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29TH ANNUAL GENERAL MEETING (YOLA 2008)

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PREFACE

The advocacy for agriculture to take its rightful position as the fulcrum of the Nigerian economy has been on for a long time, but this is far fetched despite its huge contribution to the national GDP.

The United Nation General Assembly in the year 2000 came up with the Millennium Development Goals which is geared towards addressing development goals and environmental issues. Among which are poverty alleviation, food security, gender equality and rural empowerment, etc.

All of these issues mentioned above are inherent in most developing countries such as ours. Hence, the choice of this year's conference theme "Agricultural Engineering and the Millennium Development Goals in Nigeria" Therefore, this forum avail to the Agricultural Engineers in the Universities, Polytechnics and Colleges of Agriculture, Research Institutions, Ministries and Practitioners in Industries the opportunity to exchange new technological innovations, ideas, research methods and findings, opportunities, challenges and constraints in their various fields of specializations and practice.

This year's conference proceedings include a keynote address, three (3) lead papers and 49 technical papers, which cover most of the different aspects of Agricultural Engineering and other related fields.

We thank all authors and more especially those invited to present keynote address and lead papers. Who co-operated with the set guidelines to ensure the success of preparing the conference proceedings. It is the expectation of the technical committee that these proceedings will be ready for distribution to participants at the conference venue.

Engr. Dr. Shehu A. Iya
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ACKNOWLEDGEMENTS

The Local Organizing Committee, on behalf of the National Executive Committee and the entire membership of the Nigerian Institution of Agricultural Engineers (NIAE), wishes to acknowledge the support received from all those who responded to the invitation to attend this conference and contribute towards its overall success.

The NIAE records its appreciation of the professional and sound intellectual contributions made by the Special Guests, Keynote Speaker, and the Lead Speakers.

The support both financial and in kind, received from organizations and individuals for hosting of the 8th International Conference and 29th AGM of the NIAE is greatly acknowledged with a sense of gratitude.

The enthusiasm and efficiency exhibited by all the members of the LOC and all the Sub-Committee members in the conduct of the Conference and production of the Proceedings is highly appreciated.

Thank you .

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LEAD PAPERS

The Millennium Development Goals, Information Technology and Agricultural Engineering Research

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Millennium Development Goals

In 2000, 192 United Nations member states agreed to achieve certain goals by 2015. Known as "The **Millennium Development Goals", these** goals were designed to improve the situation of the world and especially developing countries.

The full list of Millennium Development Goals is as follows:

Goal 1: Eradicate extreme poverty and hunger

Target 1: Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day

Target 2: Halve, between 1990 and 2015, the proportion of people who suffer from hunger

Goal 2: Achieve universal primary education

Target 3: Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling

Goal 3: Promote gender equality and empower women

Target 4: Eliminate gender disparity in primary and secondary education, preferably by 2005, and to all levels of education no later than 2015

Goal 4: Reduce child mortality

Target 5: Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate

Goal 5: Improve maternal health

Target 6: Reduce by three-quarters, between 1990 and 2015, the maternal mortality ratio

Goal 6: Combat HIV/AIDS, malaria and other diseases

Target 7: Have halted by 2015 and begun to reverse the spread of HIV/AIDS

Target 8: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases

Goal 7: Ensure environmental sustainability

Target 9: Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources

Target 10: Halve, by 2015, the proportion of people without sustainable access to safe drinking water

Target 11: By 2020, to have achieved a significant improvement in the lives of at least 100 million slum dwellers

Goal 8: Develop a Global Partnership for Development

Target 12: Develop further an open, rule-based, predictable, non-discriminatory trading and financial system

Target 13: Address the Special Needs of the Least Developed Countries

Target 14: Address the Special Needs of landlocked countries and Small Island developing States

Target 15: Deal comprehensively with the debt problems of developing countries through national and international measures in order to make debt sustainable in the long term

Target 16: In co-operation with developing countries, develop and implement strategies for decent and productive work for youth

Target 17: In co-operation with pharmaceutical companies, provide access to affordable, essential drugs in developing countries

Target 18: In co-operation with the private sector, make available the benefits of new technologies, especially information and communications

The Millennium Development Goals and Agriculture

According to Resnick et al. (2006), About 70 percent of the MDGs' target group live in rural areas, particularly in Asia and Africa, and for most of the rural poor agriculture is a critical component in the successful attainment of the MDGs. Even though structural transformations are important in the longer term, more immediate gains in poor households' welfare can be achieved through agriculture, which can help the poor overcome some of the critical constraints they now face in meeting their basic needs. Thus, a necessary component in meeting the MDGs by 2015 in many parts of the world is a more productive and profitable agricultural sector.
While the linkage with agriculture is particularly strong for the first MDG, or MDG 1 --halving by 2015 the proportion of those suffering from extreme poverty and hunger -- all MDGs have

direct or indirect linkages with agriculture. Agriculture contributes to MDG 1 through agriculture-led economic growth and through improved nutrition. In low-income countries, economic growth, which enables increased employment and rising wages, is the only means by which the poor will be able to satisfy their needs sustainably.
Compared with other regions of the developing world, Sub-Saharan Africa faces the largest challenge in terms of meeting MDG 1. In 2001, about 47 percent of the population was living below the international poverty line. Agriculture will be the primary means of addressing this challenge, as 65 percent of the people in the region derive their livelihoods from the sector. However, the contribution that agriculture can make in achieving the MDGs in this region depends on the particular constraints and opportunities prevailing within each of the countries. The MDG scenario combines two broad courses for improving food security and reducing poverty in developing regions: the first way is through broad-based and rapid agricultural productivity and economic growth to increase effective incomes, effective food demand, and food availability; and the second is through investments in education, social services, and health (proxied in the model by female secondary enrollment rates, the female-male ratio of life expectancy at birth, and access to clean water).

Anderson (2006) states that in the case of the hungry people, there are about 800 million people around the world who do not know where their next meal is coming from. Those are largely located in two main areas. The largest chunk is in South Asia, in India, a country that has produced an enormous pile of food, which is exporting food to a certain extent, and still has 200 million or so people going hungry every night out of a population of one billion.

The other large chunk is in sub-Saharan Africa; numbers are slightly smaller, but on the order of 200 million people out of 600 million who do not know where their next meal is coming from. There are similar areas in the rest of Asia, Latin America, and other parts of the world, but much, much less.

He found out that half of them are on small-holder farms throughout the developing world, too small to make it into a business. For example, in Africa one farm has an average of eight people in their household—one household has eight people or so. That's about half of the 800 million. Another 22 percent of the 800 million are the landless rural poor people, largely in places like India, people who don't have access to land who sell their labor. Twenty percent are urban poor, and 8 percent are poor who depend of forests and fisheries, natural resource dependent people poor.

It is a well known fact that it is very difficult for agriculture to be practiced to the point of self sufficiency in food production without sound engineering practices.

Agricultural Engineering Can Help

Agricultural engineers apply engineering science and technology to agricultural production and processing, and to the management of natural resources. Since the first curriculum in Agricultural Engineering was established at Iowa State University by J. B. Davidson in 1905 there has been continued interest in the subject because of its impact on agriculture. The advent of agricultural Engineering discipline has improved large scale production of food and will continue to help in achieving the Millennium Development goals that relate to agriculture.

Specialties in Agricultural Engineering include

power systems and machinery design;

structures and environmental science;

and food and bioprocess engineering.

soil and water engineering

processing of agricultural, food, and biorenewable products.

Information and Communications Technology

According to Wikipedia, **Information technology** (**IT**), as defined by the Information Technology Association of America (ITAA), is "the study, design, development, implementation, support or management of computer-based information systems, particularly software applications and computer hardware." IT deals with the use of electronic computers and computer software to convert, store, protect, process, transmit and retrieve information, securely.

Recently it has become popular to broaden the term to explicitly include the field of electronic communication so that people tend to use the abbreviation **ICT** (**Information and Communications Technology**).

Information Technology as a tool started its influence on Agricultural Engineering in the late Seventies and early eighties. During that period, the use of computers became quite pronounced and a lot of interests were shown in computer simulation of Agricultural systems. By the turn of the century, the advent of Internet increased the rate of the use of computers in Agriculutural Engineering because information now goes around faster than before.

Presently, computer software and hardware are used in many areas of Agricultural Engineering including:

1. Monitoring and Control of the Tractor and its implements;
2. Simulation of the behaviour of the Tractor and farm implements;
3. Moisture and Temperature Changes in Crops;
4. Drying;
5. Milling;
6. Oil Recovery from Oil seeds;
7. Solar Drying;
8. Crop Water Use;
9. Irrigation Scheduling;

and a host of others processes.

Tools

The computer is the primary hardware equipment used in Information Technology. Other tools include digital sensors for all kinds of measured properties including size, shape, moisture content, pressure, humidity, speed, acceleration, stress, strain, temperature and others too numerous to mention. Unfortunately, these are very difficult to come by in developing economies making the work of the researcher in Agricultural Engineering to be quite difficult.

Software tools are basically the various modern programming languages which include Visual Basic, Java Script, C Sharp and C++. Proficiency in one of theses languages makes the work of the researcher quite easy.

Challenges

Even though a lot of work has been done in the use of Information Technology to solve Agricultural Engineering Problems, there is still much ground to cover.

The usual challenge for many includes:

1. Non-availability of hardware tools including computers, their peripherals and digital measuring devices.
2. High cost of Software including Operating Systems which are generally pirated in developing countries
3. Inadequate computer training in Higher Institutions. Even where students are taught, they are only exposed to older languages like Fortran and Cobol which have no place in modern programming
4. Unwillingness or inability to update themselves on the use of modern software tools on the computer by older lecturers; and
5. Inability to follow the fast changing senarios of the outer world (some people even lack access to the Internet which has become ordinary and even trivial

We must rise up to these challenges. The world is moving on almost near the speed of light. One of the ways the Institution of Agricultural Engineering can help is to organise workshops periodically along this line as the Nigerian Society of Agricultural Engineers sometime does. The task can be done. It must be done.

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SECTION 1

POWER AND MACHINERY PAPER

DESIGN, FABRICATION AND TESTING OF MANUALLY OPERATED CASSAVA CHIPPING MACHINE.

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Abstract

A manually operated cassava chipping machine was designed, fabricated and tested. Reducing the size of tubers to be processed into a food product which requires fermentation and drying has been recognized as an effective method of reducing processing time and improving the quality of the products. The machine has an output capacity of 100kg of peeled cassava per hour with minimum amount of sub-standard chips and chipping efficiency of 80% and a uniformity index of 0.7. Using the equipment, chipping operations can be accomplished with relative ease and subsequent operations can be done faster. Fermenting time traditionally requires 4 – 5 days and has been reduced to 1 – 2 days. Chipped cassava dries in 8 – 10 hours depending on the loading density and weather condition. The chips dry uniformly whitish with sweet floury aroma and are friable.

Keywords: Manual operation, cassava, chipping machine, cassava chips, chipping efficiency and uniformity index

1.0 INTRODUCTION

An estimated 70% of cassava produced in Africa is processed before use. Because of its high water content, fresh cassava roots have low value per unit weight, are bulky and perishable, and are therefore expensive to transport and market. However importation of cereals in sub-Saharan Africa has significantly increased in the past 10years and the depreciation of Africa currencies during the same period has made such importation a heavy burden on the local economics. At the same time, cassava production in this region has increased substantially. Many studies have demonstrated the technical feasibility and economic advantages of using cassava as a partial or total replacement for wheat in bread making (F.A.O 1992).

To encourage greater use of cassava flour, simple technologies for producing high quality cassava flour have to be developed. The method of flour preparation is an important factor in producing quality bread. Cassava should be processed and dried immediately after harvest to avoid physiological root deterioration which discolours the flour.

Peeled cassava tubers could be sun – dried as this method is simple, available and affordable in rural areas. Sun - drying can be accelerated by chipping the cassava and drying on concrete floor. This method proved to be more efficient than traditional practice of drying chopped or whole roots. A loading density of 2.5 kg/m^2 is optimum during the rainy season but this can be increased to 3.5 kg/m^2 during the dry season. Under these conditions drying can be completed in 8 to 10 hours with maximum retention of bread making characteristics of cassava chips.

To facilitate this process, a manually operated chipping machine was developed. The chipping machine produced 10mm diameter chips which dried rapidly. This paper presents a manually operated cassava chipping machine which has been designed and constructed for use by the rural populace.

Artificial drying can be used provided the temperature is maintained below 55^{0}C and the air is circulated. Cassava chips store better than cassava flour.

Akintunde and Tunde- Akintunde (2001) designed and constructed a motorized cassava chipping machine with a maximum throughput capacity of 258.78kg/hr. Odigbo and Ahmed (1982) reported efforts made at mechanizing tuber processing in the few processing plants in Nigeria. Ajibola et al (1991) developed a cassava chipping machine whose performance was rated satisfactory at motor speed between 360 and 400 rpm. The machine also consisted of the dicing unit.

Raji and Igbeka (1994) designed and constructed a pedal operated chipping and slicing machines for tubers. Clarke (1987) observed that various chipping machines have been developed and tested in various countries especially in the Caribbean and the South East Asian countries. Leste (1987) developed a pedal operated root chipper/grater. The chipping and grating plates were joined together at the edges, but placed 11.8 cm apart.

.

2.0 MATERIALS AND METHODS

The choice of the materials for the chipping machine was based on the required chipping force, the cost of the materials and the availability of the materials.

The chipping machine was developed specifically to meet the need for efficient cutting of fibrous tubers such as cassava cutting the tubers into strips rather slices. The chipping machine consists of the chipping mechanism (chipping plate and chipping wheel), feeding chute, handle, shaft bearing and frame.

2.1 Design of the Chipping Wheel

The diameter of flat pulleys or small wheel normally ranges from 40 – 540mm. This design adopted a wheel diameter of 380 mm. The thickness of the wheel was determined from equation 1.0 given by Khurmi and Gupta, 2004

$$t = \frac{D}{200} + 6mm$$ (Khurmi and Gupta, 2004) --------1

Where:
D = diameter of the wheel.
$\therefore$ t = 7.90mm

Aluminum was used for the cast or fabrication for its antirust and hygienic condition, a wheel with a thickness of 23 mm was adopted due to the purpose the wheel will serve.

2.2 Dimensions of Arms

The number of arms may be taken as 4 for pulley diameter from 200 mm to 600 mm (Khurmi and Gupta 2004). For this design, the wheel is provided with eight arms which are elliptical in shape.

The cross section of the arm is obtained by considering the arm as cantilever i.e. fixed at the hub end and carrying a concentrated load at the rim end. The length of the cantilever is taken equal to the radius of the pulley. It is further assumed that at any given time the power is transmitted from the hub to the rim or vice versa through only half the total number of arms.

2.3 Tangential Load per arm (Wt)

The tangential load is given as;

$$W_t = \frac{2T}{R \times n}$$ (Khurmi and Gupta, 2004) -------- 2

Where
T – Torque transmitted = 12. 73 Nm
R – Radius of pulley = 0.19 m
n – Number of arms = 8

$$W_t = 16.7N$$

2.3.1 Maximum Bending Moment (M)

The maximum bending moment is given as;

$$M = \frac{2T}{n}$$ (Khurmi and Gupta, 2004) ---------- 3

= 3.18 Nm

Section Modulus

$$Z = \pi/32 \times b_i \times a_i^2$$ (Khurmi and Gupta, 2004)…… 4

Where.
b_i = minor axis, (600 mm)
a_i = major axis (25 mm)
$\therefore$ Z= 9 x 10^{-6} m^3

2.4 Dimension of Hub

The diameter of the hub (d_h) in terms of the shaft diameter (d) may be fixed by the following relation.

$$d_h = 1.5d + 25mm$$ ---------- 5

The diameter of the hub should not be greater than 2d ((Khurmi and Gupta, 2004).

Where d = 20 mm
$\therefore$ d_h = 55 mm

2.4.1 The length of Hub (L)

The length of the hub (L) was found from equation 6.0

$$L = \pi/2 \times d$$ (Khurmi and Gupta, 2004) ----------6

Where
d = diameter of the shaft
L = 31. 43mm
But for the purpose of this design 56mm was adopted.

2.5 Chipping Plate

The chipping plate was made from stainless steel of high tensile sheet of about GA 24, cut into circular plate, 360 mm diameter and pressed to form alternative 4 mm deep concentric grooves. Two rows of alternative punches of 10 mm apart were made on each groove along eight equidistant radial lines.

2.5.1 Determination of Number of Punches on the Chipping Plate.

Considering average cassava tuber with 50 mm diameter and average length of 300mm (Jeon and Halos, 1992)

Area of the tuber can be calculated using the area of cylinder πr^2

Volume of cassava tuber = Area x length
= 1963. 75 x 300
= 589, 125 mm^3

Each punch on the chipping plate is 10mm, which produce strips of 10mm. The length of the chips depends on the position of the tuber at the time of cutting. But usually the average length of chip is 60mm. (Busari, 2005)

Area of strip (chips) = πr^2
Volume of chip = Area x length
= 4713. 00 mm^3

$$Number\ of\ punches\ on\ the\ plate = \frac{vol.of\ Cassava\ Tuber}{Vol.of\ Cassava\ Stip}$$

$$= \frac{589,125m^3}{4713.00m^3}$$

= 125 punches

Therefore, 128 punches were considered which means at a complete rotation of chipping mechanism almost a cassava tuber will be chipped.

2.6 Design of Handle

In the design and evaluation of manually operated machine, tools, control or machine parts, the sizes of different limbs must be considered, that is hand size of user population.

TABLE 1: Indication of Measurement

Measurement No	Part of hand measured	Men		Women	
		Mean cm	90% confidence interval	Mean Cm	90% confidence interval
1	Circumference of hand	21.1	19.3-23.0	18.7	17.5-20.1
2	Breath of hand	10.6	9.8-11.3	-	-
3	Circumference of wrist	17.1	15.5-18.8	16.1	14.3-17.9
4	Maximum grasp circumference	13.4	12.0-15.3	-	-

Source: (Busari, 2005)

Equipment must be suitable for a range of people, not just people with average dimensions. Anthropometric data are, therefore usually presented as means with standard deviations or percentile values. Based on the above data the handle diameter of cassava chipping machine was designed to be 3.8 cm (38 mm)

2.7 Design of Shaft

The load on the shaft = weight of the chipping plate +
weight of wheel + Average weight of a man ------- 7
Average weight of man = 60kg x 9.81m/s^2 = 588 6N,
weight of component on the shaft = (0.42+ 0.18 + 2.0) kg x 9.81 m/s^2 = 2.60x 9.81 = 25.51N
Total weight acting on the shaft =614.11 N

614.11 N

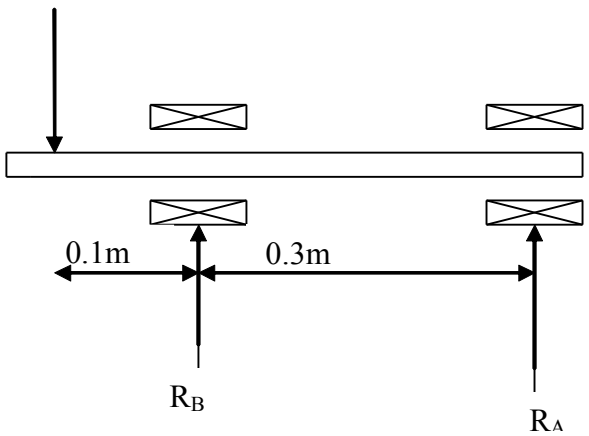


Fig.1: Forces and Reaction acting on the shaft

Summation of all vertical forces
$\sum F_y$ = $R_A + R_B - 614.11 = 0$ ----------8
$R_A = 614.11 - R_B$
Taking moment about point B

$\sum M_B = 0$
$R_A \times 0.3 + 614 \times 0.1 = 0$
$\therefore R_A = -204.7N$
And $R_B = 818.8N$

2.7.1 ***Determination of Maximum Bending Moment***

$0 \leq x \leq 0.1$

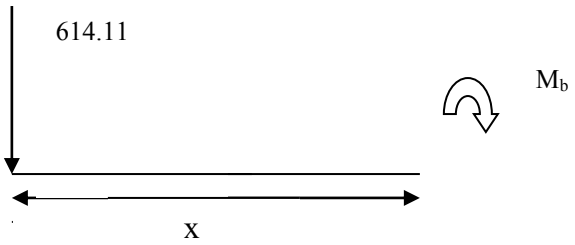


Fig.2: Bending Moment Diagram I

$S.F = Fx + 614.11$
$F_{X_i} = -614.11N$
$M_b = -614.11x = 0$
$M_b = 614.11x$
When x = 0, Mb = 0
When x = 0. 1
$M_b = 614.11 (0.1)$
$= 614 \times 6.1 = 61.411Nm.$
$0.1 \leq x \leq 0.4$

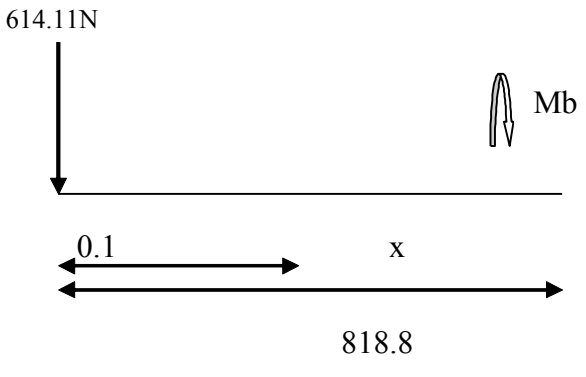


Fig.3: Bending Moment Diagram II

$S.F_2 = -w + 818.8 = -614.11 + 818.8 = 204.7$

$M_b - 614.11(x) + 818.8(x - 0.1) = 0$

$M_b = 614.11(x) - 818.8(x - 0.1)$

When $x = 0.1$

$M_b = 61.411$

When $x = 0.4$

$M_b = 614(0.4) - 818.8(0.4 - 0.1)$

$245.64 - 245.64 = 0$

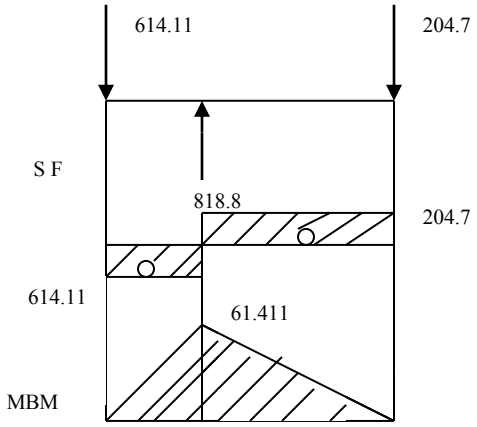


Fig 4: Bending Moment and Shear Force Diagram

2.7.2 Determination of Shaft Diameter

For a solid shaft with little or no axial loading

$$d^3 = \frac{16}{\pi Ss}\sqrt{[(K_b M_b)^2 + (K_t M_t)^2]}$$ (Khurmi and Gupta, 2004) ---------- 9

Where

d – Diameter of the shaft, m

Ss = Allowable shear stress for the shaft without key = 56×10^6 N/m^2

k_t = combined shock and fatigue factor applied to torsional moment

k_b – combined shock and fatigue factor applied to bending moment

M_b – maximum bending moment, Nm

M_t – Torsional Moment, Nm

For rotating shaft, load gradually applied $K_b = 1.5$, $K_t = 1.0$

$$M_t = \frac{9550 \times kW}{N}$$ ----------10

Where kW = power = 80 W

N = 60rpm

M_t = 12.73

$$d^3 = \frac{16 \times 92.99}{\pi \times 56 \times 10^6}$$

$d = 2.04 \times 10^{-2}$ m = 20.4 mm

With factor of safety of 1.5 and using standard shaft size, shaft diameter of 25 mm was used.

2.8 Ball Bearing selection

The approximate rating or service life of ball or roller bearing is based on the fundamental equation.

$$C = W\frac{(L)^{1/k}}{10^6}$$ (Khurmi and Gupta, 2004)--------11

Where:

L – Rating life, millions of revolutions

C – Basic dynamic load rating, N

W – Equivalent dynamic load, N

K – exponential of the life equation

= 3 for ball bearings

The relationship between the life in revolution (L) and life is working hours (L_H) is given by

$$L = 60N.L_H$$.----------12

The dynamic equivalent load, under combined constant radial load (WR) and constant axial or thrust load (WA) is given by

$W = X \cdot V \cdot W_R + Y \cdot W_A$ ----------13

Where;

V = A rotation factor; 1 for all types of bearings when the inner race is rotating.

The values of radial load factor (x) and axial load factor (v) for the dynamically loaded bearings may be taken from the table (SKF, 1989).

The values of x and y for single row bearing are 1 and 0. But in this type of loading, thrust load are not applied, hence $W_A = 0$

((Khurmi and Gupta, 2004)

But $W_R = \frac{P}{2\pi Nr}$ (Esemikose, 1995) ----------14

Where

P = power transmitted = 0 .08 kW

N = speed of rotation = 60rpm

r = radius of the shaft = 0.125m

W_R = 1018 .59N

But $W = X.V.W_R + Y.W_A$

$= 1 \times 1 \times 1018.59 + 0 \times 0$

= 1018. 59N

*For the machine working 8 hours per day and always fully utilized. The life of bearing in hours is given as 12, 000 to 20, 000 ((Khurmi and Gupta, 2004).

Therefore –

L = 60 x 60 x 12, 000 = 432, 000, 00 revolution

$$C = 1018.59 \quad \frac{(43.2 \times 10^6)^{1/3}}{10^6}$$

In order to select a most suitable ball bearing the basic dynamic radial load is multiplied by the service factor (K_s) to get the design basic dynamic radial load capacity. The service factor for the ball bearing of moderate shock load is 2.0 (Khurmi and Gupta, 2004)

$C \times K_s$ = 3, 574. 1 x 2.0

= 7148.1 N

= 7.148 kN

From the catalogue of manufacturer (SKF, 1989), bearing number 205 was selected. The dimension for bearing number 205 are as follow:

Bearing number 205, Bore diameter = 25 mm, outside diameter = 52 mm, width = 15 mm.

2.9 Machine Description

The machine (Plate1) was constructed using locally available materials. The materials used are angle iron (mild steel), galvanized sheet – gauge 16, mild steel shaft (rod), handle (mild steel and wood), stainless steel and aluminum

The basic features of the machine are the feeding chute chipping mechanism and the drive component which comprises the shaft, bearing, handle and chipping wheel.

The feeding chute was cast from aluminum with capacity to accommodate different sizes of cassava tuber. It was bolted to the frame and directly feeding the chipping mechanism. The chipping mechanism consists of chipping plate and chipping wheel. The chipping plate was made from stainless steel of about 260mm in diameter while the chipping wheel was cast from aluminum with diameter of about 380mm. The two components are joined together by riveting.

The handle is made up of 17mm bolt of about 160mm long and hollow wood of internal diameter of 12mm and external diameter of 38mm tightened to the wheel. The shaft was machined to the required diameter of 25mm while the appropriate bearings were selected after determining the radial load capacity. The bearing numbers are 205. The main frame gives support to other components and ensures stability of the chipping machine. The frame has dimension of 500 x 300 x 500mm.

2.10 Cost Analysis

The materials used and their costs as at the time of fabrication of the cassava chipping machine are as presented in Table 2 below

TABLE 2: Materials List and the Cost.

S/N	Item Description	Quantity	Unit Cost N	Total Cost N
1	Angle iron (1.5 x 1.5ft:38 x 38mm)	1 length	2000	2000
2	Chipping Plate	1	6000	6000
3	Chipping Wheel (Cast)	1	2500	2500
4	Feeding Chute (Cast)	1	500	500
5	Bearing	1 pair	250	500
6	30mm Shaft	1	500	500
7	Galvanized Sheet (50 x 30cm)	1	200	200
8	Bolts and Nuts	8	37.50	300
9	Electrode (Gauge 12)	40 pieces	5.00	200
10	Paint	I gallon	500	500

SUBTOTAL = N13, 200

Labour cost: 15% of material cost = N 1, 980
Overhead cost: 60% of labour cost = N 1, 188
TOTAL COST = N 16, 368 (USD$ 131)

2.11 Machine Testing

The cassava chipping machine fabricated was tested using the freshly harvested cassava tubers. The peeled tubers after being washed and weighed were fed against the chipping wheel through the chipping chute. As the operator feeds the tubers against the chipping wheel, he rotates the handle manually. The chips produced were then collected with a tray directly below the chipping mechanism. The weights of the operators were taken together with the number of revolutions made. The chipping capacity and the uniformity index (U.I) were calculated from equations 15 and 16 below. Table 3 below shows the results obtained.

$$Chipping\ capacity = \frac{Input\,(kg)}{Time\,(h)} \text{ ---------15}$$

$$U.I = \frac{No\ of\ chips\ with\ same\ \dim ension}{Total\ No\ of\ chips\ collected} \text{ -----16}$$

3.0 Results and Discussion

The machine was tested and the following results were obtained as shown in Table 3.

Table 3: Results of the Test

Average mass of a human being (kg)	Revolution per minute (rpm)	Chipping capacity (kg/h)
50	45	68
55	50	72
65	60	100

There is a variation in the operating speed (Table 3), this observation is normal as a result of human factor. However, the size of tubers, particularly diameter affected the cranking speed. The operation slows down when feeding bigger tubers because of the higher resistance due to increased area of contact with the chipping blade. Based on the results obtained from Table 3.0, the operation gave a chipping capacity of 68kg and 100kg of peeled tuber per hour for the average mass of a human being of 50kg and 65kg respectively. The diameter of the tuber has effect on chipping capacity. This can be related to the feeding rate; tubers of smaller diameters can be fed in batches compared to bigger tubers which are fed one after the other.

4. CONCLUSIONS AND RECOMMENDATIONS

The developed machine showed that it is a good substitute for the traditional methods of slicing cassava tubers. The machine has a chipping efficiency of 80 percent and a uniformity index of 0.7.

cassava-chipping machine is recommended to be used properly and according to the provided ii. The efficiency can be improved by proper adjustment between feeding chute and chipping plate.

procedure. It is also recommended that improvement should be done in the following areas.

i. An electric motor drive can be installed to facilitate the operation.

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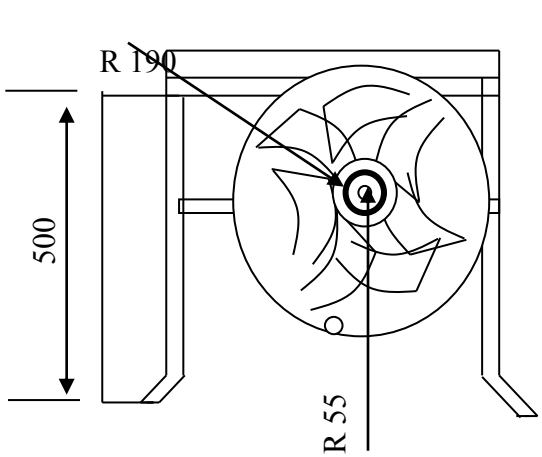
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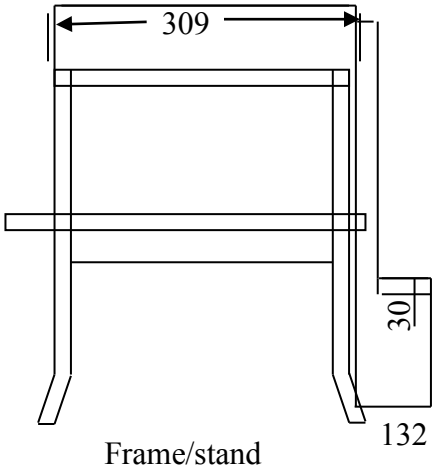
SKF(1989): General Catalogue



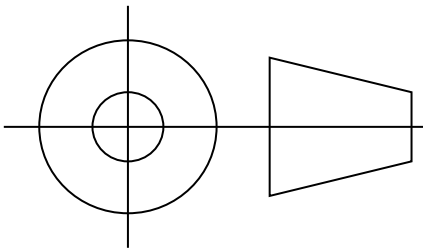
Plate 1: Manually Operated Cassava Chipping Machine



Chipping wheel



Frame/stand



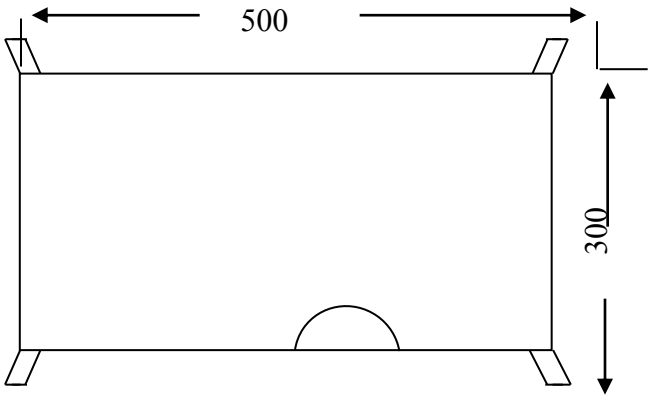


Fig. 5: Orthographic Projection of the Cassava Chipping Machine

DESIGN CONSIDERATIONS FOR AN ANIMAL - DRAWN COMBINATION TILLAGE IMPLEMENT

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ABSTRACT

An Animal drawn Combination Tillage Implement has been conceived and designed. The implement consists of chisel plough that operates simultaneously with disc ridger, for primary and secondary tillage respectively.

The implement has been designed taking into cognizance the average power output the work animals can sustain for an appreciable number of hours as well as the technology level of the rural farmers who are the end users. Materials were selected based on readily available local materials and also to minimize cost. The angle of pull was calculated to be approximately 11^0, which is within the range of optimum performance.

1.1 BACKGROUND TO THE STUDY

The general perception of farm mechanization in Nigeria for many years has been synonymous to the use of tractor and perhaps other engine powered technologies. It is for this reason that various national and state governments have invested so much on gigantic projects like the Operation Feed the Nation (OFN), Green Revolution, Food for All Programmes, etc, during when thousands of tractors were imported. However recent investigations (Ladeinde, 1996), show that fifty percent of these tractors were either broken down or unserviceable due to various reasons including; lack of spare parts, inadequate operation and maintenance, and the unhealthy national macro-economic trend which has not been favourable to agriculture and related equipment. This pathetic situation therefore calls for yet more explorations into other possible alternative farm power system such as the draught animal power for mechanizing farm operations.

The internal combustion engine may dominate farming in Japan, Western Europe and North America, but animal power is still alive and pulling virtually every where else on the planet (Scholtz, 2000). Although the importance of the use of tractors and related implements and electric motors in developing countries cannot be over emphasized, however, by far more affordable and environmentally friendly than petrol or diesel engines, draught animal still provide most of the world's people with the vital power – not only for producing crops and transporting them to markets, but for water-raising, logging, milling, road building and a host of other jobs (Scholtz, 2000).

The use of animal traction technology in Northern Nigeria for agriculture is dated as far back as 1920's. The first demonstration of oxen as a source of power took place in 1922 at Daura under the initiative of the British Government (Musa, 1990). The technology was introduced to improve groundnut production for export and also to improve the diet and income of the people living in the Northern region (Ladeinde, 1996).

Animal traction is particularly well suited for the Guinea, Sudan and Sahel Savannah zones of Nigeria. These areas cover about 21 of 37 states (including the Federal Capital Territory). These areas are trypanosomiassis free, have relatively loose soils free of root and rock impediments, and there is existing tradition of man animal interaction. The success of animal traction technology in these particular areas depends on the supervisor of farmers during the initial years. The placement of agricultural officers in the northern region increase the use of animal traction from about 1000 farmers in 1936 to an estimated 45,000 - 80,000 in 1986 (Ladeinde, 1996).

There has been much ado about the need for engineers to invent or design animal-drawn implements to fit the special circumstances. The statement is often made that implements for draught animals are old-fashioned and inefficient, and farmers are using ploughs which were used 2000 years ago (Scholtz, 2000).

Presently, in Nigeria, the popular tillage implements that have been tested proven and have since been in use by farmers in the North who have adopted animal draught technology to a great extent includes the high wing ridger, mould-board plough and

cultivator. These implements have certain limitations such as power and time losses due to the rigid nature of the implements (Hagmann, 1992), as well as poor soil manipulation in some cases. Furthermore, some soils may require both primary and secondary tillage while only one is normally done; either direct ridging alone or direct mouldboard ploughing alone, which has either directly or indirectly affected total yield. In addition, experiments carried out in field operations showed that the ridging of ploughed land gave the least average draught force, highest cutting depth, best soil physical properties in terms of high moisture content and low cone index (Ademiluyi et al., 2002). The above findings therefore brought about the idea of developing a tillage implement that can carry out both ploughing and ridging. Design considerations for the development of an animal-drawn combination tillage implement is hereby presented. The implement consists of a simple primary tillage component (Disc Ridger) and a secondary tillage implement (chisel plough) which has led to the term "Combination Tillage Implement". The implement has been designed with adequate consideration and understanding of types of animals available as sources of power and their average power outputs as well as average weights they can pull effectively for a reasonable duration to cover an appreciable area of farm land. A pair of oxen is proposed for draught power.

1.2 Objectives of the Study

Although this study is intended to be development and testing of an animal drawn combination tillage implement; the work has been divided into stages of development. This is the first stage and the objectives are as follows:

i) To develop the concept of animal-drawn combination tillage implement.

ii) To design the animal drawn combination tillage implement for use in Northern Nigeria and other places where draught animal power is practicable.

2.0 CONCEPT AND DESIGN CONSIDERATIONS OF THE IMPLEMENT

2.1 General concept of the Implement

In order to solve the problems that were mentioned earlier such as power losses resulting in high draught, common with existing animal-drawn tillage implements as well as achieve better soil manipulation, the development of a combination tillage implement has been conceived. The combination tillage implement consists of chisel plough to do the initial soil breaking and loosening without overturning, and the disc ridger which will gather the soil to form ridgers simultaneously with will gather the soil form ridgers simultaneously with the chisel plough.

In addition, the implement is expected to fulfill the following criteria:

- Ridge shape and size must be adequate; ridges must have a width of 900mm, a height of at least 250mm and a flat crest (like an inverted W).
- Weeding performance on the prepared seed beds must be satisfactory.
- The implement should be easy to handle, to facilitate its use by the rural farmers considering their level of education and exposure.
- Design should be simple and robust.
- The implement should require very little maintenance (wear and tear should be minimal).
- The implement must be affordable to an average rural farmer.
- The implement must be capable of being manufactured with locally available materials without the need for foreign currency.
- Where practicable, further attributes, such as self cleaning should be built into ridger design.

2.2 Technical Design

The combination tillage implement consists of two tillage tools: chisel plough and disc ridger (Fig. 1).

The chisel plough is made up of eight curved shanks that end up with chisel mouths (or tips) joined through a spring load to a beam. The chisel plough beam is attached to the main beam with bolts and nuts, in front of the disc ridger. The chisel plough does the initial breaking and shattering of the soil without complete burial or mixing of surface materials. This helps to reduce the soil strength and hence the draught force required by the disc ridger to gather the shattered soil together to form a ridge.

The main difference between the disc ridger and a high-wing plough-ridger is the use of revolving discs for moving the soil. These reduce frictional resistance and draught power. The disc ridger consists of a central crossed beam attached to the main beam of the implement. Two adjustable discs are attached to the central crossed beam. The

implement is pulled via a chain which allows easy operation and reduces the total load to be overcome by the animal. All adjustments can be set without spanners. Bolts with handles or bolts pushed by spring mechanisms are used.

Ridging Mode
The revolving discs scrape the chisel ploughed soil into a ridge between the discs. The width and height of the ridge can be varied by adjusting the disc-angle and the distance between the discs. This means that if the combination implement is to work on a land with existing old ridges; then it will be positioned within the furrows, such that the chisel ploughs will plough half of each adjacent old ridges, which the disc ridger gathers to form a new ridge on the furrow of the old ridgers.

Size of Discs
The frictional resistance of the discs depends mainly on the revolving movement which turns into a pushing movement the more the disc angle (angle to the direction of travel) is increased. For creation of 900mm wide ridgers, larger diameter discs need a narrow disc angle (leading to lower frictional resistance and lower draught requirement than smaller discs). The main disadvantage of big disc is their weight. The price difference between small and large discs is small.

Tilt Angle
The tilt angle (disc inclination angle) which determined the slope of the ridge shoulder has experimentally been found to have its optimum at 28^0. This angle is fixed in order to make manufacturing easier and to avoid the necessity for any adjustments.

Weight and Design Calculations
The materials for the components have been selected (Table 1) to ensure that the total weight of the implement is about 60kg. With the assumption that the effective vertical force and that the draught of the implement is about five times the effective vertical force (Inns, 1992), we have that:

Weight of implement	=	60kg
	=	600N
Effective vertical force	=	weight
of implement	=	600N
Draught of the implement	=	
5 x 600N	=	3000N
	=	3kN

To calculate the angle of pull, θ (Fig, 2)

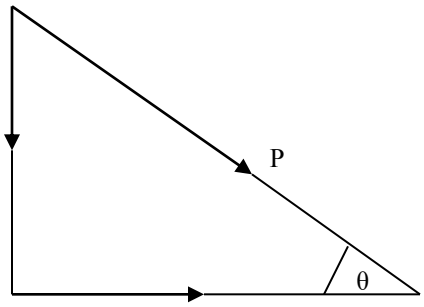


Fig 2: Triangle of forces on the implement

From Fig. 2

V	=	Effective vertical force
H	=	Draught force on the implement
P	=	Pull force
Q	=	Angle of pull
P^2	=	$600^2 + 3000^2$
P	=	$\sqrt{600^2} + 3000^2$
	=	3059.411708N
	=	3.06kN
θ	=	$\text{Tan}^{-1} \frac{0.6KN}{3KN}$
	=	11.30993247
	=	11.31^0 11.31 degrees
	=	11^0 11 degrees

3. CONCLUSION

The design consideration for an animal - drawn combination tillage implement has been presented. The implement consists of two tillage implements combined in one. They include chisel plough and disc ridger combined to one. The chisel ploughs meant to carry out the initial soil breaking and shattering without complete burial of surface materials; and the disc ridger meant to gather the logged soil to form a ridge. The combination tillage implement reduces the total draught power and time requirements, when compared to the conventional high-wing ridger and also reduces soil compaction. It is also possible to adjust the size of the ridges formed by adjusting the distance between the discs. The design and material selection as well as ease of operation and maintenance have taken into consideration the end user which is the Nigerian rural farmer in the North and his environment.

3.1 Future Work

This work is just the first stage of the Development of an Animal Drawn Combination Tillage Implement. The next stage shall involve fabrication, testing and performance evaluation. The performance evaluation and on-field use and feed back shall altogether lead to continuous design modification and performance evaluation, until a design close to perfect is obtained.

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Table 1. Material Selection for Various Component Parts of the Implement

S/No	Description	Specification	Quantity	Remark
1.	Handle arm	Rubber handle	Customized	
2.	Handle frame	10mm mild steel flat bar	2m	
3.	Main beam	50x25x6mm rectangular channel	1m	
4.	Cross beam	50x25x6mm rectangular channel	1m	
5.	Disc frame	50x25x6mm rectangular channel	1m(0.5m) each	
6.	Disc	6mm hardened steel sheet	Dia. 384.8mm	
7.	Disc frame flange	15mm mild steel x300x300mm	2 units	
8.	U-bolt	M75 x 150mm	2 Nos x 2	
9.	Chisel frame	15mmmild steel flat bar	1m	
10.	Chisel	Dia. 25mm mild steel rod	3m($^1/_2$ m length)	
11.	Hitch point	15m mild steel flat bar	150mm length	
12.	Cross bar	6mm mild steel flat bar	1m(0.45m each)	
13.	Fasteners	M10 x 60	3Nos	
		M10 x 75	3Nos	

CAUSES, IMPACTS ANDPREVENTION OF FARM ACCIDENTSON MECHANIZED FARMS.

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ABSTRACT

The occurrence of accidents in mechanized farms has been a subject of concern to farmers and researchers both locally and abroad. Accidents are caused and the costs of these accidents, on the human and financial dimensions are sometimes substantial. Diverse classes of farm workers are victims of farm accidents and this is of a great loss of the nation at large.
Accidents on mechanized farms can be prevented by being safety conscious through development of safety habits and abiding by general safety precautions to avoid complications, risks, hazards and dangers inherent in farms.
The discoveries organized in this paper are in agreement with those in previous studies both outside and within Nigeria. Also from research, poor record keeping is an identified inhibitor in farm management and hopefully, this paper would fill some information gap on the subject of discussion especially relating to mechanized farming in Nigeria in particular.

KEYWORDS: Accidents, Mechanized farms, Causes, Impacts and Prevention.

INTRODUCTION

Yisa, (2001) defined farm accident as anything unpleasant or damaging, which happens unexpectedly or by chance that result in injury, loss of life, property damaged, time loss and intangible loss as a result of operating farm machinery.

Stating further, he said it can also be referred to as all incidental occurrences related to agricultural activities such as snake-bite, bee invasion, fire outbreak, chemical explosion on the farm or at workshop, drowning in a farm dam etc.

In recent times accidents occurring on the farm have been of concern to farmers and researchers
in the developed world (Yisa, 1995 and 1996). In order to buttress the importance of farm accidents, several studies were conducted to determine the source of frequent injuries in farming communities. It is also noted that there are more accidental deaths in agriculture than in any other major industry and farm mechanization activities are the source of the majority of accidents in farming (Jain and Rai, 1980).

Research has shown that several environmental variables and machine characteristics can affect a person's performance when operating a machine (Kepner et'al, 1980). These environmental factors include air temperature, humidity, air purity, noise level, rainfall, topography, vibration, amount of physical effort required for controls, and overall visibility of the machine components and functions that needs to be watched (Kepner et'al, 1980).

Efforts were made in England and Wales to investigate tractor overturning accidents. The types of overturning accidents which occurred almost entirely on slopes were stability loss and control loss accidents and these are due to the fact that through the years from 1968 to 1978,

there was a continuous upward trend in the number of accidents as emphasized by the survey of the Health and Safety Executives (HSE) in Britain (Hunter and Owen, 1985).

Technological advances have greatly reduced man's physical burdens through the use of machines, but man's mental work has been increased.

The person who operates mechanized farm equipment must make many decisions and perform many functions to ensue that machine performs properly. The demand for more decisions may result in mistakes that lead to serious accidents (Kepner et al, 1980).

In a typical Nigerian farm, a wide range of accidents is possible as a result of the poor state of infrastructures supporting mechanized farming and the absence of requisite skills in some instances. The accidents range from snake-bites, fire disaster, field and workshop accidents (involving machinery), bees, attack, and poisoning attack from Agro-chemicals etc. The major impacts of frequent farm accidents are obvious when viewed from the perspective of the social and economic dimensions, loss of value of products, time etc.

OBJECTIVES

The objectives which are sought in writing this paper are as enumerated below:

- Identify causes, impacts and preventions of accidents in mechanized farms;
- Relate these variables to the desire to accomplish goals of socio-economic development in the country;
- Discuss the roles of the human elements in checking and ameliorating accidents on our farms

CAUSES OF ACCIDENTS ON MECHANIZED FARMS

Accidents on the farm could arise from different factors such as absence and lack of safety consciousness by operators; environmental factors; inadequate training and education; and mechanical failures.

Absence and Lack of Safety Consciousness by Operators

Some operators are not safety conscious in handling mechanized equipment this manifesting in their careless attitude, improper operation of the equipment and exceeding the capability of the equipment. An operator not guided by the need for safety consciousness would operate for example a tractor or an equipment on a slope beyond the acceptable static limits as recommended. Farm accidents resulting from mechanical failures and environmental conditions may be prevented by the development of safety habits and following the general safety precautions. Operating an equipment or tractor without proper maintenance is yet another explanation of the inadequacy of safety consciousness by operators. Research findings shows 80% of tractors operators experienced hot water scalding on their faces as a result of cooling system problem from sudden opening of an over-heated radiator cap while the system is hot (Atanda, 2004). According to the same source, 48% experienced dangerous turning leading to head on collision with oncoming vehicle on high ways. Driving a tractor at night without light on is a typical example of how carelessness leads to accidents. Yisa, (2001) found that, 50% of operators exceed the capability of equipment.

Environmental Factors

These factors are not directly controlled by man. These are topography, rainfall, fire, snake bites etc. About 82% of accidents are caused by snakes, bees and other harmful insects attack while moving inside the bush for operation, while 88% were reported to have experienced deep cuts on their body (Atanda, 2005).

Lack of Training and Education

This is caused as a result of inadequate training of operators due to low level of education attained. This problem affects most of the tractor operators. Skills, knowledge and attitude must be developed and inculcated on regular basis so that the capacity of the operators does not fall behind requirements, or they do not forget safety requirements as the needs arises. Regular assessment of the competence level of the operators to perform the tasks involved in making effective use equipment would bring to the fore gaps that need to be bridged through training. Equally important is the need for quality education in universities and polytechnics and other institutions so that adequate manpower is developed for the replacement of those who are aged and exiting employment as operators.

Mechanical Failures in Machine

Brake failure is common cause of this type of accident and other mechanical faults occur at times when machines have exceeded their recommended span. This also may occur due to shortage of fund to buy spare parts or replace the entire faulty systems.

Hydraulic lift failure in tractors moving on the highways with implement attached could create collision with vehicle coming at the rear such as other tractors, thereby causing serious accidents.

Mechanical failure in machine can be due to ignorance or lack of resources to keep the equipment technically fit for operation.

IMPACTS OF ACCIDENTS ON MECHANIZED FARMS

Injuries sustained by field workers have adverse effects on the productivity of the entire agricultural industry (Atanda 2005). This impact is also realized through the curtailment of the injured workers activities, even when slight injuries occurred.

Researchers have discovered that establishments never kept proper records of the impact of accidents in monetary terms; this is an important aspect that needs to be looked into as it is through collecting and analyzing such information that future such occurrences can be prevented.

Impacts caused by accidents either on the operator, establishment or on the equipment or tractor are classified in terms of accidents resulting in time loss, property damage, medical attention and intangible loss. Intangible loss cannot be quantified as it results into deaths of the person causing damages to the establishment. It is noted that most accidents occurrences involved males and between the age 21 – 30 years which is the prime age for the development of critical mass of the needed work force in the sector (Yisa, 2001). The same source added that about 45% of accidents result in property damage, 30% resulted in time loss, 21% resulted in medical attention and 2.67% deaths.

PREVENTION OF FARM ACCIDENTS

Cases of farm accidents can be drastically reduced and/or prevented by applying the following recommendations.

1) Proper inventory of tractors, other machinery and accidents data should be kept through proper documentation of accidents cases.

2. Tractor should be handled by well-trained operators who have adequate knowledge and skill in tractor operation and maintenance

3) Adequate training and education of tractor operators and mechanics would reduce the occurrence of accidents on our farms.

4) Adequate budgetary allocation for maintenance and purchasing of spare parts, provision of all necessary safety apparels for operators during field operation should be ensured by the managers of farm machinery.

5) Preventive measures should be taken to safeguard against accident.

6) Records keeping of selected parameters such as spare parts, use of lubricants, fuels, hours of work etc.

CONCLUSION

Accidents are caused and are costly due to inadequacy of training and retraining of operators, inadequate knowledge on the use of the equipment, low literacy level, lack of proper maintenance of tractors/implement.

If the above recommendations are duly followed then there will be a drastic reduction in cases of accidents on mechanized farms. Safety cannot be compromised for the vain pursuit of economic gains. The management of mechanized farms and the workers must not because of the quest to earn more from the use of this equipment ignore the requirements as demanded by makers for safety.

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FACTORS AFFECTING ENERGY USE IN TILLAGE OPERATIONS

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Abstract

The introduction of high-yielding varieties, intensive cropping systems, increased use of fertilizers and chemicals, and high level of farm mechanization made modern agricultural energy use intensive. Soil preparation for seed planting has been identified as one of the most expensive operation in crop production systems. Large amounts of energy are consumed because of the high draught involved in soil manipulation. Energy use for tillage has therefore become a significant cost factor in some cropping systems. This is often the case when crops are grown on soils that are difficult to manage, or when there are time constraints on seedbed preparation. Although there is enough information on the energy requirements for the production of different agricultural products, little is available on the energy requirements for tillage tools. This paper reviews the findings of several researchers on the contributions of tillage tool and soil parameters on energy needs of different crop production systems. It also highlights the contributions made by researchers in developing equations for evaluating tillage energy requirements for different tillage tools.

1. Introduction

Energy and food are the major needs of most of the developing countries and some developed nations. With the introduction of high-yielding varieties, intensive cropping systems, increased use of fertilizers and chemicals and high level of farm mechanization, modern agriculture has become energy intensive. In modern crop production systems, soil preparation for seed planting is the most expensive especially on difficult soils and rough terrain. To obtain a suitable seedbed, tillage equipments of various sizes and shapes are employed.

Tillage is a basic practice in crop production system. It is a process of mechanical manipulation of the soil by changing bulk density, aggregate size distribution and other physical properties of the soil. The objectives of agricultural tillage are to provide a suitable environment for seed germination, root growth, weed control, soil erosion control, removal of compaction and stubble incorporation. Tillage involves soil cutting, soil turning and soil pulverization, and this demands high energy, not just due to the large amount of soil mass that must be moved, but also due to inefficient methods of energy transfer to the soil. A substantial amount of energy is used to manipulate soil during tillage and planting, accounting for almost fifty percent of the total energy consumed in crop production systems (Chi and Kushwaha, 1991). Okurut and Odogola (1999) reported that besides land, farm power is the second most important input to agricultural production. Large amounts of energy are consumed because of the high draught involved in soil manipulation. These excessive draughts result in frictional and wear losses of the engaging tools. Draughts are mainly influenced by physical and mechanical properties of soil, tillage tool geometry, operating depth and speed.

Energy is used in two ways during tillage operations. The first is in driving the tractor, which constitutes traction, rolling resistance and wheel slip, and the second in pulling the implement, which is the draught. Approximately 30 % of the energy output of a tractor is absorbed into the soil in the wheel tracks, resulting in soil compaction (McPhee et al., 1995). This compaction then places an additional draught load on the implement. Energy use for tillage can be a significant cost factor in some cropping systems. This is often the case when crops are grown on soils that are difficult to manage, or when there are time constraints on seedbed preparation, such as in double cropping systems. Depth of cut, width of cut, tool shape (including cutting edges), tool arrangements and travel speed are factors that have been reported to affect draught and the energy utilization efficiency for a specific soil condition. The

effects of these parameters vary with different types of implements and with different soil conditions (Kepner, 1972). Factors such as soil texture, soil moisture content, soil compaction, tool geometry, tool operating depth, tool forward speed and tool rake angle affect the energy requirement of a tillage operation. The objective of this paper is to review the reported effects of these factors on energy requirements for tillage under varying conditions.

2 Influences of soil physical properties, tool geometry and operational parameters on energy consumption during tillage operations

In a tillage operation, energy can be expressed in terms of energy per unit area or per volume of disturbed soil (Panwar and Siemens, 1972). Since energy requirement per unit volume has the same unit as draught per unit area, it can be shown as the draught requirement to cut a furrow in an exact cross section as expressed by Mckyes (1985). Energy can also be expressed as the rate of energy per depth of operation (Darrmora and Pandey, 1995). The most important factors in the determination of energy requirement of a tillage tool are draught and the amount of soil disturbed. In other words, if draught and amount of soil disturbed are available, energy can easily be calculated as the product of draught and the length of disturbed soil. For a tillage operation, the report of energy requirement should therefore include the depth of operation as well.

Panwar and Siemens (1972) related soil moisture content and density to the energy required for pulverizing the soil, and to other soil strength parameters. Their results indicated that the energy required to pulverize a soil depends to a large extent on the strength and elastic properties of the soil. Niyamapa and Salokhe (1992) reported the relationship between energy and the rate of strain. Energy requirements to break soil specimens during quasi-static and dynamic triaxial tests were measured. Failure energy per unit volume of a silty loam soil in the quasi-static case was minimal at the lowest water content and rapidly increased with increase in water content. At similar water content, higher bulk density (1.3 Mgm^{-3}) specimens required considerably more energy to fail than lower bulk density ones (1.2 Mgm^{-3}). Failure energy of silty loam and sandy loam soils showed rapid increases with speed up to approximately 5 ms^{-1}, and then decreased. Michel et al. (1985) reported that a chisel-based tillage system produced equal yields with approximately 40% less fuel and less time for pre-plant tillage operations when working in irrigated sugar beets, dry beans and corn.

In recent times, researchers have emphasized the need to develop site-specific method of soil preparation so that energy consumption could be reduced. Site-specific tillage is a tillage practice which modifies the physical properties of the soil only where the tillage is needed for crop growth. Raper (1999) stated that the energy cost of subsoiling could be decreased by as much as 34% with site-specific tillage as compared to the uniform depth tillage. Raper et al. (2005) also reported that drawbar power reduced by 47% and 17% for tillage depths of 25 cm and 35 cm for a compacted soil, respectively by site-specific subsoiling as compared to uniform deep subsoiling. Site-specific subsoiling also reduced fuel use by 45% and 27% for 25 cm and 35 cm tillage depths, respectively. Garner et al. (1989) reported that an energy saving of 42.8% and fuel saving of 28.4% were achieved when they adapted a variable-depth tillage system as compared to uniform depth tillage.

Raper and Sharma (2004) evaluated the energy requirements of a straight shank and a minimum-tillage shank in subsoiling a coastal plain soil at different soil moisture contents. Results showed that the minimum-tillage shank required more energy and disrupted less surface soil than the straight shank. The straight shank gave the least draught and was therefore regarded to be more energy efficient. Smith and Williford (1988) compared power requirements of three subsoiler types and found that a parabolic-shaped subsoiler required less draught compared with a conventional or triplex subsoiler and also had the added benefit of producing more downward vertical force, which increased the normal load on the rear axle of the tractor and decreased slip. Smith (1993) evaluated specific energy requirements of eight implements as crop production practices were performed. Tractor instrumentation, which measured engine speed, ground speed, fuel consumption and draught, was used to collect data for up to nine combinations of gear selection and engine speed while other operating parameters were maintained constant. Results showed that there was fuel savings of 20-30%. Fuel consumption data revealed that 45-60% of the fuel consumed was required to propel the tractor. Average draught, drawbar power and specific energy requirements needed for performing crop production practices throughout

the cropping season were also obtained. Kheiralla et al. (2004) determined the power and energy requirements of mouldboard plough, disk plough, disk harrow and rotary tiller in a sandy clay loam soil in Malaysia. Disk harrow was reported to be the most energy efficient implement in terms of fuel consumption and specific energy, followed by the rotary tiller, disk plough and mouldboard plough. Raper et al. (2000) conducted a study to determine the energy requirements for shallow tillage (0.18 m) and deep tillage (0.33 m) in autumn and spring using mouldboard and chisel ploughs. It was reported that shallow tillage took approximately 50% of the draught and energy requirements of deep tillage. Autumn tillage consumed slightly less draught and energy than spring tillage.

Khalilian et al. (1988) measured draught and energy requirement of several tillage implements used for conservation tillage in coastal plain soils. Their results showed no significant differences in draught requirements between a subsoiler and a paraplow at the same depth of operation. Draught however, increased with an increase in tillage depth. The chisel plough required significantly less draught per shank. They reported values of 2.68, 4.45 and 5.00 kN/shank for the chisel, subsoiler and paraplow, respectively when operated at 0.25 m soil depth and 6.4-7.2 km/h of speed. At deeper depths, the results changed inversely. When operated at 0.35 m depth and at speeds between 6.7 and 7.0 km/h, values of 6.25 and 6.0 kN/shank were reported for the subsoiler and paraplow, respectively. Perdok and Werken (1982) studied the energy requirement of different tillage implements at different soil textures and obtained the results presented in Table 1.

Table 1: Specific work (kJm^{-3}) for the main tillage implements in several soil types.

Implement	Soil Type				
	Sand	Sandy lam	Silt	Clay loam	Heavy clay
Mouldboard plough	30 ± 5	40 ± 5	60 ± 8	80 ± 10	120 ± 20
Chisel plough	20 ± 4	27 ± 4	40 ± 6	55 ± 7	80 ± 10
Cultivator	18 ± 3	24 ± 4	36 ± 5	48 ± 6	65 ± 8
Disk harrow	18 ± 3	22 ± 4	30 ± 4	40 ± 5	55 ± 7
Rotary tiller	150 ± 15	75 ± 20	210 ± 25	250 ± 30	320 ± 40
Oscillating harrow	45 ± 8	60 ± 10	88 ± 12	118 ± 15	175 ± 20
Powered harrow	120 ± 10	5 ± 15	165 ± 20	90 ± 25	250 ± 30

Source: Perdok and Werken (1982)

3. Energy consumption in the production of crops using different tillage systems

Bockari-Gevao et al. (2005) determined the direct and indirect energy consumption of field operations in a lowland rice production system in Malaysia. Field time, fuel and other energy requirements were measured for tillage, planting, fertilizing, spraying and harvesting operations performed. Energy analysis carried out revealed that the highest average operational energy consumption was for tillage, which accounted for about 48.6% of the total operational energy consumption, followed by harvesting with 32.6% and planting with 15.7%. Fertilizing and pesticide spraying did not make any contributions to the operational energy consumption. Based on energy sources, fuel was the main consumer of direct energy with 22.2%, and fertilizing recording the highest indirect energy consumption with 63.2%. Human labour, pesticides, seeds and indirect energy for machine use had marginal importance, contributing only 0.2%, 0.6%, 6.8% and 6.9%, respectively to the total energy consumption. Bockari-Gevao et al. (2005) gave the results presented in Table 2 indicating the contribution of each field operation in the lowland rice-based cropping system.

Table 2: Operational energy consumption distributed by field operations.

Field operation	Operational energy consumption, MJ ha^{-1}		
	Off-season	Main season	Average
Tillage	1756.73	1737.92	1747.33
Planting	485.26	640.56	562.91
Fertilizing	28.61	29.32	28.96
Spraying	25.80	144.66	85.23
Harvesting	1171.31	1171.57	1171.44
Overall mean	693.54	744.81	719.18

Source: Bockari-Gevao et al. (2005)

Kosutic et al. (2005) compared the energy consumption of three soil tillage systems in the production of maize, winter wheat and soybean grown on anthropogenic Albic Luvisol. Tillage systems and implements consisted of conventional system (plough, disc harrow and combined implement), conservation system (chisel plough and multitiller) and no-till system. Results indicated that conventional tillage system consumed the greatest energy.

Comparing to conventional tillage system, conservation tillage system with chisel plough and multitiller consumed 37.5% less energy, while no-till system used 85.5% less energy. In the first season the greatest yield of maize was achieved with conventional tillage system while next to it was conservation tillage system. In the second season the greatest yield of winter wheat was achieved with conservation tillage system. Next to it was conventional tillage system followed by no-till system. In the third season, the greatest yield of soybean was obtained with conservation tillage system again, while next to it was conventional tillage system and no-till was the least. The results also showed that conventional tillage system was the greatest fuel and energy consumer. The greatest part of the energy, almost 75% was consumed during mouldboard ploughing. Conservation tillage system that introduced chisel plough instead of mouldboard plough led to the saving of 37.5%, while no-till saved 85.1% energy in comparison to conventional tillage system.

The authors also compared the tillage systems with respect to energy requirement to obtain yield. In maize growing, conventional tillage system required 233.05 $MJMg^{-1}$. Changing conventional tillage system with conservation tillage system enabled saving of 37.4% or 679.96 $MJMg^{-1}$. The greatest energy saving was with no-till system with energy requirement of only 35.73 $MJMg^{-1}$ or 84.7% less energy per Mg of maize grain. Winter wheat growing showed that conventional tillage system consumed 315.32 $MJMg^{-1}$. Conservation tillage system with 192.38 $MJMg^{-1}$ enabled saving of 39%, while no-till system with only 47.14 $MJMg^{-1}$ saved 85.1% in comparison to conventional tillage system. In soybean growing, conventional tillage system required 686.78 $MJMg^{-1}$. Using conservation tillage system required 418.13 $MJMg^{-1}$ or 39.2% less energy than conventional tillage system. No-till system required 103.5 $MJMg^{-1}$ and this enabled saving of 84.9%. The authors concluded that in comparing these data to other sources, wide variations could be expected due to soil types, field conditions and working depth. Kosutic et al. (2005) presented the result shown in Table 3 to show the energy and labour requirement of different tillage methods.

Table 3: Energy and labour requirement of different soil tillage methods (three years average)

Tillage	Fuel Consumption, L ha^{-1}	Energy Requirement MJ ha^{-1}	Work Ratio ha h^{-1}	Productivity h Mg^{-1}		
Conventional Tillage (CT)				Maize	Wheat	soybean
Plough	35.08	1357.60	0.84	0.15	0.21	0.45
Disc harrow	7.51	290.64	2.88	0.04	0.06	0.13
Seedbed implement	4.26	164.86	6.40	0.02	0.03	0.06
Total	46.85	1813.10		0.21	0.30	0.64
Conservation Tillage (RT)				Maize	Wheat	soybean
Chisel	22.43	868.04	1.62	0.08	0.11	0.23
Multitiller	6.85	265.10	3.30	0.04	0.05	0.11
Total	29.28	1133.14		0.12	0.16	0.34
No Till (NT)				Maize	Wheat	soybean
No-till planter	6.98	270.13	2.84	0.05	0.06	0.13

Source: Kosutic et al. (2005)

Burt et al. (1994) determined the energy required to produce cotton in a conventional and

conservation tillage system. Results indicated that the tillage system used had significant effect on the energy required for crop establishment. Strip tillage in wheat residue/stubble required about 50% less energy than did the conventional tillage system involving disking, field cultivating, subsoiling, and planting. Takacs-Gyorgy and Gecse (2001) evaluated the performance parameters, energetic characteristics and cost factors of direct drilling by long-term trials in Osztopan and Godollo regions in Hungary. The effect of direct drilling, disking, ploughing and soil loosening combined with disking and ploughing on the soil conditions, yields and cost factors were evaluated and based on the results of the examination. The economic comparisons were done by gross margin analysis of various technologies. It was reported that from an economic point of view, the cultivation methods evaluated did not differ significantly in comparison with the ploughing methods practiced in the areas. Even though the lowest gross margin was obtained from direct drilling while the highest was from ploughing, cultivation practice did not influence energy input significantly. The authors recommended that detailed studies and economical calculations be carried out before changing any crop production technology. Rusu (2005) determined the influence of conventional ploughing tillage technology in comparison with minimum tillage upon the soil properties; weed control, yield and energy efficiency in maize, soybean and winter wheat production. It was reported that for all cultivation practices, weed encroachment was maximum for disc harrow and rotary harrow tillage followed by chisel and paraplow. The weed encroachment was minimal for conventional ploughing. Fuel consumption was reduced by 12.4-25.3 litres of gasoline per hectare by applying the minimum soil tillage system. The power input was also reduced by 23.6-42.8% by using the minimum tillage system.

4. Model equations for the determination of energy requirements of different tillage implements

Several researchers (Bridges and Smith, 1979; Chinnan, et al., 1980; Zentner et al., 1984; Sarker and Farouk, 1992; Singh and Singh, 1992; Singh et al., 1997; Palaniappan and Subramanian, 1998; Lal, et al., 2003; Umar, 2003; Chaudhary et al., 2006; Abubakar and Umar, 2006; Chamsing et al., 2006) have reported findings on energy use in different areas of human endeavour. These researchers used established equations or modified versions of the equations in determining the different components of energy use before getting the total. Similarly, in a tillage operation, several factors could affect the draught and subsequently the energy requirement of a tillage tool. These factors can be grouped into tool parameters, soil parameters and operating parameters. To evaluate energy requirement of a tillage tool, energy requirement resulting from each group of factors should be taken into account in order to have an estimation of total energy requirement. Although several equations based on soil parameters, tool parameters and operational parameters were presented for the evaluation of draught of tillage implements, only few have been reported for the determination of energy requirement of those tillage tools or implements.

Soehne (1956) determined the draught force of inclined plane blades using different soil and tool parameters in a laboratory soil bin. He highlighted soil-metal friction, shear failure, acceleration force for each block of soil, and cutting resistance as the components that made up the draught. Payne (1956) studied the relationship between the mechanical properties of soils and the performance of flat rectangular tines. He observed that a regular soil cleavage pattern occurred under the influence of the moving tine and that once the tine has moved far enough to form one set of cleavage planes, further movement only reproduced the same pattern. Draught varied with depth, and was also linearly related with cohesion. The volume of upheaval was dependent upon angle of shearing resistance and angle of soil-metal friction. Soil-metal friction was however independent of speed. Osman (1964) examined the mechanics of soil cutting using straight and curved blades with different rake angles in three soils in a laboratory soil bin. Soil bulk density, angle of soil shearing resistance, adhesion, depth, mean surcharge and angle of soil-metal friction were used in computing the predicted values of the soil forces. He reported that at shallow depths of cut, cohesive forces are greater than frictional forces. In frictional soils, draught was affected by soil-metal friction angle.

Stafford (1979) investigated the effect of speed on the draught and soil failure patterns of narrow tines in a sandy clay loam and clay in a laboratory soil bin. For a given dry bulk density of the clay and sandy clay loam soils, cohesion and soil-metal friction increased with moisture

content, respectively. Brittle and plastic failures were observed at low and high moisture contents, respectively. At moisture contents below the plastic limit, draught increased rapidly with speed. He concluded that two types of relationship exist between draught and speed, which depend on moisture content and not on soil type.

Mckyes and Desir (1984) conducted field experiments in clay and sandy clay loam soils using flat tillage blades of varying width, depth and rake angle in the field. Measured quantities of draught and disturbed soil areas for the different test conditions were compared to those predicted by a model of soil wedge failure in front of narrow blades, with reasonable agreement. Both the specific draught per unit soil area and the degree of soil loosening were observed to increase with the relative narrowness of the tillage blades and with the rake angle, as predicted by the model. Chi and Kushwaha (1991) carried out a three-dimensional finite element analysis to simulate soil cutting with rectangular flat and triangular tillage blades at different rake angles. The draught and vertical force, soil failure and stress distribution along the tool surface were obtained from the finite element model. Laboratory tillage test was conducted in the soil bin to verify the results from the finite element model. Both the finite element model and soil bin tests showed that the triangular blade required less draught for large rake angles especially for the vertical position. Oni et al. (1992) evaluated effects of design on the draught of 29 model undercutter-sweep tillage tools in an artificial soil in a laboratory soil bin. They found out that soil failure pattern depended to a large extent on the depth of operation and tool geometry, and was little influenced by the range of velocities used. Draught increased with increase in tool speed, slide angle and lift height. Mckyes and Maswaure (1997) conducted a field experiment to observe the effects of the geometric parameters of flat tillage tools on their draught, cutting efficiency and loosening of a moist clay soil. The degree of soil loosening was generally smaller at a rake angle of 60^{o} than at 30^{o} or 90^{o}, and tended to be higher at greater depths of operation. A larger depth to width ratio generally increased the degree of loosening. Results for the soil studied indicated that the best implement design for low draught, high cutting efficiency and superior soil loosening should have a rake angle of about 30^{o} and should be fairly narrow with a depth to width ratio of 2 or more. Mouazen and Nemenyi (1999) used the finite element method to estimate the draught and vertical forces, soil deformation and normal pressure distribution on subsoiling force for four subsoiler geometrical types. The theoretical results showed that a well coordinated angle combination of the two parts of the subsoiler made a large reduction in the draught and vertical forces of the subsoiler with a shank angle of 75^{o} and a chisel angle of 15^{o}. Al-Janobi and Al-Suhaibani (1998) conducted a research to determine the effects of speed and depth on the draught of six commonly used primary tillage implements on sandy loam soils and to develop regression equations for draught based on speed and depth. They reported that implement width, operating depth and speed affected the draught of the tillage implements. It was also reported that draught depended on soil conditions and geometry of the tillage implements.

Owen (1989b) investigated the effect of tool speed on the forces and soil disturbance associated with subsoiling in a compact clay loam and a compact sandy loam under field conditions. A three-dimensional soil wedge model of soil failure was used for the investigation. Regression analysis revealed that tool speed had a highly significant linear effect on the vertical force, and had a highly significant quadratic effect on the horizontal force, total force, moment and specific resistance. Onwualu and Watts (1998) studied the effect of speed on tillage tool forces for wide and narrow plane tillage blades in a silty sand soil in a soil bin. The performance of three theoretical models based on the trial wedge approach in predicting the experimental results was evaluated. Soil cohesion, soil angle of internal friction, adhesion, angle of soil-metal friction, moisture content, and bulk density were all measured. Experimental results showed that draught and vertical forces were significantly affected by depth, rake angle and speed. The forces generally increased with the speed of operation. They concluded that the tool forces were a function of speed and the square of speed.

Vetrov and Stanevski (1972) presented the following equations for the determination of energy requirement to cut and separate a chip of soil with a sharp tool:

$$E = \frac{K_r K_v [P + \gamma V^2 A_e [\frac{\sin\alpha\cos\alpha}{\sin(\alpha+\beta)}]}{A_e} \quad (1)$$

$$K_r = 1 + \frac{V\sin\alpha}{V_d \sin(\alpha+\beta)} \quad (2)$$

$$V_d = \sqrt{\frac{\tau}{\rho}} \quad (3)$$

Where

E = Tool energy requirement, J; K_r = Ratio of mean to maximum cutting force; K_v = Coefficient of speed effect; P = Quasi-static draught, N; ρ = Soil bulk density, kg m^{-3}; V = Operating speed, ms^{-1}; V_d = Soil disruption speed, ms^{-1}; A_e = Average cut area, m^2; α= Tool rake angle; β = Angle of soil wedge rupture; τ = Soil shear strength, Nm^{-2}.

Most of the research findings on soil tillage reported in this section indicated that most researchers reported single equations for the prediction of draught or energy requirement of a particular tool at different soil and operating conditions. These equations may not be very ideal because of the non-homogeneity of soil as a complex mixture of solids, air and water which could react differently under different ambient conditions and operational situations. The equations reported also show that force and energy requirements of tillage tools are calculated in total. There is no known reported information on the subdivisions of those total forces or energies in order to know the contribution of each individual factor like soil-metal friction, cohesion, angle of soil-metal friction and others in total energy requirement. The equations which have been implemented to predict applied forces of tillage tools have been developed under specific assumptions of soil parameters, operating conditions and tool geometry which make their area of application limited. In addition, majority of the equations were modelled under controlled conditions (laboratory soil bins) and this does not accurately reflect what is obtained in the field.

5. Conclusions and Recommendations

Review of literature has shown that energy is a major cost factor in modern agricultural production systems. But little research especially in the energy requirements of different tillage tools and soil conditions is available. The review also indicated that several equations have been reported for the determination of tillage tool draught but only few gave equations for the evaluation of energy requirements of those tools even though the word 'energy' could be more familiar to the farmer than 'draught'.

To adequately evaluate crop production energy requirements and be able to choose alternative crop production systems, energy data should be collected for machinery and soils of major crop production systems. Efforts should focus on finding particular equations for particular soil, tool and operating conditions. At the same time, efforts should be made to investigate the components of total draught and energy requirements for different tillage operations. This approach will lead to a reduction of energy requirement of a particular tool by optimizing soil, tool, and operating parameters based on the information collected. Since draught multiplied by one metre of distance gives the energy value, and this energy value has the same numerical value as the corresponding draught requirement of the tool for a particular treatment, researchers should endeavour to convert and report tool forces in terms of energy which is more familiar to non engineers.

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A REVIEW OF AGRICULTURAL MECHANIZATION IN NIGERIA PROBLEMS AND PROSPECT

BY

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ABSTRACT

Nigeria is richly endowed with human resources, vast and rich agricultural land, varied and high quality natural resources, a good network of rivers and a climate that allows for farming throughout the year. Nigeria's population is rapidly increasing, necessitating the need for increasing food production. As a result, emphases are being laid on higher productivity which demands for greater supply of agricultural inputs and mechanizations specifically. This paper highlights the potential contribution of agricultural inputs and mechanization in provision of employment, foreign exchange earning, food security, poverty alleviation, supply of raw materials for industries and general economic development. Economic sustenance can be achieved through vigorous crop production, crop processing and storage programmes if access to finance, technical expertise, farmers extension and advisory services, research support, adoption of improved technologies and good marketing out fit for agricultural products are given appropriate attention.

INTRODUCTION

Nigeria is situated in the West African region and lies between longitudes $2^0$40' and $15^0$10'E and latitudes 4^0 and $13^0$50N. Nigeria has a total land area of 923, 768 square kilometers. It is bordered to the north by the Republic of Niger and Chad, to the West by the Republic of Benin, while the Republic of Cameroun shares the eastern boarders' right down to the shores of the Atlantic Ocean which forms the southern limits of Nigerian territory (Fagoyinbo, 2005).

Out of Nigeria total land area about 26% (24 million hectares) is arable. Presently, the total area under cultivation in Nigeria is 283.1 thousand hectares

(Fagoyinbo, 2005), this is less than 1.3% of the cultivable land area. According to Ikpi (1998), before the advent of the oil boom of the 1960's the economy of Nigeria was relatively based on agriculture, contributing significantly to the gross domestic product (GDP). Before the decade of the 1960's, the regional governments provided funds only for agricultural research and agriculture was able to grow at a sufficient rate to provide adequate food for an increasing population, raw material, mainly for the colonial masters, increasing public revenue for government, foreign exchange for growing external needs and employment opportunities for an expanding labour force. The support given by the regional government then was on the establishment of research, extension and crop export/marketing for export crops like cocoa, cotton, groundnut, palm oil, rubber, coffee, etc, to generate more revenue for the country. However, food self – sufficiency did not pose any problem worthy of public attention. It was evident then that, rural wealth and economic development were relatively spread and people were contented living in their villages (Ado, 2005).

Agricultural mechanization which contributes largely in crop production is the process of improving farm labour productivity through the use of agricultural machinery, implement and tools. It involves the provision and use of all forms of power sources and mechanical assistance to agriculture as well as maintenance of all types of tools, implement, machines and equipment for agricultural

production. In the last few decades, agricultural mechanization has provided solution to emerging crop production problems, for instance efficacy of agricultural inputs (seeds, fertilizers and chemicals) and natural resources (sunlight, air, land and water) usage can be increase through agricultural mechanization (Yusuf, 2006)

However, considering the growing awareness of the need to improve agriculture through improved technology and machines, several attempts were made to translate the awareness into the formulation and implementation of agricultural mechanization policies and programmes, by state and federal government because of the rapid determination in the country's widening food supply demand gaps, and increasing food import bills. The rapid decline in government revenue from agricultural exports and in the labour force required to improve agriculture became serious problems. Therefore, Government initiated several agricultural policies, programmes and projects. Namely Operation Feed the Nation (OFN), Green Revolution (GR), Back to Land (BL), River Basins Development Authority (RBDA), Agricultural Development Project (ADP) Assisted by world bank, and National Agricultural land Development Authority (NALDA) etc. to arrest the nations reliance on the importation of essential food items that increased from 143.15million in 1992 to 1956.1 million in 2003 (Table 1).

It is interesting to also mention about the existence of the Fiat and Steyr tractor assembly plants and other agricultural machinery sales, companies (T & E, SCOA, and BEWAC) which were meant to support agricultural mechanization, but suddenly folded up due to economic crunch, mismanagement, indigenization policy and privatization. The collapse of these companies has adversely affected the growth of agricultural mechanization in Nigeria (Yisa, 1997). Agricultural mechanization must be seen to provide adequate and reliable source of food and feed as well as provide a strategic fill back in emergency for food security. The agricultural sector contributes more than 70 percent of the population with habitation employment and about 40 percent of the GDP and contributes 88 percent of non-oil foreign exchange earning (Ado, 2005). Hence, the use of appropriate agricultural mechanization technique can create opportunities that will enable rural communities to increase their output for domestic consumption and export, so as to generate more revenue.

It is paramount to mention that, Nigerian government imported agricultural machinery and implements valued at over N757 million in 2000 (table 2) yet, the impact of such huge amount of money was not felt. This is because some machines imported were discovered to be unsuitable to our farming system, some machines and implements were diverted to neighbouring countries by crooks in government and party stalwarts. The machines and equipment imported were beyond the purchasing power of our Co-operative Farmers Association, because, a set of tractor with complete implements was sold at N7 million. Some machines have even broken down due to lack of spare parts. In most cases, the professional agricultural engineers where not involved in the procurement and management of the farm machines.

PRESENT STATE OF AGRICULTURAL MECHANIZATION IN NIGERIA

The level of agricultural mechanization in Nigeria can be classified in to the following:

a. Human Power

About 70 percent of the land area under cultivation in Nigeria is owned by small scale farmers, who practice mainly traditional methods of farming based on bush fallow. After slashing the weeds, farmers use fire to dispose off the excess vegetation and perhaps to supply meager mineral elements. Almost all and subsequent operations are performed by hand tools. Human power is used to operate hand tools such as hoe, cutlass, sickle, axe, shovel, rake and

equipment like weeder, sprayers, maize shellers, pedal threshers, groundnut oil extractors, seed drills and water lifting devices. The manual power continues to be the main source of farm power in most developing countries. A human can only develop about 0.08kW of energy but this of cause varies with environmental conditions and type of food intake (Kaul and Egbo, 1985).

b. Animal Power

Animal power is used to operate wide range of implements, machine, and equipment. Land preparation implements (moldboard plough, harrow, ridger), seed drill, planter, and transportation using pneumatic cart. These implement are operated with power from animals such as oxen, horses, camels and donkeys.

Despite all efforts, a number of factors militate against the continue expansions of draught animal usage in Nigeria

Notable among these factors include:

* Non availability of wide range of animal drawn implement

* Inability of farmers to maintain such animals, compelling the farmers to dispose off the animals under slightest financial pressure.

* Animal power is not fully exploited in the African continent. In some countries, like Nigeria, there are certain ecological limitations imposed by the prevalence of the tsetse fly.

* High level of illiteracy and lack of experience in the use of machinery and equipment prevails. Hence, the promotion and encouragement of the used of animal power seem to be an alternative to the high cost of tractors. There is need to develop appropriate technology to maximized the use of animal traction.

c. Mechanical Power

Mechanical power is the most modern level of agricultural mechanization derived from mobile sources (tractors, tillers etc) and stationary sources (Spark ignition, Compression ignition and electric motors).

Mobile mechanical power sources are used for field operations and transport while stationary power sources are used to operate threshers, shellers, oil extractors, rice mills, flour mills, wet grain grinder and water lifting devices to mention but few, the type of source of mechanical power and associated implement, machines and equipment depend on the size, power rating, availability and the level of sophistication of agricultural mechanization. The commonest and largest of mechanical power in agricultures mechanization is the tractor, which is available in different makes, model, sizes, and power rating.

Although Nigeria is an oil producing country, there exist a scarcity of fossil fuel, steel products and spare parts for machinery, while the supply and delivery of these items are also irregular.

Hence, majority of the farmers are still dependant on their hand tools applying poor techniques of production and limited to a small acreage, and thus the productivity per hectare and per farm worker is very low.

FACTORS AFFECTING AGRICULTURAL MECHANIZATION IN NIGERIA

Inspite of the efforts made by government and private agencies to support agricultural mechanization in Nigeria, the farmers are still faced with some constraints as discussed below.

a. Inconsistency in Government Policy.

Every government in Nigeria has claimed to place priority on agriculture. Successive government in quest for agricultural development established a number of agricultural schemes, institution, extra-ministerial department and programmes.

However, with such evolution and interventions, it seems unfair to conclude that government has neglected the agricultural sector, nevertheless, their unimpressive performance is quite apparent. The recorded failures in

execution could be attributed to interrupted changes in government and their respective agricultural policies.

The inconsistency in agriculture policy has a negative effect in the history of agricultural development in Nigeria.

b. Lack of National Policy and Strategy

There is the need for a legislation demanding the three tiers of government to contribute towards the success of agricultural mechanization through the formulation of National Policy and Strategy in agricultural mechanization related to the manufacture, sales and distribution of farm machines and implements. These three tiers of government should contribute certain percentage of their monthly allocation to the establishment of agricultural machinery assembly plants, manufacture of simple farm implements and equipment, fertilizer blending plants, research in institutions; similar to what obtains in China, Uganda, Malaysia, Singapore etc (VOA 2007).

c. Low level of Engineering Technology inputs

Farmers in developing countries like Nigeria with tropical climate face much more acute problems in managing their natural resources. Large amount of rainfall and high temperature in some part of the country makes it difficult to deal with intense diseases and pest infestation. Poor farmers are limited in their opportunities to use technology and they are more desperate to increase production even if the practices are not friendly to the environment.

Beside, the Nigerian agricultural sector must not only produce adequate food for a rapidly growing population but also increase production of export crops in an increasing competitive market, and continue to be a major employer of labour by the use of improved engineering technology in the area of production, processing and marketing machinery and equipment for improved cultural operations.

The agricultural sector now requires labour with requisite technical skills and technology to transform the crops produces into high valued finish products for consumer's benefits and export.

d. Low Income Level

Farmers in Nigeria feel discouraged about producing more food crops due to lack of reasonable market out-lets. To make a good profit compared to the high cost of farm inputs required by the farmers to meet–up with their production targets, they need some subsidies on farm inputs. The low level of yield recorded due to non-availability of farm inputs and quality of products affects their income generation earning.

e. Inadequate Infrastructure

Deficiency in physical infrastructure accounts for systemic economic problems. The provision of adequate infrastructures such as; energy, roads, railways, water supply, irrigation, storage, schools, hospitals and telecommunication facilities provide necessary inputs to sustain crop production activities, productivity and efficiency. These as whole contribute adequately to the quality of life.

f. lack of Funding

Available records indicates that, although agriculture is in the concurrent list(which under normal circumstances would imply more adequate attention to and sustained funding of agriculture by federal, state and local governments), it is a relatively neglected sector in terms of productive investment. Furthermore, private sector investors see agriculture as an unrewarding sector when it comes to quick profit making. While government looks at agriculture as purely a small farmer enterprise. Consequently, less than one percent of total annual budget is spent on agricultural research (Ikpi and Ikpi, 1998).

Poor access to capital from government, bank and market outlets, low labour productivity and other related socio – economic factors have a negative impact on agricultures production.

PROSPECTS OF AGRICULTURAL MECHANIZATION IN NIGERIA FOR ECONOMIC DEVELOPMENT

The prospects of agric mechanization shall be discussed under the following heading.

a. Agricultural Production

The agricultural sector is dominated by small holder farmers still using hand tools and dependent on nature. The sizes of their farm lands could be increased if appropriate agricultural mechanization techniques are made available to them. Farmers should be supported with subsidies not only on inputs but, the government should buy over the excess farm produces after harvest at reasonable price from the farmers to avoid exploitation by middle men..

b. Job Opportunity

The high cost of agricultural production has thrown potential farmers out of business, the effect which has encouraged young men to migrate into the cities and increased the number of motorcycle operators. Capital should be made available to interested investors at a subsidized interest rate from federal government, financial institutions such as Nigerian Agricultural Co-operative and Rural Development Bank, Nigeria Industrial Bank, Nigerian Bank of Commerce and Industry etc. This is to finance small and medium scale enterprises and other viable agricultural projects to enhance the level and quality of agricultural production and processing through the use of agricultural mechanization.

c. Foreign Exchange Earning

For the purpose of encouraging agricultural production and achieving diversification, expanding the base and widening the market for crops, it is necessary to promote the export of some selected crops and agro-industrial products. This will entail development of appropriate capacities and institutional network to address the technology input and post harvest handling needs, values addition and to meet international market standards. Export can contribute significantly and

visibly to alleviated poverty and enhance economic sustainability

d. Food security

According to Voice of America (VOA) world service (2007) China and Uganda have devised a method of highly subsidizing agricultural inputs, educating their farmers on new technology and making available agricultural machines, to co-operative farmers with free maintenance schedule to support agricultural mechanization as a good strategy for wealth creation, employment generation and poverty reduction.

Investment opportunities are bound in Nigeria using mechanized agriculture by reviving meaningful agricultural programmes, policies and project introduced by successive governments when they are made more attractive and profit oriented.

Economic Development

Fagoyinbo (2005) defined Economic Development as a realistic management and administrative policy that takes account of the natural resources available to a nation and the society. This implies that, with 24 million hectares of productive land (Upahi, 2004) and only 1.3 percent is under actual cultivation the economy of Nigeria could be improved within the shortest possible time with a sound and continuous agricultural mechanization policy.

In addition, sustainable development also implies that economic activity should be designed to create wealth for the use of present and future generations. The revival of agricultural commodity, marketing and pricing boards to monitor the prices and sale of specific commodities for farmers after harvest by government and private agencies e.g. Cocoa, groundnuts, palm produce, cotton, rubber and food grains (maize, millet, sorghum, wheat, rice and cowpeas) etc. for local consumption and export will assist in revenue generation accruing to the nation and the producers at large.

RECOMMENDATIONS

The following recommendations are made to improve on the present state of agricultural mechanization in Nigeria.

i. The Manufacture and standardization of agricultural equipment. Government should encourage indigenous design and development of simple agricultural processing machines and provide effective control on the importations of standard machines and equipment.

ii. Improving technical know how of farmers. Farmers should be exposed to new farming techniques, use of high yielding varieties and appropriate technologies in crop production and processing.

iii. Government should subsidize in all cases, the cost of land clearing, land cultivation and farm inputs to farmers

iv. Government should encourage private individuals to operate tractor hiring units by receiving bank loans to set-up private agricultural mechanization enterprise and tractor repair workshops.

v. Improvement of research and development. The government and private sector participation in commercialization of prototype, research and local fabrication of suitable equipment should be promoted

vi. Development of agricultural processing industries. More processing and storage facilities and marketing out-let should be increased to buy excess grains from the farmers by the government for processing and storage.

vii. Government should set commodity boards to grading and standardization partially for export commodities stabilize markets, safe guard the environment and build human capacity etc.

CONCLUSION

Nigeria is bestowed with abundant human and natural resources in additional to weather that is conducive for economic activities all the year round. There is the need for a redirection and potential agricultural mechanization policy not only on increase in crop production but also to reduce production cost, field losses on crops, drudgery in farm operation and create market outlet, and also improving farmers' standard of living.

Some constraints in agricultural mechanization include inconsistency in government policy, low level of engineering technology inputs, low income level, inadequate infrastructure and finance. The sustainable exploitation of these potentials holds considerable promise for providing livelihood and food security to the people and meeting their increasing aspiration

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Table 1: Nigerian's Food Import indicators and GDP (1986-2003)

Year	**GDP at current market price**	**Food import (in billion Naira)**	**Total import (in billion Naira)**	**Food import as percentage of total import (%)**	**Food import as percentage of total GDP (%)**
1986	73.0	0.92	5.98	15.3	1.3
1987	108.8	0.93	17.86	10.8	1.7
1988	145.2	1.75	21.44	8.2	1.2
1989	244.7	2.09	30.86	6.8	0.8
1990	260.6	2.89	45.71	8.5	1.4
1991	324.0	8.50	89.48	9.5	2.6
1992	549.0	13.74	143.15	9.6	2.5
1993	697.0	15.28	166.10	9.2	2.2
1994	914.0	18.39	162.78	11.3	2.0
1995	1960.7	96.65	755.12	12.8	5.0
1996	2740.5	83.26	565.62	14.8	3.0
1997	2834.8	112.48	845.71	13.3	4.0
1998	2731.5	113.05	837.41	13.5	4.1
1999	3377.3	115.56	865.52	13.4	3.4
2000	3614.2	128.07	962.97	13.3	3.5
2001	5178.2	160.2	1357.6	11.8	3.1
2002	5454.2	176.9	1380.5	11.2	3.2
2003	7180.1	226.1	1956.1	11.5	3.1

Source: CBN Statistical Bulletin and

Annual report, 2003.

Table 2: Importation of Agricultural Machinery and Implement as at 2000

Source: Federal office of statistics, Kaduna 2007.

S/N	**Type of Machinery**	**Total number imported**	**Total value of importation N'000**
1.	Farm tractor (4wheeled)	1,000	35,000
2.	Crawler tractors	800	240,000
3.	Farm tractor (2 wheeled)	8,500	212,500
4.	Boom sprayers	1,200	1,200
5.	Grain Planters	250	12,500
6.	Seed drills	100	14,000
7.	Grain threshers	850	21,200
8.	Disc plough (3,4,5 discs)	8,500	68,000
9.	Disc harrows (incline, offset)	6,500	42,250
10.	Disc ridgers (1,2,3 furrows)	4,250	31,875
11.	Tractor trailers	5,250	52,500
	Total		**757,575**

DEVELOPMENT AND PERFORMANCE EVALUATION OF A PROTOTYPE MANUAL PRECISION RICE PLANTER

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ABSTRACT

The design and construction of a manual precision rice planter was undertaken with the aim of achieving precise planting on the farm. The machine was designed, constructed and tested on the University farm in Yola-Nigeria, using locally available materials. The machine consists of roller-metering device that rotates and receives constant flow of seeds from a bottomless hopper, a furrow opener and covering device. There is a front land wheel from which the seed-metering device is directly driven through chain and sprockets. The frame is made of hollow pipe on which the entire assembly is mounted. The machine performance evaluation was carried out using paddy rice BG 302 variety. The actual field capacity of the machine was found to be 0.067ha/h with field efficiency of 77.9%, and application rate of 21.62 kg/ha. The planter has a mean planting depth of 3.2cm, hill distance of 15.12 cm and 6 seeds per hill. It was concluded that efficient and precision plating could be better achieved with this kind of machine than with rice seed broadcasters.

Key words: Manual, Precision, Rice-Planter, Hill dropping,

INTRODUCTION

Rice production is extending rapidly to areas, which are not traditional producers of the crops (Khush and Toenniessen, 1991). It is one of the world's stable food crops and primary food for more than half of the world population. Williams *et al* (1989) reported that one of the most difficult and time-consuming operations in rice production is the planting operation. In Nigeria, most farmers use traditional tools such as sticks, hoes and so on for rice planting. This makes rice planting operation tedious and time wasting, leading to low yield. To meet the growing demand for rice, these traditional tools have to be substituted with improved planting equipment.

