_{fp}}{A \Delta T} \qquad \text{...} \ (11)$$

where A is total area of the particles in the control volume

ΔT is temperature difference between fluid and particle temperature (°C)

(Tor, 2013)

$$\therefore Q_{fp} = Q_{fluid} - Q_{paste} \qquad \text{...} \ (12)$$

where Q_{fp} is heat flow from the fluid to the particles (W)

Q_{fluid} is convective heat flow of the fluid into the particles (W)

Q_{paste} is convective heat flow out of the paste (W)

$$Q_{fluid,\,paste} = mcp\left(\theta_1 - \theta_2\right) \qquad \text{...} \ (13)$$

where cp is volumetric heat capacity of the particles (MJ/m^3)

θ_1 is initial temperature of the particles and water (°C)

θ_2 is final temperature of the particles and water (°C)

m is mass of the fluid and particles (kg)

Substituting equation (13) in (12)

$$Q_{fp} = mcp(\theta_1 - \theta_2) - mcp(\theta_1 - \theta_2) \quad \text{.......................................} (14)$$

3. RESULTS AND DISCUSSION

The graphs below show the effect of the paired paddle speed on final moisture content and temperature of the preconditioned feed mash, residence time and mixing efficiency.

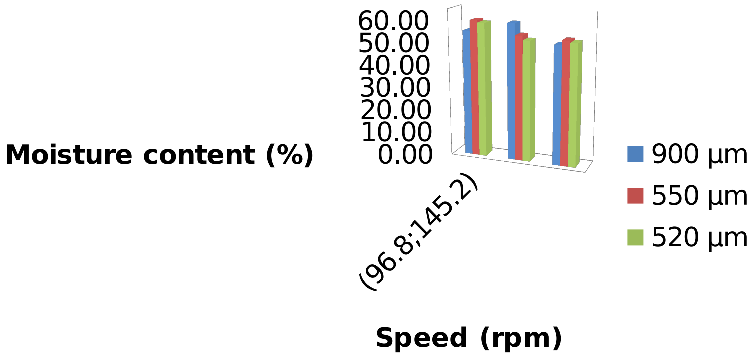

Figure 3: Variation in the moisture content with paired paddle speed in rpm and particles

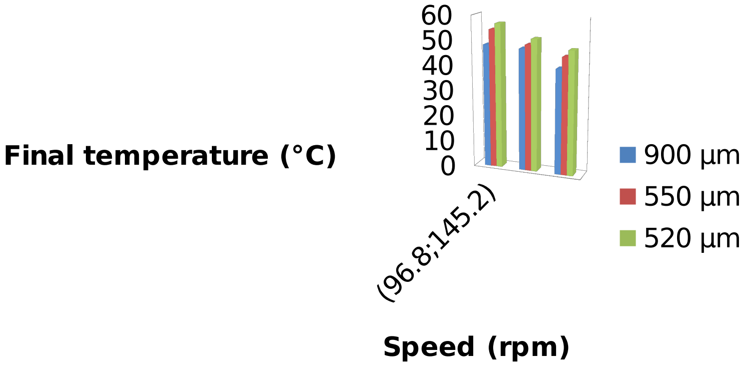

Figure 4: Variation in final temperature with paired paddle speed in rpm and particles

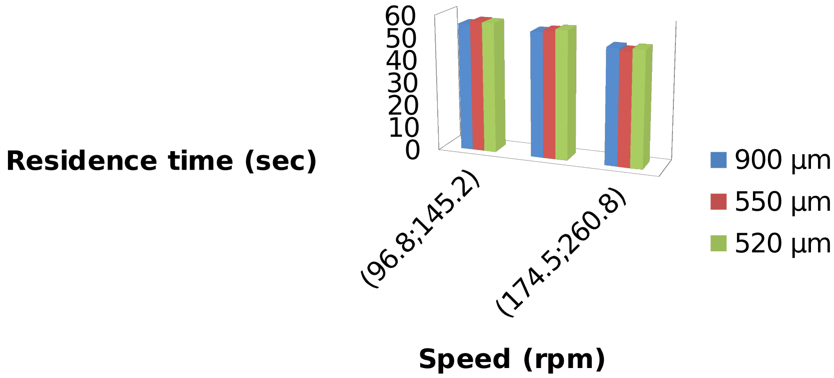

Figure 5: Variation in residence time with paired paddle speed and particles

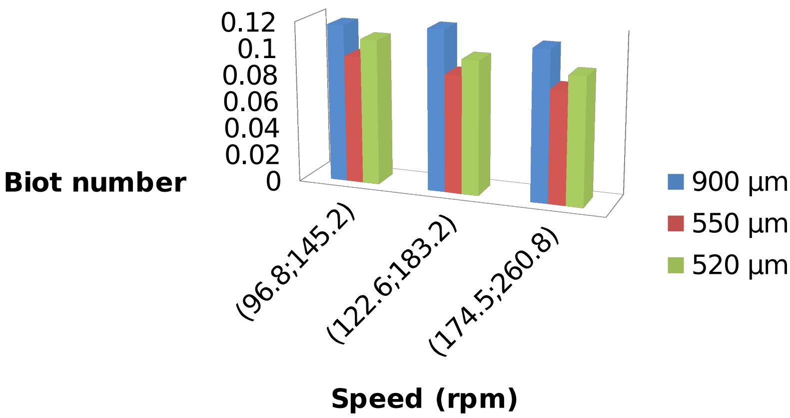

Figure 6: Variation in Biot number with paired paddle speed in rpm and particles

Figures 4, 5 and 6 shows that at paddle speed 174.5 and 260.8 rpm, the average retention time for all the particles was 49.9 seconds. At this speed the feed mashdischarged at a low temperature and moisture content level. The average temperature and moisture reading were 44.3 °C and 52.2 %, respectively. At paddle speed 122.6 and 183.2 rpm, the average retention time for all the particles was 55.46 seconds. This showed slight increase in temperature and moisture content level readings which averaged 47.6 °C and 55.1 % respectively due to increase in retention time. There were significant increase in temperature and moisture content reading at paddle speeds of 96.8 and 145.2 rpm.The average temperature and moisture content readings were 52 °C and 58.8%, respectively and an average retention time of 57.12 seconds for all the particles. This showed that all the particles absorbed more moisture and heat as the paired paddle speed of the preconditionerreduces with increasing retention time. This agrees with report by Eugenio (2004), that higher residence time improves the hydration and heat absorption rate of the preconditioned feed mash.

Figure 6 shows that, at paddle speed of 174.5 and 260.8 rpm, the average Biot number of all the particles was 0.09. However, at paddle speed of (122.6 and 183.2 rpm)and (96.8 and

145.2 rpm)the Biot number of all the particles was 0.1. This implies that the Biot number increases as the paddle speed is reduced for all the particles.

Previously reported by Eugenio (2004), this result shows that the evaluated preconditioner performed poorly at the selected speeds. However, it can be improved by further reducing the speed and increasing the retention time to obtain higher Biot number and hence higher mixing.

4. CONCLUSION

The preliminary evaluation of the machine in terms of mixing efficiency and throughput capacity indicates that it has high potential in improving the quality of feeds produced in Nigeria. Though, the mixing efficiency obtained from the test was low, further improvement on the operating conditions of the preconditioner will definitely increase the mixing efficiency of the system.

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AD002

CHARACTERISTIC STRENGTH OF WASTE SACK BAG FIBRE REINFORCED COMPOSITE BLOCKS (WSFRCB)

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ABSTRACT:
This paper presents the findings of an investigation on the strength properties of waste sack bag fibre-reinforced composite blocks. WSB fibre was used as reinforcement in blocks. Fibre contents of 0.5- 1.5 % (by weight of cement) with varied length of 35-40mm was used to produce a total of forty-eight composite blocks with 70.7 mm x 70.7 mm x 70.7 mm sizes and cured in water for 7, 14, 21 and 28 days . The density, water absorption and compressive strength were determined in accordance with BS Standards. The results showed that water absorption and density of the composite blocks increased as fibre increased. The results of tests at the 28 days showed that the compressive strength of the WSB fibre reinforced blocks ranged from 10.54 to 13.45N/mm^2 for 0.5-1.5% fibre content, compared to unreinforced blocks which were 9.04N/mm^2 for the same 28days respectively. Also, 1.5% fibre addition proved better by exhibiting a good interaction between the matrix and fibre bond as the composite adequately ductile under stresses. It was concluded that the WSB fibre can be used as reinforcement materials in the production of composite blocks, which renders more resistance to earthquake forces whilst reducing environmental pollution of such wastes in Nigeria.

Keywords: Waste fibre, Composite blocks, Compressive strength, Density, Water absorption.

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1. INTRODUCTION

One of the great contemporary challenges facing Nigeria and other developing countries in the world today is the issue of waste management. Organic and inorganic material residues form major percentage of waste generated from agricultural and industrial products. Unfortunately in developing countries like Nigeria, most of these wastes generated are wastefully disposed through land filling, spreading on reclaimed land, even sometimes deposited on water or stream way which easily causes flood that can result to loss of life and property. Continuous generation of wastes arising from industrial by-products and agricultural residue, create acute environmental problems both in terms of their treatment and disposal. However, numerous waste products have been used over years to produce composite material which involves combination of two or more materials results in better properties than individual components used alone (Lamidi, *et al*. 2016).

As noted by Alaa, *et al*. (2013), that recycling of such waste can serve as raw material alternative in brick making. It was reported that different tests conducted on the bricks manufactured from waste were exhibited high compressive strength greater than 12 times from the minimum standard recommended (Raut, *et al*. 2011). Organic waste fibres exhibit many advantageous properties as reinforcement for composites (Toledo, *et al*., 2003; Bilba, *et al*., 2003; Asasutjarit, *et al*., 2007; Olutoge, 2009; Ahmad, *et al*., 2010; Obilade and Olutoge, 2014). Natural fibre reinforced composites has gained more attention due to the low cost, easy availability, low density, acceptable specific properties, ease of separation, enhanced energy recovery, Co_2 neutrality, biodegradability and recyclable in nature Verma, *et al.* (2013).

It was reported that the advantages of composites over their conventional counterparts are the ability to meet diverse design requirements with significant weight savings as well as strength-to-weight ratio, improved torsional stiffness and impact properties, higher fatigue endurance limit (up to 60% of ultimate tensile strength), lower embedded energy compared to other structural metallic materials like steel, aluminum etc also, composites are less noisy while in operation and provide lower vibration transmission than metals, they are more versatile than metals and can be tailored to meet performance needs and complex design requirements, long life offer excellent fatigue, impact, environmental resistance and reduce maintenance. They also enjoy reduced life cycle cost compared to metals and exhibit excellent corrosion resistance, fire retardancy and improved appearance with smooth surfaces (Chandramohan and Marimuthu, 2011; Lamidi, *et al.;* 2016a).

Lamidi, *et al.* (2016b) reported that the various waste products have been used over the years to produce composite material which a combination of two or more materials that results in better properties than when the individual components are used alone. Conclusively, Oladele, *et al.* (2009) had reported that natural organic fibres have a prominent role to play in the housing problem alleviation in the world, because their abundance are not for luxurious but for good purposes like energy saving, conservation of the world's most scarce resources and human protection and his environment. Therefore, these is a gradual shifting from the use of conventional materials to newer materials like fibre, reinforced plastics, aluminum, new varieties of bricks, cement, glass and steel due to economic enhancement of the said materials. The aim of this study, therefore, was to produce and to determine the strength properties of Waste Sack bag Fibre reinforced composite blocks, produced with different fibre content thereby reducing environmental pollution from such waste generated.

2. MATERIALS AND METHODS

Materials

The materials required for this research work were locally sourced. These included waste sack bags, wooden moulds, 20 mm iron-rod, water, sand and cement. The waste sack bags were obtained from vendor dumped site located at Bodija Market Ibadan, Oyo State, Nigeria. The waste sack bag was separated and cut into a size range of 35-40mm length as shown in Plate 1 ready for use in the mixtures.

Plate 1: Fibre used in this study

2.1.2 Cement

The cement used was Ordinary Portland Cement. It was sourced from Ibadan, Oyo State, Nigeria and conformed to the requirement of BS EN 197- : 2000.

2.1.3 Fine Aggregate

The sand used in this research work was locally sourced from Ibadan, Oyo State, Nigeria. The impurities were removed and conformed to the requirements of BS 882 (1992).

2.1.4 Water

The potable water was used in all the mixes in accordance with the requirement of water concreting and curing as specified by BS 3148 (1980).

3.0 PREPARATION AND CASTING OF TEST SPECIMENS

The proportion of the constituents for the prepared cement composite mix is 1:3 (by weight) of cement and sand of maximum size 4.75 mm with varied water/cement ratio and WSB fibre is used as a ratio by volume of mixture of as a ratio by volume of mixture of 0. 5, 1.0 and 1.5% as percentage weight of cement. This done to establish the optimum percentage required for the mixing. The weighed sand and cement were mixed thoroughly until a homogeneous mixture was achieved. The above quantity of fibre was added and properly mixed to ensure uniformity after which water was added. A total 48 of 70.7 mm x 70.7 mm x 70.7mm composite blocks were cast and cured in the tank for periods of 7, 14, 21 and 28days. Three blocks were crushed using the universal testing machine at the end of each curing regime and the average strength was calculated.

3.1.1 Water Absorption Test

Water absorption test was conducted on the different composite mortar after 28days. The test was conducted in accordance with BS 1881 Part 122:1982.

3.1.2 Density Test

Density of the WSBF reinforced and control composite blocks were determined in accordance with BS 1881: Part 107:1983 specification.

3.1.3 Compressive Strength Test

Compressive strength test was conducted on the WSBF reinforced and control composite blocks. The test was conducted in accordance with BS 1881 part 116 (1983). Three cubes were cast for each curing ages. They were crushed at the end of each curing period using the compressive strength test digital machine and the average crushing strength recorded.

4.0 RESULTS AND DISCUSSION

4.1.1 Water Requirement*:* The water-cement ratio required to achieve the workable mix as the content of WSB fibre varied is presented in Figure 1. It was observed that reinforced composite blocks mixing became less workable as the waste fibre percentage increases meaning that more water is required to make the mixes more workable. This was what led to increasing the w/c ratio from 0.63 to 0.68 for the 0.5% and 1.5% WSB fibre inclusion since the mix was becoming stiff. This indicates that WSBF absorbed moisture which could be to the benefit of concrete early strength development, also, controls bleeding of concrete to avoid segregation of the ingredient of the concrete mix (Okere, 2013). Colin, (2001) observed that fibers can be imagined as an aggregate with an extreme deviation in shape from the rounded smooth aggregate. The fibers interlock and entangle around aggregate particles and considerably reduce the workability while the mix becomes more cohesive and less prone to segregation.

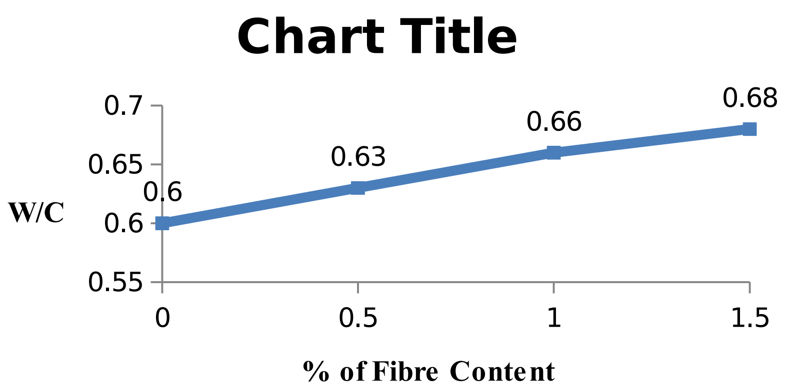

Figure 1: Effect of Waste Fibre on Water/Cement

4.1.2 Density of composite blocks: Figure 2 presents the densities of composite blocks with various WSB fibre content inclusions. The results show that the densities range between 1990, 1998 and 2035kg/m^3 respectively for 0.5, 1.0 and 1.5 % while 1957kg/m^3 for 0% as control. It was observed that density increases with increases in WSB fibre reinforced composite blocks compared to control composite blocks. Thus, the density of fibre reinforced blocks is fall within BS EN: 771-3 specifies as dense aggregate blocks that range between 1800-2100 Kg/m^3

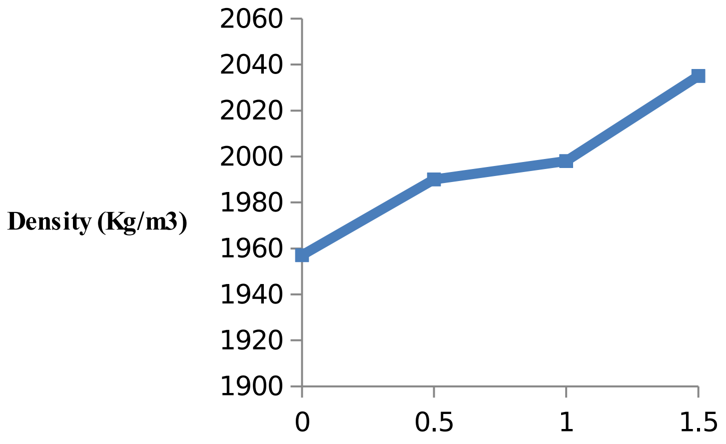

Figure 2: Effect of Waste Fibre on Density

4.1.3 Water Absorption: The values of WA obtained are presented in figure 3. The maximum WA was 7.9% for composite blocks containing 1.5% fibre. These values compared favorably with published data on WA in cement-bonded composites produced using agricultural and forestry residues such as maize stalks, coconut husk, coffee husk, arhar stalks, and rattan furniture waste (Oyegade, 2000; Ajayi, 2002; Olorunnisola and Adefisan, 2002; Okino, *et al*. 2004; Olorunnisola, 2006; Aggarwal, *et al.* 2008; Olorunnisola and Ogundipe, 2012). This can be explained by the fact that most of fibres are hygroscopic as it content increased, the ability of the composites to absorb water also increased. However, all the composite blocks satisfied the requirement of NBR 12118 (2007) that the water absorption for concrete structural blocks must be less than or equal to10%.