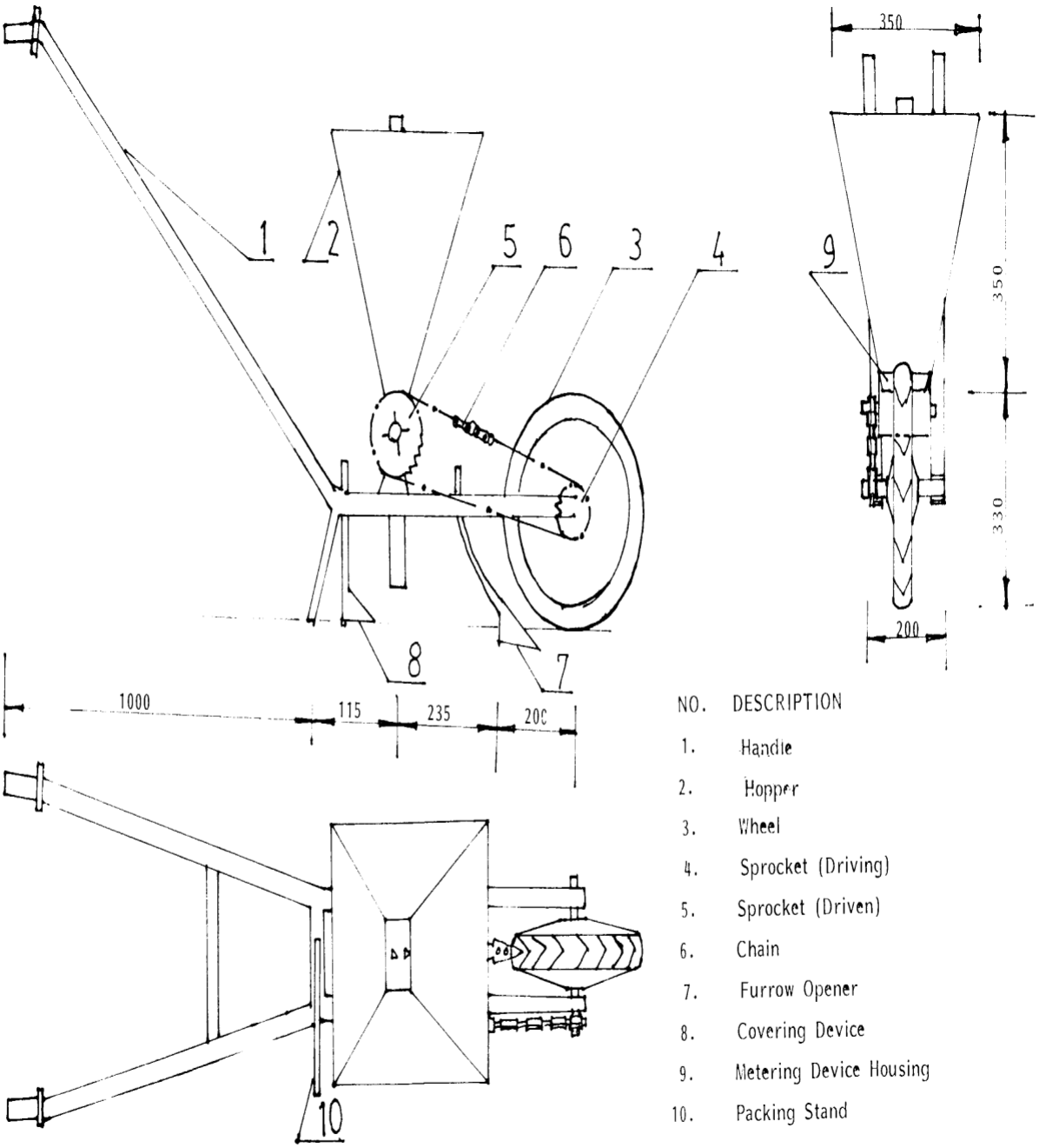
Rice broadcasters commonly used in Nigeria enable fast rice planting but have been observed to have some limitations that affect their economic utilization on small farms. These limitations, according to Bishop *et al*, (1993), include: seed position at varying depths, intra and inter row spacing, planting depth, number of seeds per hole, uneven field coverage leading to poor germination rates, seed wastage and difficulty in carrying out subsequent operations like weeding. According to Kepner *et al*, (1980) rice dibbling and drilling using local tools proved to be successful in terms of germination rates and yield, but the problem regularly encountered is irregular intra and inter-row spacing, planting depth and number of seeds per hole. To achieve efficient rice planting, a prototype manual rice precision planter was developed and tested. The results of the actual field performance evaluation of this planter are reported in this paper.

MATERIALS AND METHOD

Description of the Precision Planter

The main features of the planter are shown in figure 1, which include a hopper, roller metering device, land wheel, sprockets, chain, furrow opener, covering device, handles and parking stand.

The hopper was constructed from steel metal sheet of 2mm thickness that forms the feeding unit through which rice seeds are fed into the metering device. The metering device was constructed from hard wood. It consists of grooves into which the seeds fall from the bottomless hopper. The furrow opener and the covering device were constructed from hard steel, which has high resistance to wear and corrosion. The flute was made up of smooth and flexible plastic hose, which was attached to the metering mechanism housing.



NO.	DESCRIPTION
1.	Handle
2.	Hopper
3.	Wheel
4.	Sprocket (Driving)
5.	Sprocket (Driven)
6.	Chain
7.	Furrow Opener
8.	Covering Device
9.	Metering Device Housing
10.	Packing Stand

Fig. 1 ASSEMBLY DRAWING OF THE PLANTER

The transmission unit consists of a chain and two sprockets (driver and driven) and a front wheel that drives the metering unit through chain and sprockets. The frame forms the mounting support of the other units. It is mounted on a wheel and a parking stand.
A torque is developed on pushing the planter, which is transmitted through chain and sprocket to the metering mechanism. The seeds in the hopper are fed into the grooves of the metering device and fall into the furrow created by the furrow opener through the flute. The covering device then covers the seeds. Land markers are provided on the frame of the planer to guide the operator on the next line of planting operation.

DESIGN CONSIDERATIONS AND ANALYSIS

Agronomic parameters considered

Agronomic factors considered during the design of the rice planter include intercrop spacing between rice plants which was given as 15-16cm, inter-row spacing of 30cm, 5-8 number of seeds per hole and planting depth of 2-4cm as reported by Jackquot and Courtesis (1988)

Roller metering device

In the design of roller metering device, groove size and number of grooves are important design parameters.
The number of grooves on the roller has a great influence on the distribution of seeds. The proper number of grooves can be obtained by equating the ratio of the open angle of the groove with a desired degree of distribution, D_{sc} that is defined as a ratio of desired seed distribution to the spacing between stands. That is:

$n = 360D_{sc}/100\theta g$……..……(1)

$n = 3.6D_{sc}/\theta g$

(Chittey and Perkin 1986)

Where

n = number of grooves

θg = open angle of groove (^{0})

D_{sc}= desired degree of seed distribution range to the spacing between hills (%)

Degree of seed distribution of 25-30% is sufficient for rice precision planting (Chittey and Perkin 1986).

Number of grooves (n) calculated is shown in table 1

In roller-type-metering device, the quantity of seeds per hill is given by:

$Q_h = Q_{sr}ds/10$……..…(2)

(Chittey and Perkin 1986)

Where

d = hill length (m)

s = row space (m)

Q_{sr}= sowing rate (kg/ha)

Q_h = quantity of seeds per hill (g)

Design of shaft

The planter consists of two shafts, the traction shaft and the metering shaft, which support the metering wheel. Power is transmitted to the metering shaft from the land wheel by a chain and sprocket drive. The following equation was used to determine the shaft diameter (Mott, 1985).

$D^3 = (16 / \pi S_s) \sqrt{(k_b M_b)^2 + (k_t M_t)^2}$…(3)

Where: D= shaft diameter, m

S_s=shear stress, N/mm^2

k_b k_t = combined shock and fatigue factors applied to the bending and torsional moments respectively.

M_t = tortional moment, N mm

M_b = bending moment, N mm

An available steel shaft of diameter 0.022m was used for the planter.

The rolling resistance offered by soil on the land wheel as the planter is being operated is given by (Klenin *et al*, 1985)

$f = \varphi R$. ……(4)

Where;

f = rolling resistance, N

φ = Coefficient of rolling resistance of the land wheel on the soil. According to Klenin *etal* (1985), $\varphi R = 0.30$

R = total weight of the machine plus seeds = 437.53N

The rolling resistance (f) was calculated to be 131.3N. This is also equal to the force (F) required for pushing the planting machine in eqn 5.

The power required for pushing the planter is given by:

P = F x S……...(5)

Where

P = power required (W)

F = total draft or force required for pushing the planter (N)

S = normal walking speed of a man, (m/s). From practice an average man's pace is assumed to be S =0.71m/s even though Kaul and Egbo (1992) gave S = 0.60m/s for field sowing operation.

P = 0.60x131.3=78.8W

The power required therefore to push the planter at 0.6m/s speed is 78.8W.

Performance Evaluation

Testing the performance of the planter involved evaluation of the machine capacities and efficiencies. The parameters investigated include capacity (ha/h) and filed efficiency (%). The field test was conducted on a piece of land measuring 25m x 25m on the University farm. The materials used for testing the performance of the planter include locally available paddy rice (BG302), stopwatch, measuring tape, measuring container and weighing balance. Although the ultimate

criterion for evaluating a complete planting operation is the stand obtained in the field (Kepner *et al*, 1980). A pretest was conducted in the laboratory, to remedy some of the design deficiencies observed before testing on the field. The laboratory test was conducted by turning the land wheel of the planter 10 times in suspended position. A wetted textile material was used to collect seeds falling from the flute. This was done in order to determine the regularity of seed spacing. The average distance on the wetted material was determined. Seed spacing, distribution pattern and the standard deviation of the planter were determined using standards and procedures of evaluating planters as reported by Kepner *et al* (1980) and Kawuyo and Haque (2003).

Field Data Collection

A piece of harrowed land measuring 25m x 25m was marked out. The planter was operated without furrow opening at a speed of 0.8m/s to drop the seeds on the field. During this test no furrows were opened so as to allow for measuring the distance between stands. The planter was then operated to plant the seeds on the field. The time taken to cover the land was noted using stopwatch. The test was replicated three times using the same procedure. The planter's performance parameters were evaluated using equations 6 and 7 below:

Actual field capacity (ha/h), Ca = A/T..(6)
Field efficiency (%) = Ca/Tx100……...(7)
Where
A = Area covered by planter (ha)
Ca = Actual field capacity (ha/h)
Ct = Theoretical field capacity (ha/h)= SW
S = operating speed (m/s)
W = operating width of machine (m)
T = Total time taken to cover the field (h)

Results and discussion

Table 1 shows the design results while Table 2 shows the field test results in terms of seed spacing, number of seed per hole and the depth of planting. The distance between stands was found to be 15.12cm, number of seeds per hole 6 and average depth of planting of 3.20cm. The mass of the seed planted was 1.35kg on an area of 625m^2. The seed rate was 21.62kg/ha. This compares favourably with values (21-22kg/ha) given by Onwueme and Sinha (1999).

Table 1: Design Parameters

Sn	Parameters	Results
1	Number of grooves on the roller, n	5
2	Quantity of seed per hill, Q_h (g)	223 seeds (180g)
3	Diameter of land wheel shaft, D (mm)	22
4	Diameter of metering device shaft, D (mm)	22
5	Weight of planter plus seeds, R (N)	437.53
6	Rolling resistance offered by soil, f (N)	131.3
7	Force required for pushing the planter, F (N)	131.3
8	Power required for pushing planter, P (W)	78.8

Table 2 Field Test Results

SN	Distance between hill (cm)	Number of seeds planted per hole	Depth of planting (cm)
1	14.8	7	3.6
2	15.3	5	3.2
3	15.1	5	2.8
4	14.4	6	3.0
5	16.0	8	4.1
6	15.1	6	3.0
7	14.7	6	2.9
8	15.0	7	2.8
9	15.6	6	4.0
10	15.2	5	2.5
Mean X	15.12	6.00	3.20
Standard deviation. δ	0.43	0.94	0.50

Table 3 Test results in terms of area coverage.

S/n	Quantity of grain in the hopper Qs (g)	Area covered, Ac (ha)	Time taken to cover the area, T (min)
1	2350	0.0625	55.88
2	2350	0.0625	56.4
3	2350	0.0625	55.7
Mean	2350	0.0625	55.7

Table 3 shows the test result it terms of area coverage. The result shows that an area of about 625m^2 (0.0625ha) was planted in a mean time of 55.7 minutes (0.928h), giving the filed capacity of 0.067ha/h. the machine was found to have a field efficiency of 77.9%. This compares favorably with grain / fertilizer efficiencies of 60% to 78% as recommended by Smith and Wilkes (1990).

Conclusion

The development of the precision rice planter was carried out with the aim of achieving efficient and precise rice planting on the farm. The laboratory and filed tests of the planter show that it can be used effectively for planting rice. The tests revealed a seed rate of 21.6kg/ha and stand spacing of 15.12cm. Actual field capacity of 0.067ha/h and field efficiency of 77.9% recorded with the planter compares favorable with the agronomic specifications for planters. The power required for operating the planter is 78.8W, which is within the normal average output of a man (80W). The planter could overcome the limitations of seed broadcasters and manual operation commonly used in Nigeria.

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EFFECT OF PLOUGHING DEPTH ON STRESS DEVELOPMENT ON THE STEYR TRACTOR STABILIZERS AND BRACKETS ON A SANDY LOAM SOIL

BY

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ABSTRACT

The effects of depth of ploughing on the development of stress on the Steyr tractor stabilizers and brackets on a sandy loam soil were investigated using strain gauges. It was found that stress on these parts of the three-point linkage system increased with depth of ploughing. The use of a modified 'U' bolt was found to reduce the stress by (10%)ten percent.

INTRODUCTION

Many factors have been identified as affecting draught of tractor –mounted tillage implements. These include soil factors (soil type, moisture content, bulk density, resistance to penetrometer pressure, shear strength), tool factors (type of tool/implement, tool angle, tool speed, tool depth, tool width) and soil interface factors and operator performance (Kamal and Onwualu, 1996).

Tool parameters' effects have been studied by many. Taylor (1967), as reported by Kamal and Onwualu (1996), stated that in a test in a gray-silty-clay at a depth of 12.70cm, it was observed that draught force increased with disc angle at width of cut of 20.32cm, decreased at 10.16cm cut and remained constant at 15.24cm. Increasing the speed of operation of a disc plough increased the draught and energy requirement of the implement (Anazodo *et al*, 1987).

Kuczewski and Majewski (1983) proved that in implements with depth wheel regulation, the pull force is horizontal, above the soil and the depth wheel causes an increased total draught of the plough while in implements with automatic regulation, the pull force is inclined giving a big vertical component which acts far behind the tractor. This therefore shows that the type of regulation affects the draught of the aggregate.

With mounted cultivators, the working resistance is sharply inclined downward; this is because of the intensive penetration of the soil due to its sharp ground working elements. Because of this, the cultivator's wheels in the front are always loaded heavily and cause a large draught of the implement (Kuczewski and Majewski, 1983).

Kuczewski and Majewski (1983) gave the equations for the value of implement draught as: -

$P_r = K\ a\ b$ (for tillage implements) ---------- (1)

$P_r = K_1\ b$ (for other machines) ---------- (2)

where:

P_r = Total draught of implement, [N]

a = Depth of work, [m]

b = Width of work, [m]

K = Soil unit resistance, [N/m^2]

K_1 = Implement unit resistance, [N/m]

Stresses experienced on the tractor parts are both due to the draught of implement and the machine tractor

dynamics. This work is aimed at investigating the effect of depth of ploughing on stress development on the Steyr tractor stabilizers and brackets and reduce this stress if necessary.

METHODS

The following materials were used in this experiment: A fifty by thirty meters portion of land (measured out of the irrigation plot of the Agricultural Engineering Department of the Federal Polytechnic, Bauchi), four digital multimeters, strain gauges, 9V batteries, resistors, cables, Steyr 768 tractor and a metering tape, Sand paper, detergent, water and glue.

The surfaces of the stabilizer shafts and brackets were properly cleaned using abrasive materials, detergent and water. They were left to dry after which the strain gauges were carefully attached using glue. They were pressed firmly and allowed to dry after which they were soldered and wired with the resistors of 47Ω each. Double strain gauges were used. Figure 1 shows the circuit diagram of the electrical wiring. The soil type was determined using the method of soil type analysis (Michael, 1990). Other properties such as soil moisture content and bulk density were determined. The depths of ploughing were varied using the depth control lever. The ploughing speeds were fixed using the hand throttle. The ploughed depths were measured using a steel measuring tape with the undisturbed soil surface as the reference point.

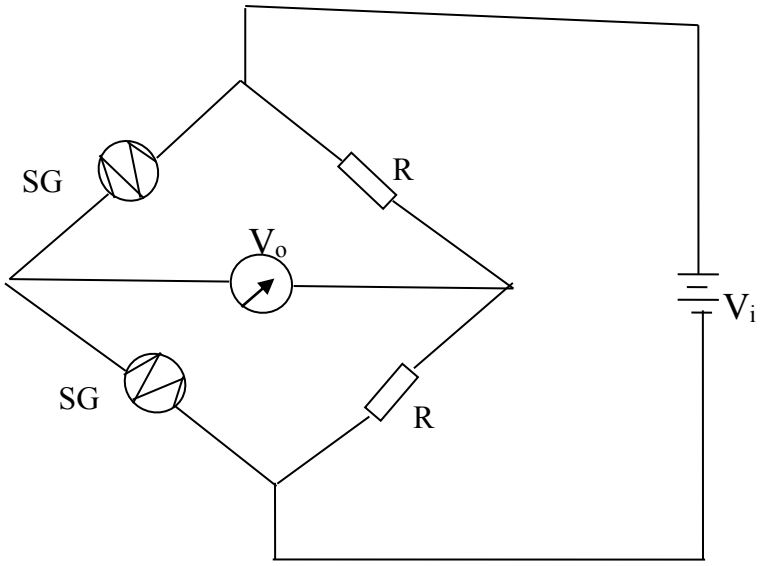


Fig. 1 Circuit Diagram for the Single Strain Gauge Connection

where :

R = external resistance of gauges

V_o = voltage output

V_i = input voltage.

SG = Strain gauge

The measurements were first taken with the original Steyr 'U" bolt (Figure 1) in place. Later, a modified "U" bolt (plate I) was designed, constructed, fitted in place of the Steyr "U" bolt after which comparative measurements were taken.

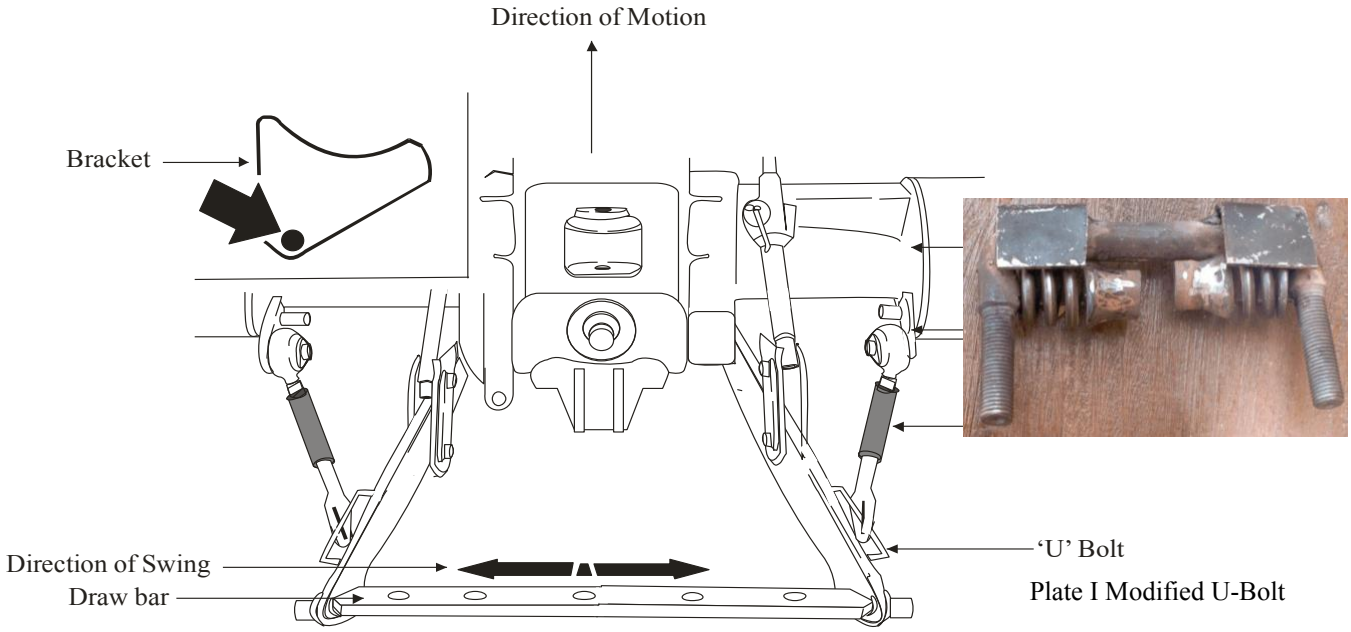


Figure 1 Steyr Tractor Lift System
(Source: Steyr 768 Operating Manual)

RESULTS AND DISCUSSION

The soil test showed the soil type as sandy loam soil. During the ploughing, the stresses on the brackets and on the stabilizer shafts were converted to voltages and read on the digital multimeters as the output voltages. Using the following relationships, these voltages were converted to stress (N/m^2).

$$\text{Strain sensitivity} \quad f = \frac{dR}{R\varepsilon}$$

$$\text{Mechanical Strain } \varepsilon = \frac{dL}{L}$$

$$\therefore \quad \varepsilon = \frac{dR}{R} \times \frac{1}{f}$$

When two gauges are used, one as a dummy, Kurtz *et al* (1984) gave

$$V_o = \frac{dR}{2R} \times V_i$$

Where

V_o = Voltage out

V_i = Voltage in

$$\sigma = \frac{E}{1-\nu^2} \times \varepsilon$$

$$\sigma_2 = \frac{E}{1-\nu^2}\left(\frac{2V_o}{V_i}\right) \times \frac{1}{f}$$

where:

σ = stress

E = Young's modulus of elasticity

ν = Poisson's ratio

Soil and moisture content analysis showed the tests were conducted on a sandy loam soil and average soil moisture content was 7.02%. As a result of the low moisture content, good soil penetration could not be achieved.

The bracket failures, as reported by Sule *et al* (2001), are brought about as a result of the interactions between the stabilizer shafts and the brackets. It would have been expected that the stress magnitudes on the stabilizers and the brackets be similar and that both should experience the same failure rates. This is not so for two reasons:

i) Stress is a function of the surface area of an object. If the force of application remains the same, the higher the surface area, the lower the stress. Evidently, the surface area of the stabilizer is greater than that of the bracket; hence the stabilizers experience lesser stresses than the brackets.

ii) The nature of the stress on the brackets is impact. This is more destructive than the compressive stress on the stabilizers (Khurmi and Gupta, 2002).

The sources of stress on the stabilizers and brackets are from stresses induced as a result of sideways swings and the tractor pull force on the implement during work.

During work though, the aspect of impact stress is reduced. The major stresses are as a result of the sideways swings. The longer the distance of swing and the number of swings, the higher the stress development. The sideways swings are affected by the roughness of the roads and speed of travel/transportation as well as roughness of the farmland. During ploughing and harrowing, sudden changes in the soil resistance as a result of obstacles on the farm (in the soil) could cause the swinging of the implement bringing about higher impact stress on the implement. A very good occasion for the development of higher impact stress during ploughing is at corners when the operators do the turns at speed. In all the tests conducted the modified 'U' bolt is seen to reduce the stress by approximately ten times of the stress using the Steyr 'U' bolt. Very high stress fluctuations are noticed on the brackets; for instance, ploughing at the depth of 9cm using the Steyr 'U' bolt, maximum, minimum and average stresses of 0.052, 0.195 and 0.031kN/mm^2 respectively were observed on the right bracket. This in essence is damaging to the brackets. On the other hand, the modified 'U' bolt seems to stabilize these stress fluctuations. This is achieved by absorbing the shocks and stabilizing the implement during ploughing.

Figures 2 and 3 show the fluctuations between the minimum and maximum stress values. These fluctuations are destructive to engineering materials.

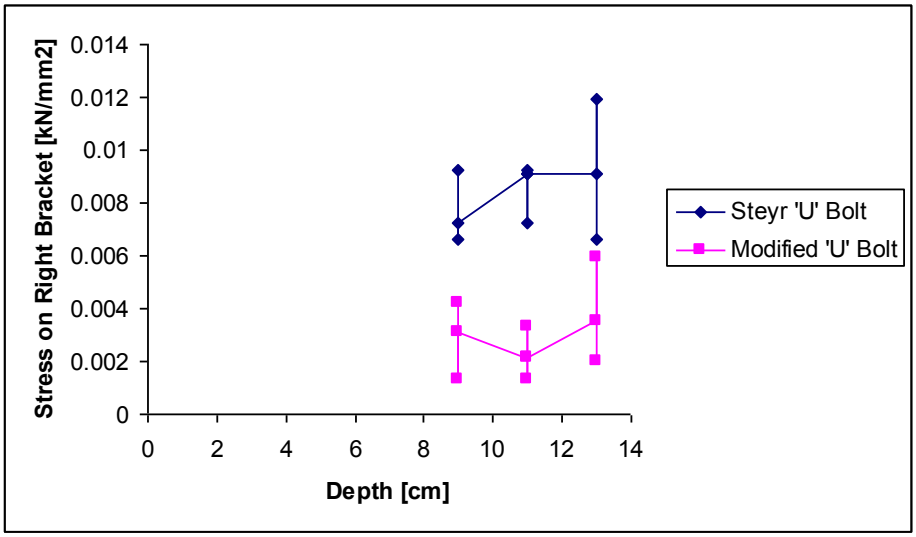


Figure 2 Effect of Ploughing Depth on Stress Development on Right Stabilizer

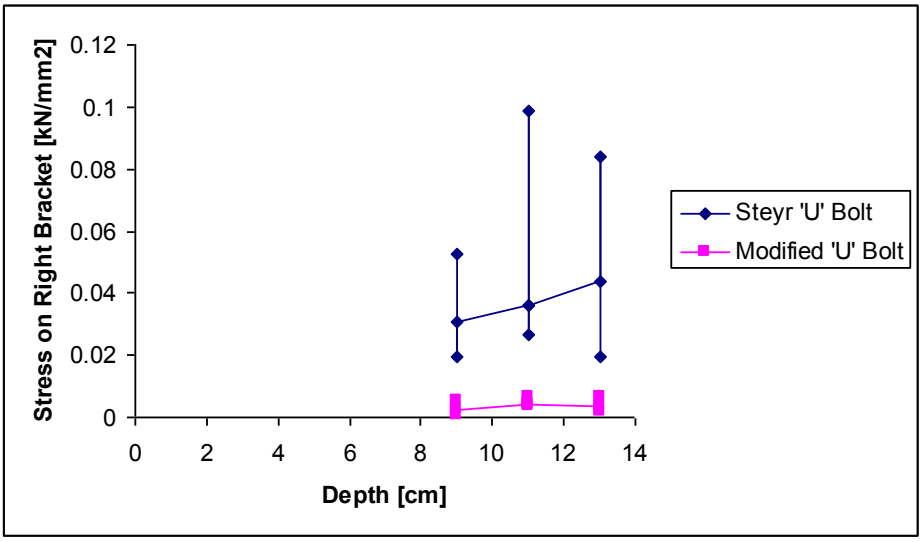


Figure 3 Effect of Ploughing Depth on Stress Development on Right Bracket

The graphs of the performance curves are presented in Figures 4 to 7. The mathematical relationship given between the stress on brackets and stabilizers both when using the Steyr 'U' bolt and when using the modified one for some of the tests conducted can be used for predictions. In Figures 4 to 7, it is observed that as the depth of ploughing increases at same speed, the tendency of sideways swings is highly reduced and the major source of stress here is pull force. The soil resistance is a major factor that influences the pull force developed. Since the soil resistance of the same soil may vary from place to place even on the same farmland, hence the variations and fluctuations in stresses as noticed in Figures 4 to 7. Generally, it is expected that as depth of ploughing

increases, the stress should also increase. The discrepancies noticed might be as a result of some variations of soil resistances on the farmland.

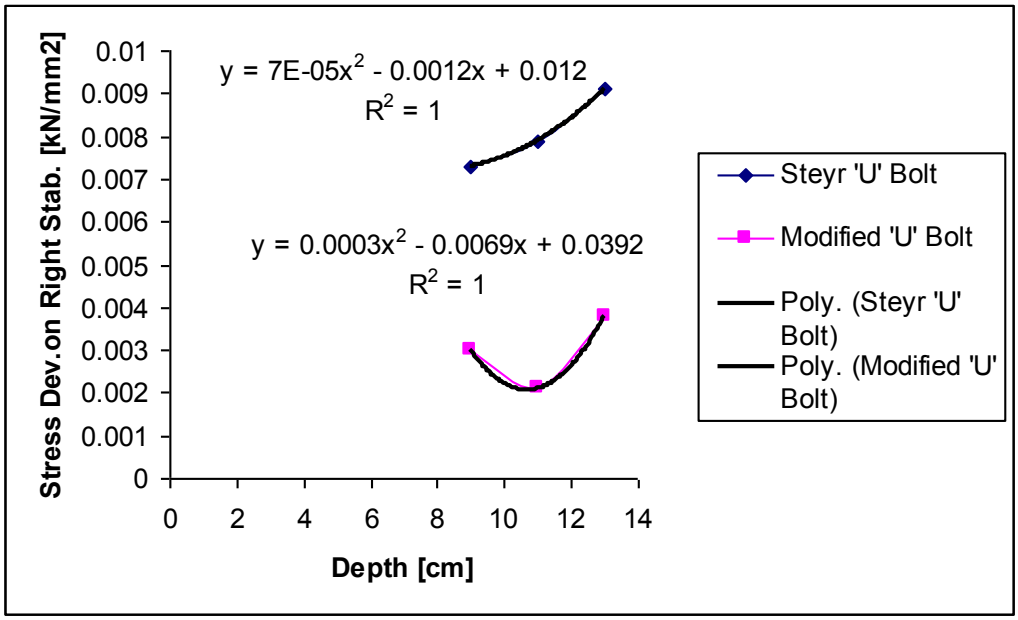


Figure 4 Relationship Between Depth of Ploughing and Stress Developed in the Right Stabilizer at the Speed of 7km/hr

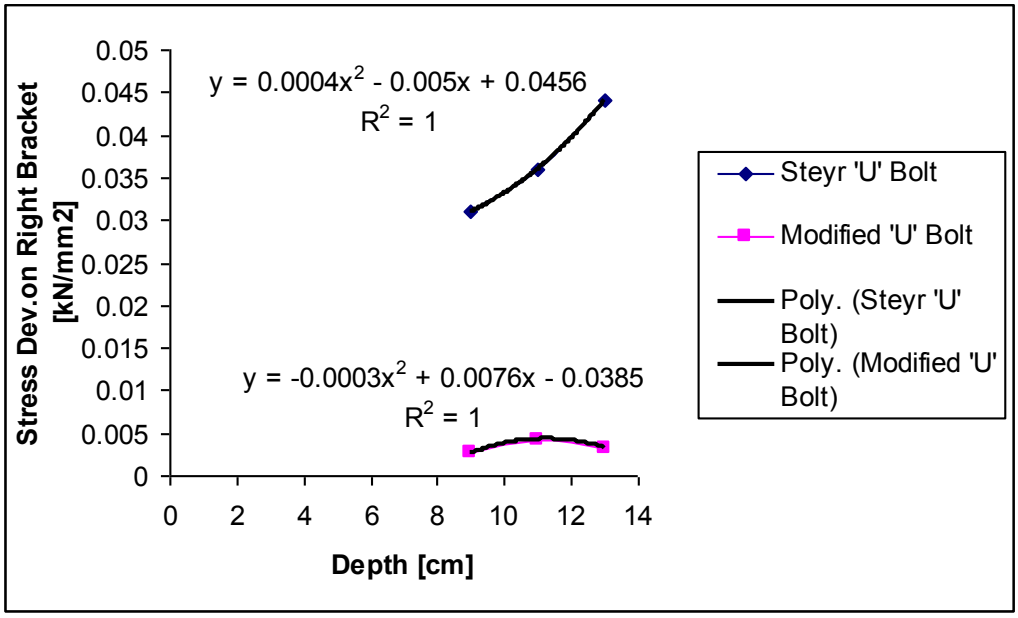


Figure 5 Relationship Between Depth of Ploughing and Stress Developed in the Right Bracket at the Speed of 7km/hr

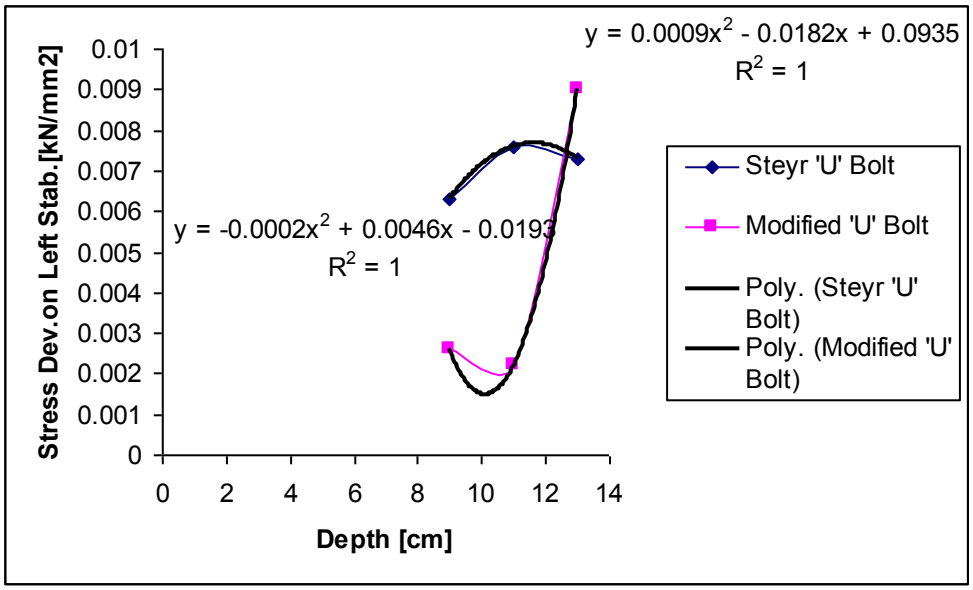


Figure 6 Relationship Between Depth of Ploughing and Stress Developed in the Left Stabilizer at the Speed of 7km/hr

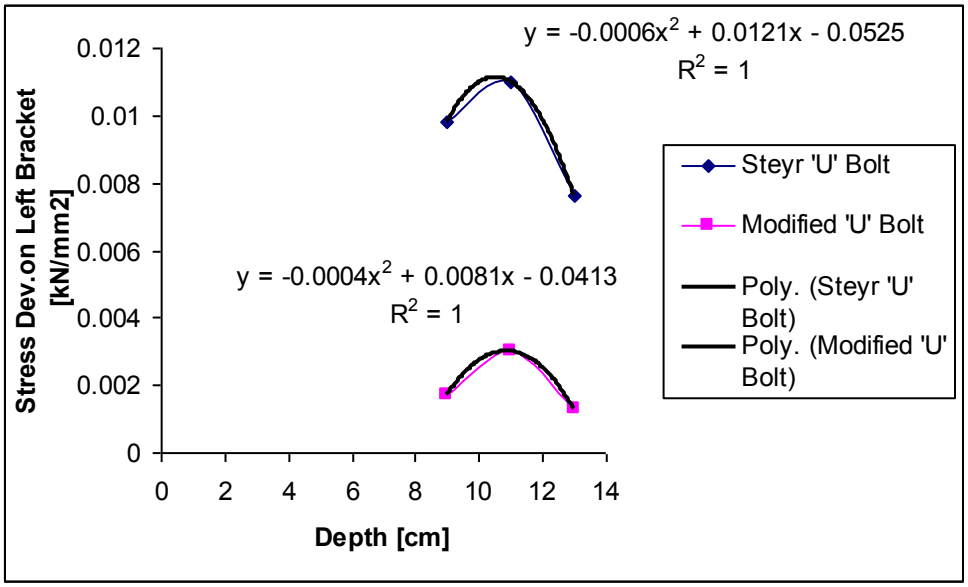


Figure 7 Relationship Between Depth of Ploughing and Stress Developed in the Left Bracket at the Speed of 7km/hr

CONCLUSION

Stress developed on the brackets and stabilizers was observed to increase with increase in depth of ploughing. Stress fluctuations associated with the use of Steyr 'U' bolt is destructive to the stabilizers and brackets but can be reduced by the use of the modified 'U' bolt. This was however believed to be influenced by the soil resistance; hence the inconsistencies observed in some of the behaviours of some of the graphs.

RECOMMENDATION

In order to avoid the breakdown of the Steyr tractor stabilizer brackets and the axle, it is recommended that the modified 'U' bolt is adopted for use on the Steyr tractor and that ploughing be done at optimum soil moisture content.

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THE INFLUENCE OF DEPTH OF HARROWING ON TRACTOR FUEL CONSUMPTION ON A SANDY LOAM SOIL

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ABSTRACT
The study was carried out to determine the effects of different depths of harrowing on tractor fuel consumption on a sandy loam soil. An MF 375E tractor with an offset disc harrow was operated at three depths of harrowing, namely 10, 20 and 25 cm. It was observed that there was a linear increase in fuel consumption as the depth of implement penetration increased. Five replicated plots were used and the mean fuel consumption values found were 7.37, 8.60 and 9.14 l/ha for the 10, 20 and 25 cm depths of harrowing respectively. A relationship was generated to estimate fuel consumption based on harrowing depth on a sandy loam soil. It was recommended that further studies be undertaken so that optimum fuel consumption levels vis-à-vis tillage depths can be achieved, thus lowering the cost of crop production.

KEYWORDS: *Tractor fuel consumption, harrowing depth, sandy loam soil*

INTRODUCTION

It is well realized that energy inputs for agricultural production contributes significantly to the success or otherwise of the farming business. Agricultural mechanization involves the use of tractors and other machinery that require energy input in terms of fuel. The relevance of soil tillage in crop production and its tasking energy requirements need not be overemphasized. A number of factors such as tillage depth and soil moisture content affect tractor fuel consumption. For instance, it was reported by Perfect et al. (1997) that fuel consumption increased with increasing volumetric water content of a soil. Even the thickness of implement cutting edges affects draft and hence fuel consumption. It was reported that as the thickness of the cutting edge of a plough increased, draught force and fuel consumption increased considerably (Natsis et al., 1999). The depth of operation influences the draft and hence the effort needed to pull an implement (engine power) has a direct bearing on fuel consumption. Implement operating depths may be governed by both internal and external factors such as weight, sharpness, size and nature of the implement, soil moisture content, nature of the soil, its organic matter content and general field conditions (Kepner et al. 1971)

Tillage depth has a direct effect on implement draft. Collins et al. (1978) reported depth to be a linear function of draft for mouldboard and chisel ploughs. Garner and Wolf (1981) investigated different zone layers of soil for a subsoiler. They showed that a linear relationship existed between draft and depth within each soil zone. Gunderson et al. (1981) found a quadratic function for draft in relation to tillage depth.

Also, Upadhyaya et al. (1984) measured subsoiler draft in coastal plain soils and found that it was proportional to depth and depth multiplied by speed squared. Wolf et al. (1981) reported a linear increase in draft of a subsoiler with an increase in tillage depth on a sandy loam soil. Brassington (1987) reported that the draft of a moldboard plough was proportional to the plough depth within the normal working condition.

Fuel consumption increases with draft requirement because deeper penetration of an implement requires more engine torque. Operating at shallow depths can significantly reduce fuel consumption since a smaller volume of soil is turned over (Plouffe et al., 1995).

Willocks (1984) reported that sandy loam soil has characteristics of high density and poor water holding capacity, which result in more energy

input while using improper tillage implements. He observed that deep tillage trials at a semi-arid site in Western Sudan brought up large clods which were difficult to breakdown by secondary implements. Plouffe et al. (1995) concluded that fuel consumption increases with draft requirement because deeper penetration of an implement gives more load unto the engine, which in turn results in more fuel consumption.

In order to optimize fuel consumption, there is the need to operate tillage implements at depths that are reasonable with respect to the crop and field type. This entails conducting studies with different tillage implements operated on various soil types so as to determine operating depths that would be recommended for each soil type. Borno state consists of several types, including sandy loam on which this study was focused. In the northern part of the state, many farmers undertake harrowing as the only tillage operation for seedbed preparation. It appears that there is no existing information on the effect of harrowing on fuel consumption on a sandy loam soil. The objective of the work was to determine the effect of harrowing depths on tractor fuel consumption on a sandy loam soil.

MATERIALS AND METHODS

The study was conducted at the Department of Agricultural and Environmental Resources Engineering Research Farm, University of Maiduguri, Maiduguri (latitude 11°50'N and longitude 13°05'E) during the 2006 farming season. The field used was divided into five main plots (A – E) and each plot was divided into three replicate sub-plots of 0.33 ha each. An alley of 10 m between the main plots was made to allow for free movement of the tractor-implement unit. An MF 375E tractor and MF 222 offset disc harrow were used in harrowing the sub-plots, using three depths of 10, 20 and 25 cm as treatments randomly allocated to the sub-plots.

The major parameter determined in the field was fuel consumption for harrowing. An average speed of 9 km/h (within the range recommended by Kepner et al., 1971) was used in operating the tractor on the field. The quantity of diesel consumed for harrowing was determined by starting operation on each sub-plot with a full tank and then refilling the tank at the end of the operation. The amount of fuel used to refill the tank, determined using a graduated cylinder, was hence considered as the quantity consumed during the operation.

Prior to harrowing the field, three soil samples were taken from each plot for the determination of three soil parameters using the following standard methods:

i. dry bulk density using the gravimetric method
ii. moisture content using the gravimetric method
iii. penetration resistance using the cone penetrometer

The data collected were subjected to simple descriptive statistical analysis. The relationship between harrowing depth and fuel consumption was established using regression analysis.

RESULTS AND DISCUSSION

Table 1 shows mean values of the five soil parameters determined before harrowing of the five plots, A – E. It could be observed that the plots were harrowed when soil moisture was at the low level prior to major rains. Fuel consumption figures might not be the same, if harrowing were undertaken under soil conditions different from the ones shown in the table.

Table 1. Mean values of some soil parameters of plots before harrowing

Plots	Soil parameters (Means of three replicates)		
	Bulk density (gcm^{-3})	Moisture content (%)	Penetration resistance (MPa)
A	1.45±0.01	6.04±0.27	2.77±0.18
B	1.44±0.01	5.95±0.11	2.93±0.11
C	1.40±0.01	5.15±0.28	3.45±0.35
D	1.39±0.02	4.59±0.44	3.89±0.11
E	1.44±0.01	5.77±0.13	2.93±0.04

Table 2 indicates the tractor fuel consumption values recorded during the study. The amount of fuel consumed increased with increasing depth of harrowing due to the increased draft required to move more volumes at higher depths. The widest range of values of fuel consumption recorded was 7.09 to 9.43 l/ha. The slight differences that can be seen in the values of fuel consumption could be as a result of the corresponding differences in the soil characteristics shown in Table 1.

Table 2. Tractor fuel consumption for harrowing various plots at various depths

Depth (cm)	Fuel consumption for harrowing various plots (l/ha)					Mean
	A	B	C	D	E	
10	7.79	7.66	7.15	7.09	7.18	7.37±0.33
20	8.79	8.56	8.52	8.46	8.66	8.60±0.13
25	9.43	9.17	8.97	8.89	9.24	9.14±0.22

It could be observed from the tables above that plot *A*, which had the highest values of bulk density and moisture content among the five harrowed plots also had the highest amount of fuel consumption at all depths of operation. This was due to the fact that soils with higher values of bulk density and moisture content require more draft in tillage operations due to increases in compaction and moisture respectively. The overall highest fuel consumption value of 9.43 l/ha was obtained at the 25 cm harrowing depth in plot *A*.

The effect of depth of harrowing on the mean values of tractor fuel consumption is depicted in Figure 1 below.

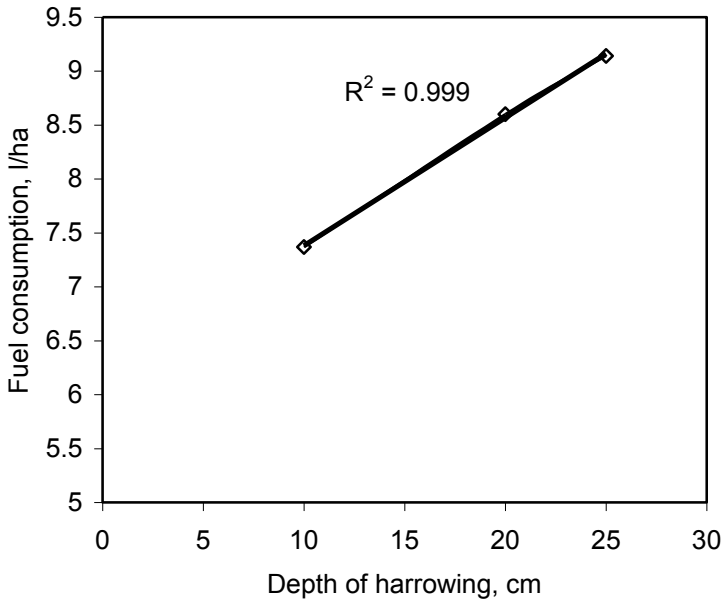


Figure 1. The effect of harrowing depth on tractor fuel consumption on a sandy loam soil

Equation 1 indicates the relationship between depth of harrowing and fuel consumption. An R^2 value of 0.999 indicates the good measure of linearity between the two parameters.

$$FC = 0.1187D + 6.1936 \quad (1)$$

Where, FC = fuel consumption, l/ha
D = depth of harrowing, cm

Equation 1 is applicable for the category of tractor-harrow unit used on a sandy loam under the specified depths and field characteristics. In order to estimate fuel consumption with different categories of tractors and implements and/or for other depths under different soil and operating conditions, there is the need to undertake different field studies. This will assist in adopting tillage practices and techniques that ensure optimum fuel consumption and minimum cost for crop production.

CONCLUSION AND RECOMMENDATIONS

he study revealed that for harrowing a sandy loam soil, tractor fuel consumption is directly related to depths of operation due to increased draft as the depth of implement penetration into the soil progresses. It was also found that the plot having the highest values of bulk density and moisture recorded the highest fuel consumption of 9.43 l/ha at 25 cm depth. The least fuel consumption recorded from the study was 7.09 l/ha. A general equation for estimating fuel consumption as a function of harrowing depth under the specified conditions was derived.

Due to the importance of conducting farming operations under optimum conditions for reduced cost and increased productivity, it is imperative that best management practices such as operating at optimum levels of fuel consumption be imbibed. It is hereby recommended that further studies on tractor fuel consumption in tillage operations with different tractor-implement sets and under different operating conditions and soil types be carried out.

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AN ASSESSMENT OF OGUN STATE FARM MECHANIZATION PROGRAMME

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ABSTRACT

It is one thing to mount a well-designed programme and another to implement it successfully. The Ogun State Agricultural Mechanization programme, under that State's Agro-Service Corporation, has been put in place since 1980. The programme was x-rayed for a period which spanned over five years; from year 2002 to year 2006, to ascertain its viability.

The various information needed for the assessment were obtained from the Agro-Service Corporation, the main operator of the programme; and farmers, the beneficiaries.

From 2002 to 2006, mechanization activities increased in slashing of farm fields, harrowing, spraying and maize shelling. There was an increased food productivity, as reported by farmers. Most of the mechanization activities were on tillage. Mechanization of seed planting, weeding, fertilizer application, crop processing, storage, soil and water conservation were absent. Only cutlass has been produced as the tool for the small-scale farmers who dominate the scene. The farmers carried out most of their farm operations manually. Though the programme design was very much in order, the available machines were underutilized.

Suggestions for improvements have been made.

Keywords: Agricultural mechanization, Programme, Viability, Operator, Beneficiaries

1. Introduction

The need for agricultural mechanization in any country, for a meaningful agricultural production, cannot be overemphasized. It is no exaggeration at all that the human muscle alone, as a source of farm power, can never feed him adequately. Human beings are limited to the production of less than 0.10kw continuous power output (Liljedahi et al., 1979), while a minimum power level of 0.40kw/ha is needed for any meaningful farming
anywhere in the world (Makanjuola, 1977). It is in the light of above facts that agricultural mechanization programmes are initiated.

The Ogun State mechanization programme, mounted by the Ogun State Government, to increase food productivity in the state, is being handled by that State's Agro-Services Corporation (ASC), with its Headquarter at Asero, Abeokuta.

The Agro-Services Corporation was established by law in April, 1980 and its functions among others, are the provision of tractors, the affiliated implements and heavy equipment, through its hiring services, to the farmers of the State so that
farm mechanization commensurate to the needs of the farmers would be achieved. In May 1996, the Engineering Services Unit of Ogun State Ministry of Agriculture and Rural Development was merged with Agro-Services Corporation by the State Government, to strengthen the Corporation's Engineering Service. To facilitate the farm mechanization programmes, the Engineering component has been grouped into the following named major units: (i) Land Clearing Unit, (ii) Tractor Hiring Services, (iii) Heavy Equipment Hiring Services (iv) Workshop Unit. The duty of the workshop unit includes the small-scale farmer tools production. So far this section has produced only cutlasses. All the units are interwoven, to ensure the smooth operation of the mechanization programme.

In Nigeria, generally, every state has its own mechanization programme but food productivity has either not improved at all or significantly. The above assertion is adduced for the fact that hunger still abounds in many homes of Nigerian people. In the present work, Ogun State is taken as a case study, to find out what holds back or delays progress in the mechanization of Nigerian Agriculture. This is with a view to highlighting and removing the areas of bottlenecks.

The most important index of any successful farm mechanization programme is increased food productivity. Even when the weather is not so favourable, larger scale production tends to even out the effects of adverse weather on productivity. Many farm tractors have been injected into the programme under review but the issue is whether the farm mechanization is being achieved; since agricultural mechanization is not synonymous with tractorization, as reported by Hoki et al. (1992). How much land area that has been cultivated, using the available machines, is another index of farm mechanization. It is recommended (Jain and Rai, 1992) that a power of 0.746kw (1hp) be considered for every 2.5 hectares of farmland. Another question is whether the mechanization is adequate and properly operated since it has been reported (Federal Agricultural Co-ordinating Unit, 1994) that the low level of agricultural production in Nigeria, and Africa in particular, is as a result of poor adaptable farm mechanization technologies and management.

2. The structure of the Mechanization Programme

For the purpose of an efficient outreach for farm mechanization, Ogun State has been divided into five zones, namely, Egba, Ijebu, Remo, Yewa South and Yewa North. Each zone has a set of machine's assigned to it. As at 31st December, 2006 the status of the functioning machine's at different zones is as shown in Tables 1and 2. The machines are operated by the operators hired to the zones by the mechanization operator. Land clearing operation is done with heavy equipment and entirely handled by Ogun State Government.

The farm mechanization, excluding ploughing, achieved in all the zones during the period in question is shown in Table 3; while Table 4 shows the general performance of the Tractor Hiring Unit (THU), in terms of the area of farmland handled from 2002 to 2006. It is worthwhile to mention at this point that the major work done by the THU is tillage.

Table 1: Status of tractors in the various zones

Zone	G(H)	G(T)	Servi-able	Bad	Total	Those ear-marked for boarding
Egba	3	Nil	3	Nil	6	14
Ijebu	4	Nil	2	Nil	6	12
Remo	3	Nil	2	Nil	5	5
Yewa South	3	Nil	3	Nil	6	11
Yewa North	3	1	1	Nil	5	5
Total	16	1	11	Nil	28	47

Legend: - G(H): Good hydraulically G(T): Good for trailing only

Table 2: Status of Implements in the various zones

Zones	Plough	Harrows	Slashers	Trailers	Sheller	Boom Sprayer	Fertilizer Spreader
Remo	3	1	1	1	1	-	-
Yewa South	3	-	1	2	1	-	2
Egba	9	1	1	4	1	1	-
Ijebu	5	2	2	3	1	1	3
Yewa North	3	1	-	3	1	1	1
Total	23	5	5	13	5	3	6

3. Materials and Methods

As the major operator of the Ogun State Mechanization policy, the Ogun State Agro-Services Corporation (OSASC) Headquarter in Asero, Abeokuta was the primary source of information. Contacts were made with the Corporation's Agricultural Engineers, of whom one of them is a co-author of the present work. The record obtained from OSASC shows that as at 2004, ninety general-purpose tractors were economically available for the operation of the mechanization programme. These machines include five new Fiat 70-66 tractors added in year 2003. In year 2005, four new Steyr (URSUS 5312)

tractors were further injected into the programme. numbers of the various tractors are as follow: Fiat 780 – 1, Steyr 768 – 9, Fiat 80-66 – 3, MF 375 – 17, Valmet 78 – 13, Fiat 70-66 – 47, Steyr (URSUS 5312) – 4. Each tractor has the complete range of affiliated implements. Some of these machines are stationed in the various mechanization zones, as shown in Tables 1 and 2. The engine sizes of the tractors used so far range from 45 to 59.68kw (60 – 80hp).

Contacts were also made with the beneficiaries of the programme – the farmers – through structured questionnaires and personal visits. Personal contacts were also made with the heads of the various zones, through whom most of the farmers were reached.

The information extracted from the farmers include the sizes of their farms, status (part-time or full-time), the various equipment for carrying out the various farm operations, farming experience, mechanization machines not available to them. Others include availability of machines, levels of yearly productivity, ability to operate mechanization machines, problems with, and impacts of the mechanization programme in the state; and their suggestions for improvement.

Table 5 shows the amount of work done by OSASC from 2002 to 2006, in the areas of slashing, spraying, ploughing, harrowing and maize shelling; while Table 4 shows the performance of the tractor hiring unit in terms of the total number of hectares on which mechanization activities were carried out. Table 5 is the summary of the responses from the farmers who were able to complete questionnaires served them.

Table 3: Work done, excluding ploughing, from 2002 – 2006.

Year	Spraying (ha)	Slashing (ha)	Harrowing (ha x 10)	Planting (ha)	Weeding (ha)	Maize shelling (tonnes)
2002	17.5	322	31.2	Nil	Nil	8.5
2003	23.9	295	27.3	Nil	Nil	17.0
2004	23.4	419	24.8	Nil	Nil	33.0
2005	91.0	298	34.1	Nil	Nil	34.1
2006	121	451	24.2	Nil	Nil	88.9

Table 4: The general performance of the Tractor Hiring Unit

Year	2002	2003	2004	2005	2006
Target (Ha)	10,000	10,000	10,000	5,600	16,800
Achieved (Ha)	3,441	2,726	2,487	3,794	2,912

4. Results and Discussions

This section is presented in the areas of the information obtained from the major mechanization programme operators (Ogun State Agro-Service Centre Headquarter), and the beneficiaries (the farmers).

Table 5: Summary of farmers' responses

Farm / operation	Range of farm sizes (ha)	Methods of farm operations	
		Manual	Machine
Land clearing	2 - 50	13	16
Tillage	2 - 50	-	29
Planting	2 - 50	29	-
Weeding	2 - 50	29	-
Spraying	2 - 50	5	17
Fertilizer application	2 - 50	29	-

4.1 Information from the main operators

For clarity, the two sets of information are graphed, as shown in Figs 1 and 2.

Table 5: Summary of farmers' responses

Farm operation	Range of farm sizes (ha)	Methods of farm operations	
		Manual	Machine
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Tillage	2 - 50	-	29
Planting	2 - 50	29	-
Weeding	2 - 50	29	-
Spraying	2 - 50	5	17
Fertilizer application	2 - 50	29	-

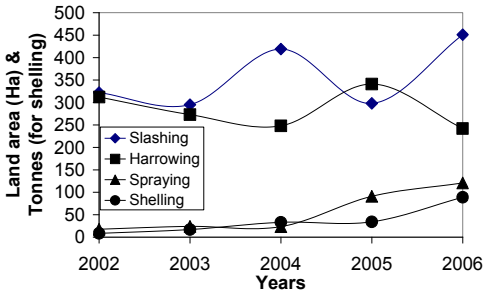


Fig.1 Amount of mechanization, excluding ploughing, from year 2002 to year 2006

On the average, the mechanization of slashing activity increased from year 2002 to year 2006 (Fig.1). The same goes for harrowing, spraying, and maize shelling operations. This is likely to be as a result of the injection of more tractors into the programme. Not all the areas ploughed were slashed, sprayed, or even harrowed. This accounted
for the lower areas of land with the above mentioned operations. Looking at maize shelling which was done for the same group of farmers, one could see an indication of an increased productivity – a sign of positive impact of the mechanization programme. This points to the fact that if all the farm mechanization machines are put in place and used to capacities the programme will be a laudable one, as more food would be produced.

Looking at the ploughing operation (Fig.2) vis-à-vis the tractor power required to handle an area of farmland, as stated by Jain and Rai (1992), namely, 0.746kw (1hp) to every 2.5ha, it can be concluded that the tractors were used very much below capacities. For instance, assuming the lower power limit (45kw) of the available tractors, it is expected that an area of 13,500ha of land would be ploughed. However, the service lives of the machines were considered and a target of 10,000ha set; yet only 2,487ha were worked upon, as depicted by Fig.2. Following the same reasoning, about 10,444ha of land were expected to

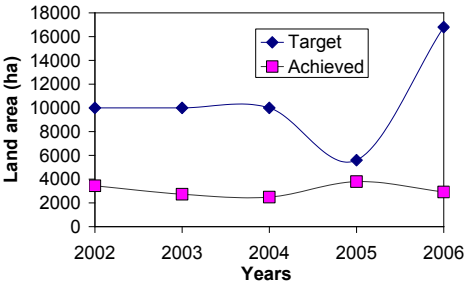


Fig.2: The general performance of the tractor hiring unit from 2002 - 2006.

be handled in year 2006 with 94 tractors. Looking at the general trend of Fig.2, it is clear that there has not been a year the target was met. This is coupled with the high level of complaints of the farmers in this mechanization programme, that they do not have enough machines to use. One may then infer the following: (i) The tractors were not properly managed, (ii) The tractors were not properly maintained that there many downtimes, (iii) The tractors were grossly underutilized, (iv) There were not enough trained machine operators to use the tractors to capacities.

It is clearly seen that planting weeding and fertilizer application operations are totally absent in the mechanization programme within the period under review. This will surely affect crop yields adversely, especially with the absence of weeders. Farmers then resorted to manual weeding with its attendant loss of timeliness.

Not much has been done in the area of small-scale farmer tool production. The unit responsible for tool production should be strengthened, in terms of production equipment procurement. In fact, at the level

of small-scale farming it is more appropriate to introduce simple tools which farmers can reach economically, and which they can manage; instead of dwelling much on tractorization which is very expensive for them. It is worth mentioning, at this point, machines that can be serviced by local smiths; while Hoki et al. (1992) put forward that agricultural mechanization cannot be achieved simply by the introduction of advance technologies.

4.2 Information from farmers.

The data collected (Table 5) indicate no machine planting, weeding, fertilizer application and harvesting. The machine clearing was more of ploughing in of vegetations. Only four people cleared with bulldozers. The mechanization programme is mainly limited to tillage operations; while others were done manually. Many farmers do not even know what processing and storage are all about. It is necessary to mount a sub-programme within the main programme through which farmers will be trained in these areas. Similarly, farmers are generally not aware of soil and water conservation aspect of farm mechanization. In addition, therefore, to including machine planting, weeding, harvesting, processing and storage aspects of farm mechanization in the programme, there is need to incorporate soil and water conservation activities too. The addition of all the missing aspects will go a long way to making the mechanization programme more fruitful.

Generally, the farmers do not keep tracks of the volumes of their yearly productivities, as to enable one evaluate the progress made so far in the programme. However, most of them responded that their yearly productivities have been on the increase. This indicates that marked positive effects of the Ogun State farm mechanization process will be realized if all the mechanization components are put in place.

5. Conclusion

The agricultural mechanization progrmme mounted by Ogun State Government in 1980 was x-rayed for its viability. The period under review is 2002 to 2006. The main operator of the programme is the Ogun State Agro-Service Corporation (OSASC), with its Headquarter at Asero, Abeokuta. The various information needed for the assessment were obtained from OSASC and the farmers who are the beneficiaries of the programme. For the purpose of the programme, Ogun State was zoned into five, namely, Remo, Yewa North, Yewa South, Ijebu and Egba.

The numbers of the mechanization machines available for the programme were ascertained and the various information on modulus operandi obtained.

There were no mechanization activities, within the period under review, in the areas of seed planting, weeding, fertilizer application, harvesting, crop processing, storage, soil and water conservation. Most of the mechanization work done was on tillage. Information obtained from farmers, who are the beneficiaries of the programme, revealed that most of that all the countries whose agriculture has been mechanized started with simple small-scale farmer tools and not tractorization. In fact Nweke (2004) stated that Research & Development on mechanization should focus on developing low cost small their farm operations, outside of tillage, were done manually. Even the simple tools that would enable them carry out planting, weeding, fertilizer application and harvesting were not available. The small-scale tool production unit of the programme has produced only cutlasses. The farmers are in much demand of many more machines and requested the Ogun |State Government to inject more machines into the programme.

Findings show that the machines that are already available for the project are grossly underutilized. Suggestions for improvements have been made both by the farmers and the authors.

6. Some of the Suggestions for Improvement generally put forward by Farmers

1. Injection of more mechanization machines into the programme, and ensuring that the machines are fully utilized.

2. Subsidizing mechanization operational charges.

3. Subsidizing the cost of fertilizers.

4. Employment of more tractor operators.

5. Purchase of tractors with readily available parts.

6. Proper monitoring of the programme

7. More training on farm mechanization to be given to them.

8. Rehabilitation of road networks in the State.

9. Provision of silos and other grain storage facilities.

7. General Suggestions

1.There is need to lay more emphasis on the tools that the farmers would be able to purchase, operate and manage to suit his level of mechanization than on tractorization. Situation might improve in the future and the farmers become able to operate at a higher level of mechanization.\

2. The farm equipment manufacturing unit of the mechanization programme, which at the moment produces only cutlass, should be strengthened to enable it produce tools that would enable the farmers plant, weed, apply fertilizers.

3. The issue of hiring farm operators should be discouraged and more permanent ones employed and trained in line with the types of machines available.

This will ensure the achievement of machine economic lives and efficient field work output.

4. There is need for proper monitoring of the programme to ensure proper operation which is in conformity with the policy of the programme.

5. From Fig.1, it is observed that no work has been done in the areas of seed planting and weeding. These operations and the efficiencies with which they are carried out determine, to a large extent, the level of crop yield. The programme should, therefore, include these operations, and with the levels of seriousness they require.

6. The inclusion of soil and water conservation aspect to the programme would be an added stimulant to the mechanization process.

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FUZZY LOGIC MODELLING OF FARM TRACTOR RELIABILITY IN KWARA STATE, NIGERIA

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ABSTRACT

Preliminary works of data collection and analysis were carried out to examine the reliability of farm tractors. Sugeno-type Fuzzy Logic model was developed to estimate the reliabilities of farm tractors and their systems. The results show that Fuzzy Logic model is reasonably accurate in predicting reliability of farm tractors. The fuel system was observed to be the most reliable of the tractor systems. The electrical system had the greatest tendency to failure on the farm tractors surveyed.

Keywords: Reliability, Fuzzy Logic model, Farm tractors.

1. INTRODUCTION

As more and more capital in the form of machinery replaces manual labour on the farm, the reliability of the equipment used assumes greater importance. Indeed, deeper insight into failures and their prevention is to be gained by comparing and contrasting the reliability characteristics of systems that make up the tractor. Reliability is defined as the probability that the equipment or system will complete a specific task under specified conditions for a stated period of time (Amjad and Chaudhary, 1988). Hence, reliability is a mathematical expression of the likelihood of satisfactory operation. A failure may be referred to as any condition which prevents operation of a machine or which causes or results in a level of performance below expectation.

Owing to the importance of timeliness of operations in obtaining high yields, machinery breakdown especially at busy period such as sowing or harvesting can lead to large losses of revenue apart from the cost of repairing the equipment. If estimates could be made of when equipment is likely to fail, this would assist in planning machinery purchases and spare parts inventories and reduce costs.

The concept of Fuzzy Logic was conceived by Lotfi Zadeh in 1965, and he presented it as a way of processing data by allowing partial set membership rather than crisp set membership or non-membership (Kaehler, 2005).In Fuzzy Logic, an assertion is allowed to be more or less true. A true value in Fuzzy Logic is a real number in the interval [0, 1] rather than the set of two true values {0,1} of Classical Logic. Areas of application of Fuzzy Logic include cement kiln control, information retrieval systems, laboratory water level controller, etc (Jaya et al., 2004).

Fuzzy Logic provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy or missing input information. A Fuzzy Logic approach control problem mimics how a person would make decisions, only much faster. It uses an imprecise but very descriptive language to deal with input data more like a human operator (Kaehler, 2005).

Fuzzy Logic is an important decision making tool for comparing a developed product with a similar product available in the market. This technique helps to transfer the opinion of experts as well as objective information, into numerical values which can be used for decision making (Jaya et al., 2004).

Fuzzy Inference system has been successfully used in predicting many biological parameters. The use of Fuzzy Inference System is a means of modelling that allows apt description of mapping inputs to outputs (Brown-Brandl et al., 2003).

Fuzzy models use qualitative relationships and can include intuitive understanding. They may be developed significantly faster than analytical models. Fuzzy models also eliminate the need of coefficients in relationships to account for uncertainty between variables (Center and Verma, 1997). Applications of Fuzzy Inference system to model complex physical and biological systems are well documented and growing (Brown-Brandl et al., 2003).

The main objective of this work was to use a Fuzzy Logic model to estimate reliability of farm tractors during their operating life. This will help in assessing the

suitability of imported tractors to Nigeria. Necessary steps can then be taken to make these imported tractors more reliable.

2. MATERIALS AND METHODS

2.1 Theoretical Development

Amjad and Chaudhary (1988) used Weibull failure model to apply reliability theory to farm machinery with special reference to mechanical reaper. It was claimed that the Weibull failure model is very basic and applicable to all farm machines such as combines, tractors etc. The Weibull cumulative distribution function (cdf) or failure function is given as

$$F(t) = 1 - \exp -[{}^{(t-\gamma)}\!/_{\alpha}]^{\beta} \quad (1)$$

where exp = base of Naperian logarithm.

α = scale parameter (months).

β = shape parameter or Weibull slope (ratio).

γ = location parameter or lower bound of life (months).

t = time between successive failure (months).

Amjad and Chaudhary (1988) also stated that in the case of farm machinery, the first failure can be expected as soon as the machine is placed in service. Hence, the lower bound of the life or location parameter (γ) is zero. Thus γ = 0 and the Weibull cumulative density function becomes

$$F(t) = 1 - \exp -[{}^{t}\!/_{\alpha}]^{\beta} \quad (2)$$

The reliability function R(t) is therefore given as

$$R(t) = 1 - F(t) \quad (3)$$

$$R(t) = \exp -[{}^{t}\!/_{\alpha}]^{\beta} \quad (4)$$

For the estimation of α and β (Weibull parameters) simple regression analysis was used. This method is based on the fact that the reliability function of Weibull distribution can be transformed into a linear function of Ln t by means of double logarithmic transformation. Taking the natural logarithm of both sides of equation (2) twice, gives:

$$Ln\left[Ln\ \frac{1}{1-F(t)}\right] = \beta\left[Ln\ t - Ln\ \alpha\right] \quad (5)$$

$$Ln\ t = \frac{1}{\beta}\left[Ln\left[Ln\ \frac{1}{1-F(t)}\right]\right] + Ln\ \alpha \quad (6)$$

This is of the form Y = Mx + C

where M = 1/ β

(Slope of the linear equation)

C = Ln α

(Intercept of the linear equation)

The Weibull model provides considerable flexibility in describing failure distribution (Amjad and Chaudhary, 1988). That is, upon setting β = 1, equation (2) becomes exponential distribution with a delay (which can be thought of as a guarantee period within which no failure can occur, or a minimum life). Thus, the assumption of a constant failure rate

(exponential model) is also included as a special case in this Weibull failure model.

Wingate-Hill (1981) and Amjad and Chaudhary (1988) pointed out that reliability of a machine is a product of the individual component's reliability. If the engine, transmission, tyre and steering have reliabilities of R_1, R_2, R_3, and R_4 respectively, for a specified condition, then the reliability, R_t , of the tractor as a whole is obtained as

$$R_t = R_1 R_2 R_3 R_4 \quad (7)$$

2.2 Data Collection and Analysis

A questionnaire was designed to collect data on time between successive failures of each of the systems of farm tractor. The tractor systems considered were engine, transmission, hydraulic, steering, electrical, traction, cooling and fuel. A total of sixty questionnaires were administered to twenty-six organizations. The organizations were well spread all over Kwara State, Nigeria. Forty-five tractors were surveyed and they were all still serviceable. They had covered a period of operation ranging from thirty to one hundred and thirty-six months. The tractors were generally the medium power rating tractors and were used for tillage, haulage and stationary barn yard operations. The data obtained from time measurement were compiled and used to quantify reliability. The data were grouped into class intervals and analysed using median rank and regression equations in conjunction with the Weibull model. The time between successive failures data for each system of all tractors irrespective of the make was analysed to obtain the overall Weibull parameters, α and β (Table 1) and reliability of each system. With the use of equation (7), the overall reliability of the whole tractor was obtained from the individual reliability of the eight systems of the tractor considered. This computation was done for various times between successive failures. The individual reliability of the eight systems of the tractor constituted the input data while the overall reliability of the whole tractor obtained from them was the output data. Hence, sets of input/output data were generated.

Table 1. Weibull Parameters (α and β) of Tractor Systems

Tractor System	α	β
Engine	31.75	2.88
Hydraulic	25.87	4.36
Steering	19.79	2.91
Transmission	23.36	2.98
Fuel	39.31	3.39
Cooling	24.99	3.51
Traction	19.12	3.14
Electrical	18.41	3.19

2.3 Modelling

The reliability input/output data set was randomly divided into two subsets. Set 1 consisted of 85 independent data points and was used in the model development. Set 2 consisted of the remaining 30 data points, and the model evaluation was completed

using this set. In a detailed analysis, a random selection of 10 data points was evaluated to ensure accurate model predictions.

Fuzzy Inference Systems

The Sugeno-type Fuzzy Inference system was developed in this research. For a system with two input variables and one output variable, Sugeno-type fuzzy logic models have the form:

If x is A and y is B, then z = f (x, y) (8)

where x and y are system input variables and z is system output variable. A and B are antecedent membership functions and f (x, y) is a crisp function in the consequent. Usually f (x, y) is a polynomial function of the input variables x and y; but it could be any function as long as outputs produced by the Fuzzy Inference system can appropriately simulate the system being modelled (Mathworks, Inc., 2002).

Clustering

Clustering is used to establish membership functions during the development of Fuzzy Inference system. Usually, cluster definition is based on spatial distances between data. In a cluster space of numerical data, the distance between any two points is less than the distance between any point in the cluster and any point outside the cluster (Mathworks, Inc., 2002). For fuzzy clusters, the boundary between any two clusters is fuzzy. Membership functions are established by assigning a degree of belonging for each data point to a given cluster as the fulfillment of the membership function. In this research, subtractive clustering was used to establish initial Sugeno-type membership functions.

Neural Network for Tuning Fuzzy Inference Systems

A key characteristic of artificial neural networks is their ability to learn, a process by which a neural system acquires the ability to carry out certain tasks by adjusting its internal parameters according to some learning algorithms. The initial Sugeno-type Fuzzy Inference system was optimized by ANFIS (Artificial Neuro-Fuzzy Inference System) (Mathworks, Inc., 2002), in which the Fuzzy Inference System is implemented into the framework of a supervised feed-forward type artificial neural network. The training, or learning, algorithm of the artificial neural network is a combination of back-propagation and the least-squares methods. The synapses in ANFIS are not given values (synaptic weights). They only indicate flow direction of data. Parameters that are adjusted are in node transfer functions. In other words, the membership function parameters are adjusted, not synaptic weights.

Fuzzy Logic Model

This model, consisting of eight inputs (individual reliabilities of the engine, transmission, hydraulic, steering, electrical, traction, cooling and fuel systems of the tractors) and one output (overall reliability of the tractors), was implemented using MatLab(Mathworks, Inc., 2002), using a Sugeno-type modelling approach. The Fuzzy Logic Model was developed using the aforementioned ‘dataset 1’ as a training set, and ‘dataset 2’ as the testing set. The model was developed using ‘genfis2’ (which utilizes subtractive clustering) within Matlab (Mathworks, Inc., 2002), and ANFIS as the neural net training routine.

3. RESULTS AND DISCUSSION

The description of the model was a set of five rules dictating the mapping of the inputs to the output. The five rules are shown graphically in Figure 1. Note that the inputs are combined as fuzzy clusters described with Gaussian membership functions. The model uses a logical ‘AND’ relationship to combine the data space into fuzzy clusters. The degree of belonging of an input vector to a particular cluster defines the contribution of the associated rules. The ultimate output is a weighted average of each of the contributing rules. Examining the rules presented in figure 1 reveals that the overall reliability of the tractor is sensitive to all the inputs (reliabilities of the tractor systems). The projections of each cluster on each of the tractor systems change dimensions at every rule which indicates that they all have some impacts on the output (overall reliability of the tractor).

A plot of the Fuzzy Logic model estimated reliability and the reliability

values obtained from reliability function equation for farm tractors (Figure 2) shows that the Fuzzy Logic model was able to capture the relationship between the eight inputs (individual reliabilities of the tractor systems) and the output (overall reliability of the tractor) with a good fit. The coefficient of determination (R^2) was 0.85, the slope was 0.96 and the standard error of the estimate was 0.15.

Fuzzy Logic model of each tractor system was also developed using time between failure as input and reliability of the system as output. The values of Fuzzy Logic model estimated reliabilities and the actual (calculated) values of reliability were very close. The coefficients of determination (R^2) were virtually unity (0.9999). However, in order to compare the relative reliabilities of the tractor systems, the Fuzzy Logic model estimated reliabilities were plotted against time between failures as shown in Figure 3. With reference to Figure 3, the fuel system was found to be the most reliable. It has the least slope. The second most reliable system was the engine. This is followed by the hydraulic, cooling, transmission, steering, traction and the electrical systems in order of decreasing reliability. The highest reliability value of the fuel system could be explained by the fact that routine maintenance of changing the fuel filters on the farm tractors reduces the frequency of breakdown of the system. The low reliability value of the traction system is understandable from the fact that the farm tractors in the area of study operate on rough terrains where tree stumps and other damaging materials are not properly removed. Likewise, the relatively low reliability value of the steering system is due to the fact that the tractors surveyed are made to work on rocky, difficult and rough fields.

4. CONCLUSION

This paper reported an investigation to assess the reliability functions from the breakdown records of farm tractors. Sugeno-type Fuzzy Logic model was developed to estimate the reliabilities of the various systems of the farm tractor and the overall reliability of the tractors. The results show that the Fuzzy Logic model estimated reliability is reasonably accurate and is comparable to the reliability values obtained from reliability functions. Comparisons of the Fuzzy Logic model estimated reliabilities of the tractor systems showed that steering, traction, and electrical systems have higher tendency to failure than other systems of the tractor. The fuel system was observed to be the most reliable of the tractor systems.

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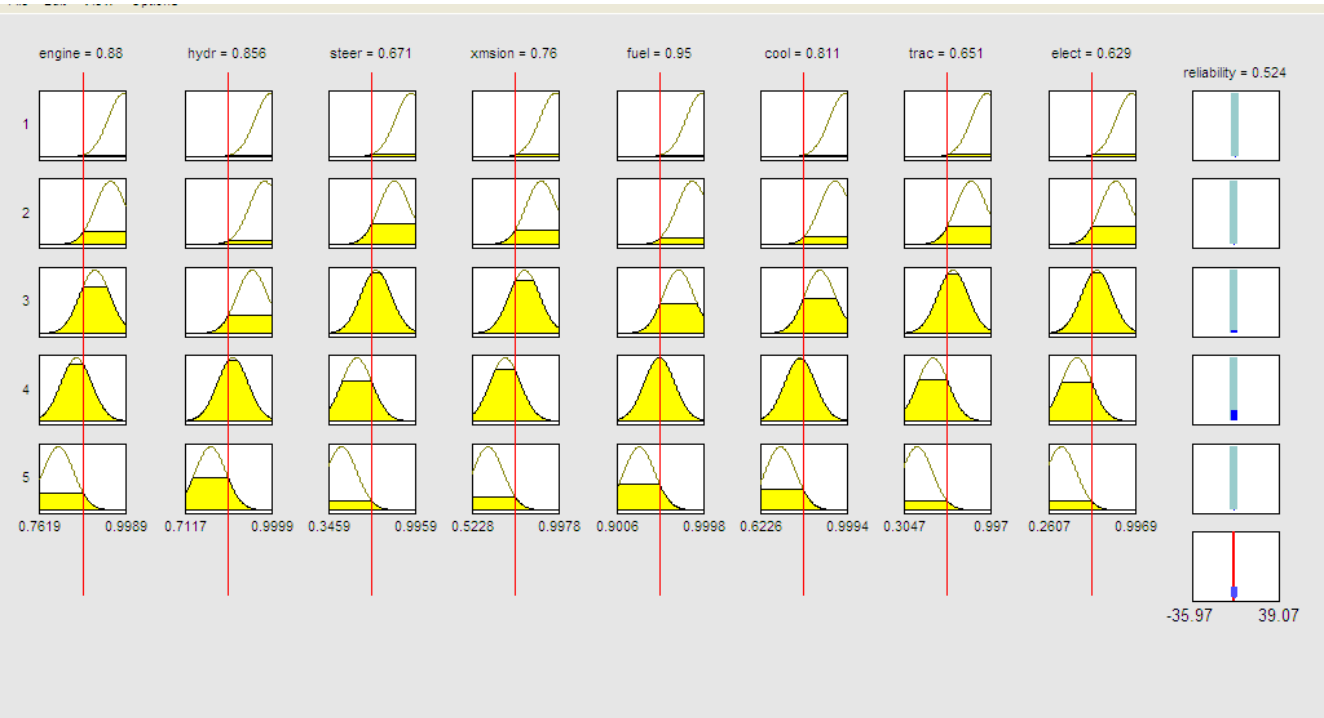


Figure 1. MatLab (Mathworks, Inc., 2002) interactive interface describing "Fuzzy Logic Model." Each row of membership functions represents a rule and consists of eight membership functions, corresponding to each input.

The first eight columns represent the eight inputs, (reliabilities of the tractor systems). The last column represents the weighted output (overall reliability of the tractor) of each of the five rules.

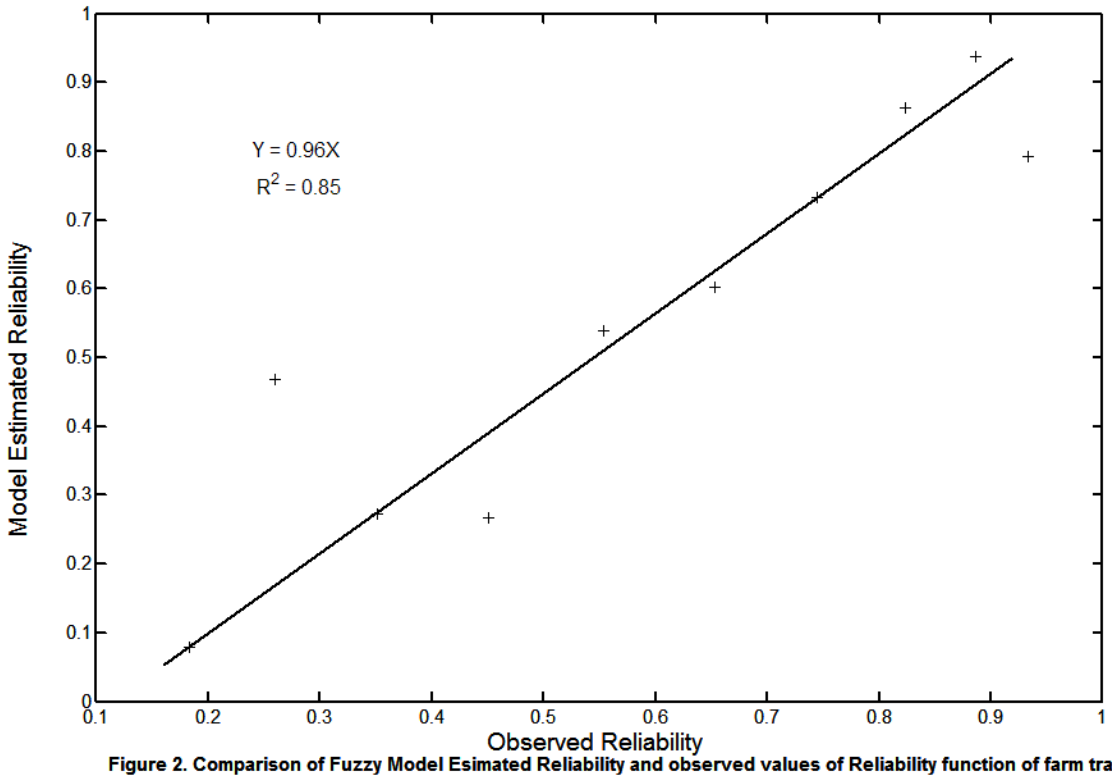


Figure 2. Comparison of Fuzzy Model Esimated Reliability and observed values of Reliability function of farm tractor.

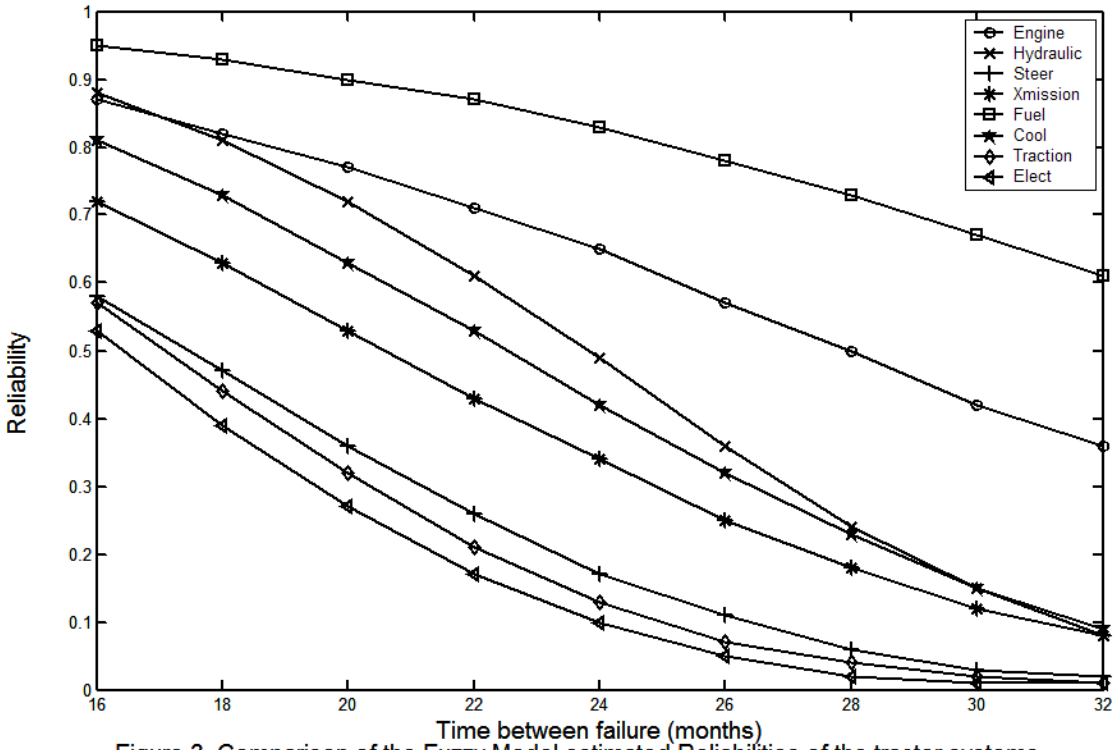


Figure 3. Comparison of the Fuzzy Model estimated Reliabilities of the tractor systems

THE ROLE OF AGRICULTURAL ENGINEERING IN ACHIEVING MILLENIUM DEVELOPMENT GOALS (MDG'S)

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ABSTRACT
Millennium development goals (MDG'S) were set by member nations of the United Nations in September 2000.The goals were to be achieved by the year 2015 by all countries who accepted and adopted MDG'S. The major objectives of the MDG'S are poverty eradication and attainment of a safe and healthy environment. This paper is a review in which various fields in Agricultural Engineering profession as practiced were outlined and the role they can play in achieving MDGs focusing on two particular goals namely Eradication of Extreme poverty and Hunger, and Ensuring Environmental sustainability. Effort of government was highlighted so also the achievements. It was concluded that to achieve MDGs by the year 2015 Government should involve professionals like Agricultural Engineers as stake holders.

INTRODUCTION

Despite all efforts that have been made both locally and internationally to eradicate poverty, many countries of the world are still classified as poor nations especially the so called developing countries. Poverty has therefore remained a global problem. The United Nations reported that over one billion people live on less than one US dollar a day. Two billion people, a third of all the people living on this planet do not have access to decent sanitation making them vulnerable to diseases. More than one hundred million children died each year before their fifth birthday largely from preventable diseases.

It is as a result of these that United Nations in September 2000 at the meeting of word leaders adopted the Millennium Development Goals (MDGS). These goals were set and are to be achieved by the year 2015 by all countries who accepted and adopted the (MDG'S).

1.0 WHAT IS MILLENNIUM DEVELOPMENT GOALS

Development is the process of changing and becoming larger stronger or more impressive successful, or advanced or of causing somebody or something to change in a way. Therefore, International Development is the journey the world must take in order for poor countries to become prosperous countries. At the very least, its about making sure that the most basic things that are taken for granted in developed countries can also be taken for granted by every man else in the world.

People in all countries should have food in their plate everyday, a roof over their heads at night, schools for their children education, nurses and medicine when they are sick, jobs which bring money into their homes.

The Millennium Development Goals describes the collective efforts of all countries which are working to free people from poverty by

i. Creating a world where every one has the opportunity to lead safe fulfilling, creative and rewarding life
ii. Creating a global society in which every one can live in peace and security, and every one has the opportunity to have a say on how their own country and the world is run.
iii. Creating a world where everyone has the opportunity to earn a decent living and the means to bring up healthy and educated children.

THE GOALS

The main target of the Millennium Development Goals (MDG'S) as presented above is to end poverty which has been defined by the dictionary as not having the minimum income level to get the necessities of life. More

elaborately, the UN report described poverty as the denial of opportunities and choices most basic to human development to live a long, healthy creative life, to have a decent standard of living.

Because the causes of poverty are many and interlinked, the international community came together in support of a comprehensive approach whose aim is to make huge strides towards a better world within a decade. The Millennium Development Goals were adopted by world leaders at the UN in September 2000[1].

The Goals are that by 2015, member states pledged to:

1. Eradicate extreme poverty and hunger
   - Reduce by half the proportion of people living on less than one U.S dollar a day and for those who suffer from hunger.
2. Achieve universal primary education
   - Ensure that all boys and girls complete full course of primary schooling
3. Promote gender equality and empower women
   - Eliminate gender disparity in primary and secondary education
4. Reduce child mortality
   - Reduce by 2/3, the number of children who die before their fifth birthday.
5. Improve maternal health
   - Reduce by ¾ the number of women who die in childbirth
6. Combat HIV/AIDS, malaria and other diseases
   - Halt and begin to reverse the spread of these killer diseases
7. Ensure environmental sustainability
   - Make sure the environment is protected so that future generation can continue to benefit from it.
   - Cut in half the proportion of people without access to safe drinking water
   - Significantly improve life for 100 million slum dwellers by 2020
8. Develop a global partnership for development
   - This includes developing an open but fair trading system, boosting freedom, justice and democracy, helping countries improve their export, providing more debt relief aid and making dongs more easily available.

Having stated what the millennium development goals are, Agricultural Engineering/Engineers needs to be defined to know what they do so as to show the role they can play in achieving these goals focusing particularly on two important goals namely, Eradicate extreme poverty and hunger and Ensure environmental sustainability.

2.0 AGRICULTURAL ENGINEERING

Agricultural Engineering is the application of engineering principles to any process associated with producing agriculturally based goods and management of our natural resources. The profession concerns itself with the development of labour saving farm machines and equipment farm buildings, irrigation and drainage systems and processing of agricultural products to useful food, feed and fiber products[2].

Agricultural Engineers are therefore the professionals who have been extensively trained in Agricultural Engineering for the purpose of:

i. Devising practical and efficient solutions for producing, storing, transporting processing and packaging agricultural products.

ii. Solving problems related to systems, processes and machine interaction with humans, plant organisms and biological materials.

iii. Develop solutions for responsible alternative uses of agricultural products, by products and wastes and of our natural resources – soil, water, air and energy and many more.

In summary Agricultural Engineering as a profession is constantly striving to ensure that the growing world population have the necessities for life, safe and abundant food and water to eat and drink, timber and fiber for shelter and clothing, plentiful and renewable energy resources, clean air and safe healthy environment to live.

It will be noticed here that the distinguishing feature between agricultural engineering and other engineering fields is the interest and commitment of Agricultural Engineering at solving problems and pursuing opportunities related to human and animal needs for food, feed, fiber and sustainable safe living and working environment[2].

3.0 OPTIONS IN AGRICULTURAL ENGINEERING

Agricultural Engineering embraces a variety of specialties, With the advancement of science and technology, new areas are created, with many overlapping with one another.

The handbook of Agricultural Engineering[3], edited by the international commission of Agricultural Engineering, gives a detailed perspective of how or what Agricultural Engineers can do or practice. The commission presented the following main fields of practice;

1. **Soil and Water Engineering:** This option deals with the scientific interaction of plants, animals, and humans with natural resources including soil and water in the atmosphere, on the earth surface, and underground. It seeks ways to control soil erosion and study the environmental effects of sediment on water quality. It involves the design, building, operation and maintenance of drainages and irrigation systems, water control structures for reservoirs, floodways and channels. The application of this option can help in channeling water which can be used for farming all year round, provide good road network for easy transportation of food and agricultural products and provide drinkable water, control erosion thereby helping in eradication of extreme poverty and hunger and also help in ensuring environmental sustainability goals of MDG.

2. **Power and Machinery Engineering:** This option involves design of farm equipments and machineries for transport, cultivation, use of engines in Agriculture, principles of mechanisms and mechanics, engine base assembly, seeders and planters fertilizer distributors' threshers, harvesters and spraying machineries and so on. The practice of this option makes farming operation easy, help in precision farming which can increase farm yield. Engineers in this field also design spraying machines which are used to spray pesticides and insecticides with precision which help in preventing spread of germs that can cause dangerous diseases. Practice of this field will help in achieving poverty and

hunger eradication and other health issues of MDGs.

3. **Animal Production and Aqua-cultural Engineering:** This option deals with the design of livestock housing and environment, knowing characteristics and performance of construction materials e.g. concretes, re-enforced concretes, steel construction, masonry and blocks and wood as a construction material, Aqua-cultural systems, Aqua-cultural Environmental requirements and materials selection for Aqua-cultural facilities. Waste management and recycling of organic matter. Environmental control of livestock housing. .Engineers in this option concentrate on increasing production while decreasing cost and environmental impact. Meat is widely accepted as the main source of protein, hence meat production is very important, engineers in this field help in boosting animal and aqua cultural species production using there knowledge of engineering their action and practice will help in poverty and hunger eradication, and will help in ensuring environmental sustainability since they also practice waste management and control.
4. **Agro-Processing Engineering:** This field of Agricultural Engineering involves study and design of machineries for handling, draying, storage, and quality control of grains, fruits and vegetables, storing forages and forage products, milk storage and control. This engineering practice help to ensure availability of food through out the year since they apply engineering knowledge to design machines for processing, drying and storage of food, therefore helping to achieve hunger and poverty eradication goal.
5. **Energy and Biomass Engineering:** This option of Agric Engineering involves study, design and use of natural and biomass energy for biological systems, energy saving in crop production, solar energy, wind energy, hydraulic energy, fuels from biomass liquid, vegetable oil and their esters (Bio-diesel), solid fuels and energy utilization of green manures and forage legumes. This practice can help in reducing deforestation by designing systems that will provide energy for cooking from biomass. They can also help by designing hatcheries like incubators for poultry production thereby helping in achievement of poverty and hunger eradication goal of MDGs.
6. **Structural and Environment:** This option deals with analysis, design and use of biological products as construction materials. These Engineers design safe, economical structures including green houses and animal housing. Storage structures for grains, fruits, and other food products; and waste handling and storage facilities.

In the environment area, the option deals with the design of systems and equipment to provide environmental control for plants, animals, processing and storage facilities, such as design of ventilation systems, and specify equipment that heats, cools, lights, reduces harmful emissions, and controls conditions

around facilities. This engineering practice will help in achieving the goal of environmental sustainability since biological products are converted to building and other useful materials.

7 **Forestry Engineering:** This option deals with the application of physical, biological and Engineering Sciences to solving problems in Natural resources and environment, forest production systems and related manufacturing industries It tends to solve problems related to equipment design. Forest access system, machine/soil interaction and erosion control.

Having known what MDG is and who Agricultural Engineers are and what field they can practice, one can see clearly that Agric Engineers has a very big role to play especially in eradication of extreme poverty and hunger, and ensuring environmental sustainability. Based on the Agricultural Engineering practice discussed above the table below gives a summary of the role each field can play in order to help in achieving two important Millennium Development Goals.

TABLE 1: ROLE OF AGRIC ENGINEERS/ENGINEERING IN MDG'S ACHIEVEMENT

		Role that can be played in	Role that can be played in
S/No	**Agricultural Engineering Field (Option)**	**Eradication of Extreme Poverty and Hunger**	**Ensuring Environmental Sustainability**
1.	Soil and Water Engineering	• Design easy and simple irrigation and drainage systems that can be used in rural areas • Develop and plan good road networks to rural areas • Participate in Creating massive awareness for rural farmers on land and water use planning for farming	• Create local awareness on land reclamation techniques and practice, soil conservation, and drainage and erosion control
2.	Power and Machinery Engineering	• Design simple, affordable, durable and easy to operate machineries for farming operation as this will reduce drudgery in farming	Design the use of these machine such soil erosion and compaction is prevented Large area cultivation with machines reduces risk of erosion and desertification.
3.	Animal Production and Aqua-cultural Engineering	• Help too design relatively cheap dwellings and livestock housing for rural people and their livestock. • Help in enlightening rural dwellers to improve on their knowledge in Aqua cultural techniques	• Teaching and enlightening local people on Aqua cultural environmental requirements. • Help in improving knowledge on waste management and recycling of organic matter.
4.	Agro-Processing Engineering	• Help in designing of machineries and systems that are simple and relatively cheap to help in processing and storage harvested crops	Design machines for treating municipal, industrial and agricultural waste for a cleaner environment.
5.	Energy and Biomass engineering	• Develop simple and easy ways of utilization of Natural and Biomass energy for biological systems • Help in teaching and creating methods of energy saving in crops production.	• Help in developing fuels from biomass, and Agricultural produce as this will help in environmental protection. • Developing ways of using solar and wind energy in farming. As this will help in ensuring protecting Natural Environment.
6	Forestry Engineering	• Provision of Forest products like wood for construction of houses/structures • Provision of food items like fruits, meat and medicinal herbs. • Recreation	• Preservation of the environment by checking desertification and soil erosion •
7	Structures and Environment	• Design of safe economical structures including green houses, animal housing and storage structures.	• Design systems and equipment to provide environmental control for animals, plants and waste handling

4.0 STATE OF DEVELOPMENT IN NIGERIA

Nigeria, which was one of the richest 50 countries in the early 1970s, has retrogressed to become one of the 25 poorest countries at the threshold of the twenty first century. It is ironic that Nigeria is the sixth largest exporter of oil and at the same time host the third largest number of poor people after China and India. Statistics show that the incidence of poverty using the rate of US $1 per day increased from 28.1 percent in 1980 to 46.3 percent in 1985 and declined to 42.7 percent in 1992 but increased again to 65.6 percent in 1996. The incidence increased to 69.2 percent in 1997. The 2004 report by the national Planning Commission indicates that poverty has decreased to 54.4 percent. Nigeria fares very poorly in all development indices. The average annual percentage growth of GDP in Nigeria from 1990 -2000 was 2.4. This is very poor when compared to Ghana (4.3) and Egypt (4.6). Poverty in Nigeria is in the midst of plenty. Nigeria is among the 20 countries in the world with the widest gap between the rich and the poor. The Gini index measures the extent to which the distribution of income(or in some cases consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution. A Gini index of zero represents perfect equality while an index of 100 implies perfect inequality. Nigeria has one of the highest Gini index in the world. The Gini index for Nigeria is 50.6. This compares poorly with other countries such as India(37.8), Jamaica(37.9), Mauritania(37.3) and Rwanda(28.9).[3]

In order to address the problem of poverty and promote sustainable development Nigeria became a signatory to the United Nations Millennium Development Goals (MDGs) program. The Nigerian government with technical and financial support from United Nations and other partners took a number of concrete steps and implement four program areas that were aligned to the MDGs these are;

1) Establishment of the National Economic Empowerment and Development Strategy (NEEDS) program.
2) The alignment, by the government, of the National medium term development blue print to the MDGs.
3) Establishment of an MDG office to monitor progress and put the country on track.
4) Establishment of a multi stake holders committee headed by the president which reviews progress after every quarter.[3]

5.0 CURRENT STATUS OF ACHIEVEMENT OF MDGs IN NIGERIA.

Annual reports on MDGs achievement started in 2004.[4] The next report was that of 2005.[3] As earlier stated this review will focus on only two goals i-e goals 1 and 7 thus level of achievements according to2004 report are presented as follows;[4]

<u>Goal 1</u>: Eradicate Extreme Poverty and Hunger

- Percentage of population living in relative poverty declined from 65.6% in 1996 to54.4% in 2004.
- Percentage of population living in extreme poverty (i-e those that cannot afford 2900 calories per day) stood at 34.9% in 2004.
- Unemployment declined from14.8% in 2003 to 11.8% in 2004.
- Percentage of underweight children fell marginally from 35.7% in 1990 to 30.7% in 2004.

Goal7: **Ensure Environmental sustainability**

- Proportion of land area covered by forest increased from 10% in 1990 to 12% in 2004.
- Proportion of gas flared declined from 68% in 1990 to40% in 2004.There is high hope for meeting zero flarering by 2008.
- Proportion of households with access to safe drinking water has been improving due to significant allocation of resources, which had resulted into establishment of many dams and water reservoirs in the country.
- Proportion of households with access to basic sanitation improved from 56.5% in 1990 to72% in 2003

6.0 CONCLUSION

Based on the 2004 progress report given above, it can be seen that efforts have been made by the Nigerian government towards achieving these MDGs by 2015, but in the whole more needs to be done. Agricultural Engineering profession is very extensive as highlighted above and can play vital role in the achievement of the MDGs. Government has recognized Agriculture as a critical sector for achieving MDGs by eradicating extreme poverty and hunger and so voted huge sums of money for the Agricultural sector. Despite this huge sums of money voted, the MDGs Nigeria working group reported that statistics show that Nigeria effort at achieving MDGs needs to be doubled the score board at half time is showing there would be no clear victory by 2015 [5].Therefore all stake holders including professionals like Agricultural Engineers must be involved to ascertain, what has worked, what has not, which strategies need strengthening, which are to be modified or thrown out for the goals to be achieved by 2015.

7.0 RECOMMENDATION

Based on this discussion the followings are hereby recommended

(i) Agencies and organizations who are involved in trying to achieve these Millennium Development Goals should engage Agricultural Engineers and its practice.

(ii) Agricultural Engineers should wake up and identify more areas where they can contribute in the achievement of these MDGs.

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DEVELOPMENT AND PERFORMANCE EVALUATION OF A GARDEN FAIL MOWER.

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ABSTRACT.
Land Clearing for establishment of gardens and pastures in Nigeria is done mainly with the traditional hand tools by peasant Farmers. This is because the conventional flail and rotary mowers used for land clearing are either too big or expensive for the Farmers whose individual land holdings are usually less than 3 hectares. It is against this background that a small power operated flail mower is developed. It is simple to operate, maintained and affordable. The developed machine consist principally of a rotary drum with flexible blades (flails) attached, three wheels and a guard all mounted on a rigid frame. Although the machine is manually pushed, the drum is powered by a 2 hp, 300 rpm internal combustion engine. The driving and driven pulleys are selected to give a desired drum speed of 200 rpm. Results of performance evaluation showed that the machine has average effective field capacity and efficiency of 0.046ha/hr and 25.41% respectively.

Key words: Flail mower, swinging blades, shreds, field efficiency.

1. 0 Introduction

Land clearing is the removal of vegetation (trees, bushes, shrubs, grasses, etc) from the soil surface. Different degrees of land clearing are necessary depending on the end use to which the land is to be put. For instance; for constructional works (highway, dam, buildings, etc) total removal of vegetation is necessary; for normal cropping, removal of vegetation up to 10cm below ground level is necessary (Kaul and Egbo, 1985) . Clearing operations are also done in gardens and surroundings of premises.

Four methods are usually employed for land clearing; viz; complete removal of trees and other vegetation by physically uprooting them and moving them to another place; cutting the vegetation at ground level and collecting the same for burning or allow to decay; knocking over and crushing down the vegetation or ploughing and mixing in the vegetation to a depth of about 20cm of soil (Kaul and Egbo, 1985).

These methods of land clearing can be done manually using axes, machetes, brush hooks, power saws, sickles, etc or mechanically using bulldozers, tree rake, tree pushers, shear blade and mowers (kaul and Egbo, 1985).

The Development of mower for cutting hay is associated with the development of the reaper. Today; various types of mowers have been designed and developed, some of which include the conventional cutter bar type, the rotary type and the flail type (Kepner, etal; 1980). Cutter bar mowers are used for crops and forage harvesting while rotary mowers for clearing of weeds in orchards and other related jobs. However, they tend to leave the materials unshredded. Flail mower however cuts and shreds stalks, small bushes, cover crops and other vegetative materials to facilitate drying or incorporation into the soil; and by its free-swinging blades, greater flexibility is provided for rocky conditions. It is less expensive in terms of maintenance and can be used for a variety of other shredding jobs. The conventional flail mowers have

cutting widths ranging from 1.2 - 3.0m, thus power requirements are considerably higher. (Kepner etal; 1980).

The use of the right size and width of an implement for a particular job minimizes the total cost per hecter for performing the operation and considering the fact that Agriculture in Nigeria is mostly undertaken by peasant Farmers with small farm lands and no capital to purchase and own farm tractors that can power bigger implements like the flail mower; there is the need to develop a flail mower which can be powered by small power units.

Thus, the objective of this work is to develop a flail mower that can be powered by a small power unit which is affordable by peasant farmers and to evaluate the performance of the machine.

2.0 Materials and Method

2.1) Design Process.

There is relatively little information on works done on flail mower that is simple enough and affordable by peasant farmers in Nigeria. In the design process, the following assumptions were made: Desired drum speed = 200 rpm (Kepner *et al,* 1980) , length of drum = 500 mm, average forward speed = 1 m/s.

The cutting assembly is designed on the principle of Rotary tiller in which Odigboh and Ahmed (1979) stated that if R is the radius of the hoe, V_m ; forward speed of the implement and ω; angular velocity of the hoe, then for cutting of soil slice to take place, $R\omega / V_m > 1$. For effective cutting of vegetation, Kepner et al. (1980) suggested a ratio of between 1.25 – 1.5.

Applying this principle to flail mower, let the angular velocity of the drum = ω_D, radius of both the drum and the blade = R_D , the machine forward speed = V_m ;and a ratio of 1.5,

Then , $R_D\omega_D / V_m > 1.5$.

Power Requirement.

The power requirement was calculated using the following equations:

$P_T = P_{RD} + P_C$…… (i)

Where P_T = Total power required; P_{RD} = Power to rotate drum with hoes, P_C =Power to cut and shred Vegetation. But $P_{RD} = T_D \times \omega_D$; where T_D = Torque on drum. ω_D = angular velocity of drum ;

and $T_D = W_{tD} \times R_D$; where W_{tD} = Weight of drum and hoes.

Thus $P_{RD} = Wt_D \times R_D \times \omega_D$ …….. (ii)

P_C = Force to cut vegetation x R_D. (NB. Force to cut vegetation depends on the characteristics of the vegetation).

Belt and shaft selection.

The belt, pulley and Shaft selection was based on ASAE standard (1986).

2.2) Description and Operation of the Machine

The machine consists of the following parts; protective guard; swinging blades, drum, v – belt, pulleys, bearings, shaft and rigid frame (Figs. 1& 2). The cutting mechanism consists of the drum with swinging blades (flails), the drum was made by folding a 2.5mm mild steel metal sheet to form a cylinder of diameter 140mm. Two circular discs of the same metal sheet with holes drilled through their centres to accommodate diameter 25mm shaft were welded at both ends of the cylinder to form the drum. The drum was then welded on a shaft that passed through it strong enough to withstand torsional stress. Pairs of 30mm flat bar with holes drilled through to accommodate 10mm bolt were then welded on to the drum in 3 rows to provide pivot for hinging of

swinging blades. These rows of pivots were staggered to allow for overlap of cutting.

The cutting blades (flails) were made of 25mm flat bar in an L-shape with holes drilled at the top to accommodate 10mm bolt; for each pivot, two blades were bolted such that they can swing freely in a vertical plane if an obstruction is hit (figs. 1& 2). When the machine is pushed forward, the drum rotates opposite to the direction of travel cutting and shredding the vegetation. Plate 1 shows the picture of the machine.

3.0) Performance Evaluation

Between June, 25th -30th 2007, half hectare of the Departmental Demonstration Farm was mapped out into plots of 10 m x 10 m. Ten of these plots were selected by randomization process and mowed. The time taken to mow each plot was noted .The following formulae were used to calculate the theoretical, effective field capacity and field efficiency.

i) **Theoretical field capacity (TFC)** = effective width of the machine x forward speed.

ii) **Effective Field Capacity (EFC**) = Actual Area covered/ Total time Taken.

iii) **Field Efficiency** = $\frac{\text{TFC}}{\text{EFC}}$ X 100.

4.0) Results and Discussion.

Table 1 shows effective field capacity and field efficiency for each test plot while table 2 is the average of each of the two parameters. The average effective field capacity and field efficiency are 0.064 ha/hr and 25.41% respectively. Kaul and Egbo (1985) estimated local field efficiency for forage harvesters to be between 30-60 %. The lower efficiency obtained for this machine (flail mower) is because the test plots were covered with tall grasses which were predominantly of *Panicum Maximum* species (guinea grass).

This species is tough and thus clogged on to the drum often; also the surface of the test plots was undulated as it was ridged the previous year.
However, the performance of this machine can be improved upon by increasing the length of hoes, width of the drum as well as the corresponding increase in power unit.

Table 1.Effective field capacity and efficiency for each plot.

plot		**1**	**2**	**3**	**4**	**5**	
area	ha	0.01	0.01	0.01	0.01	0.01	0
time	hr	0.2333	0.2181	0.2089	0.1950	0.2128	0
Eff. Field Cap.	ha/hr	0.0429	0.0459	0.0478	0.0513	0.0459	
field. Eff.	%	23.83	25.50	26.56	28.50	25.50	

Table2. Average effective field capacity and field efficiency of the machine.

plot		1	2	3	4	5	
effective field capacity	ha/hr	0.0429	0.0459	0.0478	0.0513	0.0459	0.0
field efficiency.	%	23.83	25.50	26.56	28.50	25.50	25

5.0 Conclusion and recommendation

The following conclusions can be drawn from the performance evaluations as follows:

i) Effective land clearing was obtained when mowing broad leaf grasses than guinea grass species.

ii) For tall guinea grass (*Panicum maximum*), there was clogging of blades and thus non-uniformity in cutting.

iii) The undulated nature of the field surface affected the efficiency of the machine

The following recommendations are suggested for further work:

iv) Provision for adjustment of the machine's height to account for variation in height of grasses.

v) Provision for power variation to account for changes in grass density and toughness.

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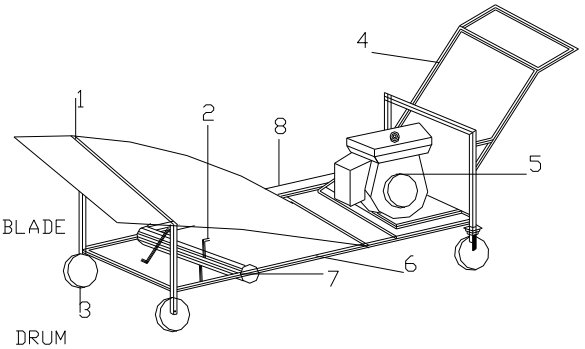
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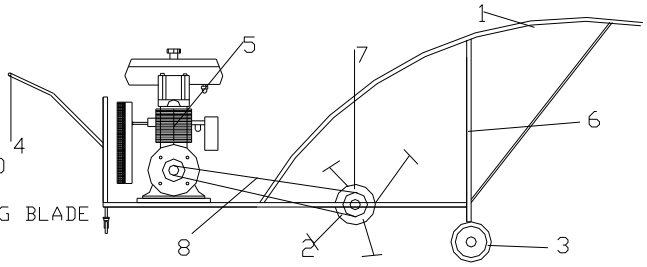


Plate 1. Picture of garden Flail Mower.



LEGEND
1. COVER
2. CUTTING BLADE
3. WHEEL
4. HANDLE
5. ENGINE
6. FRAME
7. ROTATING DRUM
8. V-BELT

FIG: 1 FLAIL MOWER (ISOMETRIC VIEW)



LEGEND
1. COVER
2. CUTTING BLADE
3. WHEEL
4. HANDLE
5. ENGINE
6. FRAME
7. ROTATING DRUM
8. V-BELT

FIG 2 FLAIL MOWER (LEFT SIDE VIEW)

PERFORMANCE EVALUATION OF GINGER SPLITTING MACHINE

By

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ABSTRACT

A ginger splitting machine was fabricated to study the effect of moisture content, cutting speed and crop varieties on splitting efficiency. Three levels of moisture content and five levels of impeller speed were used for evaluating the splitting efficiency of the machine on two ginger varieties commonly grown in Nigeria; the Tafin Giwa (yellow ginger) and Yatsun Biri (black ginger). Splitting efficiency of the machine on the two ginger varieties decreased with increase in impeller speed (cutting speed), and with decrease in moisture content Maximum splitting efficiency of the machine was found to be 82.1% on Tafin Giwa and 67.95% on Yatsun Biri, at the lowest impeller speed (240rpm) and at the highest moisture level (84.35% wet basis) respectively.

Keywords: splitting efficiency, ginger rhizomes, varieties

INTRODUCTION

Ginger (*Zingiber officinale Roscoe*) belongs to the plant family of Zingiberceae. It is an erect herbaceous plant, which produces underground tuberous stems or rhizomes characterized by its strong essence (Erinle, 1987). It is one of the oldest and most important of all the spices and condiments (Norman, 1994; Spore, 1994). It contains an essential oil, which is responsible for its aromatic odour, and Oleoresin, which is responsible for its purgent taste. Ginger as a herbal medicine is used in the treatment of a number of ailments when properly processed. It can be used in making some drugs in the Pharmaceutical industry. Medicinally, it is stomachic, digestive and carminative (Duta, 1981), and is also used in cleaning cholesterol in the blood, lowering of blood pressure, treatment of fevers and coughs, stomach ulcer, rheumatic conditions and prevention of nausea among others. Ginger is used extensively in cookery, confectionary and for seasoning and flavouring food and various fruits and vegetable (Akomas and Oti, 1988). Ginger is grown in large commercial quantity in Southern part of Kaduna state, Nigeria. Two major ginger varieties are grown, the Tafin Giwa (Yellow ginger) and Yatsun Biri (black ginger). The Tafin Giwa variety is mostly grown in the country for its spices. The ginger rhizomes undergoes some primary operations of sorting, washing splitting and drying before being packed for export .The splitting operation is the most tedious task in processing ginger in Nigeria. Ginger rhizomes are split manually using local knives. Dependence on human labour is time consuming and labour-intensive. In most cases and the operator's fingers get inflicted with injuries by the local knives.

Some ginger slicing machines have been designed and developed in Nigeria by researchers notably Iteke, *et al*. (1988) and Simonyan *et al.* (2003). These machines have not been able to split ginger rhizomes longitudinally as demanded by the farmers but slice ginger rhizomes laterally in form of shreds not acceptable to the farmers and traders. This difficulty has been mainly due to the fact that ginger has some unique characteristics; the shape is irregular and is highly fibrous. How ever it is the split ginger that commands premium prices in the international market.

To overcome the drudgery associated with the manual splitting method, a ginger splitting machine that splits ginger rhizomes longitudinally was developed with the aim of increasing the quality of splits and to provide more even splits for drying and subsequently to meet demands for

both domestic and international markets. Therefore, the objective of this study was to develop a suitable ginger splitting machine and to optimize its working parameters by studying the effects of impeller speed moistures contents and crop variety on splitting efficiency.

MATERIALS AND METHODS

This study was conducted at the processing laboratory of Agricultural Engineering Department, ABU Zaria.

Machine description and working principle

The splitting machine consisted of a hopper, splitting chamber a power drive unit and frame (Fig. 1).

Hopper

The hopper is made of guage 16 mild steel iron sheets. It is trapezoidal in shape and feeds ginger rhizomes into the splitting chamber by gravity at an angle greater than the angle of repose of ginger rhizomes.

Splitting chamber

The splitting chamber consists of a stationary blade 30cm long positioned horizontally with an upward pointing knife-edge. Fixed at its end to the circumference of the splitting chamber its centre coincides with that of the circle of the splitting chamber and the impeller shaft, which passes through a hole drilled through the centre of the blade. The impellers, which are 15cm in length, are equi-spaced across the centre of the blades's lateral cross-section and along the longitudinal axis of the shaft. This permits them to swirl across the blade without being obstructed by the blade, their lengths also within limits to avoid obstruction from the walls of the splitting chamber, which encloses the splitting assembly. Products pass out through the outlet sport at the base of the splitting chamber.

Power drive unit

Power is supplied to the impeller shaft by a petrol engine type prime mover by means of a belt and pulley drive.

Frame

The frame made of a 30x30x3mm angle iron. The frame provides support for the entire assembly. The frame has a maximum length of 1150mm, width of 42.5mm and height of 495mm.

Experimental Procedure

Five impeller speeds, 240,284,326, 345 and 388 rpm were used for the testing of the splitting performance of the machine. Ginger rhizomes of 800g were fed into the splitting chamber through the hopper. The average moisture contents of ginger rhizomes used were 84.4,77.6 and 68.2% (wb), equivalent to freshly harvested, one week after harvest and two weeks after harvest respectively. The most commonly grown ginger varieties in Nigeria, Tafin Giwa (yellow ginger) and Yatsun Biri (black ginger) were used for the experiment. The moisture content of ginger rhizomes was determined by the oven dry method (ASAE, 1994).
A LUTRON Digital photo/Contact Tachometer was used for measuring impeller shaft speed.

Experimental design and analysis

The machine performance was analysed at five impeller speeds, three moisture contents levels and using two varieties by using a completely randomized design (CRD) of 5x3x2 factorial experiments with three repetitions in each treatment.
Data for the performance evaluation were subjected to the analysis of variance (ANOVA) for the test of significance of experimental factors and their interactions. Mean separation with observed significant differences was compared using the Duncan's Multiple Range Tests (DMRT). The analysis of variance for each factor was determined using the Genstat statistical software package.

Performance evaluation

The performance of the machine was evaluated based on the following parameters:
Splitting efficiency (SE) = $(Q_{CSU}/Q_{O)\ x\ 100}$……. (1)
Where,

Q_{CSU} = quantity of ginner longitudinally and completely split unbruised (kg),

Q_O = Total quantity of ginger fed into the machine (kg).

RESULTS AND DISCUSSION

Effect of speed on splitting efficiency of Tafin Giwa ginger is shown in Fig.2. It shows that the splitting efficiency of Tafin Giwa ginger decreased with an increase in impeller speed. It was also observed that splitting efficiency of the machine decreases with a decrease in moisture content. The highest splitting efficiency of Tafin Giwa was obtained at 84.35% moisture content (MC1). This was followed by the splitting

efficiency at 77.6% moisture content (MC2). The lowest splitting efficiency of the machine on Tafin Giwa was at 68.2% moisture content (MC3) Table 1 indicates that at the lowest speed of 240rpm maximum splitting efficiency of 82.1% was obtained for Tafin Giwa at a moisture content of 84.35%. The splitting efficiency decreased to 66.69% at higher impeller speed of 388rpm at the same moisture content. At 77.6% and 68.2% moisture contents the splitting efficiencies of Tafin Giwa ginger also decreased with increase in impeller speed from 72.2% and 66.69% at 240rpm to 66.18% and 57.67% at 388rpm respectively.

The effect of splitting efficiency of Yatsun Biri ginger variety at the different impeller speeds and moisture contents is shown in Fig 3. The splitting efficiency decreased with an increase in impeller speed at all moisture contents levels. At all speed settings the splitting efficiency of Yatsun Biri ginger decreased with decrease in moisture content.

Table 1 shows that at 84.35% moisture content, the splitting efficiency of Yatsun Biri ginger decreased from 67.95% at 240rpm to 64.1% at 388rpm. The splitting efficiency at 77.6% moisture content decreased from 49.97% at 240rpm to 45.79% at 388rpm. A similar trend was also observed at 68.2% moisture content with splitting efficiency decreasing rapidly from 75.90% at 240rpm to 43.94% at 388rpm. This is similar to the studies by Simonyan *et al* (2003) that moisture content has significant effect on slicing efficiency of ginger. They reported that slicing efficiency decreases with decrease in moisture content. Balasubaramanian *et al*. (1993) also reported that slicing efficiency decreases with increase in cutting speed. High moisture content is likely to give better softening of the fibres making it easier for the knife to destroy fibrils and split the ginger rhizomes. Further more, at higher moisture contents, the fibres are likely to be more loosely packed, permitting better knife penetrability and enhancing splitting efficiency. However, at lower moisture contents, shrinkage of the rhizome occurs and the fibres be come difficult for the blade to cut. Kanafojski and Karworski (1976) observed that the drier the plant material, the more lignified is its fibres, causing higher resistance to cutting. The decrease in splitting efficiency with increase in impeller speed for the two ginger varieties could be due to lack of synchronization in the flow of ginger rhizomes into the splitting chamber due to higher rotation of the impeller which tends to obstruct the flow of ginger rhizomes into the splitting chamber.

The difference in the behaviour of Yatsun Biri ginger variety to that of Tafin Giwa ginger variety suggests that crop variety has an important effect on slitting efficiency of ginger rhizome. Erinle (1988) reported the Tafin Giwa ginger as an improved variety with a larger size compared to the local Yatsun Biri variety, which has a smaller physical structure. Size property plays vital role in the effective constraining of the ginger rhizomes in the splitting chamber against the stationary blade, ready for impact by the impeller. Furthermore, rhizomes that are incorrectly positioned and impacted are incorrectly split. The Yatsun Biri ginger variety being smaller in size than the Tafin Giwa variety, is disadvantaged in regard particularly wit respect to the splitting chamber. The size of the splitting chamber influences the performance of the equipment with respect to splitting of the ginger rhizome

Conclusion

The following conclusion can be drawn from the study:

- The splitting efficiency of both Tafin Giwa and Yatsun Biri ginger varieties decrease with increase in impeller speed at all moisture contents.
- The highest splitting efficiencies of 82.1% and 67.95% for Tafin Giwa and Yatsun Biri ginger varieties were obtained at lowest operational speed of the impeller (240rpm) and at the highest moisture content level (84.35%). The best condition to obtain maximum splitting efficiency of Tafin Giwa and Yatsun Biri ginger varieties is at 84.35% and 240rpm for the moisture contents and speed ranges studied.
- At the same impeller speed, the splitting efficiency of Tafin Giwa ginger variety was higher than that of Yatsun Biri ginger variety

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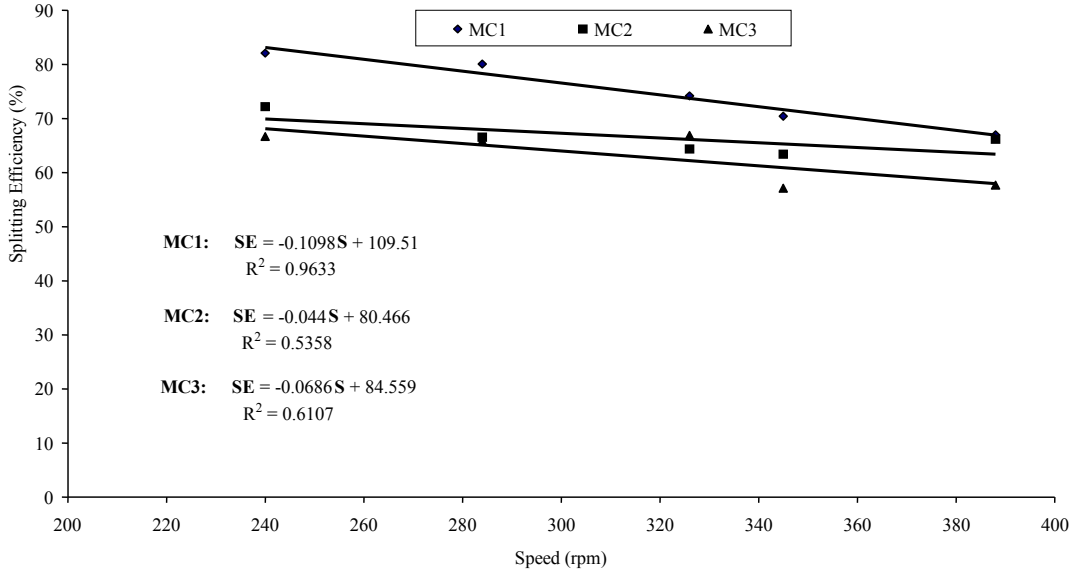


Figure 2: Effect of speed and moisture content on splitting efficiency for the Tafin Giwa ginger variety

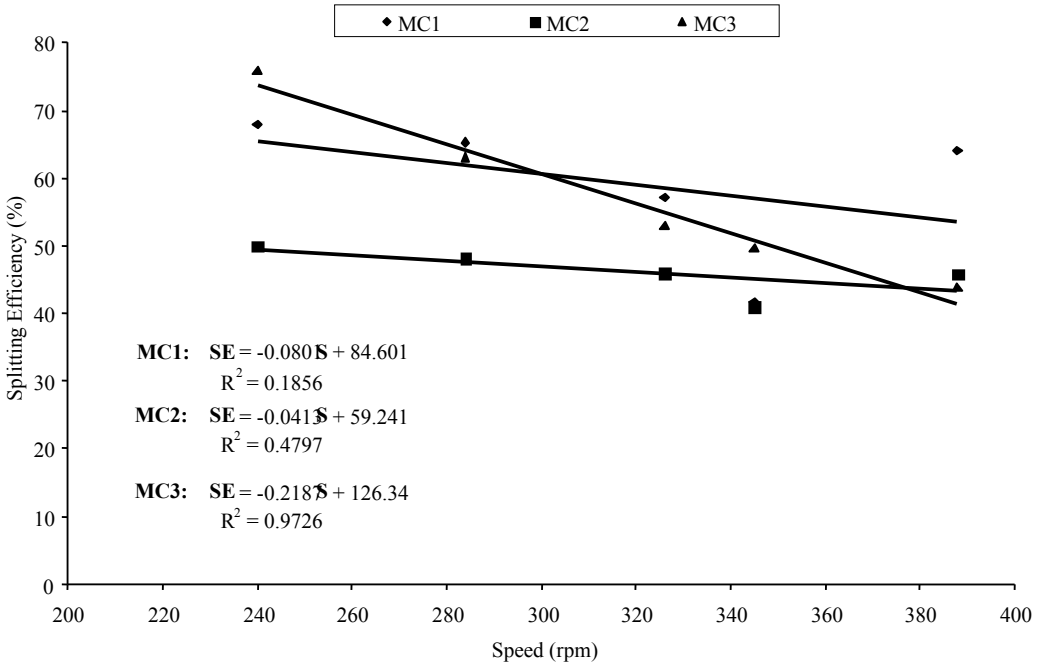


Figure 3: Effect of speed and moisture content on splitting efficiency for the Yasun Biri ginger variety

Table 1: Interaction of moisture content, speed and crop variety on splitting efficiency

	Moisture content (% wet basis)											
	84.35					77.6						
	Impeller speed (RPM)					Impeller speed (RPM)					Imp	
Crop variety	240	284	326	345	388	240	284	326	345	388	240	284
Tafin Giwa (Ci)	82.09 a	80.09 a	74.18 abc	70.42 abc	66.99 bcd	72.20 abc	66.54 bcd	64.36 cde	63.42 bcde	66.18 bcd	66.69 bcd	65.8 bcd
Yatsun Biri (C2)	67.95 bcd	65.28 bcd	57.10 def	41.73 g	64.08 bcde	49.97 fg	48.16 fg	45.97 fg	40.94 g	45.79 fg	75.90 ab	63.1 cde

Means followed by the same letter are not significantly different

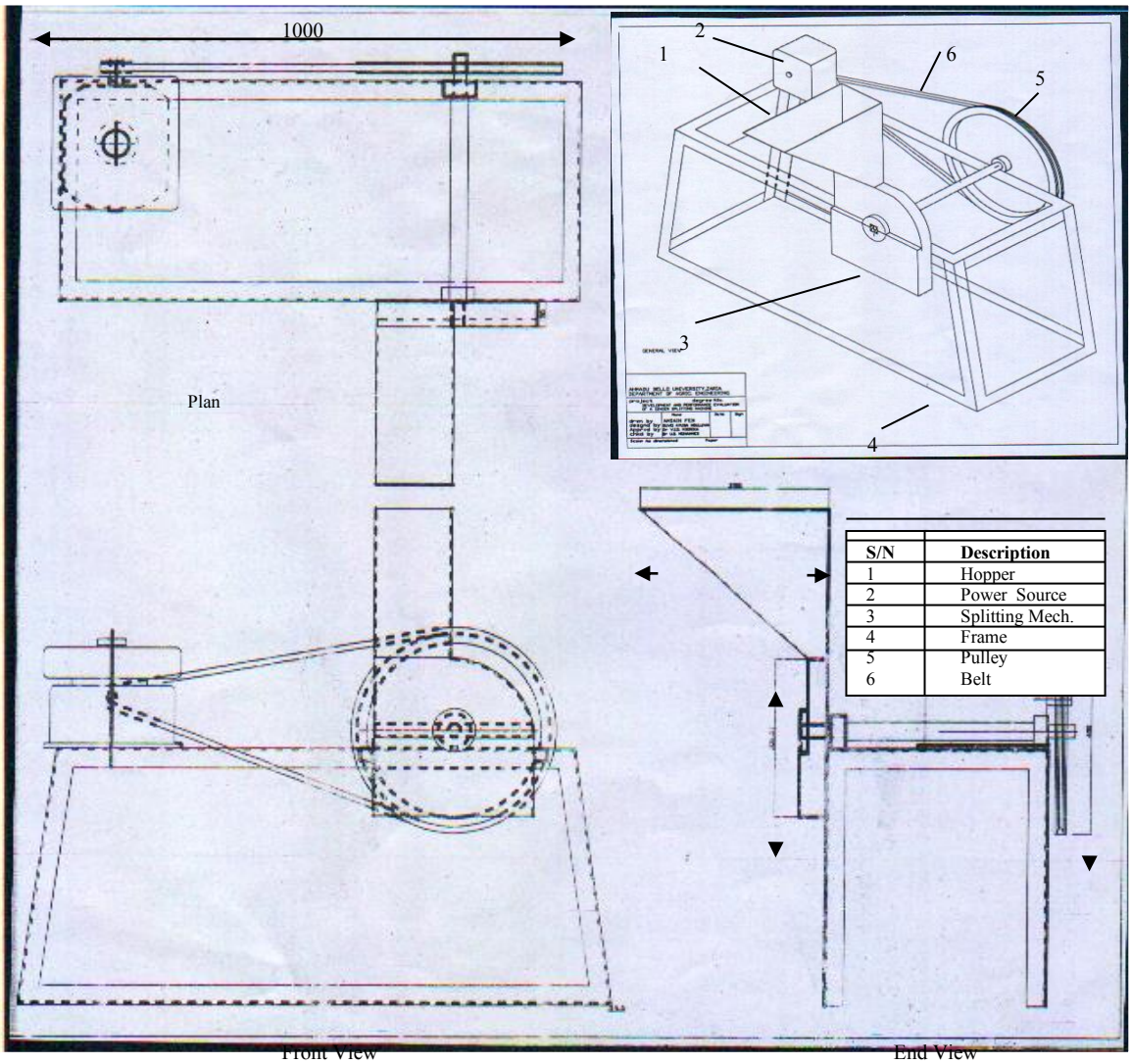


Fig.1 Orthographic Views of Ginger Splitting Machine

SECTION 2

SOIL AND WATER ENGINEERING

DRAINAGE PROBLEMS OF NSUKKA URBAN

By

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ABSTRACT

The provision of adequate infrastructural facilities is very crucial in urban development. This paper examines the drainage conditions of Nsukka urban (Long.$7^0 22^{in}$E and Lat. $5^0 50^{in}$N) and the adequacy of the drainage facilities. Certain fundamental problems were identified, such as absence of a central drainage master plan, uncontrolled inversion of public green areas by the poor, illegal developments near the town boundaries, and lack of maintenance culture, as well as the topography and climate of the area in which the town is located. Some of the effects of poor drainage condition in Nsukka urban, as observed in the study, were flooding and erosion of residential, business and agricultural areas, including roads. It was observed that high rates of runoff, which eventually culminate into flooding, result from heavy rainfall on steep land slopes, which characterize Nsukka urban and its surrounding areas.

It is concluded that the requirements for an effective urban drainage system in Nsukka urban include a master plans for drainage, which should be prepared on a priority basis, provision of quality infrastructure, from design through to construction and maintenance. Also, the adoption of SUDS, which is a preferred alternative to convectional drainage systems, has been suggested as a sustainable strategy to solving drainage problems of Nsukka Urban.

Keywords: Drainage, urban areas, Nsukka.

1. Introduction

Drainage is a word of many meanings. For example, urban drainage may be defined as the disposal of excess storm water from cities through inlets to buried conduits or gutters to the point of disposal. (Agunwamba, 2001). Drainage is frequently associated with runoff from rainfall events. The storm water that reaches the ground surface does not constitute runoff until the micro depressions of the earth's surface are filled and the soil matrix becomes saturated. The runoff moves by gravity down the slope to accumulate water that must be removed through a suitable outlet by the process of drainage, if such area is not to be waterlogged.

Similarly, a high ground water table constitutes a drainage problem since it results in a saturated root zone thereby impending aeration (Schwab et al, 1993). However, both urban and agricultural drainage is aimed at removal of excess runoff from an area or lowering the ground water below the root zone to improve plant growth. The runoff is usually discharged into a ditch.

The aim of this paper therefore is to present an overview on the state- of – the- art of drainage problems of Nsukka urban, causes and possible sustainable solutions.

2. Need for Urban Drainage

Urban areas are considered as long densely populated areas with a characteristic infrastructure. In some urban areas such as Nsukka, the population density may be as low as 30 inhabitants per m^3, while in other areas, as many as 300 or more people live on one hectare. Usually, the population density in an urban area is not uniform, but may greatly vary. However, besides public and office buildings, commercial and industrial zones, urban areas may include playground and parks.

Drainage serves for the removal of excess water from an area by surface or sub-surface means as stated above. Excess water in urban areas may be domestic and industrial wastewater or storm runoff. The need for urban drainage systems seems so obvious considering the number of people living in urban areas and the effects of storm water flooding or wastewaters on human health. Good disposal of storm water flooding or wastewaters contribute to human well-being and to the proper functioning of urban communities. In some less developed towns, the method of excreta disposal on surface of the ground in surrounding bushes, the bucket

latrine and the pit latrine pose serious health problems. Only a very small percentage of people use flush toilets connected to septic tank or a server system (Geiger et al, 1987). Health hazards emanating from deposing excreta on the surface of the ground in bushes and open fields around houses and roads are grave, since it leads to the spread of diseases like typhoid fever, cholera, amoebic dysenteries, etc. The old popular saying that "there are no votes in sewage" is still very appropriate in some developing towns with the result that up to 90 percent of the diseases and accident cases which doctors treat in hospitals and clinics are caused by poor, inadequate or non-existing sanitary conditions and drainage systems. (Oluwande, 1979).

In urban areas, numerous cases of flooding caused by urbanization and resulting in loss of lives and immense damages has been reported in almost all the towns by researchers (Oludara, 2001). Such problems emphasize the need for appropriate urban drainage, which would provide for disposal of waste water and storm runoff without increasing runoff peaks to a critical level at which down-stream flooding would occur and without creating local flooding and health hazard within urban areas. As a current example of drainage problem aggravated by flooding, drainage problems in Nsukka are presented herein.

2.1 An Overview of Drainage Problems of Nsukka Urban.

The study area, Nsukka, is located on longitude $7^{0}22^{in}$ E and latitude $5^{0}50^{in}$N in the South Eastern part of Nigeria. The characteristic topography of the area is fold hilly with steep slopes in many places. The rainfall pattern is heavy convective type. During rainy season, heavy rainfall results in high amount of runoff, which quickly generates and flows down the hills via the steep slopes with high velocity. This often results in erosion of roads leading to farmlands (especially the untared or already dilapidated ones) and eventual flooding of farmlands, roads, residential and business areas located down the slopes.

Drainage problems are aggravated by factors such as:

i. Absence of central drainage plan,
ii. Refuse dumping to block culverts or river channels,
iii. Absence of central drainage system or lack of culverts (gutters),
iv. Absence of drainage facilities in most places around the town, which results in a very poor drainage of the urban areas worsen the situation.

The following have been identified as the causes of the drainage factors listed above:

i. High ground water table.
ii. Little or no town planning services.
iii. Inadequate maintenance culture.
iv. Poor installations/ construction of facilities.
v. Topography and climate.

The combined effects of the characteristic topography of Nsukka urban areas (as described earlier) and the poor drainage conditions as shall be highlighted later in this work include:

i. Flooding
ii Erosion
iii Destruction of roads, properties etc
iv Water logging
v Surface drainage often leads to pollution and health hazards.

2.1.1. University of Nigeria, Nsukka Campus

The University of Nigeria Nsukka Campus gate is situated at location 1 on fig 2. in appendix 2. The area is on a contour of 1450 feet above mean sea level. Inside the campus, some places are at a very high contour like Odenigwe, Margaret Cartwright Avenue that is situated at location 3 on fig. 2 appendix 2 with a contour of 1600 feet above mean sea level. The characteristic topography of this area of study is hilly and steep slopes in some places. It was observed that because of the surrounding hills the water dept in some places during rainfall might be as much as 20-40cm, which creates serious infrastructural problems for the university environments. An example is at the University of Nigeria main gate where flooding usually causes great damages. The entire section of the roads leading to the gate is poorly drained with no sufficient cambering of pavement surfaces. Other locations where flooding usually occur within the campus area are: Departments of Agricultural and Electrical Engineering, Faculty of Agriculture Science, Entrance into the University of Nigeria Secondary School, etc. All these problems are attributed to lack of a proper drainage plan and system, anthropogenic factor (that is, human activities); creating foot paths haphazardly which result in removal of surface vegetation which exposes soil surface giving room to over flooding. It also creates gullies, which sometimes could affect main roads.

2.1.2Catering Rest House Road

Catering Rest house is situated at location 2 in Fig 2 appendix 2. The area is on a contour of 1300 feet above sea level, down a gentle slope, which ends up in a valley. The culvert is the point of intersection of the sloping road from the University of Nigeria, Nsukka main gate and the one from the University of Nigeria, Nsukka second gate, located opposite Tobechukwu Motors/ Zik's flat. By both sides of the road are open drainage channel, which empty at the culvert. The culvert is a continuation of a river channel where the runoff and excess water from most of the surrounding areas and roads empty into after rainfall.

However, insight observation after rain events as shown in Fig.1. plates 1a and 1b, in appendix 1, reveals that the area under rain study is still suffering serious drainage problems, which are detrimental to residential houses, roads, agricultural lands and other properties around the place. Also the road construction was not properly done to suit the drainage facilities provided for the runoff. The drainage channels provided are not deep enough and this causes over flow of runoff considering the topography of the area, which is characteristically hilly.

In some portions of the road, flooding is also being experienced as a result of blockage of the drainage facilities with debris. The culvert size in this case study is inadequate and wrongly situated as presented previously on fig.1 plates 1a and 1b, in appendix 1 respectively.

2.1.3 The University Road

The University road is situated at location 7 in Fig 2 appendix 2. The area is on a contour of 1450 feet above sea level, down a gentle slope, which ends up under a big culvert behind the University of Nigeria, Nsukka Campus gate. The culvert is a continuation of the drainage channels from the University where the runoff and excess water around the campus and Nsukka main borehole areas empty into during or after rainfall.

An observation of the study area shows that after rainfall, the area still suffer serious drainage problems. As shown in Fig.1 plates 2 and 3, in appendix 1. It was observed that excessive rainfall and erected of buildings on roads and culverts sites together with inadequate urban planning were the major causes of flooding at the University road. At this study area, existing drains at both sides of the road are being blocked with refuse. For example, the side of the road just opposite the junction leading to Ogige Community Bank Ltd. has been turned into a refuse dump. When there is heavy rainfall, the runoff washes away the materials dumped on the main road to block the drains with sand or other hard objects like motor tires, logs of wood and even bundles of book from the nearby book binders. The bookbinders and printing press located by the side of the road make use of the open drains as refuse dumps thereby causing a lot of problems on drainage. This situation can cause road accidents especially at night during rainfall, since the roads will be covered with storm water.

2.1.4 Enugu/Aku Roads

Enugu road situated at location 9 on fig.2 in appendix 2 on a contour of 1450 feet above sea level. Starts from Total filling station round-about where the road comings from UNN main Gate and the one going to Odenigbo all converge. It is undulating and stretches uphill, then goes straight on a fairly level ground. Just before the last hilly part, by the side of Bishop Shanahan Hospital and before Ifesinachi Luxurious Bus Park, Aku road branches by the right (i.e. on the way to peace motor park).

Aku road situated at location 8 on Fig. 2 in appendix 2. The area is on a contour of 1500 feet above sea level. It occurs at the base of the last hilly part of Enugu road, which appears to form a sort of valley with the joining part of Enugu road from the round about. These roads as could be seen from Fig.1 plates 4a and 4b,in appendix 1 have fundamental drainage problems; such as lack of side drains and of course there is no evidence of any existing central drainage system where all the runoff and flood waters could drain to after heavy rainfall event. Therefore, as revealed in fig.1 plates 4a and 4b,in appendix 1, runoff, floodwaters and any form of excess water find their natural course under the influence of gravity. The waters cut through the soil along and across roads forming gullies and frequently rendering Aku road flooded and unmotorable with a lot of debris deposited on the road after heavy rainfall events.

Also from business and residential areas along the roads, a lot of waste materials are usually deposited carelessly either on the road or natural water channels. This cause blockages and eventually flooding of motorable roads and business areas, hindering

or slowing down economic and social activities.

2.1.5 University Market Road

The University market road is situated at location 6 on fig. 2 in appendix 2. This study area is on a contour of 1500 feet above sea level. It is of a characteristic hilly topography with steep and long gradients. It branches off to the left, just a few meters after University of Nigeria Nsukka main gate and then links to Ogige Market Road. The drainage problem at the University market road is attributed to lack of proper maintenance and blockage of existing drainage channels with refuse dumps located at the uppermost part of the hill. It was observed that both domestic, market and farm waste such as empty cans, turn plastic buckets; polythene bags and other waste do not fully permit smooth flow of water entering the drainage channels. The presence of such materials at the drainage channels enhances the formation of a new base level, thereby encouraging vegetative growth by the sides of road as shown in fig.1 plates 5a and 5b, in appendix 1. This flooding along the road causes the interruption of socio-economic activities and also makes human and vehicular movement difficult after rainfall. Another major problem of drainage at these study areas is the presence of steep slope in the area with inadequate urban planning taking into consideration the topography and climatic factors of the place.

2.1.6 Onuiyi Road

Onuiyi road location 4 on fig. 2 in appendix 2.runs along the back fence of Zik's Flat. It is on a contour of 1300 feet above sea level, undulating end of gentle slope. At this study area, after-rain events including heavy runoff and flooding cause serious damages on roads and residential houses and waste disposal methods of people living in the environment, which often block and impair the constructed and natural drainage facilities plate 6, in appendix 1. Also, the huge refuse dump makes it very difficult for cars and pedestrians to pass through the place after rainfall.

2.1.7 Ibeziakor Street

This area of study is situated at location 5 on fig. 2 in appendix 2. It is on a contour of 1300 feet above sea level, down a gentle slope, which ends up inside a gully down the street. From investigations carried out in the course of this study, it was discovered at a time that part of the untared portion of this street at Onuiyi was being eroded by the edges. At this time the site was looking very ugly and stability of the road was being threatened. So the residents of the street organized themselves to build drainage facilities (gutters and culverts) as shown in fig. 1 plate 7, in appendix 1, in order to save the road from being destroyed by erosion. This proved effective to a reasonable degree at the first end of the road.

Meanwhile, it was observed that the cause of this erosion encroachment into the road was as a result of absence of side drains. As a result, the water that was supposed to drain off though the gutters now flows through to the road, hence causing saturation of underlining materials.Fig.1 Plates 8a and 8b in appendix 1 reveals that the big gully created by runoff at the study area has been turned into a refuse dump with domestic wastes and palm fronds in a bid to stop erosion. This method is very ineffective in controlling erosion. Its ineffectiveness arises from the fact that the palm fronds and domestic waste decay over time. An observation after-rain event as shown in plate 8c, in appendix 1, reveals that the area under study suffers serious drainage problems, which are detrimental to residential buildings with agricultural land being seriously eroded. As a result of this, some houses have been abandoned or rendered inhabitable because of flood. Frequent flooding at this study area has led to blockage of roads with deposit of debris and spread of water borne diseases from environmental pollution, which is very dangerous to health.

3. Strategies for Solving Drainage Problems in Nsukka Urban at Once.

To improve on surface drainage problems, first, identify, and then correct the contributing factors. One of the major difficulties in Nsukka Urban development is how to enforce legislation on the inhabitants as a result of absence of drainage master plan. To control the urbanization impact of flow, it is necessary to create new regulations for urban development, for instance a limit of peak flow in Nsukka urban (June – July) every year results to a new developments. But since invasion of public undeveloped areas by non-indigenes, building of illegal structures often occurs, the developments in the town boundaries are made without formal approval by the state town planning authorities. These difficulties are some of the excuses by the town planning authorities for not passing the regulation and the drainage master plan.

This paper however, suggests some strategies, which can be adopted to develop the drainage volume control in Nsukka urban by

the state and local government authorities. They are:

3.1 Provisions and Improvement of Drainage Facilities.

The storm water drainage improvement shall involve the provision of upgrading of primary drainage systems within the town so that major flooding experienced in various identified locations could be avoided. Also, wastes being dumped into the drains cause blockages. Good refuse dumps should be provided at strategic places in the town to avoid dumping of wastes inside the drainage channels. All local and regional planning must take into consideration the initial drainage system necessary to manage the runoff that is expected to occur once every 2 to 5 years. The initial drainage system plans will reduce loss of life and major damage to the community and its infrastructure.

However, since open space provides significant urban social benefits, the use of stabilized, natural drainage ways often is less costly than constructing artificial channel. Combining the open space needs of a community with major drainage ways is a desirable combination that reduces land costs and promotes riparian zone protection and establishment over time (Herbertson et al. 1992).

3.2 Regular Maintenance

Routine maintenance is needed to effect the removal of deposited materials in drainage channels. When this is done, it is going to be of good help especially at the university market road where the existing drainage has been blocked with refuse coupled with potholes, which make the road unmotorable. Therefore, Sub-catchments of the urban areas have to be planned for the future development by evaluating its natural capacity and the limits of the developments in order to cope with flood conditions. This can be done through limits in the peak flow increase and also by implementing public facilities with urban detention gutters/ponds. The uncontrolled flow of the towns can be damped by these ponds. The area has to be occupied with public facilities before they are invaded or developed.

However, there is need for education and legislation against indiscriminate dumping of waste/refuse and the erection of buildings on the drainage areas to encourage people to desist from such practices. Farmers should be instructed not to cultivate pieces of land that are situated very close to existing gully edges to avoid overflow of runoff. This is because the cultivation of such areas that is close to gullies, favour the advancement of gullies.

3.3 Proper Design and Construction of Drainages

Urban areas should be properly planned and equipped with effective drainage systems. Since the hydrological and topographical characteristic of Nsukka is of fold hilly type, road drainage channels should be planned carefully and installed to avoid side incisions. For the already existing gullies, like the one at Ibeziakor Street, further development can be checked by the construction of embankments and proper drainage channels. This will serve to reduce the velocity of runoff and their erosive capability. Also, construction of wider gutters or culverts for proper channelization of floods from town centers is very important.

Design and construction of new streets and major roads should be fully integrated with drainage needs of the urban area for better streets and major roads and better drainages to avoid creation of flooding hazards. The location of burrow pits needed for road construction should be integrated with broad planning objectives, including storm runoff detention.

3.4 Participation of Relevant Government Agencies and the Private Sector

Various government agencies such as the town planning authorities and Enugu State Environmental Protection Agencies (ENSEPA) should initiate flood plain management programs. This includes a comprehensive criteria designed to encourage, where necessary, the adoption of permanent state or local measures which will lessen exposure of property and facilities to flood losses, improve long-range land management and use of flood-prone areas, and inhibit, to the maximum extent feasible, unplanned future development in such areas. Flood insurance should be an integral part of a strategy to manage flood losses. The towns around Nsukka urban are encouraged to continue to participate in the state and federal flood insurance program if they exist.

The Enugu State Environmental Protection Agency (ENSEPA) should also address the problem of dumping of refuse inside open drainage systems. Public enlightenment of effects of flooding, if the drainage facilities are blocked, is very essential. Also, the NGOs have a great part to play by educating the public on the importance

of drains and on the health hazards of drainage problems.

3.5 Application of sustainable urban drainage systems (SUDS)

Sustainable Urban Drainage Systems (SUDS) is an alternative approach to conventional drainage and deals with runoff where it occurs. Johsnston Smith Consulting Limited, website assessed on (11/09/07). The local approach to drain developed areas is having a damaging impact on our environment and is not sustainable. SUDS offer a wide range of strategies which can be adopted. Suds does this by introducing into a surface water system the following:

- Porous pavements to roads and car parks.
- Infiltration trenches to road, car parks and drainage
- Swales to slow surface water flows
- Infiltration basins as storage tanks
- Permeable conveyance systems or French drains
- Passive treatment systems such as filter strips, detention basins, retention pods and wet lands.

According to John Smite Consultant, SUDS is considered a better alternative method of draining surface water in a more sustainable manner more than the conventional drainage systems because

- It save money
- It reduces pollution
- It improves the environment and urban amenities
- It reduces the risk of flooding.

While in the conventional drainage systems, roofs and paved areas do not allow rainwater to soak into the ground as effectively as green- field sites. The use of pipes and concrete channels in this type of system increases the volume of runoff coupled with faster flow rates that leads to increase in flooding downstream. This can result in damage of property, erosion, and the need for engineering work downstream to cope with the changed flow regime.

Water quality is also affected by the increase in water quality. This is so because as the roofs and paved areas are washed away intermittently by heavy rain, the pollutants loading varies during a storm, with contaminants being concentrated in some portion of the runoff. This has an impact on receiving watercourse leading to a reduction in water quality. Even when the drains are connected to a combined sewerage system, the increase inflow may become great for the sewer to cope with and the water over reflows. This may results in flooding of an area or a discharge to a water course. As the sewer carries both runoff and foul water when it overflows, the floodwater contains faecal material and other gross pollutants hazardous to health. Although, building of a separate surface and foul sewers are one attempt to reduce this problem in a conventional drainage system, but the washing off of contaminants from impermeable areas and continued flooding, problems still occur.

A more sustainable approached to this problem could therefore be the adoption of SUDS. This is because SUDS offer the following advantages:

- It reflects the natural drainage of the site and gives sustainable management of the water environment
- It offers considerable visible safety advantage for children and adults.
- It offers cost effective and economic infrastructure and drainage systems.
- It is very easily and economically maintained.
- It creates natural wildlife habitant areas, which can be readily used for education purposes.

Conclusion

Poor drainage has been identified as a crucial problem Nsukka Urban, negatively affecting roads, houses, land, water, and human health. This problem has been seen as a direct effect of topography, climate and absence of central drainage plan and system. Nsukka is characterized by fold hills of mostly steep gradients. During heavy rainfall events, flooding usually results from quick concentration of runoff via the steep gradients. It was observed that absence of side drains on most of the roads around the town accelerates erosion encroachment into the roads. It is suggested that central drainage plan and system be designed, developed, and maintained in order to effectively combat the drainage problems of Nsukka Urban.

However, Sustainable Urban Drainage Systems (SUDS) has also been identified as a major tool for solving drainage problems, which can be applied in Nsukka urban areas. These approaches to surface water drainage can now be promoted by the Enugu State Environmental Protection Agency (ENSEPA)

in Nsukka, and is hopeful to become their preferred option in the future.

Finally, a widespread adoption of these strategies sated above in Nsukka urban areas, will see a long term improvement in the quality of our urban roads, contributing to a more varied and attractive urban environment built on a sustainable basis.

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APPENDIX 1





Plate 1B



Plate 2



Plate 3

Fig. 1: Pictures showing sites affected by drainage problems in Nsukka urban.



Fig. 1: Pictures showing sites affected by drainage problems in Nsukka urban continued.





PLAT





PLATE 8B

Fig. 1: Pictures showing sites affected by drainage problems in Nsukka urban continued.

APPENDIX 2

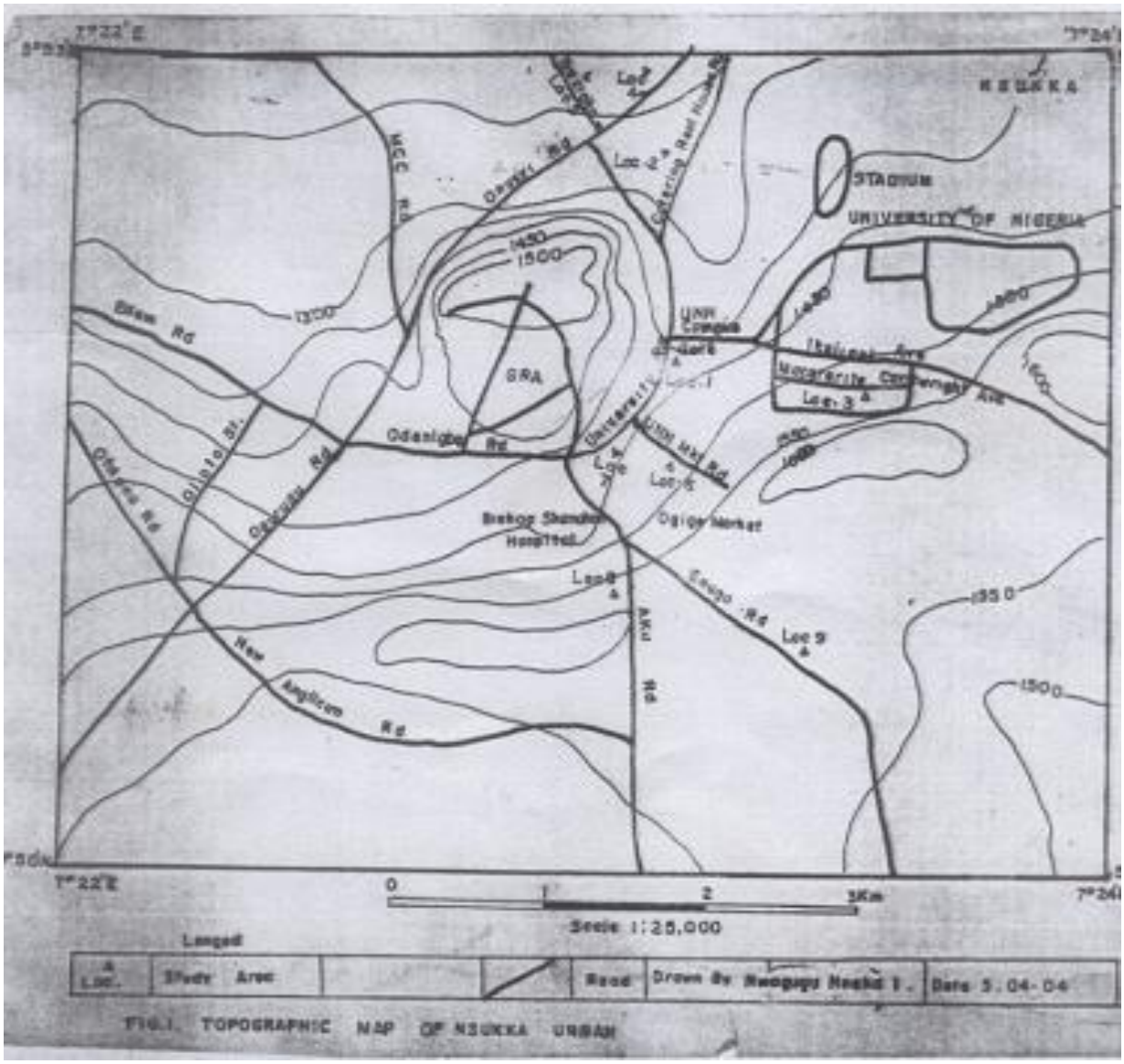


Fig. 2: Topographic Map of Nsukka Urban.

PERFORMANCE EVALUATION OF A DRIP IRRIGATION SYSTEM

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ABSTRACT

Performance evaluation of a developed drip irrigation system (DIS) was carried out on the research farm (lysimeter field) at the National Centre for Agricultural Mechanization (NCAM); Ilorin, Nigeria. The system was made up of a main line, sub main laterals and dripper lines using PVC pressure pipes with diameter sizes 34 mm, 27 mm, 20 mm, and 13 mm respectively. The drippers were made of micro-tubes that deliver water from the lateral. Water from the overhead tank was supplied to the field by gravity, hence the system required no energy source for pumping water to achieve the desired pressure.

The system operated and delivered water to the field crops within the desired constraints. The sub main line that supplied water to the laterals from the main line took about four minutes to pressurise. There were slight fluctuations in flow rate for short time duration as valves turned off and on within fifteen minutes duration. The system, which was designed and installed using local materials, was evaluated using irrigation efficiency as a parameter to assess the performance of irrigation water used from a water conservation perspective.

The measures of performance were based on the output's amount, timing and uniformity of water delivered to the field. The efficiency measures of performance used, related the desired output to certain input in the form of ratios. The irrigation conveyance efficiency, farm irrigation efficiency and field irrigation or application efficiency determined for the system were 87 %, 95 % and 97 % respectively. The overall performance of the system was 84 %.

Keywords: coefficient, conveyance, drip, efficiency, emitter, irrigation,

1. INTRODUCTION

Drip irrigation technology was originally developed for agriculture as a technique to improve the efficiency of water delivered to plants, especially in environments where water supplies are limited. This technique involves delivery only those amounts of water that plant actually use into the root zone and relies on horizontal as well as vertical movement through the soil to disperse the water.

Nigeria has relatively short history and experience of formal irrigation. Modern irrigation development in Nigeria dates back to 1973. Many of the irrigation schemes since then have not been successfully operated mainly due to very high imported inputs and technology. For irrigation scheme to succeed, however, it is essential that the components of the scheme be suitably conceived, phased, designed, constructed, operated, maintained and managed. Irrigation developments have been costly and past experiences show that investments have not paid off as expected (World Bank, 1995). Musa, (2001) outlined Nigeria's estimated physical potential for irrigation in the order of 3 - 14 million ha which is about 10 times more than the land currently under formal irrigation (100,300 ha).

Irrigated agriculture in the world today is of low efficiency and the largest consumer of water (Pimental et al., 1996). The wide spread perception that irrigation projects typically perform far below their potential has led to many operational intervention and research activities designed to diagnose problems and remedy deficiencies. Engineers and scientists often focus on irrigation efficiencies to improve the performance of irrigation systems.

An evaluation of the performance of an irrigation system would help to compare the observed value of the performance indicator with some standard that has been established for the indicator. Indicator of irrigation efficiency is a measure of performance, which relates the output of irrigation water at some place in the system to the input of irrigation water at some other place. Thus, irrigation efficiency is a parameter to assess the performance of irrigation water use from a water conservation perspective. It is considered to be a technical measure of efficiency since it is a ratio of water output to water inputs. Small and Svendsen (1990) developed a conceptual framework designed to establish the relation of irrigation performance assessment.

Efficiency becomes a meaningful concept only when it compares useful or desirable outputs to inputs; all efficiency measures must incorporate explicit or implicit value judgements associated with the identification or definition of "useful output". Bos and Nugteren (1990) defined three irrigation efficiency measures: application efficiency, tertiary unit efficiency and overall or project efficiency. These measures incorporate a common measure of useful output; the "volume of irrigation water needed, and made available for evapotranspiration by the crops to avoid undesirable water stress in the plants through the growing cycle".

As a result of water shortage and rapidly - increasing water use at the National Centre for Agricultural Mechanization (NCAM), the exploration of bore hole water for agricultural production would promote the interest of irrigation activities in the Centre. The gradual development and implementation of bore hole water source would go a long way in alleviating the problems associated with growing competition for water use.

In order to meet water demands for agriculture, irrigation efficiency needs to be improved drastically. To achieve this, irrigation water losses need to be reduced through the introduction of appropriate technology and improved water management and cultural practices.

The adequate transportation, distribution and optimal use of water at appropriate time and in proper amount through the irrigation systems would help to reduce the risk of crop failure and to increase production.

The objective of this research is to evaluate the performance of a developed drip irrigation system with measures of irrigation efficiencies.

2. MATERIALS AND METHODS

The Drip Irrigation System (DIS) was developed to provide an efficient application of water. This system was installed on an hectare of land of the lysimeter research field at the National Centre for Agricultural Mechanization (NCAM), Ilorin, and Kwara State of Nigeria, which is often referred to as Middle Belt of Nigeria. Ilorin is situated 370 m above sea level with about 1000 mm of rainfall per annum, with the mean monthly temperature of 31^{o}C and lies on Longitude 4^{o} 30' East and Latitude 8^{o} 26' North (Ahaneku 1997).

The soil of the site was sandy clay with a natural slope of 0.2 %. The land was divided into two areas, each having the same topography along different direction. Each area was divided into four equal zones, with each zone comprising two blocks and each block having six different plots with an area of 10 m x 5 m (Adeogun et al., 2004).

A well water source was used from the main borehole at NCAM, which supplied water to the overhead tank (3 m height) on the field. Water from the overhead tank with 700 litres capacity then supplied to the field by gravity through a main pressure pipe that supplied water to the sub-main and then to the laterals before the water trickled out from the dripper lines.

The water control centre was placed at the highest elevation in the field. Water from the deep well was pumped to the reservoir tank and flows by gravity from the reservoir tank to the field. When water is opened at the main control centre, the main line supplied water to the sub-main of each zone. The movement of water is therefore now controlled by the use of gate valve to different plots. Usually two plots are monitored at a given time. There are ten number of dripper lines at each plots, with each dripper line having eight drips / emitters.

Water application to different zones is guided by opening and closing of the gate valve at each plot. The total flow of water to different zones via different block is monitored by determining the total water flow at a given time.

The dripper lines were spaced 1 m from each other on the lateral while the drippers were spaced 60 cm apart. The main system supplying water from the NCAM borehole to the main field was monitored with a water meter, the amount of water supplied to the field and each block of different zone was also monitored with water meter.

The application efficiency of the system depends on the variation of emitter discharge, pressure variation along the lateral and seepage below the root zone. The variability is largely due to the materials of the emitter.

2.1 System evaluation

2.1.1 Irrigation Efficiencies

The overall irrigation efficiency is defined as the fraction of water diverted to the irrigation system that is ultimately effectively stored in the root zone.

$$\text{Irr. eff.} = \frac{\text{Rootzone storage}}{\text{main system supply}} \qquad (1)$$

Bos and Nugteren (1990) distinguished three levels of irrigation water management in the transport of water to crop:

. conveyance efficiency
. farm irrigation efficiency and
. field irrigation efficiency or application efficiency.

These can be expressed as follows:

$$\text{Irr. Conv. eff.} = \frac{\text{Farm supply}}{\text{Main system supply}} \quad (2)$$

$$\text{Farm Irr. eff.} = \frac{\text{Field application}}{\text{Farm supply}} \quad (3)$$

$$\text{Field Irr. eff.} = \frac{\text{Rootzone storage}}{\text{Field application}} \quad (4)$$

The overall performance of the system is determined using Larry's (1998) equation:

$$Ei = \frac{Er}{100} x \frac{Ec}{100} x \frac{Ea}{100} \quad (5)$$

where :
Ei = overall system efficiency,
Er = reservoir storage efficiency
Ec = conveyance efficiency,
Ea = application efficiency
(field irrigation efficiency).

2.1.2 Determination of head losses in the system

The irrigation pipes; main, sub main and laterals are connected in series to form a pipeline network that distribute irrigation water to the drippers that are connected in parallel to one another.

Losses are calculated per unit weight and each unit weight of the fluid passes through each pipe in succession. The total loss of energy per unit weight over the whole pipeline is the sum of losses for each pipe together with any separation losses such as might occur at the junction, entrance or exit.
Loss of head at entry (h_e) is calculated by the equation

$$h_e = k \upsilon_1^2 / 2g \quad (6)$$

where: k = 0.25

Loss of head in friction (h_f) is calculated using Darcy formula

$$h_f = \frac{4 f l_e}{d} \frac{\upsilon_1^2}{2g} \quad (7)$$

where: f = 16/Re,
Re = ρvd / μ
l_e = pipe length
d = pipe diameter

Loss of head at the reduction (h_r) is calculated using the equation

$$h_r = (\upsilon_1 - \upsilon_2)^2 / 2g \quad (8)$$

Loss of head at exit (h_x)

$$h_x = \upsilon_2^2 / 2g \quad (9)$$

Total head losses h_T is the summation of head losses

$$h_T = h_e + h_f + h_r + h_x \quad (10)$$

The uniformity coefficient (UC) is computed from field observation of depth of water caught in an open cans placed under the emitters.

$$CU = 100(1.0 - \frac{\sum X}{mn}) \quad (11)$$

where:
m = average application rate (mm),
n = Total number of observation point,
X = numerical deviation of individual observations from the average application rate (mm)

In determining the friction coefficient in pipes, the equation applied is shown below

$$f = \frac{0.316}{(R_n)^{1/4}} \quad (12)$$

where f = friction coefficient,
Rn = Reynolds number

The following equations are used to determine the energy drops by friction.
For the main line

$$\Delta H = 15.27(\frac{Q^{1.852}}{D^{4.871}})L \quad (13)$$

For the submain or lateral

$$\Delta H = 5.35(\frac{Q^{1.852}}{D^{4.871}})L \quad (14)$$

where
ΔH = total energy drop by friction, m,
Q = total discharge in pipe,
D = inside diameter in pipe,
L = total length of pipe

To determine energy drop ratio in drippers

$$R_i = 1 - (1 - i)^{2.852} \quad (15)$$

$$i = \frac{l}{L}$$

where
R_i = energy drop ratio,
L = total length

ℓ = a given length measured from the head end of the line

The uniformity for emitters is given as EU (Nakayama et al., 1979).

$$EU = 1 - (0.8\ Cv / n^{0.5}) \quad (16)$$

where :
EU = emission uniformity,
Cv = manufacturer's coefficient of variation,
n = number of emitters per plant.

The computation of frictional losses in the main line, laterals and drippers with different diameters was carried out using Darcy – Weisbach equation (Nakayama et al., 1979).

$$H_f = K\ L\ Q^{1.75}\ D^{-4.75} \quad (17)$$

where :
H_f = frictional head loss (m),
K = a constant = 7.89×10^5 for SI units for water at 20°C,
L = pipe length (m),
Q = total pipe flow (ℓ / s),
D = inside diameter of pipe (m)

3. RESULTS AND DISCUSSION

The design of DIS was based on a point source emitter principle with coefficient of variation of 0.03. The pressure at which the lateral would operate so that the emitter could deliver the specified amount of water was obtained from the manufacturer's chat and the value was 0.96 m. ASAE (1985) affirmed that the pressure variation in the lateral is normally kept within the range of the emission uniformity, hence the calculated value of the uniformity emitter discharge rate of the system is 0.976.

Table 1 shows the average values of irrigation water applied for the system from the main borehole supply to the field. On the average, two zones of twenty-four plots were irrigated daily in less than three hours. With irrigation intervals of two days, irrigation of 0.5 ha of the field was completed within two days.

Table 2 shows the frictional head losses calculated in the pipes of different diameters and the drippers. The average drip rate of the dripper line was 1.5 ℓ / hr. There were ten dripper lines per plot with eight drips per dripper line. This implies that the flow rate of drippers in each plot was 120 ℓ / hr.

The flow rate for each plot was determined by observing the readings on the flow meter for a given period of time. The average drip rate of the dripper line was 1.5 ℓ / hr. There were ten dripper lines per plot with eight drips per dripper line. This implies that the flow rate of drippers in a plot was 120 ℓ / hr. Irrigation of a zone was carried out under three hours with a 360 litres volume of water by gravity flow.

The experiment was carried out mainly on half an area of the field (0.5 ha), which comprised of four zones. The capacity of water reservoir on the field was 700 litres. Averagely two zones of twenty-four plots were irrigated daily under three hrs. With irrigation intervals of two days, irrigation of 0.5 ha of land was completed within two days. However, a reservoir capacity of 1,500 litres can conveniently serve irrigation of 0.5 ha per day.

When a field main line valve was opened a high flow rate was observed for about four minutes. The average flow rate decreased in field sub main lines that had previously reached pressurized flow rates. These fluctuations were for short duration and probably did not adversely affect the total water applied to any of the plots.

Output data were collected at fifteen minutes intervals to determine average flow

rate after main line pressurization and length of time to pressurize field sub main before they were turned on to the laterals. The total water flow and number of valves turned on were recorded (Fig. 1). It was however observed that the further the irrigation zone to the main water supply, the lower the total flow rate into the zones. Zone AB has a high total flow rate, which is close to the main water supply (overhead tank). Fluctuations in water flow occurred as valve was opened or closed during one daily irrigation cycle.

The volume of water emitted by the drippers determined the moisture storage; this is the amount of water input into the soil assuming a 100 % infiltration rate when there was no runoff from the point of drip.

The design of DIS was based on a point source emitter principle with coefficient of variation of 0.03, since one emitter is being considered in the design. From the manufacturer chat, pressure variation should be maintained at 0.96 m. From the design, emission uniformity is calculated as given in Equation 16, with uniform coefficient of 91.3 % (Table 3).

$$EU = 1 - (0.8\ Cv / n^{0.5})$$

$$EU = 0.976$$

This value is close to the pressure at which the lateral would operate so that emitter could deliver the specified amount of water. The irrigation conveyance efficiency, farm irrigation efficiency and the field irrigation efficiency or the application efficiency calculated for the system were obtained as 87 %, 95 % and 97 %, respectively. The overall performance of the system using Larry (1998) equation was found to be 84 %.

4. CONCLUSIONS AND RECOMMENDATIONS

The development of the DIS using local materials withstood the test of time in meeting the ASAE standards for drip irrigation for design evaluation of mainline, laterals, dripper's number and spacing of the emitters.

Each field main line took about four minutes to pressurize along with the sub main lines before valves were turned on for water to flow in the laterals.

The design of one flow meter per zone was feasible and cost effective. This system was also an energy saving device, for it required no energy source for operation.

The performance evaluation carried out on the DIS showed that the system functioned properly and effectively by applying the needed water on a daily basis.

The system has resulted in a great deal of water savings. Conveyance loss was minimal; evaporation, runoff and deep percolation were significantly reduced as compared to other traditional irrigation methods.

The system is however recommended for use in crop plantation, shrubs, flowers, and vegetables as well as for subsistence farming, mechanized farming and household vegetable gardens. This will lead to constant availability / abundance of seasonal crops / vegetables.

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Table 1. Average volume of irrigation water.

	Volume of water (ℓitres)
Main supply	735
Reservoir capacity	700
Field application	640
Root zone storage	622

Table 2 Head losses in irrigation pipes

Pipe	Main	Sub main	Lateral	Dripper
h_e (m)	1.7×10^{-5}	4.30×10^{-5}	3.60×10^{-5}	1.25×10^{-7}
h_f (m)	6.29×10^{-3}	1.58×10^{-2}	1.32×10^{-2}	4.6×10^{-4}
h_r (m)	-	2.36×10^{-5}	1.69×10^{-4}	3.47×10^{-7}
h_x (m)	1.87×10^{-3}	1.72×10^{-4}	1.44×10^{-8}	5.02×10^{-7}
h_T (m)	8.177×10^{-3}	1.60×10^{-2}	1.34×10^{-2}	4.61×10^{-4}

Table 3 Hydraulic characterization of the system

	Dripper	Lateral	Main	Submain
Emission Uniformity	0.976	-	-	-
Uniformity Coefficient (%)	91.3	-	-	-
Frictional Coefficient	0.14	0.19	0.06	0.06
Discharge rate (ℓ / hr)	1.5	120	120	120
Energy drop (m)	0.96	2.868	4.773	4.432

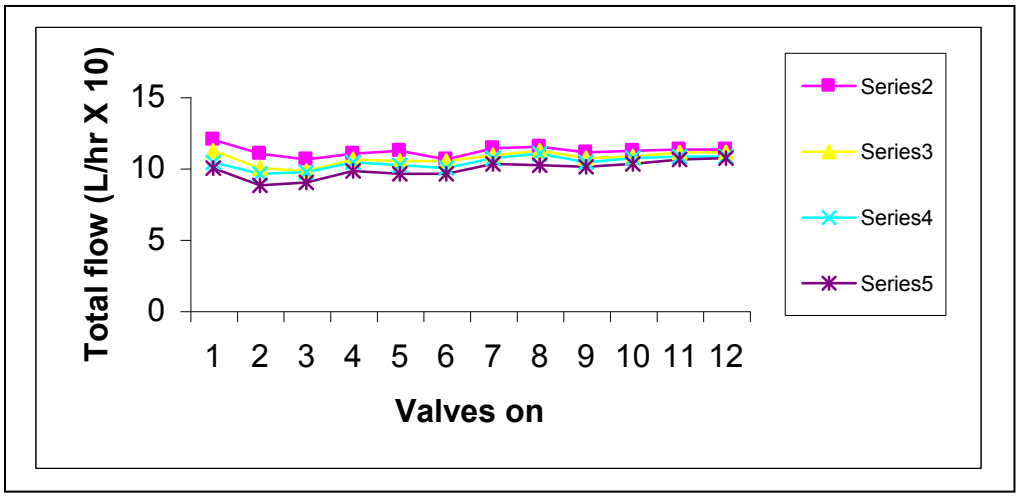


Figure 1

The DIS system will only irrigate a zone of 12 plots at a time.

Series 2 – graph for zone AB, Series 3 – graph for zone EF

Series 4 – graph for zone CD, Series 5 – graph for zone GH

SOIL AND WATER QUALITY UNDER SMALL SCALE IRRIGATION IN LAKE GERIYO IRRIGATION PROJECT, YOLA ADAMAWA.

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ABSTRACT
Soil and water quality parameters for small-scale irrigation of vegetable farms in three locations of phase I, II and Damare plots in Lake Geriyo irrigation project were investigated. The soils were found to be sandyclayloam, clay and loamy clay in texture. Fertility indicators showed that nitrogen in the soil ranged between (0.10 – 0.22%), calcium (0.90 – 11.5 Cmol (+) kg^{-1}), cation exchange capacity (37.4 – 49.8 Cmol (+) kg^{-1}) and magnesium (20.1 – 28.3 Cmol (+) kg^{-1}). Calcium and magnesium were the dorminant bases. Electrical conductivity of (1.32 – 2.74 dsm^{-1}) and exchangeable sodium of (0 – 6.7%) suggest no substantial accumulation of soluble salt and exchangeable sodium in some sections. Water from the three locations belong to low salinity, low sodium water category with Total Disolved Solid of 192 mg/l, electrical conductivity of 0.21dsm^{-1}, sodium adsorption ratio of < 4, Residual sodium carbonate of < 0 and pH < 8 belong to low salinity, low sodium water category. The results shows that the water is free from salinity/sodicity problems and suitable for irrigation purposes.

KEYWORDS: water quality, salinity, fertility indicator, ameliorative, irrigation

1. INTRODUCTION

In the semi-arid areas of the world, rainfall is often inadequate in amount and erratic in timing, thus necessitating irrigation in order to satisfy the moisture requirement of the crops needed to meet demand for food and fibre (Micheal, 1978). At the beginning of the twentieth century, the world's irrigated area stood at less than 10 million hectares, making up 13% of the world's arable land (Groove, 1985). According to Barrow (1987), out of 91 million hectares of irrigated land world wide during the late 1980's at least 30 – 46 million hectares were in a poor state due to salinity. Ajai et al, (1990) observed that in the more arid part of Africa, 80 million hectares suffer from salinity development often due to faulty irrigation. The salinity problems has worsened in recent decades as the extent of land under irrigation has increased.

A number of soil properties are affected consequent to salinity/sodicity development which includes structural destruction leading to decreased infiltration, permeability as well as aeration, soil fertility deterioration and reduction in overall productivity. The objective of this study was to evaluate soil and water quality status of some selected small scale irrigated farms in lake Geriyo irrigation project so as to enable timely ameliorative measures to be taken. the results of the test are presented in this paper.

2.0 MATERIALS AND METHODS

2.1 THE STUDY AREA

The study area is located between longitude 12^0 22' and 12^0 28' E and latitude 9^0 16' and 9^0 19' N; which is bounded to the North-East by River Benue which flows in a Westerly direction (Fig. 1). While to the south and south east is the limit of Jimeta town in Adamawa state. The area has two distinct seasons dry and wet season, with temperature and humidity varying with the seasons. The wet season begins in April and ends in November. 70% of the total rainfall in the area falls within the months of May to August. The mean annual rainfall for the area is 982mm, while temperature ranged from 27^0 C to 40^0 C. The vegetation is the savannah type (Sudan savannah). The soil is fertile alluvial deposit with poorly developed soil deposit due to the probable geological youthfulness of the soil (U.B.R.B.D.A., 1983).

2.2 Field Data Collection

The study area was randomly demarcated into three plots based on the apparent similarity in physical features. The demarcated plots were designated as phase I, II, and Damare plots. Random samples at three depths 0 – 10, 10 – 20, 20 – 30cm of the soil were collected by auger from each section of the plots for laboratory analysis. A 2 – litre water sample was collected from main canal, tertiary canal and main drain properly designated for easy identification.

Each soil sample collected was air dried, grounded where necessary, screened through a 2mm sieve and the following parameters included in Tables 1 – 2 were then analysed following the procedure as described by Page et al (1982), percentage sand, silt and clay, textural class and total nitrogen.

Particle size analysis was performed by the Bouyoucos hydrometer method and the texture determined on the USDA triangle. Total N was determined by the Macro Kjeldahl digestion – distillation method. Cation exchange capacity (CEC) was estimated by the ammonium saturaturation method. Exchangeable Ca, Mg, K, and Na were extracted with the neutral normal NH_4O_{AC}. In the extract, the former two were determined by EDTA titration method while other two by flame photometry. Soil pH measurement was made in ratio 1:1 soil: water and CaCl on a pH meter. Electrical conductivity (EC) was determined in a 1:5 soil – water extract at 25^0C on a conductivity meter. Base saturation (BS), percentage and exchangeable sodium percentage (ESP) were computed as follows:

$$BS = \frac{Ca^{++} + Mg^{++} + K^{+} + Na^{+} \times 100}{CEC} \quad (1)$$

$$ESP = \frac{Na^{+} \times 100}{CEC} \quad - \quad (2)$$

Where, exchangeable cations and CEC are in Cmol (+) kg^{-1}

Each figure inTable 1 – 2 is a mean of data obtained for three random soil sample collected from each section as earlier mentioned.

Table 1: Particle Size Distribution, Texture and Tatol N in phase I, II and Damare plot of Geriyo Irrigation Project

Particle – size distribution (%)						
Location	Depth (cm)	Sand	Silt	clay	Texture	Total N
Phase I irrigation plots	0 -10	58.0	21.6	20.4	Sandy clay loam	0.21
	10 – 20	54.0	25.8	20.2	Sandy clay loam	0.16
	20 – 30	50.0	28.8	21.2	Sandy clay loam	0.11
Phase II irrigation plots	0 -10	24.0	34.4	41.6	Clay	0.22
	10 – 20	18.0	40.4	41.6	Clay	0.18
	20 – 30	14.0	24.8	61.2	Clay	0.10
Damare irrigation plots	0 -10	36.0	42.8	21.2	Loam	0.23
	10 – 20	34.0	44.4	21.6	Loam	0.14
	20 – 30	26.0	52.2	21.8	Clay	0.12
LSD $_{(0.05)(Depth)}$		3.03**	15.08*	14.32**		0.8*

* = significant at P = 0.05 ** = highly significant at P = 0.01 ns = not significant
LSD = least significant difference

Table 2: Exchangeable Properties and Salinity/Sodicity Indicators for Soils in Geriyo Irrigation Project and Environs

Location	Depth (cm)	Exchangeable bases in Cmol (+) kg				Total Base	pH	EC (dsm^{-1})	HCO_3	CO_3	B	CEC	BS (%)	ESP (%)	SAR
		Ca	Mg	K	Na										
Phase I irrigation plots soil	0 – 10	11.0	20.1	0.10	0.04	31.2	5.75	1.37	20.0	2.64	0.10	37.9	82.0	0.10	0.01
	10– 20	0.90	23.5	0.09	0.00	24.4	5.49	1.42	18.0	5.30	0.02	37.4	87.0	0.00	0.00
	20- 30	11.5	24.0	0.05	0.16	35.7	7.66	1.32	30.0	9.01	0.04	42.0	85.0	0.40	0.04
Phase II irrigation plots soil	0 – 10	10.8	28.2	0.65	0.16	39.8	6.72	1.35	38.0	9.42	0.00	47.1	85.0	0.50	0.04
	10– 20	10.5	28.3	3.50	1.20	43.5	6.96	1.36	37.0	12.8	0.04	49.8	87.0	2.40	0.27
	20- 30	9.50	25.1	1.00	3.21	38.8	6.82	2.74	30.0	9.43	0.001	47.7	81.0	6.70	0.77
Phase III irrigation plots soil	0 – 10	8.60	20.3	2.20	0.98	32.0	6.80	1.95	30.0	5.54	0.02	37.8	85.0	2.60	0.26
	10– 20	10.1	22.9	3.60	0.32	36.9	5.66	2.04	35.0	8.02	0.03	43.1	86.0	0.70	0.08
	20- 30	8.21	22.0	3.30	0.32	33.8	5.15	1.54	32.0	7.04	0.001	39.8	85.0	0.80	0.08
LSD (0.05) (Depth)		8.70^{ns}	10.2^{ns}	1.80^{ns}	2.20^{ns}		2.20^{ns}	1.30^{ns}	11.65^{ns}	4.50^{ns}	5.04^{ns}	5.04^{ns}	4.50^{ns}	4.90^{ns}	0.60^{ns}

* = P = 0.05

ns = not significant

LSD = least significant difference

Water Quality Analysis

The water samples were analysed for parameters indicated Table 3, following the procedures described by Chopra and Kanwar (1991). Total dissolved solids (TDS) were determined by the evaporation – drying method. The pH and EC were read at 25^0c on a pH meter and conductivity meter respectively. Calcium and magnesium were estimated by EDTA titration method, while K and Na by flame photometry. Carbonate and bicarbonate were obtained by volumetric titration method. The anions Cl^-, SO_4^-, and NO_3^- were read on a LED photometer. Boron was determined by the calorimetric indigo – ceramine method. Residual sodium carbonate (RSC) and sodium adsorption ratio (SAR) were calculated as follows:

$$RSC = (CO_3^- + HCO_3^-) - (Ca^{++} + Mg^{++}) \quad (3)$$

$$SAR = \frac{Na^{++}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} \quad (4)$$

Where, ionic concentrations are in $meql^{-1}$

RESULTS AND DISCUSSION

SOIL TEXTURE

The surface soils in the selected plots of Lake Geriyo Irrigation Project with values of 26 – 58% sand, 22 – 52% silt and 21 – 61% clay were predominantly sandy clay loam in texture exce in phase II which was clay throughout the sections (table 1). Generally, the sand separate tended

to decrease with soil depth while clay to increase with depth. Phase II contained significantly more clay than others. The texture of the Damare plot changed from depth of 0-10, 10-20cm from loam to clay down the profile (table 1).

The lake Geriyo irrigation area soils are of the fadama type. The predominantly sand nature in the surface is in conformity with observation of Usman and Abdulmumini (1998) that the Savanna soils are sandy at least in the surface layer. Sandy material eroded from surrounding upland and carried down by wind and water, as well as those brought in through flood as sedimentation load are through (Singh, 1997), to be contributory to the sandy nature of fadama soils.

SOIL QUALITY IN TERMS OF FERTILITY STATUS

Nitrogen Fertility

Total N in the 0-10cm soil ranged within 0.20-0.23 (mean 0.22) percent; it tended to decrease with depth (Table 1). For the Savanna soils, ESU (1991) set low, medium and high fertility category limit with total N as < 0.15, 0.15-0.20 and > 0.2% respectively. The soils with total N 0.20-0.23 (mean 0.22) percent can thus be classified into medium N-fertility category.

Ca, Mg and K-Fertility

Table 2 shows the surface soil contained (values I Cmol (+) vg^{-1}) 8.6-11(mean 240 mg and 0.1-22 (mean 1.2) K; Ca and Mg being the dominant bases as well also observed erlier (Ibrahim and Garba, 1995) ESU (1991) fixed low, medium and high fertility category limits (values in Cmol (+) vg^{-1}) as < 2, 2-5 and > 5 for Ca; < 0.3, 0.30 fork. Accordingly, lake

Geriyo irrigation project soils can be rated as high in Ca- fertility, high in Mg-fertility and medium in K-fertility.

CATION EXCHANGE CAPABILITY AND BASE SATURATION.

The surface soil CEC ranged from 37.4 - 49.8 (mean 44) Cmol (+) vg $-^{1}$ (Table 2). The observed ranged puts lake Geriyo irrigation project area soils into high CEC category. This is based on the limits <6, 6-12 and > 12 Cmol (+) vg $^{-1}$ for low, medium and high CEC category respectively a set by Adepetu et al, (1979).

Adepetu et al, (1979) also set low, medium and high percentage base saturation class limits as < 50, 50-80 and > 80. Accordingly, the surface soils with 81-87 (mean 84) percentage base saturation may be placed into high class.

Overall Fertility Assessment

On the whole, soils in lake Geriyo irrigation project area are found to be medium in total N (0.22%), Ca (9.8 Cmol (+) Kg – 1) and CEC (44 Cmol (+,)Kg $^{-1}$); high in Mg (24 Cmol (+) Kg $^{-1}$) and base saturation (84%); and medium in K (1.2 Cmol (+)nKg $^{-1}$).

Soil Quality In Terms of Salinity/ Sodicity Status

The values of soil PH, EC and ESP, the indicator of salinity sodicity status, are given in Table 2. the surface soil PH range was 5.66-7.66 (mean 6.7). then indicates a slightly alkaline PH which favours the growth of most vegetables grown in Lake Geriyo irrigation project Usman and Abdulmumini (1998).

The EC values for surface soils ranged from 1.32-2.74 (mean 2.0) in phase I and II' according to FAO (1976), soil with EC range of 0-2dsm $^{-1}$ are classified as salt free soil ad 4-6 dsm^{-1} as slightly saline restructing the yield of many crops. Most of the EC values fell within the range where no salinity problem is expected.

Irrigation Water Quality

The suitability of water for irrigation purpose is judged on the basin of its content of total dissolved solids (TDS), electrical conductivity (EC), sodium adsorption ratio (SAR) and residual Sodium carbonate (RSC). Besides these, concentrations of various elements/ions which may, accumulate in soils to phototoxic levels are considered. The data on these quality indicator for water from main canal, tertiary canal and the main drain are given in table 3.

TABLE 3. INDICATORS OF QUALITY OF IRRIGATION WATER IN GERIYO

According to US salinity laboratory staff (1954), the irrigation water can be placed in the following four classes on the bases on EC (dsm^{-1}) with corresponding TDS values (mg/l) as given by Landon (1991).

C1 - Low salinity water: EC 0.0.25, TDS< 200

C2 - Medium salinity water: EC 0.25-0.75, TDS 200-500

C3 – High salinity water: EC> 0.75 – 2.25, TDS >500 – 1500 and C4 – very high salinity water: EC >2.25, TDS, > 1500

TABLE 3: INDICATORS OF THE QUALITY OF IRRIGATION WATERS IN GERIYO IRRIGATION PROJECT

Parameter	Phase I Plot Ww1	Phase I Plot Ww2	Damare Plot Ww3	Mean	USDA LIMITS	WATER CLASS	REMARK
TDS(mg)	82.0	296	198	192	5-1000	GOOD	Acceptable for use
EC ($dsm^{-1)}$	0.13	0.34	0.15	0.21	0-0.25	GOOD	Low salinity water
PH	5.56	8.09	6.68	6.78	6.5 - 8.5	GOOD	Less risk of salinity development
Ca (mg/1)	25.0	28.2	18.5	23.9			
Mg	18.0	20.4	13.8	17.4			
Na	6.00	5.00	0.34	3.78			
K	8.00	1.00	0.06	3.02			
CT	20.0	17.0	8.00	15.0			
HCO_3	28.0	35.0	23.6	28.7			
SO_4	72.4	75.0	64.0	70.5			
NO_3	21.0	23.0	8.00	17.3			
CO_3	12.0	10.5	4.00	8.83			
B	0.40	0.08	0.02	0.20	0.7-(>2)	PERMISIBLE FOR USE	Satisfactory for most crops.
SAR	1.29	1.01	0.08	2.38	<10–(>20)	EXECELLENT	The water can be used with no sodium problem
RSC	- 3.0	- 3.1	- 4.7	-3.6	< 0	LOW RSC CATEGORY	The water is safe for use on all soils

Based on SAR classes are:
S_1 – Low Sodium water: SAR < 10
S_2 – Medium Sodium water: SAR 10 – 18
S_3 – High Sodium water: SAR 18 -26 and
S_4– Very Sodium water: SAR 26

Accordingly, the waters from various sources in Lake Geriyo irrigation project area with TDS (mean 192) < 200, EC (Mean 0.2 dsm^{-1}) , SAR (Mean 2.38) < 10 , RSC. (Mean – 3.6) < 0, and PH about neutral (Table 3), can be placed into C_1 S_1 – low salinity, low Sodium water category. They appear free from salinity/soditciy problems and safe for irrigation purposes.