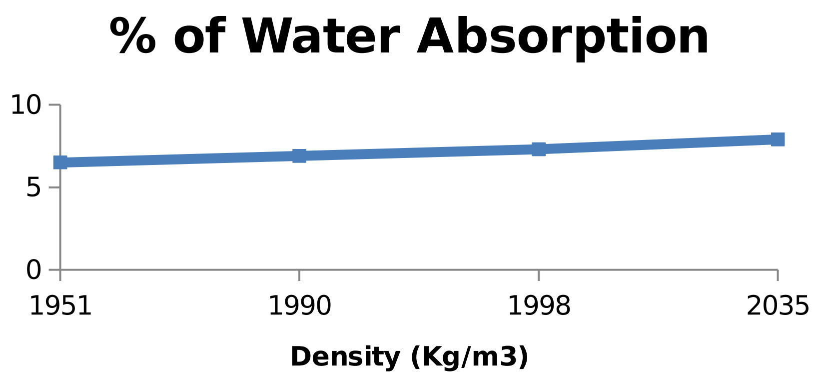

Figure 3: Percentage of Water Absorption by Composite Blocks

4.1.4 Compressive Strength*:* The effect of curing ages and fibre content on the compressive strength of W*SB* fibre reinforced blocks is shown in Figures (4) and (5). It was observed that compressive strength generally increases with curing period and increases with increased irrespective of the amount of WSB fibre inclusion. However, the compressive strength increases as WSB fibre content increases throughout the curing ages at 7, 14, 21 and 28days respectively. for unreinforced blocks of 0% WSB fibre, the compressive strength at 28 days is 9.04 N/mm^2 while that of 0.5, 1.0 and 1.5% are 10.54, 12.15 and 13.45 N/mm^2 respectively representing increases of 16.6, 34.4 and 48.8% respectively. These values compared favorably better with those reported by

Olorunnisola, *et al.* (2005) and Olorunnisola, (2007) and were higher than the value 1.4 N/mm^2 recommended by Opoko, (2004) for bricks for use as bearing walls for bungalows and one storey houses in Nigeria.

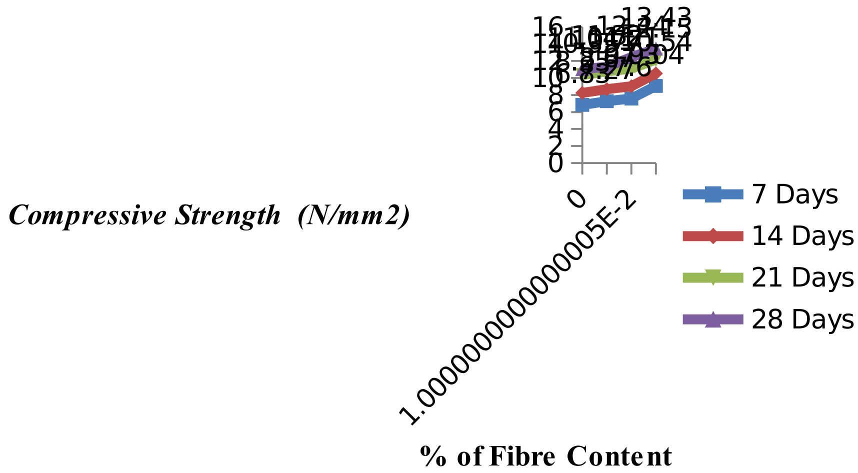

Figure 4: Effect of WSF Content on Compressive Strength

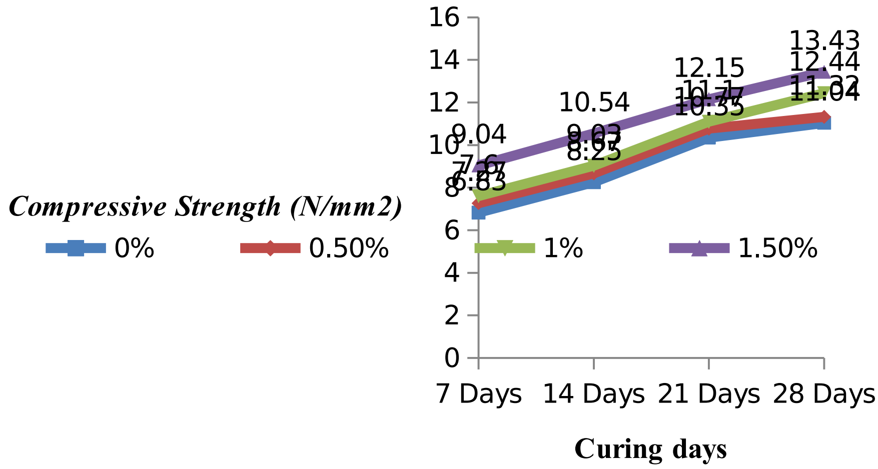

Figure 5: Effect of Curing on Compressive Strength

5.0 Failure modes*:* It was observed in Plate 2 that all the control specimens failed in a brittle manner when a maximum load was attained, one or more of the specimen surfaces spall off as load dropped rapidly before a complete failure collapse of the specimens. But WSB fibre reinforced specimens exhibited ductile behavior under the same loading condition, in which a fine cracks was appeared on the specimen surfaces and as load dropped gradually after the failure the specimens maintain a considerable incidence of pull-out fibre and some voids left by pull-out fibre that remained attached to the opposite facture surfaces for the specimens with 0.5 and 1.0% fibre addition while specimens with 1.5% fibre addition proved more better by remained as composite unit exhibited a good interactions between the matrix and fibre bond as the composite till together after maximum load has reached. It is therefore, showed a warning period prior to the final failure or collapse, thus this behavior of fibre reinforced blocks is attributed to the presence of waste fibre distribution within such composites. This present study has supported the recent research carried out by (Lamidi, *et al*. 2016c) stated that WRF reinforced clay bricks failed with minor pull out of the fibre matrix like hair crack which visually prevented the spread of cracks on the specimens for being failed suddenly and such blocks are considered for most structures localized in an earthquake prone zone.

0.0% fibre 0.5% fibre 1.0% fibre 1.5% fibre

Plate 2: Failure Pattern

5.0 CONCLUSIONS

The use of waste sack bag fiber, a waste obtained from vendor dumped site located at Bodija Market Ibadan, in reinforcement of composite blocks had provided an avenue for the recycling of waste which otherwise will have constituted an environmental nuisance. In this study, the results of tests at the 28 days showed that the compressive strength of the WSB fibre reinforced blocks ranged from 10.54 to 13.45N/mm^2 for 0.5-1.5% fibre content, compared to unreinforced blocks which were 9.04N/mm^2 for the same 28days respectively. It was also observed that 1.5% fibre addition proved better by exhibiting a good interaction between the matrix and fibre bond as the composite adequately ductile under stresses. This satisfied specified by Nigeria Industrial Standard (NIS 587, 2007) for load bearing wall. Conclusively, such composite blocks can render more resistance to earthquake effects in Nigeria.

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Development of an Energy Storage Chamber to Enhance Solar Drying of Grain at Night

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Abstract

Solar drying is the one of the effective means of preserving grains amongst the different method of drying. It is a simpler, cleaner and safer method of drying. However, most available solar dryer are inefficient due to non-availability of solar energy during period of low insolation which eventually leads to moisture re-absorption with pronounced effect particularly at night, causing growth on dried grains. To solve this problem, an energy collector and storage chamber was developed and connected to a developed solar dryer to serve as the heat source at night.