STRATEGIES FOR SOIL AND WATER MANAGEMENT

The soils n Lake Greiyo irrigation project on the whole can be said to be sandy clay loam to clay in texture, medium in fertility as well as water retention capacities. With 58% sand separate in Phase I and 61. 2% clay in Phase II, the soil are expected to present difficulties in their management. Their low moisture retention capacities would lead to losses of plant nutrient through leading crops growing on such soils would experience frequent moisture stress. Besides being prone to erosion, such soils invariably do not keep shape and capacity of irrigation channels with render water losses in transit. Excessive irrigation water percolating down the profile may raise the ground water table because the higher percentage of clay (61%) in Phase II and the fact that clay that clay soil are poorly

drain soils, the risk of soil salinization/sodification may crop in. therefore, judicious application of organic matter/ crop residues may protect the soil from erosion besides improving its physico-chemical properties.

The medium total N (Mean 0.22%) in the soil warrants judicious application of organic and chemical fertilizers to enrich them with nitrogen. The fertilizers should however be based on appropriate soil testing as advocated by Singh (1995).

Lastly, a continues periodic monitoring of soil and water qualities is essential so as to embark on appropriate ameliorative measures as and where necessary.

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WATER AUDIT AND DEMAND MANAGEMENT IN THE JAMAARE AND MISAU SUB-CATCHMENTS OF YOBE RIVER BASIN

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ABSTRACT

A water audit and water demand analysis was carried out in the Jamaare River and Misau River sub catchments of the Komadugu Yobe River (KYB) basin of Nigeria. The two rivers are tributaries of KYB which has been in the focus of the international community because of the observed unsustainable water resources development in the upstream areas culminating into reduced river flow that have seriously affected the middle course and downstream areas leading to the shrinking of the Lake Chad.
Data quality analysis show that stream flow records are consistent for the common years (1971-1992), however deviations were observed between 1983 and 1988, and this was found to be coincident with the second drought cycle in the basin. Mean annual runoff (MAR) at Bunga, Foggo and Katagum stations on the Jamaare river is 1693 MCM, 2054 MCM and 1713 MCM respectively. The MAR of the Misau River at Kari is 324 MCM; this was reduced to 135 MCM at Dapchi station.
Mean annual indirect recharge of 418 MCM was obtained in the Jamaare system while 167 MCM was obtained on the Misau system; direct recharge of 65 mm and 85 mm were obtained on the Jamaare and Misau systems, respectively. Estimates of water demand for the sub catchment was 400 MCM, 436 MCM and 505 MCM for the years 2006, 2010 and 2020 respectively. This means that the available water is capable of satisfying demand presently but after year 2020 demand would have overshot supply if the current development rate is not controlled. Activities which utilize water unsustainably should be discouraged in the area; this can only be achieved through the use of incentives to the rural people and enlightenment of water users.

Keywords: Water audit; demand; Management and Sustainability.

INTRODUCTION

Water is important for the sustenance of life. The ecosystems of the earth are linked and maintained by water, which is also a universal solvent and provides the major pathway for the flow of sediment, nutrients and pollutants. The uneven distribution of fresh water in the world has posed a considerable challenge to the water resources managers in terms of sustainable development and proper management.
The Komadugu Yobe (KYB) river basin of Nigeria has been in the focus of the world because of the observed uncoordinated and uncontrolled water resources development in the upstream areas which have seriously affected the middle course and down stream areas leading to reduced flow of water to Lake Chad. The Lake has been reported to have shrunk significantly, from approximately 40,790 km^2 in 1963 to less than 5,000 km^2 in 1997 (Adewuyi, 2005). The key reasons for this phenomenon have been identified as overgrazing, deforestation contributing to a drier climate and large, unsustainable irrigation projects in Cameroon, Chad, Niger and Nigeria which have diverted water from the lake.
Literatures show that the Komadugu Yobe River is sustained by three main tributaries; Hadejia River, Jamaare River and Misau River (Shultz, 1976; Sanyu, 1994; Diyam, 1996; HNWCP, 1997; Edmund et al, 2002; Sobowale, 2005). The annual flow from the Hadejia River has been reported to have reduced greatly since 1974 due to the construction of fifteen dams in its catchment; and the Misau River has also been reported not to be flowing into the Komadugu Yobe River, having been cut off in the late 1970s. This leaves the Jamaare River as the only uncontrolled river contributing to the KYB.

The persistent outcry of water scarcity in the downstream areas of the basin calls for urgent intervention by policy makers, water managers and all other stakeholders. The livelihood of the people in the basin has been eroded leading to migration of people to water-rich areas. For example, it was reported that as Lake Chad receded, people moved along with it till they have migrated out of Nigeria into the Republic of Cameroun.

Integrated water resources management (IWRM) is the only solution to the numerous problems that have been identified; another affected area in the basin is the Hadejia-Nguru Wetlands which has been acclaimed worldwide to be very rich in biodiversity and capable of providing livelihood to millions of people. The aim of this paper therefore is to examine water availability, analyse water demand and suggest IWRM strategies for the Jamaare and Misau sub-catchments of the KYB basin.

Description of the study area

The Jamaare and Misau River sub catchments are integral part of the Komadugu Yobe River basin of northern Nigeria, the sub catchment has a total area of about 40,790 km^2. The Jamaare River and Misau river systems stretch across four states namely Plateau, Bauchi, Jigawa and Yobe states. Two different regions are recognized in the basin: the upper catchment area containing the headwaters of the Jamaare River system and consisting of relatively mountainous rocky land and the lower watershed area containing the flood plains and consisting of flat upland and lowland plains which are extensively used for the production of food and fibre (Schultz, 1976).

The geologic formation of the upstream part of the basin consists of largely impermeable basement complex rocks while the lowland area is of alluvial sediments of the Chad formation. The rainfall period is from June to October, and has annual mean of over 1,000 mm in the upstream basement complex area and approximately 500mm in the Hadejia-Nguru Wetlands (Sanyu, 1994).

The Jama`are River has its headwaters in the Jos plateau, it collects water from a number of tributaries, notable among them are Delimi, Mara, Dogwala, and Iggi Rivers.

The most important of these rivers is the Delimi, which rises close to the center of the Jos plateau and is met by the Mara River about 3km downstream of the proposed Kafin Zaki dam site on the Jama`are River. Other tributaries to the river are the Iggi River, the Dogwala that flows to form the Fakate River south of Birnin-Kudu. The Iggi River joins the Fakate to form the Katagum River at about 5km south west of Kiyawa Town. The Katagum River then flows northeast to join the Jama`are River at about 8km south west of Sakwa.The river then flows in the northeast direction to meet the Hadejia River 23km upstream of Gashua.

The Misau River has it headwaters in the hilly areas close to Bauchi town, it flows in the north eastern direction past Kari town and later past Dapchi to form the Komadugu Gana as it is locally called. Shultz (1976) reported that the Misau River flow into the Komadugu Yobe River near Gumsa. Recent information show that the river no longer contributes to the Yobe River due to the recent low flows and high evaporation in the wetland formed near the border of Nigeria and Niger. The map of the KYB is shown in Figure 1.

MATERIALS AND METHODS

Water audit and estimation of water demand in the sub catchments were carried out. The area was divided into two hydrological sections (HS) via: Jamaare River up till Katagum (HS 1) and Misau River system (HS2); surface water resources were estimated by considering the basic flow statistics of the main rivers, the available flow data were scanty and not up to date and hence was subjected to quality control using double mass analysis to check for consistency before being employed for analysis. Simple linear models (SLM) was used to extend the flow data by transforming the input function (rainfall) into a corresponding discharge function of time up till 1999 giving thirty five (35) years of flow data.

Inventory of dams was also carried out to ascertain their storage capacities and mean annual water availability. Groundwater recharge in the study area was estimated using the water balance method described by Essien (2001) and Sobowale (2005). Groundwater recharge was considered to occur in two different regimes: indirect recharge (river channel seepage) and direct recharge from the

land surface. The model used for indirect recharge is:

$$\mathbf{Q_{Inflow} - Q_{Outflow} - Q_{Abstractions} = \quad Channel\ Seepage} \qquad \mathbf{(1)}$$

Abstractions identified in the area include: Irrigation, evaporation, domestic and industrial uses. Direct groundwater recharge was estimated on a daily scale for thirty-one (31) years (1971-2003) using a water balance model on a regional scale. Recharge (re) is therefore estimated as the balance when the soil moisture deficit of the previous day (SMD_{n-1}), direct surface runoff of present day (Ro_n) and evapotranspiration of the present day (Et_n) have been deducted from precipitation of the present day (P_n). The model is stated below:

$$re_n = P_n - Ro_n - Et_n \pm SMD_{n-1} \qquad (2)$$

where, re = potential recharge in mm; n = present day; n-1 = previous day

Negative values of re represent an increase in soil moisture deficit (SMD) while positive values indicate potential recharge. Recharge to groundwater can only take place when $P \geq Et + Ro$ and SMD=0. This limited the period of recharge to only three months in the year (i.e. July, August and September). In order to apply the model, a number of simplifying assumptions were made as follows:

a. Excess soil moisture above field capacity and below saturation point percolates as recharge to the ground water table i.e. gravitational water.
b. Rainfall in the month of June and July reduces SMD to zero.
c. Evapotranspiration takes place at a potential rate.

Domestic and industrial water demand was estimated using population data and per capital water demand, irrigation demand was estimated using crop water requirement and irrigated area, livestock demand was estimated for nine species of livestock identified in the area using their water requirement and livestock population, and forestry/ecological demand was estimated using fao water requirement per girth increase. The estimated available water were then compared with present and projected water demands in order to determine sustainability of supply and to suggest appropriate water management strategies for the sub catchments.

RESULTS AND DISCUSSION

Data Quality analysis and Stream Flow Syntheses

The double mass curve for stream runoff at Bunga and Katagum stations on Jamaare River is presented in Figure 2. The mass curve for the common years (1975-1992) shows consistency at the beginning (1975-1982), a change was observed from 1983 which coincided with the second drought cycle in the catchments, a resumption of consistency was observed in 1988, this shows that the data can be used for flow forecasting on the Jamaare River. The flow data available for the Misau River were very scanty, however consistency was observed within the short period of available data. The flow data for Dapchi station on the Misau River were too scanty to be used for analysis. Table 1 presents a 5-yearly analysis of flow statistics in the two sub catchment.

Surface water Resources

Figure 3 presents the hydrograph of the Jamaare River at Bunga, Foggo and Katagum stations, the mean annual runoff at these stations are 1693 MCM, 2074 MCM and 1713 MCM, respectively. The reduced flow at Katagum was due to stream channel recharge between Foggo and Katagum arising from the presence of a hydro geological divide between the upstream basement complex and downstream Chad formation.

Analysis of stream flow contribution to the Yobe River show that the Jamaare River is presently the major tributary and is responsible for the bulk of the river flow in the Komadugu Yobe River. The river is therefore the main source of river flow into the northern pool of the Lake Chad. The Misau River flows mainly

in the wet season from June to October, the annual mean flow at Kari is 324 MCM, this value was however reduced drastically at Dapchi station with a value of 135 MCM. Careful analysis suggests that this may be due to ground water recharge in the stream channel. Two dams were identified on the Jamaare River system at Galala and Kawali with total available water of 16.8 MCM annually. None of the dams are operated to release water for down stream use; hence a bulk of the water stored in the reservoirs is lost to evaporation. Due to the importance of the Jamaare River to the flow into Lake Chad, it is strongly advised that the river should not be controlled and all efforts to dam the river should be banned by legislation. The mistake made in the past by constructing large dams in the Hadejia sub catchment should not be repeated on Jamaare River because doing so will lead to further drying up of Lake Chad and increased poverty in the downstream areas.

Ground water resources

Indirect recharge of 418 MCM was estimated on the Jamaare River while about 167 MCM was obtained on the Misau River. This contribution to ground water system recharges the downstream Chad formation. The trend of direct ground water recharge from rainfall on identified agricultural land in the two river systems are shown in figure 4. The Jamaare River system has a mean annual ground water recharge depth of 65 mm, while the Misau River system has about 85mm. The trend shows that there were no ground water recharge in the sub catchment in 1990 and 1993; this was due to very low rainfalls in the area at those periods as observed from the rainfall records.

Water Demand Management and Sustainability

Table 2 presents the water demand in the sub catchment and its projections for years 2010 and 2020. The water demand included estimates for domestic and industrial, irrigation, livestock and ecological uses. The irrigation water requirement was estimated based on current development rate in the area. The analysis show that present demand will increase by 9% and 26% in year 2010 and 2020 respectively. These sub catchments of the Komadugu Yobe River basin is largely rural with low water demands. If the proposed Kafin Zaki dam and irrigation project is implemented, farmers will migrate to the area and create acute water scarcity. The available water in the area is still capable of sustaining the identified water requirements presently. Actions to maintain sustainability should be implemented from now without delays.

Since the water resources of the area is more or less fixed with little variations due to climate change, it is pertinent therefore to begin radical water demand management to ensure that water needs do not overshoot available supply.

The projected demand by 2020 will surely overshoot supply as can be seen in Table 2. At this time it is predicted that acute water scarcity will be begin. Since indirect recharge in the stream channel is the main mechanism of ground water recharge in the area, it is then expedient to ensure that activities that use large amount of water such as irrigation are regulated. It is advised that formal irrigation schemes should not be implemented, rather informal system using ground water should be adopted.

CONCLUSION AND RECOMMENDATIONS

The results of this study estimated the available surface and ground water resources of the Jamaare and Misau Rivers sub catchment of the Komadugu Yobe River basin. The projected trend of water resources development in the area show that the current development rate is not sustainable as demand will clearly overshoot supply by the year 2020. An integrated water resources management (IWRM) should therefore be pursued to ensure sustainability. It is also advised that radical water demand management be applied to the area. Efforts to discourage uneconomic use of the water resources should be aggressively pursued through sensitisation and advocacy. Activities that waste water should be discouraged, this will lead to water trade offs between upstream and downstream areas; development of large and medium scale irrigation schemes should be banned by law.

Government should play a central role in managing demand for water by ensuring that efficient legislation which control water development and promote integrated management is put in place and enforced. In Nigeria, Government seems to be the only investor in river basin water development; this scenario should be reversed and let

government be a regulator only. This is only possible if the capacities of other organisations are enhanced towards integrated water resources management. Eco system sustainability is very paramount and must be given topmost priority, in case the eco system becomes threatened, the government should discourage activities which utilizes water unsustainably. Furthermore, the cultivation of crops which require large amounts of water (e.g. rice) should be discouraged in the basin; this is only possible if government gives incentives for the production of crops which require less amounts of water. The two river systems are largely rural, hence the prevalence of illiteracy; the rural communities lack awareness of water management principles which leads to wastage of economically viable water in the area, there is then the urgent need to improve agricultural extension network in the area.

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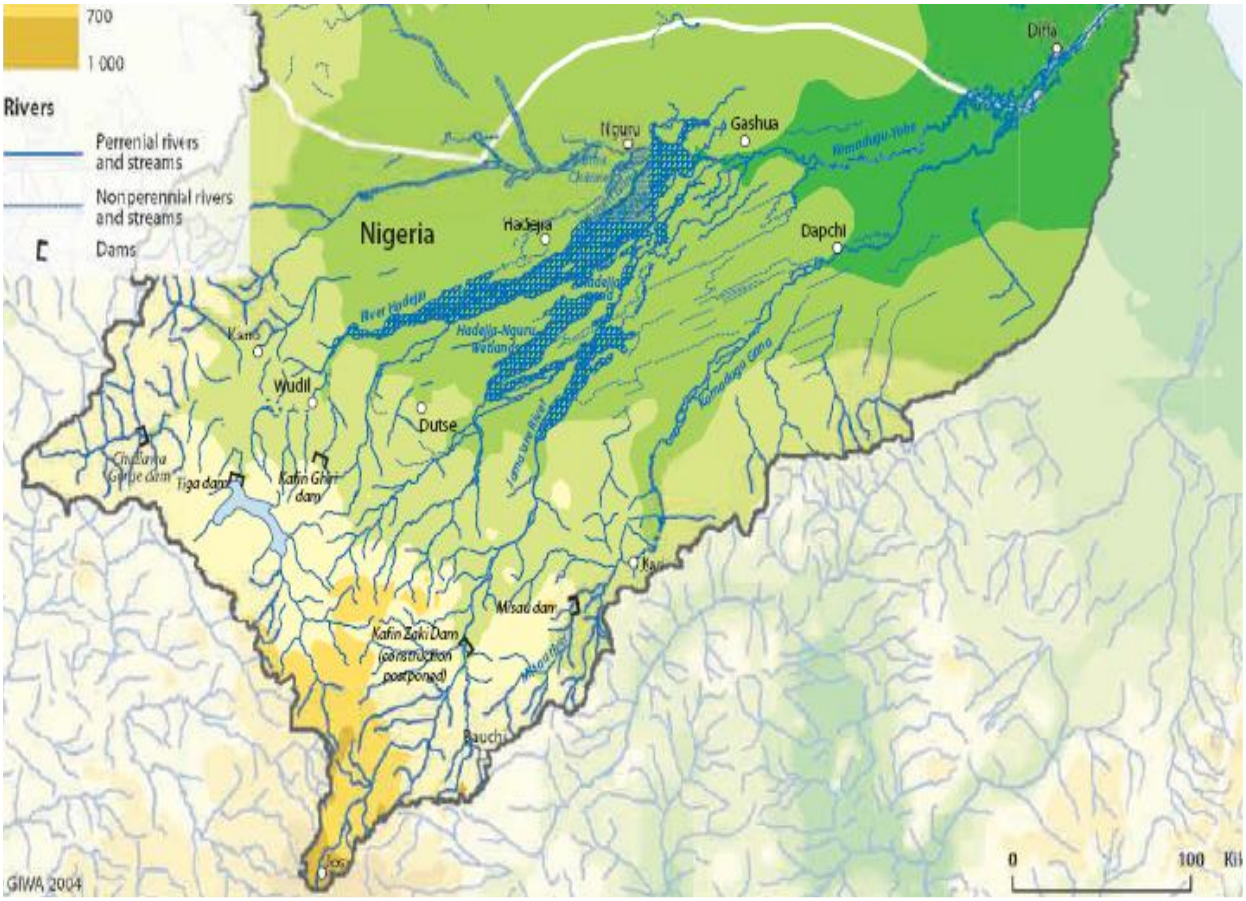


Figure 1: Map of the Komadugu Yobe River basin (Giwa, 2004)

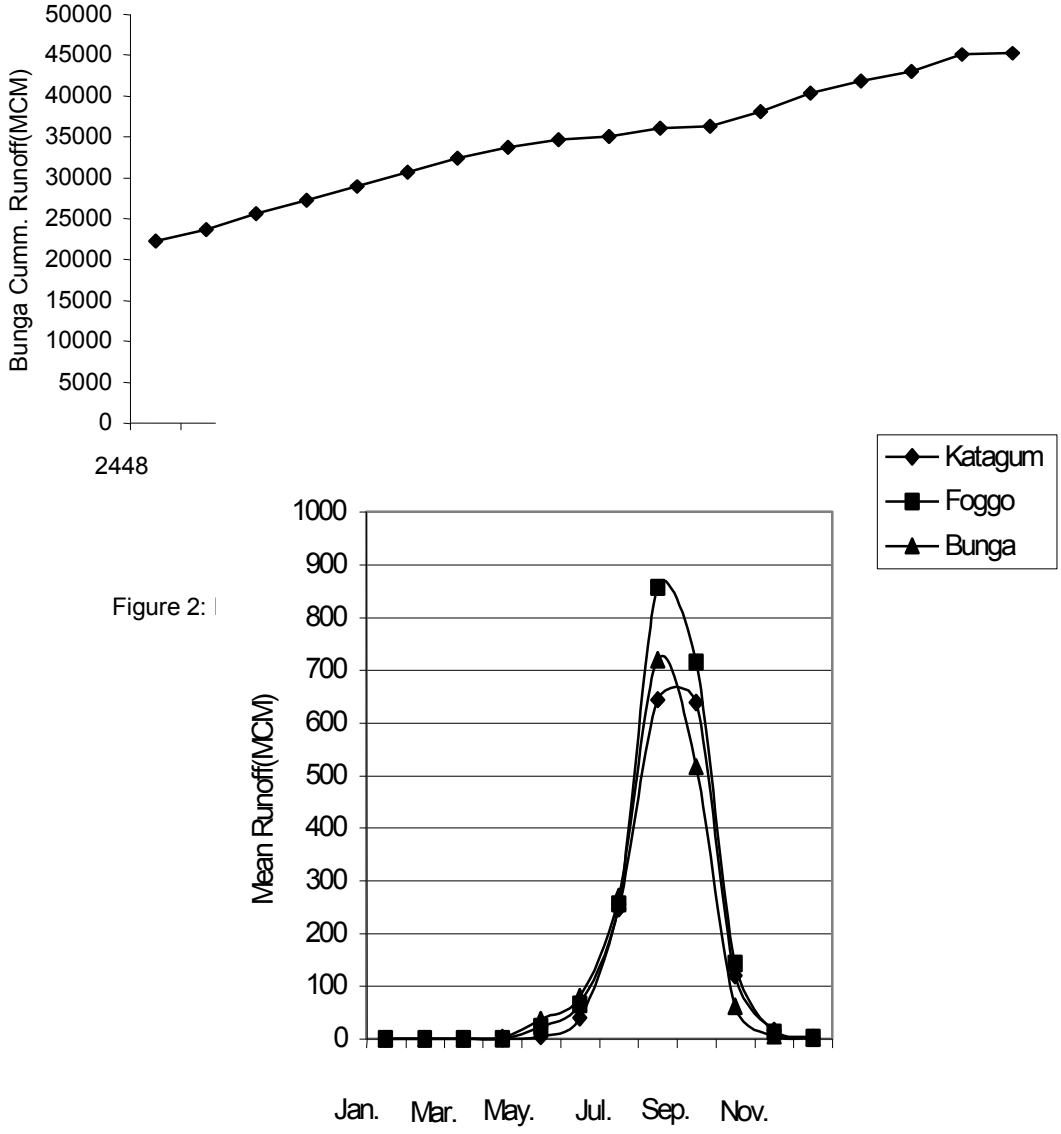


Figure 2:

Figure 3: Hydrographs of the Jamaare River at three stations

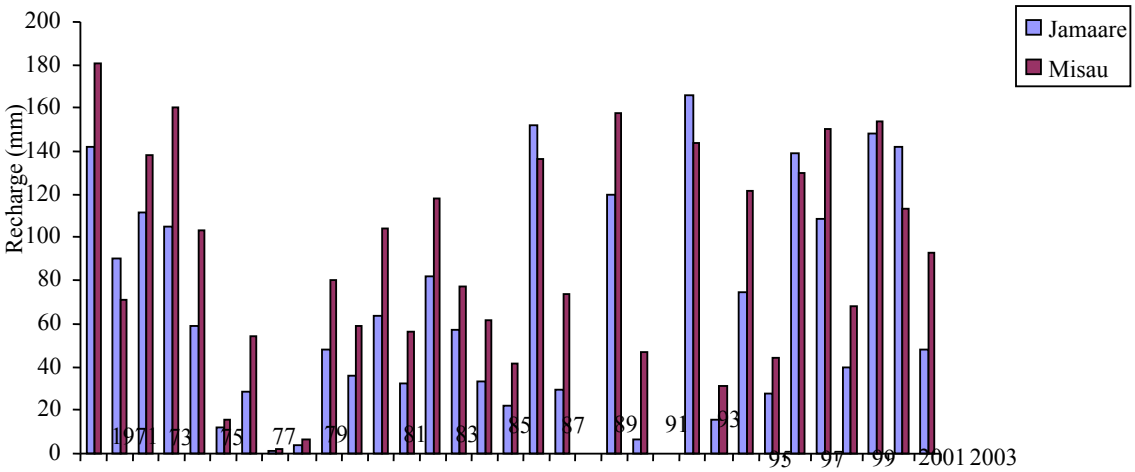


Figure 4: Trend of ground water recharge in Jamaare and Misau sub catchments

Table 1: 5-yearly analysis of flow statistics in the Jamaare and Misau sub catchment

Station Name	Sub Catchment	Annual Statistics	1965-1999	1965-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000
Iggi Bridge	Jamaare	Mean	77.9	77.6	128.7	112.6	80.3	46.4	46.4	47
		Std Dev	50.4	37.1	37	94.5	37	0.5	0.5	0
		Std Err	8.5	15.1	16.5	42.2	16.5	46.4	0.2	0
Bunga Bridge	Jamaare	Mean	1693.2	2082.8	1938.2	1702.4	1064.8	1377.8	1950.4	1649.5
		Std Dev	736.2	340.8	808.2	197.2	460	739.9	1368.8	419.6
		Std Err	124.4	139.1	361.4	88.2	205.7	330.9	612.1	209.8
Foggo	Jamaare	Mean	2154.2	2524.3	1899.6	1812.8	2201.2	2189.2	2193	2192
		Std Dev	382.2	423.1	507	566.5	14.5	3.6	5.6	5.7
		Std Err	64.4	172.7	226.7	253.3	6.5	1.6	2.5	2.8
Katagum	Jamaare	Mean	1712.6			1823.8	1199	1826	1607.2	1930.2
		Std Dev	552.9			291.5	509.9	648.2	496.3	572.9
		Std Err	110.5			110.2	228	289.8	221.9	286.4
Kari	Misau	Mean	323.7	514	392.8	224.8	149.8	274	332.8	342.9
		Std Dev	184.1	236.7	223	183.7	91.6	50.4	18.9	16
		Std Err	31.5	96.7	99.7	82.1	41	22.5	8.5	8

Table 2: Projected water demand in the Jamaare and Misau sub catchment

Sub catchment	Land Area (km^2)	Water Demand (10^6 m^3)		
		2006	2010	2020
Jamaare River	22,700	352	379	424
Misau River	18,090	48	57	81
Total	**40,790**	**400**	**436**	**505**

THE USE OF ANTHILL MATERIAL (TERMITARIUM) FOR CONTROL OF SEEPAGE IN IRRIGATION CANALS

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ABSTRACT
The study outlines the potentials in the usage of local anthill soil as an alternative canal lining material for the reduction of seepage in irrigation canals. To achieve this, physico-chemical properties and compaction characteristics of anthill soils were investigated and an experimental canal was constructed to measure seepage losses using the inflow and outflow method on a 50m reach of the canal. Two 90^0 V-notch weirs were used to measure the discharge. The mean canal seepage losses were estimated using two equations, BS 3680 and USBR formulae. The estimated seepage values stood at 9.16×10^{-4} $m^3/day/m^2$ for the unlined canal and a mean value of 2.33×10^{-4} $m^3/day/m^2$ for the lined canal equivalent to about 75% improvement. The result satisfies the requirement for use of anthill soil as lining material for reduction of seepage in irrigation canals. The prospect of combining anthill with other materials for compacted earth lining in canal sections was recommended.

KEYWORD: anthill, canal lining, seepage, compaction

INTRODUCTION

The need to control the use of water whether for drinking, farming or industrial uses so as to minimize all forms of wastages cannot be over emphasized. A canal is an artificial waterway constructed for the conveyance of water. The diggings of canals for irrigation dates back to the beginning of agriculture and traces have been found in regions of ancient civilizations.

There are continuous losses in canal system right from the canal head works to the agricultural fields. These losses are known as transmission losses (or transit or conveyance losses). The transmission losses are substantial, especially when canals are unlined. It is estimated that about 50% of the water that enters the canal at the head works is lost in transmission (Arora, 2001). The transport of water from the source to the point of use (agricultural field) has been a problem to farmers since the beginning of time. In unlined canals losses due to seepage are high (20 – 50%) (Arora, 2001) and excessive seepage from unlined canals can cause accumulation of salt in the soil, which leads to unfavourable soil and water relationship and decreases the yield of crops. The land ultimately goes out of cultivation unless suitable remedial measures are taken.

Traditional canal lining material typically includes compacted earth, stone and bricks mansonrites, reinforced concrete etc. However, for some jobs, these materials are not always available because they are either too expensive or not locally available. The major of canal lining is the reduction of seepage losses. Canal lining not only has advantage in reducing seepage losses but also have other advantages such as increasing channel resistance o scour and reduction of weed infestation along the canal (Khair and Daulat, 1978). According to Khair et al (1984), as muchg as 47% of total amount of water

diverted were lost as seepage in unlined channels in India. Dutta (1981) also reported that as much as 60% of the total water diverted was lost during conveyance. This therefore, necessitates the need to line channels with good materials to curtail this magnitude of losses. Khair and Daulat (1978) reported that the initial high cost of standard types of lining is at present prohibitive for many projects. Therefore, there is need to investigate into other lining materials that are relatively cheap without affecting the satisfactory performance.

Biswas and Islam (1975) showed that cow dung cum clay lining, 75mm thick when laid carefully reduces seepage losses, similarly Kinori (1970) reported that sand with clay as binding material can reduce seepage losses but could not resist scour caused by water satisfactorily. Khair and Daulat (1978) concluded that lining made of indigenous material may reduce seepage losses considerably but is less permanent and less effective than concrete lining. In a similar effort Kasali et al (2002) reported that local composite of clay, sand loam, cow dung and sand at a mix ratio of 1:3:1:2 were found to be satisfactory as a lining material in terms of strength and seepage reduction. However, because of their low load carrying capacity, they were recommended for use in laterals and shallow farm ditches where high flow velocities do not prevail. Following the common observation that anthill withstand adverse weather condition, it is proposed to investigate the suitability of anthill material for use as impervious materials on canal bed to reduce seepage of water.

Termites are found in about 2/3 of land area of the world but are more prominent in the grassland (savannas), forest-zone, tropical and subtropical (both humid and semi arid zones). The quantity of soil material incorporated into termites' mounds can be enormous up to 2.4million kg/ha has been recorded. Depending on the species involved and on environmental conditions, termites may build mounds up to six (6) meters or more in height and may extend them to greater depth into the soil in search of water or clay layers (Brady and Weil, 1999).

The study therefore, looks at anthill as an alternative canal lining materials that are locally available, less expensive and compatible with other conventional materials.

MATERIAL AND METHODS

The experiment was conducted at the irrigation farm in Bajabure, Girei Local Government, Adamawa State, Nigeria. The location of the area is latitude 9^0 11' and 9^0 39' north and longitude 12^0 21' and 12^0 49' East with a total landmass of 2,186 sq km. The area has distinct dry and wet seasons with temperature and humidity varying with season. 70% of the total rainfalls in the area happen to fall within 4 months of May – August with an average of 62 rain days, while the average amount of rainfall recorded is 972mm. Temperature ranges from 27^oc – 40^oc and the natural vegetation of the area is the Sudan savannah type. The soil is a fertile alluvial deposit with poorly developed soil deposit due to the probable geological youthfulness of the soil (U.B.R.B.D.A, 1983).

The sources of irrigation water to the farms are Lake Gerio and River Benue.

The field of study was divided into three equal parts (I, II, II) and representative sample of the anthill material were collected by excavation at different points. Particle size distribution analysis was conducted on the soil samples using the sieve and hydrometer methods to determine the percentage sand, silt and clay. The organic matter content was determined using the standard Walkley – Black method. The compaction characteristics was determined using the standard compaction mould and rammer at 25, 27 and 55 rammer blows following proctor compaction, British standard (BS), West African standard (WASC), and Modified AASHO respectively (Stirling Civil Engineering, 2005). The permeability (saturated hydraulic conductivity) of each soil sample was measured using the falling head permeameter, while dry bulk density and optimum moisture content were determined by the standard methods (Walker, 2002).

Field compaction method was also carried out by putting the anthill material into an excavated canal as a lining material and a rammer of 4.0kg attached to an iron handle was used to compact the material in three layers to the thickness of 150mm (Vazirani and Chandola, 1985).

For field evaluation of the anthill material, a trapezoidal channel of size a x b x c cm were dug. The channel was allowed to cure, thereafter, it was impounded with water to a certain level. The surface of the water was sealed up with black engine oil to eliminate surface evaporation. Seepage measurement of the lined canal was done by adopting the inflow and outflow method by selecting a 50m reach of the canal under investigation. Discharge observations were taken at the beginning and end of the reach for seven consecutive days. By monitoring the level of water until when the seepage rate became relatively constant. The rate at which water was lost along the canal was also investigated by installing two 90^0 V – notch weirs at the entrance point (head) and the tail of the canal. The V-notch at the head of the canal measured the quantity of water (Q_1) that flows into the testing portion of the canal, while the second V – notch at the tail of the canal measured the quantity of water (Q_0) flowing out of the testing portion of the canal. The loss of water by seepage was the difference between the water inflow and outflow through the V-notches ($Q_1 – Q_0$). The loss was expressed as depth of water lost in a day over area of wetted perimeter (Punmia and Lal, 1990).

The results of the amount of canal seepage losses obtained for the material were compared with the existing values for other materials and were also subjected to statistical analysis (ANOVA) to determine level of significance of the results.

RESULTS AND DISCUSSIONS

Table 1 shows the summary test data on Anthill soil sample. The physical composition of the anthill soils was dominated by the presence of sand size particles while silt and clay content are relatively small in all the samples. The texture of the anthill soil was

found to be sandy loam and it was observed to remain unchanged for all samples tested.

Table 1: Some Physical Properties of the Anthill soil Samples

Sample no.	Particle size distribution (%)			Textural class	Organic carbon (%)	Organic matter (%)
	Sand	Silt	Clay			
I	62.2	24.8	13.0	Sandy loam	1.18	2.03
II	61.0	25.5	13.5	Sandy loam	1.17	2.01
III	59.8	21.6	18.6	Sandy loam	1.13	1.94
Mean					1.16	1.99

The result for the amount of organic matter content observed in the tested soil samples as shown in Table 1 revealed that the mean value of organic matter content in samples was 1.99%. According to soil testing laboratories in Utah Pradesh, the result of percentage of organic carbon contained was high if it is greater than 0.80%. Organic matter is important for soil structure, while the degree of aggregation of individual soil particles is important in soil and water relationship studies. The amount of organic matter found in the soil samples may have been incorporated into the anthill material as plant residues the termites used as food.

Table 2 shows the compaction test carried out on the soil sample. The laboratory compaction test was aimed to serve as a guide for comparison of field compaction as reported by Singh, (2002). For all types of soil and with all method of compaction, the effect of increasing the compactive energy is to increase the maximum dry density and to increase the optimum moisture content

Dry density values increase with increased moisture content for the material at 25, 27 and 55 compaction blows. Density values increased until optimum moisture content were attained. Further compaction beyond these levels resulted in lower dry density values. The average values conformed with the average values of other soil groups obtained under standard proctor compaction and agreed with the relative desirability of soil for compacted earth lining of canal section as reported by Singh (2002). The results of dry density and moisture content for the field compacted material stood at 2.08g/cm^3 and the corresponding optimum moisture content values was 8.21%.

The field compaction value obtained for maximum dry density is higher than that obtained in the laboratory compaction, also the optimum moisture content value in the field is higher than that obtained in the laboratory. This could be as a result of the adequate compaction of the materials in the field.

Table 2: Results of Dry Bulk Density and Moisture Content for the anthill soil

Sample number	Number of blows (Level of compaction)	Dry Bulk Density (g/cm^3)	Moisture Content (%)
I	27	1.81	2.06
	25	1.89	7.05
	55	1.86	9.00
II	27	1.96	2.00
	25	1.99	4.52
	55	1.90	6.20
III	27	1.98	2.20
	25	2.02	3.97
	55	1.94	6.10

The permeability test conducted on each of the compacted material is presented in Table 5. The values obtained varied with the amount of compaction. In descending order, the values are 3.4 x 10^{-2} m/day, 1.98 x 10^{-2} m/day and 1.23 x 10^{-2} m/day for various level of compaction I, II and III respectively. The decrease in the value (K) can be attributed to the reduction in pore spaces as a result of increasing the compactive energy, which decreases the rate of water movement as reported by Jaiswal (2004) and Singh (2002).

Table 3: Coefficient of permeability of the compacted samples

Compacted samples	Level of compaction	Coefficient of permeability K (m/day) ++	Permeability class △	Permeability Rating *	Seepage rate $m^3/m^2/day$
I	27	3.4 x $10^{-2\,++}$	Slow	Impervious	9.93 x 10^{-3}
II	25	1.98 x $10^{-2\,++}$	Slow	Impervious	6.39 x 10^{-3}
III	55	1.23 x $10^{-2\,++}$	Slow	Impervious	2.59 x 10^{-3}

++ = Values are means of three replications

△ = Class according to Jaiswal (2004)

* = Rating after Singh (2002)

The estimate of seepage rate calculated from the coefficient of permeability for each of the compacted samples is presented in Table 6. From the table, it can be seen that the rate of seepage is proportional to the coefficient of permeability. Also increase in level of compaction to the samples decreases the seepage rate values. The trend of result obtained could be due to reduction in the pore geometry of the samples. Ohu et al (1985) reported that the flow of water in the soil is mostly affected by change in volume, size and shape of voids resulting from compaction.

The mean values of inflow and outflow heads of water, calculated mean seepage losses from the inflow and outflow data using BS 3680 and

USBR equation are presented in Tables 4, 5 and 6 respectively. From the field test data the actual inflow and outflow discharge were established. Other parameters such as losses and seepage rate were determined. The discharge equations

$Q_{act} = 8/15 \sqrt{2g}C_D \tan\theta/2 \bullet h^{5/2}$ and $Q_{act} = 2.49h^{2.48} C_D$ revealed the calculated mean seepage rate of 2.57 x 10^{-4} $m^3/day/m^2$ and 2.10 x 10^{-4} $m^3/day/m^2$ respectively. From this result, the anthill soil can be classified as impervious as shown in Table 4 above hence; the anthill material satisfied virtually the requirement for use as lining materials for irrigation canals. More so, these values are 3 to 4 times less than that obtained in the case of the unlined canal or about 75% improvement. This proves that management or savings of irrigation water could be by lining.

Table 4: Mean values of inflow and outflow Head of water in lined canal.

Measurement number	INFLOW				OUTFLOW			
	Head of water (m)				Head of water (m)			
	I	II	III	Mean	I	II	III	Mean
1.	0.048	0.052	0.050	0.050	0.047	0.050	0.050	0.049
2.	0.068	0.070	0.069	0.069	0.065	0.068	0.069	0.067
3.	0.058	0.056	0.058	0.057	0.055	0.055	0.057	0.055
4.	0.051	0.050	0.050	0.048	0.050	0.048	0.046	0.048
5.	0.060	0.058	0.056	0.058	0.058	0.058	0.054	0.056
6.	0.057	0.058	0.055	0.056	0.055	0.056	0.054	0.055
7.	0.048	0.052	0.050	0.050	0.050	0.050	0.048	0.048

Source: Field measurement (2005).

Table 5: Calculated Mean Canal Seepage Losses from the inflow and outflow Data using BS 3680

Measurement number	Inflow discharge (Q_1) (m^3/s)	Outflow discharge (Q_0) (m^3/s)	Losses (Q_1 – Q_0) (m^3/s)	Seepage Rate (q) $m^3/day/m^2$
1.	7.68 x 10^{-7}	7.03 x 10^{-7}	3.80 x 10^{-8}	1.36 x 10^{-4}
2.	1.71 x 10^{-6}	1.59 x 10^{-6}	1.20 x 10^{-7}	4.15 x 10^{-4}
3.	1.06 x 10^{-6}	9.75 x 10^{-6}	8.50 x 10^{-8}	2.94 x 10^{-4}
4.	6.94 x 10^{-7}	6.24 x 10^{-7}	7.00 x 10^{-8}	2.43 x 10^{-4}
5.	1.11 x 10^{-6}	1.01 x 10^{-6}	9.00 x 10^{-8}	3.11 x 10^{-4}
6.	1.02 x 10^{-6}	9.75 x 10^{-7}	4.50 x 10^{-8}	1.55 x 10^{-4}
7.	7.68 x 10^{-7}	6.94 x 10^{-7}	7.40 x 10^{-8}	2.56 x 10^{-4}
Mean	1.01 x 10^{-3}	8.12 x 10^{-4}	7.45 x 10^{-5}	2.57 x 10^{-4}

Source: Field data (2005)

Table 6: Calculated Mean Canal Seepage Losses from the inflow and outflow Data using USBR Formula.

Measurement number	Inflow discharge (Q_1) (m^3/s)	Outflow discharge (Q_0) (m^3/s)	Losses (Q_1 – Q_0) (m^3/s)	Seepage Rate (q) $m^3/day/m^2$
1.	8.60 x 10^{-7}	8.18 x 10^{-7}	4.20 x 10^{-8}	1.45 x 10^{-4}
2.	1.91 x 10^{-6}	1.77 x 10^{-6}	1.40 x 10^{-7}	4.84 x 10^{-4}
3.	1.19 x 10^{-6}	1.09 x 10^{-6}	1.0 x 10^{-8}	3.46 x 10^{-4}
4.	7.77 x 10^{-7}	7.77 x 10^{-7}	0	0
5.	1.24 x 10^{-6}	1.13 x 10^{-6}	1.10 x 10^{-7}	3.8 x 10^{-4}
6.	1.13 x 10^{-6}	1.09 x 10^{-6}	4.0 x 10^{-8}	1.38 x 10^{-4}

7.	8.60×10^{-7}	7.77×10^{-7}	8.3×10^{-8}	2.87×10^{-4}
Mean	1.13×10^{-3}	1.06×10^{-3}	7.35×10^{-5}	2.10×10^{-4}

Source: Field data (2005)

CONCLUSION

An attempt to estimate seepage based on average soil permeability yielded relationship between soil permeability and seepage rate. The rate of seepage is proportional to the coefficient of permeability. Increase in the level of soil compaction decreases the seepage rate values. These features if well exploited are good indices for assessing the suitability of anthill soil to reduce canal seepage loss. Attention is hereby drawn to the use of anthill material as an alternative canal lining material because the quality parameters measured compared favorably with the existing soil type. The prospect of combining anthill with other commonly used soil materials (clay, sand etc) for compacted earth lining in canal sections need to be investigated.

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THE EFFECTS OF SOIL AGGREGATE AND MOISTURE CONTENT ON AIR PERMEABILITY OF A NEW VERTISOLS MARTE, BORNO STATE, NIGERIA

BY

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ABSTRACT

Soil of 20cm depth of the virgin soil profile of New Marte vertisol was taken for the study. The soil was air dried and passed through 2 mm, 2 – 4 mm, 4 – 6 mm and 6 – 8 mm sieves to obtain four different aggregate sizes. The samples were divided into seven parts each and each part was mixed at different moisture content levels of 5, 10, 15, 18, 20, 25 and 30 per cent respectively. Measurement of air permeability was done, using the air permea-meter, after stabilizing the soil. Statistical analysis of the air permeability – moisture content relationship shows that Pearson correlation coefficient, $r^2 = 0.5103$, using REGRATION procedure. The results indicate that air permeability decreases with increase in moisture content, and increases as the particle size increases.

INTRODUCTION

Vertisols as a soil name was introduced in 1960 for those soils formerly called Grumusols (Soil Survey Staff, 1960). The formative element ert, from the Latin word verto which means turn, was chosen as the basis for a soil order that would include Grumusols of the United States and Tropical Black Clays, Black Cotton Soils, Tirs, Regurs, and Black Earths of other countries.

Features of vertisols are high clay content, high shrink – swell potential, cracks that are open to the surface at some period of the year; most vertisols are dark in colour, low in organic matter and alkaline or near-neutral in reaction (Soil Survey Staff, 1975).

Vertisols are a unique soil resource that comprises nearly 260 million hectares on the face of the earth (Ahmed, 1983). The genesis of these soils is strongly influenced by soil movement and turbation.

Good soil aeration is essential to plant growth. Soil aeration is dependent on the size-range and quantity of soil macro-pore spaces through which gases can move and diffuse freely within the soil and by which soil air can be constantly replenished from the atmosphere (Fariran, and Areola, 1978).

Permeability of soil is its capacity to transmit water and air through its self. The amount of air available to a crop after different tillage practices will help farmers and researchers plan effectively the tillage practices required for a given crop. Air availability can be obtained in the field only if there is an equipment to measure the rate of movement of the air in different agricultural fields. This lead to the development of an air permeameter by Ndirmbita (1989), which was calibrated and found suitable for use in agricultural research.

Bowen and Coble (1966) in their table for environmental and emergence data for irrigated and non-irrigated plots, found that average air permeability of 33.414×10^{-8} cm^2 over a period of seven days resulted in 100% emergence of seeds while lesser values registered almost 0% emergence. This experience indicated how important soil air is for germination of seeds.

Air movement in soils is influenced by many environmental factors such as temperature, barometric pressure and rainwater or irrigation water occupying pore spaces, and action of winds (Baver, 1972).

Grover (1955) suggested an equation based on Darcy's law that air permeability of a soil is inversely proportional to the viscosity, which is a temperature dependent factor.
The equation was given as

$$V/t = kF\,Dp/n \quad \text{……..(i)}$$

Where:

V = Volume of air forced into the soil (cm^3)

Dp = Gauge pressure ($dyne/cm^2$)

F = Constant which depends on the geometry of the air flow boundaries in the soil (cm).

n = Viscosity of air poise

t = Time taken for a given volume of air to move through the soil (sec).

k = Air permeability

Air permeability was calculated in absolute units (μ^2) by (Grover) 1955 equation.

"F" in the equation is a constant which depends on the geometry of the air flow boundaries in the soil (cm).

D = Inside diameters of access tube 20cm

L = Depth of accession = 10cm

D/L = Z, this is used to find the value of F/L.

Dp = pressure difference occurring with the manometer as the float goes down, it is read just few second before readings of the float is taken.

Pressure due to fluid is given by:

$$P = \delta gh \quad \text{…….(ii)}$$

Where

δ = Density of water = ($1000\ kg/m^3$)

g = Acceleration due to gravity = ($9.8 m^3/s$)

h = $y_1 - y_2$

y_1 = Initial water level in the manometer (cm)

y_2 = Final water level in the manometer (cm)

Dp = $\delta g y_1 - \delta g y_2$

$\therefore$ Dp = $\delta g (y_1 - y_2)$

MATERIALS AND METHODS

The New Marte vertisol was used for the purpose of this experiment. Four different aggregate sizes were prepared by passing the sample through 2 mm, 2 – 4 mm, 4 – 6 mm and 6 – 8 mm sieves.

A small portion of the soil was taken and oven dried in order to determine its initial moisture content. After the initial moisture content determination, the samples were divided into seven parts each, and each part mixed at different moisture content of 5, 10, 15, 18, 20, 25 and 30 per cent.

The mixtures of the soils were put into polythene bags to avoid moisture loss, for 24 hours to stabilize the soils. After stabilizing the soils, each part was put into square mold of 22 x 22cm, and at each moisture content, air permeability was determined by the use of the air permeameter, which was developed and calibrated by Ndirmbita (1989).

RESULTS AND DISCUSSION:

The results obtained from the work carried out are shown in the Table below:

RESULTS:

Moisture Contents (%)	Air Permeability (μ^2) Soil Aggregate			
	2 mm	2-4 mm	4-6 mm	6-8 mm
5	38.18	53.10	87.78	99.95
10	34.50	48.26	74.27	94.53
15	23.60	35.45	57.39	81.45
18	20.91	29.54	52.21	59.24
20	16.52	24.50	48.52	52.45
25	9.46	18.72	28.49	30.52
30	4.51	9.85	18.12	21.50

From the results obtained, for 2 mm soil aggregates, at 5% moisture content, the air permeability was $38.14\mu^2$, while at 30% moisture content, the air permeability was $4.51\mu^2$. This shows that air permeability decreases with increase in moisture content. However, crops germinate faster at lower moisture content than at higher moisture content.

Similarly, at smaller particle size, less air will penetrate into the soil, while at larger particle size more air will penetrate into the soil. For example, for 2 mm soil aggregate at 5% moisture content the air permeability was $38.14\mu^2$, also for 6 – 8 mm soil aggregate at the same per cent moisture content, the air permeability was $99.95\mu^2$. This shows that air permeability increases as the particle size increases and crops germinate faster on larger particle sizes than on the smaller particle sizes.

From the results obtained, it has been found that aggregate sizes and moisture content significantly affect air permeability of the soil.

CONCLUSION

It could be concluded here that:

i. Air permeability decreases with increase in the moisture content.
ii. Air permeability increases with increase in the size of soil aggregates.

RECOMMENDATIONS

The following were recommendations suggested for application:

i. Factors that compact soil should be avoided, e.g. Heavy machinery on the field in order not to damage the soil structure.
ii. Favourable moisture content should be considered, before any work is undertaken on the field.

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SECTION 3

POST HARVEST ENGINEERING

DEVELOPMENT AND PERFORMANCE EVALUATION TEST OF A MOTORISED CASSAVA MASH SIFTER

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ABSTRACT

A motorised cassava sifter was developed and evaluated. The sifter is powered by a diesel engine, the overall dimension of the machine is 1,117 x 1045 x 500mm.
Test result show that the sifter has the highest sifting efficiency of 90.00% at 48% moistore content (wet basis) at the sifting speed of 450 rmp. Output capacity of 132.35kg/hr was obtained and this increases as the moisture content of the cassava mash in creases. From 40-48%.
The particle size analysis of the sifted mash ranges from 0.378 to 0.38mm while the fineness modules is 1.91 the machine is affordable and adequately manageable therefore recommended for the small scale cassava processor.

KEY WORDS: Development, Cassava, Sifter, Motorised

INTRODUCTION

Cassava is one of the most important food crop grown in tropical

Africa , because of its efficient production of food energy, year-round availability and tolerant of extreme environmental stresses making it eminently suitable for farming [IITA, 1989]. Cassava consists of 60 –70% water, processing it in to a dry form reduces the moisture content and product with less volume, which makes it more transportable. Processing is also necessary to eliminate or reduce the level of cyanide in cassava to 5mg or less per 100g for low- cyanide cassava or 10mg or more per 100g for high cyanide cassava varieties. Thus improving the palatability of the food products. [IITA, 1990]

Approximately two-thirds of the cassava used in Africa for food is eaten after specialized traditional processing, usually at the farm or village level. The processing method comprises combination of some of the following activities: peeling, boiling, steaming, slicing, grating, soaking, fermenting, pounding, frying, pressing, sitting and drying. Such traditional processing is done mainly by women and it requires a high labour input, time consuming especially for peeling, grating and sifting. Thus high processing loses are sometime incurred while the processors are exposed to health hazards, also unhygienic processing condition may contaminate such products as in the case of sifting cassava mash using local sifter (raffia made sieve) [IITA, 1990].

Traditionally, cassava roots are processed by various methods into different products and used in diverse ways. Therefore, improvement of post harvest product and processing techniques in cassava would greatly decrease labour, increase efficiency, productivity, raise income and standard of living for cassava farmers, and cassava processing entrepreneur. It would also enhance the shief life of the product and make their transportation easier, improve marketing opportunities and upgrade their nutritional value.
Cassava sifting is one of the unit operation in the processing of cassava tubers to gari. But with the advent of motorised cassava sifter now available , large percentage of grated cassava are still been sifted manually using local sieves made from plant materials.

Pulverisation of pressed mash/sieving of dewatered mash is necessary to achieve efficient heat transfer during frying. OAU Ife research group (1998) reported that in Osun and Ondo State, manual sieving method is still dominated (84.6%) and 15.4 % of processors

use the machined and of these 66.7 % utilize the grater, while the remaining 33.3% use the mechanical shaker. They also reported that the mechanical shaker is unreliable while some processors sieve the pulverised material with raffia sieve after using the grater this is because the grater dose not remove the fibre but only achieve further size reduction.
The raffia sieve on the other hand has a major complain in the sifting position because, it requires bending and stretching which result in aches and pain on the back and sometime may injure the person carrying out the sifting operation.

The NCAM developed motorised sifter has eliminated all the drudgery and danger associated with the use of raffia sieve.

Fig 1 shows the flow chart for the production of cassava tubers into gari

OBJECTIVES

To develop an efficient motorised cassava mash sifter that would increase gari production with a multiplied effects on the earnings of the Nigerian farmers.

DESIGN FEATURES

The hopper

This is made of galvanized iron sheet of gauge 1.5mm. The hopper is square at the top with dimension 60x360x360mm it is then shaped as a prism with 220 x 360 x 360mm and finally square again of dimension 4x80x80mm.

The Stopper

It is made of flat-galvanized Iron sheet and rectangular in shape. It is 150mm by 80mm and bent at an angle 45 upward to serve as the handle. This is slotted in and out through a clearance of 2mm which is the clearance between the hopper and the upper cover. It serve as a regulator for the flow of the cassava mash into the sifting chamber.

Top Cover

It's made of galvanized Iron sheet of guage 1.5mm, concave in shape with length of 800mm and width of 400mm. The top cover encloses the sifting unit and the hopper is connected to the top cover with bolts and nut.

The Sifting Unit

It is made of a shaft of 980mm long and diameter 25mm. On the shaft are welded 16mm rod, arranged alternatively, at the ends of the rods are welded 16mm flat bars with two holes drilled on them through which are bolted bristle scrubbing brushes that does the pulverisation. Four 6mm rod are welded to the main shaft. These serve as spikes and are between the first two brushes arranged alternatively. The spikes assist in breaking the Cassava mash lumps.

The Brushes

These scrubbing brushes are made of wood and raffia tips. They are 6 in numbers and are connected to the main shaft via 18mm rod. And does the actual pulverization by rubbing the cassava mash against the sieve.

The Sieve

The sieve is made of 1.5mm thick stainless steel and concave in shape with length 800mm and diameter of 400mm. It is perforated all through and the size of the hole is 2mm. These is a rubber seal in between the upper cover and the sieve, this prevents cassava mash being sieved from escaping from the sifting chamber.

The Outlet

The outlet is rectangular in shape with length 830mm, width of 480mm and height of 250m, it also tapers from height 250mm downward. The outlet is below the concave sieve.

Residue Outlet

This is made of galvanized iron sheet of guage 1.5mm It is welded to the main frame and this is where residue from the sifted cassava mash passed into the collection trough.

Collecting Trough

It is made of galvanized iron sheet of gauge 1.5mm it's 830mm x 480mm x 750mm. This is where the residues from the sifting chamber are being collected.

The Frame

The frame is made of an angle iron with length of 900mm, width of 500mm and height of 800mm.

DESIGN CONCEPT

The machine was design based on the concept that sifting is by rubbing the cassava mash on two surfaces (The sifting unit and the sieve). The design of the concave canopy is such that there is decreasing gap exist between the brushes and the concave canopy with a maximum clearance of 75mm at the top. This allows the mash fed into the hopper flows down the sifting chamber. The clearance decrease as the sifting unit moves to the side of the concave canopy (angle ø= 0). It then increase gradually to a clearance of 1.5mm at the bottom where the sifting unit [brushes] rub the mash against the sieves thus effecting sifting . The particles of sifted mash that are of the same sizes as the sieve passes through while bigger ones which are the ungrated cassava root parts and fibres are retained and converged to the residue collecting trough by the sifting unit which also serves as an auger. Fig 3 shows the exploded view of the motorised sifter.

OPERATION OF THE MACHINE

When the prime mover is energized to propel the shaft, cassava mash is introduced through the hopper provided at the upper concave cylinder. A stopper, situated inbetween the neck of the hopper and upper concave cylinder regulates the flow of cassava mash into the sifting chamber. As the mash flows down by gravity into the sifting chamber through the spaces in between the alternatively arranged brushes, the lumps are broken down by the rods and these is further robbed on the sieves by brushes.

Cassava fibres and parts of cassava root that were not properly grated are conveyed as residue by the sifting unit which also act as an auger into a collecting trough.
Fig 2 show the isometric view of NCAM motorised sifter.

PERFORMANCE TEST

Test Methodology

The NCAM motorized cassava sifter was tested at speed between 340-500rpm. 15kg of cassava mash was weighed in three replication and the moisture content determined before the test.

Result from the motorised sifter were compared with that of the mechanical (manual) and traditional sitter using following parameters:

a. Time of feeding
b. Time of sifting
c. Weight of sifted mash
d. Weight of residue

After sifting, sample of sifted mash from each method was analyzed in order to determine the particle size and fineness modulus using the Tyler sieves analysis method at the end of the test analysis and the following were calculated.

a. Throughput Ic (kg/hr): This determines the input capacity of the sifter and it is expressed as:

$$Ic\ (kg/hr) = \frac{W_1}{T_2}\ kg/hr \quad \ldots\ldots\ldots\ldots(1)$$

Where W_1 = Initial weight of the cassava mash (kg)
T_2 = Time of sifting (min)
Ic = Input capacity (kg/hr)

b. Output Capacity (kg/hr) O_c: This determines the quality of cassava mash sifted per hour and is expressed as

$$O_c = = \frac{W_2}{T_2}\ kg/hr \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where: O_c = Output Capacity (kg/hr)
W_2 = Weight of sifter mass (kg)
T = Time of sifting (min)

c. Sifting Efficiency (%): This determines how efficiently the Cassava Sifter is sifting and is expressed as:

$$Es\ (\%) = \frac{W_2}{W_1} \times 100\% \quad \ldots\ldots\ldots\ldots\ldots 3$$

Where: Es (%) = Sifting efficiency
W_2 = Weight of Sifter mash (kg)
W_1 = Initial weight of Cassava mash (kg)

d. Fines Modules FM: This shows the uniformity of the sizes of the sifted cassava mash and is calculated by the equation

$$F.M. = \frac{\Sigma(\text{Percentage materials retained} \times \text{Pan No})}{100} - 4$$

e. Particle size analysis (mm): This is done to determine the sizes of the particles produced from the sifter and

is indicated by a modules number F.M and is calculated by the equation.

$D_m = 0.0041 \times 2.54(2)^{FM}$ (mm)…….5

RESULT AND DISCUSSIONS

The machine was tested at operating speeds of 340, 450 and 500 rpm respectively using cassava mash samples of 40, 46, and 48% m. c. wb in line with IITA/UNICEF 1990.

At 450rpm and 48% M.C. (wet basis) the machine has the highest output capacity of 132. 35kg/hr with sifting efficiency of 90.00%. As the speed of the sifter increases from 340 to 450rmps the output capacity increases it then decreases as the speed increase to 500rmp. It implies that some of the mash that were supposed to be sifted has been conveyed along with the residue because the operating speed was too high for the sifting unit to adequately sift the cassava mash thus leading to decrease in quantity of cassava mash sifted.

The test result was compared with mechanical and traditional (local) sifter at the same varying moisture content (wet basis) 40, 46 and 48%. The manual sifter has a capacity of 70.kg/hr while local sifter has 28.29kg/hrs being the lowest. The local sifter has the highest operating time of 30.26min followed by the manual sifter with 12minutes and the motorised sifter has the least 6.10minutes as shown in Table 1,2 & 3.

The particle size analysis shows that the sizes of sifted cassava mash obtained from the motorised sifter is 0.38mm and fineness modulus is 1.91 while that from manual sifter is 0.37mm with 1.92 fineness modulus and that for local sifter is 0.4mm and 0.70 for particle size and fineness modulus respectively.

Fig. 4 shows the graph of output capacity against moisture content for motorized, mechanical (manual) and local sifter respectively.

CONCLUSION

The motorised cassava sifter was observed to perform efficiently at all the sifting speed when compared with mechanical and local sifter. However, the highest sifting efficiency of 90 .00% was obtained at sifting speed of 450rmp and at moisture content of 48% which is within the range of the recommended moisture content required for sifted cassava mash before frying into gari, IITA/UNICEF, 1990.

The values of the out put capacity obtained was very high which means more of the cassava mash being sifted are recovered.

The particle size of the sifted mash obtained (0.388mm) is within the required size as those of the local gari processors which is 0.4mm

The motorised sifter is therefore considered appropriate for small and medium scale farmers that may want to go into gari processing.

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Table 1 Average Performance Evaluation Indices of NCAM Motorise Cassava Mash Sifter

Speed of prime mover (rpm)	Speed of sifter (rpm)	Moisture content of cassava mash (%)	Weight of cassava mash W_1 (kg)	Time of sifting T (MIN)	Weight of sifted cassava W_2 (kg)	Weight of residue W_3 (kg)	Input capacity (kg/hr)	Output capacity (kg/hr)	Sifting efficiency (%)	
2000	340.00	40.00	15.00	7.23	12.93	1.70	123.97	106.86	86.20	
2500	450.00	40.00	15.00	6.88	11.81	2.95	130.98	102.70	78.33	
3000	500.00	40.00	15.00	6.09	11.58	2.37	134.46	113.53	77.20	
2000	340.00	46.00	15.00	7.00	12.82	1.80	128.21	109.77	85.47	
2500	450.00	46.00	15.00	6.60	12.90	2.83	136.36	117.27	86.00	
3000	500.00	46.00	15.00	6.50	12.10	1.60	138.89	112.04	80.67	
2000	340.00	48.00	15.00	6.32	13.00	0.89	123.81	123.81	86.67	
2500	450.00	48.00	15.00	6.10	13.50	0.95	132.35	132.35	90.00	
3000	500.00	48.00	15.00	6.00	13.10	0.90	131.00	131.00	81.33	

Value are means of three replication

Table 2: Average Performance Evaluation Indices Test Mechanical (Manual) Sifter

Moisture content of cassava mash (%)	Weight of cassava mash W_1 (kg)	Time of sifting T (MIN)	Weight of sifted cassava W_2 (kg)	Weight of residue W_3 (kg)	Input capacity (kg/hr)	Output capacity (kg/hr)	Sifting efficiency (%)	Particle size of sifted mash (mm)	Fineness modulus (FM)
40	15.00	12.50	13.60	1.20	72.12	65.39	90.63	0.37	1.92
46	15.00	12.20	14.00	0.85	73.89	68.97	93.33	0.37	1.92
48	15.00	12.00	14.17	0.80	75.00	70.85	94.47	0.37	1.92

Value are means of three replication

Table 3 Average Performance Evaluation Indices Of Local (Rafia Made) Sifter

Moisture content of cassava mash (%)	Weight of cassava mash W_1 (kg)	Time of sifting T (MIN)	Weight of sifted cassava W_2 (kg)	Weight of residue W_3 (kg)	Input capacity (kg/hr)	Output capacity (kg/hr)	Sifting efficiency (%)	Particle size of sifted mash (mm)	Fi mo (Fl
40	15.00	32.00	13.00	1.02	27.42	23.77	86.67	0.40	0.7
46	15.00	31.20	13.90	1.00	28.85	26.73	92.67	0.40	0.7
48	15.00	30.26	14.23	0.93	29.76	28.29	94.87	0.40	0.7

Value are means of three replications

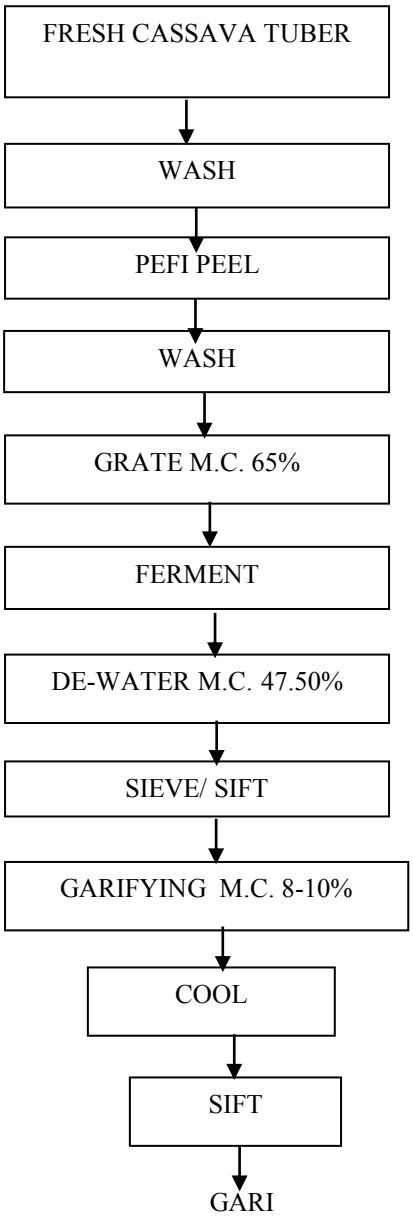
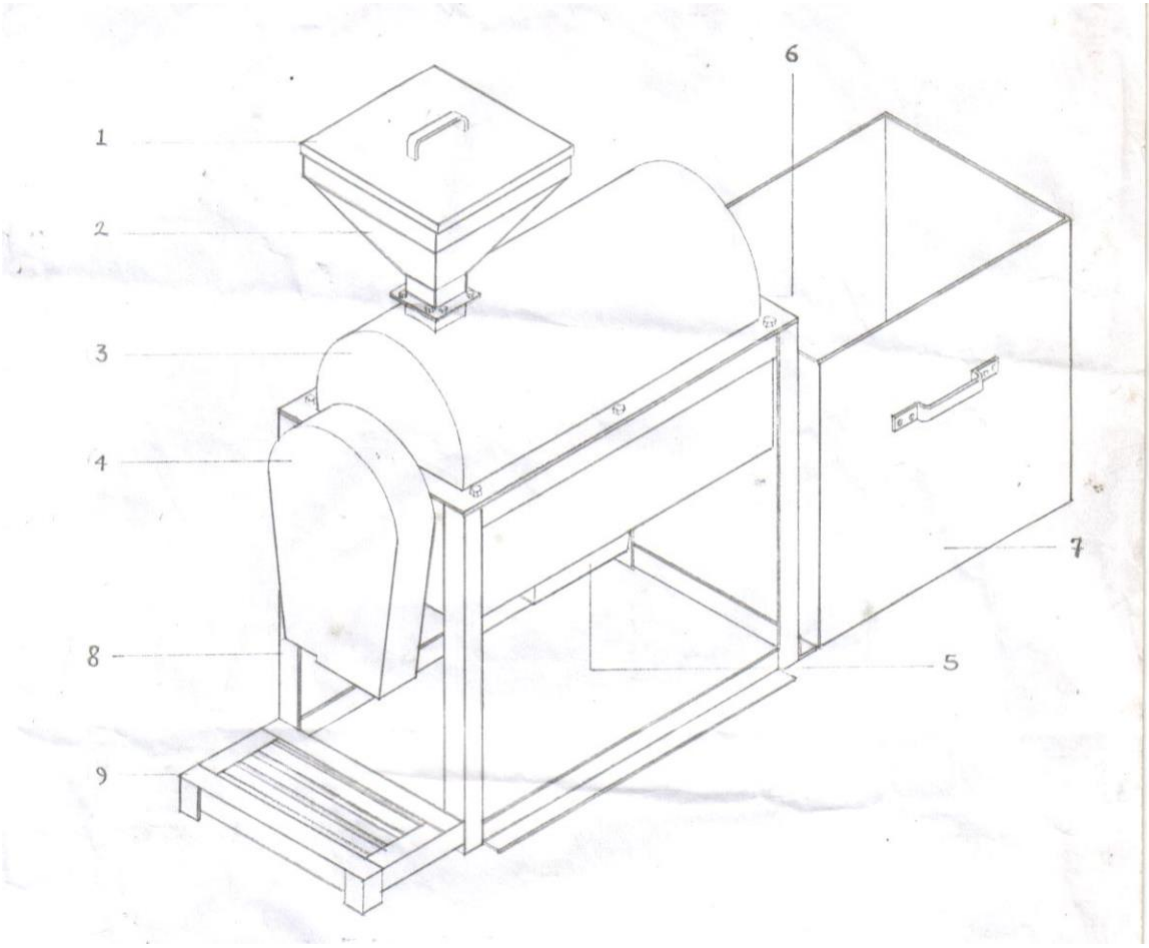


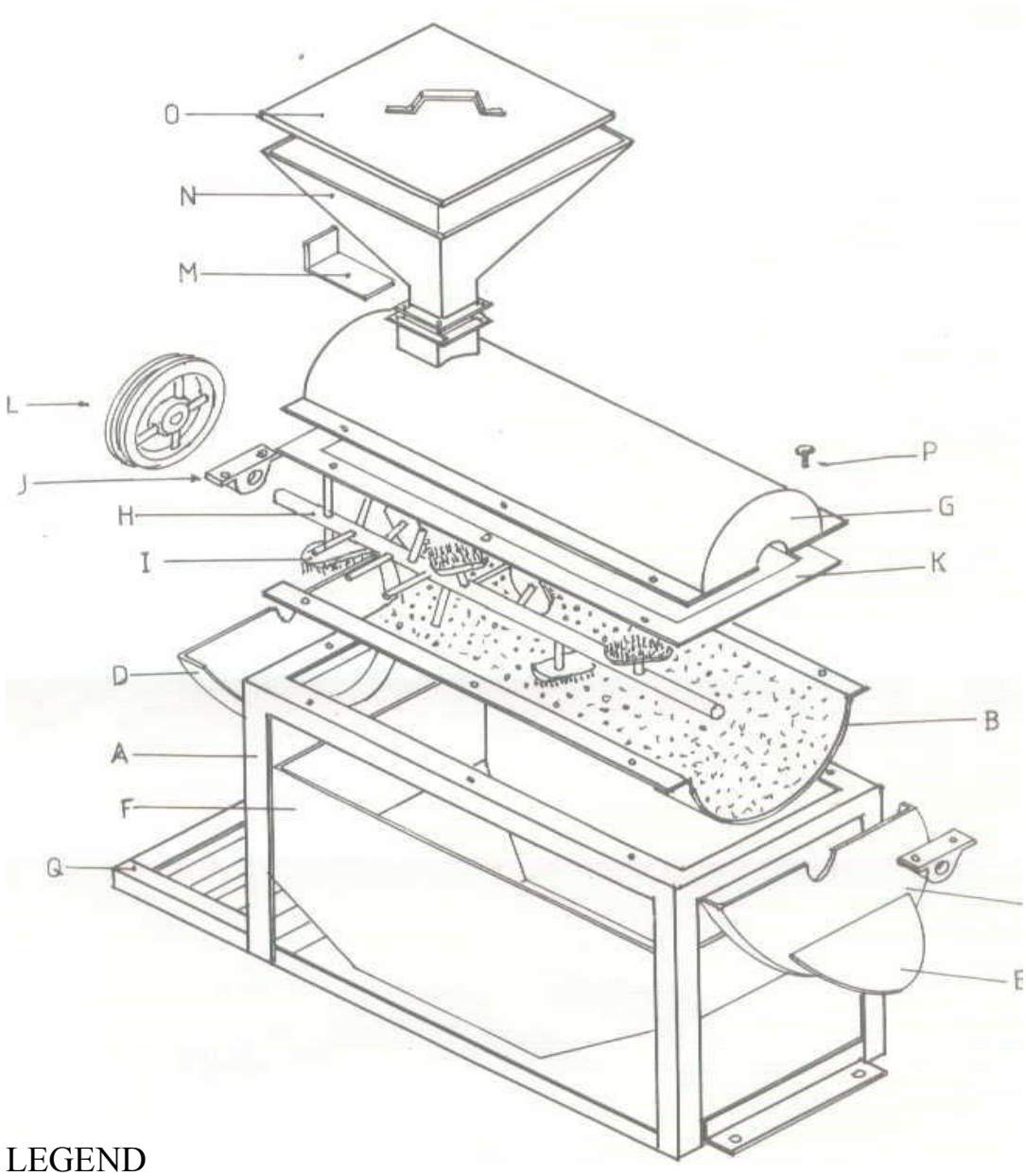
Fig. 1 Flow Chart for the Production of Cassava Tubers in to Gari



LEGEND

1. HOPPER COVER
2. HOPPER
3. TOP SIEVE COVER
4. BELT GUARD
5. SIFTED-MASH OUTLET
6. CHAFF OUTLET
7. THROUGH
8. MAIN FRAME
9. EIGINE SEAT

Fig. 2: Isometric view of Motorised Cassava Mash Sifter.



LEGEND

A. Main frame	G. Top cover	M. Metering device
B. Sifting net	H. Central shaft	N. Hopper
C. End cover I	I. Shifting brush	O. Hopper lid
D. End cover II	J. Pillow bearing	P. Bolt
E. Chaff outlet	K. Seal	Q. Prime mover
F. Shifted mash outlet	L. Pulley	

Fig 3: Exploded View of the motorised cassava sifter

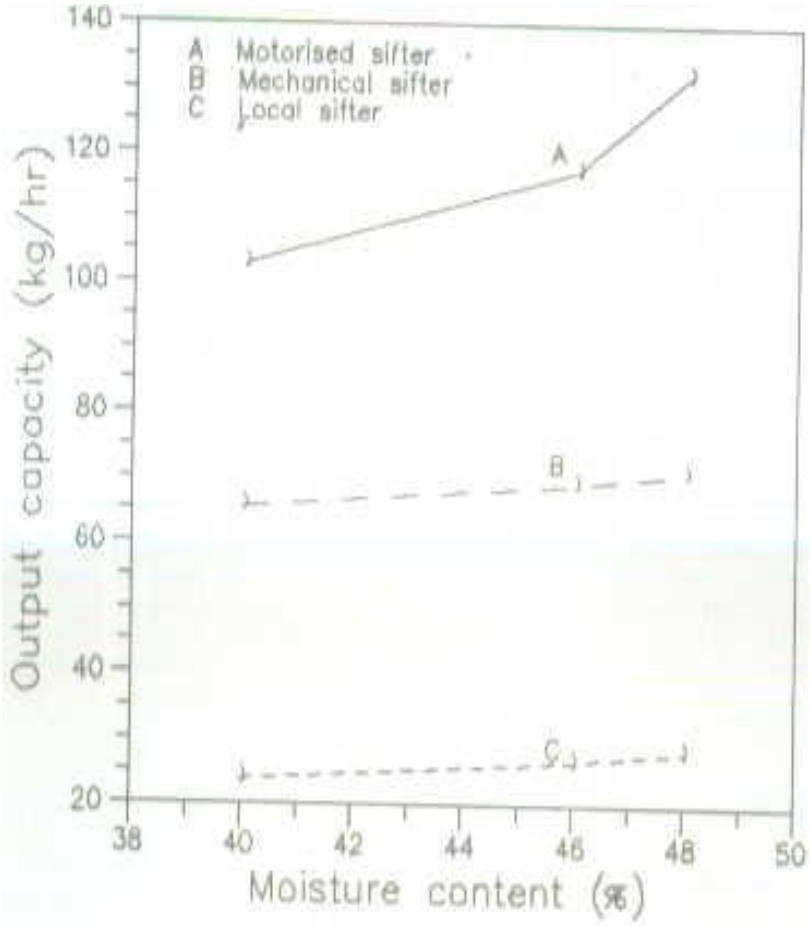


Fig 4: Graph of Output Capacity against Moisture content of the three Cassava Sifters

TECHNOLOGY INNOVATION AND ADOPTION: A CASE STUDY OF IMPROVED RICE PARBOILER ADOPTION IN KAFIN GANA VILLAGE OF JIGAWA STATE.

By

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ABSTRACT

Parboiling, an important operation in rice processing, is being undertaken with poor and inefficient tools in Kafin Gana village despite the large yearly production of rice in the area. An improved parboiler was introduced using appropriate extension methodology. The results revealed a high level of adoption. This shows that with proper sensitization and group mobilization/organization of end users, equipment demonstration and training on its use/maintenance, coupled with extensive monitoring; a proven technology with comparative advantage(s) could be adopted.

Keywords: Technology, adoption, rice, parboiling.

INTRODUCTION

Technology, in the context of agricultural equipment, may be defined as any device that tend to reduce drudgery, facilitate production or processing techniques and maintain or even add value to the final output. Adoption, on the other hand can be defined as the decision to make full use of innovation as the best course of action.

Over the years, introduction of improved technologies to farmers have been and is still the mandate of National Agricultural Extension & Research Liaison Services (NAERLS), Zaria. This role is being complemented by the extension units National Research Institutes using States Agricultural Development Projects (ADPs) as a platform to reach farmers. This joint collaboration has given rise to On-farm Adaptive Research (DFAR), Small Plot Adoption Technique (SPAT) Technology Review Meeting (TRM) and Fort Nightly Trainings (FNT). Despite all these programmes, there is still lack of willingness on the part of the farmers and processors of agricultural products to adopt improved production and processing tools/equipment. This view is supported by Suleiman et al. (2006) who noted that inefficient utilization of improved agricultural innovations and unwillingness of the farmers to accept and adopt innovations in agricultural production systems have led to declined of the sector contribution to Gross Domestic Product (GDP).

Review of past efforts in improved tools/equipment transferred to end users revealed that much is still left to be desired in our extension methods. This is because at organized shows such as trade fairs, exhibitions and trainings both at National, States, Local Government and even at Institutes level, there is usually a lot of interest and strong desire to acquire some of these tools/equipment but the numbers of such tools/equipment actually acquired are minimal. As a result, most of them developed by the National Research Institutes are still on-shelf.

Preliminary investigation revealed that unlike crops sub-commodity which usually go through the full circle of adoption process (and therefore recording high adoption rate), the tools/equipment sub-commodity hardly go through complete adoption process. In most cases, they are merely demonstrated at organized events or purchased and distributed to end users by government and other organizations without adequate training on operation and maintenance. Where there are training, there are hardly any follow-up or monitoring to support the users. The results being that the end users hardly realize the full potential of the given tools/equipment.

Rice is a major staple crop in Nigeria among the cereals. Globally, it is the most important staple food of about half of the human race. The current annual demand of rice in Nigeria is estimated at about 5.0 million metric tones of milled rice while local production is just about 3.0 million metric tones, leaving a deficit of 2.0 million tonnes (FMARD, 2003). It is, therefore, not surprising that

Nigeria is still the major importer of rice in West Africa sub-region (FMARD, 2003). The rice import bill before 1999 was US $259.0million. This almost tripled to US $655.0 million and US $756.0 million in 2001 and 2002 respectively (CBN). From these figures, it is evident that a lot of the country's hard earned foreign exchange is expended on rice importation.

However, there has been steady increase in rice production in Nigeria (Nnanna, 2003). This was as a result of provision of improved variety and expansion in cultivated land area. However, it has been noted that the solution to increasing food production may not lies alone in developing crop varieties with high yield potentials (Sanzidur, 2003). It, also, depends on our ability to develop and utilize improved processing techniques that can add value to the final output which at present are lacking. In the same vane, technology adoption for agricultural development needs an effective understanding of the farmers' conditions and priorities (IITA, 1995).

Parboiling is an important process in rice processing. According to Gariboldi (1974) parboiled rice yields higher head rice, retains more B-vitamins and protein fraction and increases the resistance of the paddy to insect attack. In many parts of Nigeria where rice is grown, this important operation is undertaken in small scale with earthen or metal pots resulting in time wasting, low output and drudgery. There are numerous opportunities in rice processing in Nigeria but these opportunities could only be realized if constraints such as lack of improved processing facilities, low capital base of the rice processors and others are adequately tackled (Isiaka and Abdulsalam, 2006). It is therefore the objective of this study to carryout intensive adoption process using improved rice parboiler as test equipment.

METHODOLOGY

The study was conducted at Kafin-Gana village. It is a farming settlement located about 27km South-East of Dutse along Kano-Maiduguri road in Birnin-Kudu Local Government Area of Jigawa State as shown in figure 1. Available information showed that the area normally receives the highest rainfall in the state with a mean annual value of 1492.70 mm with an average minimum and maximum temperatures of 15 and 33.1°C respectively (JARDA, 2002). The area has a good fertile clay loamy soil in the "fadama" areas and sandy loamy soil in the upland farmlands. Farming is done all year round, using rainfall in wet-season and irrigation water in the dry-season. The major crops grown include millet, sorghum, rice, groundnut, cowpea, sugarcane, wheat and vegetables. Rice processing and oil extraction by the women are the most prominent economic activities in the area.

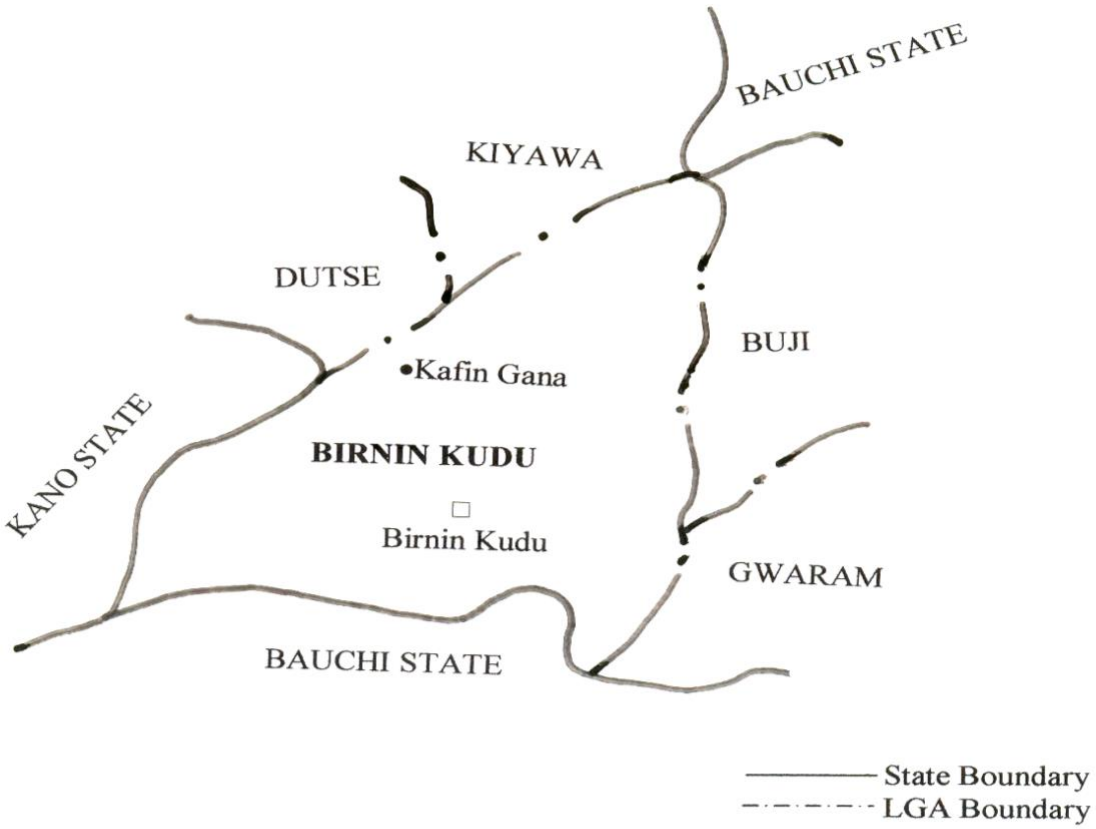


Fig. 1: Map of Birnin Kudu Local Government Area of Jigawa State

The study utilized appropriate extension methodology comprising of the following:

i. Sensitization visits and meetings with village and household heads.
ii. Identification of women Rice Processors and their formation into group
iii. Equipment demonstration
iv. Training on parboiling procedures, equipment usage and maintenance
v. Monitoring to encourage and assess group performance.

The approach was necessary because extension must go beyond its traditional role of just passively passing information to end users as observed by Arokoyo (1998).

The equipment used were improved and local parboilers. The former consists mainly of metal drum and metal cooking stand. The accessories include removable screened platform covered with jute bag (to separate water and rice grains), support rods, draining valve and lock. The later is mainly an aluminum pot. The accessories include corn stalk covered with jute bag (for separation of rice grains and water) and triangular stones stand. The improved parboiler has a capacity of 40 k/batch while the local parboiler has capacity of 23 kg/batch.

The Programme started in May 2005 with preliminary meeting with the village and ward-heads. The objectives of the programme were discussed and their supports were equally solicited for the success of the programmes. Another meeting was held in June 2005 to sensitize the community members. Selected processors between the ages of 20 – 40 years were briefed, formed into groups and the improved parboiler was demonstrated to them. The local parboiler was also demonstrated side by side with the improved parboiler. During the demonstration, performance data were collected from the two methods and descriptive statistics such as means and percentages were used for comparison.

The training was conducted for three days in August 2005. It covered practical steps in parboiling such as cleaning, soaking, steaming, drying and milling. Other areas covered were equipment handling, adjustment, operation and maintenance. At the end of the training, four parboilers were provided at four designated centers for the continuation of the processing activities of the women. The activities of the centers were monitored at weekly intervals for two months. Subsequent visits were made on monthly basis for one year.

RESULTS AND DISCUSSION

Sensitization Meetings.

Five people attended the sensitization meeting with the village head while 30 people attended the other meeting with the members of the community. At the end of the meetings the village head and all the community members that were in attendance welcomed the idea of introducing the new technology and they were all convinced about the important of the programme to the community. Some of them pledged not only to allow their wives to participate but also to assist them financially to acquire the parboiler if it works to their satisfaction. The success of these meetings led to nomination of twenty women processors. These processors were briefed and organized into group with Hajia Taiba A. Alai (Chairman), Walayya Sadiku (secretary), Fatima A. Gambo (Treasurer) and Adama Aminu (Public Relation Officer).

Equipment Demonstration.

The demonstration was conducted with twenty people in attendance. The performance results of the two parboilers were as summarized in Table 1. From the results, it is clear that there is substantial reduction in time required to accomplish parboiling operation. From soaking, steaming and drying operations, there was a time saving of about 18 hours 10 minutes (34.4%) over the local parboiler. This was achieved despite the fact that the capacity of the improved parboiler is 17 kg higher than that of the local parboiler. The head rice recovered was also high for improved parboiler (about 3.5% difference). The percentage breakages were 18% and 8.5% for local and improved parboilers respectively with 9.5% difference. In the case of colour and impurities assessment, 95% of panel of 20 judges ranked the quality of the improved parboiler as bright with low impurities level as compared to dull with high level of impurities for local parboiler. The milled rice from the improved parboiled attracted N320 per “mudu” as compared to N290 per “mudu” for the local parboiler. This implies that the product from the improved parboiler is more attractive to the consumers and they are ready to pay more because of the quality. Ironically, the cost of the improved parboiler (N2,500) is lower than that of the local parboiler (N3,000). From the results, the improved parboiler has a comparative advantage over the local parboiler in terms of capacity, time saving, product quality and revenue accrue from the use of the equipment.

Table 1: Summary of Performance Results during Demonstration

Assessed Parameter	Local Parboiler	Improved Parboiler	Level of Difference
Equipment cost	N3,000:00	N2,500:00	-N500:00
Optimum capacity	23 kg	40 kg	+17 kg
Soaking duration	16 hrs	6 hrs	-14 hr
Teaming Duration	35 min.	25 min	-10 min
Drying Duration	32 hrs	28 hrs	-4 hr
Head Rice Recovered	56.5%	60%	+3.5%
% Breakage	18%	8.5%	9.5%
Colour Appearance	Dull	Bright	--
Level of impurities	High	Low	--
Selling price/mudu	N290	N320	N30

Training on Operation and Maintenance

The training was conducted with twenty-seven participants (twenty-four females and three males) in attendance. The parameters evaluated for were percentage breakage, milling yield and level of impurities/appearance of the milled product. The results obtained are as presented in Table 2. From the table, the levels of breakage were 18 % and 8.05% for local and improved parboilers respectively. This shows an improvement of 9.95% over the traditional parboiler. The amounts of rice grains obtained from the paddy (milling yield) on the average were 56.52% and 60% for traditional and improved parboilers respectively. With this result, an improvement of 3.48% has been recorded for improved parboiler. Though, the milling yield recorded is below grains recovery of 65 to 70% for parboiled as against 50 – 56% for un-parboiled rice depending on rice grade, however, the value obtained for improved parboiler is 3.48% high than that for the local parboiler. Using 20 panelists to assess the level of impurities and appearance, 96.25% preferred the rice grains from the improved parboiler while only 3.75% showed preference for the rice grains from the local parboiler. With difference of 92.5%, this means that there was an overwhelming preference for the milled product from the improved parboiler.

Table 2: Comparative Assessment of Milled Rice Grains

Parameters		Parboiling Method		Level of Difference
		Local	Improved	
Breakage (%)	1	18.00	8.50	9.50
	2	18.10	7.90	10.20
	3	18.00	8.60	9.40
	4	17.90	7.20	10.70
	Mean(%)	18	8.05	9.95
Milling yield	1	56.09	58.75	2.66
	2	57.39	61.25	3.86
	3	55.65	59.50	3.85
	4	56.96	60.50	3.54
	Mean(%)	56.52	60	3.48
Preference test	1	-	20	20
	2	-	20	20
	3	2	18	16
	4	1	19	18
	Mean(%)	3.75	96.25	92.5

Therefore, from these results (Tables 1 and 2) it can be said that the quality of the milled grains from the improved rice parboiler is better than the one obtained from the local parboiler. At the same time, considering other factors, the improved parboiler has clear advantages over the traditional parboiler.

Monitoring of Group Performance

The monitoring has further encouraged the women group. This is evidence in increase in their number and demand for more improved parboiler to cope with their operation. During this period, higher quality rice with 65% milling yield and 7%

grain breakage was obtained. Within this period, also, Jigawa State Agricultural and Rural Development Authority sponsored additional training for women rice processors in Chiyeko village. This showed an acceptance not only by the rice processors but also by the authority responsible for dissemination of improved technologies to the end users. It was observed during the process of monitoring that groups have been formed in different locations for the purpose of pursuing their processing activities. Most of these groups have expanded their activities through contribution from members and technical assistance from the state ADP under the National Special Programme for Food Security (NSPFS).

CONCLUSIONS

The following conclusions could be made:

i. Sensitization of end users, the household heads and the village/community heads is an essential component for any technology dissemination and adoption.

ii. Group formation could be an important tool in technology adoption. This is necessary for capacity building and economic empowerment of the members in particular and the group in general.

iii. In equipment adoption, demonstration of the new technology and the existing one is necessary to stimulate interest. This should be followed by proper training of the end users on operation and maintenance of the technology.

iv. Monitoring should be an essential component of any adoption process. This is necessary for technical guidance and encouragement of the recipient(s). The length of monitoring could be determined by level of adoption.

v. In this study, the level of adoption of the parboiler has been high and this can be attributed to its simplicity, easy of operation, high efficiency and low cost. The parboiler is now popular among the women groups.

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FIELD PERFORMANCE EVALUATION OF A TRACTOR-MOUNTED ROTARY CHAIN - SLASHER FOR CROP RESIDUES DISPOSAL

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ABSTRACT
The development of a tractor - mounted Rotary chain slasher machine was undertaken with the aim of slashing crop residues of various intensity and eliminating the drudgery associated with the traditional methods of clearing crop residues on a farm. The machine was developed and tested at the Federal University Technology, Yola farm, using locally available materials. The machine consists of three freely swinging chains attached to a centrally located gearbox unit. The chains rotate at a high speed to cut any material at the base of the machine. The frame is made from angle iron and galvanized metal steel sheet on which the entire assembly is mounted. The slasher is powered by the tractor power take off (PTO) shaft. The machine field performance was evaluated at tractor power take off (PTO) speed of 1000 rpm. The actual field capacity was found to be 0.38ha/h with field efficiency of 86.3%. Efficient slashing can be achieved on stalks with diameter less than 30mm.

KEY WORDS: Tractor-mounted, Rotary slasher, Chain, Crop residues, Performance evaluation

INTRODUCTION
The pressure to increase food production requires more efficient method of bush clearing (Borshchov *et al*, 1988). In many parts of Nigeria, land is still cultivated mainly with simple hand tools such as cutlass, axe, and hoe, with slash-and-burn technique. This is extremely labor intensive to farmers (Kaul and Egbo, 1985).

Many agricultural machines and equipment imported and used in Nigeria to reduce the difficulties involved in land clearing for crop production. However, economic utilization of these machines has some limitations on small farms. These limitations include; initial high costs of these machines, high running cost, excessive traction, severe soil compaction and low level of technical manpower to maintain the machines (Culpin, 1982; Griggs and Courtney, 1994). Many of these machines are ultimately abandoned.

According to Culpin (1982), bush-clearing machines such as bulldozers used for bush and edge clearing, take too much agricultural soils with the bushes thereby making burning difficult and exposing the land to soil erosion, which is a major environmental problem in some farming areas, especially in arid and semi-arid regions of Nigeria. High speed reciprocating or rotating cutter knives used for bush clearing get broken or damaged when they come in contact with obstacles or shrubs with bigger diameter. Non-availability of alternative method of disposing crop residues on the field with minimum disturbance of the agricultural soil has lead to the use of the traditional method of bush clearing, which is labor intensive. Lageman (1987) reported that peasant farmers do not usually attempt full clearing and stumping of the land because they possess only simple tools such as cutlass, axe and hoe for manual operations. Full clearing, therefore, becomes extremely laborious. Miller (1976) stated that different land types require different clearing techniques. Therefore, land clearing should be carried out with great care. Attention is, therefore, being geared toward locally built machines and equipment that employ proper machine for operation while the available ones with design deficiencies need to be modified. Aliyu and Kabri (2000) designed and constructed a rotary chain slasher mechanism for bush clearing, using chain as the cutting unit. The method of using chain is very productive and causes minimum disturbances to topsoils. This paper is to report on the actual field performance evaluation of the machine for crop residual disposal.

2.0 Materials and Method

2.1 Materials
Materials used for the evaluation were; a tractor (Fiat 650), rotary chain slasher, stopwatch, measuring tape, and marking pegs. The machine was operated on a field with 10% soil moisture content dry basis.

2.2. **Description of the Rotary Chain Slasher**

The main features of the rotary chain slasher as shown in figure 1 include, a three point linkage connecting bar (1), casing (2), gearbox unit (3), chain connecting link (4), back protective plate (5), rotor plate (6), rotor cover (7) and front plate (8).The cutting mechanism of the slasher works on the principle of rotary impact. The chains are designed to rotate at a tractor power take off speeds of 540 or 1000rpm during operation depending upon the nature of vegetation. The cutting chains (4) located at the base of the casing (2) are driven directly from tractor power-take-off through the gearbox unit (3). When the tractor moves forward, the front plate (8) bends the plants forward and the chain assembly (4) suspended freely under the metal casing (2), revolving at 540 or 1000 rpm shred plants with the blunt edges of the chains.