No load test was carried out at night when the dryer was subjected to four different conditions: valve opened and collectors' surfaces covered; valve opened and collectors' surfaces uncovered; valve closed and collectors' surfaces covered; and valve closed and collector's surfaces uncovered. Load test was conducted by drying five different grains; maize, soyabean, groundnut, cowpea and sorghum during daytime using the dryer and applying the best combination of energy supplied and collectors' surfaces at night.

The result showed that the highest temperatures difference of 35^0 C and 33^0 C were attained in the flat plate collector and drying chamber respectively, when the valve was opened and the collectors' surfaces were covered. The load test shows that there was slight reduction in moisture content of grains between 12 midnight and 5 am. The highest moisture reduction (4%) was recorded during drying of sorghum while the least moisture reduction (1%) was recorded when drying cowpea at night. In conclusion, for continuous solar drying of grains at night using stored energy, the valve controlling the heat storage chamber should be opened and the collectors' surface should be covered to obtain optimum temperature within the drying chamber. Conserved heat energy from the energy storage chamber ensures continuous drying of smaller grains (sorghum) and at least prevents moisture re-absorption in larger grains (cowpea and maize).

Keywords: Solar, Energy- Storage, Drying, Night and Grains

Introduction

Despite the readily availability of solar energy, its continuous use have not be fully explored. This is due to the unpredictable nature of solar energies, resulting in varying thermal insolation at different times of the day. Studies on the solar intensity of different places on a typical day as reported by different researchers show that the day usually starts with low solar insolation (6am – 9am), follows by high insolation (12noon – 3pm) and then moderate insolation (4pm - 6pm). Thus, attaining high temperature particularly during period of low insolation may be difficult. If continuous drying is to be achieved, solar dryer may be practically inefficient at night when there is no solar insolation. To effectively make use of solar dryer during this period, a suitable mean of thermal energy storage should be incorporated into the design of a solar dryer.

Such systems have been reported by various researchers (El-Sebaii, et al, 2002; Madhlopa and Nwagalo, 2007 and Fagunwa, et al, 2009). These systems have heat storage units incorporated within the solar dryer. One major advantage of these systems is that during the day the heat storage increases the heat within the drying unit, thus increase the efficiency of the system. However, at night when there is no solar insolation, the drying chamber loses its heat fast and because the heat energy storage is integrated within the drying chamber, there is lost of heat from the drying unit. Generally, when designing a solar dryer, the initial and the desired safe moisture content of the grain to be dried, average available insolation in the area, duration of drying, material of insolation, condition of the surrounding air and the mean of collecting solar radiation should be considered.

The two basic devices used for collecting solar radiation are the flat plate collector and parabolic collector. The basic components of a flat plate collector are the collector plate fitted with passage for the working fluid, one or more transparent cover plates (glass or plastic) and the surrounding insulation. The collector absorbs incident radiation and transfers the energy to the working fluid. The cover serves to reduce radiative and convective heat losses from the hot surface of the collector plate. The insulation prevents lose of heat to the surrounding air. On the other hand, a parabolic collector focuses solar energy collected over a large area onto a small area. This focusing is only possible with the direct solar radiation and not with the diffuse, long wavelength component. The original ray that is parallel to the principal axis of a mirror is converged to a focus upon reflection. This point of convergence is called the focal point (Duffie and Beckman, 1980).

For any type of collector used, to optimize the energy collection, the surface which absorbs the solar radiation must be in a vacuum to avoid conduction and convection losses, the surface must have an absorption coefficient close to unity to maximize radiation collection, the surface of the collector must be able to absorb solar radiation with minimum attenuation and the surface which absorbs the solar radiation and all other parts of the system at elevated temperature in vacuum must have an emmisivity close to zero. Apart from these criteria, the absorber material should be of high absorptivity, low emissivity, good thermal conductivity, durable, stable at temperature encountered during operation and of low cost and weight per unit area

(Igbeka, 2013). However, if a solar dryer with energy storage is to be developed, it is essential to also consider the major characteristics of a thermal storage system.

According to Kreider and Kreith (1981), the following should be considered when selecting material for thermal storage: its capacity per unit volume or weight, the temperature range over which it operates, the means of addition and removal of heat and the temperature differences associated therein, the temperature stratification in the storage unit, the power requirement, the means of controlling power losses from the storage and its cost. Different storage materials have been identified by different researchers, but gravel has peculiar characteristics that make it desirable for solar energy applications. The heat transfer between air and solid is high; the cost of storage material is low; the conductivity of the bed is low particularly when airflow is not present. Also gravel bed exchangers have high coefficient of heat transfer between air and solids of the bed; this tends to maximize temperature difference from air to solids on heating the bed, and solid to air on cooling the bed (Kreith and Kreider, 1978). Considering all these essential factors, this work design a standalone thermal energy storage chamber (parabolic collector) connected to a solar drying system (comprising of flat plate collector and drying chamber) to collect and store thermal energy using black coated gravel in order to prevent moisture re-absorption at night.

The Experimental Solar Dryer

The solar dryer (Figure 1) was designed and fabricated as a simple, low cost and easy to operate equipment that required little or no supervision during use. The equipment was fabricated using durable materials that can withstand harsh climatic conditions in the tropics. It basically, consists of the flat plate solar collector, drying chamber, heat circulation unit (fan) and heat control unit (valve) and energy storage unit (parabolic collector).

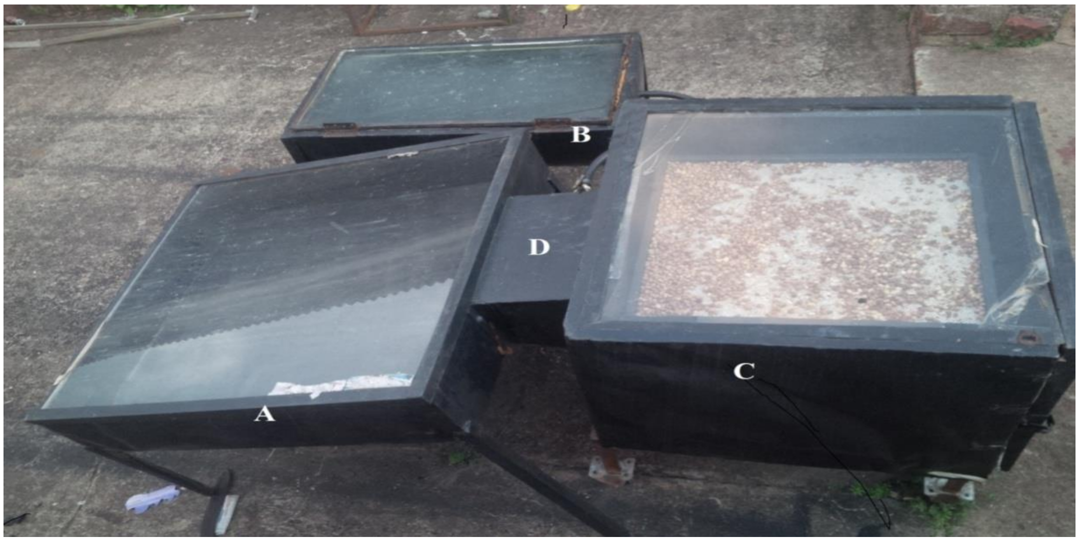


Fig 1: The Experimental Solar Dryer

A – Flat Plate Solar Collector B – Parabolic Solar Collector (Heat Storage Chamber)

C – Drying Chamber D – Airduct Unit

Thermal storage chamber

The thermal storage chamber (Figure 2) basically comprises of a parabolic-shaped black plate, two end plates, a transparent cover and a receiver (absorber plate) on which incidented heat is collected. These parts are coupled together and the arrangement is supported by four angle irons that serve as the equipment stand.

Mode of Operation of the Dryer

The mode of operation of the dryer at daytime and night are shown in Figure 3 and 4 respectively. During the day, the source of heat energy used to dry the grains are direct heating by the solar radiation on the drying chamber and convective heating by the heated air from the flat plate collector. The fan in the air duct ensured that the heated air is properly circulated around the drying chamber for uniform drying across the trays in the drying chamber. At night, when there is no solar radiation from the sun, the source of energy is the heat energy collected and conserved in the energy storage chamber. A control valve located at the exit of the

Figure 2: Thermal Storage Chamber

chamber is closed and opened during daytime and at night respectively to ensure continuous operation of the dryer. The combined operation of the dryer during day and night times is shown in Figure 4.

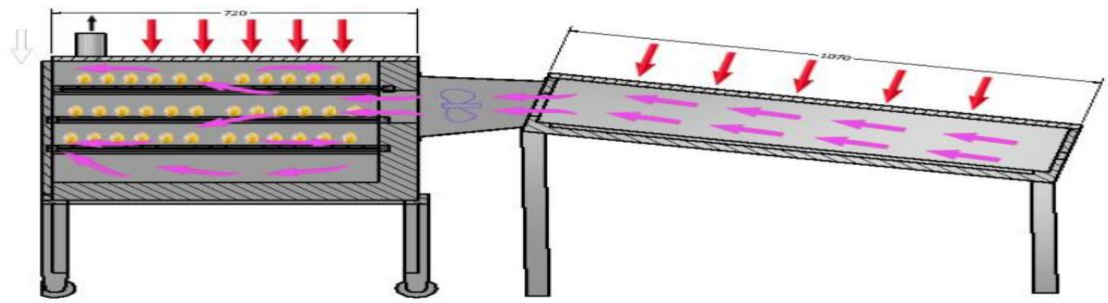


Figure 3: Diagram showing the heat source and airflow direction in the dryer at daytime

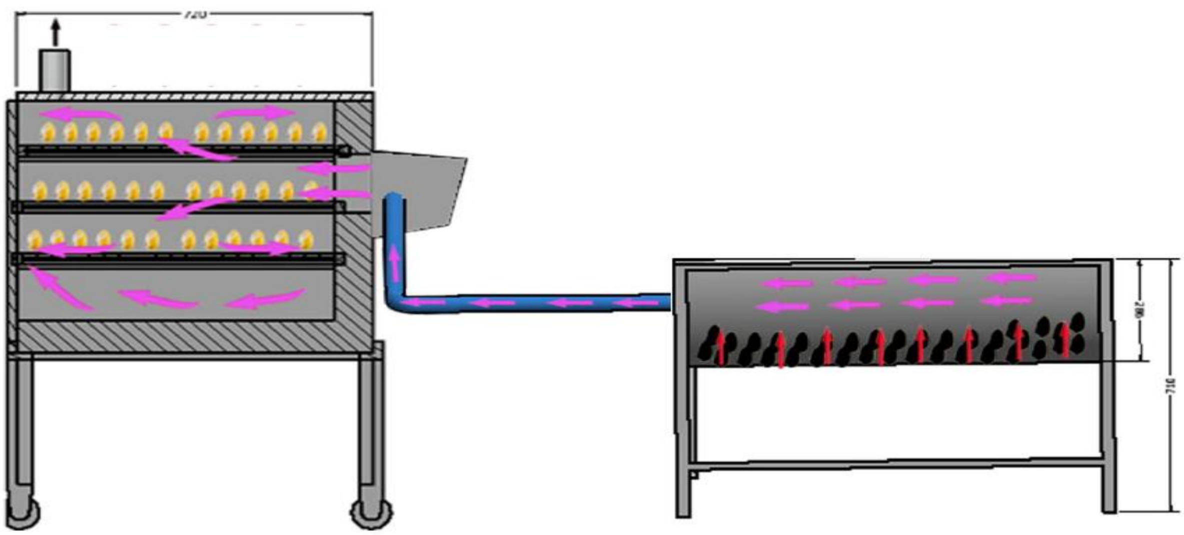
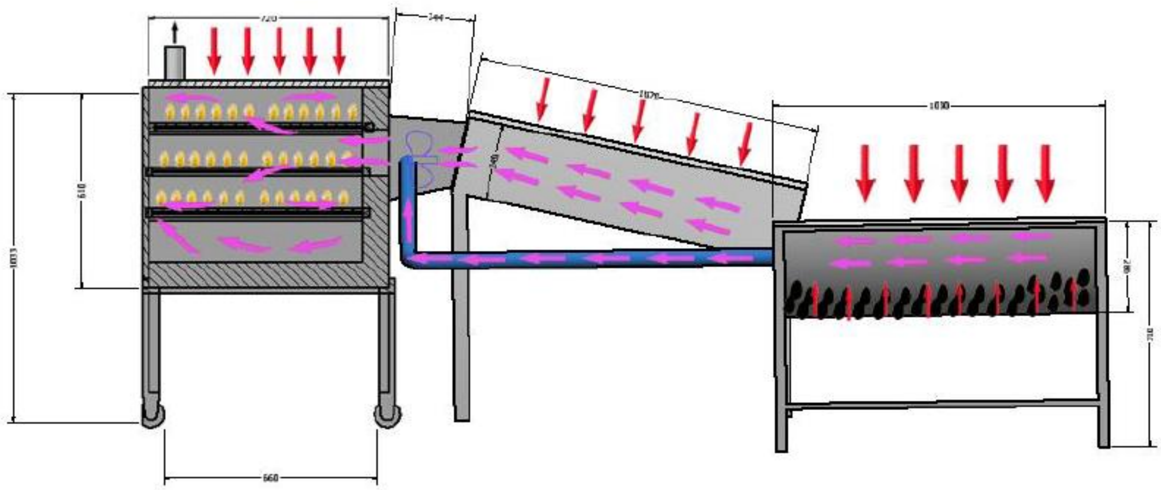


Figure 4: Diagram showing the heat source and airflow direction inside the dryer at night



shows the direction of heat source

shows the direction of the air flow

Fig 5: Diagram showing the combined heat sources and airflow direction inside the dryer during daytime and at night

No Load Test at Night

At night, the three collectors; flat plate collector, parabolic collector and heat storage chamber were covered with a tarpaulin and the internal temperature of these three components were recorded when the solar dryer was subjected to four combinations of valve position and collector condition; when the heat storage valve is opened and collectors were covered, when the heat storage valve is opened and collectors were uncovered, when the heat storage valve is closed and the collectors were covered and when the heat storage valve is closed and the collectors were uncovered. The internal temperatures of the three components of the dryer were measured using a thermo-anenometer (K-type, LM 8010, Lutron Instrument).

Load Test at Night

Five selected grains (cowpea, soyabean, groundnut, sorghum and maize) were obtained from the Teaching and Research Farm of the Obafemi Awolowo University, Ile-Ife, Nigeria. Prior to the drying test at daytime, the initial moisture content of each grains were determined using oven drying method according to ASABE standard as described by Aregbesola, et al, (2012) sorghum, Taraghi, et al, (2011) for maize, ASI, (2012) for groundnut and Ajibola, et al, (2003) for cowpea and soyabean. 3kg of each of the selected grains were placed on the three trays inside the solar dryer and allowed to dry at 0.94 m/s. At night, the fan was switched off to prevent loss of heat from the dryer. The moisture content of the grains drying each drying run was determined hourly using a portable digital moisture meter (MC 7825G). The solar radiation during the drying period was measured using global radiation meter (GRM 100). The airspeed, relative humidity and ambient temperature of the prevailing air near the dryer were measured using a thermo-anenometer (K-type, LM 8010, Lutron Instrument). The temperatures of the plates inside the collectors were measured with a thermocouple thermometer (K-type, XMTA-7000 TAIFA®).

Results and Discussions

The variation in the internal temperatures of the various components of the solar dryer (flat plate collector, drying chamber, heat storage chamber) with respect to the ambient at night using the four combinations of valve position and collectors' condition are shown in Figure 6 (a-d) and discussed as below:

Effect of Collectors' Covering and Heat from Storage Chamber on the Internal Temperature of Flat Plate Collector at Night

The curves show that the highest temperature (33^0C) was attained on the flat plate collector when the surface was covered and the energy storage chamber was closed at 5am whilst the least internal temperature (26^0C) was achieved when the collector was uncovered and the energy storage chamber was closed at 5am. The low temperature recorded at this time was due to lost of heat energy from the surface of the collector. It may also be due to condensation of moisture on the outer part of the collector, which in turn tends to lower the internal temperature of the collector after sometime with pronounced effect observed when dew start falling early in the morning (5am).