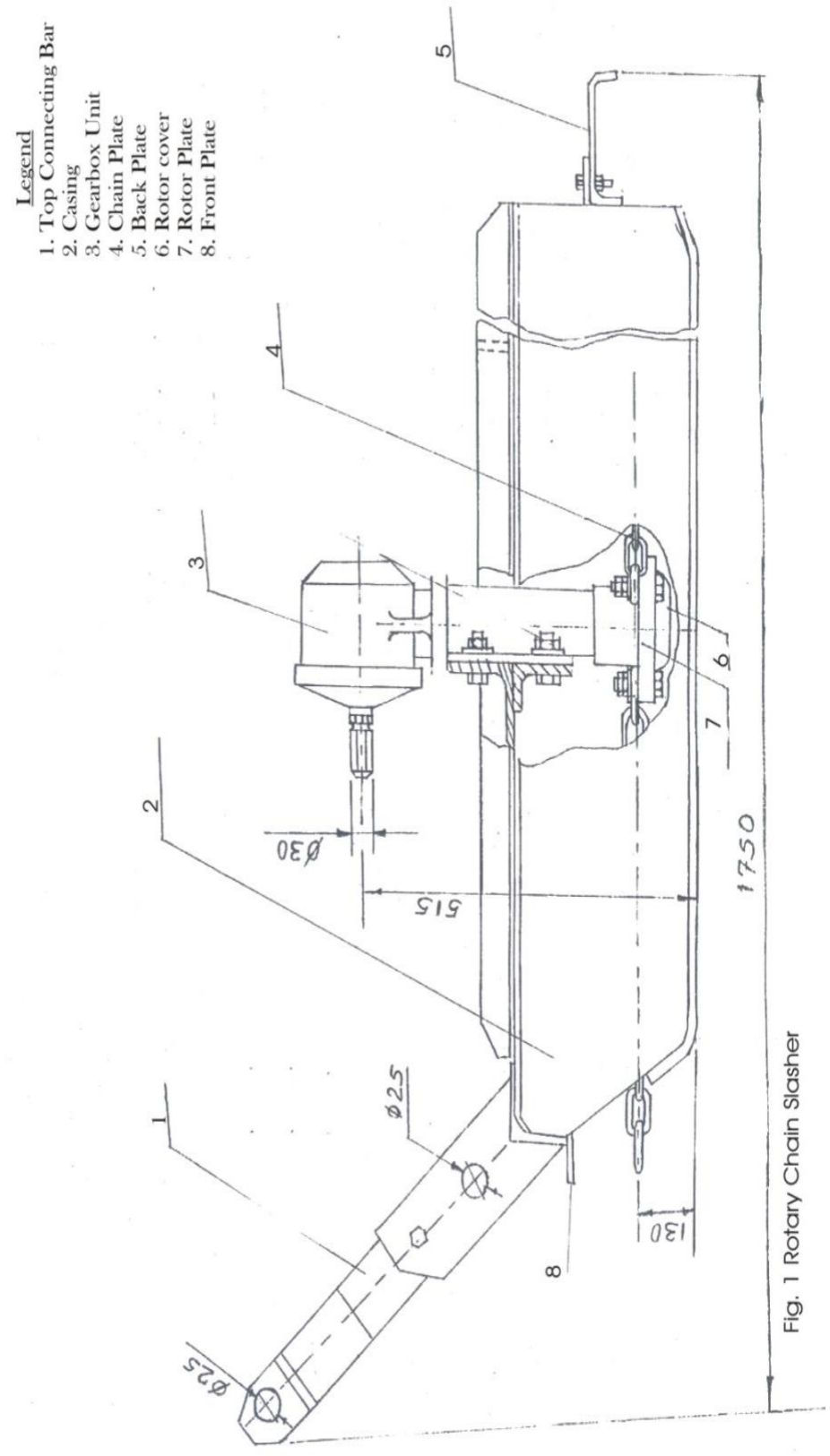


Fig. 1 Rotary Chain Slasher

3.0 **Performance Evaluation**

Testing the performance of the slasher involved evaluation of PTO performance, field capacity (ha/h) and field efficiency (%).

Field tests were conducted on a piece of land measuring 150 x 150m on the University of Technology, Yola farm using Fiat 650 tractor.the land was divided three plots measuring 50m x 50m.

The materials used for the performance test were the rotary chain slasher machine, stopwatch, measuring tape and marking pegs.

3.1 **Power Take Off (P.T.O) Field Performance Test.**

A preliminary P.T.O performance test was conducted in order to determine the best speed of operation. The machine was operated at tractor speed of 3.7km/h with P.T.O revolution of 540 and 1000 rpm respectively. The slasher performance in terms of plot clarity was graded by mere visual inspection (Culpin 1982).

3.2 **Field Performance Evaluation**

The slasher was operated at a tractor speed of 3.7km/h and P.T.O revolution of 1000 rpm to clear the field of grasses and shrubs. The time taken to clear the area was noted using the stopwatch. The total time spent on the field was also noted. This was done in order to determine the field capacity and efficiency of the machine. The procedure was repeated three times. The height and diameter of the stubble cut at were measured.

The machine field performances were evaluated using equations 1,2,and 3 below.

(1). Actual effective field capacity (ha/h) = A/Ta……..(1)

(2) Field efficiency (%) = EFC/TFC x 100. ……(2)

(3) Field efficiency in terms of time = Ta/T x 100 …… (3)

Where

A = area slashed by the machine (ha)

Ta = actual time for slashing (h)

T = total field time which include stoppage and adjustment. (h)

EFC = Actual field capacity (ha/h)

TFC =Theoretical field capacity (ha/h) = 0.1 x b x S

b = Operating width of the slasher (m) = 140m

S = Forward normal speed of tractor (km/h)

3.3 **Results and Discussion**

The slasher PTO performance in terms of plot clarity was graded by mere visual inspection (Culpin 1982). The test showed that P.T.O. revolution of 1000 rpm at tractor speed of 3.7km/h gave better results in terms of quality of clearing.

The field performance results obtained are shown in Table 1. The results show that an area of 2500m^2 (0.25ha) was slashed in a mean time of 0.66h. The field capacity was found to be 0.38ha/h. The machine was found to have a field efficiency of 86.3%. This compares favorably with Rotary cutter bar mower field efficiencies of 75 to 90% as reported by Smith and Miller (1952). The results from the field test also showed an uneven and extremely longer cut of some stubble at the height of 90-130mm instead of slashing the over grown shrub and reducing them to reasonable proportions. The uneven cut was attributed to the diameter of the stems being greater than the required maximum diameter of 30mm the slasher can cut (Aliyu and Kabri, 2000). The slasher units instead of cutting the stem directly tend to uproot it thereby leaving an uneven and longer cut of stalk. The maximum diameter of stalk the slasher can effective slash is 30cm.

Table 1: **Performance Evaluation results**

Sn	Area of Slashing As (ha)	Actual slashing time Ta (h)	Total field time T (h)	Actual field capacity (ha/h)	Field efficiency (%)
1	0.25	0.6553	0.7593	0.3815	86.31
2	0.25	0.6551	0.7591	0.3816	86.29
3	0.25	0.6552	0.7592	0.3816	86.30
Mean	0.25	0.655	0.7592	0.3815	86.3

4.0 **Conclusion**

The development of the rotary chain slasher was carried out with the aim of achieving efficient bush clearing and agricultural crop residue disposal on the farm. The machine's actual field capacity of 0.38ha/h and field efficiency was found to be 86.3%. The result shows that the machine can be used effectively

on grasses and shrubs of various intensities with maximum diameter of 30mm. The machine has over come the limitation of rotary or reciprocating cutter bars commonly used in Nigeria. Therefore, efficient land clearing for agriculture is achievable with a rotary chain slasher machine.

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PERFORMANCE EVALUATION OF AN ACTIVE EVAPORATIVE COOLER UNDER VARIED PARAMETERS IN A SEMI ARID REGION

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Abstract

The performance efficiency of an active evaporative cooler (Fan and Pad), in terms of the saturation efficiency (S_E), under varied levels of water flow rate (W_R), pad thickness (P_T) and air velocity (A_V) was evaluated. Theoretical analysis of the evaporative cooling processes at the pad - end and inside the storage chamber, revealed that: pad thickness (P_T), air velocity (A_V) through the pad and water flow rate (W_R) onto the pad which affects the degree of saturation and consequently the saturation vapour pressure within the pad are the most important parameters that affect the saturation efficiency of an evaporative cooling system.

Three levels of water flow rate (3.5 L/min., 4.5 L/min. and 5.0 L/min.), three levels of pad thickness (30mm, 60mm and 90mm) and five levels of air velocity (0.8m/s, 1.3m/s, 1.8m/s, 2.3m/s and 2.8m/s) were used in an interactive study to determine their effects on the saturation efficiency of an active evaporative cooler, constructed with local stem sponge as the pad. The saturation efficiency showed an initial significant increase with increase in the levels of all the variables, then tend to either increased only slightly, remained constant or declined marginally. The best performance efficiency of 84.6%, at a temperature of 21.5 $^{\cong}$ C and relative humidity of 85% from an ambient conditions of 38$^{\cong}$C and 15%., temperature and relative *humidity respectively, was obtained at a combination level of W_R, of 4.5L/min, P_T of 60mm ad A_V of 2.3m/s.*

Introduction.

Evaporative cooling occurs when air that is not saturated is blown across a wet surface. Heat in the air is utilized to evaporate the water, resulting in a drop in the air temperature and increase in relative humidity (Harper, 1976, Henderson, 1976, and Perry; Kays, 1979, FAO/SIDA, 1986 Brooker *et al*, 1992). According to Rusten (1985), evaporative cooling is generally more efficient where air temperatures are high, relative humidity very low, water is available for the purpose and air movement is available. In Northern Nigeria, a semi arid region, these conditions are typical.

An active evaporative cooling system consists of a pad (moist material), fan, storage cabin and water pump. Apart from the general requirements for the efficient operation of an evaporative cooling system, the efficiency of an active evaporative cooler depends on the rate and amount of evaporation of water from the pad. This is dependent upon the air velocity through the pad, pad thickness and the degree of saturation of the pad, which is a function of the water flow rate wetting the pad (Hanan et al, 1978, Wiersma, 1983, Thakur and Dhingra, 1983)

The objectives of this study were to evaluate the performance of an active evaporative cooler under varied levels of these parameters and to determine the best combination levels of these parameters for the efficient operation of the cooler.

Materials and Methods

An active evaporative cooler as in Dzivama et al (1999), was constructed and tested under varied levels of water flow rate, pad thickness and air velocity. The cooler consists of a pad - end of dimensions 1000mm x 1500mm made of local stem sponge, a storage cabin of dimensions 1000mm x 1300mm x 1500mm, made of plywood and internally insulated with 50mm polystyrene, a suction fan of 20watts power rating and water pump with a discharge capacity of 7.5L/min and power rating of 150watts. The complete schematic diagram of the cooler is presented in Figure 1.

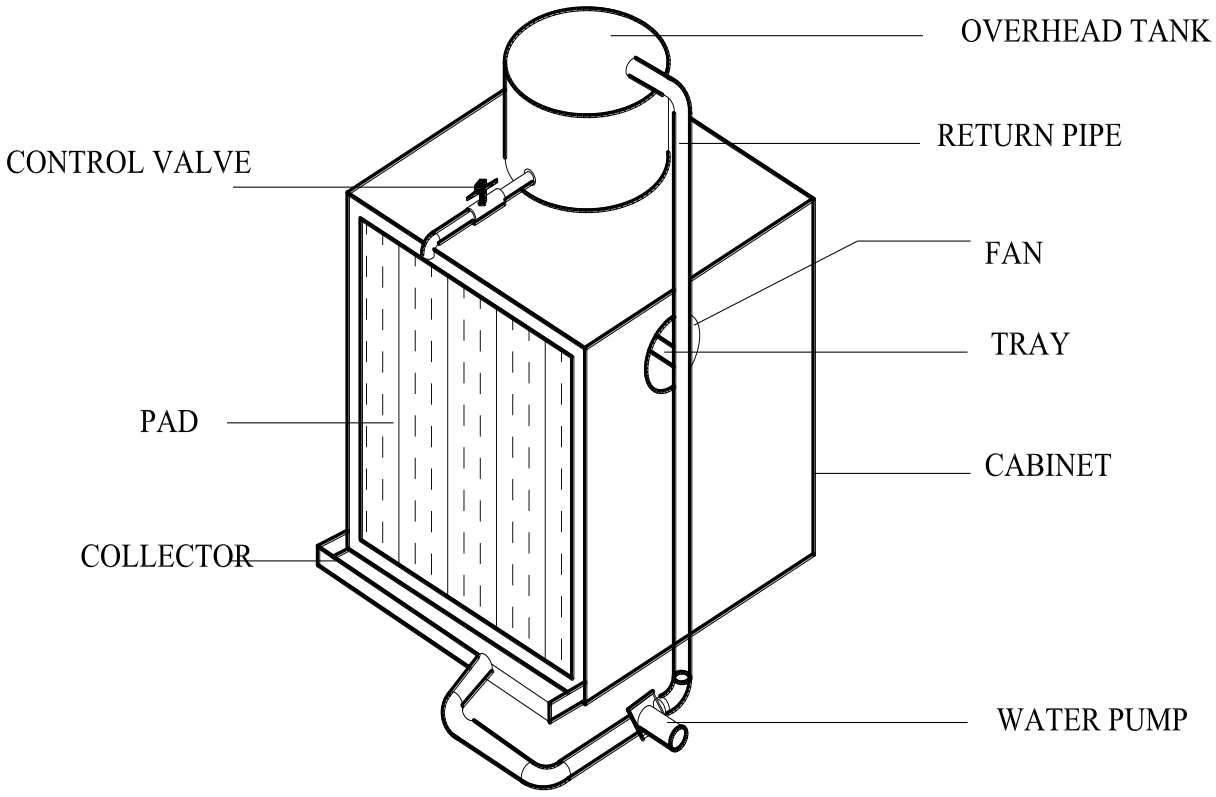


Fig.1. Schematic Diagram of the Evaporative Cooler

The experiment involved an interactive study of the effects of water flow rate, pad thickness and air velocity on the saturation efficiency of them cooler. Three levels of the water flow rate, W_R (3.5L/min. , 4.5 L/min. and 5 L/min., three pad thickness, P_T (30mm, 60mm and 90mm) and five levels of air velocity, A_V (0.8m/s, 1.3m/s, 1.8m/s, 2.3m/s and 2.8m/s) were used. The choice of these levels of the parameters was based on available information (Thakur and Dhingra, 1983, FAO/SIDA Hellickson and Walker, 1983, Brooker et al 1992) and factors related to the construction properties of the local sponge into a pad for use in the cooler.

The parameters were combined in a split - split plot design experiment, which is best suited for a three factors experiment (Gomez and Gomez, 1983). The water flow rate was considered as the main plot, the pad thickness and air velocity were referred to as the subplot and sub - sub plot respectively. The lay out of the design experiment is shown in Table 1.

Table 1: Experimental layout split - split plot design

W_R, L/min.	P_T, mm	Air velocity, m/s. A_{V1}	A_{V2}	A_{V3}	A_{V4}	A_{V5}
W_{R1}	P_{T1}	$W_{R1}P_{T1}A_{V1}$	$W_{R1}P_{T1}A_{V2}$	$W_{R1}P_{T1}A_{V3}$	$W_{R1}P_{T1}A_{V4}$	$W_{R1}P_{T1}A_{V5}$
	P_{T2}	$W_{R1}P_{T2}A_{V1}$	$W_{R1}P_{T2}A_{V2}$	$W_{R1}P_{T2}A_{V3}$	$W_{R1}P_{T2}A_{V4}$	$W_{R1}P_{T2}A_{V5}$
	P_{T3}	$W_{R1}P_{T3}A_{V1}$	$W_{R1}P_{T3}A_{V2}$	$W_{R1}P_{T3}A_{V3}$	$W_{R1}P_{T3}A_{V4}$	$W_{R1}P_{T3}A_{V5}$
W_{R2}	P_{T1}	$W_{R2}P_{T1}A_{V1}$	$W_{R2}P_{T1}A_{V2}$	$W_{R2}P_{T1}A_{V3}$	$W_{R2}P_{T1}A_{V4}$	$W_{R2}P_{T1}A_{V5}$
	P_{T2}	$W_{R2}P_{T2}A_{V1}$	$W_{R2}P_{T2}A_{V2}$	$W_{R2}P_{T2}A_{V3}$	$W_{R2}P_{T2}A_{V4}$	$W_{R2}P_{T2}A_{V5}$
	P_{T3}	$W_{R2}P_{T3}A_{V1}$	$W_{R2}P_{T3}A_{V2}$	$W_{R2}P_{T3}A_{V3}$	$W_{R2}P_{T3}A_{V4}$	$W_{R2}P_{T3}A_{V5}$
W_{R3}	P_{T1}	$W_{R3}P_{T1}A_{V1}$	$W_{R3}P_{T1}A_{V2}$	$W_{R3}P_{T1}A_{V3}$	$W_{R3}P_{T1}A_{V4}$	$W_{R3}P_{T1}A_{V5}$
	P_{T2}	$W_{R3}P_{T2}A_{V1}$	$W_{R3}P_{T2}A_{V2}$	$W_{R3}P_{T2}A_{V3}$	$W_{R3}P_{T2}A_{V4}$	$W_{R3}P_{T2}A_{V5}$
	P_{T3}	$W_{R3}P_{T3}A_{V1}$	$W_{R3}P_{T3}A_{V2}$	$W_{R3}P_{T3}A_{V3}$	$W_{R3}P_{T3}A_{V4}$	$W_{R3}P_{T3}A_{V5}$

45 x 3 = 135 experiments.

To each level of water flow rate randomly selected was assigned a level of pad thickness and air velocity also randomly selected and the evaporative cooler was then operated. The change in temperature and relative humidity inside the storage chamber was measured with a hygroskop GT - L Hygrometer. Readings were taken in replicates at 10 minutes interval, until a steady state condition was reached. Each test was conducted in three replicates and the average temperature and relative humidity achieved at the steady state condition, was calculated and recorded as the temperature and relative humidity achieved at that particular setting. The saturation efficiency of the cooler was calculated from the expression suggested by Harris, (1987), as

$$\text{Saturation efficiency, } S_E, \% = \frac{T_O(db) - T_I(db)}{T_O(db) - T(wb)} \times 100 \quad 1$$

Where:

$T_O(db)$ = out door dry bulb temperature, °C

$T_I(db)$ = inside cooler dry bulb temperature, °C

$T(wb)$ = out door wet bulb temperature of the region, °C

Statistical analysis

The statistical analysis (analysis of variance, mean comparison and regression) was carried out to determine the level of significant of the parameters and their interactions on the saturation efficiency of the cooler.

Analysis of variance

Analysis of variance of a split - split plot design for three factorials, was carried out as described by Gomez and Gomez (1983). The Duncan multiple range test (DMRT), was used for the comparison test. DMRT is more appropriate for the test of experimental variables, with many levels (Gomez and Gomez; 1983).

A method of multiple non-linear regression analysis as described by Ott (1977) and Babatunde (1997), was used to derive the response equation. Ott (1977) and Babatunde (1997), gave the possible response equation for a multiple regression of dependent variable Y (X_1, X_2), where X_1 and X_2 are independent variables in a 2 –factor factorial design experiment, as

$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_1^2 + b_4X_2^2 + b_5X_1X_2 + b_6X_2^2X_1 + b_7X_1^2X_2 + b_8X_1^2X_2^2$ 52

Where b_0, b_1 ----------b_8 are constants. Equation 2 is adopted and modified to take care of the 3 – factor factorial design experiment in this study. The possible response equation based on the modified form of equation 2 of a multiple regression of dependent variable Y

(X_1, X_2, and X_3), in a 3 – factor factorial design is expressed as:

$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b4X_1^2 + b5X_2^2 + b_6X_3^2 + b_7X_1X_2 + b_8X_1X_3 + b_9X_2X_3 +$
$b_{10}X_1X_2\,X_3$ ---------- 3

Where:

Y = the saturation efficiency (S_E) of the cooler in %.

X_1 = water flow rate (W_R), L/min.

X_2 = pad thickness (P_T), mm

X_3 = air velocity (A_V), m/s

The response equation is determined by the inverse of the 135 x 9 matrix.

Results and Discussions

The results of the saturation efficiency calculated by the equation 1, from the temperature measured inside the cooler is presented in Table 1.

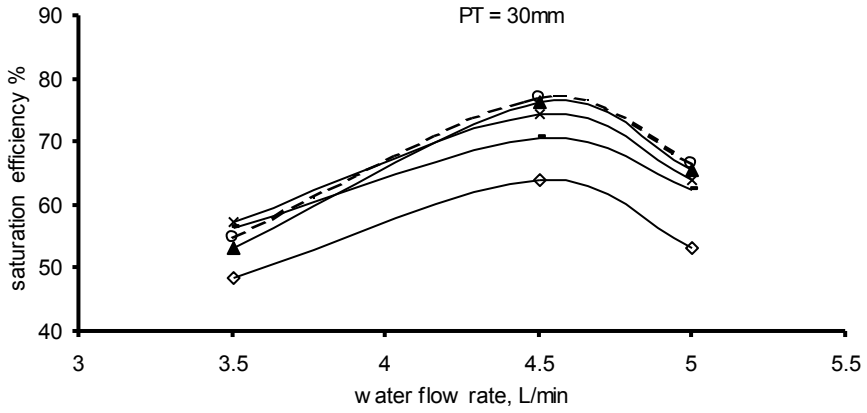
Table 2. Saturation efficiency, % calculated from the temperature achieved in the cooler.

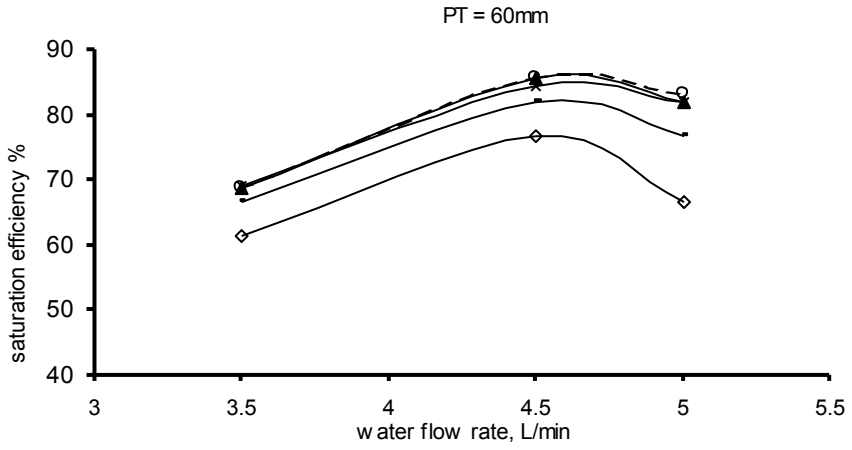
W_R, L/min.	**P_T, mm**	**Air velocity, m/s.** 0.8	1.3	1.8	2.3	2.8
		Saturation efficiency, %.				
3.5	30	48.7	56.4	57.4	55.4	54.9
	60	61.5	66.7	69.2	68.7	68.7
	90	56.4	61.5	65.6	66.7	66.7
4.50	30	64.1	70.8	74.4	74.4	76.9
	60	76.9	82.1	84.6	84.6	84.6
	90	69.2	79.5	82.1	84.1	83.1
5.00	30	53.3	62.6	64.1	65.1	66.7
	60	66.7	72.8	79.5	82.1	84.6
	90	64.7	69.2	76.9	80.1	82.6

Effect of water flow rate on the saturation efficiency of the cooler

The effect of the water flow rate on the saturation efficiency of the cooler is shown in Figure 2. The result in the Figure 2 showed that the saturation efficiency of the cooler increased significantly with increase in the level of the water flow rate from 3.5L/min to 4.5L/min, and the declined with further increase of the water flow rate to 5 L/min. The initial increase in efficiency with increase in W_R from 3.5 L/min to 4.5 L/min. could be explained by the fact that, at low level of water flow rate (3.5L/min), the water could only

partially moisten the pad. This could have reduced the wet surface area for air - water contact, which also reduced
the amount of evaporation taking place, thus low efficiency. As the water flow rate increase to 4.5 L/min., the pad became sufficiency moist and increased the wet surface area for air - water contact and the amount of evaporation, and consequently the efficiency. However further increase in water flow rate to 5 L/min. could have made the pad excessively moist. The excess water might have blocked the pore spaces within the pad fibres thereby impending the flow of air through the pad to effect evaporation. This could have accounted for the decline in the efficiency at higher level of the water flow rate.





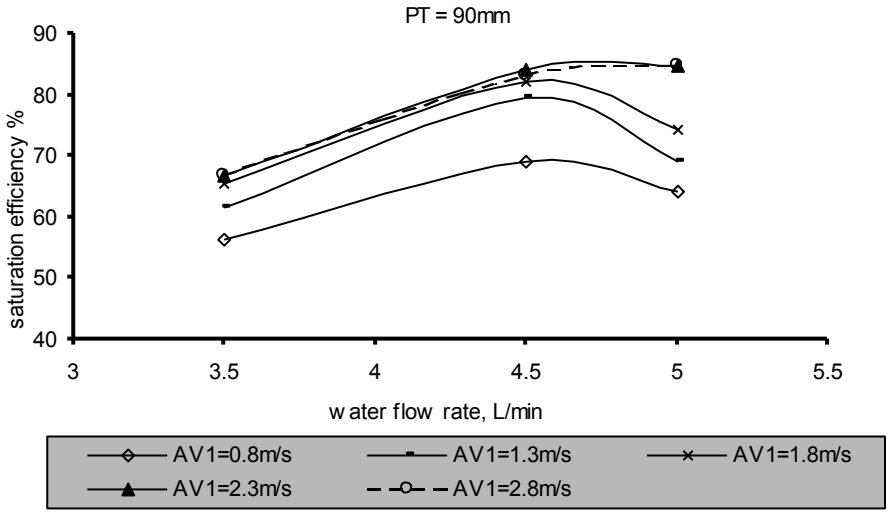


Figure 2 **Effect of water flow rate on the performance efficiency of the cooler for various air velocities at pad thickness of. A) 30mm, B) 60mm and C) 90mm**

Effect of Pad thickness on the Saturation Efficiency of the cooler

The result of the saturation efficiency under increasing pad thickness is presented in Figure 3. The result in Figure 3 showed a similar pattern to that of the water flow rate. That is there was a significant initial increase in saturation efficiency with increase in pad thickness and then it declined also on further increase in the pad thickness. This could be due to the fact that at low pad thickness (30mm) the distance of travel for the air was short, which reduced the residence time of the air within the pad for the air - water contact time and therefore the amount of evaporation. Increasing the pad thickness to 60mm, increased the distance of travel and thus the residence time for the air - water contact and hence more evaporation and high efficiency. The decline in the efficiency with further increase in the pad thickness to 90 mm, could be due to the combined effects of the pad thickness, water flow rate and air velocity. At pad thickness of 90mm, though the distance of travel by the air has increased, the water may not be adequate to moisten the pad, which might have created some dry spots within the pad, through which the dry air could pass directly without evaporation. This could have accounted for the low efficiency at pad thickness of 90mm.

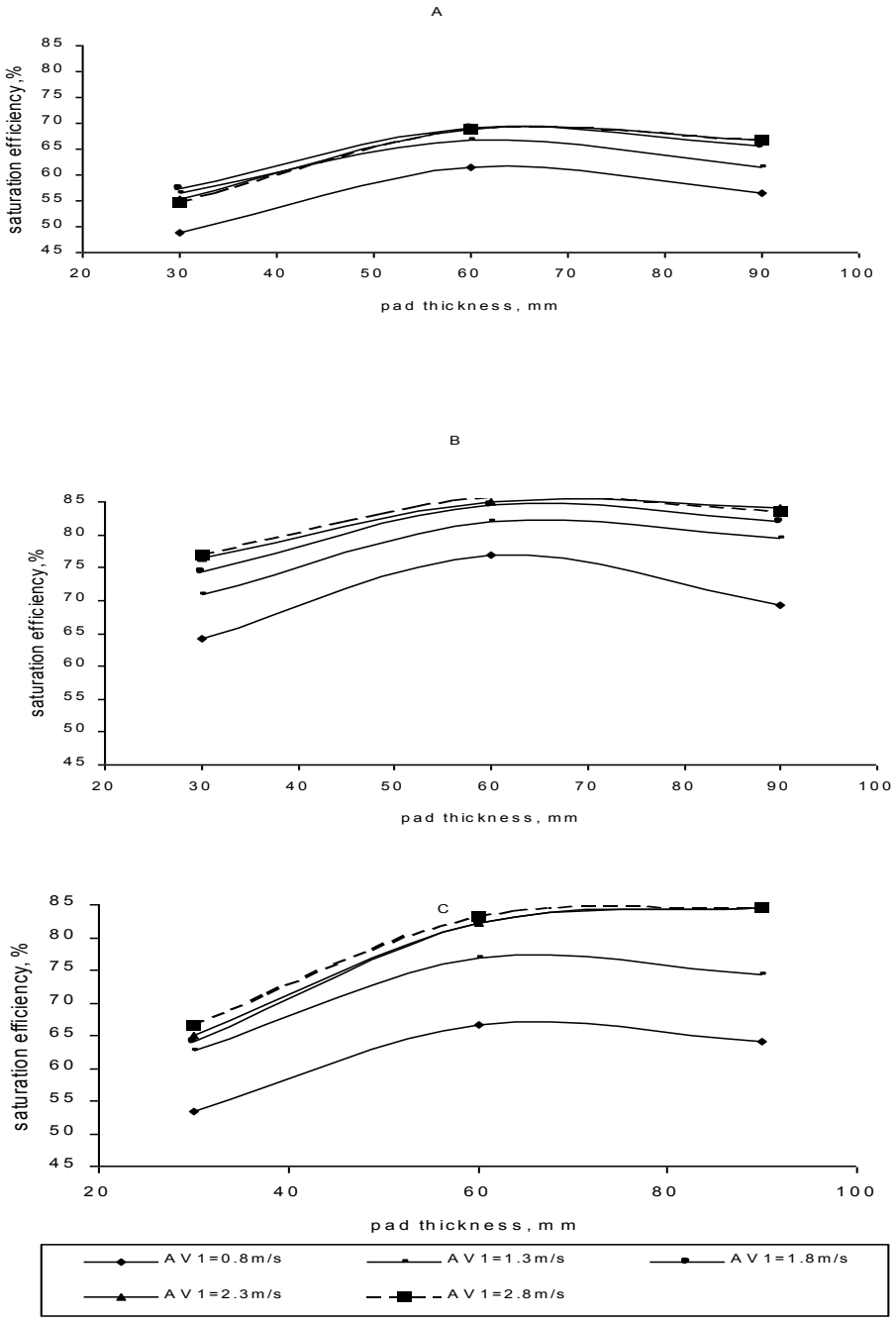


Figure 3. Effect of the pad thickness on the Saturation efficiency of the Cooler at various water flow rate and air velocities

Effect of air velocity on the saturation efficiency of the cooler

The result of the saturation efficiency under increasing air velocity is presented in Figure 4. The result in Figure 4 showed that the saturation efficiency increased significantly with initial increase in the air velocity and then tend to either increase only slightly, remained constant or declined marginally. This could be attributed to the fact that at low air velocity, 0.8m/s the suction through the pad was not effective to effect good evaporation. As the air velocity increases to 1.3, 1.8 and 2.3m/s, suction through the pad improved which could effect good evaporation and hence increased efficiency. But further increase in air velocity

might have caused the air to pass through the pad fast without enough residence time for good evaporation to take place. The additional pressure resulted in physical displacement of water mass instead of evaporation as evidenced by the presence of water droplets within the cabin at air velocity of 2.8m/s and high water flow rate.

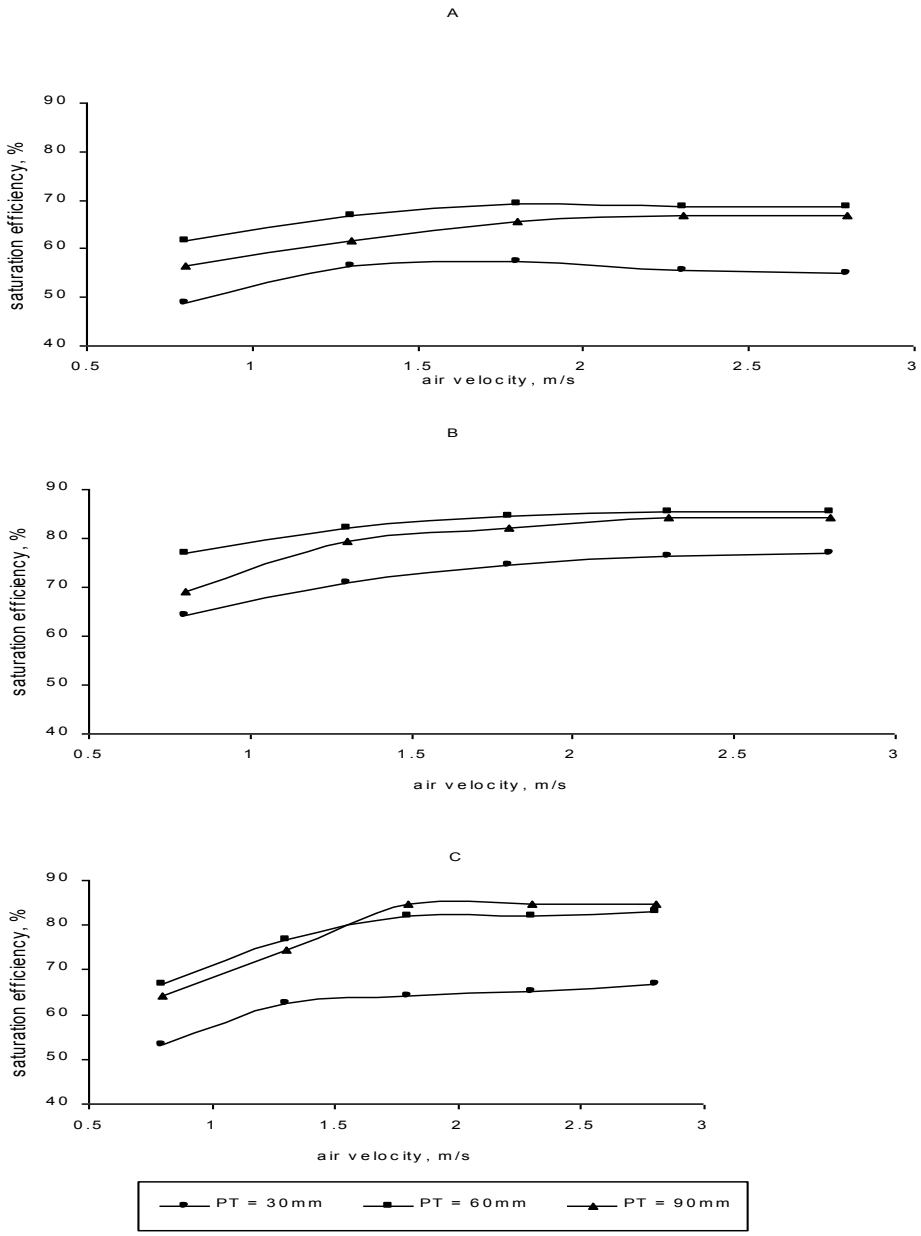


Figure 4 Effect of air velocity on the performance efficiency of the cooler, for various pad thickness and water flow rates of: A) 3.5L/min. B) 4.5L/min and C) 5L/min

Optimum operating levels of the parameters

The optimum operating combination levels of the of the parameters was found to at water flow rate of 4.5 L/min, pad thickness of 60mm and air velocity of 2.3m/s, which gave the highest efficiency of 84.6 %, at a temperature within the cooler of 21.5 ≅C compared to 38 ≅C out door temperature. For a region of low out door relative humidity and high temperature it is possible to obtain a saturation efficiency approaching 85 to 100 % (Rusten, 1985, FAO/SIDA, 1986). This could be explained by the fact that at water flow rate of 4.5 L/min and pad thickness of 60mm, the pad was sufficiently moist and at an air velocity of 2.3m/s the suction through the pad was good enough to effect more evaporation. This situation allowed for increased in mass and heat exchange and thus increased saturation efficiency of the system.

Analysis of Variance

The result of the analysis of variance (ANOVA) is presented in Table 3. The result in Table3, showed that all the main factors: water flow rate, pad thickness and air velocity and their two - way interactions W_R x P_T, W_R x A_V and P_T x A_V are significant at 5 %. But the combined effects, W_R x P_T x A_V is not significant at 5 %. This result confirmed the earlier observation that the slight decline at high levels were due the combined effects of the variables which seemed to counteract each other.

Table 3. Result of the Analysis of Variance

Source of variation	Sum of squares	DF	Mean squares	F	Sig. of F
Main effects	3864.801	8	1733.100	435.209	0.000
W_R	6649.169	2	3324.585	834.857	0.000
P_T	4317.889	2	2158.945	542.146	0.000
A_V	2897.743	4	724.436	181.917	0.000
2 - way interactions	708.849	20	35.442	8.900	0.000
W_R x P_T	338.115	4	84.529	21.227	0.000
W_R x A_V	249.297	8	31.162	7.825	0.000
P_T x A_V	121.437	8	15.180	3.812	0.001
3 - way interactions	97.859	16	6.116	1.536	0.105
W_R x P_T x A_V	97.859	16	6.116	1.536	0.105
Explained	14671.50	44	333.443	83.733	0.000

Comparison Between the treatment Means

The result of the comparison between the treatment means is shown in Table 4. The result in Table 4 showed that: The W_{R2} and W_{R3} are significantly higher than W_{R1} but W_{R2} is significantly higher than W_{R3}, P_{T2} and P_{T3} are significantly higher than P_{T1}, however P_{T2} is higher than P_{T3} and A_{V4} and A_{V5} are not significantly higher than each other but they are all significantly higher than A_{V1}, A_{V2} and A_{V3}. This showed that W_{R2} (4.5L/min), P_{T2} (60mm) and A_{V4} (2.3m/s), beyond which there was no significant increase in the saturation efficiency of cooler are the optimum combination levels for the operation of the cooler as earlier observed from the graphs in Figures 2,3&4.

Table 6.4: Results of the DMRT for the experimental parameters at 5%.

Levels	**A_V**	**P_T**	**W_R**
	Mean		
	62.322[a]	63.120[a]	61.6133[a]
1	70.1556[b]	76.0667[bc]	78.1160[bc]
2	73.7889[c]	73.880[c]	73.460[c]
3	74.300[cd]		
4	74.556[d]		
5			

Any two means with a common letter in same column are not significantly different

Regression analysis

The regression analysis was carried to establish the relation between the independent variables: water flow rate (W_R), pad thickness (P_T), air velocity (A_V) and the dependent variable, which is the saturation efficiency (S_E) obtained experimentally at the pad – end. The resulting regression equation obtained from equation 2 is given as:

$S_E = 7.9 - 0.013W_R + 0.85P_T + 22.2A_V + 0.27W_R^2 - 0.008P_T^2 - 6.2A_V^2 +$
$0.067W_RP_T - + 1.07W_RA_V - 0.029P_TA_V$ with, $R^2 = 0.95$ or 955 and S = 2.402.

Conclusion.

The main conclusion arising from this study could be summarised as follows.

1. The highest saturation efficiency of 84.6%, which was at a temperature of 21.5 ≅C and 85% relative humidity from an ambient condition of 38≅C and 15% temperature and relative humidity respectively is considered efficient.
2. The possibility for the preservation of fruits and vegetables at the conditions obtained within the cooler of 21.5 ≅C and 85% should be evaluated.
3. Further investigations are recommended on more pad surface area, structure, orientation and mode of water application(spray or sheet) and the possibility of re-circulating the cooled and humidified air from the cabin, with a view to increasing the saturation efficiency of the cooler.

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APPRAISAL OF VILLAGE LEVEL GRAIN STORAGE PRACTICES IN ADAMAWA STATE, NIGERIA

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ABSTRACT
Grain storage practices at Village level in Adamawa State varies according to culture and socio-economic level of the inhabitants. A survey was undertake to appraise these practices, through administering of well-structured questionnaires, interviews, personal observations and storage sampling. Results show that the performances of existing storage structures in the state were not satisfactory. The main structures were mud '*rhumbus'* thatched '*rhumbus',* underground pit, platform, cribs, vertical poles, gourd, clay pots, Hessian and jute bags and plastic or steel containers. Most of the structures were not moisture and rodent-proof and were without adequate inlet and outlet facilities. The suggested improvements include the following among others; discontinuation of the thatched *'rhumbus'* due to high rates of pest and rodent infestation and constant fire occurrence; provision of mud *'rhumbus'* due to high rates of pest and rodent infestation and constant fire occurrence; provision of mud 'rhumbus' with strong elevate based and inclined steel outlet with application of water-proof and plaster, replacement of existing underground pit structures with concrete or brick mansory structures, and ventilation of the Local crib and keeping the with at 0.77m or less.

Key Words: Appraisal, Village; Adamawa, Storage, Grain.

INTRODUCTION

Grain storage is a container that is constructed to perform the function of safety keeping of grains. It may involve modification of the existing structures to perform this act of storage (Mijinyawa, 2002).

A stored grain bulk is a man made ecological system in which living organisms and their non-living environment interest on each other Deterioration of stored grain results from interactions among physical, chemical and biological variables (Igbeka, 1996). Some of these variables interrelate with one another. When they interact, they come out with something worse. It is therefore important to understand the interactions of these variables for safe storage (Shinha, 1973). In a nutshell, these variables can be summarized into four factors namely; moisture content of grain, relative humidity of air, temperature of grain and physical properties of grain bulk. The interaction of temperature and moisture content can lead to condensation as far as 3-4cm in the stored grain (Olumeko, 1991).

The basic requirement of storage is to maintain the quality of grain from one season to the next season. Grain can also be stored for even three years to be used during famine, war earthquake, flood, fire outbreak and other natural disaster. This is in agreement with the United States. Troops during the first and second world wars where they survived on stored dry food throughout the period of war (FAO, 1991).

Storage can be achieved in three different ways: On farm storage here quality control starts, collection point and terminal point. It can also be classified into improvised, traditional and modern (Henderson, 1952). Which ever one you adopt, the main objective still remains that it should keep grain cool and dry, protect grain from insects, rodents, preserve the quality of the harvest, maintain its quality for aestheric values. Ajisegiri *et al.* (1999) reports that there is a recent grain storage programming mission for Peace Corps at refuse camps in Costa Rica. This may serve as a model for similar programming mission elsewhere.

However Adamawa State is situated in the north eastern part of Nigeria consisting of Twenty one local government areas. There is southern zone with annual rainfall of 675.64mm; Middle or Central zone with annual rainfall of 590.19mm and northern zone with rainfall or 535.24mm (AADP 2002).

It has a comparatively year round high temperature (Average 35^0C) that poses no serious limitation to the growth of tropical agricultural crops. In all the zones, the major grains. Rice, Maize,

Sorghum, Millet, Cowpea wheat, Sorghum Vulgare (Jigari), and Soybeans are cultivated. There are three categories of farmers in Adamawa State: The rich and enlightened few (10%); the intermediate half-literate, plenty (80%); and the dwindling, old illiterate, and poor group which form 10% of he farming population (FMA, 1997). Intermediate farmers produce more than 85% of the food consumed in the State. Their average farm size is 1-5 ha (AADP, 1996). Some of them include unemployed school leaves. The Nigeria government initially came up with incentives to help this group of farmers through interest free loans and subsidize land preparation costs and inputs e.g. tractors. This has increased production per hectare but the storage system among these farmers have remained inadequate. High losses estimated at one Million tones of grains in the state have been reported due to mold, pest infestation and poor storage facilities (FMA, 1997). This study therefore was undertaken to evaluate or appraise the existing village level storage practices.

Materials and Methods:

Field workers and enumerators were used in the survey. Questionnaires that were simple to administer and easy to analyse were formulated. One set of questionnaire was for the farmers while another set was for government establishments. In addition to the questionnaires, personal interviews were employed. The farmers' questionnaire was to give the following information; type of structure, capacity, materials of construction, commodity stored, approximate length of storage, storage problems and losses.

Farmers were also asked if they would be ready to accept improved or new type of structures. Visual observations were made of the structures to appraise their effect, state of grains in storage. Photographic camera was used for sampling pictures of grains in storage structures and other relevant information.

The questionnaire for the government establishments was designed to collect information o government involvement in storage; level of operation and extent of involvement.

Fifty questionnaires were administered in each local government and the mode of distribution was seven or ten questionnaire forms to each district area depending on the number of district in a given local government area. on the whole, one thousand and fifty questionnaires were administered through simple random sampling techniques. Out of this, one thousand and thirty one (representing, 98.2&) questionnaires were retrieved.

Results and Discussion

Before discussing the storage structures, it is pertinent to understand the harvesting culture and time. The time of harvesting services slightly between grains according to climatic changes (Table 1).

Table 1: Harvesting Period of Grains in Adamawa State.

Crop	Period
Rice	September/October,
Maize	August/September
Cowpea	November/December
Soy beans	October/November
Sorghum	December/January
Millet	August/September
Wheat	March/April
Sorghum Vulgare (Jigari)	August/September

Table 1 gives the different harvesting period of crop between August and January in the state. Harvesting is usually done by hand using sickle, cutlass and other simple tools. Grains may be stored in threshed or unthreshed forms. If threshed, they are then sun dried and manually winnowed before they are transported to appropriate storage structures. The appraisal of the structures, together with recommendations is hereby discussed.

Table 2: Storage Structures and their carrying capacities

Crop	**Capacity of storage structure (kg)**	**% Storage**
Gourds, basket	20-50	20
Hessian, Jute bags, plastic containers baskets.	51-100	30
Trees, Platform, Metal containers	101-200	30

Trees, Platform, Metal containers	201-300	20
Meta bin, and Small 'rhumbus'	310-500	20
Tree and crib	501-1000	10
Mud rhombus	1001-2000	10
Pit, crib, Platform	2001 and above	30

Table 3: Design of Storage Structures:

Storage Structure	Features
Mud and thatched rhumbu, improvised structure	Low elevated base:
Crib, platform trees	With high elevated base:
Crib, metal bin, mud & thatched rhumbu, underground pit	With loading facilities
Tree, platform poles	Without loading facilities
Gourd, metal bin, plastic container, barrel.	Moisture o\proof.
Underground pit, gourd, earthen pot	Air tight:
Thatched rhumbu, trees and platform	High risk of fire & theft.

Table 4: Durability of Storage Structures

Storage Structure	**Durability**
Mud ruhumbu	10 years
Thatched rhumbu	5 years
Underground pit	8 years with annual cleaning
Gourd	2-3 years
Earthen pot	3-5 years
Platform	2 years
Tree and Crib	10 years and above
Plastic container	5-10 years
Hessian/jute bag	1-2 years
Basket	2 years

Table 5: Storage Structures and Materials of Construction.

Storage Structure	*Construction Materials*
Murd rhumbu	Reinforced mud with straw, stone pillars at the base, floor wood. Thatched roof
Thatched rhumbu	Woven grass floor, wood or stone supported, robe, thatch.
Underground pit	Straw mat, "Zana' Corn husk padding, polyethylene, metal sheets, literate. Gourd and robe tighten at the neck.
Guord pot	Burnt clay over
Earthen pot	Wood, thatched roof or corn stalk, grass stalk,
Platform	Bamboo, palm, stalks, grass stalk wire netting reinforced with wood, thatched
Tree and Crib	roof or corrugated metal sheet Plastic materials
Plastic container:	Hessian, jute, polyethylene, plant fibres
Bag	Special plant fibres and robes.
Basket	

General Observation

Some storage systems which are common in all parts of the state are bag storage, rhombus and plastic containers. The bag storage has been found to be convenient for bulk storage of shelled or threshed grains at the bag is very convenient in transporting grains. But the ware chouses where these bags give way not well constructed. Hence were losses due to rats, insets and rain, sometimes, the bags give way during handling due to wear and tear as a result of many times of re-use. Other observations include the following:-

(i) Most of the structures especially mud and thatch rhombus were found to have low elevated base, making them susceptible to moisture migration. Some had comparatively high elevations, but the supporting pillars were rough and the rat guards not properly installed.

(ii) The loading and unloading facilities are inadequate.
(iii) The structures were not moisture proof and airlight, therefore, pest control through fumigation is difficult.
(iv) The supporting pillars were weak, so the structures could easily be blown down by heavy strong winds.
(v) The woods in the structures (floor) were found to be attacked by termites.
(vi) High risks of fire and theft in thatch rhombus, platform, trees and cribs; tons of grains have been lost to fire.
(vii) Grains stored in underground structures or to some extent, protected against insect attaché beached of reduced oxygen levels.
(viii) Underground pit is easy and cheap to construct and requires minimum materials; the same size can be used for up to eight years but with annual redigging and cleaning.
(ix) Grains stored in pit were found to undergo changes in texture, appearance and flavour. Also, the viability of these grains have been found to be quite low.
(x) Underground pit is not rodent proof and sometimes termites can invade the grain if the pit is located in a termite zone.
(xi) It is difficult to empty and clean the pit structure.

Recommendation

The recommendations include suggestions to improve the specific structures and the storage facilities in Adamawa State. In making suggestions, many factors were taken into consideration. Other recommendations include:

(i) Due to the high risks involved with the thatched rhombus, it is recommended that this structure be discouraged and discontinued; the same goes for open platform structures.
(ii) The farmers were discouraged from using earth pots and gourds, which are fragile, susceptible of insect infestation, instead, small to medium sized metal bins (barrels) made of galvanized sheets have been suggested. The metal bin could be 400-1000kg. in capacity and has inlet and outlet at the top. Pests control is made easy with this structure.
(iii) The crib has been found to be an effective storage structure throughout the state it is therefore, recommended that it should be fully adopted but in a modified form. The modified modern crib, which takes into account the climatic conditions, has been suggested. It should have a width of 2 meters and made of wire mesh reinforced with wood. Also, rodent guards should be installed. This design is already being used by the semi-literate farmers in the State. The underground pit could be improved upon. If it is necessary to use such a structure. A permanent birck Mansory of reinforced concrete structure is suggested. This will eliminate water seepage and make I t easy for hygienic measurement.

Conclusion

The modern post-harvest technologies can be applied to improve the food security at the village level; the process should first take into consideration the existing technologies of the farmers. The farmers will readily accept a concept or technology that builds upon or improves that which they are used to rather than one rich imposes a totally new idea. Extension work should now be geared towards ensuring food security by advising farmers to adopt improved grain storage practices. If farmers will lean how to store grains effectively there will be a limit to grain deterioration.

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DEVELOPMENT OF A HALF TONNE CAPACITY RICE PARBOILER FOR COTTAGE MILLERS

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ABSTRACT

A 500kg capacity pressure paddy parboiler was developed to meet the need of small scale rice millers. It consists of a firewood-heated 0.45m^3 boiler connected by galvanized pipe of 0.05m inner diameter to a cylindrical 0.85m^3 soaking/streaming tank. A network of perforated galvanized steel pipes 0.38m diameter in the soaking/steaming tank distributes steam evenly to the soaked paddy. Preliminary performance test of the parboiler was assessed for three defference steaming durations by determining the percentage chalky grains and broken grains in the resultant milled rice. Cooking times for the milled samples was also determined. It ranges from 19 minutes for sample parboiled for 20 minutes to 33 minutes for sample parboiled for 40 minutes. Test results showed that least grain breakage and least chalky milled rice grain were obtained for a steaming duration of 40 minutes resulting in 98% parboiling efficiency. The equipment is therefore, recommended for cottage rice millers and cooperative societies to improve the quality and quantity of their milled rice production.

Key words:- Parboiling, Soaking, Steaming, Chalky, Translucent.

INTRODUCTION

The Nigerian rice sector has seen some remarkable development over the last quarter-century (Lancon et al., 2003). Both rice production and consumption have vastly increased during the period. The production increase however, has been insufficient to match the consumption increase and rice imports continues to take up an important share of Nigeria's agricultural imports, there is considerable political interest in increasing the consumption of local rice. This has made rice one of the highly political commodities in Nigeria.

Past policies have not been successful in securing the market share for local rice (Lancon et al., 2003). There is a need to draw lessons from the past policies and prepare farmers on improved post-harvest activities of rice to be able to handle the increase in production of rice that may results due to Federal Government ban on importation of rice.

Lancon et al. (2003) reported that among the stake-holders consulted during a survey, it was generally agreed that one of the major constraints that affect the development of Nigerian rice sector is the inability of the local rice to match the quality of imported rice. It is a known fact that parboiling is the most important pre-milling treatment which improves the quality of rice.

Parboiling of paddy is an important age-old pre-milling process practiced in all rice producing areas of the world. Paddy is normally (Traditionally) parboiled by soaking in water to saturation level (30-31% moisture contet) for typically 24-48h followed by draining and steaming of the soaked paddy (Guha and Ali, 1998; Charkraverty and De,

1981; Araullo eta al., 1976; and Miah et al., 2003). Other processes, like pressure parboiling (steaming of partially soaked paddy at fairly high pressure, 2.5kg/cm^2 or higher) and dry heat parboiling (roasting of fully soaked paddy) have also been developed (Guha and Ali, 1998). Some of these developments do have some inherent problems. For example Essien and Ikrang (2005) reported some problems associated with traditional methods to include partial cooking, discolouration, and time it takes to remove the steamed paddy from the hot water at the end of parboiling.They proposed some modification on the basis of which they built a parboiler with a boiling kettle at the bottom separated from the steaming chamber by a perforated sub-floor in a plate fitted with small diameter steaming tubes. The problem associated with this improvement is reclaiming of paddy after steaming. Since the tank has to be tilted, this limits its capacity to a size that human power would be able to handle.

Marshall et al. (1993) as in Miah et al. (2002) reported that in- complete parboiling results in partial surface starch gelatinization. The dried Kernels produce translucent outer layers and opaque or white centre (chalky) from the non- gelatinized starch. Completely gelatinized parboiled rice kernels are translucent and an indication of fully parboiled rice. The cooking quality of rice expressed in terms of time of cooking, swelling capacity, expansion ratio, and colour, are also measure of extent of parboiling. Charkraverty and De (1981) reported that raw rice takes about 15 – 20min. to become fully cooked in boiling water, whereas parboiled rice requires about 30-40min for a comparable degree of softness.

Cooking time of raw rice is determined by a glass plate opaque core method (Guha and Ali; 1998). It was difficult to apply the same method for parboiled rice, it being fully translucent. Other authors have also encountered this difficulty and some alternative methods have being proposed (Sowbhagya and Ali; 1991). The effectiveness of parboiling in improving the quality of milled rice is well known and reported by many authors.

It is in view of this that a 500kg capacity mild pressure parboiler was designed and developed to suit the peculiar situation of the Nigerian farmer and to make available the next level of post-harvest technology of improved quality rice production.

MATERIALS AND METHODS

Design Considerations.

The design of this parboiler was based on the following considerations.

i. The availability of materials locally to reduce the cost of production;
ii. The tank should serve the dual purpose of soaking and steaming;
iii. The tank should be able to maintain the temperature of water during soaking at 65^0 – 75^0c, hence the necessity for lagging it.
iv. The shape and orientation of the tank is designed to ease loading and off-loading of paddy and to allow free flow of hot water (80^0c) into the tank.
v. The water is to be boiled using fire wood or rice husk
vi. The boiler drum is mounted horizontally over the fire place to increase the heating surface area for more efficient and faster heating.
vii. The collection platform is to serve as a tempering medium.

viii. The developed parboiler would reduce process time, improve milled rice quality, and increase the production capacity of the local processor at moderate capital investment.

Description of the Parboiler

The soaking and steaming is done in the same mild steel cylindrical tank lagged with a 50mm thick fibre glass. Steam from the boiler enters through a central perforated 0.05m diameter pipe and is distributed to a network of perforated 0.03m pipes arranged radially along the length of the tank spaced 0.02m apart. The base of the tank is conically shaped and closed at the bottom by a water tight hatch 0.025m diameter. At the side of the hatch, there is a valve for draining off the steeping (soaking) water. The tank is raised 0.06m above the ground by 0.023m thick wall. Plate 1 show the photograph of the parboiler and figure 1 is the schematic diagram of the parboiler.



Plate 1 Photograph of the parboiler (A-boiler; B-steam pipe; C-soaking/steaming tank; D-support flange; E-wall support; F-tempering chamber; and G-furnace.)

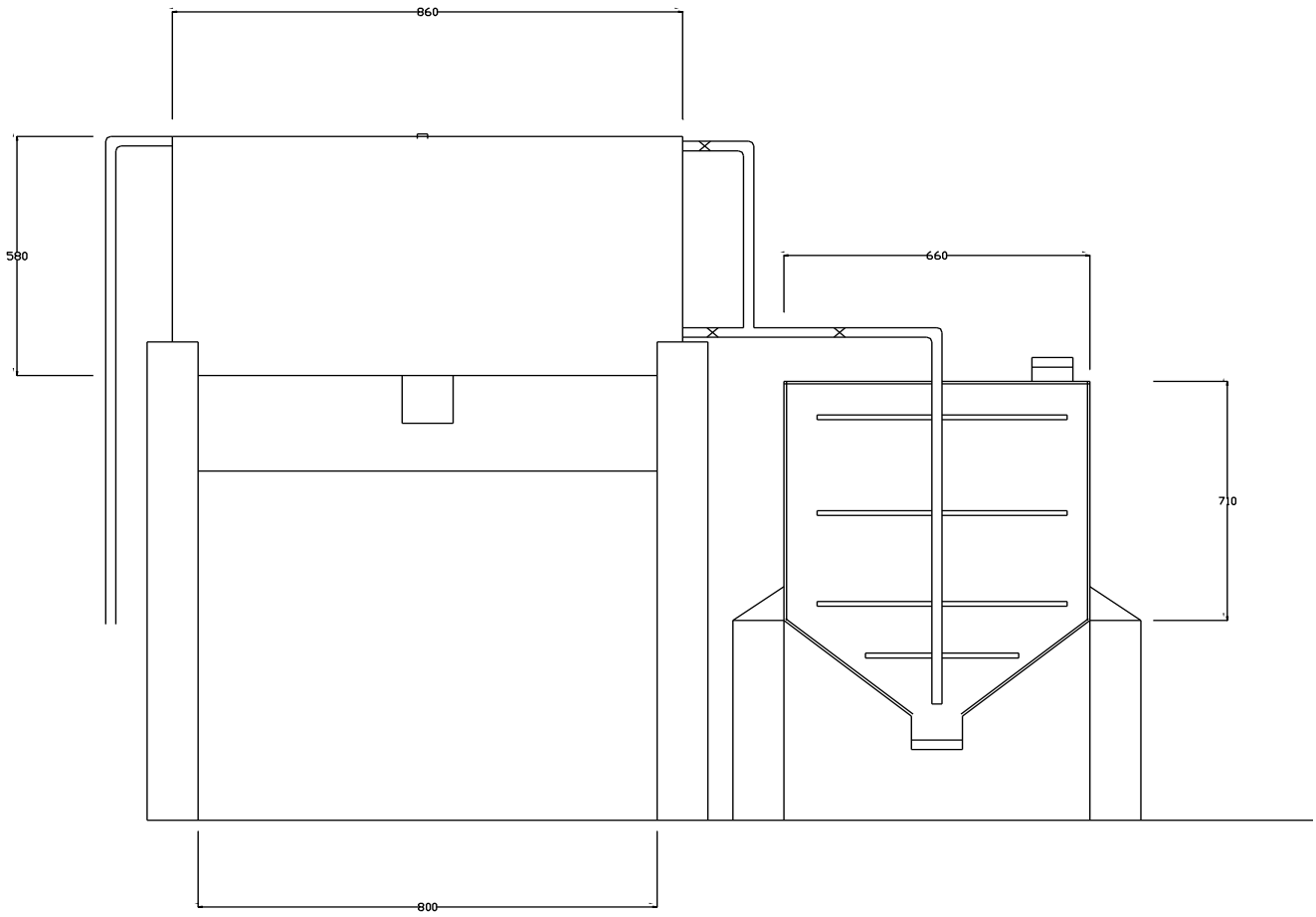


Figure 1 Schematic diagram of the parboiler showing the steaming pipes net work.

Operation of the Parboiler

During parboiling operation, tank 1 is filled with tap water and heated by fire to 85^0C. The washed paddy is then poured into tank 2. The temperature of water would drop to 68^0C. After four hours steepings, the water is drained off. By closing value 1 and opening value 2, pressurized steam is then released into the soaked paddy through the network of perforated steaming pipes.

Performance Tests

The paddy used for the performance tests was obtained from a homogenous lot of 300kg Faro 52 variety. The lot was thoroughly mixed and shared into three 100kg fractions and bagged. The bags were allotted by standard statistical techniques into three experimental units labeled A, B, and C.

The three units were soaked under the same conditions as described above but the steaming time was varied. Sample A was steamed for 20 minutes, sample B for 30minutes and sample C for 40 minutes. At the end of steaming the paddy was collected from the bottom hatch, tempered and there after dried under shade to a moisture content of 14.05% (d.b). Milling was done using a Satek Japanese Rubber Roll Rice husker/polisher.

Representative samples of milled rice were obtained from the three parboiled lots by spreading each lot evenly on a table. The table top was divided into nine squares from which some quantities were collected and pooled to get 50g sample.

Milled Properties Assessment:

A magnifying glass was used to separate the translucent kernels, white belly (chalky) and broken grain from the samples. The white belly efficiency and the parboiling efficiency were determined using the conventional relationship reported by Agidi and Zibokere (2005).

$$Wb = \frac{Mwb}{Ms} \times 100 \text{ ---------- (1)}$$

$$Eff_p = \frac{Ms - Mwb}{Ms} \times 100 \text{ ------(2)}$$

Where Wb = white belly efficiency
Mwb = weight of the white belly
Ms = weight of the sample
Eff_p = Parboiling efficiency

Cooking Time:- The method reported by Sowbhagya and Ali (1991) was used. In this method, cooking of rice in boiling water was continued, till the cooked parboiled rice showed a similar firmness to that of cooked raw rice by sensory method. The moisture content at this stage was found to be 75% (w.b). Time taken to reach this moisture was recorded as cooking time.

Results and Discussion

Milled properties:- Physical properties of milled parboiled rice are presented in Table 1. Sample A which was steamed for 20 minutes contained considerable proportion (about 50%) of white belly grains, while sample B which steamed for 30 minutes contained (about 30%) of white belly grains. But sample C which was subjected to a longer duration of steaming (40 minutes) contained only 2% of white belly grains which can be regarded as negligible. In comparison sample C which has a parboiling efficiency of 98% is darker in colour.

Cooking quality:- Results of cooking time, which is an important cooking quality parameter of rice, is presented in Table 2 for three samples of the variety used. It could be seen that the cooking time for sample A was 19 minutes which is close to 18 minutes cooking time for the same variety reported by Guha and Ali (1998). Sample B takes about 25 minutes to reach the same degree of softness as sample A. The cooking time of Sample C was 33 minutes.

Table 1 Average Milled Property of the Parboiled

Sample	Sample weight (g)	Steam Temp (^{0}C)	Steaming Duration (min.)	White belly content (g)	Percentage white belly (%)	Breakage content (g)	Parboiling efficiency (%)
A	50	100	20	25	50	27	50
B	50	100	30	15	30	9	70
C	50	100	40	1	2	5	98

Table 2 Average Cooking Time of the Milled rice

Sample	Time (Min.)
A	19
B	25
C	33

Conclusion

The above results have demonstrated that paddy rice could be parboiled by partial soaking, tempering and steaming under relatively mild pressure, since parboiling efficiency of 98% was achieved using this equipment. The cooking quality and breakage content are under acceptable limits.

It could be concluded that the parboiler will be suitable for a cottage rice mill since the maximum time required to parboil 500kg paddy is six hours, therefore it can serve a tonne capacity mill. It is hereby recommended that, further work should be carried out on scaling up of the equipment to one tonne capacity.

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DEVELOPMENT OF A HALF TONNE VERTICAL FEED MIXER

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ABSTRACT

A 500kg vertical feed mixer was designed and constructed. It was put to a performance test to determine its evenness of mix. The mixer was driven by a 5hp 3-phase electric motor running at 1,950rpm idle speed. Three batches of mix were carried out. The number of tracers in every batch was counted manually. The values obtained for the tracer presence after every 5 minutes of mixing were analyzed using a statistical tool to determine the standard deviation. A mean concentration of the tracer was computed to be 2.01 and a standard deviation of 0.1 was computed thus making the mixer acceptable for utilization. The developed mixer has a total mixing time of 44.50 minutes per batch of mixing and has a capacity of mixing 4 tonnes of feed per 8-hour working day. It can be adopted for commercial mixing of feed. The mixer had a production cost of ₦74,650 and a running cost of ₦8.20 per batch.

Keywords: Feed, Evenness of Mix, Standard Deviation

INTRODUCTION

Recent years have witnessed considerable changes in farming techniques, combined with greater specialization and intensity of production. More intensive rearing and farming systems have also been introduced for certain classes of livestock e.g. poultry as a result of the Federal Government's ban on the importation of poultry and poultry products. This policy, in addition to the fact that the major animal protein supply stock for Nigerians are from the ruminants (cattle, sheep and goats), the non ruminants or the monogastrics (poultry, pigs and rabbits), fishes and the mini livestock (grasscutter, and guinea pigs) gave rise to commercial poultry farming which was not matched with equal level of feed production.

Feed, also called animal feed, is foodstuff grown or developed for livestock and poultry, selected and prepared to provide highly nutritional diets that both maintain the health of the animals and increase the quantity of such end product as meat, milk or egg (Atteh, 2002). Nevertheless, in terms of commercial production of finished feeds in Nigeria, more than 95% of the production are ascribed to monogastric sector especially poultry and piggery (RMRDC, 1996). Also of this percentage of commercial feed production, about 90% are for the poultry sector.

RMRDC (1996) reported that the installed capacity for livestock feed production in Nigeria has been estimated to be 151.082 metric tones (MT) while the current annual production capacity is put at 44,008.50MT giving a shortfall of 70% (RMRDC, 1996). This short fall is drastic compared to the installed capacity. The major reason for this can be attributed to the high cost of machinery which is mostly imported into the country.

Mixing is the dispersion of components, one through another (Earle, 1983). It is the blending of ingredients for animal feeds, fertilizers and seed stocks (Henderson and Perry, 1976).

A satisfactory mixing process produces uniform mixture in minimum time and with minimum costs for overhead, power and labour. Mixing can either be by batch or continuous process. For mixing in which micro ingredients are to be dispersed, the use of batch mixers is dominant (Fahrenholz, 1994). Batch mixers can either be vertical or horizontal (such as ribbon and paddle mixers (Fahrenholz, 1994; Earle, 1983; Henderson and Perry, 1976)

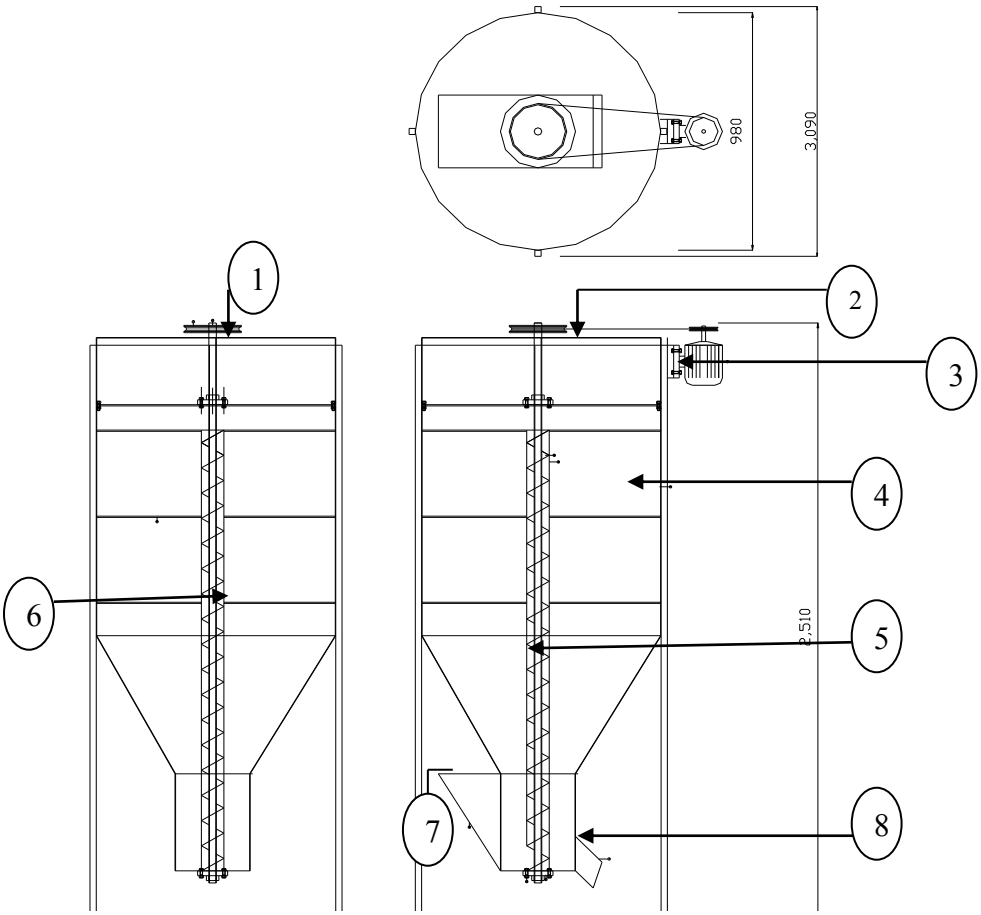
MATERIALS AND METHODS

Description of the Machine

The mixer is made up of a vertical steel container within which is single vertical rotating screw which lifts solids from the bottom to the top of a cone-bottomed mixing tank. The various components of the mixer are shown on Figure 1.

When solids reach the top of the screw, they are flung towards the wall and descend slowly through the bed of articulate solids. A pyramidal shaped hopper with a rectangular cross section is provided at the bottom to serve as the loading port. A smaller port is provided adjacent to the inlet hopper as the discharge chute.

Figure 1: The Vertical Feed Mixer



1- Pulley, 2- Belt 3- Electric Motor 4- Mixing Tank 5- Screw Conveyor 6- Barrel 7- Hopper 8- Discharge Chute

Design Considerations

The design of the mixer was based on the following considerations;

i. Local availability of materials to reduce cost of production
ii. The hopper should be wide enough to allow loading of ingredients directly or from the size reduction mill
iii. The screw conveyor was the half standard to aid vertical lifting
iv. It was designed to ensure minimum loss of ingredients during operation
v. The design was to allow the loaded ingredients to be thrown against the walls of the mixing tank to effect mixing

The Construction of the Mixer Parts

1. ***The Feeding Hopper:*** A 1.5mm mild steel sheet was used in the construction of the hopper. The sizes of top length of 500mm x 400mm and the bottom sides of 150mm x 100mm were developed out and used to mark out the pyramidal shape which was then folded to make the cone shape of the hopper

2. ***The Mixing Tank:*** A 1.5mm mild steel sheet was used in the construction of this part. The conical end was developed along side with the cylindrical top. Both were folded to shape and joined together to form the required shape.
3. ***The Screw Conveyor:*** The central shaft was constructed from a 32mm outside diameter thick pipe with both ends bushed with mild steel shaft turned to close bearing tolerance of 25mm at both ends. The scroll was made with a series of round metal plates of thickness 3mm and with a central hole of 42mm in diameter drilled through. These were sliced and the open ends joined round the central pipe.
4. ***The Barrel:*** This was constructed from an existing pipe. 5mm mild steel plate of diameter equal to that of the barrel was cut, drilled to allow passage of shaft and welded to the pipe. This plate served two purposes, to close the lower end of the barrel and to serve as seat for the mounting lower bearing.
5. ***The Clamping Bar:*** This was constructed from a 10mm x 100mm iron bar. A 30mm diameter hole was drilled at the centre for shaft passage. It was to serve as the seat for the bearing at the top of the barrel.

Performance Tests

The ability of the mixer to mix feed was tested for using the standard test procedure for solid mixing equipment for animal feeds as detailed in ASAE standard S303.1.

The following criteria, as specified in the standard, were used in the judgment of the performance. They are;

i. The uniformity of dispersion of the ingredients through the entire batch (i.e. the evenness of mix)
ii. Time required for batch mixing
iii. The throughput and
iv. Starting and operating power

The standard provides for a mixture of 90% of feed components to 10% of the tracer. In line with this, the composition for the mixture is as in Table 1 below;

Table 1: Feed composition

S/N	COMPONENT	MEAN DIAMETER (mm)	MASS (kg)	%
1	Maize offal	0.85	112.5	22.5
2	Rice Offal	0.85	112.5	22.5
3	PKC	0.85	180.0	36.0
4	Limestone	0.85	45.0	9.0
5	Red Sorghum	1.50	50.0	10
			500	100
TOTAL				

The mixer was run by a 5hp 3-phase motor with rated speed of 2890 rpm. The speeds of the motor and that of the auger while running empty were measured using a tachometer and when running fully loaded.

The components were fed in one after the other with a 30-second delay time between loadings. The tracer was loaded last. The total time for loading was recorded. The time of mixing started with the last drop of the tracer. Ten samples, each weighing 200g, were measured out at 10minutes of mixing and at 5 minutes interval thereafter.

The concentration on each of the samples was determined by counting the number of the tracer items in the samples. The counts were treated to a statistical evaluation.

RESULTS, CALCULATIONS AND DISCUSSIONS

The results of the measurements are presented below and in Tables 2 – 5.

Speed of motor running empty = 1950rpm
Speed of motor running with load = 1755rpm
Speed of auger running empty = 58.60 rpm
Speed of auger running with load = 23.25 rpm
Total time of loading = 19.50 minutes
The standard deviation values computed from;

$$\overline{p_i} = \frac{\sum_{i=1}^{n} p_i}{n} \qquad (1)$$

and

$$S = \sqrt{\frac{\sum_{i}^{n} p_i^2 - \overline{p}\sum_{1}^{25} p_i}{n-1}} \qquad (2)$$

(Uhl and Gray, 1969)

Variance = S^2

Where,

p_i = Proportion of tracer = half the weight of tracer

$\overline{p_i}$ = Mean concentration of tracer

S = Standard deviation
n = Number of samples = 10
The values are reported in Tables 2 to 5

Costing

The costing was done for the production and running
The production cost comprised of the following;

Cost of materials and consumables	= ₦55,650
Labour cost (Two artisans @ N750 per day for 7 days	= ₦10,500
Overhead Costs	= ₦8,500
Total	= ₦74,650

The running cost was determined as follows;

Electric motor size	= 5hp = 3.73kW
Time taken per batch of mixing	= 44.5 minutes
	= 0.742 hours
Power consumption per batch	= 3.73kW * .742hrs
	= 2.77kWh
Power charge rate	= ₦4per kWh
Power consumption cost	= ₦(2.77 * 4) per hour
	= ₦11.07 per hour

For a batch of mixing,
Power consumption cost = ₦11.07 * 0.742
= ₦8.20 per batch

Discussion

Figure 2 (based on Table 6) shows the relationship between the mixing time and the variance. Since the variance is the determining factor for ascertaining the degree of mixing, it can be concluded that variance decreased with mixing time. As could be seen from Tables 2 to 5, the p^2 values increased with increase in time. The p^2 value and the variance (which is an indicator of the evenness of mix) are inversely proportional. This agrees with the submissions of ASAE (1984) and Uhl and Gray (1969) and is illustrated by Figure 2.
.Since the mixing time can however not be infinite; the optimum mixing time for this mixer has to be determined. In further evaluation of this mixer it will be pertinent to study the followings;

i. Relationship between mixing time and degree of mixing with a view of determining the optimum mixing time.
ii. Relationship between the moisture content of the feed components and the degree of mixing
iii. Relationship between the speed of the screw and the degree of mixing and
iv. The correlations of the three variables above.

These will be evaluated in the performance evaluation of the vertical mixer

CONCLUSION

The evenness of mix was estimated using the relations of Uhl and Gray (1969). The variance decreased with the increase in mixing time at mixing auger speed of 23.25 rpm. These results agree with literature submissions on theory of mixing. There is however the need to evaluate the evenness of mix in relation to mixing speed, moisture content of the components and an elongated time of mixing.
The developed mixer has a total mixing time of 44.50 minutes per batch of mixing and has a capacity of mixing 4 tonnes of feed per 8-hour working day. It can be adopted for commercial mixing of feed

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Table 2: Concentration of Tracers after 10 Minutes

Sample No.	Weight of Tracer (g)	p_i	p_i^2
1	2.0	1.00	1.00
2	2.5	1.25	1.56
3	1.0	0.50	0.25
4	1.5	0.75	0.56
5	2.8	1.40	1.96
6	3.0	1.50	1.25
7	3.1	1.55	2.40
8	0.0	0.00	0.00
9	2.6	1.30	1.69
10	3.7	1.85	3.42
	Total	10.43	15.09

Table 3: Concentration of Tracers after 15 Minutes

Sample No.	Weight of Tracer (g)	p_i	p_i^2
1	2.0	1.00	1.00
2	2.5	1.25	1.60
3	4.5	2.25	5.10
4	1.5	0.75	0.56
5	4.0	2.00	4.00
6	4.0	2.00	4.00
7	3.0	1.50	2.25
8	2.5	1.25	1.56
9	3.5	1.75	3.06
10	3.8	1.90	3.61
	Total	15.65	26.74

Table 4: Concentration of Tracers after 20 Minutes

Sample No.	Weight of Tracer (g)	p_i	p_i^2
1	4.0	2.00	4.00
2	4.5	2.25	5.06
3	5.0	2.50	6.25
4	3.0	1.50	2.25
5	3.5	1.75	3.06
6	3.8	1.90	3.61
7	3.9	1.95	3.80
8	4.4	2.20	4.84
9	4.5	2.25	5.06
10	4.0	2.00	4.00
	Total	20.30	41.93

Table 5: Concentration of Tracers after 25 Minutes

Sample No.	Weight of Tracer (g)	p_i	p_i^2
1	4.0	2.00	4.00
2	3.9	1.95	3.80
3	3.8	1.90	3.61
4	4.1	2.05	4.20
5	4.6	2.30	5.29
6	4.0	2.00	4.00
7	4.0	2.00	4.00
8	3.9	1.95	3.80
9	3.8	1.90	3.61
10	4.1	2.05	4.20
	Total	20.01	40.50

Table 6: Summary of Values

S/N	Time of Mixing (mins)	$\overline{p_i}$	S	S^2
1	10	1.043	0.68	0.46
2	15	1.565	0.50	0.25
3	20	2.030	0.20	0.04
4	25	2.010	0.10	0.01

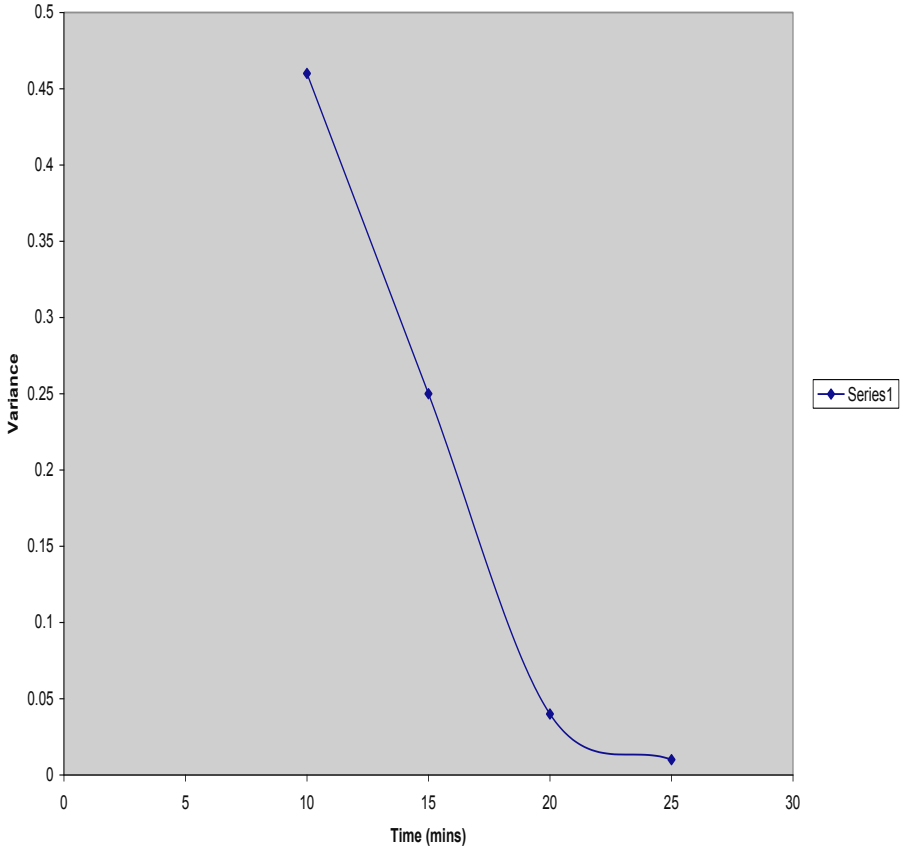


Figure 2: Relationship between Variance and Mixing Time

PROCESSING OF AFRICAN LOCUST BEAN (*PARKIA SPP.)* IN NIGERIA: PROBLEMS, PROSPECTS AND CHALLENGES

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Abstract

African Locust Bean is used as a seasoner in most African dishes. Its use in African dishes has witnessed a rapid decline since the advent of industrially synthesized seasoners (which received wide acceptance despite its seemingly unfriendly status to the human health). This paper reviews the primary and secondary processing of this produce as it exists at the moment. The problems associated with its processing in Nigeria and the likely prospects are also reviewed. It is intended to pose challenges to agricultural processing engineers for search into appropriate technologies for the processing and packaging of locust bean with the aim of re-invigorating its adoption, particularly in Nigeria

Keywords: Locust Bean, Processing, Prospects, Challenges

Introduction

African locust bean (*Parkia Spp.*), is one of 34 known species of the *Genus parkia*, whose origin is traced to South America (Sina, 2006). The four most commonly used species are *Parkia bicolor, Parkia clappertoniana, Parkia fillicoida* and *Parkia biglobosa***.**It is an agro-forestry tree specie of the family of *Mimesacease* (a leguminous group) spread throughout the African Sudanian savannah, from Senegal in the west to Uganda in the east (Kudabo *et al,* 1999). It is an important, socio-economic specie in high demand by local communities for its multiple uses in food, traditional medicine and pharmacy, preservation and improvement of soil fertility, rites and customs etc. No wonder Mongo Park described the tree as one of the most useful economic trees in Africa, during his travels through the interior district of Africa in 1879 (Campbell and Platt, 1972).

Parkia Spp. is rarely cultivated by human but it is often found growing widely in forests and savannah regions. Unlike other beans which grow on vines or bushes, the locust bean grows in pods on medium sized trees. The fruits appear in bunches of pods. The pods vary in length from 12 to 27cm. They contain a yellow dry powdery pulp called *dozim*, which is rich in carbohydrates (Kordylas, 1990).

The seeds are black or dark brown in colour. They contain about 20 percent semi-liquid oil, and are rich in minerals, especially calcium, phosphorus and iron. All parts of the fruit; the pod, the yellow pulp, and the seeds are used as cattle feed. The pod is high in fibre, poor in protein but contains a fair proportion of minerals and it is used in making pulp. The *dozim* is a cheap source of protein. It contains natural salt and has been analysed to be a very good remedy for diabetic patients.

Locust bean seeds are fermented into paste to make a condiment with a stray smell used in flavouring soups and stews. The condiments are variously called *dadawa* in Hausa, *iru* in Yoruba and *Ogiri* in Igbo dialects in Nigeria.

Processing of Locust Bean

The processing of *Parkia Spp.* Can be treated under two headings. These are;

a) Primary Processing and
b) Secondary Processing

While the secondary processing entails the conversion of the raw form into usable forms (such as condiments), the primary processing is entirely by engineering applications.

Primary Processing of Locust Bean

Primary processing of *Parkia Spp entails*

i. Decortication
ii. Dehulling and
iii. Washing

Any processing beyond this point will be with the intent of preserving it or converting it to consumable forms.

Decortication involves the breaking open of the pods to remove the beans embedded in the *dozim.* This process requires a large amount of energy due to the hardened and fibrous nature of the pods.

Agricultural engineering researches have revealed that the speed of the decorticating cylinder and the interaction between the cylinder speed and the moisture content of the pods are significant in the

decorticating or shelling efficiency of any equipment developed for that purpose (Oni, 1990). To reduce shelling efforts (it was reported) there may be the need to reduce the moisture content of the pods to below 11% (wb) (Oni, 1990).

Further researches also reveal that feeding rate has significant effect on the shelling/decorticating efficiency. Infact it was revealed that feeding rate with linear speed gave equivalent linear efficiency (i.e. high feeding rate at high speed gave high efficiency) (Ajayi, 1991).

These few literature facts have been used in the design and evaluation of developed decorticators/shellers. Kudabo *et al* (1999), using a cylinder speed of 1000 rpm had threshing efficiency of 88%. The interaction of the speed and the moisture content was however not reported.

While literature reveals very little engineering input to the decortication/shelling of locust bean, no significant facts are available on the engineering solutions to the dehulling and washing of locust bean. Even the few developed and evaluated decorticators are not commercially available. This confirms the submissions of Ukatu (2006).

The combined effects of these is that the primary processing of locust bean has been dependent on manual labour. The same applies in the secondary processing of the produce. This calls for intervention by agricultural engineers.

As at today, the processing of the locust bean is still predominantly traditional.

Secondary Processing of Locust Bean

Traditionally, the raw beans are cooked for upward of 12 hours in excess water until they are soft enough to allow for hand de-hulling (Achi, 2005). Figure 1 presents the sequence of events for the processing of locust bean in Nigeria.

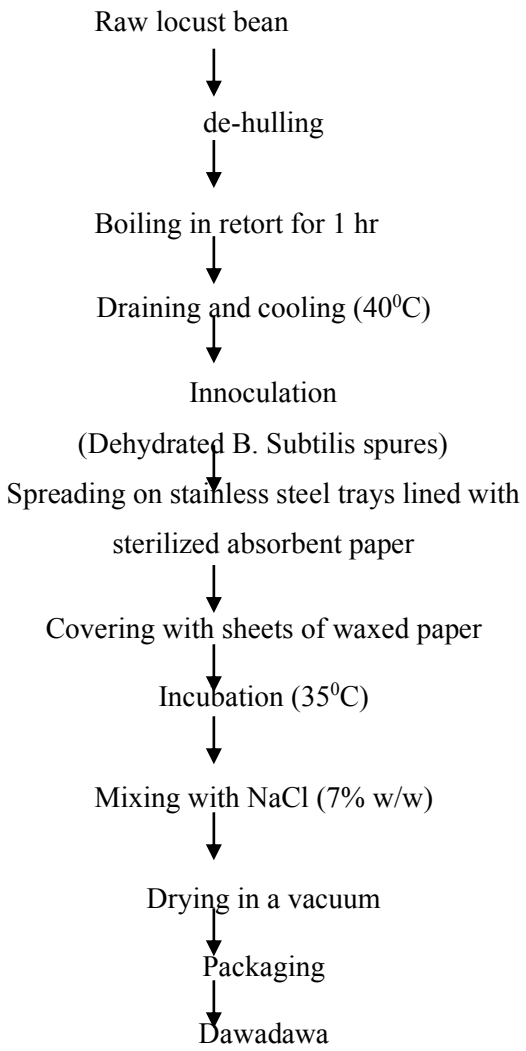


Figure 1: *Flow Chart for Industrial Production of Condiment*
Source: Achi (2005)

At present, de-hulling is done using the tedious method of hand separation. Abrasive de-hulling of

dry beans is not possible because of the strong adherence of hulls to the seed. Nevertheless, roasting prior to boiling in water has been identified as a technique for effecting reduction in cooking time (Achi, 2005). Boiling in excess water serves not only the purpose of partial cooking, but facilitates microbial penetration and human digestion because the bean (endosperm) is softened. However, before the beans undergo the process above, they are pounded using mortar and pestle to remove the *dozim* and then washed in a bath of water.

After cooking and de-hulling processes have been completed, the cotyledons are prepared for fermentation.

Fermentation of Locust Bean

Fermentation processes play important roles in food technology in developing countries. In traditional fermentation processes, natural micro-organisms are employed in the preparation and preservation of different types of food. These processes add to the nutritive value of qualities associated with digestibility and edibility.

The methods employed in the manufacture of fermented condiments differ from one region to another because these processes are based on traditional systems. A basic scheme of locust bean fermentation for production of dawadawa is depicted in Figure 1. According to local custom and climate conditions, specific process variations occur (Achi, 2005). In general, fermentation takes place under conditions which the producers have found to be favourable for the appropriate growth and activity of the microorganisms.

State of Development in Nigeria

The traditional alkaline fermentation of locust bean using *Bacillus subbtilis* was modernized in the production of dawadawa cube. The greatest advancement, however, is the production, on an industrial scale, of *iru* (dawadawa) as cubes by Cadbury Nigeria (Odunfa, 1985).The advertisement of dawadawa cubes utilizes attractive packaging to appeal to the consumer's preference and taste. This has enhanced patronage, particularly among elite housewives.

As at today the development of machinery for the primary processing of locust bean is still at its lowest ebb.

Economic Prospects in the Processing and Use of Locust Bean

Though the traditional technologies for the processing of locust bean are not easily adjustable to industrial processes without altering the natural state of the bean in terms of it's flavour and acceptability, there is the need for modernization of the processing technologies. This is for the following economic reasons:

i. *Mimesecease* tree (from which locust bean is gotten) is widely grown. It demands very little attention as it grows. So, a large area of cultivation will result into a large output which implies high economic returns.
ii. Processed agricultural produces command good price. The products from

the processing of *Parkia spp.* (particularly into *dawadawa*, *iru* or *ogiri*) are products that will be highly accepted by Nigerians especially when they are properly processed and packaged. Thus there are prospects for economic emancipation on the side of not only the farmers but more so on the side of the processors.

iii. It will encourage the establishment of small and large scale industries. This will create employment for the teaming populace.

Constraints in the Processing of Locust Bean and Challenges before Agricultural Engineers

Processing of locust bean into food, play an important socio-economic role in Nigeria; as well as making a major contribution to the protein requirement of the people. Traditionally fermented foods are made under primitive conditions, which result in low yield and poor hygeine.

Traditionally, women carry out fermented food processing activities. The production is craft based despite the dawn of science and technology. The techniques used are labour intensive, time consuming and low output.

The processing techniques used are often characterized by the use of simple, non-sterilized equipment, unregulated conditions, and un-attractive packaging of the processed product.

Processed locust bean products are usually exposed to environmental contamination. The smell is often repelling and unappealing to consumers. Consumer appeal and patronage may be enhanced by proper packaging of the product. Lack of this is what is responsible for its non-adoption by the elites. Dawadawa cubes (well packaged) are attractive and more appealing than *iru* packaged in broad leaves.

Therefore, the following challenges are before the agricultural engineers (particularly in Nigeria)

i. There is the need for studies into the engineering properties of *Parkia spp.* to determine parameters that can be used in the design of processing machinery for this agricultural produce.

ii. Consequent upon (i) above, agricultural engineers should embark on the development of machineries for the unit operations in the processing and conversion of locust bean seeds into indigenous seasoners. Presently, the Federal Government, through the Small and Medium scale Enterprises (SME) and the Small and Medium scale Industries (SMI), grants support to cottage industries.

iii. Agricultural Engineers should go into collaborative studies with related disciplines with the aim of developing modern technologies for the production, harvesting processing, packaging and extension of the processed products from the bean. Particular interest should be on the de-odourization of the seasoners (*dawadawa*, *iru* or *ogiri*)

iv. A cartel of interested engineers should venture into the business of processing

and marketing of locust bean and its by-products

v. As a challenge to food engineers and scientists; they should embark on research on the convertibility of the shell and the dozim to usable products.

vi. Industrial relationships should be sought with industries for the commercial production of the developed equipment. Food industries like Cadbury and others should be encouraged to sponsor such projects

Conclusion

Coordination between research, industry, and development is important for the advancement of research in biotechnology which may be applied to improve the raw materials (locust beans) and enhance the development of appropriate machinery for its processing.

Large scale production involving the use of heavy machinery, however, is expensive and demands high capital input. It is therefore, a challenge to agricultural engineers to come up with appropriate and affordable processing plant that will fit in to the local traditional processing community.

Although, agronomic facts are not available to the authors on the scale of production of locust bean trees in Nigeria, it is believed that when the processing is fully mechanized and the converted products fully adopted it will trigger the scale of production

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CONSTRUCTION AND PERFORMANCE EVALUATION OF A MANUAL OPERATED GROUNDNUT SEED DRUM ROASTER FOR FARMERS IN NORTHERN NIGERIA

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ABSTRACT

The wide range usage of groundnut and its products has led to increase in its demand. However, the local methods of roasting Groundnut seeds after it has been shelled has some associated problems and difficulties which makes it ineffective, laborious, and time consuming. The traditional methods of roasting are time and energy consuming. A Prototype manual operated Groundnut seed Drum Roaster was designed and constructed with the aim of improving on the traditional methods commonly used in the Northern Nigeria .The prototype shows the roasting efficiency (Er) to be in the realm of 98.9% with percentages of seed damaged (loss) in the range of 1.1 – 2.0%. The Groundnut seed roasting machine throughput capacity was estimated to be in the range of 33 – 36 kg/h using SAMNUT-10 (RMP-9) variety of groundnut seeds. The minimum time for roasting was estimated to be in the range of 2.5 – 3.0 minutes.

Keywords :Drum Roaster, Traditional Method, Performance evaluation, Manual

Introduction

Among the agricultural products that are of great value to both man and animals is the groundnut. It serves as raw material for industry. Groundnut oil is also used as vegetable oil for human consumption, while groundnut seed cake is being used as part of ingredients in animal and poultry feeds (Burkul, 1985; Pattee, etal, 1995). The wide range of usage of this agricultural product has led to increase in its demand. Among the problems in processing agricultural materials is that of roasting the seeds.