Effect of Collectors' Covering and Heat from Storage Chamber on the Internal Temperature of the Drying Chamber at Night

Similarly, Figures 6(a-d) show that a maximum temperature of 32^0C was attained inside the drying chamber when the collector was covered and the energy storage chamber was opened. The reason for the high temperature when the dryer was subjected to these conditions compared to others was as a result of the insulating effect of the tarpaulin cover and the heat supplied from

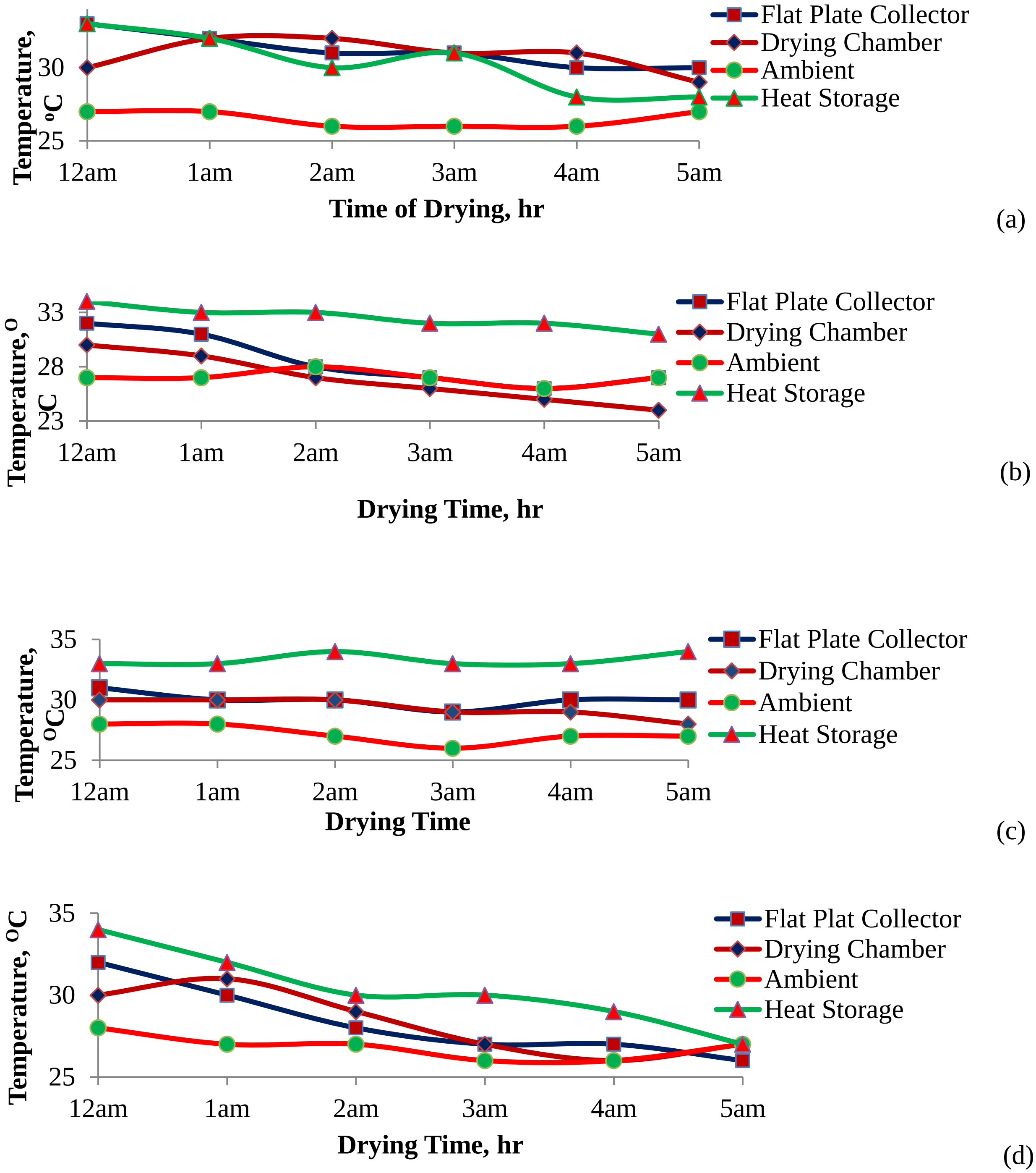


Fig 6: Temperature of solar dryer parts when (a) collector covered and valve opened (b) collector covered and valve closed (c) collector uncovered and valve opened (d) collector uncovered and valve closed at night

the energy storage chamber into the drying chamber, both of which ensured that heat is retained within the drying chamber. On the contrary, the least temperature was recorded when the collector was covered and the heat storage chamber was closed. The low temperature recorded during this condition was as a result of the condensed moisture on the outer part of the collector, resulting in reduction in the internal temperature of the heat storage chamber. Analysis of means and differences shows that there was no significant difference in the internal temperatures of the drying chamber when subjected to the four different combinations of factors (collector covering and heat energy from the heat storage chamber) except when the collectors were uncovered and valve was closed which was significantly different from others at ($P<0.05$). From this result, it shows that both the tarpaulin used to covered the collectors and the heat supplied into the drying chamber at night are important at least to prevent moisture re-absorption into chamber. This is evident in the temperature recorded at 5am when the collectors are uncovered and valve closed. There is high possibility of moisture re-absorption when the dryer is subjected to these conditions.

Moisture Content of Grains at During Load Test at Night

The variation in moisture contents with time of the five selected grains dried using the solar dryer at night is shown in Figure 7. There were slight reductions in moisture content between 12 midnight and 5am in the morning, with the highest moisture drop of 4% recorded

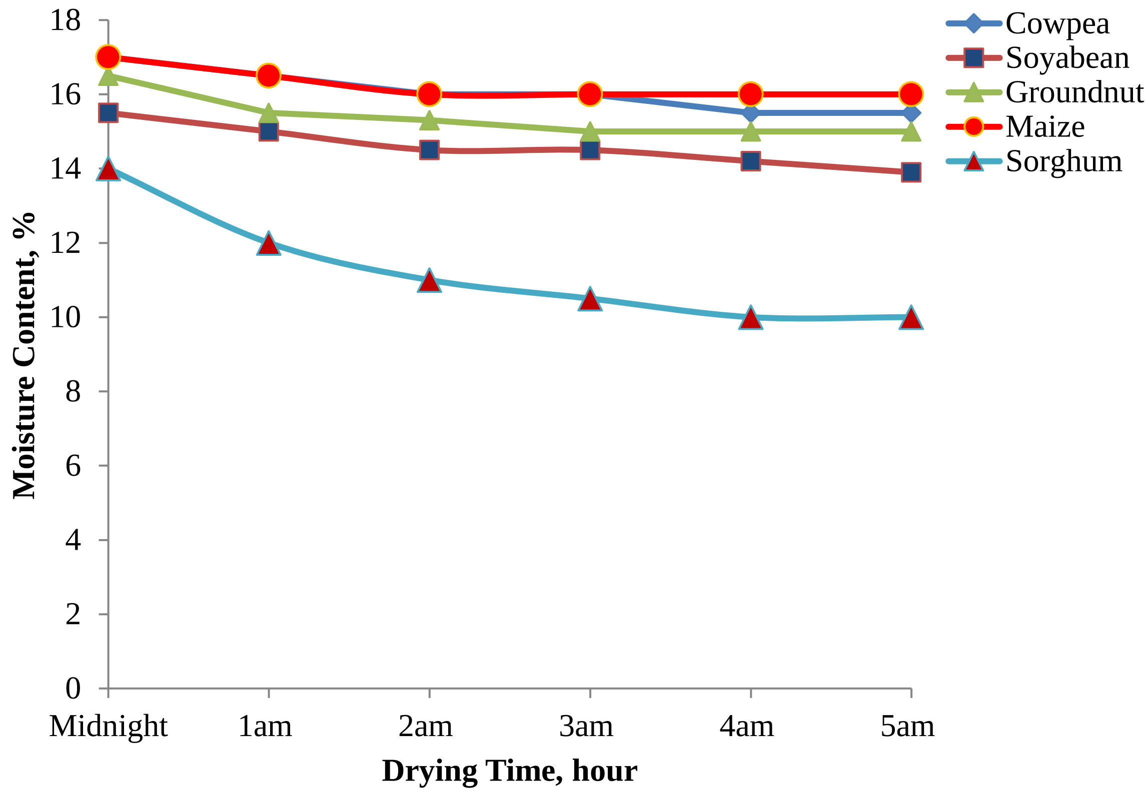


Figure 7: Variation in Moisture Content of Grains Using the Solar Dryer at Night

during drying of sorghum. The reason for this high value was due to the small size of the grains that required less energy for drying compared to other grains that are larger in sizes. The least moisture drop of 1% was recorded when drying maize. The small drop in moisture content of maize was due to the structural and molecular compositions of maize grain which consist of fibrous and cellulose materials that required more energy than smaller grains. However, for all the grains the differences in moisture contents of grains between midnight and at 5am were higher than 1%. Implying that there was moisture reduction during this period, which indicates continuous drying at night, thus it is proceed at a very slow rate but at least it evitable that there was no case of moisture re-absorption recorded at night during drying of any of the grains.

Conclusion

It can be concluded from this work that covering the surface of solar collectors and opening heat storage chamber increase the internal temperature inside the drying chamber. This ensures continuous drying of smaller grains (sorghum) and at least prevents moisture re-absorption during drying of large grains at night.

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EFFECT OF CRITICAL PROCESSING CONDITIONS ON PROXIMATE AND FUNCTIONAL PROPERTIES OF COWPEA (*VIGNA UNGUICULATA)* FLOUR.

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ABSTRACT

This study was carried out to determine the appropriate soaking time needed for the production of two local cowpea varieties flour (Ife-B.P.C and Ife Brown) with the best proximate composition and functional properties to access their potential use in the food industry. Cowpea (Vigna unguiculata) seeds (Ife-B.P.C and Ife Brown) were soaked in water at room temperature at 15 minutes time interval, dehulled, dried in a cabinet dryer, milled in an attrition mill, and screened. Proximate and pasting properties were carried out using standard methods. From the results obtained, it was observed that there were significant ($P< 0.05$) variations in the proximate composition and functional properties as affected by varying soaking time. The proximate composition of Ife B.P.C. ranged from 10.15 to 12.41%,; protein, 18.57 to 24.35%; crude fat, 0.03 to 1.27%; ash, 3.08 to 4.19%; carbohydrate, 50.15 to 62.19%; crude fibre, 2.63 to 7.97%; bulk density, 0.75 to 0.83g/dm^3; oil absorption capacity, 2.13 to 2.31 g of oil/g of flour; water absorption capacity,; 2.16 to 2.97g of water/g of flour and swelling power, 2.33 to 2.64). While variations for Ife Brown, are for moisture, 11.91 to 12.85%; protein, 18.12 to 22.46%; crude fat, 0.30 to 2.61%; ash, 3.13 to 3.93%; carbohydrate, 51.02 to 60.85%; crude fibre , 3.97 to 8.01%; bulk density, 0.61 to 0.80g/dm^3; oil absorption capacity, 1.93 to 2.14 g of oil/g of flour); water absorption capacity,; 1.74 to 2.11 g of water/g of flour and swelling power, 1.98 to 2.68. The results showed that soaking time has significant effect on the proximate compositionand functional properties of the two varieties of cowpea.
Key words: cowpea, soaking time, proximate properties and functional properties

INTRODUCTION

Grain legumes are rich and less expensive source of dietary proteins and water – soluble vitamins. Legumes contain twice as much protein as cereals and, except for the sulphur containing amino – acids (Methionine and lystine) which are adequate Cereals, the amino acids of most legumes complement those of Cereals (Fashakin and Ojo, 1988; Nielson, 1991).Cowpea contributes to the total protein intake of many rural and urban families (Dolvo *et al.*, 1976). The ever escalating prices of animal protein sources and its insufficient local production has led to an increasing demand for alternative, cheap, good quality protein foods such as cowpea(Akinleye and Onigbinde,1988).

Cowpea (*Vigna unguiculata*), is a leguminous plant belonging to the *fabaceae* family. Cowpea, like other grain legumes is important food stuff in tropical and subtropical countries (Chinma *et al.*, 2008).

Soaking of Cowpea is by itself a long process and numerous ways to shorten it have been devised. Some of these methods have to do with mechanically increasing the rate of water inhibition by applying a vacuum infiltration technique, but more commonly increasing the temperature of the soaking water is used to increase the inhibition rates. The latter technique is quite effective and soaking can be reduced from 16hr. at room temperature to 1hr.at 90^0C (Kon, 1979). In the commercial food processing operation of these products, dry beans are traditionally soaked overnight (8-16hr.) in water at room temperature or soaked using high temperature (82-100^0C) for 20-40 minutes with the aim of raising the moisture content of the beans to a range of 53-57%. Soaking prior to milling and cooking has been found to influence both the texture of paste and its cooking time. Several authors have reported that soaking prior to milling (wet milling) and cooking reduced the hardness of Cowpea seed of various species and that the difference in gelatinsation pattern of the bean starch and the susceptibility of cell constituents to softening contributed to the overall textural characteristics of legumes, (Sefa-Dedah *et al.*, 1978, 1979; Silva *et al.*, 1981 and Drake S. R., Muehlbanar (1985)

Cowpea has a wide range of varieties and it is highly rich in protein. The analysis of the effect of soaking time on the quality of developed breed Cowpea in Nigeria will help predict suitable soaking time that will help in the processing of Cowpea seeds into flour with an optimum and good functional characteristics and proximate composition.

This study examined the impact of some processing conditions on the proximate composition and functional properties of cowpea flour.

MATERIALS AND METHODS

Seeds of two varieties of cowpea (Ife-B.P.C and Ife Brown) were obtained fromthe Plant breeding unit of the Institute of Agricultural Research And Training, (I.A.R&T), Moor Plantation Ibadan, Nigeria. The seeds were cleaned, and foreign matters Cracked, broken, damaged and immature seeds were removed. The samples were stored in plastic containers with cover and kept at room temperature before making any measurement.

About 200g each variety of the cowpea in triplicates was soaked at ambient temperature (25± 2^0C) at 15mins interval for 1hr. The dehulled Cowpea (*V. unguiculata*, IFE- BPC and IFE BROWN) were placed in a cabinet dryer at the temperature of 60^0C for 40 minutes in a cabinet oven until its moisture content reached 12%. The dried Cowpea (*V. unguiculata*, IFE- BPC and IFE BROWN) seeds were milled finely in an attrition milling machine and screened with a mesh screen.

Determination of functional properties

The Water and Oil Absorption Capacities (WAC and OAC) was determined as described by Sathe *et al.*, 1982a). Bulk Density was determined as described by Akpapunam and Markakis (1981). Swelling power was determined according to the method reported by Oladele and Aina (2007).

Proximate Analysis

Method reported by Kirk and Sawyer (1991) was used to determine moisture, protein, fat, crude fibre and ash content. Carbohydrate was calculated by difference. Southgate (1978) method was used to calculate the energy value (kJ) by multiplying the amounts of protein and fat by the factors of 17 and 33kJg$^{-1,}$ respectively.

RESULTS AND DISCUSSION

The result of cowpea varieties soaked at fifteen (15) minutes time interval until it reaches its critical absorption points is shown in Tables 1 – 2 and Figure 1.

Table 1: Mean water absorbed by cowpea (IFE – BPC AND IFE BROWN) at different soaking time.

Cowpea variety	15 (min)	30 (min)	45 (min)	60 (min)
IFE – BPC	119.57(±0.193)	134.43(±0.148)	145.22(±0.251)	151.25(±0.448)
IFE BROWN	166.14 (±0.235)	203.08(±0.160)	214.40(±0.537)	222.80(±0.221)

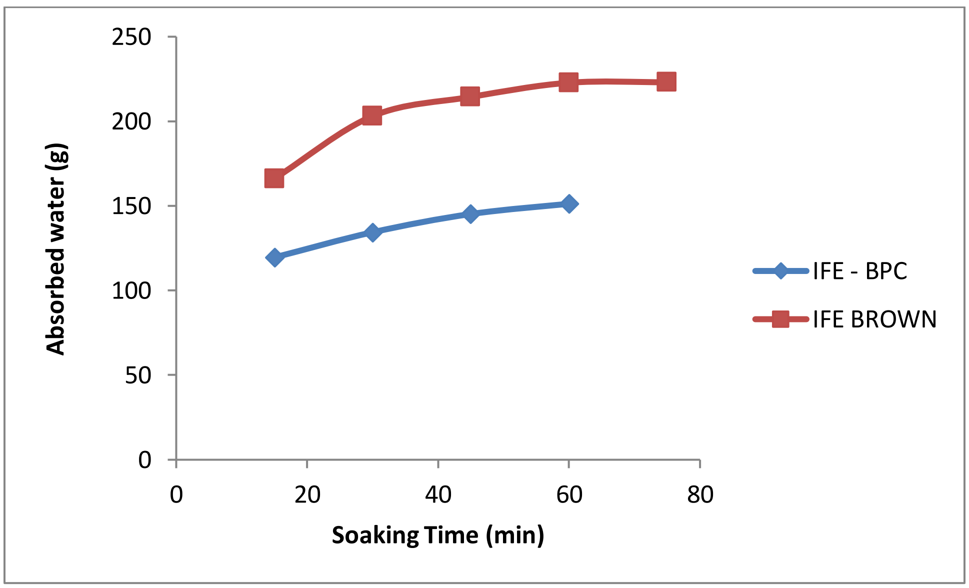

Fig. 1 Water absorbed by cowpea (IFE- BPC and IFE BROWN) at different soaking time

Table 2: Proximate composition (%) of cowpea flour (IFE-BPC) processed at different Soaking time.