Pattee etal,(1995); Maria, etal, (1996); and Olapade and Akinoso,(2004), defined roasting as the process of generating characteristic aroma, flavour and colour required by consumers for acceptance of such roasted food. Roasting of food bring about thermal changes in the chemical components at relatively high temperature. This is accomplished by either using a hot air or small metal surface to heat up the material to the required temperature at which the material changes to required colour and according to Gell and Porto (1996) must be abruptly stopped using cool air to avoid food destruction. However, Roasting operation is traditionally done using different pots such as clay pots, aluminum pot, etc on an open fire until they are brown (Ihekonye and Ngoddy, 1985). This method is ineffective, time consuming and laborious and subject people to back pain and expose them to smokes and heat from fire apart from firewood wastage. Oguntunde (1987) suggested the use of infrared heating in roasting operations to improve on the traditional techniques. This involves designing and constructing of a machine that will handle this operation more effectively than the traditional methods. The machine after construction will enhance increase in groundnut oil/ cake production, which will serve as raw material for relevant cottage industries in Nigeria. The machine is also designed to eliminate the drudgery associated with the traditional method of roasting groundnut.

Materials and Methods

Selection of materials used in construction of the Drum Roaster placed emphasis on some criteria like cost, durability, strength, availability, size and weight of such materials.

Description of the Drum Roaster

The various component of the manually operated, low cost, groundnut seed drum roaster is as shown in fig 1 and 2.

The Roaster machine comprises of five major parts the frame, the stirring paddle, the roasting chambers, the heating source and the fan.

The Frame is fabricated from (30x30mm) angle iron. The frame is welded to shape as shown in fig 1. It provides support to the entire components of the roaster.

The stirring shaft comprises of the driving shaft and stirring paddles. The driving shaft is made up of a mild steel rod and the stirring paddles welded directly on the driving shaft as shown in fig 1. As the operator cranks the handle, the stirring shaft and the its accessory rotate thereby setting up a centrifugal force in the roasting chamber. This turns the seeds in the chamber.

The Roasting chamber comprises of the drum and some outlets. The roasting drum has two outlets (i.e. the inlet and the seed outlets).

The heating chamber is positioned directly under the roasting drum as shown in fig 2. It is the source of heat to the roaster. It is fabricated from galvanized sheet. It has a blower positioned by the side to supply air that allows the charcoal to burn continuously. The blower gives uniform amount of heat to the entire drum.

The optimum speed of operation is estimated to be 30 – 40 rpm.

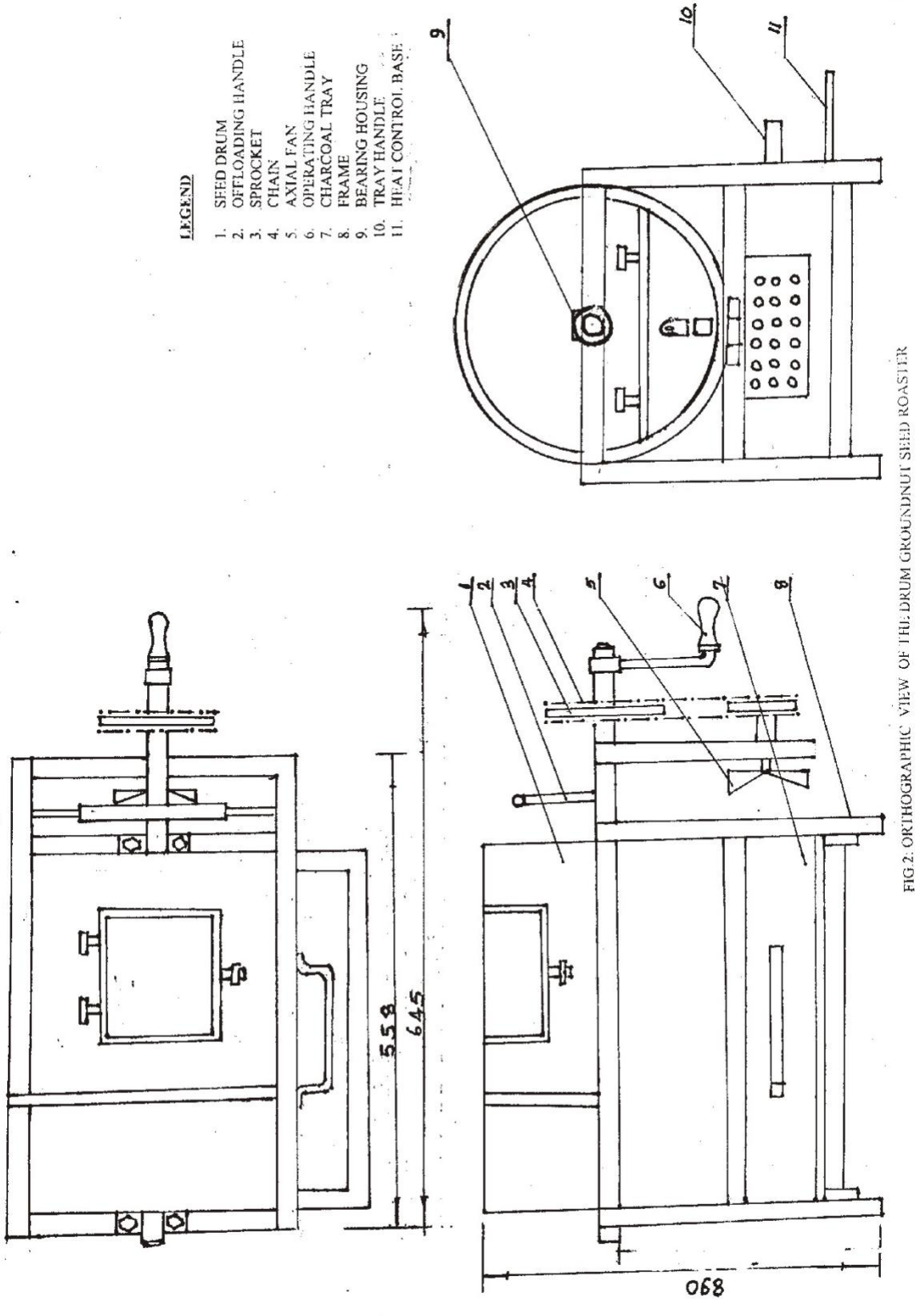


FIG 2: ORTHOGRAPHIC VIEW OF THE DRUM GROUNDNUT SEED ROASTER

Performance Evaluation.

The parameters used in evaluating the groundnut seed drum roaster are the roasting efficiency (Er)% and Man-Hour per kilogramme of seeds roasting, (Mh). Also the mathematical evaluation expression for roasting efficiency were used as stated in equation (1) and (2):

Roasting efficiency (Er)% = (W_r / W_t) X 100 ……(1)

The percentage of seed losses (El) = (W_d / W_t) X 100 ……(2)

Where: W_d= weight of roasted seed damaged (over roasted)

W_r= weight of roasted seed not damaged

W_t = total weight of seed roasted (W_r + W_d)

The man-hour –kilogram (Mh)

Table 1 shows the comparative analyses results and it involves comparing the output of the various manual methods of roasting with that of the prototype roaster.

This comparative analysis has to do with efficient utility of time by the various methods. Hence, the throughput capacity (Qt) and Man-hour per kilograms for roasting seeds by the three (3) different methods are analyzed and displayed in table 1. Other performance parameters like roasting efficiency and percentage of seed damage are also displayed in table 2.

Result and Discussion

Table 1 shows the comprehensive performance of the groundnut seed roaster. The evaluation parameters used are the roasting efficiency (Er), throughput capacity (Qt), effective time (Te) and percentages losses of seeds. The roaster efficiency appears to be generally high in the range of 97.8 to 98.9 % at five different level of roasting groundnut seeds in the drum roaster. Seed losses (El), was observed but at a low level in the range of 1.1 to 2.2 %. In addition, the throughput capacity (Qt) of the roaster was evaluated to be in the range of 33 to 35 kg/h as shown in table 2.

One of the distinguishing features of the roaster is that instead of using firewood as the source of energy, wood Charcoal was used to supply heat the roaster.

Conclusion and Recommendation

The groundnut seed roaster constructed during this investigation was observed to roast groundnut seeds at faster rate than any other manual methods as shown in table 1. Although, there is the need for sun drying of the seeds before roasting

The drying required was observed to be lighter, because the moisture content required at shelling is almost the moisture content require for roasting. Also the roaster was observed not to have any negative effect on the market value of the roasted seeds.

Table 1. Performance Evaluation Parameters Of the Groundnut Seed Drum Roaster

S/n	Weight of G/nut seed Wt (kg)	Weight of Roasted seed Wr (kg)	Weight of seeds damaged Wd (kg)	Time T (min)	Roasting efficiency (Er)%	Loss (El)%	Throughput capacity Qt (kg/h)
1	0.46	0.44	0.01	0.82	97.8	2.2	33.66
2	1.39	1.34	0.03	2.5	97.8	2.2	33.36
3	2.78	2.74	0.04	4.9	98.6	1.4	34.04
4	5.50	5.42	0.06	9.5	98.9	1.1	34.02

Where

Wt – weight of groundnut seed before roasting
Wd – weight of seeds over roasted (damaged)
Wr – weight of roasted seeds (unbroken and broken) that are not damaged
Ts- time taken to roast the groundnut seeds

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EFFECT OF KNEADER CONFIGURATIONS OF A MOTORISED GROUNDNUT OIL EXTRACTOR ON EXTRACTION TIME

BY

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ABSTRACT

A 200kg/hr Capacity, 5Hp, 2500rpm petrol engine driven groundnut oil extractor was designed and constructed with facility for interchanging kneader heads. Two kneader configurations; Anchor Kneader (K_2) and Helical Ribbon Kneader (K_3) were also developed and compared with an existing Institute of Agric Research (IAR) Rotary Kneader (K_1) to study and establish the effect of kneader configuration on the extraction time of a groundnut oil extraction machine using 3 paste levels Q_1=8.8kg, Q_2=10kg and Q_3=13.2kg respectively. Randomized complete Block Design (RCBD) and Duncan Multiple Range Test (DMRT) were used to evaluate extraction time as a kneader dependent input. The analysis of variance of the effect of kneader types indicated that there was a highly significant effect ($P \leq 0.01$) of kneader type, paste quantities and the interaction of both factors on extraction time. The ranking shows that K_1 significantly took more time for extraction than both K_2 and K_3 while the difference in extraction time between Anchor and Helical Ribbon Kneaders K_2 and K_3 were not significantly different ($P \geq 0.05$). The ranking of the effect of the interaction of the various combinations K and Q on the extraction time indicated that irrespective of paste quantities kneaded, the extraction time was highest using the IAR Kneader and lowest using the Helical Ribbon Kneader, though all combinations except K_1Q_3, and K_2Q_3 were statistically at par. When compared with the IAR Kneader, the Helical and Anchor Kneaders had a 9% and 7% reduction in kneading time above the existing IAR Kneader. Based on these results the Helical Ribbon Kneader is recommended as a better Kneader for groundnut oil extraction.

INTRODUCTION:

Groundnut, *Arachis Hypogeum* is traditionally a tropical Leguminous plant, thriving well under a variety of horticultural practices and environmental conditions. Its protein content being as high as between 21-36% and 36 –54% of lipids (Woodroof, 1983) and 51-63% oil content depending on the variety (Holaday and Pearson 1974), all these makes it an essential constituent of dietal needs. Its processed products in all forms of its presentation are high income generating, this is justified by its large scale utilization and consumption as high quality edible oil (Harris, 1982), food drink (Sanda, 1997), animal feed, roughages biomass, filler and as an organic amendment for fertilizer production.

In a personal survey conducted in Zaria and Kaduna metropolis in year 2004, 60% of processors indicated that the oil is the most important product of interest in the crop and this was corroborated by Dumade, (1991) in which groundnut oil is the leading vegetable oil most commercially produced in Northern Nigeria.

Processing or extracting or expressing oil from groundnut involves a wide range of traditional, mechanical, chemical and sometimes a combination of trado-mechanical, and mechano-chemical activities. The purely traditional method of processing groundnut oil involves using a mortar and pestle for the kneading operation (IDRC 1973; Sanda, 1997; Ola 2000) although this method is cheaper and easily adopted as reported by Nalumansi (1982), Dumade (1991); UNIFEM (1987) but is slow, ineffective, labour intensive, having low output, hardly completed, low efficiency (averagely 40%). These limitations have led to improvements in the purely traditional methods with particular interest in the kneading components and kneading stage of the oil extraction process, some of the improvements are, the IAR Rotary Kneaders and motorized Rotary Kneaders.

Mechanical methods of groundnut oil extraction had been done using screw jack expellers (Asiedu 1989), hydraulic extraction (Reddy and Bohle 1993, Eke et al 1988). Pneumatic hydraulic oil extraction (Ducote 1945) and other

developments as reported by National Agricultural Extension Research Laison Services (NAERLS) (1994), Abubakar and Yiljep (1996) and Ola (2000). These mechanical methods have relatively higher operating cost, higher efficiencies (usually between 50-73%) than traditional methods. They are usually more adaptable for small and medium scale producers.

Chemical methods or solvent extraction which are done either by continuous solvent extraction or aqueous extraction have the danger of contamination, limited use of its by-products and cost of operation. The extraction is faster (extraction time can be lower than 1 minute) and have higher efficiencies 86 – 95%. (SEDIAC 1978 Carter 1973, Tooley 1971 and Hutchins 1956).

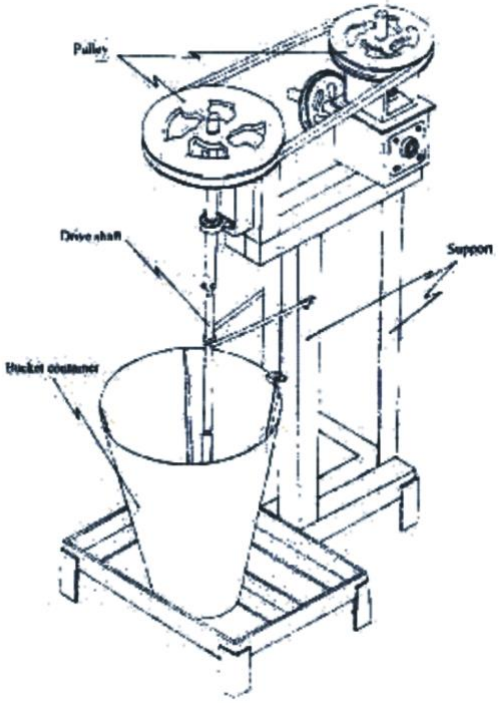
Mechano- chemical extraction which involves using the cake from the mechanical extraction as a solute to which a solvent is introduced to further release oil held in the cells are complex, expensive, time requiring but are the most efficient with efficiencies as high as 100% (SEDIAC, 1978)

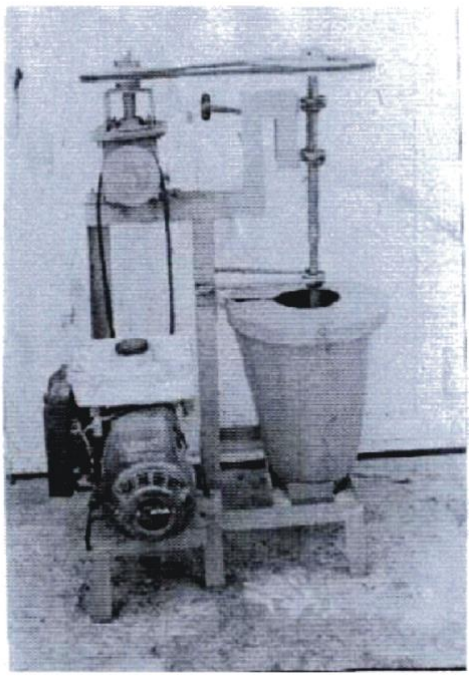
A survey by Dumade (1991) indicated that 73% of the women dominated oil processors used purely traditional methods for groundnut oil extraction. The improved traditional methods like the NAERLS/IAR Rotary Kneaders indicated a reduction of 33 -52.2% or 3.3 – 3.5 min/kg in extraction time during groundnut oil processing depending on the paste quantity used and other factors. The review of all the improved traditional groundnut oil extraction methods have indicated that time input which affects the economics and efficiency of extraction is a function of the extraction methods kneader configuration, paste texture and weight, type of leaching agent, kneader speed etc.

The survey of the year 2004 further indicated that the kneading components and kneading stage which is period of centrifugal, mixing and shearing the oil bearing cells in the paste to facilitate the leaching of the oil molecules in the most energy demanding, efficiency and time determining component in the non-chemical groundnut oil extraction processes. Therefore the objective of this study is to present the effect of kneader configurations on groundnut oil extraction time using a motorized groundnut oil extraction.

MATERIALS AND METHODS

To study the effect of kneader configurations on extraction time a 200kg/hr capacity 5Hp, 2,500 rpm petrol driven engine groundnut oil extractor was designed and constructed (Fig-1, plate 1). It consist of a frustum shaped 146607.66cm^3 capacity 2mm thick galvanized extraction bucket in which the paste is contained during extractor.





On the inside of the bucket were welded 4– equi spaced 4cm wide baffles to facilitate mixing, and to avoid vortexing and mass movement of the paste. The power transmission was by a 1:1 pinion and wheel bevel gear, transmitting power from the petrol engine through a calculated 168.6cm and 227.8cm driving and driven non-positive or friction belts as recommended by Kuntz *et al,* (1984). A 5cm and 3.8cm diameter mild steel (C1040) shaft were use for the gear shaft of the bevel and kneader shaft respectively.

Two other kneader heads, the Anchor kneader and the Helical Ribbon Kneaders were also designed and developed Fig 2a, 2b and plate 2, their performance with respect to extraction time were to be compared with and existing IAR Rotary kneader fig 2c and plate 2.

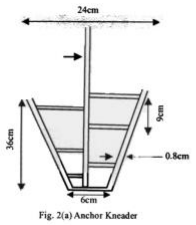


Fig. 2(a) Anchor Kneader

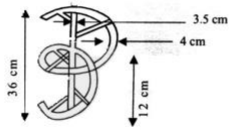


Fig. 2(b) Helical Ribbon

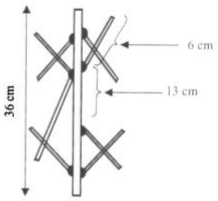


Fig. 2(c) IAR Rotary Kneader

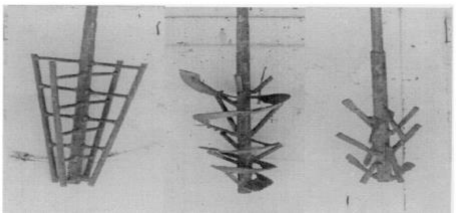


Plate 2. The photographs of Anchor. Helical Ribbon and IAR Kneaders

The Anchor Kneader had 4 wings made from 8mm diameter mild steel rods welded to a 3.5cm diameter central shaft. The upper and lower span of the Anchor was determined to be 24cm and 6cm respectively this was to give a 4cm clearance between kneader edge and baffles in the bucket. The Helical Ribbon Kneader was made from 4mm thick and 4cm wide galvanized bar of 150cm total length welded on a 3.5cm diameter central shaft but held in place by 8mm re-inforcement rods inclined at 30^O, helping the helix maintain 12cm as pitch. The diameter of the helix decreased downwards so as to fit into the bucket and increase pressure on the paste. The IAR Rotary kneader was made of 8mm diameter fingers and 6cm length mild steel rods all welded to a 3.5cm central shaft, with the fingers alternately inclined at 30^O and 120^O to the perpendicular and having 13cm and 10cm spacing between alternate and parallel fingers respectively.

The experimental design used was Randomized Complete Block Design (RCBD) involving 3 kneader configurations. IAR Rotary Kneader (K_1) , Anchor kneader (K_2) and Helical Ribbon kneader (K_3) and three groundnut paste quantities Q_1 = 8.8kg, Q_2 = 10kg and Q_3 =13.2kg. To generate data, the petrol engine was calibrated to run at an even speed using a Tachometre for the various paste levels, after which the paste quantities were introduced into the bucket and the engine started. At intervals of time, specified quantities of water were added to the paste depending on the paste quantities. This water facilitates the leaching process during the extraction after sufficient oil extraction as indicated by separation of yellow coloured oil from the paste, the engine was stopped and kneading time which is the time taken for the extraction process were recorded. Because the experiment was RCBD, various combinations of the kneader type (K) and paste quantities (Q) were replicated 3 times randomly and the means of extraction times recorded as shown in Table 1.

RESULTS AND DISCUSSION

The extraction time as defined for various treatment of kneader and paste quantity with each treatment replicated three times are presented in Table 1.

Table 1 Means of Extraction Time T (Min) using various Kneader types and paste quantities

Kneader Type(K)	Q_1 (Kg)	Q_2 (Kg)	Q_3 (Kg)
K_1 (Rotary Kneader)	6.34	6.66	7.24
K_2 (Anchor Kneader)	6.34	6.38	6.45
K_3 (Helical Kneader)	6.10	6.21	6.27

Generally, from the means of extraction kneading time Table 1 and the graph of kneading time for various paste quantities using various kneaders (Fig. 3) the following were observed:

i. The kneading/extraction time increased with increase in paste quantities for all types of kneaders i.e $T \alpha Q$, this relationship was more pronounced with the IAR Kneader. This implies that irrespective of kneader type used for oil extraction, the kneading time generally increases with increased paste quantities. This agreed with Sanda (1997) in which Extraction times increased with increasing paste quantities. This was because, with increased quantities the more time is required for the shearing, mixing and pressing of the paste and oil cells and for interaction between kneader elements or components with the paste so as to complete the extraction of oil from the cells.

ii. For corresponding paste quantities, the extraction time was longer with the IAR Rotary kneader (K_1) see Table 1 and Fig. 3 than with the Anchor kneader (K_2) and it was

iii. least with the Helical ribbon kneader (K_3). This follows the order $K_1 > K_2 > K_3$ with respect to extraction time only.

iv. For smaller paste quantities the kneading times using either Anchor Kneader or Helical Ribbon was about the same, implying either of Anchor Kneader and Helical Ribbon Kneader can be used with smaller paste quantities with no significant variation in their kneading time.

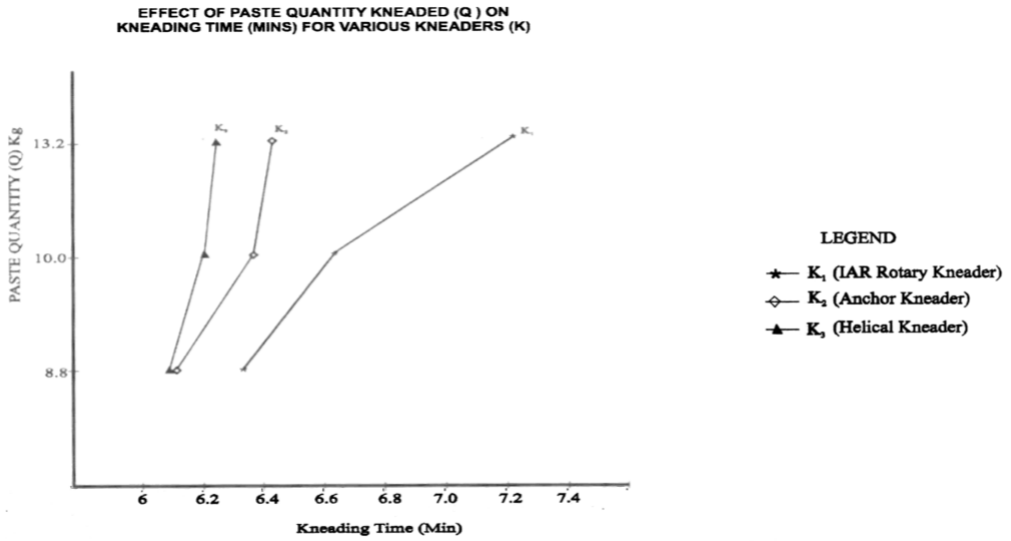


Fig 3: Effect of paste quantities on Kneading Time for various kneaders

Fig 3: Effect of paste quantities on Kneading Time for various kneaders

iv. That for higher paste quantities e.g. Q_3 the difference in extraction times becomes more obvious, implying that for higher paste quantities e.g. 13.2kg time input for kneading becomes a critical factor of consideration. See Fig 3 above.

The obvious implication of (i-iv) above is that there will be more energy requirement and consumption by the IAR kneader to knead and extract about the same volume of oil from the same quantity of groundnut paste, when compared with the Helical Ribbon Kneader. This is because, the Helical nature of the kneader K_3 having higher surface area enhances the rate of oil extraction better than the other two kneader types.

When the totals of the kneading times were considered the Anchor kneader K_2 had a 7% reduction in kneading time below IAR kneader K_1 and Helical kneader K_3 had a 9% reduction in kneading time below kneader K_1 and K_3 had a reduction in time of 2% below K_2.

Using statistical analysis of variance it was found that there was a significant ($P \leq 0.01$) effect of kneader type (K) and paste quantities (Q) and the interaction of the two factors K x Q on the time required for extraction (i e at 99% level of probability).

Also the kneader types and the paste quantities determines, to a large extent, the extraction time. This also proves that the various combinations of kneader types and paste quantities also affect the time input in oil extraction processes.

The ranking of the kneader types, paste quantities and their interaction are presented in Table 2 and Table 3 respectively.

Table 2 Rankings using DMRT of Kneaders and paste

Quantities for the Various Effects

Kneader types	Extraction time (min)
K_1	6.7511a
K_2	6.3200b
K_3	6.1889b
Significance	* *
Paste Quantity	Extraction time (min)
Q_1	6.1911c
Q_2	6.4122b
Q_3	6.66567a
Significance	* *
Interaction K_{vs} Q	**

Means with same alphabets are not significantly different
* * = $P \leq 0.01$;

Table 3 Interaction table of effect kneader types and paste

quantities on Extraction time

Factor	**Q_1**	**Q_2**	**Q_3**
K_1	6.35b	6.66ab	7.24a
K_2	6.12b	6.38b	6.46ab
K_3	6.10b	6.19b	6.27b

Means with the same alphabet are not significantly different

From the ranking using DMRT, it was observed that when the means of the kneading times were ranked it further confirmed that the IAR rotary kneader K_1 took significantly more time for Extraction than the Anchor kneader (K_2 and the Helical ribbon kneader (K_3) which agrees with the results in Table 1

However, the time input between kneader K_2 and K_3 were not significantly different Table 2. This shows that any of either K_2 or K_3 takes less time to extract oil from same quantity of paste.

When the time required to knead the various paste quantities Q_1, Q_2 and Q_3 were ranked (Table 2) it indicated that with increase in paste quantities there was a significant difference in the time required for kneading. This confirms that the more the paste mass the more the time requirement for kneading. This finding agreed with Sanda (1997) in which kneading times increased with paste quantities.

From the ranking of the effect of the interaction of the various combinations of K and Q on the time requirements for oil extraction as presented in Table 3, it was observed that all combinations or interaction except K_1Q_3, and K_2Q_3 were statistically at par; this meant that considering time input only between other combinations, there would be no appreciable difference in their time requirement for oil extraction. However, K_1Q_3 had a significantly higher time requirement than all other interactions. This indicates that using the IAR kneader (K_1) with high paste quantities like Q_3 will requires a significantly higher time for oil extraction over all other interactions.

CONCLUSIONS

From the findings it can be concluded that irrespective of paste quantities kneaded, kneader configurations have a highly significant effect on the extraction time in groundnut oil processing. And of the three Kneader configurations tested, the Helical Ribbon Kneader proves the best with respect of extraction time having the advantage of more interaction with paste mass during extraction, hence better leaching of the oil molecules. From this we can conclude that, kneader with higher surface areas with potential for more interactions with paste

kneaded will reduce time requirements and energy input during oil extraction and consequently improve the economics of oil groundnut processing

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DESIGN, CONSTRUCTION AND PRELIMINARY TESTING OF A FORCED CONVECTION ELECTRIC OVEN MEAT DRYER

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ABSTRACT:-This paper reports on the design, construction and performance evaluation of a forced convection electric meat dryer. The dryer system was developed in order to take care of the deficiencies posed by the available methods of drying in the study area (Bauchi metropolis). These including environmental abuses such as wind borne dirt human and insect infestations and unregulated temperature and climatic changes . The drying process is carried out in a hygienically controlled environment and it is affordable. The design and construction were based on forced convection principle. The design adopted a fan pressure of 1kPa to provide the draught and a heater of 1000 Watts to generate the heat required for drying. The dryer oven chamber size is 300 mm x 300 mm x 400 mm. Test results showed that 0.5kg of sliced fresh raw beef can be dried in 60mins. It has the capacity of removing 81.33% of the moisture content in the meat.

Keywords: Meat, deterioration, forced convection drying, electric, preservation

1 INTRODUCTION

Meat drying is an important process of preparing meat for consumption or preservation as a food diet due to its high protein content; it provides the necessary ingredient for tissue building and growth. Deterioration of meat begins after exsanguinations (i.e. termination of life of the animal) and may be due to microbial, chemical and physical processes. It is necessary to prevent deterioration in order to preserve the meat in a condition fit for human consumption. Food preservation is broadly defined as any method of treating food to prolong the length of time in which it retains its quality and appeal. This definition applies to meat as well, meat being food (Frank, 1971). By placing meat in a temperature unsuitable for the development of putrefactive bacteria, deterioration in meat is inhibited.

This study is specifically based on dehydration principle to achieve drying. The preservative effects of dehydration are due to the reduction of water.
Without water most micro-organisms and enzymes which cause spoilage can not operate. In this principle of dehydration sufficient heat is transferred to the meat causing most of its water to evaporate (Priestly, 1979). The process of heating is continuous until a time the meat is assessed to be adequately dried. The available methods of drying meat in the area include the following:

1.1 Sun drying

Drying meat in the sun can be achieved by spreading out the meat under the sun in an open atmosphere. The radiant energy of the sun provides the heat to evaporate the water in the meat. The chief disadvantage is that it takes days before the shelf stable product can be produced (Crabtree et al., 1984). In addition the meat being dried is unprotected from rain, wind borne dirt and dust and from infestations by insect, rodent and other animals, culminating to zoonotic infection (Alan, 2006).In such a case the quality and quantity of the product are seriously degraded sometimes so far that they are inedible.

1.2 Meat curing

Meat curing is the aspect of meat preservation in which salts, nitrate, phosphorous and other curing agents are used in order to improve the colour of the meat and its acceptability. This method requires the use of chemical and series of tests before the meat can be passed for preservation or consumption (Peckham, 1975). This may be costly.

1.3. Solar drying

For vegetable fruit drying, Fagge et. al (2006) recommended solar drying as an effective drying aid .This method requires design and construction of a solar drying system to effect the drying of meat. The effective application of solar system makes use of solar panels which may be out of reach of an average man

and is often interrupted by the absence of sun light (Carl and Denny, 1979).

1.4. Salting and smoking

Dry salting and pickling of meat have been practiced since the fifth century B. C. It requires highly sensitive instrument to detect what level of salt in meat is medically allowable for a healthy living, (Peckham, 1975).

1.5. Freeze drying

Freeze drying meat consists of quickly freezing the product by placing it in a chamber oven at a reduced pressure and raising the temperature so that the meat is kept near triple point of water, drying dehydration, (Ikeme, 1990). The rate of freeze drying is limited by the rate of heat transfer and drying can be increased by placing the meat directly on heat shelves or micro waves. This equipment is at the moment being imported leading to drainage of scarce foreign reserve.

As a result of long duration and environmental abuses of sun drying, cumbersome testing procedures required by meat curing method, expensive, unpopular and delicate technology of solar drying among the local populace, the risk of salt intake by salting and smoking processes, the elusive technology of freeze drying method, in view of the above the design, construction and testing of a forced draught electric meat dryer was undertaken. The machine was produced based on forced convection, motion of fluid initiated by a fan in relation to the source of heat generated by the heater element resulting in thermal processing.The fabrication of meat drying machine lead to achievable to preservayion method which reduces hunger leads to healthy living .(Uday, 2006). Onwuka (1997) recommended that a good method of processing meat will improve the quality of the product. In this process the three mechanisms of heat transfer, conduction, convection and radiation are involved in the transport of heated air to the surface of the meat placed in the heating chamber tray.

The aim of this paper is to design, construct and fully characterize a meat dryer using forced convection principle that will solve the problems of conventional drying methods enumerated above.

2 MATERIALS AND METHODS

2.1 Design and construction

The machine was designed to achieve a target of 85% moisture removal. A sectional view of the machine is shown in Fig. 1 while plate 1 shows the pictorial view of the constructed machine.

In the meat dryer design, consideration was to meet the following requirements:

(i) Low cost
(ii) Effective drying mechanism
(iii) Use of locally available materials
(iv) Availability of technology for reproduction
(v) Ease of construction, installation and maintenance.

The machine consists of a 450 mm x 450 mm x 430 mm box which houses the fan assembly and the heating chamber. The heating chamber is of dimensions 310 mm x 310 mm x 310 mm. At the top end, the drying chamber is fitted with a chimney 200 mm high. The whole system is mounted on a table support of 500 mm high.

2.2 Design of component units

Unit designs of the component parts were done taking into consideration the specific function of each unit. The main units are heating chamber (oven), heater element, fan and the insulator (see figure 1).

Heating chamber: - It was designed to accommodate 5kg of meat per batch and in addition have sufficient space for exchange of fresh heated and expended air to be discharged into atmosphere through the chimney. The design of the chamber was based on the volume requirement of the chamber to accommodate 5 kg of beef with adequate spacing for heated air circulation.

The material used was mild steel sheet of 3mm thickness.

Operation capacity: - The dryer operating capacity was based on the available heat energy. The quantity of heat energy required for drying 5kg of red meat was calculated from energy balance equation given as (Anyakoha, 2005) as

$$Q = mC\Delta\theta \qquad (1)$$

Where

Q = quantity of heat required (kJ)
m = mass of meat being dried (kg)
C = specific heat capacity of meat (kJ / kg.K)
$\Delta\theta$ = change in temperature of the meat (K)

The power developed for drying the amount of meat is

$$P = \frac{Energy}{time} = \frac{Q}{t} \qquad (2)$$

Where

Q = heat energy (Kj)
t = time of drying the meat (seconds)
P = power required for drying

The time of drying can thus be determined from the above relation as:

$$t = \frac{Q}{P} \qquad (3)$$

The power to be developed by the fan: - To provide the draught for enhancing the drying of the meat the power required can be determined from the correlating equation given by Carl and Denny (1979), as

$$P_{fan} = \frac{\dot{Q}h}{60} \qquad (4)$$

Where

P_{fan} = fan power (W)

$\dot{Q}$ = air flow (m^3 /min)

h = total pressure developed by the fan (Pa)

The insulation thickness of the drying chamber

The material selected for lagging the drying chamber was asbestos board wrapped with heat resistant paper. This is because of its good thermal ability, cheap and readily available. The required insulation thickness was determined using the following correlating equation for conduction heat transfer through the wall of the chamber combined with convection heat transfer as (Frank et al, 1985):

$$Q = \frac{A(T_c - T_{ambient})}{\frac{1}{h_{ambient}} + \frac{X_1}{K_1} + \frac{X_{ins}}{K_{ins}} + \frac{X_2}{K_2} + \frac{1}{h_{air}}} \quad (5)$$

Where

Q = quantity of heat produced (W)

A = surface area of the drying chamber (m^2)

T_c = operating temperature of the dryer (K)

$T_{ambient}$ = temperature of the surrounding air (K)

h_{air} = convection heat transfer coefficient of the air inside the drying chamber (W / m^2. K)

$h_{ambient}$ = convection heat transfer coefficient of the surrounding air (W / m^2. K)

X_1 = thickness of the drying chamber inner layer material (m)

X_{ins} = thickness of the insulator (m)

X_2 = thickness of the outside wall of the drying chamber (m).

K_1, K_2 and K_{ins} are the thermal conductivities of the inner, outer layers of the drying chamber materials and the thermal insulator respectively. The values for these parameters are $K_1 = K_2 = 15.6$ W/m.K and $K_{ins} = 0.30$ W/m.K (Eckert, 1979).

The convection heat transfer coefficient of the surrounding air was estimated using the following correlation (Kreider and Frank, 1981)

$$h_{ambient} = 5.7 + 3.8V_w \quad (6)$$

Where V_w is the prevailing wind speed in m/s.

The convection heat transfer coefficient of the air inside the drying chamber may be determined using the following forced convection heat transfer correlation (Frank and David, 1985):

$$N_u = 0.0296R_e^{4/5}P_r^{1/3} \quad (7)$$

Where N_u is the Nusselt number; R_e is the Reynold number and P_r is the Prandtl number. The value of Pr is obtainable from Tables (Rogers and Mayhew, 1981).

The value of Re was obtained based on the fan velocity, V, as

$$R_e = \frac{VL}{\upsilon} \quad (8)$$

Where L is the length of the drying chamber; υ is the kinematic viscosity of the air, which is obtainable from Tables of thermodynamics and transport properties of fluid (Rogers and Mayhew, 1981).

Once the value of Nu have been obtained from equation (7) above, the convective heat transfer coefficient, h_{air}, is thus obtained as

$$h_{air} = \frac{KN_u}{L} \quad (9)$$

Test Procedure

Fresh raw cow meat was used as sample. A mass of ½ kg of the meat sample was collected, sliced into 2 mm thick and spread thinly on a perforated tray before being placed in the drying chamber. The mass of the meat sample was determined at regular time interval of 15 minutes by weighing using spring balance in order to determine the amount of moisture removed from it. The temperature of the meat sample and the time of drying were measured respectively using a digital thermometer and a stopwatch.

For any given time interval of drying the percentage moisture removed from the meat can be determined as

$$M_c = \frac{M_{sb} - M_{sa}}{M_{sb}} x100\% \quad (10)$$

Where M_c = percentage moisture removed (% wb)
M_{sb} = mass of the sample before drying
M_{sa} = mass of the sample after drying

3. RESULTS AND DISCUSSION

Table 1 shows the values of the temperature of the drying chamber, and that of the exit air and the corresponding percentage moisture removed from the meat sample at each time of drying. The amount of moisture removed was expressed as percentage of the mass of meat charged at specific time and as percentage of the total mass (0.5 kg) of the meat sample used. Within the first fifteen minutes of the drying process, the amount of moisture removed from the meat sample was 10%. This low amount of moisture removed at the beginning of the drying process may be due to the fact that some amount of heat is required to raise the temperature of the meat sample as well as raising the internal energy of the air and other materials of the drying chamber before the evaporation process really begins. The maximum amount of moisture removed (expressed as percentage of mass charged in the dryer at a time) from the meat was 28.57% after 45 minutes of drying. The percentage moisture removed dropped to 22% at the end of the drying period.

The variation of the instantaneous values of moisture removed from the meat sample is shown in Fig. 2 over the drying period. It can be seen from the graph that there is a maximum moisture removal occurring between the 30th and 45th minute that can be achieved by this dryer when operating under the conditions shown in Table 1. As the drying process continues, there will be less water content in the meat to remove; hence the drop in the values of the percentage moisture removed from the meat from a maximum value as corroborated by the pattern of the curve shown

in Fig. 2. During the whole time of drying which was limited to 60 minutes for the fresh raw meat sample the cumulative moisture removed from the mass of 0.5 kg of fresh raw meat dried was 61%. This means that the fresh raw meat containing initially 75% water was dried to 14% (wet basis). This is a favorable condition for preserving the meat since the recommended moisture content limit for preserving the meat is 15% (Peckham, 1975). This result indicates that the machine has the capacity of removing 81.33% of the total moisture content in the fresh meat within only 60 minutes of operation. This level of moisture removed could be higher if the drying process was prolonged. The 14% water content left over in the dried meat in this work is to avoid over drying for a better handling and storage of the dried product.

Figure 3 shows the variations of the drying chamber temperature and the exit temperature of the air from the chimney with time as the drying process proceeds. The initial values of temperature of both the drying chamber and inlet air were 300K, which corresponds to the ambient temperature measured at the start of the testing period. The air entering the drying chamber exits through the chimney at a maximum temperature of 415K, while the drying chamber attained a maximum temperature of 450K during the test period studied. At any time of drying, the temperature of the exit air is lower than that of the drying chamber. This may be because as the drying process proceeds, the vaporized water from the meat is taken away by the air into the atmosphere; hence the exit air becomes moist and its temperature lowered. The drying process was aided by the fan which continued to force both the fresh air entering the heating chamber and the expended air to the roof top of the chamber thereby sinking into the atmosphere through the chimney.

The relationships between the drying chamber temperature, T_d, the exit air temperature, T_{exit}, and the time of drying, t, may be represented by second order polynomial functions, respectively expressed as follows:

$$T_d = -0.0365t^2 + 4.4905t + 307.57 \quad (11)$$

$$T_{exit} = -0.0143t^2 + 2.8238t + 299.57 \quad (12)$$

4. CONCLUSION

This forced draught electric oven meat dryer designed, constructed and tested was found effective in the drying of meat. It is small, simple to operate and maintain. Meat is an important food from the stand points of human nutrition and internal trade. The overall process of meat drying by simple machine technology can achieve protection, preservation and storage; has the benefits of employment generation, local technological innovations and complement meat production efforts in order to guarantee the nation's food security.

Air at natural buoyancy and at ambient temperature of 300K enters the dryer through the window opening which is heated up to 415K in the oven chamber. Heat generated within the drying chamber is conveyed to the meat through the air and causing evaporation thereby resulting into the drying. Test result showed that 0.5kg of raw meat can be dried in 60 minutes with 81.33% moisture content removed leaving the meat in a condition suitable for consumption and preservation.

Table 1: Variations of temperature and moisture removed with drying time for fresh raw cow meat

Time (min)	Drying chamber temp. T_c (K)	Exit air Temp. T_o (K)	Mass before drying M_{sb} (kg)	Mass after drying M_{sa}(kg)	Moisture removed (instanta-neous values) M_c(%)	Moisture removed from sample M(%)
0	300	300	0.5	0.5	0	0
15	385	340	0.5	0.45	10	10
30	400	365	0.45	0.35	22.22	20
45	430	405	0.35	0.25	28.57	20
60	450	415	0.25	0.195	22	11

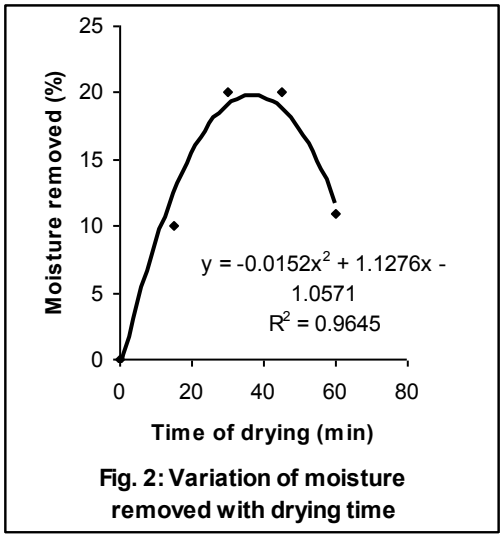


Fig. 2: Variation of moisture removed with drying time

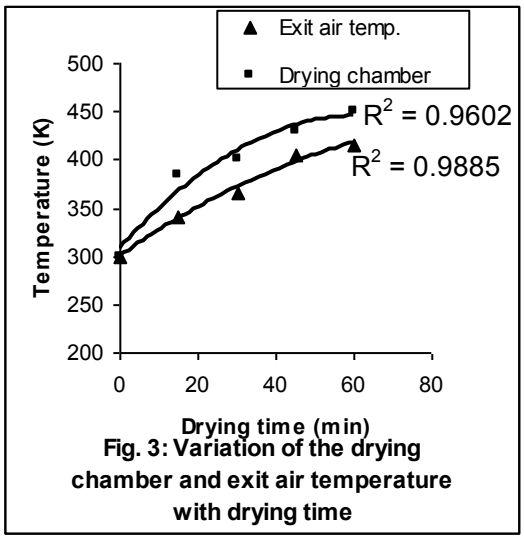


Fig. 3: Variation of the drying chamber and exit air temperature with drying time

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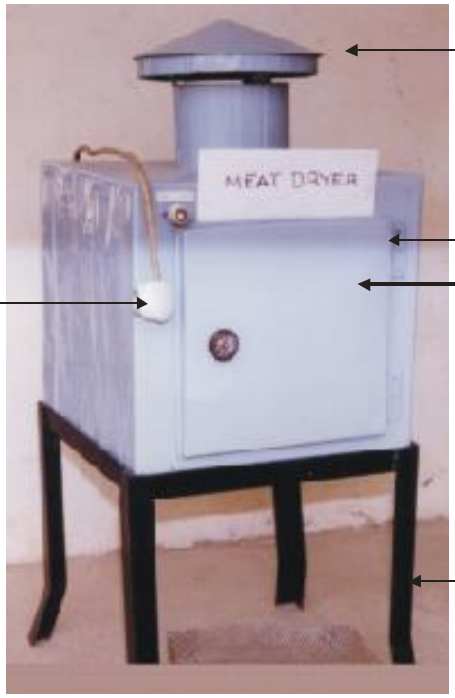
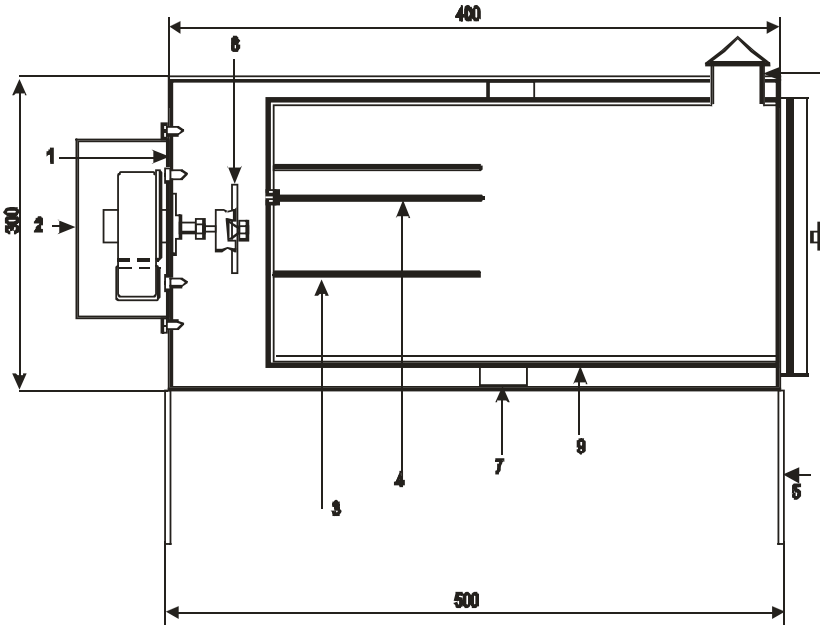


Plate 1: Pictorial view of the Forced Draught Electric Meat Dryer



LEGEND

UNIT NO	DESCRIPTION	QTY	MATERIAL
1.	Fan Coupling	1	Mild Steel
2.	Fan Motor cover	1	Mild Steel
3.	Tray - Chase	2	Aluminium
4.	Electric heater element	1	Copper
5.	Support Stand	1	Angle Iron
6.	Door handle	1	Wood
7.	Assembly bracket	4	Mild Steel
8.	Fan	1	
9.	Insulator Slab	4	Asbestos/Air
10.	Chimney	1	Mild Steel

Fig. 1 Sectional view of a forced draught electric meat dryer
All dimensions in mm
Scale 1:5

DETERMINATION OF SOME MECHANICAL PROPERTIES OF BAMBARA NUTS (*VIGNA SUBTERRANEA L. VERDC*) RELEVANT TO SHELLING

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ABSTRACT

Some mechanical properties of bambara nuts (*Vigna Subterranea L. Verdc*), such as comprehensive breaking force, rupture energy, Young's modulus, stiffness modulus and toughness are very essential in the design and development of shelling machines for bambara nuts. Three varieties of bambara nuts, namely Kwapurto, Kwakekeru and Kuruvu, commonly grown in Adamawa State, were sampled at random and subjected to uni-axial compression tests at two different loading speeds of 2mm/min and 5mm/min and at two loading positions, lateral and longitudinal positions. Moisture contents and sizes of the bambara nuts were also determined. The average moisture contents of the samples tested were found to be 13.6, 12.6 and 13.6% wet basis for Kwapurto, Kwakekeru and Kuruvu varieties respectively. The sizes of bambara nuts were evaluated in terms of lengths and diameters, of which the lengths were found to be 20.3mm, 17.3mm and 17.8mm for Kwapurto, Kwakekeru and Kuruvu varieties, respectively. The compressive breaking force averaged 63.7N and 19.2N in the lateral and longitudinal axes, respectively, for the three varieties, at a loading speed of 2.00 mm/min, showing that breakage was easier in the longitudinal axis than in the lateral axis. However, at a speed of 5.00 mm/min, the compressive breaking forces were found to be lower, averaging 58.6N and 12.3N in lateral and longitudinal axes, respectively, for the three varieties, implying that 5mm/min speed is more convenient for mechanical shelling of bambara nuts. The three–factor factorial (3 x 2 x 2) experimental results were analysed statistically by means of analysis of variance (ANOVA).The variety of bambara nuts and position of loading showed significant effects on the compressive breaking force and the toughness of bambara nuts, at 99% level of probability. The interactions between variety, speed of loading and position of loading also had significant effects on the compressive breaking force while the loading position and the loading speed had significant effects on the rupture energy and Young's modulus, respectively, at the 99% probability level. The implications of these findings in relation to shelling of bambara nuts are discussed.

1.0 INTRODUCTION

Bambara nut is the third most important legume after groundnut and cowpea among the main legumes of the African lowland tropics. It grows satisfactorily in many soil types and is produced in many parts of the world (Wijngarden, 1988; Duke, 1981). In Nigeria, it is cultivated largely in Northern parts of the country with Adamawa State being the largest producer. It is also produced in parts of Anambra and Enugu States (Nwokolo and Smarth, 1987). World production of Bambara nut has been estimated to be over three hundred and thirty thousand tones annually with half coming from West Africa and Nigeria producing more than half of the West African proportion (Linnemann, 1986; Coudert, 1984). Also, among grain legumes of the African lowland tropics, Bambara nut ranked third in annual production in the mid-seventies after groundnut and cowpea (Wijngarden, 1988)

The crop is a very rich leguminous food and its nutrient contents were reported by Akubuo and Uguru (1999), as follows: Carbohydrate (52.60%), Protein (17.52%), and Oil (6.66%) for dehulled Bambara nut seeds, and Carbohydrate (48.60%), Protein (16.99%) and Oil (6.20%) for whole seeds.

The development of any machinery for harvesting and processing an agricultural material depends greatly on the physical and mechanical properties of such an agricultural product. Mechanical properties of agricultural products are most conveniently measured with the force-deformation curve. From this curve, a number of mechanical properties can be determined, such as maximum force or energy to rupture, stiffness modulus and deformation (Khazaei and Mann, 2004). Linear limit, Young's modulus of elasticity and bio-yield point can as well be obtained from the force – deformation curve, while toughness is determined as the area under the curve, as was done for whole cocoa pods by Maduako and Faborode (1994).

Bambara nut is a very valuable proteinous diet for diabetic patients, but despite this nutritional contribution, it has been under-exploited in Nigeria. The shelling of Bambara nuts in Nigeria is still performed traditionally through the rupturing of the pods on hard surfaces like metals and stones. A knowledge of the force-deformation characteristics or breaking behaviour of bambara nut will find applications in the design of its shelling machines. An investigation of the mechanical properties like linear limit, Young's modulus, toughness, and stiffness modulus of Bambara nuts has now been carried out and reported in this paper.

2.0 MATERIALS AND METHODS

2.1 Sampling

Three varieties of Bambara nut commonly grown in Adamawa State of Nigeria, namely Kwapurto, Kwakekeru and Kuruvu were sampled for testing. Two hundred and forty nuts were randomly picked from three 50kg bags of the three Bambara nut varieties, i.e. 80 pods from each 50kg bag of each variety.

2.2 Moisture Content Determination

The moisture content of Bambara nuts was determined using the oven-dry method whereby the electric oven, model N30C, Genlab Widness was set at a temperature of 105^{o}C for 24 hours, after which the weights of the samples were found to be constant. Five crucibles of each variety were used as replications. The weights of empty crucibles, the weights of crucibles with air-dry samples, and the weights of crucibles with oven-dry samples were determined using Mettler Toledo AT400 Digital Analytical balance, having the accuracy of 0.1mg.

2.3 Size Determination

Measurements of length and diameter of each pod at air-dry moisture content were done using a Mitutoyo Digital Vernier Caliper accurate to 0.01mm. Averages of twenty (20) measurements of each variety were computed.

2.5 Experimental Design and Analysis

2.4 Uni-Axial Compression Tests

All compression tests were performed using Laboratory Testometric Micro 500 Universal Testing Machine at the National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State of Nigeria. The machine has an accuracy of 0.1 kN and a maximum capacity of 50 kN.

Bambara nuts whose diameters were already determined were loaded individually using a laboratory thumb on the compression jaws or grips. The load cell which sent the pressure transmitted to the console or PC monitor was sand-witched between the upper jaw and the cross head which were driven by a screw press. When the upper jaw was lowered well enough to grip the samples, the laboratory thumb was withdrawn and the start button was pressed to commence the test. Compression force was exerted and the biomaterial failed as it was accompanied by a "crack sound" and a corresponding drop on the force-deformation graph, which was plotted concurrently on the PC monitor. When the sample thus failed, the "end tests" button was pressed on the console. The experiment was repeated with twenty (20) pods for each of two levels of speed 2.0mm/min and 5.0mm/min and for each of the two axes, lateral and longitudinal, making eighty (80) pods of each variety tested.

The PC monitor displayed the results of linear limit, Young's modulus of elasticity and bioyield point, which were therefore printed out. Stiffness modulus was computed using Equation (2), as reported by Maduako and Faborode (1994):

$$\text{Stiffness Modulus} = \frac{\text{Maximum breaking force (N)}}{\text{Maximum deformation at breakage(mm)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Toughness was determined by measuring the area under the force-deformation curve using a planimeter.

Three (3) varieties, Kwapurto, Kwakekeru and Kuruvu, respectively, 2 loading speeds and 2 loading positions or axes, making twelve (3 x 2 x 2) factorial experiments, were conducted with a total of two hundred and forty (240) randomly selected pods. The experimental results were analysed statistically by means of analysis of variance (ANOVA) to determine the effects of variety, loading speed and loading position on the mechanical properties of Bambara nuts.

3.0 RESULTS AND DISCUSSION

3.1 Moisture Content

From the mean values of moisture content (wet basis) presented in Table 1, Kwapurto, Kwakekeru and Kuruvu (whole nut pods, with seeds inside them) had mean values of 13.6%, 12.6% and 13.6% respectively which were found to be consistent with the findings of Duke (1981) on moisture content of pulses and oil seeds. It also falls within the range of moisture obtained by Manaja (2004) in his work on the physical properties of Bambara nut. Also it compared favourably with the findings of Maduako and Hamman (2005) in their work on some physical properties of three ground nut varieties. This moisture level is therefore considered suitable for the storage and shelling of Bambara nuts.

3.2 Size of Bambara Nut

The sizes of Bambara nut pods were determined in terms of lengths and diameters. Table 1 also shows the mean values of the lengths and diameters of each pod tested. The mean values of lengths obtained for Kwapurto, Kwakekeru and Kuruvu were 20.3 mm, 17.3 mm and 17.8 mm respectively,

while the mean values of diameters were 16.0 mm, 15.2 mm and 14.0 mm corresponding to Kwapurto, Kwakekeru and Kuruvu respectively. These pod dimensions are necessary in determining the concave clearance under the shelling drum of a bambara nut pod shelling machine.

Table 1: Moisture Contents and Sizes of Bambara Nuts
(mean* ± standard deviation)

Parameter	*Variety*		
	Kwapurto	Kwakekeru	Kuruvu
Moisture Content, % wet basis	*13.6*	*12.6*	*13.6*
Length , mm	*20.3 ± 0.30*	*17.3 ± 0.14*	*17.8 ± 0.41*
Diameter, mm	16.03 ± 0.20	15.2 ± 0.16	14.0 ± 0.15

** Mean value of twenty (20) measurements*

3.3 Mechanical Properties of Bambara Nut Pods

The mechanical properties of Bambara nut pods determined are shown in Tables 2 and 3.

Table 2 : Mechanical Properties of Bambara Nut Pods

(mean* ± standard deviation) at test speed of 2.00 mm/min.

Mechanical Properties	Variety		
	Kwapurto	Kwakekeru	Kuruvu
Compressive Breaking Force, N			
Lateral axis	120.3 ± 1.3	111.0 ± 0.9	59.9 ± 0.6
Longitudinal axis	14.8 ± 0.8	20.4 ± 0.7	22.3 ± 0.7
Rupture Energy, J: Lateral axis	0.1018 ± 0.06	0.2120 ± 0.07	0.1750 ± 0.001
Longitudinal axis	0.1109 ± 0.08	0.141 ± 0.07	0.1017 ± 0.009
Young's Modulus, N/ mm^2			
Lateral axis	8.60 ± 0.01	3.2 ± 0.06	4.0 ± 0.04
Longitudinal axis	8.30 ± 0.03	5.0 ± 0.04	12.1 ± 0.02
Linear Limit, N: Lateral axis	124.1 ± 4.6	166.5 ± 5.4	165.0 ± 4.4
Longitudinal axis	90.4 ± 2.2	67.5 ± 2.16	73.5 ± 2.2
Stiffness Modulus, N/mm			
Lateral axis	11.0 ± 0.8	32.6 ± 1.69	24.1 ± 1.74
Longitudinal axis	23.9 ± 2.2	10.2 ± 0.9	10.9 ± 0.8
Toughness, N / mm: Lateral axis	0.1028 ± 0.07	0.1938 ± 0.07	0.1642 ± 0.09
Longitudinal axis	0.0699 ± 0.04	0.0978 ± 0.06	0.0789 ± 0.06

* Mean value of 20 measurements

Table 3: Mechanical Properties of Bambara Nut Pods

(mean* ± standard deviation) at test speed of 5.00 mm/min.

Mechanical Properties	Variety		
	Kwapurto	Kwakekeru	Kuruvu
Compressive Breaking Force, N			
Lateral axis	50.7 ± 0.22	74.6 ± 0.40	50.6 ± 0.30
Longitudinal axis	14.3 ± 0.17	20.2 ± 0.09	12.3 ± 0.06
Rupture Energy, J: Lateral axis	0.1324 ± 0.09	0.1889 ± 0.08	0.1848 ± 0.09
Longitudinal axis	0.032 ± 0.002	0.0561 ± 0.03	0.0714 ± 0.06
Young's Modulus, N/ mm2			
Lateral axis	3.40 ± 0.06	2.80 ± 0.09	3.8 ± 0.02
Longitudinal axis	15.9 ± 0.06	11.4 ± 0.06	16.4 ± 0.03
Linear Limit, N: Lateral axis	170.7 ± 0.10	134.7 ± 0.2	157.2 ± 0.2

	Longitudinal axis	71.1 ± 0.03	70.5 ± 0.02	79.2 ± 0.02
Stiffness Modulus, N/mm				
	Lateral axis	16.2 ± 0.01	26.9 ± 0.01	17.3 ± 0.01
	Longitudinal axis	28.8 ± 0.02	40.6 ± 0.02	11.6 ± 0.03
Toughness, N / m:	Lateral axis	0.1133 ± 0.006	0.1779 ±0.007	0.1755 ± 0.008
	Longitudinal axis	0.0296 ± 0.002	0.0476 ±0.003	0.0675 ± 0.005

* Mean value of 20 measurements

The compressive breaking force in lateral axis averaged 20.3, 111.0, and 59.9N for Kwapurto, Kwakekeru and Kuruvu, respectively, at a loading speed of 2.00mm/min, whereas in the longitudinal axis, it averaged 14.8, 20.4 and 22.3N, respectively, for the three varieties, at the same loading speed, as shown in Table 2. Also, the compressive breaking force in longitudinal axis averaged 50.7, 74.6, and 50.6N for Kwapurto, Kwakekeru and Kuruvu, respectively, at a loading speed of 5.00mm/min, whereas in the longitudinal axis, it averaged 14.3, 20.2 and 12.3N, respectively for the three varieties, at the same loading speed, as shown in Table 3.

This means for the three varieties, a grand average compressive breaking force of 63.7N and 19.2N in the lateral and longitudinal axes, respectively, at a loading speed of 2.00 mm/min, showing that breakage was easier in the longitudinal axis than in the lateral axis. However, at a speed of 5.00 mm/min, the compressive breaking forces were found to be lower, averaging 58.6N and 12.3N in lateral and longitudinal axes, respectively, for the three varieties, implying that 5mm/min speed is more convenient for mechanical shelling of bambara nuts. The same trend was observed for rupture energy, Young's modulus of elasticity, linear limit, stiffness modulus and toughness, as shown in Tables 2 and 3.

3.4 **Statistical Analysis:**

The statistical analysis of variance (ANOVA) of the results showed that the variety axis and varietal differences in breaking strength of the pod structure. To exploit the line of minimum resistance, it is advisable in machine design to align the pods to present the of Bambara nut and loading position had significant effects on the compressive breaking force at 99% level of probability. The speed did not show any significant effect at 99% level of probability. The implication of this is that the position of loading, lateral or longitudinal, determines the compressive force, but changing the loading speed does not significantly affect the required compressive force. It also means that some varieties require more compressive force than others e.g Kwakekeru.

Likewise, the position of loading was found to be significant at 99% level of probability. This further implies that the position of loading has effect on the rupture energy which means that the lateral axis is stronger than the longitudinal axis. Khazaei and Mann (2004) reported that rupture testing is a measurement of firmness of many food products. Also from the analysis of the effects of Bambara nut variety, speed of loading and position of loading on Young's modulus, it was found that the variety of Bambara nut and speed of loading were significant at 99% probability level. Wang (2004) similarly found the speed of loading to have effect on Young's modulus. This implies that one machine can be designed for shelling all varieties of Bambara nuts. Also, variety and position of loading had significant effect on toughness at 99% level of probability, probably because of its natural cleavage plane in the longitudinal

longitudinal axis to the hammer during breaking operation.

3.4 Graphical Patterns of Force-Deformation

The graphical patterns of force-deformation in the lateral axis shown in figures 1, 2 and 3 exhibited no bio-yield points, except figure 2 which showed bio-yield point conspicuously in Kwakekeru variety. Likewise, in the longitudinal axis, figures.4, 5 and 6 show that there was no much difference between the three different varieties, except Kwakekeru in figure 5 which exhibited a bio-yield point. The graphs were generally linear and non-elastic, a situation similar to what was described by Mohsenin (1988) on some agricultural products like eggs and some convex shaped food materials. Most of the figures exhibited no bio-yield point, as was the case with whole cocoa pods reported by Maduako and Faborode(1994).

4.0 CONCLUSION

Force-deformation tests on bambara nut pods have revealed the breaking behavior of Bambara nut pods in both lateral and longitudinal axes. Less energy is required in rupturing the pods in the longitudinal axis than the lateral axis. This suggests that the longitudinal axis is weaker than the lateral axis under compressive breaking forces. The longitudinal loading position particularly at the rate of 5 mm/min has low demands of energy and therefore, is more convenient for shelling of the pods.

It was observed that Kwapurto variety needed less compressive breaking forces and energy to break, while Kwakekeru had higher energy and force requirements. Graphical patterns of force-deformation indicated the absence of bio-yield points in almost all the curves plotted at 5mm/min, but were noticeable in the curves plotted at 2mm/min for Kwakekeru variety only.

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Figures 1, 2 and 3

Figures 4, 5 and 6

DETERMINATION OF SOME PHYSICAL PROPERTIES OF NIGERIAN FERTILIZERS

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ABSTRACT

Six different types of fertilizers, locally produced and imported were purchased in the open market in Samaru and PZ, Zaria, Kaduna state. They were tested in the laboratory for the particle size distribution analysis, granule hardness, angle of repose and bulk density. Results showed that the mean diameter of fertilizers range between 2.54 mm and 3.09 mm. More strength were, however required to break the granules of NPK 15-15-15(Dan hydro) and NPK 15-15-15(Golden) than the other fertilizer types tested, NPK 20-10-5 +10Ca (Morris), SSP18%P_2O_5 (F&C), Urea (Muka), and Urea (Golden). The highest angle of repose obtained was 37.05^0 for NPK 20-10-5-10 % (Morris) while NPK 15-15-15(Golden) has the least angle of repose of 33.5^o. The highest packed bulk density and loose pour density of 1.35 g/cm^3 and 1.23 g/cm^3 respectively was obtained for SSP 18% P_2O_5 (F&C) while the least loose pour density and packed bulk density of 0.78 g/cm^3 and 0.87 g/cm^3 respectively was obtained for Urea (Muka) . Data obtained from the study would serve as essential information for designers of fertilizer application equipment and those involved in the distribution, handling and storage of fertilizer.

Keywords: Particle size distribution, granule hardness, angle of repose, bulk density

INTRODUCTION

Physical properties are of great importance in the production, handling, storage, transportation and application of fertilizers (Mohsenin, 1978). Good physical condition of fertilizers ensures easier, faster, more uniform and less expensive application on the field (TVA, 1978). Understanding the physical characteristics governing the response of fertilizers to handling operations is essential for maximum application efficiency.

However, little has been reported on the physical properties of fertilizers available in the country despite the increasing fertilizer applications (Simonyan et al, 1995). These properties are essential engineering data required for design of machines, structures, processes and controls. The particle size of fertilizers is important to determine the actual size of hole in the hopper and the metering mechanism design. The grain of fertilizers requires adequate mechanical stability to withstand normal handling without fracturing and excessive sloughing to form dusts. Also the rate of dissolution and active ingredients availability of some fertilizers have been shown to be dependent on the particle sizes. The larger the fertilizer particles sizes, the slower the nutrient release (TVA, 1978). Bulk density is required to determine the capacity of storage bins and transport devices. Angle of repose is a property which has considerable influence on the capacity of storage bins, hoppers, chutes and conveyors (Kepner et al, 1980). This article reports on some physical properties of fertilizers in Nigeria, both locally manufactured and imported tested.

MATERIALS AND METHODS

Six different fertilizer types, NPK 15-15-15(Dan hydro) , NPK 15-15-15(Golden), NPK 20-10-5 +10Ca (Morris), SSP18%P_2O_5 (F&C), Urea (Muka), and Urea (Golden), three locally produced and three imported were purchased in the open market in Samaru and PZ, Zaria, Kaduna State, Nigeria in November 2000. The fertilizer samples were tested in the Soil Science Laboratory of the Samaru College of Agriculture, Ahmadu Bello University, Zaria to determine the particle size distribution analysis, angle of repose, bulk density and granule hardness. Samples were obtained from the following fertilizer companies- Fertilizer and Company (F&C) Kaduna; Morris, Minna; Muka; Golden Fertilizer and Dan hydro , inscribed on the bags. NAFCON brands were not available in the market at the time of the test.

Particle Size Distribution of samples

A representative sample obtained by multipoint sampling from a fertilizer bag, composited and thoroughly mixed was poured into a plastic container and weighed. A set of standardized Tylers wire mesh sieves with openings ranging

from 0.5- 6 mm was used for the particle size distribution test. Fertilizer samples were poured into the uppermost screen of the stack and shaken with mechanical shaker (Ro tap) for 5 minutes. The fertilizer retained on each screen were collected and weighed individually. Ten (10) replicates were carried out and the average for each fertilizer sample determined. The mean particle size, $\overline{d_m}$, of the fertilizer samples were determined as described in Mecabe *et al*,(1985):

$$\overline{d_m} = \frac{1}{\left(\sum_{i=1}^{n} \frac{f_i}{d_{em}}\right)} \quad 1$$

$$f_i = \frac{W_i}{W_o} \quad 2$$

$$d_{em} = \frac{d_{i-1} + d_i}{2} \quad 3$$

Where:

f_i = weight fraction retained on sieve i.

W_i = weight retained on sieve i, g.

W_o =Total weight of fertilizer used, g.

d_{i-1} = diameter of sieve above the sieve of interest ,mm.

d_i = diameter of sieve where weight w_i is taken and determined, mm

d_{em} = average diameter ,mm

Bulk Density of samples

The loose pour density of fertilizer samples were determined using the method described by Waziri and Mittal (1983), pouring fertilizer samples into a box with internal dimension 120 mm x 80 mm x 55 mm from a height 10 cm above. The filling point was moved around the box to avoid coning and resultant segregation. The top was levelled with the straight edge and weighed on the lever weight balance (Phillip Haris Max 1000g, d= 1g). The packed bulk density was also determined in the same manner, but after filling the box, it was lifted and dropped 5 times from a height of 5 cm. The box was refilled and redropped until there was essentially no further compaction. The sample was levelled with the straight edge and weighed. Ten replicates were taken for each fertilizer sample and averaged.

Angle of Repose of samples

Fertilizer sample was placed in the glass box dimensioned 450 mm x 300 mm x 300 mm with metal plate. The front panel was quickly removed as described by Oje and Ugbor(1991) allowing the fertilizer to flow in its natural slope. The angle with the horizontal when piled was measured with protractor and recorded, 10 replicates were done and averaged.

Granule hardness of samples

This involves determination of the crushing strength of individual granule. Random samples of fertilizer granules retained on each sieve were placed on a kitchen scale (0-20Kg) as given by Tennesse Valley Authority (TVA) (1978). Flat metal rod was used to crush the granule. The position of the scale pointer at breaking was taken and recorded. Thirty (30) replicates for each granule size were taken and averaged.

RESULTS AND DISCUSSION

Particle size distribution of fertilizer samples.

Results of particle size distribution analysis of fertilizer samples are presented in Table 1. Urea (Golden) has the highest mean grain size diameter of 3.09 mm; closely followed by SSP 18% P_20_5 with mean grain size diameter of 3.08 mm, NPK 20-10-5 +10Ca (Morris) has the least grain size diameter of 2.54 mm. The standard for the particle size distribution in USA specifies 90% minimum diameter range of 1.00-3.35 mm, 0% larger than 4.75mm and no more than 2% finer than 0.6 mm (TVA, 1978).

Bulk density of fertilizer samples

The loose pour density and packed bulk density of the fertilizer samples is given in Table 1. From the result SSP 18% $P_2O_{5(}$ (F&C) has the highest loose pour density of 1.23 g/cm^3 while the lowest loose pour density obtained was for Urea(Muka) with value 0.78 g/cm^3. The highest packed bulk density of 1.35 g/cm^3 was obtained for SSP 18% P_20_5 (F&C) and the lowest of 0.87 g/cm^3 was obtained for Urea (Muka). Packed bulk density is usually 6-12% higher than loose pour density (TVA, 1978) for granular fertilizers.

Angle of Repose of fertilizer samples

The angle of repose for the fertilizer samples is given in Table 1. NPK 20-10-5 +10% Ca (Morris) has the highest average angle of repose of 37.05^0 while NPK 15-15-15(Golden) has the least angle of repose 33.75^0. The highest angle of repose obtained for NPK 20-10-5+10% Ca may be due to a wide range of the particle size which enables the grains to be piled. NPK 15-15-15(Golden) has a close range uniform grain sizes which allows the grain to flow easily. The range of angle of repose for granular fertilizers is 30-40 degrees (TVA, 1978) the results obtained for the fertilizer samples tested are within this range.

Granule Hardness of fertilizer samples

Figure 1 shows the effect of the grain diameter on the crushing strength for each fertilizer sample. It can be seen that the grain crushing strength increases with increase in the particle size of fertilizers. A higher slope indicates that more strength was required to break the granule. More strength was needed to break NPK 15-15-15(Golden) and NPK 15-15-15(Dan hydro) than Urea (Muka) and NPK 20-10-5 + 10% Ca (Morris).

A second degree regression equation describing the effect of fertilizer size on the granule hardness is given by

$$Y= AX^2 + BX +C \qquad 4$$

Where

Y= granule hardness, kg
X= fertilizer size, mm
A&B =regression coefficients
C =regression constant.

Table 2 gives the regression constants of the equations describing the curves. Granule hardness of 2.27 and more is reported to be desirable to reduce caking and fracturing during handling (TVA, 1978).

CONCLUSIONS AND RECOMMENDATIONS

Some physical properties of Nigerian fertilizers, locally and imported were carried out. It was observed that the angle of repose is influenced by the granule size. NPK 20-10-5 + 10% Ca (Morris) has the highest angle of repose 37.05^0 while NPK 15-15-15(Golden) has the least angle of repose of 33.75^0.

The highest packed and loose pour density was obtained for SSP 18%P_20_5 having 1.35 g/cm^3 and 1.23 g/cm^3 respectively while the least loose and packed bulk densities of 0.78 g/cm^3 and 0.87 g/cm^3 were obtained for Urea(Muka) respectively. The data obtained would provide useful information for designers of fertilizer application equipment.

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Table 1: Physical Properties of Nigerian Fertilizers

Physical Properties (Average)	NPK 20-10-5+10%Ca (Morris)	SSP 18% P2O5 (F&C)	NPK 15-15-15 (Golden)	NPK 15-15-15 (Dan hydro)	Urea (Muka)	Urea (Golden)
Mean particle size $\overline{d_m}$ (mm)	2.54	3.08	2.91	2.69	2.69	3.09
Loose pour density(g/cm^3)	0.91	1.23	1.06	1.17	0.78	0.85
Packed bulk density(g/cm^3)	1.04	1.35	1.20	1.21	0.87	0.90
Average angle of repose	37.05	35.75	33.75	37.00	34.00	35.75

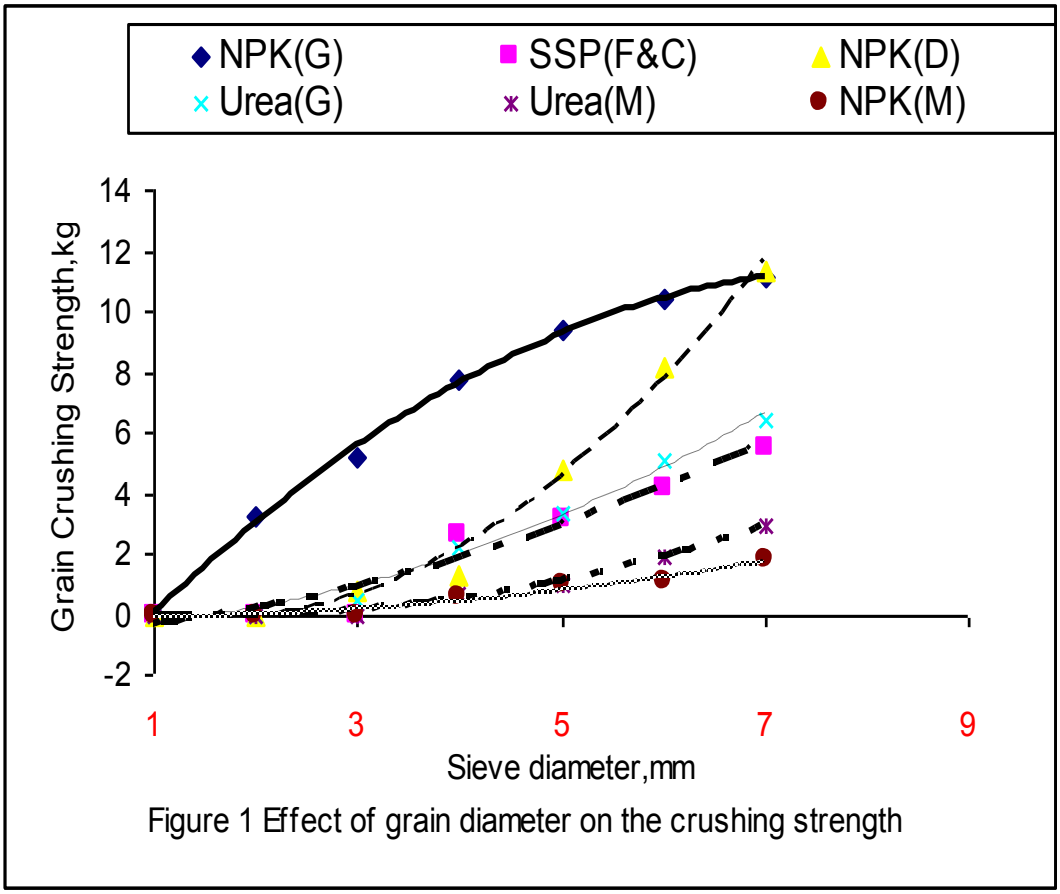


Figure 1 Effect of grain diameter on the crushing strength

Table2: Regression constant of the effect of fertilizer grain diameter on crushing strength

Fertilizer type	A	B	C	R^2
NPK(G)	-0.2274	3.6726	-3.4286	0.99
NPK(D)	0.4107	-1.3464	0.9429	0.99
Urea(G)	0.1405	0.0262	-0.4143	0.99
SSP(F&C)	0.0929	0.2571	-0.6857	0.95
Urea(M)	0.1036	-0.3464	0.2429	0.99
NPK(M)	0.0429	-0.0357	-0.0714	0.96

Technology Innovation and Adoption: A Case Study of Improved Rice Parboiler Adoption in Kafin Gana Village of Jigawa State.

By

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ABSTRACT

Parboiling, an important operation in rice processing, is being undertaken with poor and inefficient tools in Kafin Gana village despite the large yearly production of rice in the area. An improved parboiler was introduced using appropriate extension methodology. The results revealed a high level of adoption. This shows that with proper sensitization and group mobilization/organization of end users, equipment demonstration and training on its use/maintenance, coupled with extensive monitoring; a proven technology with comparative advantage(s) could be adopted.

Keywords: Technology, adoption, rice, parboiling.

INTRODUCTION

Technology, in the context of agricultural equipment, may be defined as any device that tend to reduce drudgery, facilitate production or processing techniques and maintain or even add value to the final output. Adoption, on the other hand can be defined as the decision to make full use of innovation as the best course of action.

Over the years, introduction of improved technologies to farmers have been and is still the mandate of National Agricultural Extension & Research Liaison Services (NAERLS), Zaria. This role is being complemented by the extension units National Research Institutes using States Agricultural Development Projects (ADPs) as a platform to reach farmers. This joint collaboration has given rise to On-farm Adaptive Research (DFAR), Small Plot Adoption Technique (SPAT) Technology Review Meeting (TRM) and Fort Nightly Trainings (FNT). Despite all these programmes, there is still lack of willingness on the part of the farmers and processors of agricultural products to adopt improved production and processing tools/equipment. This view is supported by Suleiman et al. (2006) who noted that inefficient utilization of improved agricultural innovations and unwillingness of the farmers to accept and adopt innovations in agricultural production systems have led to declined of the sector contribution to Gross Domestic Product (GDP).

Review of past efforts in improved tools/equipment transferred to end users revealed that much is still left to be desired in our extension methods. This is because at organized shows such as trade fairs, exhibitions and trainings both at National, States, Local Government and even at Institutes level, there is usually a lot of interest and strong desire to acquire some of these tools/equipment but the numbers of such tools/equipment actually acquired are minimal. As a result, most of them developed by the National Research Institutes are still on-shelf.

Preliminary investigation revealed that unlike crops sub-commodity which usually go through the full circle of adoption process (and therefore recording high adoption rate), the tools/equipment sub-commodity hardly go through complete adoption process. In most cases, they are merely demonstrated at organized events or purchased and distributed to end users by government and other organizations without adequate training on operation and maintenance. Where there are training, there are hardly any follow-up or monitoring to support the users. The results being that the end users hardly

realize the full potential of the given tools/equipment.

Rice is a major staple crop in Nigeria among the cereals. Globally, it is the most important staple food of about half of the human race. The current annual demand of rice in Nigeria is estimated at about 5.0 million metric tones of milled rice while local production is just about 3.0 million metric tones, leaving a deficit of 2.0 million tonnes (FMARD, 2003). It is, therefore, not surprising that Nigeria is still the major importer of rice in West Africa sub-region (FMARD, 2003). The rice import bill before 1999 was US $259.0million. This almost tripled to US $655.0 million and US $756.0 million in 2001 and 2002 respectively (CBN). From these figures, it is evident that a lot of the country's hard earned foreign exchange is expended on rice importation.

However, there has been steady increase in rice production in Nigeria (Nnanna, 2003). This was as a result of provision of improved variety and expansion in cultivated land area. However, it has been noted that the solution to increasing food production may not lies alone in developing crop varieties with high yield potentials (Sanzidur, 2003). It, also, depends on our ability to develop and utilize improved processing techniques that can add value to the final output which at present are lacking. In the same vane, technology adoption for agricultural development needs an effective understanding of the farmers' conditions and priorities (IITA, 1995).

Parboiling is an important process in rice processing. According to Gariboldi (1974) parboiled rice yields higher head rice, retains more B-vitamins and protein fraction and increases the resistance of the paddy to insect attack. In many parts of Nigeria where rice is grown, this important operation is undertaken in small scale with earthen or metal pots resulting in time wasting, low output and drudgery. There are numerous opportunities in rice processing in Nigeria but these opportunities could only be realized if constraints such as lack of improved processing facilities, low capital base of the rice processors and others are adequately tackled (Isiaka and Abdulsalam, 2006). It is therefore the objective of this study to carryout intensive adoption process using improved rice parboiler as test equipment.

METHODOLOGY

The study was conducted at Kafin-Gana village. It is a farming settlement located about 27km South-East of Dutse along Kano-Maiduguri road in Birnin-Kudu Local Government Area of Jigawa State as shown in figure 1. Available information showed that the area normally receives the highest rainfall in the state with a mean annual value of 1492.70 mm with an average minimum and maximum temperatures of 15 and 33.1^{o}C respectively (JARDA, 2002). The area has a good fertile clay loamy soil in the "fadama" areas and sandy loamy soil in the upland farmlands. Farming is done all year round, using rainfall in wet-season and irrigation water in the dry-season. The major crops grown include millet, sorghum, rice, groundnut, cowpea, sugarcane, wheat and vegetables. Rice processing and oil extraction by the women are the most prominent economic activities in the area.

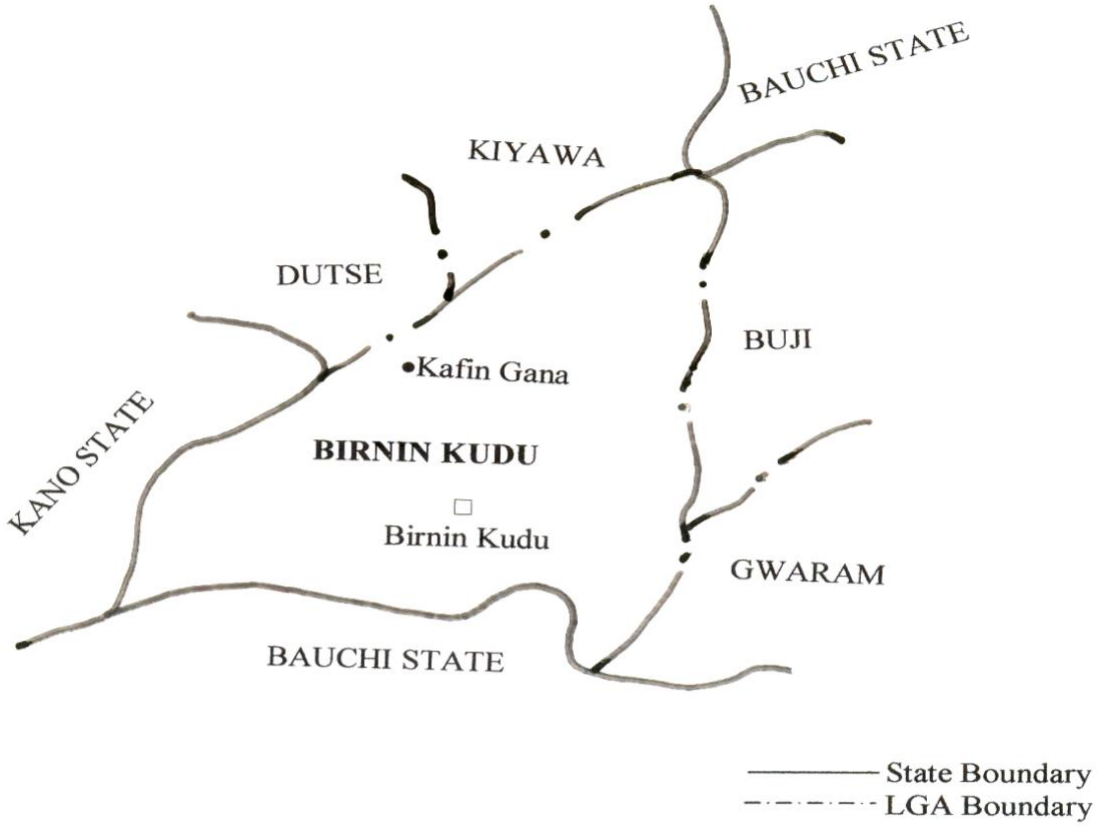


Fig. 1: Map of Birnin Kudu Local Government Area of Jigawa State

The study utilized appropriate extension methodology comprising of the following:

vi. Sensitization visits and meetings with village and household heads.
vii. Identification of women Rice Processors and their formation into group
viii. Equipment demonstration
ix. Training on parboiling procedures, equipment usage and maintenance
x. Monitoring to encourage and assess group performance.

The approach was necessary because extension must go beyond its traditional role of just passively passing information to end users as observed by Arokoyo (1998).

The equipment used were improved and local parboilers. The former consists mainly of metal drum and metal cooking stand. The accessories include removable screened platform covered with jute bag (to separate water and rice grains), support rods, draining valve and lock. The later is mainly an aluminum pot. The accessories include corn stalk covered with jute bag (for separation of rice grains and water) and triangular stones stand. The improved parboiler has a capacity of 40 k/batch while the local parboiler has capacity of 23 kg/batch.

The Programme started in May 2005 with preliminary meeting with the village and ward-heads. The objectives of the programme were discussed and their supports were equally solicited for the success of the programmes. Another meeting was held in June 2005 to sensitize the community members. Selected processors between the ages of 20 – 40 years were briefed, formed into groups and the improved parboiler was demonstrated to them. The local parboiler was also demonstrated side by side with the improved parboiler. During the demonstration, performance data were collected from the two methods and descriptive statistics such

as means and percentages were used for comparison.

The training was conducted for three days in August 2005. It covered practical steps in parboiling such as cleaning, soaking, steaming, drying and milling. Other areas covered were equipment handling, adjustment, operation and maintenance. At the end of the training, four parboilers were provided at four designated centers for the continuation of the processing activities of the women. The activities of the centers were monitored at weekly intervals for two months. Subsequent visits were made on monthly basis for one year.

RESULTS AND DISCUSSION

Sensitization Meetings.

Five people attended the sensitization meeting with the village head while 30 people attended the other meeting with the members of the community. At the end of the meetings the village head and all the community members that were in attendance welcomed the idea of introducing the new technology and they were all convinced about the important of the programme to the community. Some of them pledged not only to allow their wives to participate but also to assist them financially to acquire the parboiler if it works to their satisfaction. The success of these meetings led to nomination of twenty women processors. These processors were briefed and organized into group with Hajia Taiba A. Alai (Chairman), Walayya Sadiku (secretary), Fatima A. Gambo (Treasurer) and Adama Aminu (Public Relation Officer).

Equipment Demonstration.

The demonstration was conducted with twenty people in attendance. The performance results of the two parboilers were as summarized in Table 1. From the results, it is clear that there is substantial reduction in time required to accomplish parboiling operation. From soaking, steaming and drying operations, there was a time saving of about 18 hours 10 minutes (34.4%) over the local parboiler. This was achieved despite the fact that the capacity of the improved parboiler is 17 kg higher than that of the local parboiler. The head rice recovered was also high for improved parboiler (about 3.5% difference). The percentage breakages were 18% and 8.5% for local and improved parboilers respectively with 9.5% difference. In the case of colour and impurities assessment, 95% of panel of 20 judges ranked the quality of the improved parboiler as bright with low impurities level as compared to dull with high level of impurities for local parboiler. The milled rice from the improved parboiled attracted N320 per “mudu” as compared to N290 per “mudu” for the local parboiler. This implies that the product from the improved parboiler is more attractive to the consumers and they are ready to pay more because of the quality. Ironically, the cost of the improved parboiler (N2,500) is lower than that of the local parboiler (N3,000). From the results, the improved parboiler has a comparative advantage over the local parboiler in terms of capacity, time saving, product quality and revenue accrue from the use of the equipment.

Table 1: Summary of Performance Results during Demonstration

Assessed Parameter	Local Parboiler	Improved Parboiler	Level of Difference
Equipment cost	N3,000:00	N2,500:00	-N500:00
Optimum capacity	23 kg	40 kg	+17 kg
Soaking duration	16 hrs	6 hrs	-14 hr
Teaming Duration	35 min.	25 min	-10 min
Drying Duration	32 hrs	28 hrs	-4 hr
Head Rice Recovered	56.5%	60%	+3.5%
% Breakage	18%	8.5%	9.5%
Colour Appearance	Dull	Bright	--
Level of impurities	High	Low	--
Selling price/mudu	N290	N320	N30

Training on Operation and Maintenance

The training was conducted with twenty-seven participants (twenty-four females and three males) in attendance. The parameters evaluated for were percentage breakage, milling yield and level of impurities/appearance of the milled product. The results obtained are as presented in Table 2. From the table, the levels of breakage were 18 % and 8.05% for local and improved parboilers respectively. This shows an improvement of 9.95% over the traditional parboiler. The amounts of rice grains obtained from the paddy (milling yield) on the average were 56.52% and 60% for traditional and improved parboilers respectively. With this result, an improvement of 3.48% has been recorded for improved parboiler. Though, the milling yield recorded is below grains recovery of 65 to 70% for parboiled as against 50 – 56% for un-parboiled rice depending on rice grade, however, the value obtained for improved parboiler is 3.48% high than that for the local parboiler. Using 20 panelists to assess the level of impurities and appearance, 96.25% preferred the rice grains from the improved parboiler while only 3.75% showed preference for the rice grains from the local parboiler. With difference of 92.5%, this means that there was an overwhelming preference for the milled product from the improved parboiler.

Table 2: Comparative Assessment of Milled Rice Grains

Parameters		Parboiling Method		Level of Difference
		Local	Improved	
Breakage (%)	1	18.00	8.50	9.50
	2	18.10	7.90	10.20
	3	18.00	8.60	9.40
	4	17.90	7.20	10.70
	Mean(%)	18	8.05	9.95
Milling yield	1	56.09	58.75	2.66
	2	57.39	61.25	3.86
	3	55.65	59.50	3.85
	4	56.96	60.50	3.54
	Mean(%)	56.52	60	3.48
Preference test	1	-	20	20
	2	-	20	20
	3	2	18	16
	4	1	19	18
	Mean(%)	3.75	96.25	92.5

Therefore, from these results (Tables 1 and 2) it can be said that the quality of the milled grains from the improved rice parboiler is better than the one obtained from the local parboiler. At the same time, considering other factors, the improved parboiler has clear advantages over the traditional parboiler.

Monitoring of Group Performance

The monitoring has further encouraged the women group. This is evidence in increase in their number and demand for more improved parboiler to cope with their operation. During this period, higher quality rice with 65% milling yield and 7% grain breakage was obtained. Within this period, also, Jigawa State Agricultural and Rural Development Authority sponsored additional training for women rice processors in Chiyeko village. This showed an acceptance not only by the rice processors but also by the authority responsible for dissemination of improved technologies to the end users. It was observed during the process of monitoring that groups have been formed in different locations for the purpose of pursuing their processing activities. Most of these groups have expanded their activities through contribution from members and technical assistance from the state ADP under the National Special Programme for Food Security (NSPFS).

CONCLUSIONS

The following conclusions could be made:

vi. Sensitization of end users, the household heads and the village/community heads is an essential component for any technology dissemination and adoption.

vii. Group formation could be an important tool in technology adoption. This is necessary for capacity building and economic empowerment of the members in particular and the group in general.

viii. In equipment adoption, demonstration of the new technology and the existing one is necessary to stimulate interest. This should be followed by proper training of the end users on operation and maintenance of the technology.

ix. Monitoring should be an essential component of any adoption process. This is necessary for technical guidance and encouragement of the recipient(s). The length of

monitoring could be determined by level of adoption.

x. In this study, the level of adoption of the parboiler has been high and this can be attributed to its simplicity, easy of operation, high efficiency and low cost. The parboiler is now popular among the women groups.

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Specific Heat and Thermal Diffusivity of Okra as affected by Moisture Content and Bulk Density

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Abstract

The objectives of this study were to investigate the effect of moisture content and bulk density on specific heat and thermal diffusivity of okra.

The study was conducted on okra in the market as at when the experiment was conducted for thermal properties of the sample (okra: chopped, ground (dry), and fresh whole). The chopped okra experiment was conducted in the moisture content range of 10 - 80% (wb). The bulk density of okra sample was determined following the AOAC (1980) recommended method. The experiments at each moisture levels and bulk density were replicated three times.

The results obtained show that specific heat capacity varied between 7.3069 to 19.8864 J/mKg^{0}C and has no significant difference at 5% level of significance; thermal diffusivity values varied in range of 0.5736 to 3.0919x10^{-8} m^2/s has significant difference at 5% level of significance. For the ground okra, the parameters have significant difference at 5% level of significance. Same procedure applies to fresh okra; the parameters have significantly difference at 5% level of significance. For bulk density in the range of 170 to 280 Kg/m^3, the specific heat varied in the range of 9.5628 to 19.8864 J/mKg^{0}C and is not significantly affected at 5% level of significance while thermal diffusivity varied from 1.3685 to 5.7360x10^{-8} m^2 /s and is significantly affected at 5% level of significance.