Proximate Composition (%)	Standard values	15 (min)	30 (min)	45(min)	60(min)
Moisture	11.10	12.41	10.15	11.85	13.18
Protein	24.60	24.35	21.72	20.06	18.57
Crude Fat	0.62	1.27	0.15	0.19	0.03
Ash	3.80	3.85	3.54	3.08	4.19
Carbohydrate	51.78	50.15	60.10	62.19	60.02
Crude fibre	8.10	7.97	3.34	2.63	4.01

Table 3:Proximate composition (%) of IFE-BROWN flour processed from different Soaking time.

Proximate Composition (%)	Standard values	15 (min)	30 (min)	45(min)	60(min)	15(min)
Moisture	11.60	11.97	10.25	11.91	12.27	12.85
Protein	23.10	22.46	20.16	20.03	18.87	18.12
Crude fat	0.58	2.61	1.70	0.89	0.81	0.30
Ash	3.80	3.93	3.64	3.13	3.96	3.85
Carbohydrate	53.77	51.02	57.13	60.07	60.03	60.85
Crude fibre	6.45	8.01	7.12	3.97	4.06	4.03

Table 4:Functional properties of cowpea (IFE-BPC) flour processed at different soaking time

Functional Properties	Standard values	15 (min)	30 (min)	45 (min)	60 (min)
Bulk density (g/cm3)	0.79	0.81	0.83	0.76	0.75
OAC (g/g)	2.31	2.28	2.31	2.17	2.13
WAC (g/g)	2.13	2.97	2.71	2.42	2.16
Swelling power	2.69	2.64	2.33	2.41	2.53

Table 5 Functional properties of IFE-BROWN flour processed at different soaking time.

Functional Properties	Standard values	15(min)	30(min	45(min)	60(min)	75(min)
Bulk density (g/cm3)	0.82	0.80	0.67	0.71	0.65	0.61
OAC (g/g)	2.18	2.14	2.07	1.97	2.01	1.93
WAC (g/g)	2.14	2.11	2.01	1.18	1.84	1.74
Swelling power	2.72	2.68	2.25	2.05	2.07	1.98

- OAC – Oil absorption capacity
- WAC – water absorption capacity

Discussion

According to Chinma *et al*. (2008), composition differences in cowpea could be attributed to soil type, cultural practices, environmental condition, and genetic factors. When subjected to treatments such as soaking and drying temperature, their proximate composition may vary. Generally, higher protein content of IFE – BPC, suggests that it is a superior source of protein than IFE BROWN as shown in Tables 2 and 3. Generally there was significant difference ($p < 0.05$) in the proximate composition in the values obtained for IFE – BPC and IFE BROWN, while there was no significant difference ($p > 0.05$) in their moisture, ash, and carbohydrate content.. As regards to crude fibre, 15 minutes soaking time has a high crude fibre content than other samples of both cowpea varieties (IFE – BPC and IFE BROWN) processed from other soaking time, and this will be useful in providing bulk to foods in order to relieve constipation. For protein content, it was found to decrease as soaking time increases for both varieties, (IFE – BPC and IFE BROWN). With prolong soaking; cowpea will not be able to reduce nutrient leaching was possible Also with soaking time increases, the fat content reduces for both varieties Due to the varied high content or less significant variation/differences in the ash and carbohydrate content, this indicated that cowpea varieties (IFE – BPC and IFE BROWN), could be important source of minerals and energy for consumers (Brown, 1991 According to Hoseney (1994), it was stated that starch needs sufficient moisture to gelatinize, peak areas for gelatinization diminish at successively lower moisture and that at a very low moisture content, gelatinization will not occur. Relative high moisture content of cowpea flour showed that they correspond to those found in dough used for snack chip preparation (Ward *et al*., 1995) and suitable for fried cowpea paste 'Akara' (McWatters and Brantley, 1982).

The high bulk densities observed in cowpea varieties used in this study indicated that their flours are heavy. The bulk densities were similar to other cowpea varieties (0.71g/cm^3) but higher than pigeon pea (0.68g/cm^3); (Butt and Batool, 2010). For IFE-BPC and IFE BROWN, flour samples processed from 15 and 30 minutes soaking time were heavier and will occupy less space per unit weight compared to flour samples processed from 45 and 60 minutes; 60, and 75 minutes soaking time respectively. However, IFE-BPC and IFE BROWN samples processed from 45 and 60; soaking time respectively will be easier to transport as it was lighter. On the other hand, since flour of IFE-BPC samples processed from 45 and 60 minutes soaking time was least dense it would occupy greater space and, therefore would require more packaging material per unit weight and so could have high packaging cost (Oluwatoyin *et al*., 2002; Padmashree *et al*., 1987). The high bulk densities of the flours suggest their suitability for use in various food preparations. According to Padmaasshre *et al.* (1987), a higher bulk density is desirable for greater ease of dispersibility of flours. In contrast, however, low bulk densities would be an advantage in the formulation of complementary foods (Akpata and Akubor, 1999). Since flour samples processed from 45 and 60 minutes soaking time for IFE BPC and flour samples processed from 60 and 75 minutes soaking time for IFE BROWN had the least bulk density, it could be the most suitable for complementary foods (Appiah, *et al.*, 2011).

The water absorption capacity of IFE-BPC and IFE BROWN was highest for samples processed from 15, 45, and 60 minutes; 15, and 30 minutes soaking time respectively. However the water absorption capacity of all samples of each cowpea variety (IFE – BPC and IFE BROWN), were higher than the by values (1.60 and 1.94 g/g) reported by Chinma *et al.*(2008),for other cowpea varieties in Nigeria. According to Butt and Batool (2010), protein has both hydrophilic and hydrophobic properties, and so can interact with water foods. Carbohydrates have also been reported to influence water absorption capacity of foods (Adejuyitan, 2009). The ability of protein to bind water is indicative of its water absorption capacity. The observed variation in water absorption among the samples of cowpea flour may be due to different protein concentration, their degree of interaction with water and their conformational characteristics (Butt and Batool, 2010). On the other hand, Kuntz (1971) reported that lower water absorption capacity is due to less availability of polar amino acids in flours. The observed high and low water absorption of cowpea flours could be attributable to the degree of presence of hydrophilic proteins.

Therefore, samples of IFE-BPC and IFE BROWN flour processed under 15 and 30 minutes would be useful functional ingredients in bakery products.The oil absorption capacity of samples of these cowpea was found to be higher than some other Nigerian cowpea varieties as reported by (Chinma *et al.,* 2008). The ability of the proteins of these cowpea varieties (IFE – BPC and IFE BROWN), makes them useful in food systems where oil imbibitions is desired. The flours could therefore, have functional uses in foods such as sausages production. The high oil absorption capacity also makes the flours suitable in facilitating enhancement in flavor and mouth feel when used in food preparations. IFE-BPC and IFE BROWN flour samples processed from soaking their respective seeds within 15 and 30 minutes; 15, 30, and 60 of soaking time respectively are superior to samples processed from 45, 60; 45, 75 minutes of soaking time respectively as flavor retainer since they had significantly higher oil absorption capacity.

The swelling powers of the samples of the cowpea varieties (IFE – BPC and IFE BROWN), in this study, were observed to be high but lower than for cereal starches (24 to 42; Tester and Morrison, 1990). The high swelling powers suggest that the cowpea flours could be useful in food systems where swelling is required.
From the Anova analysis, it is deduced that soaking time has no effect on the functional properties of cowpea flours, but there is a slight change in the functional properties across soaking time as shown in table 4.5 and table 4.

CONCLUSION

The findings of this study showed that cowpea varieties used in this study (IFE – BPC and IFE BROWN), are rich in protein and have good physicochemical properties which could be exploited for nutrition and food formulation. The good functional properties make them useful in foods such as bean cake, sauces, and stews, pastries, and composite flours where they could play functional roles. The cowpea flours could be used to fortify conventional flours which are low in protein. Consumption of foods based on these cowpea varieties would be important steps towards alleviating protein malnutrition. Nonetheless, from the results gotten from this study, compared to the standard proximate composition and functional properties of IFE-BPC and IFE BROWN, prolonged soaking tends to reduce the quality of cowpea flour. For IFE-BPC and IFE BROWN, a minimum of 15 minutes and a maximum of 30 minutes soaking time of their respective seeds may be preferable for production of quality cowpea (IFE – BPC and IFE BROWN) flour. This is necessary since cowpea flours processed within 15 and 30 minutes were associated with best functional properties and proximate composition.

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