Keywords: Okra (A*belmuschus spp*): Specific heat; Thermal diffusivity; Moisture content; Bulk density

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1. Introduction

Okra is a powerhouse of valuable nutrients. Nearly half of which is soluble fiber in the form of gum and pectins. Soluble fibre helps to lower serum cholesterol, reducing the risk of heart disease. The other half is insoluble which helps to keep the intestinal tracts healthy, decreasing the risk of some forms of cancer, especially colorectal cancer. Nearly ten per cent of recommended levels of vitamin B6 and folic acid are also present in a half-cup of cooked okra. Appreciable research has been carried out on thermal properties of grains and seeds. However, there is not much research on the thermal properties of okra. Their importance hence need to be investigated and exploited especially in okra that is known to be consumed in most part of the world especially in India and West Africa as is seen from literature. The vegetable is well known and enjoys a wide popularity and importance but the thermal properties are undermined.

Specific heat has often been measured with calorimeters of one form or another using the method of mixture while Timbers (1975) and Drusas et al. (1986), measured thermal diffusivity using the Dickerson (1965) apparatus, while Kazarian and Hall (1965), Shepherd and Bhardwaj (1986) and Dutta et al. (1988), determined it from the measured values of specific heat, thermal conductivity and bulk density. Hwang and Hayakawa (1979) reported the use of a vacuum bottle calorimeter in measuring the specific heat of food, and Mohsenin (1980) and Lund (1983) described the differential scanning calorimeter (DSC). Shepherd and Bhardwaj (1986) and Dutta et al. (1988) used an aluminum calorimeter placed inside an insulated vacuum flask to measure the specific heat of pigeon pea and gram respectively. Otten and Ezeike (1976) developed a continuous adiabatic calorimeter and Ezeike (1987) presented a technique for measuring the specific heat of agricultural products with a modified adiabatic drop calorimeter.

Some investigators have calculated the specific heat of seeds and grains from other

thermal properties such as thermal conductivity and thermal diffusivity while others made direct measurement of the specific heat. Tang and Sokhansan, (1990) carried out a study to determine the specific heat of Laird lentil seed as affected by moisture content and temperature using differential scanning calorimeter. Specific heat value ranged from 0.8 to 2.2 KJ/Kg K increasing with increase in moisture content over the range from 2.1 to 25.8% (wet basis) and with temperature varying from 10 to 80^0C. Information on the thermal properties of lentils is valuable for drying and storage. Tang et al. (1991) used the differential scanning calorimeter (DSC) to determine the specific heat of lentil seed. The values of lentil seeds ranged from 0.81 to 2.2KJ/KgK specific heat increased quadratically with increase in moisture content over the range from 2.1% to 25.8% (wb).

Jekendra et al., (1995) conducted an experiment to determine the thermal diffusivity of wheat, maize, sorghum, black grain and Sesa num using standard methods. The thermal diffusivity of grain decreased as moisture content increase. Fasina and Sokhansanj (1995) used the line heat source method to obtain bulk thermal conductivity and thermal diffusivity of Lucerne pellets with moisture contents in the range 7.5 – 18.0% (wet basis).

2. Experimental Procedure

2.1 Materials and methods

The study was conducted on the variety which was in the market as the study was conducted for okra pods (fresh) chopped and ground (dry).the chopped okra experiment was conducted using 10 through 80 % moisture content wet basis and current input(0.5 to 1.5A). The variety in stock is called 'ila Oyo', by the market women which is the long, dented okra at the base. Because of very high moisture content of okra, the sample was gotten from market according to the quantity needed to perform the experiment at a time.

The plates 1 and 2 show the type of okra from the market and that at 20% (wb) used for the experiment. The moisture content was determined by oven dry method using the weighing balance.

The bulk density of chopped (sliced) okra was determined following the AOAC (1980) recommended method. It involves the filling of a 100ml cylinder with chopped okra from a height of 15cm, and then weighing the content on a weighing balance to determine the mass of the sample. The ratio of the weighed mass of the sample in 100ml cylinder to the bulk volume was taken which is the bulk density.

The specific heat capacity of okra was calculated for each moisture content of 10through 80% wet basis from heat generated from thermal conductivity experiment, each calculated value of specific heat of moisture content was done at a replication of three (3). The calculated specific heat capacity was gotten after passing current in the ranges of 0.5, 1.0, 1.5 A through each moisture content.



Plate 1: Sample of the okra bought from the market.



Plate 2: Okra at 20% wet basis moisture content.

Using $Q = I^2 R$ for the heat generated in the chamber at a resistance of the wire of 6Ω, which is constant.

Hence,

$$Q = I^2 R = MCp\Delta t \quad . \quad . \quad . \quad (1)$$

$$Cp = \frac{Q}{Mx\Delta t} = \frac{I^2 R}{Mx\Delta t} \quad . \quad . \quad . \quad (2)$$

Where,

Q = heat input (J/m)
M = mass of sample in chamber (Kg)
Δt ($T_2 - T_1$) = change in temperature (^{0} C)
I = current input (A)
R = resistance (Ω)

The thermal diffusivity was determined from the calculation using the calculated values of specific heat, experimental values of thermal conductivity, and the bulk density from the equation given below.

$$Di = \frac{K}{P_b \cdot C_p} \quad . \quad . \quad . \quad (3)$$

Where,

Di = thermal diffusivity (m^2/s)
K = thermal conductivity (W/m ^{0}C)
P_b = bulk density (Kg/m^3)
C_p = specific heat capacity (J/mKg ^{0}C)

Thermal diffusivity is determined for the moisture content of 10, 20, 30, 40, 50, 60, 75, 80% wet basis and it covers the diffusivity of fresh (whole) okra at 87.2% (wb) and that of dry ground okra at 12% (wb).

The results obtained in respect of the thermal conductivity, K, thermal diffusivity, Di, and the specific heat capacity, Cp, at various moisture content, MC, are presented in this chapter.

The ANOVA Tables as well as different graphs are also given in the appendices.

3 Results and discussion

3.1 Specific heat

The results of Specific heat measurement for okra when chopped with moisture content, when chopped with current input, when dry ground with current input, when fresh (whole) okra with current input and when chopped with bulk

density are summarised and presented on Tables 11, 12, 13, 14, and15 and on Figures 1, 2, 3, 4, and 5.

Table 1: Specific heat of chopped okra as affected by moisture content.

MC (%)	Specific heat (J/mKg^{0}C)
10	9.5628
20	13.7255
30	18.0412
40	17.*7665*
50	13.1579
60	7.3069
75	19.8864
80	10.4790

Table 2: Specific heat capacity of chopped okra as affected by current input

Current input (A)	Specific heat (J /mKg^{0}C)
0.5	2.9445
1.0	11.7778
1.5	26.5001

Table 3: Specific heat of ground okra as affected by current input

Current input (A)	Specific heat (J/mKg^{0}C)
0.5	1.0232
1.0	4.0928
1.5	9.2087

Table 4: Specific heat of fresh okra as affected by current input.

Current input (A)	Specific heat (J/mKg^{0}C)
0.5	1.2417
1.0	4.9669
1.5	11.1755

Table 5: Specific heat capacity of chopped okra as affected by bulk density.

Bulk density (Kg/m^3)	Specific heat (J/mKg^{0}C)
170	9.5628
180	13.7255
220	18.0412
230	12.7437
240	*19.8864*
280	10.4790

The cubic equation is the equation that correctly fit for the specific heat variation at various moisture content is given as;

$$Cp = -2.7663 + 1.5448M - 0.0374M^2 + 0.0003M^3 \quad (R^2 = 0.317) \quad . \; . \; . \quad (4)$$

Where,

Cp = Specific heat capacity (J/mKg^{0}C)

M = Moisture content at wet basis (%).

The specific heat increased with increase in moisture content of 10 to 30% wet basis from 9.5628 J/mKg^{0}C to 18.0412 J/mKg^{0}C while at moisture content increase of 40 through 60% wet basis, the specific heat decreases from 17.7665 J/mKg^{0}C to 7.3069 J/mKg^{0}C. It (specific heat) increased again at 75% to 19.8864 J/mKg^{0}C before it then reduces to 10.4790 J/mKg^{0}C at 80% wet basis. The specific heat increased, as the current input increased from 0.5A to 1.5A, from 2.9445 to 26.5001 J/mKg^{0}C, for chopped or sliced okra. For dry ground okra, the specific heat increased with current input of 0.5A to 1.5A from 1.0232 J/mKg^{0}C to 9.2087J/mKg^{0}C. For fresh okra, the specific heat increased, with current input of 0.5A to 1.5A, from 1.2417 J/mKg^{0}C to 11.1755 J/mKg^{0}C. The specific heat of chopped okra, with bulk density of 170 to 220 Kg/m^3, was seen to increase from 9.5628 J/mKg^{0}C to 18.0412 J/mKg^{0}C. The specific heat, with bulk density 230 Kg/m^3, reduces to 12.7438 J/mKg^{0}C. The specific heat at bulk density of 240 Kg/m^3 rose to 19.8864 J/mKg^{0}C for that of bulk density of 230Kg/m^3 which then reduces to 10.4790 J/mKg^{0}C for the bulk density of 280 Kg/m^3.

The analysis of variance of the specific heat with moisture content shows no significantly difference ($P \leq 0.05$), but the specific heat with current input shows high significant difference ($P \geq 0.05$). The specific heat with current input for fresh (whole) okra shows significant difference ($P \geq 0.05$). For dry ground okra, the specific heat shows significant difference ($P \geq 0.05$) with current input. Finally, the specific heat was found or seen not to be significantly different ($P \geq 0.05$) with bulk density

The specific heat capacity varied from 7.3069 to 19.8864 J/mKg^{0}C in this study, looking at it in the light of other studies carried out by other researchers like Tang and Sokhansanj (1990) using Laird lentil seed in the range of 0.8 to 2.2 kJ/KgK with moisture content range of 2.1 to 25.8%, is different since their percentage difference is high

Specific heat, which is the amount of heat required to raise the temperature of a unit mass of grain by 1^{0}C is important in aeration, drying, milling, etc. of food crops. It has to do with variation of temperature with amount of heat store within the substance, and as such finds application in cooling operations. The limited capacity of commercial or on the farm driers often necessitates cooling of stored grains to dissipate the heat build up due to respiration and keep the grains at temperature close to ambient temperature until drying.

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3.2 Thermal diffusivity

The results of thermal diffusivity measurement for okra when chopped with moisture content, when chopped with current input, when dry ground with current input, when fresh (whole) okra with current input and when chopped with bulk density are summarised and presented on Tables 6, 7, 8, 9, 10 and on Figure 1, 2, 3, 4, and 5.

Thermal diffusivity decreases with increase in moisture content (10 to 30%) from 3.0919x10^{-8} m^2/s to 0.5736x10^{-8} m^2/s,

Table 6: Thermal diffusivity of chopped okra as affected by moisture content

MC (%)	Thermal Diffusivity (m^2/s) (x 10^{-8})
10	3.0919
20	1.3685
30	0.5736
40	0.9904
50	1.4417
60	3.9138
75	2.0189
80	2.9761

Table 7: Thermal diffusivity of chopped okra as affected by current input.

Current input (A)	Thermal Diffusivity (m^2/s) (x 10^{-8})
0.5	1.2735
1.0	1.9581
1.5	2.9090

Table 8: Thermal diffusivity of grinded okra as affected by current input.

Current input (A)	Thermal Diffusivity (m^2/s) (x 10^{-8})
0.5	1.2162
1.0	1.6612
1.5	2.4302

Table 9: Thermal diffusivity of fresh okra as affected by current input

Current input (A)	Thermal diffusivity (m^2/s) (x 10^{-8})
0.5	1.2892
1.0	2.2321
1.5	2.7932

Table 10: Thermal diffusivity of chopped okra as affected by bulk density

Bulk density (Kg/m^3)	Thermal diffusivity (m^2/s) (x 10^{-8})
170	3.0919
180	1.3685
220	5.7360
230	2.1153
240	2.0189
280	2.9761

The cubic and quadratic regression equations are shown below,

$$Di = 7.2x10^{-8} - 5.0x10^{-9}M + 1.3x10^{-10}M^2 - 9.0x10^{-13}M^3 \quad (R^2 = 0.721) \quad . \; . \; . \quad (5)$$

$$Di = 2.4 \times 10^{-7} - 2 \times 10^{-9} P_b + 4.7 \times 10^{-12} P_b^2 \quad (R^2 = 0.524) \quad . \; . \; . \quad (6)$$

Where,

M = Moisture content (wet basis) (%)
Di = Thermal diffusivity (m^2/s)
P_b = bulk density (Kg/m^3)

While the thermal diffusivity with moisture content of 40 to 60% wet basis increased from $0.9904x10^{-8}$ to $3.9138x10^{-8}$ m^2/s, thermal diffusivity with moisture content of 60 to 75% wet basis decreased from $3.9138x10^{-8}$ m^2/s to $2.0189x10^{-8}$ m^2/s, the thermal diffusivity with moisture content of 75 to 80% wet basis increases from $2.0789x10^{-8}$ to $2.9761x10^{-8}$ m^2/s. The effect of current input on thermal diffusivity when the current input was 0.5A through 1.5A, the thermal diffusivity increased from $1.2735x10^{-8}$ to $2.9090x10^{-8}$ m^2/s for chopped okra. For ground dry okra, the thermal diffusivity, when the current input was from 0.5A to 1.5A for moisture content of 12% wet basis, was from $1.2162x10^{-8}$ to $2.4302x10^{-8}$ m^2/s. For fresh whole okra, the thermal diffusivity when the current input was 0.5A to 1.5A at moisture content of 87.2% wet basis increased from $1.2892x10^{-8}$ through $2.7932x10^{-8}$ m^2/s. Thermal diffusivity of okra decreased from $3.6919x10^{-8}$ to $0.5736x10^{-8}$ m^2/s at bulk density of 170 to 220 Kg/m^3 . The thermal diffusivity, at 230 Kg/m^3 bulk density, increased to $2.1153x10^{-8}$ m^2/s, finally, thermal diffusivity increased for bulk density of 240 to 280 Kg $/m^3$ from $2.0189x10^{-8}$ to $2.9761x10^{-8}$ m^2/s.

The analysis of variance (ANOVA) for thermal diffusivity shows that there is significant difference since ($P \geq 0.05$). Duncan Multiple Range test was used to find how much difference is gotten. The effect of current input on thermal diffusivity is significantly different ($P \geq 0.05$) F cal is greater than F tab for chopped okra. For dry ground okra, the analysis of variance of the

effect of current input on thermal diffusivity is significantly different (P≥0.05), it shows that F tab is less than F cal. The analysis of variance for fresh okra shows that the thermal diffusivity is significantly different since F cal is greater than F tab. The effect of bulk density on thermal diffusivity shows that it is significantly different. The level of significance is also carried out by the use of Duncan Multiple Range Test.

Other researchers reported studies on the thermal diffusivity, (Screenarayanan and Chattopadlyay (1986)) are in the range of 1.08 $x10^{-7}$ to 9.95 x 10^{-8} m^2/s on rice bran with moisture range of 7 to 15% (wet 1basis). The percentage difference shown compare to this work is 94.27% which is significantly different and also for high range of value, the percentage is 74.52% which is also significantly different, due to the high moisture content of okra.

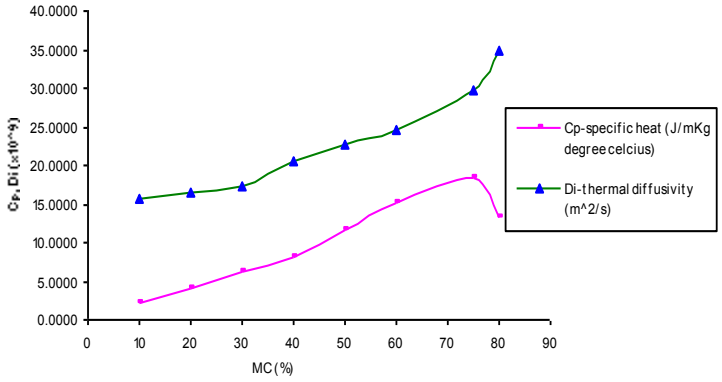


Fig. 1: Thermal properties of chopped okra against misture content, MC (%) at 0.5A contant current.

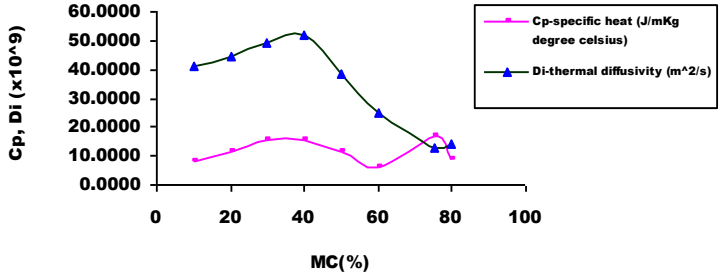


Fig. 2: Thermal properties of chopped okra against moisture content, MC (%) at 1.0A constant current.

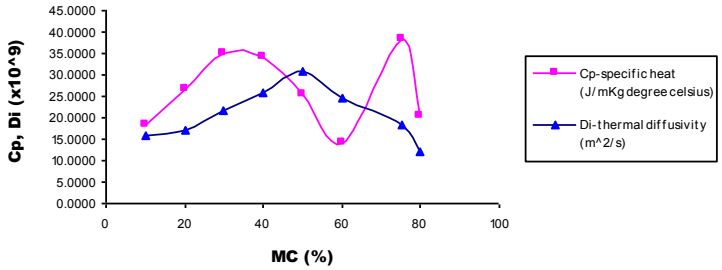


Fig. 3: Thermal properties of chopped okra against moisture content MC (%) at 1.5A constant current.

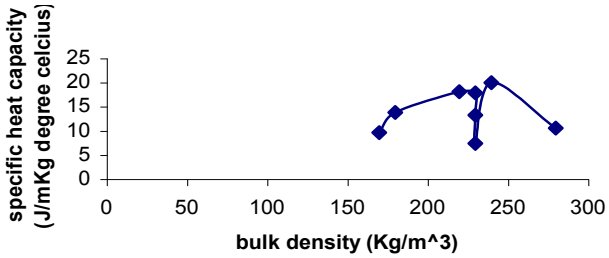


Fig. 4: Specific heat capacity against bulk density

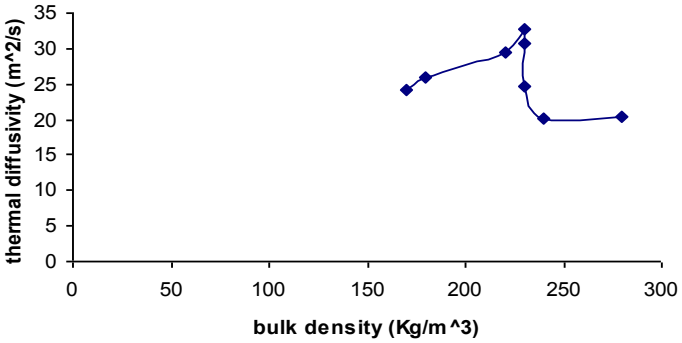


Fig. 5: Thermal diffusivity against bulk density

Conclusions

The following conclusions could be drawn from this study:

i) Specific heat of chopped okra with moisture content in the range of 10 to 80 %, varied from 7.3069 to 19.8864 J/kg^{0}C, while with bulk density of 170 through 280 Kg/m^3, it varied from 9.5628 to 19.8864 J/kg^{0}C.

ii) Thermal diffusivity of chopped okra with moisture content of 10 to 80 % varied from 0.5736 to 3.0919x10^{-8} m^2/s, with bulk density range from 170 to 280 Kg/m^3, it varied from 1.3685 to 3.0919x10^8 m^2/s.

iii) All the two parameters increased at fresh and ground state with current input with values of 1.0232 to 9.2087 J/mKg^{0}C for ground, 1.2417 to 11.1755 J/mKg^{0}C for fresh okra of specific heat; 1.2162 to 2.4302x10^{-8} m^2/s for ground, 1.2892 to 2.7932x10^{-8} m^2/s for fresh okra of thermal diffusivity

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EFFECT OF MOISTURE CONTENT ON SOME AERODYNAMIC PROPERTIES OF SAMARU SORGHUM 17

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ABSTRACT
The aerodynamic properties of Samaru Sorghum (SAMSORG 17) in terms of the terminal velocity of materials to be separated during winnowing such as threshed ear, grain, stalk and chaff of sorghum were determined using a vertical wind tunnel. Result showed that the terminal velocity of sorghum grain is higher than the sorghum chaff and stalk. The terminal velocity of sorghum grain ranged between 5.79 m/s and 6.79 m/s while the chaff and stalk ranged between 2.53 m/s and 3.96 m/s and 2.29 m/s and 4.32 m/s respectively within the moisture range of 8.89 and 16.50 % wb.

Keywords: Aerodynamic properties, sorghum, cleaning, straw, chaff, stalk, terminal velocity.

INTRODUCTION

Threshed materials presented to the sieves for separation and cleaning is a complex mixture of particle fractions with a range of physical and aerodynamic properties (Farran and Macmillan, 1979). The threshed sorghum materials include well-defined single particles such as sorghum grain and chaff as well as the highly variable ones such as the sorghum ear with and without grain and straws of various lengths. Aerodynamic characteristics of particles mixture are important in cleaning; the knowledge of the aerodynamic properties of the materials to be separated and cleaned is necessary and essential to be able to produce sorghum at the right quality, quantity and prices. Straw is one of the major contaminants in the mixture of threshed crop material being separated from the grain which posses a lot of challenges because it is neither symmetrical in shape nor uniform in density. This lack of symmetry often resulted in aerodynamic instability, which poses a lot of challenges during the cleaning operation.

Terminal velocity is the velocity when the drag force and the gravitational force are at equilibrium. It is a function of particle moisture content; increasing with increasing moisture content (Joshi, et al., 1993). An object attains a terminal velocity when net gravitational accelerating force equals resisting upwards drag force. Vertical wind tunnel has been used to find the suspension velocities of the particles in an air stream (Gorial and O'callaghan, 1990). Farran and Macmillan (1979) found that higher air velocities are required to separate chaff from grain than to suspend chaff on its own. Smith and Stroshine (1985) reported that complete pneumatic separation of cornstalks from stalks was impractical because of the overlapping of the terminal velocities of stalks with those of the cobs. Khoshtaghaza and Mehdizabeh (2006) published that mass and moisture content have significant effects on the terminal velocity. Alonge and Adigun (1999) studied the effect of moisture content on the aerodynamic and physical properties of two varieties of sorghum, *saccharatum* group (sweet sorghum) and *Technicum* group (small seed sorghum) relevant to developing threshing and cleaning machine. Their result showed that within the moisture range of 12.50-25 % wb and 28.57- 37.50 % wb for *saccharatum* and *technicum* groups

respectively, the average terminal velocity varies between 6.99m/s and 9.89 m/s.

Aerodynamic properties are a complex function of the velocity of particle relative to air, effective particle size and shape and the turbulence condition in air stream. The study of the dynamics of a grain in a fluid is essential to understand the process of pneumatic separation (Miu, 2003). This paper reports on the effect of moisture content on the aerodynamic properties of SAMSORG 17 which are required for the separation and cleaning of sorghum grain from straw materials.

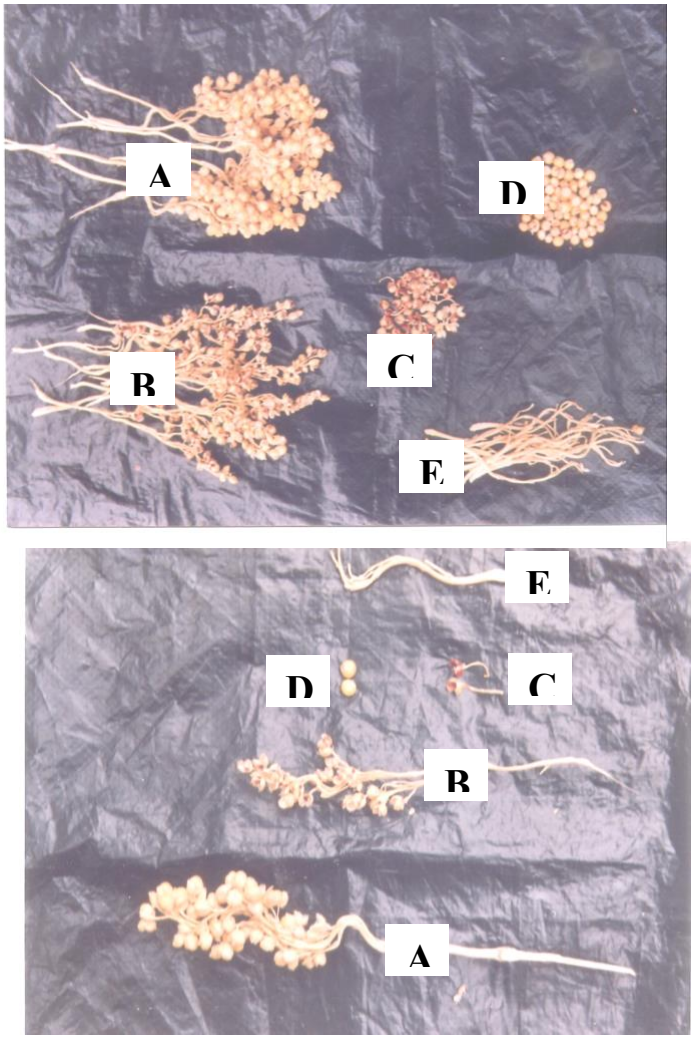
MATERIALS AND METHODS

Test Crop

SAMSORG 17 seed was obtained from the Seed Multiplication Unit of the Plant Science Department, Institute for Agricultural Research, Ahmadu Bello University, Zaria. SAMSORG 17 was selected as test crop due to its economic importance and growing market demand in malting and baby food industries as well as other agro-based industries (Rural Sector Enhancement Programme, 2001). It is a late maturing variety suitable for the guinea savanna vegetation zone of Nigeria.

The sorghum used for the experiment was planted in June 2003 in the College of Agriculture farm at Samaru (11° 11' N, 07° 38'E, 685 m above sea level) in the Northern Guinea Savannah Zone in Kaduna State, Nigeria. The soil is classified as alfisol (Moberg and Esau, 1989). The crops mainly grown in the area are maize, sorghum, millet, cotton and groundnut.

The sorghum grain and straw materials such as threshed ear, stalk and chaff were obtained after mechanical threshing. Figure 1 shows the different samples.



A =Unthreshed Sorghum ear; B = Threshed Sorghum ear; C = Chaff; D = Sorghum grain; E =Stalk

Figure 1: An array and individual sorghum samples

Laboratory Determinations

Three groups of 50 sorghum grains samples were drawn randomly from each moisture content level. From each group, 20 grains were picked randomly and were thoroughly mixed together from which 30 sorghum grains were randomly selected. Micrometer screw gauge (Sheffied S 139 Br) with least resolution count of 0.01mm was used to determine the diameter of the sorghum grains and stalk.

To study the effect of moisture content on the sorghum grain and straw materials, samples were conditioned to obtain different moisture contents in the range between 8.89 and 16.50 %wb. This was obtained by rewetting the samples to higher moisture content by soaking a bulk quantity of samples in a calculated quantity of clean water. Five grams of the various samples were soaked at 30 minutes intervals up to 2 hours to obtain moisture levels of 8.89, 10.87, 12.33, 14.56 and 16.50 % wb respectively. At the end of soaking, the samples were spread out in thin layer to dry in natural air in the room temperature of 29^{o}C. To enable stable and uniform moisture content to be obtained, samples are put in separate polythene bags and kept in the refrigerator at 4^{o}C for four days to allow for equilibration of moisture in the sample mass. Moisture content of the samples was determined using the procedure detailed by Henderson, et al., (1997). The samples were dried at 130^{0}C for 18 hours (ASAE, 2003). The weight loss of the samples was recorded at the moisture content determined in percentage. Five replications of the moisture content were made.

$$MC = \frac{W_i - W_d}{W_i} x100 \qquad 1$$

Where

MC_{wb} = moisture content, wb %

W_i = Initial weight of sample, kg

W_d= Dried weight of sample, kg

The diameter of each individual sorghum grain was measured triaxially along the principal axis, major (L_1), intermediate (L_2) and minor (L_3). Its equivalent diameter D_e was calculated using the using equation 2 given by Ciro, 1997 reported by Asoegwu, et al., (2006).

$$D_e = \frac{\left(F_1 + F_2 + F_3\right)}{3} \qquad 2$$

Where

F_1 = Arithmetic mean diameter= $\left(L_1 + L_2 + L_3\right)/3$,mm

F_2 = Geometric mean diameter= $\left(L_1 L_2 L_3\right)^{1/3}$,mm

F_3 = Square mean diameter $= \left[\frac{\left(L_1 L_2 + L_2 L_3 + L_3 L_1\right)}{3}\right]^{1/2}$, mm

The diameter of the sorghum stalk is measured at three points, the tip, middle and bottom. The average of the three measurements is the diameter of the stalk. Thirty replications were taken at random and each parameter determined.

The projected area of the samples was obtained by tracing method as described by Oje and Ugbor (1991).The projected area was determined

by tracing out the boundary on a linear graph paper and counting the number of square boxes the traced boundary covered.

The mass of sorghum samples were determined using an electronic mettler balance (Sarturlus 2355, max160g, d= 0.001g).Thirty replications were taken.

The volume of samples was determined by water displacement method as described by Oje, (1993). The samples were put in a polyethylene bag attached to a thread and immersed in water inside a measuring cylinder (100ml). The volume of the empty polyethylene bag was obtained with the aid of a sinker. The volume of water displaced was measured. The volume of the samples is the difference in water level minus the volume of the polyethylene. The average volume was obtained by dividing the volume obtained by the number of materials that made up the samples. The representative value was taken as the average of thirty replications. The particle density of samples was determined by dividing the sample mass by the sample volume.

Description of the Vertical Wind Tunnel

A vertical wind tunnel (Figure 2) available in the Agricultural Engineering Technology Programme, Samaru College of Agriculture, Ahmadu Bello University, Zaria was used to carry out measurements of the aerodynamic properties of sorghum samples. A petrol engine (Bernard moteurs 417, 1.13kW) was used to power the machine.

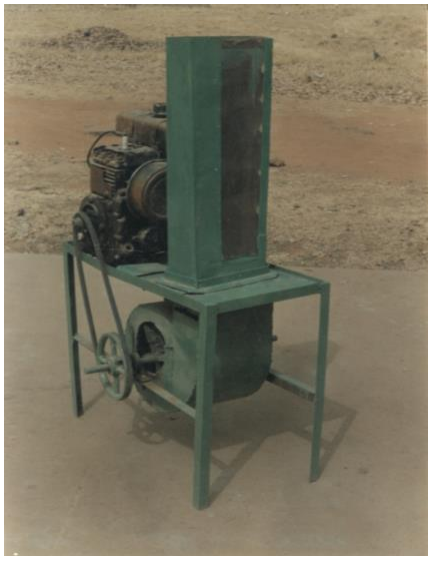


Figure 2: Vertical Wind Tunnel

The major components of the vertical wind tunnel are: the frame, wind tunnel, and fan. The frame is 60 cm long and 30 cm wide and 50 cm high was constructed using 13 mm angle iron. The frame also provides the seat for the petrol engine. The wind tunnel was constructed with 1 mm sheet metal into rectangular shaped tunnel, 54 cm high, 20 cm long and 10 cm wide. A Plexiglas 50 cm long and 15 cm wide is slotted at the front to allow for the visibility of the samples inside the wind tunnel. The base of the wind tunnel and the throat of the fan chamber are fixed on plywood, dimensioned 28 cm by 28 cm. A 20 cm by 10 cm air space was cut on the plywood to enable passage of air. Wire nettings were placed in the air passage to prevent the samples from falling into the air stream. A centrifugal fan with straight blade blower, each of the 4 blades, dimensioned 6 cm long and 13cm wide produced the vertical air stream. A gate to vary the flow rate of the air stream was provided. The orthographic views of the vertical wind tunnel are given in figure 4.

Test Procedure

Terminal velocity of sorghum grain and straw materials such as threshed ear, stalk and chaff needed in the separation and cleaning process were determined. Terminal velocity was measured by placing samples of sorghum grain and straw materials on the screen at the bottom of vertical wind tunnel (Elutriator) equipped with a hand operated valve for controlling the air flow rates. The air flow rate was adjusted until the samples were suspended inn the air stream. The air velocity in the center of the elutriator at the exit of the wind tunnel was measured using a hand held anemometer (Pruufschein fur anemometer, L- Nr 3010/112546) and recorded. Ten replications were taken for each sample.

RESULTS AND DISCUSSION

Some Physical Properties of Sorghum Grain and Straw Materials.

Table 1 presents the mean values and standard errors of the axial dimensions of the sorghum

grain at different moisture contents. The table also contains the arithmetic mean diameter, geometric mean diameter, square mean diameter and the equivalent diameter of the sorghum grain. The average diameters obtained from the arithmetic mean, geometric mean and equivalent diameter were 4.20 mm, 4.16 mm and 4.18 mm respectively at moisture content of 16.50 %wb. At moisture content of 8.89% wb, the values were 3.32 mm, 3.31 mm and 3.31 mm respectively. The average diameter of the sorghum grains calculated by the arithmetic mean, geometric mean and equivalent diameter methods in the moisture range of 8.89 – 16.50 % wb are almost the same (Table 1) which could be as a result of the spherical shape of SAMSORG 17. The result obtained from this study are slightly different from those of Picket and West (1988) who obtained arithmetic mean and geometric mean diameters of 3.73 and 3.66 mm respectively, while Gorial and O'Callaghan (1990) obtained equivalent and geometric diameters of 3.5 and 3.61 mm respectively for sorghum, though the variety and moisture content for which their result were based was not specified. However, the values obtained are higher than the 2.72 mm obtained by Waziri and Mittal (1983) for LS187 variety of sorghum which shows that the diameter of SAMSORG 17 is bigger than the LS187.

Table 1: Means and standard errors of axial dimensions of sorghum grains

MC %wb	Major axis, L_1, mm	Medium axis,L_2, mm	Minor axis, L_3, mm	Arithmetic mean, $L_1+L_2+L_3/3$,mm	Geometric mean, $(L_1L_2L_3)^{⅓}$ mm	Equivalent diameter, D_e mm	Square mean diameter, F_3,mm
8.89	3.70(0.29)*	3.18(0.30)	3.08(0.22)	3.32	3.31	3.31	3.31
10.87	3.81(0.22)	3.29(0.18)	3.09(0.24)	3.40	3.38	3.41	3.39
12.33	4.04(0.04)	3.50(0.03)	3.61(0.05)	3.72	3.71	3.71	3.71
14.56	4.45(0.07)	4.39(0.12)	3.40(0.38)	4.08	4.05	4.06	4.07
16.50	4.62(0.06)	4.53(0.01)	3.44(0.07)	4.20	4.16	4.18	4.18

*Standard error (SE)

The average mass, projected area and particle density of sorghum grain and straw materials is presented in Table 2. The average mass, projected area and particle density are 0.044g, 4.66 mm^2 and 1.02 g/cm^2 respectively for sorghum grain at moisture content of 8.89% wb.

Table 2: Some physical properties of sorghum grain and straw materials

Sample	Mass, g	Projected area,mm^2	Particle density,g/cm^3
Threshed	0.37 ± 0.5	64.98 ± 16.66	0.31 ± 0.06
Grain	0.044 ± 0.007	4.66 ± 0.85	1.02 ± 0.20
Stalk	0.067 ± 0.02	26.14 ± 5.9	0.09 ± 0.02
Chaff	0.032 ± 0.008	7.34 ± 1.53	0.05 ± 0.01

* Standard error (SE)

Terminal Velocity of Sorghum Grain and Straw Materials against Moisture Content

The graph of terminal velocity of sorghum grain and its associated constituents against moisture content between 8.89 and 16.50 % wb is presented in Figure 3.

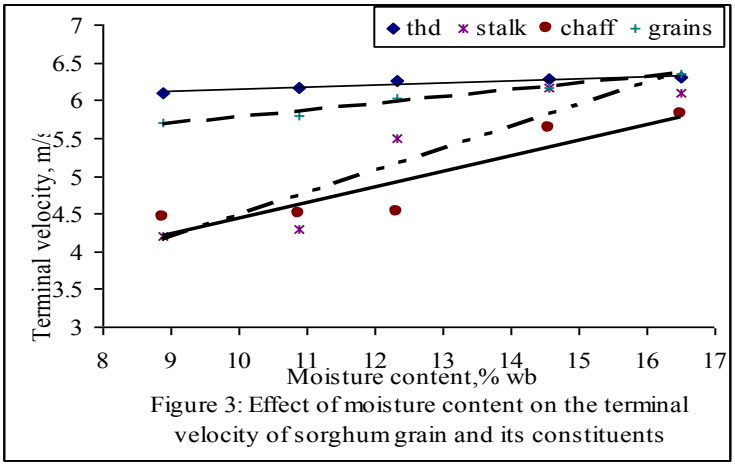


Figure 3: Effect of moisture content on the terminal velocity of sorghum grain and its constituents

Table 3: Summary of regression coefficient of terminal velocity of grain and straw materials

Materials	A	C	R^2
Threshed ear	0.0269	5.8858	0.85
Grain	0.0881	4.8968	0.97
Stalk	0.294	1.5345	0.86
Chaff	0.2071	2.3689	0.84

There was an increase in the terminal velocity of threshed ear, stalk and chaff with increasing moisture content between 8.89- 16.50 % wb. The terminal velocity of threshed sorghum ear increased from 6.10 m/s to 6.30 m/s. The terminal velocity of sorghum stalk increased from 4.20 m/s to 6.09 m/s and also the terminal velocity of sorghum chaff increased from 4.45 to 5.81 m/s .

The terminal velocity of sorghum grain increased with increasing moisture content ranged 8.89- 16.50 % wb. The values of the terminal velocity increased from 5.70 m/s to 6.35 m/s when the moisture content increased from 8.89 to 16.50 % wb. The increase in terminal velocity with increase in moisture content within the study range may be attributed to increase in mass of an individual grain per unit frontal area represented to the airflow. The terminal velocity of sorghum grain obtained in this study is within the range of 4.33-8.58 m/s obtained by Ajav and Ojediran(2006) between the moisture range of 10-20% for a sorghum sample obtained from Maiduguri (The variety is not known). However, the value is lower than 9.45-13.72 m/s and 9.7 m/s obtained by Picket and West (1988) and Gorial and O'Callaghan (1990) respectively. The variety and moisture content on which their results were based was not specified. The value obtained was also lower than 6.99 m/s and 9.89 m/s for *saccharatum* and *Technicum groups* of sorghum obtained by Alonge and Adigun (1999) within the moisture range of 12.50 to 25 % wb and 28.57 to 37.50 % wb respectively. The closeness and overlap of the terminal velocity of sorghum grain and the straw materials would continue to pose a lot of problem during cleaning. This has been the reason for sorghum being a difficult crop to clean. At lower air speed, the threshed sorghum ear and stalk were not separated; it was only the chaff that s blown to some extent. When higher air speeds than the terminal velocities are used, the sorghum grain was blown along with the threshed ear, stalk and the chaff.

The amount of change in the terminal velocity associated with a unit increase in moisture content is given in Table 3. The regression equation describing the effects of terminal velocity against moisture content is a straight line represented by

$$Y = AX + C \qquad (3)$$

Where

Y= Terminal velocity, m/s
X= Moisture content, % wb
A= Regression coefficient

C= Regression constant

The coefficient of determination R^2 values ranged between 0.84 and 0.97.

CONCLUSIONS

1. Threshed sorghum materials for separation and cleaning are a complex mixture of particle types, each having a range of aerodynamic properties.
2. The aerodynamic properties such as the terminal velocity of threshed ear, sorghum grain; stalk and chaff of sorghum were determined using a vertical wind tunnel.
3. Result showed that the terminal velocity of sorghum grain is higher than the sorghum chaff and stalk. The terminal velocity of sorghum grain ranged between 5.79 m/s and 6.79 m/s while the chaff and stalk ranged between 2.53 m/s and 3.96 m/s and 2.29 m/s and 4.32 m/s respectively.

ACKNOWLEDGEMENT: The provision of SAMSORG 17 seed by the Seed Multiplication Unit of the Department of Plant Science of the Institute for Agricultural Research, Ahmadu Bello University, Zaria is gratefully acknowledged.

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SURVEY ANALYSIS OF POST HARVEST INCOME GENERATING ACTIVITIES OF WOMEN IN ADAMAWA STATE

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Abstract
Awareness of post harvest practices is required for tackling the problem of technology rejection of intended user's populace. These post harvest technologies must be conceived and adopted to meet the specific needs of women most of whom are small-scale farmers. Survey was conducted to investigate and evaluate women post harvest needs, ability, participation, resources and income generation in Adamawa State. The state was divided into Northern, Central and Southern Zones. Each zone comprises of seven local governments. 100 women from each zone were randomly selected for Rapid Rural Appraisal (RRA). 300 structured questionnaires were administered and an interview was conducted. Parameters considered are tools used, procedure, period of operation / quantity processed, income generated, and percentage of women involvement for each activities. Eight prominent activities were found throughout the season. It was found out that subjects carried out all these activities with manual tools. Depending on the post harvest activities, the procedures vary from food processing to crop threshing. Percentage of women involvement and income generating per week ranges from 30 % to 90 % and ₦ 300.00 and ₦ 630. 00 respectively. The analysis of variance shows that the F- cal is greater than the F- tab, the differences were seen significant at $p < 0.05$ between the considered post harvest operations and $p < 0.01$ between the zones. This study is a step for knowing appropriate technological intervention in the area bearing in mind the manual skills, economic and affordability of the women in the area.

Key words: Women, Post harvest, Activities, Income, Technology.

Introduction

Globally, women constitute an important sector of peasant farming by their involvement in all aspect of agricultural activities (Buvinic and Ywdeman 1990) and Lange (1998). In Africa between 60 % to 80 % of women are into post harvest activities (Russo et al 1989). Majority of women involved in agricultural activities are small scale farmers , does most of the post harvest activities and contributed significant source of labour (Adeyokunnu, 1981 ; Kaul, 1998 and Klingshirin, 1977). Majority of Nigerians that go into post harvest operations are women farmers and account for about 70 % of the total agricultural output (El – Okene and Suleiman, 1996). Social and economic development initiatives have been focusing on women in terms of their activities, contribution, needs, problems, constrains and improved technologies needed (Atala and Maigida,1996).

In Adamawa State, about 50% of the arable land is estimated to be under agricultural production (Babarinsa, 1997 ; Anyanwu and Adebayo, 2005). Mende (1995) reported that despite the involvement in agricultural business, a good proportion of (30 – 40 %) of the total agricultural produce is lost during post harvest processing. It is in similar direction that government at all levels continues to enunciate various policies and programs under Agricultural Development Projects (ADPs) and the use of various input and output price incentives to promote accelerated adoption of improved post harvest technology (Oni, 2003 and Asota,1989). Despite the crucial role-played by these women, they are faced with numerous challenges including poverty and lack of improves tools (Igbeka, 2003; Info, 2004; AD ADP, 2004 and Anyanwu and Adebayo 2005). In situation where there is improvement they were often rejected by the rural women. This is simply because no grassroots approach to find what they need, how they need, what they can afford and maintain was incorporated in the initial design of such improvement.

Appropriate post harvest technological intervention should start from participatory evaluation of farmers needs in any area (Maunde et al., 2005). There was no report on the analysis of post harvest income generating activities of women in Adamawa state, which forms the subject of this paper.

Materials and Methods

This study was carried out in 2004 and 2005 at Yola, latitude 12º 30' N and longitude 900 13, E of the three zones {Northern (12 º 30 N, 13' 90) ; Central(13 º 34, 15' 88) and Southern (11 º 27 N, 8' 23) of Adamawa state in Nigeria, Fig. 1. The state has twenty one local governments. The shaded areas on the map indicate the zonal head quarters. Each zonal head quarter comprises of seven local governments.

Random sampling technique was used to select the subjects for the study. Parameters considered are age, experience in the activities, group or individual participation. The subjects for the study were adults' women age range between 35 – 45 years. According to Anyanwu and Adebayo (2005) these are the active women group in the area. Rapid Rural Appraisal (RRA), questionnaires, and oral interview / discussions were used as instrument for data collection as described by Ifem (1990). This instruments covers percentage of women involvements, quantity processed, income generated and tools used for each of the major post harvest operations. RRA collected in the three zones informed the actual major post harvest activities in the area. Major here means where more than 20 % of such activities are done by women. 300 questionnaires were distributed and recollected after filling to the selected subject in the said areas.

At the time of collection of forms, discussions and oral interview was carried out. One staff from Adamawa State Agricultural Development Programme (AD ADP) in each zone assisted with the exercise, which lasted for one month for each year. Data obtained were subjected to analysis of variance as described by Gomez and Gomez (1984) and Akindele (1996).

Results and Discussion

Summary of data obtained from the women responses for the post harvest income generating activities in the study area are presented in Table 1. Average Summary of these activities is presented in Table 2. Analysis of variance for the activities is presented in Table 3. Each zonal head quarter as shown in Figure 1 is comprises seven local governments. The results of RRA, SQR and OD out of 300 analytical tools are 240, 230 and 235 respectively. The remaining balances out of the total 300 are discarded due to non conformity to the aim of the study. For instance tailoring is income generating but not post harvest activities. These responses arrived at eight post harvest activities carried out in the area. These activities are : Traditional rice per boiling, fish smoking , groundnut oil extraction , milk processing , cassava processing , cowpea , maize and rice threshing. These are considered as the major because more than 20 % of the women are involved. For instant in all the studies there is only one woman found into poultry business. The woman said the large initial minimum of ₦ 50, 000.00 to set small scale poultry farm prevent women into the business. Poultry business in the area is regarded as minor with less than 10 % of women involvement. Ifem (1990) reported the need for RRA to evaluate the status of farmers before going into any further assistance intended for easy starting. In related development, Kaul (1996) reported that " *it is very necessary to get some rapid surveys done, in the area or activity where technological intervention is intended"* Results obtained serve as a guide to post harvest activities and other related parameter that may be use in improving women income generating activities in the area .

Procedures used to carry out the tasks depend on the type of post harvest as : Food processing e.g rice per boiling , ground nut oil extraction , fish preservation , milk processing and cassava processing into (starch, gari and alebo flour). And post harvest threshing of maize, rice and cowpea. Even though they are all post harvest, in most cases the post harvest activities come before the food is further processed. That is why the time when the activities are carried out differs. For instant post harvest threshing may be year round but the peak period was found from Nov. to April. Similarly the milk processing is abundant during raining season, and becomes scarce during the dry season. For all the activities income generation depends on quantity processed. All the tools used by the subjects are manually operated tools.

Excluding initial capital expenses for the food processing, income generated and percentage of involvement range from (₦ 300.00 - ₦ 630.00) and (30 % - 90 %) for fish smoking and groundnut oil extraction respectively. Combining income generated and percentage of women involvement informed the ranking. The ranking starts from 1 (highest) to 8 (lowest), as shown in Table 2. Women uses the little amount generated from post harvest activities to assist in feeding their families. Anyanwu and Adebayo (2005) reported that 53 % of the women were engaged in farming alone while that 47 % combined farming with other post harvest income generating activities to assist

feed their families. They further reported a lot has to be done to transfer improved technology and other extension services to the women farmers in Adamawa state.

However, Atala and Maigida (1996) reported that personal income determines the working capital and purchasing power of women and their affordability of improved technology. This is because majority of rural women are not income earners. So , therefore, have very low financial status which prevent them from purchasing some of the improved farm tools and equipment. This therefore calls for the need of a feasibility study before venturing into any improved technology to know the financial status, needs and ability of intended users of any intended new technology (Maunde, 2005).

The statistical analysis of variance shows that the F- cal is greater than the F- tab, the difference was seen significant at $p < 0.05$ between the considered post harvest operations and $p < 0.01$ between the zones as presented in Table 3.

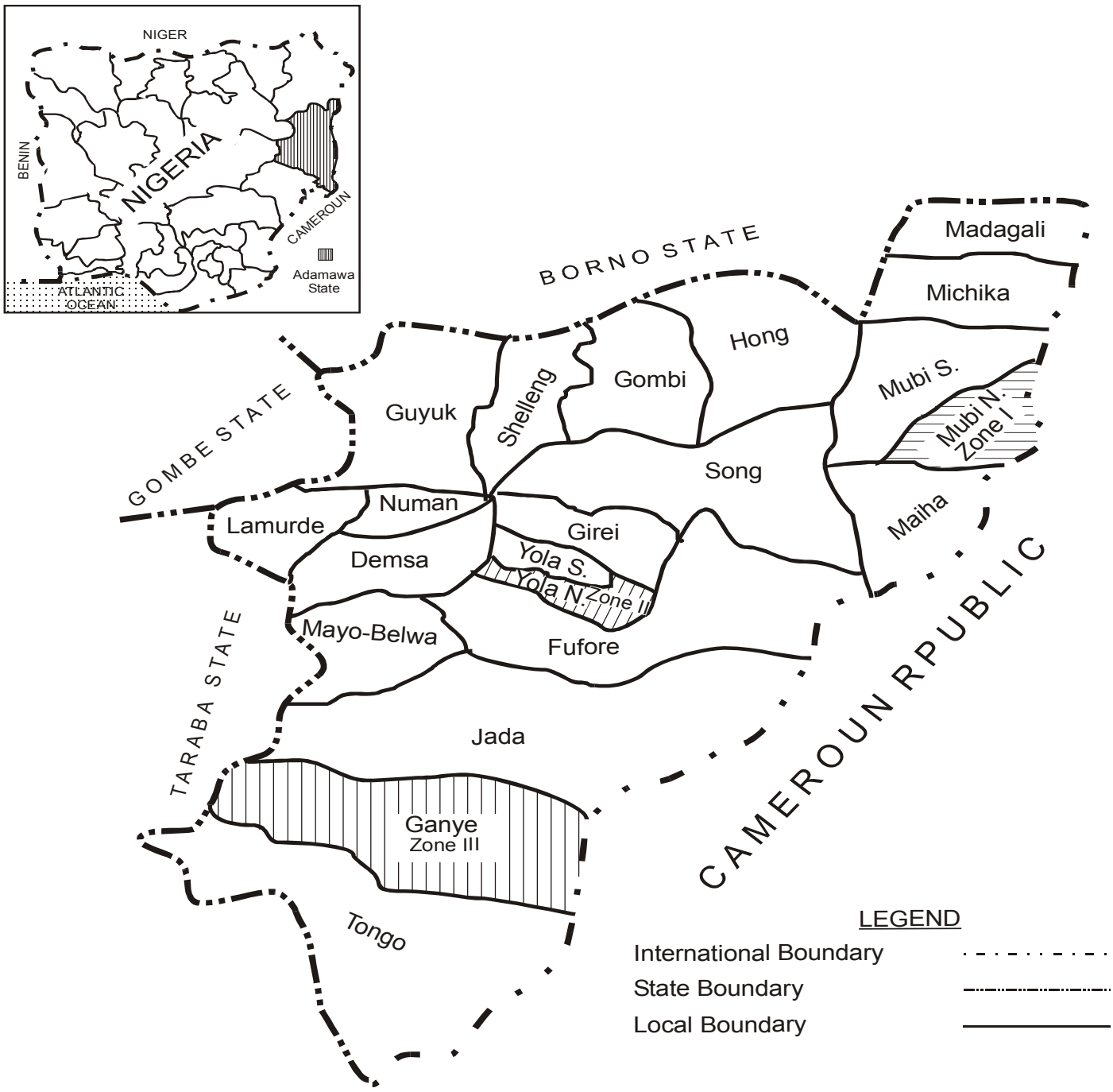


Figure 1: Map of Adamawa State showing the three shaded Zonal Headquarters in the Study Area.

Table 1: Summary Analysis of Data from the Respondents

Zonal Head Quarters	Responses out of 300 Analytical Tools		
	RRA+	SQR*	OD**
Northern Zone I	70	35	65
Central Zone II	95	150	100
Southern Zone III	75	45	70
Total	240	230	

\+ Rapid Rural Appraisal
* Structural Questionnaire
** Oral Discussion.

Table 2: Average Post harvest Income Generating Operations in Adamawa State.

	* Evaluation Parameters					
Post Harvest Activities	Tools Used	Procedure Involved	Yearly Duration	Income Generation /Quantity processed Minus expenses (₦)	Frequency Involvement (%)	Ranking
Traditional Rice per boiling	Pot, mat; fire wood	Steaming, enclose and sun drying	Dec. – April (5 months)	50 kg rice will give 350.00	40	6th
Fish smoking	Wire barb, fire wood	Gently drying of fish over open fire	Sep.- Feb. (6 months)	30 medium size bunny fish will give 300.00	30	8th
Groundnut oil Extraction	Bucket, wood stirrer, fire wood and plank	Traditional Kneading of paste with wood stirrer	Year round	16.5 kg paste will gives 630.00	90	1st
Fresh milk processing	Pots, fire wood, churner	Boiling and churning of cheese	Year round	3 liters of milk will give 350.00	45	5th
Cassava processing	Knives, grader, bowls, sacks and mats	Pelling , grading, fermenting or frying to produce gari of stach or flour	Jan,- May (5 months)	20 tubers of cassava gives 400.00	40	7th
Cowpea threshing	Sticks, mats, bowls, calabashes mortar and pestle.	Hitting with sticks and gently pounding mortar with pestle	Nov. – April (6 months)	250 kg of cowpea Gives 582.00	80	2nd
Maize threshing	Same as cowpea	Same as cowpea	Nov. – April (6 months)	250 kg of maize gives 420.00	60	3th
Rice threshing	Same as maize	Same as cowpea	Nov. – April (6 months)	250 kg of maize gives 420.00	50	4th

all values are means of five replicates

Table 3 : Analysis of Variance for Post Harvest Activities in the area

Source of Variation	d.f	s.s	m.s	Fcal	Ftab
Provenance (Post harvest activities)	8	57	3.77	2.2*	1.92
Block (Zones)	3	45	15.15	9.6**	2.4
Error	41	74	1.8		
Total	52				

* Significant at P <0.05
** Significant at P < 0.01.

Conclusion and Recommendations

Eight prominent post harvest income generating operations were identified in Adamawa state. Tools used were all manually operated, and incomes generated were analyzed on weekly bases which range from ₦ 300.00 to ₦ 630.00. Percentage of women participation also ranges from 30 % (fish smoking) to groundnut oil extraction (90 %). The statistical analysis shows that the F- cal is greater than the F- tab, the difference was seen significant at $p < 0.05$ between the considered post harvest operations and $p < 0.01$ between the zones. Outcome of this survey will assist in choosing area of interest where technological intervention can come. Recommendation is therefore made for intervention in groundnut oil extraction and cowpea threshing using participatory design approach incorporating the user's needs, affordability, financial considerations and interest.

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FRACTURE RESISTANCE OF PALM KERNEL SEED TO COMPARESSIVE LOADING

BY

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ABSTRACT

Quasi-static compression tests were carried out on treated single palm kernel seeds to study the effects of temperature, moisture content and loading position on the rupture force, deformation and toughness of the kernels. The levels of moisture content and temperature considered were 5%, 7% and 10% w.b and 70^0C, 90^0C and 110^0C each at the horizontal and vertical loading position. Twenty palm kernel seeds were tested at each moisture and temperature level in both horizontal and vertical loading positions making a total of 480 kernels that were individually measured and tested. The average compressive force required to rupture a palm kernel seed under compressive loading decreased as the moisture content of the seed increased from 7% to 10% (wb), while the corresponding deformation increased from 1.18mm to 1.43mm but decreases from 1.18mm to 1.03mm as the temperature increases. Maximum toughness occurred at 7% moisture content and 70^0C temperature respectively, indicating the optimum moisture content and temperature for absorbing compressive energy. The value of Toughness is an important indicator of the ability of the palm kernel to resist mechanical damage during loading. The loading position has significant effect on the rupture force and should be considered when palm kernel seeds are being loaded.

KEYWORDS: Resistance, compression loading, rupture, palm kernel, toughness

INTRODUCTION

During processes like planting, harvesting storage, processing and transportation, agricultural products are often subjected to mechanical forces. These forces most of the time results to deformation of the crops. Deformation may either sometimes be enough to result to cutting, pressing, crushing, tearing or just very small especially during harvesting and threshing to avoid severer damage. Thus mechanical strength like compression tensile strength and shear strength of agricultural products plays an important role in harvesting, storage and processing of the crop.

Sitkei (1986) reported that most agricultural products are visco-elastic in nature, they respond differently to tensile or compressive forces and also behave differently when they are subjected to vibration. Therefore, a fundamental knowledge of agricultural product behaviour under mechanical forces is essential in determining the power requirement for different operations like cutting, crushing, pressing, milling etc.

It is generally agreed that the oil palm (Elaeis guineensis) originated in the tropical main forest of West Africa. The main belt runs through the southern latitudes of Cameroon, Cote d' Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, Togo and into the equatorial region of Angola and the Congo Food and Agricultural Organization (FAO), 1993). Because of its economic importance as an high-yielding source of edible and technical oils, the oil palm is now grown as a plantation crop in countries with high rainfall in tropical climates within 10^0 of the equator. The palm tree bears its fruits in bunches (see Fig. I) which vary in weight from 10 to 40kg. The individual fruit ranging from 6 to 70g, is made up of an outer skin (the exocarp), a pulp (mesocarp) containing the palm oil in a fibrous matrix, a central nut consisting of a shell (endocarp) and the kernel, which itself contains an oil, quite different to palm oil, resembling coconut oil (FAO, 1993), see Fig. 2.

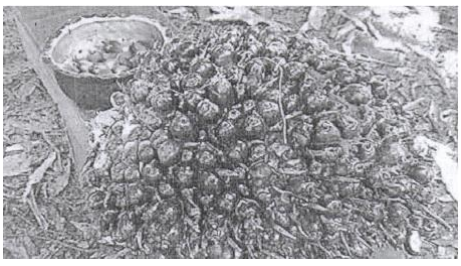


Fig. 1 Fresh palm fruits in Bunch

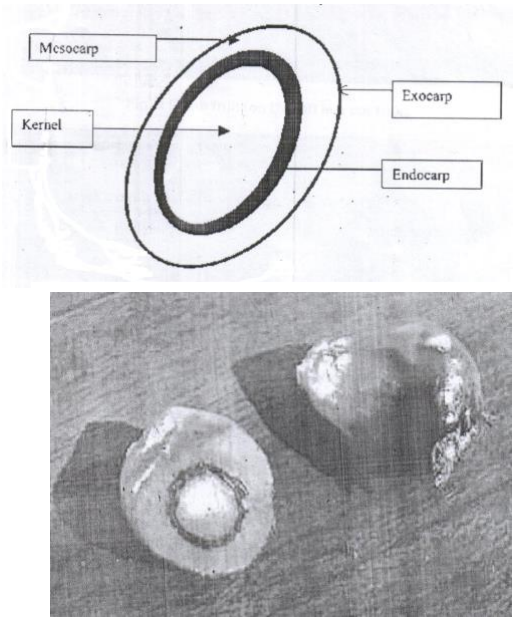


Fig. 2 Cross –section of an individual Palm fruit Showing the main parts.

Extraction of oil from palm kernels is generally different from palm oil extraction, and is often carried out in mills. The stages in this process comprise size reduction (i.e. grinding the kernels into small particles), heating (cooking), and expression/extracting the oil using an oil seed expeller or petroleum derived solvent (FAO, 1993).

Several researchers have investigated the physical and mechanical properties of some crops considered relevant to the design of suitable machines and equipment for their production and processing. Adebayo (2004) carried out a compression test on Dura varieties of the palm nut in order to determine the force required for cracking the palm nuts. Dev et. al (1982) investigated the size and shape of sorghum as essential properties for the analysis of the behaviours of grains during handling, storage and processing, Paulsen (1978) studied the average compressive strength, deformation and toughness of soybean seed coat rupture under quasi-static loading. Ezeaku et al. (1998) studied the measurement of the resistance of Bambara groundnut seed to compressive loading, while Makanjuola (1972) did a study of some of the physical properties of melon seeds.

Such similar work appears not to have been done on palm kernel seeds. A similar information on some of its mechanical properties would be essential in the design of equipment and system for the loading and processing of palm kernel into palm kernel oil.

Sequel to the above, a study of the resistance of palm kernel seeds to compressive loading was undertaken.

The objectives of this study are:

i) To determine the average compressive force, deformation and toughness at palm kernel seed rupture under compressive loading.
ii) To determine the effect of loading position, moisture content and temperature on the compressive force, deformation and toughness at palm kernel seed rupture.

2.0 MATERIALS AND METHODS

Samples of Dura variety of palm kernel at moisture content of 4.7% w.b was obtained from an open market at Okuku in Osun State, Nigeria. The kernel was manually cleaned to remove dirt and other foreign materials in compliance with Nigeria Industrial Standard. Moisture contents were determined by oven drying ground respective samples (100g) at 103^0C for 6 hours as recommended for oil crops by Young et. al. (1982). While the samples were conditioned to desired moisture levels 5%, 7% and 10% (w.b) by adding distilled water as calculated from equation (1) according to Hammond et. al (1997) as follows:

$$water \text{ to be added} = \left(\frac{100 - M_p}{100 - M_g} - 1 \right) x\ W_s \quad \ldots(1)$$

Where M_p = present moisture content
M_g = required moisture content (%)
W_s = weight of samples in grammes (g)

After adding water, each sample was sealed in separate polyethylene bag and kept at 5^0C in a refrigerator for a week to enable the moisture distribute uniformly throughout the samples. The seeds were weighted using an electronic weighing balance, while a vernier calliper was used in measuring the dimensions of the seed. The average minor diameter, intermediate diameter and major diameter of palm kernel seeds used for this investigation were 11.16mm, 13.4mm and 21.11mm respectively.

Heating of the samples to the desired temperatures of 70 C, 90 C and 110C was achieved by spreading the kernel seeds in a closed container in a

preset temperature controlled

gallenkamp or 440 oven at the

different temperatures for 30 minutes

in line with Olaniyan

All laboratory quasi-static compression tests were performed using the Instron Universal Testing Machine (UTM) equipped with a 50kN load beam available at the National Centre for Agricultural mechanization Ilorin, Nigeria (see figure 3). The loading rate adopted throughout the test was 2.5mm/min. as recommended by Olaniyan (2006) for oil-bearing seeds. Each palm kernel seed was loaded by hand between two circular seated nosepieces by chuck attachment pins. The force at bio-yield point and the corresponding deformation for each seed sample were read off from the force deformation curve. The effect of the palm kernel seed position was determined by loading the seed in either the horizontal or vertical loading position.

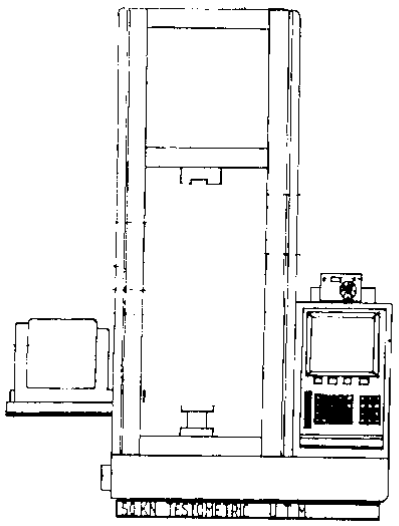


Fig.3. The Instron Universal Testing Machine (UTM)

Before loading, the palm kernel seeds were visually inspected. Those with visible cracks were not tested, thus results from the tests should be considered as the maximum force or toughness that a palm kernel seed sample could withstand and prior to rupture. The average room temperature throughout the duration of the test was 30^0C.

A 3 x 4 x 2 factorial experiment in a Randomized Complete Block Design (RCBD) (Cox, 1952 and Mentgomery,

1976) was used to evaluate the effects of moisture content, temperature and loading position on rupture force, deformation and toughness of palm kernel seed under compressive loading. The factors included in the design were moisture content, temperature and loading position, with moisture content being blocked. The range of each factor was selected based on findings from literature review and preliminary investigations. Twenty palm kernel seeds were tested at each moisture level and each temperature level in each loading position, making a total of 480 seeds that were individually measured and tested.

The volume of individual palm kernel was calculated from the principal dimensions earlier measured. Assuming ellipsoidal shaped material, the volume as given by Mohsenin (1978) and Sitkei (1986) is

$$V = \frac{\pi}{6}(abc) \quad \text{.....(2)}$$

Where a = major diameter (mm)
b = intermediate diameter (mm)
c = minor diameter (mm)
and v = volume of palm kernel seed (mm^3)

Toughness is regarded as the energy absorbed by palm kernel up to the rupture point per unit of the kernel volume. The energy absorbed during compression was indicated by the data from the UTM as energy at breakage (rupture).

Toughness was then calculated by using equation 3 according to Mohsenin (1978) as:

$$P = \frac{E}{V} \quad \text{.....3}$$

Where p = toughness (J/mm^3)
E = energy (J)
V = volume of kernel (mm^3)

The data recorded as means of twenty test samples in each test condition were subjected to analysis of variance

test and Duncan's New Multiple Range Test was used to compare the means.

3.0 RESULTS AND DISCUSSIONS

All palm kernel seeds tested typically exhibited a force – deformation curve as shown in Figures 4 and 5. The bio-yield point in the force – deformation curves indicates the seed rupture point and this point was determined by a visual decrease in force as deformation increased. The force-deformation curves obtained in this investigation are similar to those obtained by previous researchers on different agricultural products (Ezeaku et al., 1998, Paulsen 1978 and Anozodo 1980) and those reported in ASAE Standards American Society of Agricultural Engineers Standards (ASAES) 368.1 (1980). Tables 1 and 2 show summaries of the raw data obtained while the effects of temperature, moisture content and loading position on the average force, deformation and toughness are shown in Tables 3, 4 and 5. These effects are thus discussed hereunder:

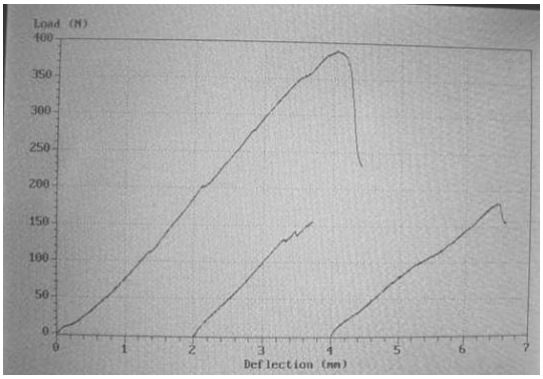


Fig. 4: A typical Load-Deformation curve of Palm Kernel under Horizontal Compressive Loading.

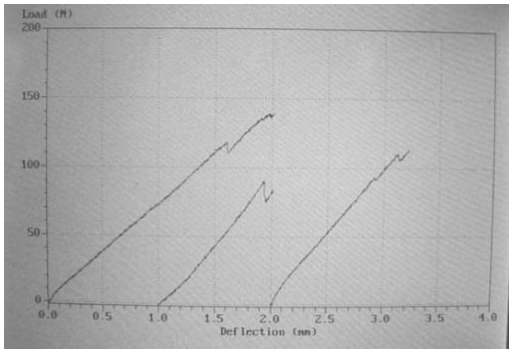


Fig. 5: A typical Load-Deformation curve of Palm Kernel under Vertical Compressive Loading.

3.1.1 Effect of Temperature

The effects of temperature on the average rupture force, deformation and toughness at palm kernel seed rupture are presented in Table 3. The table shows that average rupture force and deformation at seed rupture are significantly affected by the seed temperature at P (0.05) level, while the seed temperature does not significantly affect the toughness. However, the table also shows that as the temperature increases, the deformation and toughness decreases respectively. This may be attributed to the weakening of the cell walls of the kernel as a result of high temperature, thus yielding easily to pressure.

3.2 Effect of Moisture Content

The effect of moisture content on average rupture force, deformation and toughness is presented in Table 4. The table shows that the average rupture force, deformation and toughness are significantly affected by the moisture content of the palm kernel seed at P (0.05) level. The force required to initiate seed rupture increased when moisture content increased from 5% to 7% and later begins to decrease as the moisture content approaches 10%. This may be attributed to the fact that as the seed absorbs more moisture; it softens and tends to yield easily under pressure. Also, it may be indicated, within the range of moisture contents tested that palm kernel with lower moisture contents are generally more resistant to rupture, under compressive loading than those with higher moisture content.

3.3 Effect of Loading Position

The effect of loading position on average rupture force, deformation and toughness is presented in Table 5. The table shows that rupture force and toughness are significantly affected by the loading positions, while the deformation is not significantly affected. This suggests that when palm kernel seeds are compressed, they absorb more energy at the horizontal position than at the vertical position. Thus, consideration should be given to the manner in which palm kernel seeds are loaded with respect to compression surfaces since loading position has significant influence on the rupture force.

4.0 CONCLUSIONS

1. The average compressive force required to cause palm kernel seed to rupture decreases as

moisture content of the seed increased from 7% to 10% (w.b).

2. Loading position has significant influence on the rupture force. Palm kernel seeds loaded horizontally require higher rupture force than those loaded vertically.

3. Deformation of palm kernel seed generally decreases as temperature increased and increases as moisture content decreases, suggesting that palm kernel seeds at lower moisture content are harder and less susceptive to rupture than palm kernel at higher moisture contents.

4. Toughness is significantly different at all temperatures, suggesting that increase in temperature weakens the cell walls of the kernel, thus making it yield easily to pressure and consequently reducing the toughness of the kernel. However, the lower the moisture content of the kernel, the higher the toughness.

Table 1. Summary of Mechanical Properties of Palm Kernel at Seed Rupture for three Moisture Levels and two Loading Position

Moisture Content (%)	Loading position	Mechanical Properties		Toughness J/mm^3
		Rupture force (N)	Deformation at Rupture (mm)	
5	Horizontal	256.05 (38.46)	1.48 (0.38)	2.7938 x 10^{--4}
	Vertical	181.23 (30.21)	1.310 (0.35)	2.4290 x 10^{--4}
7	Horizontal	475.79 (78.12) SD	1.24) (0.32)	4.2409 x 10^{--4}
	Vertical	192.52 (31.64)	1.12 (0.30)	2.8034 x 10^{--4}
10	Horizontal	323.56 (58.44)	1.23 (0.32)	2.4678 x $10^{—4}$
	Vertical	208.60 (46.26)	1.63 (0.40)	1.8171 x 10^{-4}

SD Values in parenthesis are standard deviations

* Each value is the means of 20 test samples

Table 2. Summary of Mechanical Properties of Palm Kernel at Seed Rupture for three Temperature Levels and two Loading Position

Temperature ^{0}C	Loading position	Mechanical Properties		Toughness J/mm^3
		Rupture force (N)	Deformation at Rupture (mm)	
70	Horizontal	252.49	1.22	1.33 x 10^{--4}
	Vertical	159.57	1.13	1.12 x 10^{--4}
90	Horizontal	599.18	1.14	1.2 8 x 10^{--4}
	Vertical	217.53	1.02	1.06 x 10^{--4}
110	Horizontal	210.33	1.07	1.136 x $10^{—4}$
	Vertical	205.25	0.98	1.072 x 10^{-4}

* each value is the means of 20 test samples

Table 3 Effect of Temperature on Average Rupture Force, Deformation and Toughness of Palm Kernel Seed

Temperature ^0C	Rupture Force (N)	Deformation at Rupture (mm)	Toughness at Rupture X 10^{-4} J/mm^3
70	206.03(a)*	1.18(c)	1.23(b)
90	408.36(b)	1.08(c)	1.17(a)
110	207.79(a)	1.03(c)	1.10(c)

* In each column, means with the same letters are not significantly different at P (0.05) based on Duncan's New Multiple Range Test.

Table 4 Effect of Moisture Content on Average Rupture Force, Deformation and Toughness of Palm Kernel Seed

Moisture content (%)	Rupture Force (N)	Deformation and Rupture (mm)	Toughness X 10^{-4} J/mm^3
5	218.64(a)*	1.409	2.61(a)
7	33.4.16(b)	1.18(b)	3.52(b)
10	266.08(a)	1.43(a)	2.15(c)

* In each column, means with the same letters are not significantly different at P (0.05) based on Duncan's New Multiple Range Test.

Table 5 The Effect of Loading Position on the Average Rupture Force, Deformation and Toughness of Palm Kernel Seed

Loading Position	Rupture Force (N)	Deformation at Rupture (mm)	Toughness X 10^{-4} J/mm^3
Horizontal	352.90(a)*	1.23(a)	2.04(a)
Vertical	194.12(b)	1.20(a)	1.55(b)

* In each column, means with the same letters are not significantly different at P(0.05) based on Duncan's New Multiple Range Test.

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COMPARATIVE ANALYSES OF TRADITIONAL METHODS OF ROASTING SHELLED GROUNDNUT WITH THE DEVELOPED DRUM ROASTER

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ABSTRACT

A comparative analysis test was conducted to evaluate the performances of using three different traditional groundnut-roasting methods as against a developed Prototype Drum groundnut roaster. The test was conducted using SAMNUT-10 (RMP-12 groundnut seed variety.. a groundnut seed weighing 0.46kg at 6% db moisture content was used and replicated. The prototype roasting drum was undertaken at a speed of 30rpm.The performance of the prototype showed the roasting efficiency (Er) to be within the range of 98.9% with 0.5 – 2.2% as percentages of seed damaged (loss) and throughput capacity of 33 – 36 kg/h. The minimum time for roasting was in the range of 2.5 – 3.0 minutes. Traditional methods of roasting shows efficiencies of 91.3%, 93.5% and 95.7% respectively with percentages damage of 8.7%, 6.5% and 4.3% using Cast pot, Aluminum Pot and Light metal pot, respectively with minimum time of roasting of 7.3, 6.2 and 5 minutes respectively.

KEY WORDS

Comparative, Drum Roaster, Traditional Method, Performance evaluation, Manual

Introduction

The wide range usage of groundnut product has led to increase in its demand. Among the agricultural products that are of great value to both man and animals is the groundnut. It serves as raw material for industry. Groundnut oil is used as vegetable oil for human consumption, while groundnut seed cake is being used as part of ingredients in animal and poultry feeds (Burkul, 1985; Pattee, *etal*, 1995, Asiedu, 1989). Among the problems in processing these agricultural materials is that of roasting the seeds.

Pattee *etal*, (1995); Maria*, etal*, (1996); Park, *eta*l, (1995) and Olapade and Akinoso,(2004), defined roasting as the process of generating characteristic aroma, flavour and colour required by consumers for acceptance of such roasted food. Roasting of food bring about thermal changes in the chemical components at relatively high temperature. This is accomplished by either using a hot air or small metal surface to heat up the material to the required temperature at which the material changes to required colour and according to Gell and Porto (1996) the roasted material must be abruptly cooled using cool air to avoid food destruction.

In Nigeria mechanical roasting machines such as Cashew roaster, Cowpea, Cake and Peanut roaster are available but the high cost and inaccessibility to most people makes traditional roasting the common practice. Traditional roasting is done using different pots such as clay pots, aluminum pot, etc on an open fire until they are brown (Ihekonye and Ngoddy, 1985). This method is ineffective, time consuming and laborious and subject people to back pain and expose them to smokes and heat from the fire. Oguntunde (1987) suggested the use of infrared heating in roasting operations to improve on the traditional techniques. This involves designing and construction of a machine that will handle this operation more effectively than the traditional methods. The machine after construction will enhance groundnut oil/ cake production, which will serve as raw material for relevant cottage industries in Nigeria. The machine is also designed to eliminate the drudgery associated with the traditional method of roasting groundnut. It is base on this principle or concept that a groundnut drum roaster was designed and its performance is then compared to that of three different methods used traditionally to roast groundnut seeds. The objective of this comparisons is to investigate some of the parameters such as roasting time, throughput capacity and the efficiency of roasting with a view of coming up with parameters that will be used in the development of improved and efficient roasting machine.

Materials and Methods

The various construction materials that make up the component of the manually operated, low cost, groundnut seed drum roaster is as shown in figs 1 and 2.

Selection of materials used in construction of the Drum Roaster placed emphasis on some criteria like cost, durability,

strength, availability, size and weight of such materials.

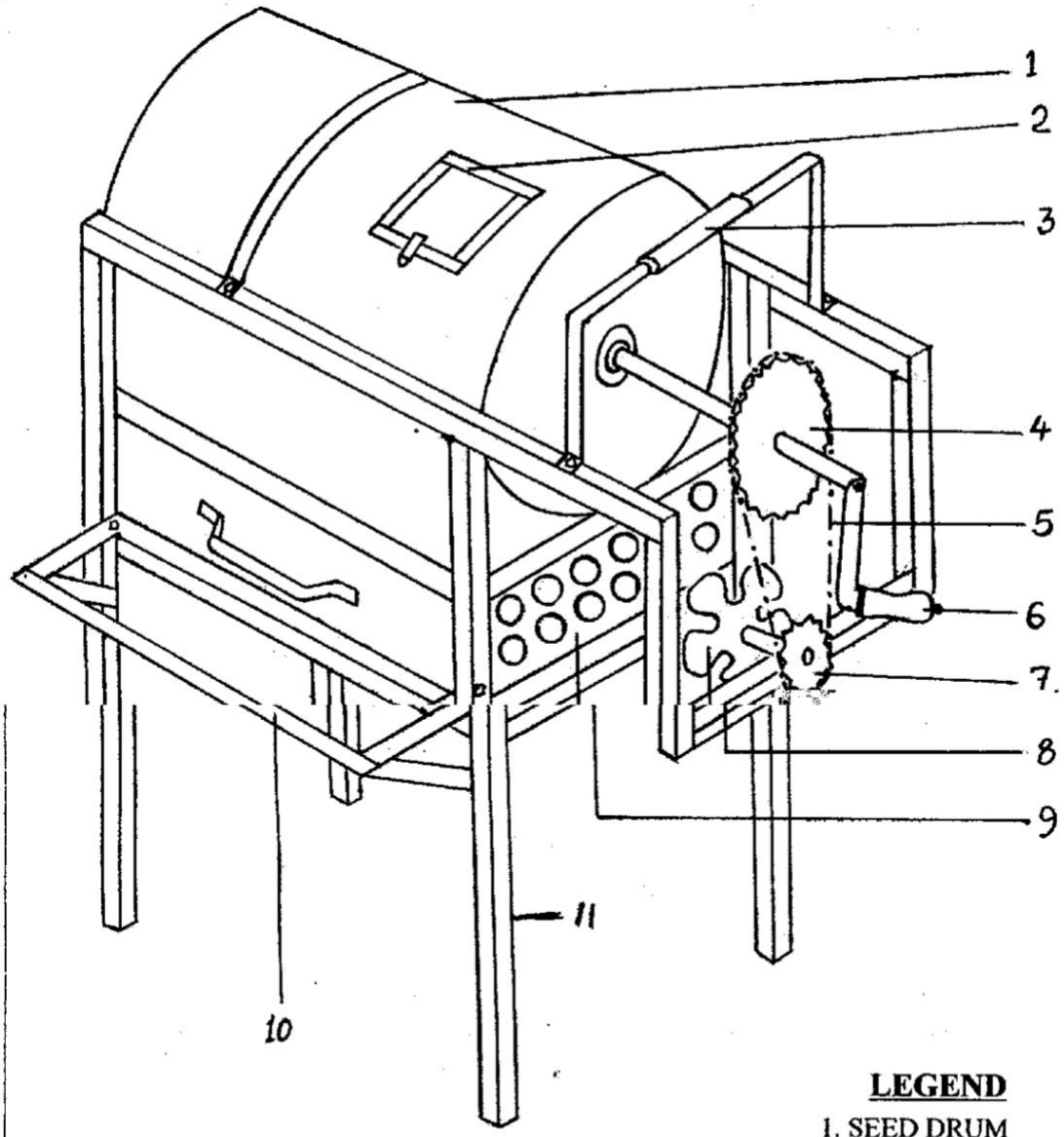
The Roaster machine comprises of five major parts the frame, the stirring paddle, the roasting chambers, the heating source and the fan.

The Frame is fabricated from (30x30mm) angle iron and is welded to a shape as shown in fig 1. It provides support to the entire components of the roaster. The stirring shaft comprises of the driving shaft and stirring paddles. The driving shaft is made up of a mild steel rod and the stirring paddles welded directly on the driving shaft as shown in figs 1 and 2. As the operator cranks the handle, the stirring shaft and its accessory rotate thereby setting up a centrifugal force in the roasting chamber. This turns the seeds in the chamber.

The Roasting chamber comprises of the drum and some outlets. The roasting drum has two outlets (i.e. the inlet and the seed outlets). The heating chamber is positioned directly under the roasting drum as shown in fig 2. It is the source of heat to the roaster. It is fabricated from galvanized sheet. It has a blower positioned by the side to supply air that allows the charcoal to burn continuously. The blower gives uniform amount of heat to the entire drum.

The optimum speed of operation is estimated to be 30 – 40 rpm.

The materials used for the performance evaluation was: Cast pot, Aluminum pot, light metal pot, SAMNUT-10RMP-12 groundnut variety, stopwatch, weighing balance, wood charcoal, kerosene, match for lighting charcoal, and the prototype roaster. The testing was conducted with the groundnut variety at moisture content of 6% db. The moisture content required at shelling is almost the moisture content require for roasting 4%-6% db (Vanke, 2003).



LEGEND

1. SEED DRUM
2. DRUM OPENER
3. OFFLOADING HANDLE
4. SPROCKET
5. CHAIN
6. OPERATING HANDLE.
7. SPROCKET
8. AXIAL FAN
9. CHARCOAL TRAY
10. HEAT CONTROL BASE
11. FRAME

FIG.1: ASSEMBLY DRAWING OF THE MODIFIED DRUM GROUNDNUT SEED ROASTER

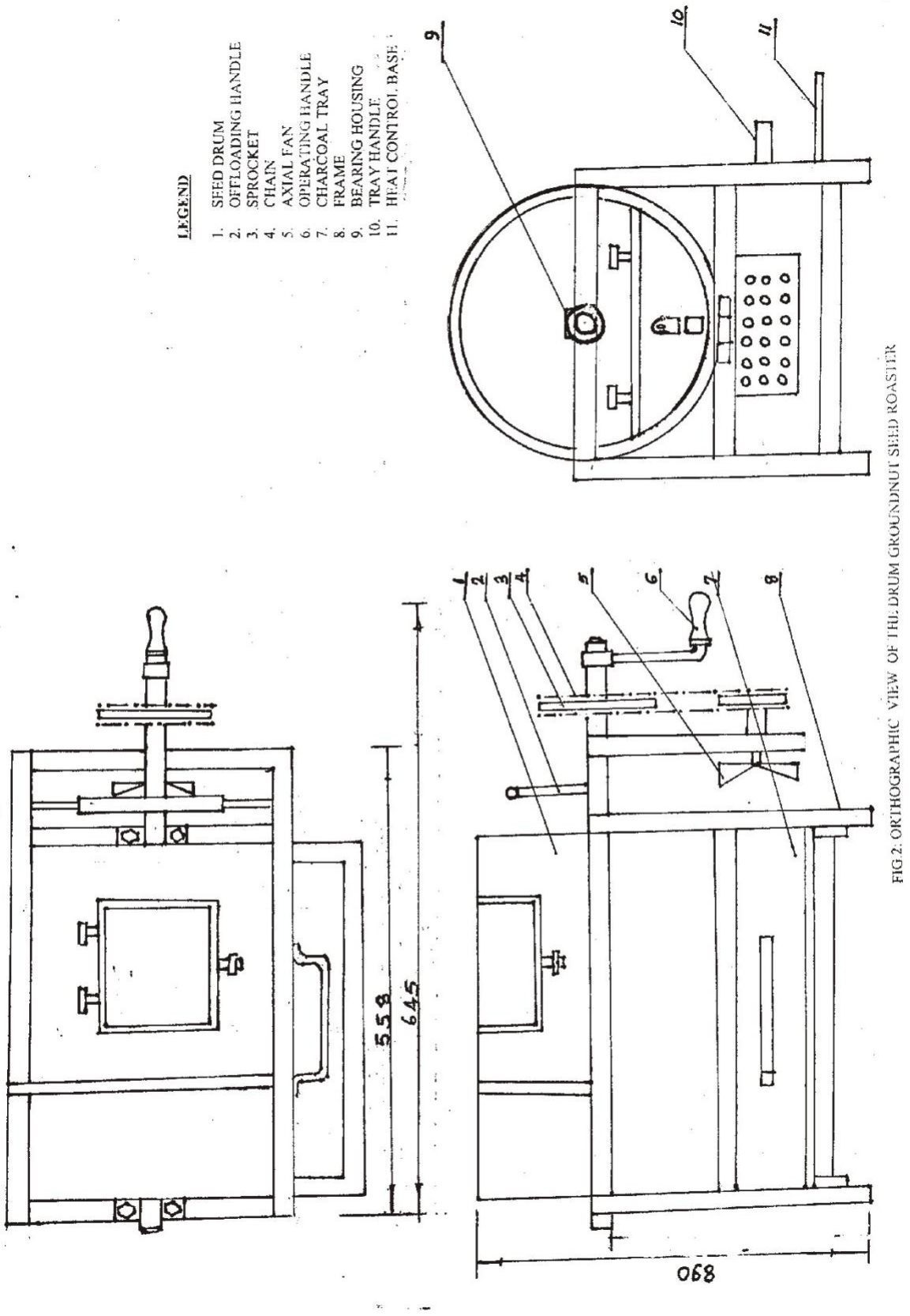


FIG 2: ORTHOGRAPHIC VIEW OF THE DRUM GROUNDNUT SEED ROASTER

Performance Evaluation.

The parameters used in evaluating the groundnut seed drum roaster are the roasting efficiency (E_r)% and Man-Hour per kilogramme of seeds roasting, (M_h).

The available quantity of groundnut sample weighing 5.52kg was used for the test. The sample was divided in to twelve (12) equal parts each weighing 0.46kg. Each of the samples was used to carry out the test using the three different roasting methods. The time taken to roast the groundnut was recorded using stopwatch. The procedure was replicated three times and weight loss was determined using ASAE (1998) standards and procedures for determining data from crop processing machines. The prototype roaster was also evaluated using the same quantity of 0.46kg in the drum. The roaster was operated with the handle that constantly stir the seeds in the drum. The time taken to roast the seeds was recorded and replicated three times also and the values are shown in Tables 1 and 2.

Mathematical evaluation expression for roasting efficiency were used as stated in equation (1) and (2):

Roasting efficiency $(E_r)\% = (W_r / W_t) \times 100$ ……(1)

The percentage of seed losses $(E_L) = (W_d / W_t) \times 100$ ……(2)

Where: W_d= weight of roasted seed damaged (over roasted)

W_r= weight of roasted seed not damaged

W_t = total weight of seed roasted ($W_r + W_d$)

The man-hour –kilogram (M_h)

Man – Hour = T / Wt…… …….(3)

Where:

T = Total roasting time (h)

Wt = total weight of seed roasted

Table 1 shows the comparative analyses of results of the output of the different manual methods of roasting groundnut to that of the prototype roaster.

This comparative analysis has to do with efficient utility of time by the various methods. Hence, the throughput capacity (Q_t) and Man-hour per kilograms for roasting seeds by the three (3) different methods are analyzed and displayed in Table 1. Other performance parameters like roasting efficiency and percentage of seed damage are also presented in Table 2.

Result and Discussion

Table 1 shows the result of various investigations made during the study. The different methods of roasting groundnut seed were observed and compared with one another. A comparison in table 1 shows that the roasting using cast pot has roasting efficiency of 91.3% The roasting rate was observed to be on the higher side of about 7.3 minutes when compared to the other roasting methods, this explained why it has high Man – hour per kilograms (0.27hr/kg) with about 3.83kg/h as throughput capacity which happen to be the lowest. The Aluminum pot has roasting efficiency of 93.5%, roasting capacity of 4.60kg/hr with Man-hour of 0.22h/kg and roasting time of 6.2 minutes. However, the light metal pot has a better roasting performance with roasting capacity of 5.75kg/h and Man – hour of 0.16h/kg and efficiency of 95.7% with roasting of 4.5 minutes. The higher roasting performance of this light metal pot conforms with the prototype drum roaster evaluation carried out and the results showed that it has a throughput capacity of 33.66 Kg/h with a Man – hour of 0.03h/kg and efficiency of 97.8%and roasting time of 49.2 seconds (0.82 min). Hence the prototype has a better performance as against the other traditional methods of roasting groundnut seeds.

Table 1.Comparative analyses of groundnut traditional Roasting Methods with Prototype

Roasting methods	Observations	1	2	3	Mean values	Man-hour T/Wt (h/kg)	Throughput capacity (kg/h)	Efficiency (%)
Cast pot	Wt (kg)	0.46	0.46	0.46	0.46	0.27	3.83	91.3
	Wr (kg)	0.42	0.41	0.42	0.42			
	Ts (min)	8	7	7	7.33			
Aluminum pot	Wt (kg)	0.46	0.46	0.46	0.46	0.22	4.60	93.5
	Wr (kg)	0.43	0.43	0.42	0.43			
	Ts (min)	6.5	6	6	6.2			
Light metal pot	Wt (kg)	0.46	0.46	0.46	0.46	0.16	5.75	95.7
	Wr (kg)	0.45	0.45	0.43	0.44			
	Ts (min)	5.6	4	4	4.5			
Prototype	Wt (kg)	0.46	0.46	0.46	0.46	0.03	33.66	97.8
	Wr (kg)	0.45	0.45	0.44	0.45			
	Ts (min)	0.83	0.82	0.80	0.82			

Wt- weight of groundnut before roasting
Wr- weight of roasted groundnut (broken and unbroken)
Ts- time taken to roast the groundnut seeds

Table 2 shows the comprehensive performance of the groundnut seed roaster. The roaster efficiency appears to be generally high in the range of 97.8 to 98.9 % at five different level of roasting. With roasting capacity in the range of 33.66 to 34.74kg/h. Seed losses (E_L), was observed to be at a low level in the range of 0.5 to 2.2 %.

Table 2. Performance Evaluation Parameters of the Groundnut Seed Drum Roaster

No of test	Weight of G/nut seed Wt (kg)	Weight of Roasted seed Wr (kg)	Weight of seeds damaged Wd (kg)	Time T(min)	Roasting efficiency (Er)%	Loss (El)%	Throughput capacity Qt (kg/h)
1	0.46	0.44	0.01	0.82	97.8	2.2	33.66
2	1.39	1.34	0.03	2.5	97.8	2.2	33.36
3	2.78	2.74	0.04	4.9	98.6	1.4	34.04
4	5.50	5.42	0.06	9.5	98.9	1.1	34.02
5	11.00	10.85	0.14	19.0	98.7	0.5	34.74

Where

Wt – weight of groundnut seed before roasting

Wd – weight of seeds over roasted (damaged)
Wr – weight of roasted seeds (unbroken and broken) that are not damaged

One of the distinguishing features of the roaster is that instead of using firewood as the source of energy, wood Charcoal was used to supply heat to the roaster.

Conclusion and Recommendation

The groundnut seed roaster constructed was observed to roast groundnut seeds at faster rate than any other manual methods as shown in Table 1.during this investigation.

The roaster will encourage more production of the product and enhance increase in groundnut oil / cake production, which will serve as raw materials for relevant cottage industries in Nigeria.

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DETERMINATION OF NATURAL FREQUENCIES OF VIBRATION OF SOME TOMATO FRUIT CULTIVARS

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Abstract

In this study, the natural frequency of vibration of fresh tomato fruits which is of great interest in the study of loss prevention during transportation and handling had been determined for some popularly grown cultivars in Nigeria. The cultivars are *chico*, *roma* and *cherry*. The property was determined at two maturity stages, turning and fully ripe. The property was determined using compression test from which the modulus of elasticity of the fresh tomatoes was computed. The natural frequency was then determined using an established relationship. The results show that the average natural frequency of vibration for fresh tomato fruit at turning stage of maturity were 17.61, 14.91and 9.10 Hz for *chico, roma* and *cherry* varieties respectively and these were significantly different ($\alpha = 0.05$). At ripe maturity stage, the average values were, 14.66, 14.20 and 13.24 Hz for *chico, roma* and *cherry* respectively. It can be concluded from the results that the average values of the natural frequency differed significantly between the cultivars ($\alpha = 0.05$). The natural frequency of the cherry variety is significantly lower than those of *roma* and *chico*, while that of *roma* is significantly lower than *chico's* at turning stage of maturity. The practical importance of these data is in the area of selecting travelling speed for vehicles used in hauling this fresh fruit to minimize mechanical damage.

Key words: ***fresh tomato, natural frequency, handling, mechanical damage***

Introduction

Tomato (*Lycospersicon esculentum)* is a major vegetable fruit widely grown and utilized in Nigeria. During harvest, there is glut in the production areas, so in order to have good prices for the produce, traders and farmers send trucks of the produce to distant markets with attendant problem of mechanical damage resulting mainly from impact and vibration. One important property of this fresh produce, which directly influences such damage, is the natural frequency of vibration of the fruit itself.

Fresh fruits and vegetables contain high moisture content ranging from 75 to 95 % in some cases. They are therefore susceptible to mechanical damage especially during transportation and handling (Singh and Singh, 1992). Impact, friction and compression occur during harvest, handling and transportation resulting in mechanical injury (Berardinelli *et al*., 2005). The problem of damage during transportation can be studied from the context of vibration theory based upon which it is possible to reduce the damage. Several factors are responsible for fresh produce damage during transportation. The factors can be those due to bad roads, the dynamic characteristics of the vehicles, poor handling containers and the physical properties of the produce itself.

Several research works had been carried out on the physical and mechanical properties of fresh fruits and vegetables generally (O'Brien *et al*., 1965; Mohsenin 1978; Roudot *et al.,* 1991; Peters, 1996; Jan *et al*., 1997; Batu, 1998; Dewulf *et al.,* 1999; Nwanekezi and Ukagu, 1999; Idah *et al.,* 1999, Idah *et al*., 2006). One property that is very crucial to damage of fresh fruits during transport is the natural frequency of vibration of the fruit.

It has been observed that it is when the natural frequency of vibration of the fruit being transported coincides with the excitation frequency of the haulage vehicle resonance occurs leading to increase in acceleration that eventually culminates in produce damage (O'Brien *et al*., 1965, Ogut *et al.,* 1999). It is therefore noted that the damage can be reduced if this condition is avoided by letting the natural frequency of the containers of fruits to be away from the range of frequencies of excitation force while in transit (Ogut et al., 1999). But there is dearth of data on the natural frequency of the

varieties of tomato fruits grown in Nigeria. The knowledge of this property of the fruit can greatly assist in reducing losses that are currently being incurred during handling. This can be achieved by selecting appropriate travelling speed that will eliminate the conditions that will lead to resonance and subsequent damage of the fruits. Contrary to the general belief, the processors of these fresh fruits are just as much concerned about mechanical injury to the fruits they receive as the fresh fruits retailers (Altisent, 1991). It is therefore desirable to determine the natural frequency of vibration of the major varieties of tomato fruits grown in Nigeria with the view to curtailing the mechanical damage done to such produce especially those resulting from vibration and impact during transportation.

Materials and Methods

Fresh tomato fruits of three varieties at two maturity stages (turning and red) were harvested from some farms in *Gidan Kwanu* in Minna, Niger State of Nigeria. The samples were sorted, weighed and classified into four mass groups. The dimensions, major, minor and intermediate diameters were measured using the principal axes method described by Mohsenin, (1978). The volumes and densities were also determined using the water displacement method described by Mohsenin (1978). The oven drying method was used to determine the moisture content. For each of the varieties and from each maturity stage under each of the mass groups, five samples of the fruits were subjected to compression test using a Triaxial testing equipment which was adopted for the test following the procedure specified in ASAE standards (1998). The equipment is motor driven and has constant head travel. A speed (loading rate) of 2 mm/min was used for the test. Force-deformation curves were plotted from the compression tests. Using these curves and the other measured parameters, the modulus of elasticity was computed from the relationship;

$$E = \frac{0.388\left(1-\mu^2\right)F}{D^{3/2}}\left[K_u\left(\frac{1}{R_u}+\frac{1}{R_u^{'}}\right)^{\frac{1}{3}} + K_l\left(\frac{1}{R_l}+\frac{1}{R_l^{'}}\right)^{\frac{1}{3}}\right]^{\frac{3}{2}} \qquad [1] \quad (ASAE, 1998)$$

where, E = modulus of elasticity (Pa), D = deformation (m), F = force (N), μ = Poisson's ratio, R_u R'_u = minimum and maximum radii of curvature respectively at the point of contact for the upper convex surface (m), R_l, R'_l = minimum and maximum radii of curvature respectively at the point of contact for the lower convex surface (m).

K_u, K_l are determined from Table (ASAE, 1998).

The natural frequency of vibration F_n of the fruits were determined by

$$F_n = \frac{1}{4\lambda}\sqrt{\frac{Eg}{\rho}} \qquad [2] \quad (Ogut\ et\ al., 1999)$$

where, F_n = natural frequency (Hz), E = modulus of elasticity (Pa), ρ = density of fruit (kg/m^3), λ = depth of column of fruit (m), g = acceleration due to gravity (m/s^2).

The data obtained were subjected to statistical analysis (ANOVA) and Ducan Multiple Range Test (DMRT) to ascertain the effects of variety , maturity and size on the values of the natural frequency.

Results and Discussion

Figures 1 and 2 show some samples of the force-deformation curves obtained from the compression tests. The curves follow the usual pattern or shapes (sigmoid) of curves obtained for visco -elastic substances such as biomaterials (Mohsenin, 1978).

The average values of the natural frequency of vibration obtained for the tomato fruits of various sizes for the three varieties at turning stage of maturity are shown in Table 1, while that of fruits at fully ripe maturity stage is shown in Table 2. The results show that the average natural frequencies of the fruits at turning stage of maturity and various sizes range from12.40 to 17.22; 14.08 to 19.40 and 7.25 to 10.56 Hz for *chico, roma* and *cherry* respectively. At fully ripe stage these figures are 12.75 to 16.85; 12.93 to 16.77 and 11.09 to 15.53 Hz for *chico, roma* and *cherry* varieties respectively. The values obtained compared favorably with the results obtained by O'Brien *et al*., (1965), though for different varieties. The overall means for the natural frequency of the varieties studied irrespective of stages of maturity and sizes are, 15.92, 14.76 and 11.17 Hz for *chico, roma* and *cherry* respectively.

The data obtained were subjected to statistical analysis to ascertain the effects of variety and size on the values of the natural frequencies. The results of the ANOVA for the data obtained are shown in Tables 3 and 4.

The results show that there were no significant differences between the mean natural frequencies of the different cultivars of the fresh tomato fruits assessed at fully ripe stage of maturity. However, at turning stage, the mean natural frequencies differed significantly between the varieties (Table 3). It is worthy to note that it is at the turning stage that the fresh produce meant for distant markets are harvested. These results are therefore important and can serve as a guide when selecting produce to be distributed to long distance markets. In other words, the *chico* and *roma* varieties which are naturally stronger than the cherry variety should normally be selected for long distance markets since they can withstand more stresses resulting from vibration and hence less susceptible to mechanical injury.

The Duncan Multiple Range Test (DMRT) carried out on these data revealed that the mean natural frequency of *cherry* variety is significantly lower in comparison to both *roma* and *chico.* That of *roma* is also significantly lower than *chico* at turning stage of maturity (Table 5). The means do not differ significantly between the different masses of the fruits as far as the results are concerned. In other words, the sizes of the fruits do not influence the value of the natural frequencies determined. This result differs from another finding because it has been revealed that the natural frequencies of apples decreased with increase in apple size (Renfu and Abbott, 1996). Apples and tomatoes differed greatly in their internal structures, hence one should expect such difference.

Hitherto, there are no data on the natural frequency of the fresh tomato cultivars popularly grown in Nigeria. The absence of such vital information/data could be part of the factors responsible for the huge mechanical damage and losses being experienced in this product in the distribution and marketing system. Hence, the values of the natural frequencies obtained for the varieties of tomato commonly grown in Nigeria could form a data bank. This can be explored by handlers, designers of packaging containers, transporters of fresh tomatoes and those involved in marketing of these products in the quest to reduce mechanical damage and ensure deliverance of high quality products.

The data obtained and the results of the analyses can also be used to select the varieties of fresh tomatoes that are more suitable for long distance distribution with minimal losses. It can be seen from the results that the *chico* variety is likely to be more resilient in this case than the other two. This result correlates with earlier studies on other engineering properties of these tomato varieties (Idah *et al*., 2006).

Conclusion

It can be concluded from the study that the average values of the natural frequency differed significantly between the cultivars. The natural frequency of the *cherry* variety is significantly lower than those of *roma* and *chico*, while that of *roma* is significantly lower than *chico*'s at turning stage of maturity, which is the stage the produce meant for distance markets are usually harvested. The data and the results of the analyses can be used to reduce losses resulting from mechanical damage during transport by selecting appropriate speed of the haulage vehicle at which the excitation frequency will be different and far from that of the fresh fruits being transported to avoid resonance condition.

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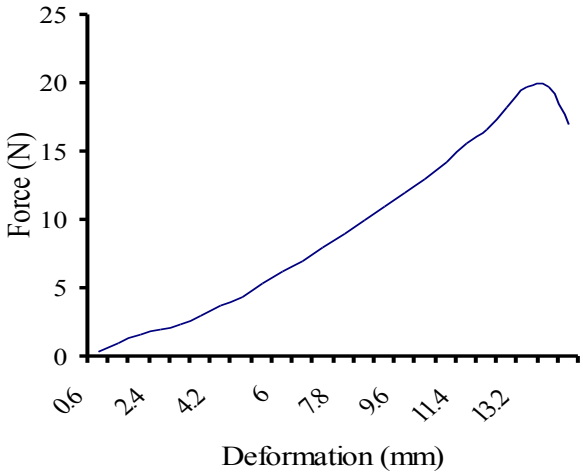


Fig. 1 Force- deformation curve of a fresh turning sample of tomato under compression

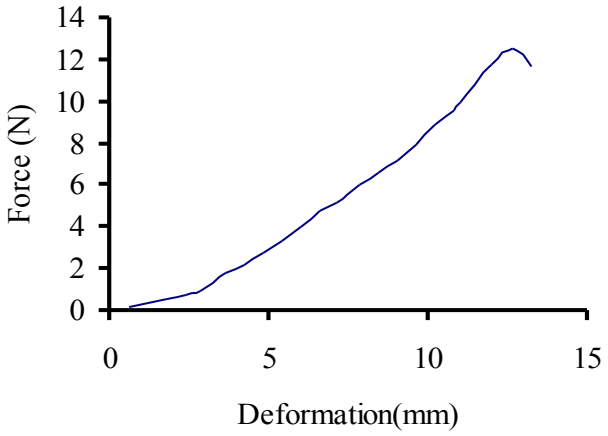


Fig.2 Force-deformation curve of a fully ripe tomato sample

Table 1: The Mean Natural Frequency of fresh Tomatoes at turning Stage of Maturity and different fruit sizes

Variety	Natural frequency (Hz)				Overall mean (Hz)
	Mass 1	Mass 2	Mass 3	Mass 4	
chico	19.30	19.40	17.67	14.08	17.61
roma	15.11	14.92	12.40	17.22	14.91
cherry	10.56	9.92	7.25	8.65	9.10

Table 2 Mean Natural Frequency of fresh Tomatoes at fully ripe Stage of Maturity and different fruit sizes

Variety	Natural frequency (Hz)				Overall mean (Hz)
	Mass1	Mass 2	Mass 3	Mass 4	
chico	15.67	13.38	16.85	12.75	14.66
roma	16.77	12.93	13.50	13.58	14.20
cherry	11.93	15.53	14.43	11.09	13.24

Table 3: Results of the statistical analysis (ANOVA) on the data obtained for fruits at turning stage of maturity

Source of variation	Sum of Squares	Degree of freedom	Mean Square	F-ratio
Varieties	525.33	2	262.67	14.77**
Size	75.66	3	25.22	1.42
Interaction	152.57	6	25.43	1.43
Error	853.80	48	17.79	
Total	1607.36	59		

** Significant at 5% level of confidence.

Table 4: Results of the statistical analysis (ANOVA) on the data obtained for fruits at fully ripe stage of maturity

Source of variation	Sum of squares	Degree of freedom	Mean Square	F-ratio
Varieties	30.64	2	15.32	1.07
Size	59.80	3	19.93	1.39
Interaction	85.66	6	14.28	1.00
Error	688.76	48	14.35	
Total	864.86	59		

Table 5 Results of DMRT carried out on the mean Natural frequencies of the different tomato cultivars

Variety	Mean Natural frequency(Hz)
Roma	14.91 a
Cherry	9.10 b
chico	17.61c

NB figures with same letters along the column are not significantly different.

DESIGN AND CONSTRUCTION OF AN ELECTRIC INCUBATOR FOR HATCHING CHICKEN EGGS

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Abstract

This paper presents the development and performance of an incubator which is considered suitable for small scale poultry farming. The incubator box was made using plywood and planks, which are locally available raw materials. Two electric bulbs of 60W each were used to generate the required heat and temperature control was achieved using a thermostat. A dc motor was employed to automatically turn the egg trays whereas and electric fan was used to ensure even circulation of heat within the cabinet. The unit was tested with 90 eggs only over a period of 21 days during which a total of 68 eggs were hatched.

Keywords*:* Incubator, temperature control, egg Hatching.

1.0 Introduction

Incubation refers to the management of fertilized eggs to ensure satisfactory development of the embryo into a normal chick (Oluyemi and Robert, 1979). It may be either natural or artificial. In natural incubation, the bird provides the required conditions for the relatively few eggs she lays by sitting on the eggs intermittently until they hatch in an open space. An artificial incubator is a chamber in which temperature, humidity and ventilation are controlled for the purpose of hatching a relatively large number of eggs than a single hen can handle at a time (Ensiminger, 1974).

Artificial incubation dates back to thousands of years traced to the Chinese who initially utilized the heat of roting manure for hatching eggs and to the Egyptians who built mud bricks incubators with central corridor having a series of ovens on either side (Ensminger, 1974).

The natural incubation produces chicks which are in small proportion compared to the number of chicks required for egg production world wide. This shortage in chicks produced by natural incubation led to the conception and development of artificial incubator. In recent years, there had been calls by Nigerian government to step up food production, particularly protein for the well being of the citizens which led to the launching of various programmes such as National Accelerated Food Production Programme (NAFPP), Operation Feed the Nation (OFN) and Green Revolution (GR) (Jibrin, 2005). The abundance of chicken at affordable price means more protein to the Nation and this could be met by the use of efficient artificial incubators that are affordable to the rural and semi urban dwellers. This paper therefore presents the design and construction of an affordable small scale electric incubator.

2.0 Material and Methods

The most important units are power supply, control, alarm/light, heat and ventilation unit. These were individually designed, implemented and coupled together to form the complete system.

2.1 Power Supply Unit

The main power supply unit shown in figure 1, consists of a transformer with full wave rectifier and efficient filtering devices. The main AC supply of 240V is stepped down to 12V, with 500mA transformer, rectified by the bridge rectifier and smoothened by the filtering capacitor (c_1). The rectified voltage is then regulated to 12v using the LM7812 IC regulator. C_2 and C_3 further filters out the ripples whereas D_3 and D_4 are required to lift the common terminal of the IC regulator to a voltage of 1.4v above ground.

A 12v battery which charges through the stabilization unit is used to supply the essential loads in the case of power failure.

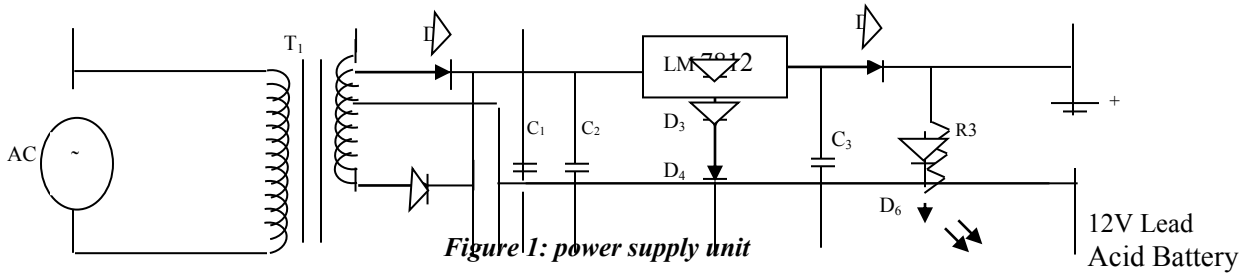


Figure 1: power supply unit

2.2 Control Unit

This unit consists of the power failure alarm and the egg turning control. The power failure alarm unit is controlled by a simple relay of coil resistance = 400Ω, operating voltage = 12v, rated contact current =20A and current drawn = 30mA. The relay acts as a key, when energized by the source it opens the relay and thus the alarr
In the absence of power supply, the relay will not be energized and therefore it relaxes back closing and completing the alarm circuit. The alarm is supplied by the standby dc battery and not the Ac supply.
This is illustrated in figure 3 below.

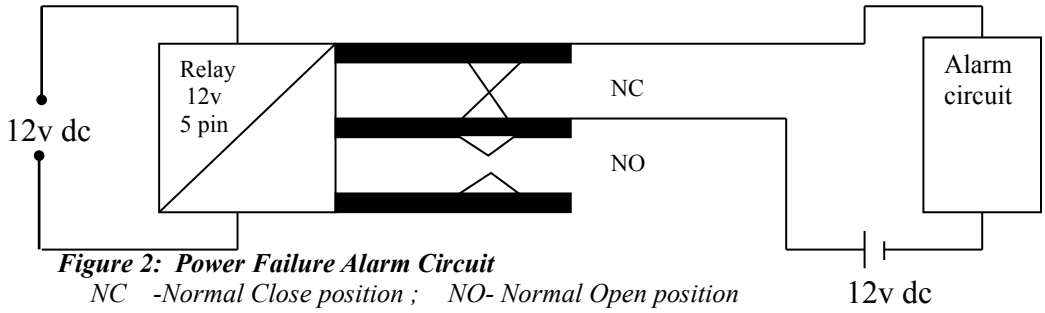


Figure 2: Power Failure Alarm Circuit

NC -Normal Close position ; NO- Normal Open position

The egg trays are controlled by 3 relays. The relays are used together with astable multivibrator. The output of the AMV shown in figure 3 is fed to the first relay (RL_1). The first relay completes the circuit for the other two relays.(RL_2 and RL_3) as shown in figure 5. Relay RL_1 turns the egg trays in the clock wise direction for about 3minutes (180 seconds). Whereas the other two relays are utilized to turn the trays in anti-clockwise direction for about 57 minutes (3420 second). These timing were achieve with help of astable multivibrator circuit whose components values were computed using the following formulae.

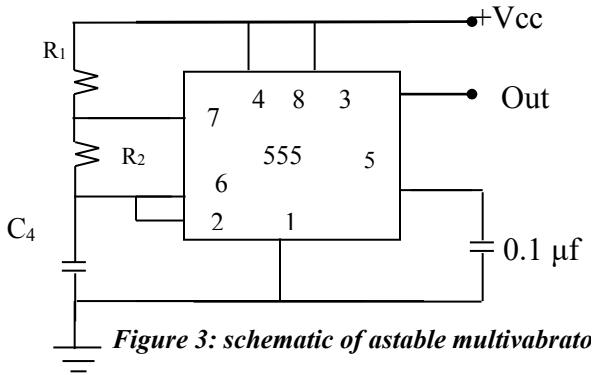


Figure 3: schematic of astable multivabrator

High time: $T_H = 0.693\ C_4\ (R_1+R_2)$ .. … (1) (***Theraja & Theraja, 2001)***

Low time: $T_L=0.693C_4\ R_2$ … … … (2) (***Theraja & Theraja, 2001)***

Where, T_H and T_L are(3420s) and (180s). respectively

R_1, R_2, C_4 are the timing components

Assuming R_2 =5MΩ, C_4 was found from equation (2) to be 987 μf. Substituting the values of R_2 and C_4 into equation (1), R_1 was found to be 900 MΩ.

The heating is achieved with bulbs mounted at the plywood near the water tray. The heating is controlled through a light dimmer and a thermostat. Specific ventilation is required during incubation, ie a moderate distribution of heat is necessary. High air forced ventilation is needed for high humidity to the eggs during hatching. This is achieved by increasing or reducing the resistance of the circuit. A water heater thermostat and a 220v ac motor were used for heating and ventilation units respectively. The quantity of heat and the number of heater (bulbs) needed for the incubator were determined as follows:

$Q=MC\theta$ … … … … … … (5) (***Raven, 1987)***

Where;
Q – Quantity of heat required
M – Mass of air in the chamber (kg)
C – Specific heat capacity of air, C = 0.24kJ/kgk
θ – Change in temperature(^{0}k)

The mass of air in the incubator was determined as follows:
$M = v_{invub}\, x\rho\ air = LxBxH\ \rho\ air$ … … … (6) ***Raven F.H (1987)***

Where
V_{incub} L, B, H – volume, length, breadth and height of the incubator, L =1.03m, H=0.51m, B=0.52m ρ air-density of air, ρ air = 1.2kg/m^3 at room temperature of 35^{O}C and atmosphere pressure of 750mmHg.
Θ = Temperature in incubator – normal room temperature
Θ = (38 + 2730 – (35 + 273) = 6k
Q was found to be 4.72x10^{-1}J

The power of the bulbs required in the incubator was determined thus:
P=VI cos α … … … … (7)

Where,
Cosα = 0.8
V – Ac voltage, V=220V
I – current rating, I =500mA. ∴ P=220 x 500 x 10^{-3} x 0.8 =88watts
Two 60w bulbs were used and both of them together produce 120w. Hence, the light dimmer is used to reduce the intensity of the bulbs to achieve the required 88 watts.

2.3 Alarm/Light Indicator Unit
This unit is built around 555 timer to generate audible tone with 50% duty circle as shown in figure 4.

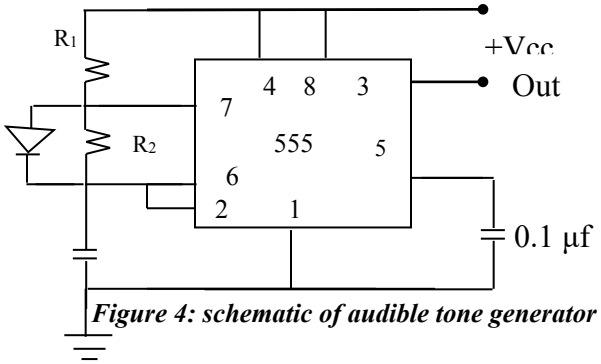


Figure 4: schematic of audible tone generator

Thus $T_H=T_L$= 0.4s … … … … (3)
But now T_L= 0.693 C_5R_4 … … (4) (***Theraja & Theraja, 2001)***
Taken $R_3 = R_4$ = 2.2 kΩ
From equation (3), T_L =0.4 seconds

Substituting the value of T_L, C_5 was found to be 262μf. A standard value of 250 μf was adopted. The front view of the constructed system is shown in figure 6.

3.0 Results and Discussion

The device was fully tested with 90 eggs out of which 68 eggs were successfully hatched. The reasons for non-hatching of some of the eggs included infertility of eggs, cracks shell during first candling; ring blood, dead eggs and sticking to the shell during the second candling. During the third candling all the remaining 68eggs were found developed and alive. The result is presented in table 1. As at 2005, the total cost of construction of the incubator was ₦38, 615 only. Overall, the incubator is about 75% efficient.

Table 1: Average Performance of the incubator

Eggs Input	Hatched Chicks	Infertility	Cracked	sticking	Ring blood	Dead eggs
90	68	9	1	6	4	2

4.0 Conclusion and Recommendations

The constructed automatic electric incubator with hatchers, egg candler and sound/light indicator is functional and reliable as the performance test carried out was successful with 75% hatching. The incubator was constructed from locally available materials/components thus making it cheap and affordable. The device can therefore be used by small scale farmers in developed and developing countries.

With little modifications such as using microcontrollers for the control tasks and a more linear temperature sensor, the performance of the device could be greatly improved.

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Figure 6: Picture of the constructed incubator

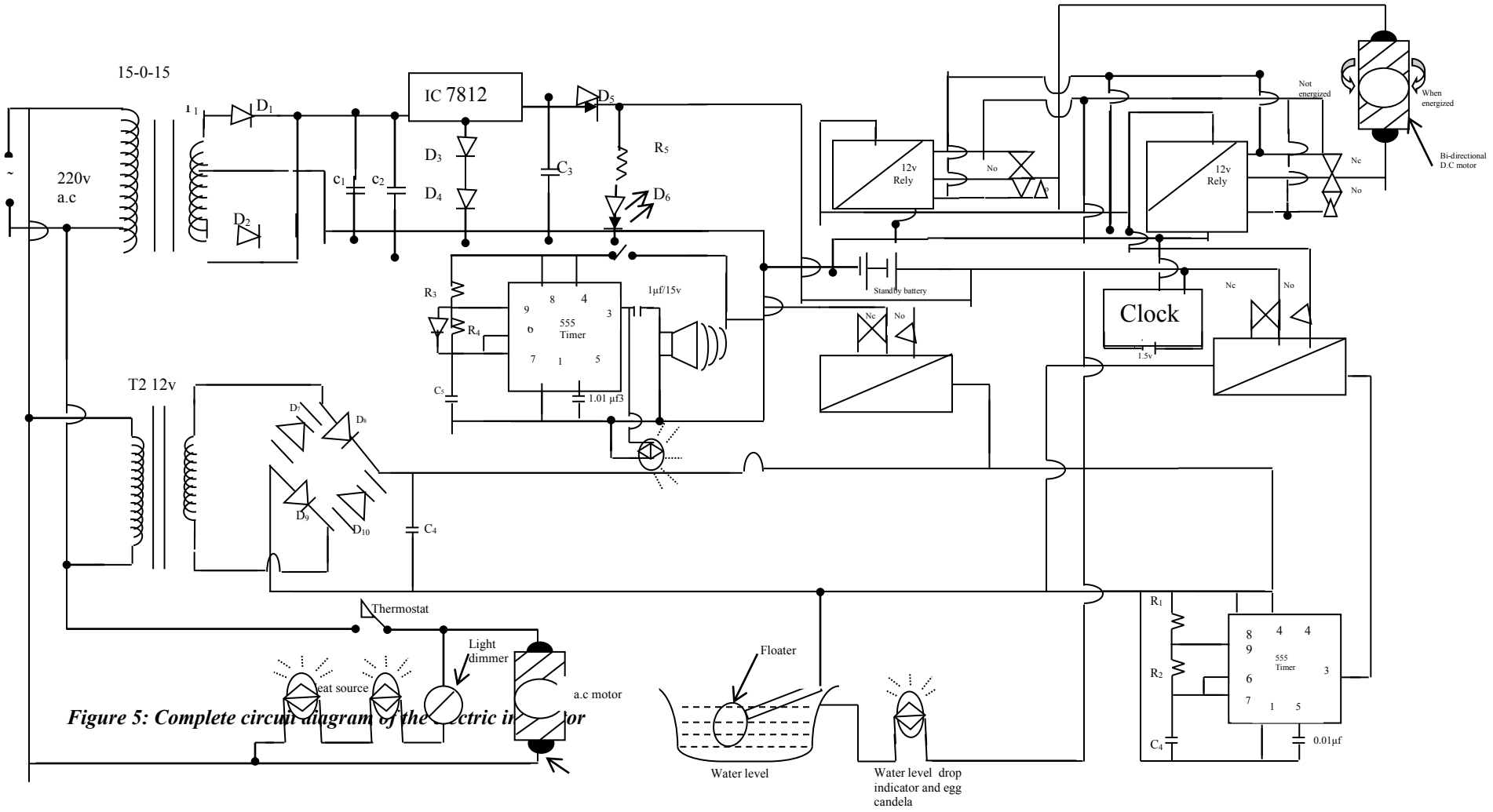


Figure 5: Complete circuit diagram of the electric incubator

AN OVERVIEW OF *AQUATOX* AND ITS APPLICATION

By

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ABSTRACT

The increasing worldwide contamination of freshwater systems with thousands of industrial, agricultural and natural chemical compounds is one of the key environmental problems facing humanity. Although most of these compounds are present at low concentrations, many of them raise considerable toxicological concerns, particularly when present as components of complex mixtures. Ecosystems are complex, with seasonal and annual variations and multiple interactions among species. Hence, it is difficult to predict how the aquatic community will respond to changes in pollutants or environmental conditions with simple methods of analysis, especially if the methods address a single stressor at a time. *AQUATOX* is a complex simulation model designed to address the fate and effects of pollutants in aquatic ecosystems.

This paper presents an overview of the *AQUATOX* model and its potential applications, especially in a tropical environment. *AQUATOX* can help to identify and quantify the cause, effect and relationships between chemical water qualities, the physical environment, and aquatic ecosystem. Hence *AQUATOX* model is well suited for analysis of water bodies, such as nutrient and eutrophication analysis, links between water quality and aquatic life, bioaccumulation and ecological effects of organic toxicants. *AQUATOX* is therefore a valuable tool for water quality modeling and ecological risk assessments of aquatic ecosystems.

The United States' EPA supports the use of *AQUATOX* to assess the nation's waters. A developing country like Nigeria could adopt the model to assess, so as to protect its water resources from avoidable pollution. The model can also help to explore cost- effective and appropriate remediation measures and water treatment technologies for ailing aquatic environments and aquacultural production systems.

Keywords: **Water quality, *AQUATOX* and Applications**

1. Introduction

One of the biggest challenges to protecting or restoring our nation's waters is to adequately understand the relationships between the chemical and physical environment and the organisms that live there. The biological communities in many water bodies are impaired, but the causes of the impairment may not be obvious in the face of numerous environmental stressors. The first step in corrective action is to know what stressor (or combination of stressors) is causing the impairment. In view of this, in the United States of America, the Clean Water Act- formally the Federal Water Pollution Control Act Amendments of 1972 (Public Law 90-50) and subsequent amendments in 1977, 1979, 1980, 1981, 1983, and 1987 called for the identification, control, and prevention of pollution of the nation's waters (US EPA, 2004). Under sections 303(d) and 305(b) of the CWA, States are required to identify and list water bodies that don't fully support the aquatic life uses as designated in their state water quality standards (WQS), to prioritize them, and to develop Total Maximum Daily Loads (TMDLs) for the pollutants of concern. This has led to the development of the model called *AQUATOX* by the United States Environmental Protection Agency.

The National Water Quality Inventory report (2000) as documented by US EPA (2002) reported that 40% of river reaches and 45% of lakes that were assessed are impaired for one or more of their designated uses. Also, in the most recent state 303(d) lists, there are over 34,000 impaired waters and over 58,000 associated impairments in the U.S (US EPA, 2006). Metals, pathogens, nutrients, and sediment are the most common pollutants included in the list. Nutrients are the third leading listed cause of water quality impairments, representing 9% of all impaired segments. Sediment ranks fourth, representing 8% of all impaired water bodies in the U.S. Sediment is listed for its physical impairment to aquatic habitats, whereas nutrients are listed for impairment by organic enrichment, i.e., through excessive algal growth, which can lead to depletion of dissolved oxygen, among other problems. Additionally, several nitrogen (N) species have detrimental impacts on water quality: ammonia is toxic to fish, and high levels of nitrates cause *methemoglobenemia* in infants (Borah *et al*., 2006).

Ecosystems are complex, with seasonal and annual variations and multiple interactions among species. Hence, it is difficult to predict how the aquatic community will respond to changes in pollutants or environmental conditions with simple methods of analysis, especially if the methods address a single stressor at a time. The importance of a complex simulation model (AQUATOX), which predicts the fate, and effects of various pollutants in aquatic ecosystem is therefore paramount.

2. AQUATOX – the model

AQUATOX is a PC – based freshwater ecosystem simulation model that predicts the fate of various pollutants, such as nutrients, sediments and toxic organic chemicals, and their effects on the ecosystem, including fish, invertebrates, and aquatic plants**.** The ecosystem model is one of the few general ecological risk assessment models that represents the combined environmental fate and effects of toxic organic chemicals. The fate portion of the model, which is applicable especially to organic toxicants, includes: partitioning among organisms, suspended and sedimented detritus, suspended and sedimented inorganic sediments, and water; volatilization; hydrolysis; photolysis; ionization; and microbial degradation. The effects portion of the model includes: chronic and acute toxicity to the various organisms modeled; and indirect effects such as release of grazing and predation pressure, increase in detritus and recycling of nutrients from killed organisms, dissolved oxygen sag due to increased decomposition, and loss of food base for animals. The model also considers several trophic levels, including attached and planktonic algae, submerged aquatic plants, several types of invertebrates, and several types of fish. It can represent a variety of aquatic ecosystems, including vertically stratified lakes, reservoirs and ponds, and rivers and streams. The model has been implemented for streams, small rivers, ponds, lakes, and reservoirs (US EPA, 2004).

AQUATOX represents the aquatic ecosystem by simulating the changing concentrations (in mg/L or g/m^3) of organisms, nutrients, chemicals, and sediments in a unit volume of water (**Figure 1**). The model is intended to be used to evaluate the likelihood of past, present, and future adverse effects from various stressors including potentially toxic organic chemicals, nutrients, organic wastes, sediments, and temperature. The stressors may be considered individually or together. It can be implemented as a simple model (indeed, it has been used to simulate an abiotic flask) or as a truly complex food-web model. Often it is desirable to model a food web rather than a food chain, for example to examine the possibility of less tolerant organisms being replaced by more tolerant organisms as environmental perturbations occur. “Food web models provide a means for validation because they mechanistically describe the bioaccumulation process and ascribe causality to observed relationships between biota and sediment or water” (Connolly and Glaser 1998). AQUATOX is a valuable tool for ecologists, biologists, water quality modelers, and anyone who performs ecological risk assessments for aquatic ecosystems.

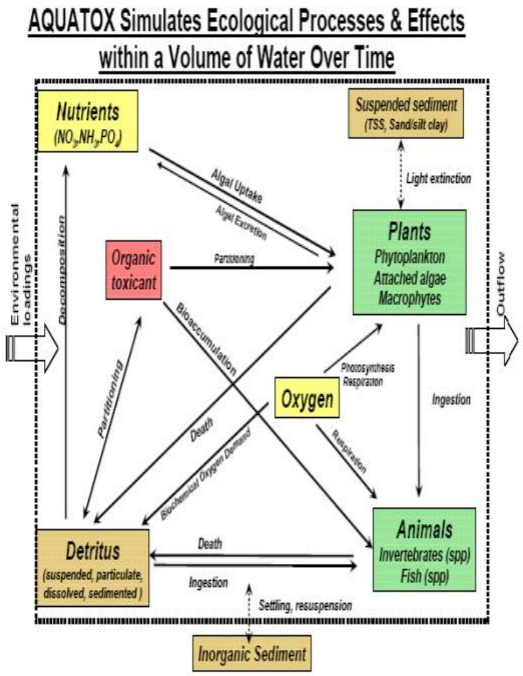


Figure1. Conceptual model of ecosystem represented by AQUATOX
Source: US EPA (2004)

2.1 AQUATOX Background and Development History

AQUATOX is the latest in a long series of models, starting with the aquatic ecosystem model CLEAN and subsequently improved in consultation with numerous researchers at various European hydrobiological laboratories, resulting in the CLEANER series (Park *et al*., 1975, Park, 1978; Scavia and Park, 1976) and LAKETRACE (Collins and Park, 1989). The MACROPHYTE model, developed for the U.S. Army Corps of Engineers (Collins *et al*., 1985), provided additional capability for representing submerged aquatic vegetation. Another series started with the toxic fate model PEST, developed to complement CLEANER (Park et al., 1980, 1982), and continued with the TOXTRACE model (Park, 1984) and the spreadsheet equilibrium fugacity PART model. *AQUATOX* combined algorithms from these models with ecotoxicological constructs; and additional code was written as required for a truly integrative fate and effects model (Park, 1990). The model was then restructured and linked to Microsoft Windows interfaces to provide greater flexibility, capacity for additional compartments, and user friendliness (Park *et al*., 1995). Release 1 from the U.S. Environmental Protection Agency (US EPA) was improved with the addition of constructs for chronic effects and uncertainty analysis, making it a powerful tool for probabilistic risk assessment (US EPA, 2000a, b, c). Release 1.1 (US EPA, 2001a, b) provided a much enhanced periphyton submodel and minor enhancements for macrophytes, fish, and dissolved oxygen. Release 2, which has a number of major enhancements including the ability to model up to 20 toxic chemicals and more than twice as many biotic compartments and linkage to *BASINS* System, was released in early 2004. Release 2 has also been improved to Release 2.1 and the latest is 2.2 which can output retention time of a water body and also took care of some minor and major coding errors of Release 2.1 (US EPA, 2004).

2.2 The Structure of *AQUATOX*

AQUATOX simulates the transfer of biomass, energy and chemicals from one component of the ecosystem to another. It does this by simultaneously computing each of the most important chemical or biological processes for each day of the simulation period; therefore it is a **process-based** or **mechanistic model**. This means that it explicitly simulates the numerous biological and ecological processes that operate to link the ecosystem together.

Any ecosystem model consists of multiple components requiring input data. These are the abiotic and biotic **state variables** of compartments being simulated. In *AQUATOX* the biotic state variables may represent trophic levels, guilds, and/or species. The model can represent a food web with both detrital- and algal-based trophic linkages. Closely related are **driving variables**, such as temperature, light, and nutrient loadings, which force the system to behave in certain ways. In AQUATOX state variables and driving variables are treated similarly in the code. This provides flexibility because external loadings of state variables, such as phytoplankton carried into a reach from upstream, may function as driving variables; and driving variables, such as pH and temperature, could be treated as dynamic state variables in a future implementation. Constant, dynamic, and multiplicative loadings can be specified for atmospheric, point- and nonpoint sources. Loadings of pollutants can be turned off at the click of a button to obtain a **control** simulation for comparison with the **perturbed** simulation (US EPA, 2004).
The model is written in object-oriented Pascal using the Delphi programming system for Windows. An object is a unit of computer code that can be duplicated; higher-level objects also can inherit its characteristics and methods. For example, the organism object, including variables such as the *LC50* (lethal concentration of a toxicant) and process functions such as respiration, is inherited by the plant object; that is enhanced by plant-specific variables and functions and is duplicated for three kinds of algae; and the plant object is inherited and modified slightly for macrophytes. This modularity forms the basis for the remarkable flexibility of the model, including the ability to add and delete given state variables interactively (US EPA, 2004).

AQUATOX utilizes **differential equations** (such a change in volume, algae, macrophyte and etc. equations) to represent changing values of state variables, normally with a reporting time step of one day. These equations require starting values or **initial conditions** for the beginning of the simulation. If the first day of a simulation is changed, then the initial conditions may need to be changed. A simulation can begin with any date and may be for any length of time from a few days, corresponding to a microcosm experiment, to several years, corresponding to an extreme event followed by long-term recovery. The **process equations** (such as change in animal biomass, current limit, light limit, mortality and etc. equations) contain another class of input variables: the **parameters** or **coefficients** that allow the user to specify key process characteristics. For example, the maximum consumption rate is a critical parameter characterizing various consumers. However, as a mechanistic model with many parameters; default values are available so that the analyst only has to be concerned with those parameters necessary for a specific risk analysis, such as characterization of a new chemical. Finally, the system being modeled is characterized by **site constants**, such as mean and maximum depths. At present one can model small lakes, reservoirs, streams, small rivers, and ponds—and even enclosures and tanks. The generalized parameter screen is used for all these site types, although the hypolimnion entries obviously are not applicable to all. The temperature and light constants are used for simple forcing functions, blurring the distinctions between site constants and driving variables (US EPA, 2004).

2.3 Theory of *AQUATOX*

A few of the aforementioned differential and process equations are presented here. Details of these equations will be presented subsequently.

2.3.1 Volume

Volume is a state variable and can be computed in several ways depending on availability of data and the site dynamics. It is important for computing the dilution or concentration of pollutants, nutrients, and organisms; it may be constant, but usually it is time varying. In the model, ponds, lakes, and reservoirs are treated differently than streams, especially with respect to computing volumes. The change in volume of ponds, lakes, and reservoirs is computed as

$$\frac{dVolume}{dt} = Inflow - Discharge - Evap$$

Where:

dVolume/dt = derivative for volume of water (m^3/d),
Inflow = inflow of water into waterbody (m^3/d),
Discharge = discharge of water from waterbody (m^3/d), and
Evap = evaporation (m^3/d),

Evaporation is converted from an annual value for the site to a daily value using the simple relationship:

$$Evap = \frac{MeanEvap}{365} \cdot 0.0254 \cdot Area$$

Where:

MeanEvap = mean annual evaporation (in/yr),
365 = days per year (d/yr),
0.0254 = conversion from inches to meters (m/in), and
Area = area of the waterbody (m^2).

2.3.2 Velocity

Velocity is calculated as a simple function of flow and cross-sectional area:

$$Velocity = \frac{AvgFlow}{XSecArea} \cdot \frac{1}{86400} \cdot 100$$

Where

Velocity = velocity (cm/s),
AvgFlow = flow (m^3/d),
XSecArea = cross sectional area (m^2),
86400 = s/d, and 100 = cm/m.

$$AvgFlow = \frac{Inflow + Discharge}{2}$$

Where:

Inflow = flow into the reach (m^3/d);
Discharge = flow out of the reach (m^3/d).

It is assumed that this is the velocity for the run of the stream. No distinction is made in terms of vertical differences in velocity in the stream.

2.3.3 Washout

Transport out of the system, or washout, is an important loss term for nutrients, floating organisms, dissolved toxicants, and suspended detritus and sediments in reservoirs and streams. Although it is considered separately for several state variables, the process is a general function of discharge:

$$Washout = \frac{Discharge}{Volume} \cdot State$$

Where:

Washout = loss due to being carried downstream (g/m^3 "d);
Discharge = flow out of the reach (m^3/d),
Volume = volume of stream reach (m^3), and
State = concentration of dissolved or floating state variable (g/m^3).

2.3.4 Temperature

Temperature is an important controlling factor in the model. Virtually all processes are temperature-dependent. These include stratification; biotic processes such as decomposition, photosynthesis, consumption, respiration, reproduction, and mortality; and chemical fate processes such as microbial degradation, volatilization, hydrolysis, and bioaccumulation. On the other hand, temperature rarely fluctuates rapidly in aquatic systems.

$$Temperature = TempMean + \left(-1.0 \cdot \frac{TempRange}{2} \cdot \left(\sin\left(0.0174533 \cdot \left(0.987 \cdot \left(Day + PhaseShift\right) - 30\right)\right)\right)\right)$$

Where:

Temperature = average daily water temperature (°C);
TempMean = mean annual temperature (°C);
TempRange = annual temperature range (°C),
Day = Julian date (d); and
PhaseShift = time lag in heating (= 90 d).

2.3.5 BIOTA

The biota consists of two main groups, plants and animals; each is represented by a set of process-level equations. In turn, plants are differentiated into algae and macrophytes, represented by slight variations in the differential equations. Algae may be either phytoplankton or periphyton. Phytoplanktons are subject to sinking and washout, while periphyton are subject to substrate limitation and scour by currents. Bryophytes are modeled as a special class of macrophytes, limited by nutrients in the water column. These differences are treated at the process level in the equations (Table 1). All are subject to habitat availability, but to differing degrees. Taxonomic group also characterizes plants, which is primarily a way of organizing preferences for grazing and to identify blue-green phytoplankton as floating (US EPA 2004).

Animals are subdivided into invertebrates and fish; the invertebrates may be pelagic invertebrates, benthic insects or other benthic invertebrates. These groups are represented by different parameter values and by variations in the equations

Table 1. Significant Differentiating Processes for Plants

Plant Type	Nutrient Lim.	Current Lim.	Sinking	Washout	Sloughing	Breakage	Habitat
Phytoplankton	•		•	•			•
Periphyton	•	•			•		•
Macrophytes						•	•
Bryophytes	•					•	•

Source: US EPA (2004)

Table 2. Significant Differentiating Processes for Animals

Animal Type	Washout	Drift	Entrainment	Emergence	Promotion	Multi-year
Pelagic Invert.	• •					
Benthic Invert.		•	•	•	•	
Benthic Insect		•	•	•	•	•
Fish			•		•	•

Source: US EPA (2004)

2.3.5.1 Algae

The change in algal biomass—expressed as ash-free dry weight in g/m^3 for phytoplankton, but as g/m^2 for periphyton—is a function of the loading (especially phytoplankton from upstream), photosynthesis, respiration, excretion or photorespiration, nonpredatory mortality, grazing or predatory mortality, sloughing, and washout; as noted above, phytoplankton also are subject to sinking. If the system is stratified, turbulent diffusion from one layer to the other also affects the biomass of phytoplankton:

$$\frac{dBiomass_{phyto}}{dt} = Loading + Photosynthesis - Respiration - Excretion - Mortality - Predation \pm Sinking - Washout \pm TurbDiff$$

$$\frac{dBiomass_{peri}}{dt} = Loading + Photosynthesis - Respiration - Excretion - Mortality - Predation - Slough$$

Where:

dBiomass/dt = change in biomass of phytoplankton and periphyton with respect to time (g/m^3"d and g/m^2"d);
Loading = loading of algal group (g/m^3"d and g/m^2"d);
Photosynthesis = rate of photosynthesis (g/m^3"d and g/m^2"d),
Respiration = respiratory loss (g/m^3"d and g/m^2"d),
Excretion = excretion or photorespiration (g/m^3"d and g/m^2"d),
Mortality = nonpredatory mortality (g/m^3"d and g/m^2"d),
Predation = herbivory (g/m^3"d and g/m^2"d),
Washout = loss due to being carried downstream (g/m^3"d),
Sinking = loss or gain due to sinking between layers and sedimentation to bottom (g/m^3"d),
TurbDiff = turbulent diffusion (g/m^3"d),
Slough = loss due to sloughing (g/m^2"d),

2.3.5.2 Animals

Zooplankton, benthic invertebrates, benthic insects, and fish are modeled, with only slight differences in formulations, with a generalized animal submodel that is parameterized to represent different groups:

$$\frac{dBiomass}{dt} = Load + Consumption - Defecation - Respiration - Excretion - Mortality - Predation - GameteLoss - Washout \pm Migration - Promotion + Recruit - Entrainment$$

Where:

dBiomass/dt = change in biomass of animal with respect to time (g/m^3"d);
Load = biomass loading, usually from upstream (g/m^3"d);
Consumption = consumption of food (g/m^3"d),
Defecation = defecation of unassimilated food (g/m^3"d),
Respiration = respiration (g/m^3"d),
Excretion = excretion (g/m^3"d),
Mortality = nonpredatory mortality (g/m^3"d),
Predation = predatory mortality (g/m^3"d),
GameteLoss = loss of gametes during spawning (g/m^3"d),
Washout = loss due to being carried downstream by washout and drift (g/m^3"d),
Migration = loss (or gain) due to vertical migration (g/m^3"d),
Promotion = promotion to next size class or emergence (g/m^3"d), and
Recruit = recruitment from previous size class or through reproduction

(g/m^3"d),
Entrainment = entrainment and downstream transport with flood waters (g/m^3"d), (US EPA 2004).

3. Applications of *AQUATOX*

AQUATOX can be used to address a wide variety of issues requiring a better understanding of the processes relating the chemical and physical environment to the biological community. Shoemaker *et al*., (2005) also reported that *AQUATOX* could help to identify and quantify the cause and effect relationships between chemical water quality, the physical environment, and aquatic ecosystem. It can be used to address water management issues and program (water quality criteria and standards, Total Maximum Daily Loads, and ecological risk assessment etc.). *AQUATOX* can be used to predict ecological responses to proposed management alternatives. It may help to determine the most important of several environmental stressors, e.g. where there are both nutrients and toxic pollutants. Hence *AQUATOX* is well suited for analysis of waterbodies, and such typical analysis includes: nutrient and eutrophication analysis, links between water quality and aquatic life and bioaccumulation and ecological effects of organic toxicants. *AQUATOX* can be used to analyze complex relationships in impaired ecosystems and to suggest the relative importance of various causes of impairment.

- **Developing Water Quality Criteria**

AQUATOX has the potential to predict quantitative responses of all components of the aquatic ecosystem to reduction in pollutants. It can also predict both changes in biomass and composition. This can provide decision makers with another approach to analyzing the threshold, proportionate, and ramifying effects of nutrient reductions in the context of other stressors

- **Developing numeric nutrient targets based on desired biological endpoints.**

AQUATOX has its roots in what was basically an eutrophication model, and it provides a reasonable representation of the effects of nutrient enrichment. It can be configured to depict a complex food web that is both phytoplankton- and detritus- based, with both game fish and bottom fish- often considered regulatory endpoints. It also reports phytoplankton both as biomass and as chlorophyll a, which is an important index of water quality. Dissolved oxygen is another important index that is computed. The Secchi depth, an indicator of clarity, also is estimated (USEPA, 2004).

- **Evaluating which of several stressors is causing observed biological impairment.**

Multiple stressors due to agricultural runoff can be predicted; it can be used to control pesticides and all pollutants. For example: are nuisance levels of attached algae in a stream controlled primarily by nutrients, sediments, grazing by snails, or flow conditions? *AQUATOX* can independently analyze each stressor.

- **Predicting effects of pesticides and other toxic substances on aquatic life.**

As the only general fate and effects model of potential toxic chemicals in aquatic ecosystems, *AQUATOX* is well suited for risk assessment of organic toxicants even in a pond mesocosm. For example: will sublethal concentrations eventually cause game fish to disappear? Will reduction of one group of organisms reduce the food supply for other more beneficial species, or lead to increases in nuisance species? US EPA (2004) reported a successful comparative risk assessment of twenty-five pesticides with *AQUATOX*.

- **Evaluating potential ecosystem responses to invasive species.**

Another possible impact on the stream ecosystem could come from invasion of snails. *AQUATOX* has been used to show possible interaction within the ecosystem by invasive snails. The invasion of the exotic species; mud snail (*Potamopyrqus antipodarum*,) in the Yellowstone National Park River within two years showed that the *Potamopyrqus* goes from 1 to $6g/m^2$. Also a five (5) years simulation shows that a seasonal maximum of $6g/m^2$ is maintained (US EPA 2006).

- **Estimating time to recovery of fish or invertebrate communities after reducing pollutant loads.**

AQUATOX can forecast the consequences of planned and unplanned modifications to a stream. For example: the removal of Polychroninated Biophenyls (PCB) from a creek/river. Part of the remedial investigation, is estimating the time of recovery once the contaminants are removed. This can be done by running the model for a sufficiently long period and noting when a pollutant drops below the level of concern.

• **Determining effects of land use changes on aquatic life by using the linkage with *BASINS*.**
This allows one to take pollutant-loading predictions from HSPF (Hydrological Simulation Programme- Fotran) or SWAT (Soil and Water Assessment Tool) watershed models and input them directly to *AQUATOX*. It also provides a linkage to GIS (Geographical Information Systems). This will help water quality management decisions. They can plan more accurate water protection programs, knowing yield variation within a pond or an aquacultural system. Fish farmer can also be adviced on better ways to perform more timely operation, which will invariably translate to increased net returns. Improved efficiency of inputs such as nutrients, fertilizers and chemicals will reduce threat to water quality; and increased management skills.

4. AQUATOX and Other Water Quality Models

AQUATOX differs from most water quality models in several ways. Most models include few if any biological components, whereas *AQUATOX* is an ecosystem model. It includes not only numerous types of plants, invertebrates and fish, it also treats the biota as interacting with the chemical/ physical system. As mentioned above, *AQUATOX* is a process-based model, as opposed to an empirical model, which is often based on statistical relationships. Empirical models may establish that correlations between variables exist, but do not explain why, or the mechanisms of the relationship.

Unlike most models, *AQUATOX* contains an ecotoxicology submodel that computes acute and chronic toxic effects from the concentration of a toxicant in a given organism, using the critical body residue approach. Because the model simulates toxicity based on internal concentrations as a consequence of bioaccumulation, both water and dietary exposure pathways are represented equally well. Furthermore, as an ecosystem model, *AQUATOX* can simulate indirect effects such as loss of forage base, reduction in predation, and anoxia due to decomposition following a fish kill. It is a truly integrated eutrophication, contaminant fate and effect model. *AQUATOX* allows a user to specify preferences at multiple levels, thus modeling complex food webs. The model can simulate conditions with and without a perturbation in order to distinguish impacts. This means that a simulation doesn't have to be perfectly calibrated to evaluate an impact unlike other models.

It differs from population models, which represent the changes in numbers of individuals. As O'Neill *et al.*, (1986) stated ecosystem models and population models are complementary; one cannot take the place of the other. Population models excel at modeling individual species at risk and modeling fishing pressure and other age/size-specific aspects; but recycling of nutrients, the combined fate and effects of toxic chemicals, and other interdependencies in the aquatic ecosystem are important aspects that *AQUATOX* represents and that cannot be addressed by a population model.

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5. Conclusion

The increasing worldwide contamination of freshwater systems with thousands of industrial and natural chemical compounds is one of the key environmental problems facing humanity. Although most of these compounds are present at low concentrations, many of them raise considerable toxicological concerns, particularly when present as components of complex mixtures. The importance of *AQUATOX* in addressing water-quality problems caused by pollutants and also in assessing the impacts of these pollutants on aquatic life, which invariably affects human health and productivity cannot be overemphased.

The U.S EPA has applied and is still using this model to assess the nation's waters with the view of protecting or restoring it from total degradation. Developing nations especially Nigeria need to adopt this laudable program so as to monitor the effluents by some industries and also to protect our waters from avoidable pollution. This model will also help us to explore cost-effective and appropriate remediation and water-treatment technologies. This will in turn improve the sustainability of our growing aquaculture industries, which will in turn boost our economy.

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DESIGN, CONSTRUCTION AND PERFORMANCE EVALUATION OF A BATCH TYPE BIOGAS DISGESTER IN NSUKKA, NIGERIA

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ABSTRACT

A batch type biogas digester was designed, constructed and the performance evaluation undertaken under Nsukka weather. The digester was made of fermentation and gas storage chambers, a stirrer, and inlet and outlet channels. A pressure gauge to monitor the level of gas generated was incorporated. The digester has a total volume of 80 litres which is able to support a family of four. The biodigester was tested using 25 kg each of samples of poultry droppings, cow dung, and pig manure respectively. Combustibility of the gas generated was conducted using a biogas burner designed for the purpose. The flame test conducted showed combustible gas from the 21st day for poultry dropping, 9th day for cow dung and 15th day for pig dung under the chamber and ambient temperature range between 31 – 35°C and 27 – 30°C respectively. The results of the performance evaluation revealed that a total of 105 litres of biogas was generated by poultry droppings, 123 litres of gas by cow dung and 99 litres of gas by pig manure in 47, 42 and 40 days of the experimental study.

Key words: Biodigester, fermentation, poultry, cow dung, pig manure, biogas.

1.0 Introduction

Energy plays a vital role in domestic and industrial applications. In the recent time it has become very clear to national and international organizations involved in energy matters, the environment and development that action has to be taken to stimulate the dissemination and the use of new and renewable energy resources in the developing countries. It is perhaps in recognition of this that a lot of research efforts have been geared towards various aspects of renewable energy resources. One area that has witnessed tremendous amount of research attention in Nigeria in the last one decade is biogas generation. This probably is due largely to the realization that the nation's fossil fuel resources are depletable and therefore exhaustive. (Zueu et al, 2001)

However, despite the growing volume of research interest, there appears to be a poor dissemination network towards the expected socio-economic impact on the people especially those living in the rural areas. Nigeria is known to have large amount of biomass resources ranging from human, animal wastes, sewage disposals and crop residues. The country has about 112 millions poultry, 62 million goats, 21 million cows and 9.6 million pigs producing about 245.5 metric tones of animal wastes annually (Garba, 2004). The indication is that the country is endowed with natural energy resources which if harnessed can greatly improve the present day household energy needs. Utilization of biomass energy probably for rural domestic applications such as in food preparation will enhance and improve the living standard and economic empowerment of the people as well as creating a benign environment. For instance, biogas, a product of biomass through anaerobic digestion of substrate has many potential applications. Some of these applications include for domestic cooking, electricity generation, refrigeration and frying of food items. It is also very useful in room warming, thus poultry houses may need this for egg incubation and hatching process (Yerima et al, 2001). The remnant from the fermentation process usually called spent slurry is improved composed manure and this can be used by farmers as soil enhancer or conditioner for crop production.

Biogas generated from animal droppings has been widely used in countries like Malaysia, India, China and United Kingdom in power generation systems. In Nigeria, domestic heating fuels such as kerosene, woodfuel and cooking gas are increasingly becoming very expensive. Many studies (Gupta and Kelly, 1992; Itodo and Kucha, 1997 and Zuru et al, 2001) on biogas generation abound. To disseminate the biogas technology, the need for family size biodigesters for household applications is therefore very imperative. Its utilization for domestic applications such as in food preparation could serve as a way of popularizing the technology. Such biodigesters when in use will derive and make use of the abundant animal wastes like poultry droppings, cow dung pig manure and crop residues as charging substrates. This will form a good check to environmental pollution caused by these wastes.

2.0 Description and design of the biogas digester

The biogas digester is a batch type with conical shape (Fig. 1). The body of the digester is constructed with gauge 16 metal sheets. It consists of a stirrer, inlet and outlet channels for inlet slurry and spent slurry. The design was based on the basic principles governing biogas production through anaerobic fermentation of biomaterials. The major consideration was to design a batch system capable of sustaining and cooking a family of four meals. The total volume of the biodigester is 80litres.Thus it is described as constant volume type.

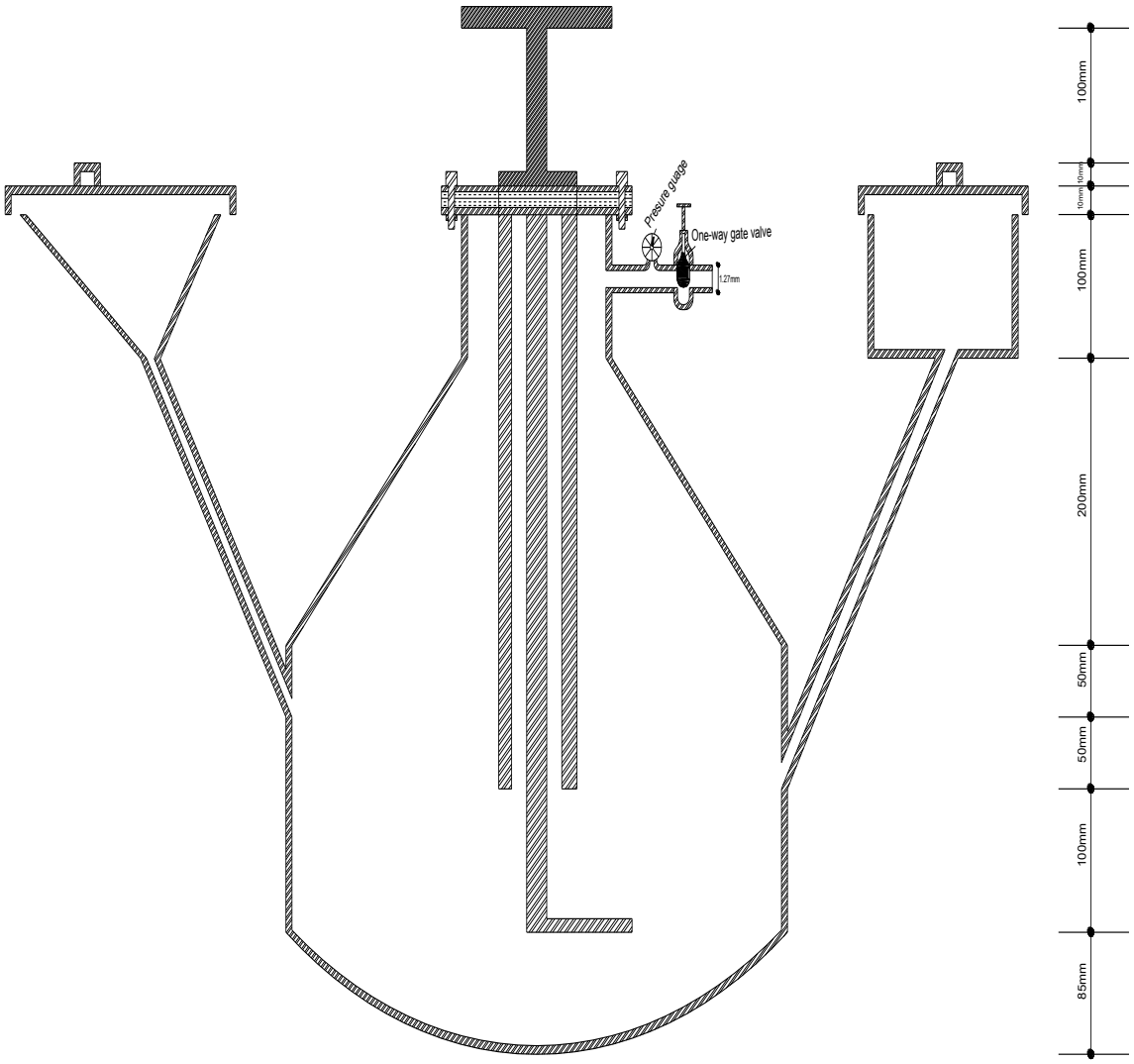


Fig 1: cross sectional view of the biogas digester.

The total volume of the biodigester was determined using the expression

$$V_T = V_1 + V_2 + V_3 + V_4 \quad (1)$$

Where V1 = volume of the dome shaped bottom, given by

$$V_1 = \frac{\prod}{6} f_1\left(3R + f_1^2\right) \quad (2)$$

f = vector rise of the digester bottom
R = Diameter of the fermentation tank
V_2 = volume of the digester cylindrical body given as (NCERD, 2000)

$$V_2 = \frac{1}{3}\prod R^2 H \quad (3)$$

H = height of fermentation chamber
V_3 = volume of the frusta body given by

$$V_3 = \frac{1}{3}\Pi R^2 H - \frac{1}{3}\prod r^2 h \quad (4)$$

r = radius of the frustum
V_4 = volume of the top cylinder given as

$$V_4 = \frac{1}{3}\prod r^2 h \quad (5)$$

The volume is divided into two parts – the fermentation chamber where the slurry is charged and the gas storage chamber. Charging and discharging are through inlet and out let channels. A stirrer for agitating the slurry was incorporated.

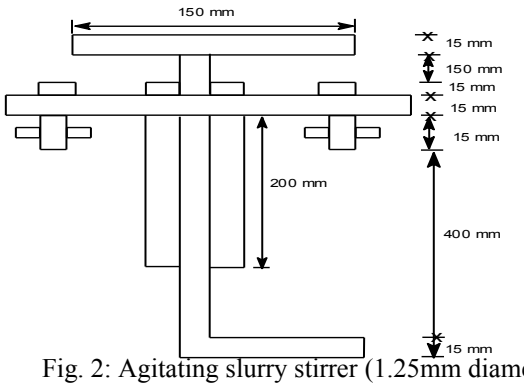


Fig. 2: Agitating slurry stirrer (1.25mm diameter mild steel rod)

The stirrer is made of 1.25mm diameter mild steel rod and a circular manifold fitted with screw bolts. Other members of the stirrer were welded on the rod. The stirrer was installed into the digester chamber through an open manifold and fitted air tight using polystyrene and bolted together. The quantity of heat required to sustain fermentation and gas production at mesophilic temperature was estimated using the expression

$$Q = mC_s\Delta T \quad (6)$$

Where
m = mass of slurry, kg
C_s = specific heat capacity of slurry, J/kg
ΔT= change in temperature, ^oC
The gas flow rate from the storage chamber into the pipe line outlet was estimated by

$$Q_g = VA \quad (7)$$

Where, Qg = gas discharge rate, m^3/s
V = velocity of gas in the pipe, m/s
A = cross sectional area of pipe, m^2

2.0 Performance Evaluation of the Biodigester

The biogester was tested using Poultry dropping, cow and pig dung within the ambient condition of Nsukka. The poultry dropping and pig dung were collected fresh from the University of Nigeria animal farm while cow dun was

collected from Nsukka main market abattoir. Animal wastes of 25kg each were mixed with water at a ratio of 1:2 using weighing balance. The ratio is to create enabling environment for the microbes to act on substrate and also to liquidify the sludge. Each was charged into the digester in batch. The quantity of gas produced was determined by water displacement method (Fig. 3) while the combustibility of the gas was tested with a gas burner (Fig. 4), Note: Moisture content of animal wastes was not determined.



Fig. 4: Combustibility test of gas generated

The pressure of the gas generated was measured with pressure gauge while the temperature of the digester and environmental conditions and PH of gas were monitored using thermometer and universal indicator respectively. The experimental study lasted for a total period of 130 days. The measurement of gas produced was immediately after charging, because it is known that bio wastes generate gas hours after charging. The gas quality and composition were not however characterized. This was due to the unavailability and lack of the basic facilities. Test of combustibility (flame) established the presence of methane gas. Each set of experimental study was replicated three times and average of the data taken. Note: carbon-nitrogen ratio of substrate was not ascertained due to lack of facility.

3.0 Results and Discussion

Figures 5, 6 and 7 showed the graphs of biogas generated by poultry, cow and pig droppings over the period of experimental study. The study showed that poultry dropping (Fig 5) started to produce combustible gas by the 21 days of charging the digester with the slurry at slurry and ambient temperatures of 31 ^{o}C and 28 ^{o}C at 2.9 x 10^{-3} m^3/day of gas. The pH of the displaced slurry is 7. The volume of gas produced continues on the increase daily. Between 27th and 42nd day the biogas generated was at maximum with highest volume being on the 29th day at a volume of 4.15 x 10^{-3} m^3/day at a mesophilic temperature of 32 ^{o}C. There after the quantity of gas generated decreased. By the 47th day the volume deceased to 2.615 x 10^{-3} m^3 day. The Profile indicates almost a uniform gas generation with in the peak period of gas production which lasted for about two weeks. The total volume of gas produced by the poultry dropping was 105 litres. Note: increase temperature increases microbial activities.

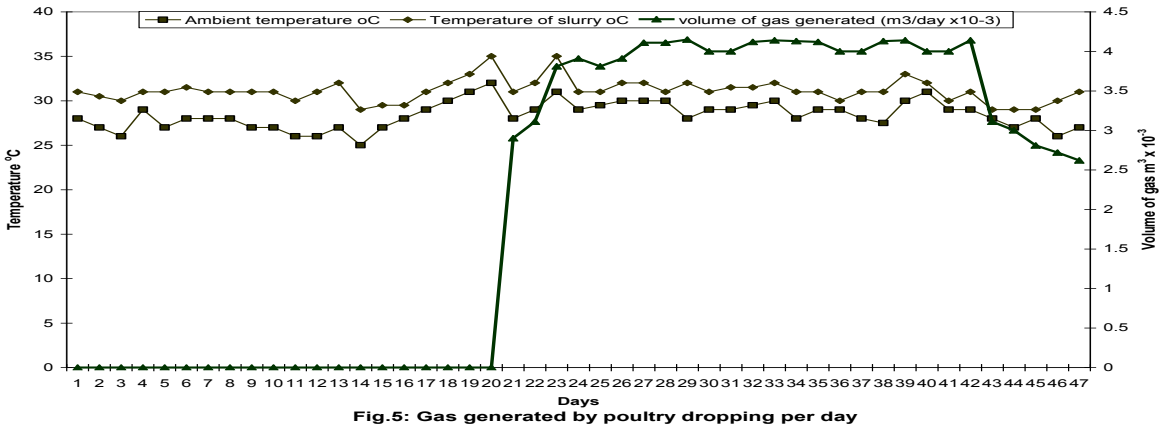


Fig.5: Gas generated by poultry dropping per day

From Fig. 6 the indication is that the cow dung commenced gas production on the 9th day of charging the biodigester with slurry. The quantity of gas produced was 3.52 x 10^{-3} m^3/day at a mesophilic temperature of 30 ^oC and 27 ^oC ambient. The highest volume of gas produced was on the 30th day of the experimental study at a slurry temperature of 35 ^oC. The pattern of gas produced was observed to fluctuate with temperature of the slurry. When it was clear that less gas were generated on daily basis the experiment was terminated. Total volume of gas generated at the end of the experimental study was 122 litres at a retention time of 40 days.

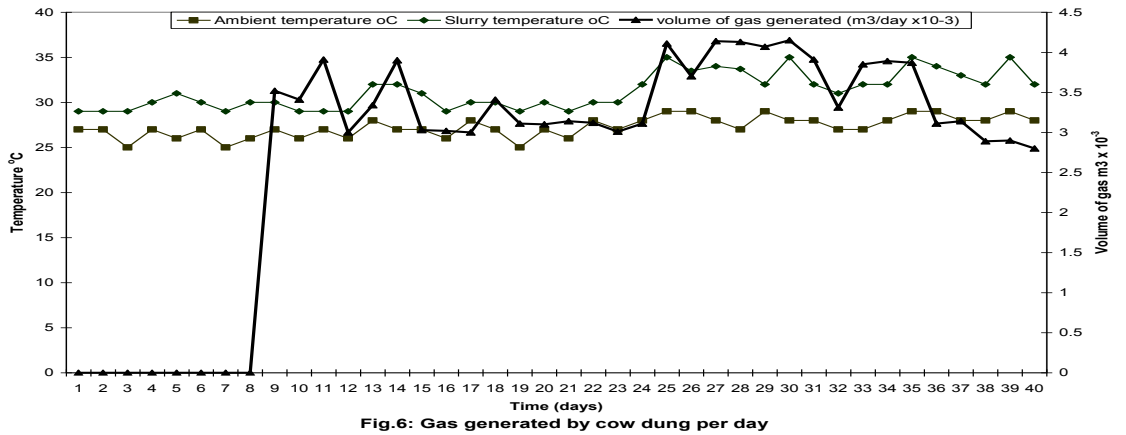


Fig.6: Gas generated by cow dung per day

Figure 7 is the profile of biogas generated with pig manure. Gas production started on the 15th day of charging the biodigester with pig manure at a slurry temperature of 38 ^oC. The maximum volume of gas was produced on the 24th day at 4.51 x 10^{-3} m^3/day at 34 ^oC. Total volume of gas produced was 99 litres in 42 days of retention period.

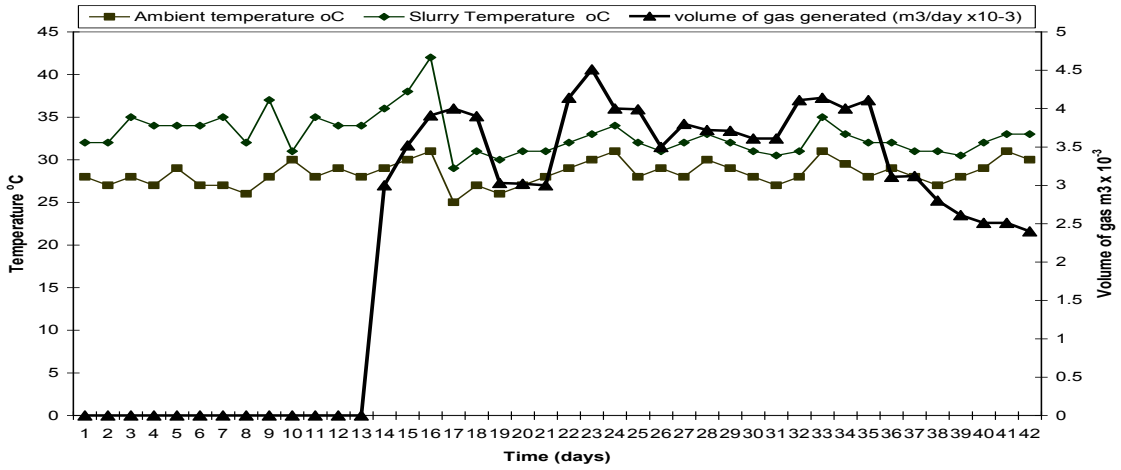


Fig.7: Gas generated by pig dung per day

5. Conclusion

The design, construction and test performance of a conical batch type biogas digester has been presented. The study revealed that about 105, 123 and 99 litres of methane gas were generated using poultry dropping, cow dung and pig manure from 25 kg of each of the substrate between mesophilic and ambient temperature range of 31 – 35 oC and 27 – 30 oC respectively. The study revealed that the biodigester is capable of producing methane gas to support a family of four at a rate of 3.0 litres per day for poultry dropping, 3.2 litres for cow dung and 2.4 litres per day for pig manure. These can help prepare a meal per day for the family.

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Environmental modification of livestock building for efficient productivity under a tropical climatic condition: a challenge to the Nigerian Agricultural Engineer

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ABSTRACT

The tropical climate is characterized by high temperature and humidity that jointly provide a heat stressed environment for both livestock and husbandmen. Animals are very susceptible to heat stress, the effect of which is usually found in reduced productivity and hence loss in the farms' income. The exposure of farm animals to severe heat stress, THI $\geq 27.9^0$C (temperature-humid index) which is prevalent in a tropical environment adversely affects both growth and reproduction rate as well as reducing resistance to diseases. Weight gain of rabbit were 79.58, 75.82, 74.17 and 62.89 gram/week were recorded for THI values of 32.49, 33.82, 34.21 and 35.40 ^{o}C, respectively, while feed efficiency were, respectively, 68, 65, 61 and 55 % for the same thermal comfort levels. The physiological characteristics of pulse rate , rectal temperature and respiration rate of rabbit also flow the same pattern but with the lower rates being for the lower THI value of the animal enclosure. Various production conditions were reviewed in this paper to provide design basis for the agricultural engineer to gear up to the challenges for enhanced livestock productivity.

Key words: Agricultural engineer; farm animal; heat stress; temperature humidity index; thermal comfort; micro-environment.

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INTRODUCTION

Agricultural Engineering research according to Stout (2000) and Munack, (2002) has by far moved from nuts and bolts to broader tasks that are of high relevance for the society: more and higher quality of food, reduction of world poverty, helps poor farmers raise their income, pollution control, resource conservation, a safer workplace, and reduced drudgery. The growing world population will according to Munack (2002) put new challenges on food production, and increasing prosperity will enable more people not only to look after their daily food but consider its quality, too. Animal production the world over has been and still being done under two major programmes of *open range* and *confinement management* methods; the latter may be *partial* or *total*. Confinement has already met with acceptance, particularly in areas of high land value and mostly in the developed countries of the world. In most developing countries, Nigeria inclusive, production is mostly by open range management method and where the confinement method is used it is just as shelter from direct sun, rain and heavy wind as well as protection against predators and theft. Not much consideration is given to the actual needs of the animal apart from their feeding and physical health.

Under tropical climatic conditions animals often suffer from heat stress which induces thermoregulatory and biological changes that lead to impairment of production and reproduction (Abdel-Ghani and Hathout, 1966; Hafez, 1968; Habeeb et al., 1996; Farghaly et al., 1997; Marai e t al., 1995; 1999; 2002a; 2006). These changes include disturbances in metabolic, water, protein, energy and mineral balances, enzymatic reactions, hormonal secretion and blood metabolites; depression in feed intake efficiency and utilization so also are reduction in milk yield and growth rate (Johnson, 1980; Wittroff et al., 1988, Habeeb et al., 1992; Kasa and Thwaites, 1992; Marai et al., 1995; 2001, 2002a). Armstrong (1994) stated that dairy cows respond to heat stress in such ways as reduced feed in take, increased water intake, changed metabolic rate and maintenance requirements, increased evaporative water loss, increased respiration rate, changed blood hormone concentration and increased body temperature.

This article reviews the effect of environmental factors on the productivity of farm animals in the temperate and subtropical regions and the possible adaptation for an enhanced production in a tropical area particularly Nigeria.

Livestock heat stress indicator

Heat stress occur when any combination of environmental conditions cause the effective temperature of the environment to be higher that the animal's thermoneutral (comfort) zone, (Hafez,

1968; Gwasdauskas et al., 1975; Fuquay, 1981; Collier et al., 1982; Armstrong, 1994; Ogunjimi, 2007). According to Buffington et al., (1981), Armstrong, (1994) and Marai and Rashwan, (2004) four environmental factors of air temperature, relative humidity, air movement and solar radiation influence effective temperature. However, the relationship with the relative humidity seems to be the most important, since the feeling of warmth under hot ambient temperature increases with high relative humidity (Marai et al., 2002a). To estimate the extent of heat stress induced by an animal's environmental condition at various times, a temperature-humidity index, THI, according to the livestock and poultry heat stress index (LPHSI, 1990) was developed. This takes into consideration the fact that the stressfulness of an environment was found to be a major function of the interaction between temperature and relative humidity of an enclosure. For cattle, sheep and goat THI is cited in the Agricultural Engineering Guide, Clemson University, Clemson, SC 29634, USA, (Marai et al., 1999) using the following formula:

$$THI = db^0F - (0.55 - 0.55RH)\ (db^0F - 58)$$

Where db^0F is dry bulb temperature in Fahrenheit and RH = RH%/100. Marai et al., (2001) modified this formula for rabbit's situation in the subtropical region of Egypt as:

$$THI = db^0C - (0.31 - 0.31RH)\ (db^0C - 14.4)$$

where db^0C is dry bulb temperature in Celsius.

The THI values were classified as < 22.2 = absence of heat stress, 22.2 ≤ 23.3 = moderate heat stress, 23.3 ≤ 25.6 = severe heat stress and 25 6 and above = very severe heat stress for larger animals such as cattle, sheep and goat (Marai et al., 2000). While for rabbits the values are < 27.8 = absence of heat stress, 27.8 – 28.9 = moderate heat stress, 28.9 - 30 = severe heat stress and 30 and above = very severe heat stress (Marai et al., 2002a).

Growth performance as affected by heat stress

It has been found by various researchers that there is an optimum temperature under which animals will produce profitably, this temperature is also observed to vary from animal to animal and that within the same age group, it varies with breed, age, sex, weight and condition. For each species, growth ceases near some low and high limiting temperatures at which survival is impossible. Growth according to Hafez, (1968); Marai et al., (2002a) involves a complex set of metabolic events which are genetically and environmentally controlled. Marai et al., 1995 observed that summer heat as compared with winter decreased significantly the relative growth rate and daily solids gain of Friesian calves. The depression in growth of heat stressed calves may be attributed to the decrease in

voluntary feed intake and thyroxine level which cause the decrease in anabolic synthesis and increase in catecholamines and glucocortcoids (Thompson et al., 1973; Marai et al., 1995), Table 1.

Generally, heat stress (i.e. increase in perception of warmth during the hot climate conditions) induces decline in feed intake, weight gain, feed efficiency in livestock. Marai et al., (2005) on rabbits concluded that heat stress induced a highly significant ($P < 0.01$) decline in each of final live weight, daily weight gain, food intake, final body solids, daily body solids gain, plasma T3 hormone, total proteins, albumin, globulin, total lipids, glucose, electrolytes (Na, K, Ca, Mg and P), pre-slaughter weight and kidneys with fat weight. However, in contrast hot conditions were accompanied by a significant ($P<0.01$) increase in water intake, body water concentration (mg/100g body solids), plasma urea-N, creatinine and physiological body reactions (respiration rate and rectal, skin and ear temperatures).

Armstrong (1994) stated that when temperature exceeds 27^0C even in low humidity the effective temperature is above the comfort zone for high producing dairy cows (Armstrong, 1994). Dairy cows, according to Armstrong (1999) respond to heat stress in such ways as: i) reduced feed intake, ii) increased water intake, iii) change in metabolic rate and maintenance requirements, iv) increased evaporated water loss, v) increased respiration rate, vi) changed blood hormone concentration, and vii) increased body temperature. In growing rabbits Marai et al., 2001, reported that the final live body weight, daily weight gain, feed intake and digestibility coefficients of dry matter (DM) and crude protein (CP) were lower while water intake, water/feed ratio were higher for summer seasons than for the winter season when fed the same diet and regime.

Table 1

Growth and reproductive performance of female rabbits as affected by heat stress*

Items	Winter	Summer	References
Daily weight gain	38.5	32.6	Chiericato et al. (1996)
(g)	26.0 ± 0.4	20.0 ± 0.4	Ayyat and Marai (1997)
	21.4	16.1	Habeeb et al. (1997)
	36.6	25.5	Boiti et al. (1992)
Conception rate	71.1	66.3	Bassuny (1999)
(%)	57.0	20.0	Marai et al. (2001)
Gestation length	31.0 ± 0.2	30.0 ± 0.1	Bassuny (1999)
(days)	32.0	33.0	Mahrose (2000)
	32.0	33.0	Marai et al. (2001)
Kit weight (g) at			
Birth	64.0 ± 2.9	60.0 ± 3.3	Bassuny (1999)
	56.0	48.0	Habeeb et al. (1999a)
	53.06	50.4	Marai et al. (2000a)
21 days	329.0 ± 11.2	305.0 ± 15.3	Bassuny (1999)
	282.0 ± 17	267.0 ± 19	Habeeb et al. (1999a)
	380.0 ± 3.9	371.0 ± 2.8	Marai et al. (2000a)
28 days	472.0 ± 14.2	437.0 ± 17.2	Bassuny (1999)
	422.0 ± 21.0	374.0 ± 23.0	Habeeb et al. (1999a)
	525.0 ± 4.6	526.0 ± 4.6	Marai et al. (2000a)
Litter size (no. of kits)at			
Birth	6.6 ± 0.2	5.8 ± 0.2	Ayyat and Marai (1998)
	7.3 ± 0.3	6.0 ± 0.3	Bassuny (1999)
	7.0 ± 0.2	7.2 ± 0.1	Habeeb et al. (1999a)
Weaning	5.3 ± 0.2	3.8 ± 0.2	Ayyat and Marai (1998)
	5.4 ± 0.2	4.5 ± 0.3	Bassuny (1999)
	6.2 ± 0.1	5.0 ± 0.1	Habeeb et al. (1999a)
Mortality (no.of kits) at		2.6 ± 0.2	Ayyat and Marai (1998)
Birth	1.7 ± 0.1	7.0 ± 0.2	Habeeb et al. (1999a)
	6.0 ± 0.5	0.6 ± 0.1	Ayyat and Marai (1998)
Weaning	0.4 ± 0.1	10.0 ± 1.0	Habeeb et al. (1999a)
	0.0		
Average milk yield (g/100/day)			
1st week	96.8 ± 7.9	105.0 ± 17.3	Nasr (1994)
	109.0 ± 5.2	98.0 ± 9.1	Habeeb et al. (1999a)
2nd. week	156.0 ± 9.7	112.8 ± 9.5	Nasr (1994)
	157.0 ± 10.1	158.0 ± 10.0	Habeeb et al. (1999a)
3rd. week	172.8 ± 14.5	135.7 ± 17.3	Nasr (1994)
4th. week	85.6 ± 11.6	83.5 ± 13.4	Nasr (1994)

*Source: Marai et al. (2002)

The depression in body weight gain may be due to the impairment of feed intake, the apparent decrease in feed digestibility and a consequent shortage of energy substrates; this is as a result of a depression in the production of digestive enzymes due to heat stress (Habeeb et al., 1992).

Reproductive performance as affected by heat stress

According to Wolfenson et al., (1995, 2000) and Jordan, (2003) the effect of heat stress on reproductive performance of animals is noted worldwide and it inflicts heavy economic losses on the industry. Puberty between the same breed and sex of animals is affected by several environmental factors such as ambient temperature, relative humidity, photoperiod and nutrition level, of which ambient temperature is the most important (Esmay and Dixon, 1986; Marai et al., 1991, 2002a). In particular, summer heat stress is the major contributing factor to low fertility in lactating cows in hot environments, (Wolfenson et al., 2000; Marai et al., 2002a). These effects of heat stress have been attributed to high temperatures above the thermo-neutral (comfort) zone of the animal and that cool seasons appear to preserve fertility and reduce the risk of reproductive disorders, irrespective of the level of milk yield. Rabbit puberty was found to be delayed (Daader and Seleem, 1999) and, accordingly, age at first mating was increased (Daader et al., 1999a, b) with increasing environmental temperature, Table 2.

Conception rate in animals are also significantly affected by severe heat stress and seasonal variations (Marai et al., 2002a). Ibrahim (1994), and Bassuny (1999) found that conception rate decreased significantly in summer and autumn when compared to winter and spring kindling seasons in rabbits. Sittmann et al., (1964) revealed that female rabbits refused mating most frequently in autumn months, but less frequently in spring months. He further stated that the conception rate from forced mating which were practiced in such cases was, generally, low and inversely proportional to the seasonal frequency of this type of mating. In adult female rabbits, the conception rate, litter size and weight at weaning and pups pre-weaning weight gain decreased while pre-weaning mortality rates increased due to heat stress (Marai et al., 2001).

Table 2
Reproductive performance as affected by heat stress in male rabbits*

Items	Winter	Summer	References
Ejaculate volume	0.69	0.22	Pingel and Abo-El-Ezz (1981)
(ml)	0.68 ± 0.04	0.38 ± 0.05	El-Sherbiny (1994)
	0.40 – 0.71	0.23 – 0.51	Marai et al. (1996)
Advance motility	53.4 ± 3.02	9.2 ± 2.23	Marai et al. (1996)
(%)	43.21	29.29	Daader et al. (1997)
	50.50	47.50	Daader et al. (1997)
Dead spermatozoa	25.5	30.30	Pingel and Abo-El-Ezz (1981)
(%)	17.0 ± 1.40	28.6± 3.44	Marai et al. (1996)
	28.64	42.93	Daader et al. (1997)
Sperm concentration	517.4	156.6	El-Sherbiny (1987)
(10^6 x ml)	237.0	189.0	Ibrahim (1996)
	486.8 ± 37.0	23.6 ± 3.44	Marai et al. (1996

*Source: Marai et al. (2002)

Environmental temperature influences reproductive function in the male by altering spermatogenesis and reducing semen quality, leading to decreased male fertility (Curtis 1983; Casu et al., 1991). The seasonal incidence of estrus in sheep is inversely related to the day length and latitude. At the equator, where the day length is constant, any seasonal sexual activity is probably conditioned by environmental temperature, rainfall, pasture condition and nutrition. The onset of sexual season in sheep has been experimentally modified by alteration of the photoperiodic environment (Hafez, 1952).

Hafez (1987) reported that the sexual activity of rams was the lowest in summer and the highest in autumn followed by late winter and spring, respectively. However, Abi-Saab and Hamadah (1984) explained that the lowest semen quality was during summer and winter and the highest was during the period of change in daylight duration (i.e. during autumn and spring). Sperm output and semen characteristics in ram were adversely affected with exposure to long daylight (long daylight is associated with an increase of ambient temperature). The time of birth in Nubian (Zaraibi) goats of Egypt according to Marai et al., (2002b) was found to have a significant effect on age at first kidding, kidding interval and kilogram kids produced at birth and at weaning/lifetime of doe, abortion rate and litter size at birth.

Effects of season of kindling were found to be highly significant on conception rate, gestation period, total litter weight at birth, litter weight at 21 days of age and weaning and kit weight at birth (Marai et al., 2006). Uiberg and Burfening (1967) found that conception rate was reduced if the ambient temperature was high enough to elevate rectal temperature of females by 1 to 2^0C. During the hottest season (during the very severe heat stress in summer), most of the estimated values were the lowest, while kindling interval and pre-weaning mortality were the highest (McNitt and Moody, 1991; Bassuny, 1999, Marai et al. 2006). For Nubian (Zaraibi) goats of Egypt, age at first kidding, kidding interval, litter size at birth and kilogram kids produced at weaning/doe lifetime in November-December surpassed those at February-March (Marai et al., 2002b). Hence they concluded that the time of birth had a significant effect on age at first kidding, kidding interval and kilogram kids produced at birth and at weaning/lifetime of doe, abortion rate and litter size at birth.

In rabbits, high pre-weaning mortality rate may be attributed the direct effect of heat stress on the sensitive young offspring, in addition to a reduction in dams milk production due to general depression of metabolic activity in such conditions (Shafie et al., 1984; Ayyat et al., 1995; Marai et al., 1996; 2001)

Physiological body reactions as affected by heat stress

Animals exposed to high ambient temperature try to balance the excessive heat load by using different means to dissipate, as much as possible, their latent heat. Generally, if such fails, the animals use other strategies that include: depression in feed intake, utilization efficiency,disturbances in water, protein, energy and mineral metabolism balances, enzymatic reactions, hormonal secretions and blood metabolites (Hafez, 1968; Johnson, 1980; Wittroff et al., 1988; Habeeb et al., 1992; Sallvik and Pedersen, 1999). Under heat stress animals' pulse rate (Ismail et al., 1995), rectal temperature and respiration rate (Marai et al., 1997; El-Darawany, 1999) and sweating increased, Table 3. With high rectal temperature the reproductive traits of female animals are seriously impaired, conception rate decreases, mortality increases while size of litter and weight at birth of the kids are all adversely affected reducing the profit margin of the husbandman (Lanada, et al., 1999; Marai et al., 2002; Wabacha et al., 2004;). In male rams increased rectal temperature influences reproductive function by altering spermatogenesis and reducing semen quality, leading to decreased fertility (Curtis, 1983; Casu et al., 1991). In rabbits according to Marai et al., (1994) increase in rectal temperature may be due to a failure of the physiological mechanisms to maintain the thermal balance.

Table 3
Physiological body reaction in rabbits as affected by heat stress*

Items	Winter	Summer	References
Respiration rate	69.0	190.0	Johnson et al. (1957)
(rpm)	143.0	244.0	Abd El-Malek (1967)
	98.5	133.0	Marai et al. (1994a)
	79.4 ± 1.8	125.2 ± 1.7	Gad (1996)
	81.9 ± 2.1	127.0 ± 1.6	Gad (1996)
	97.7 ± 0.04	108.5 ± 1.4	Marai et al. (1996)
Air temperature	9.6 – 30.2	37.2 – 39.4	Gonzalez et al. (1971)
(^{0}C)	31.5 ± 0.42	37.2 ± 0.13	Gad (1996)
	31.5 ± 0.33	37.0 ± 0.10	Gad (1996)
Rectal temperature	39.1 – 39.3	39.1 – 40.5	Gonzalez et al. (1971)
(^{0}C)	38.5	40.0	Marai et al. (1994a)
	39.1 ± 0.07	40.2 ± 0.05	Gad (1996)
	39.0 ± 0.05	40.1 ± 0.06	Gad (1996)
	39.4 ± 0.14	39.8 ± 0.09	Marai et al. (1996)
Skin temperature	39.0 ± 0.09	40.4 ± 0.06	Gad (1996)
(^{0}C)	38.9 ± 0.06	40.3 ± 0.06	Gad (1996)
Daily feed consumption	159.1	110.3	Marai et al. (1994a)
(g)	152.2	102.3	Marai et al. (1996)
	101.0 ± 0.5	75.0 ± 0.05	Habeeb et al. (1997)
Daily water intake	268.0	325.4	Marai et al. (1994a)
	390.5	616.6	Marai et al. (1996)
	285.0 ± 6.0	331.0 ± 6.0	Habeeb et al. (1997)

*Source: Marai et al. (2002)

THE CHALENGE TO THE NIGERIAN AGRICULTURAL ENGINEER

Modern animal husbandry which is the science of raising of livestock profitably, through a careful selection and breeding, adequate feeding, proper maintenance of health, and the supply of appropriate housing is geared towards a monetary economy; the farmer keeps an animal with the eventual aim of selling it or its products for profit in line with the findings of Soyebo and Jibowo, (2002). It has been noted from the various reviewed works that the comfort level of an enclosure is significantly a function of the interactions between the ambient temperature and relative humidity. This interaction depending on the levels of both temperature and humidity, produces either heat or cold stress that affect the productivity of farm animals generally. Heat stress is the most appropriate term in a tropical climatic condition; this affects such production characteristics of feed intake, weight gain, and feed utilization efficiency, level of core body temperature, respiration rate, pulse rate and reproductive traits. Table 4 derived from personal research work reports the reactions of rabbits as affected by level of heat stress in a tropical environment Ogunjimi, 2007). The nature of effect on the animal will seriously depend on the type of animal, age, sex and condition of health. Reduction of heat stress can reduce or even eliminate these effects and ultimately the possible attendant production losses.

Table 4
Growth and physiological performance of rabbits as affected by heat stress index (THI)*

Rabbit characteristics	THI mean values for difference buildings (^{0}C)			
	50%/90^0 32.49	50%/45^0 33.82	30%/90^0 34.21	30%/45^0 35.40
Daily weight gain, (g)	79.58	75.82	74.17	62.89
Feed efficiency, (%)	68	65	61	55
Pulse rate, (bpm)	173.18	180.62	197.70	204.16
Rectal temperature, (^{0}C)	37.85	38.93	39.11	39.46
Respiration rate, (rpm)	41.08	46.78	47.04	54.42

*Source: Ogunjimi, (2007)

In tropical areas, alleviation of the heat load by providing suitable feeding, housing and management may help heat-stressed animals to express their genetic potentialities. This conforms to Beede and Collier (1986) suggestion of three basic management schemes for reduction of thermal stress which are: 1) physical modification of the environment, 2) genetic development of breeds that

are less sensitive to heat, and 3) nutritional management. Going through the various results of studies in livestock production and their interactions with their environment, the agricultural engineer have a lot to do in improving both the income and nutrition level of the developing nations from animal production. The agricultural engineer's challenge is to provide a thermally comfortable environment for the stock through physical modification while considering all the characteristics of both the animal, and the building and its equipment. The engineer is both theoretically and professionally equipped to design and construct an appropriate system for this purpose. In the design process he considers the animal physical, biological and production characteristics combined with the environmental factors of the location and building parameters to arrive at the most appropriate.

In considering the animal characteristics, the agricultural engineer employs his knowledge of livestock characteristics of species feeding pattern; heat and moisture production and dissipation; waste and wastewater production characteristics, gas and particulate contaminants; physical characteristics of average weight (age-to-age grouping); foot pattern, size and physiological characteristics of sweating or nonsweating nature. The forgoing characteristics of the animal in conjunction with the environmental factors of maximum and minimum temperature, relative humidity, solar radiation, length and intensity of light, wind speed, and rainfall duration, distribution and annual intensity are the tools in the hand of the agricultural engineer for the provision of an environmentally comfortable building for the farm animal.

Designing a micro-environment for livestock production encompasses an effective combination of the various animal, environmental and building parameters in arriving at the design data for each of the building and handling facilities. The resultant data arrived at by the design should be such that will provide a thermally favourable environment for both the stock and the husbandman. The animal heat and moisture balance rate he must consider critical with the prevailing surrounding environment, the ventilation rate and the building structural form and layout. He (the engineer) considers the orientation of the building as very critical in the maintenance of heat and moisture balance in a livestock building, knowing fully well that most holding pen areas do add to the tropical heat stress because they lack ventilation. Building orientation in a humid tropical area should be one with the long axis is an east-west direction; this will reduce the heat load due to the direct incidence of morning and evening sun; the area under this type of building will be cooler this conforms with the findings of (Buffington and Skinner 1980; Boutet 1987; Armstrong 1994; Barrington et al 1994; Ogunjimi 2007).

An appropriate building orientation with adequate ventilating openings located effectively will provide the required air movement that is mostly needed for natural ventilation in a tropical developing nation where power generation and distribution is highly inefficient and costly. To improve the thermal comfort level of stock houses the design should be provide for air movement through adequate side openings and roof ridge vent that will encourage ventilation by thermal buoyancy particularly when the roof is steep and ridge vent is adequate this is as observed by Ogunjimi (2007). A steep roof slope of about 33% (4 in 12) with a ridge opening equal to 5cm/3m of building width but never less than 20cm is required to provide an air volume large enough to remove quickly adequate heat and moisture from within the building (Barrington, 1994; Ogunjimi, 2007).

For the design of the physical structure of the building the engineer is in position to select the appropriate construction material(s) that will be efficient in both conservation and quick dissipation of heat from the building, allow good water removal from within and a high level of sanitation. In the construction, he decides the various material combinations that will provide good strength in use, heat conservation and/or dissipation, constant scrubbing and discourage the habitation of microorganisms and rodents. The location he selects should be such that will not give chance to ponding of runoff water around the building and hence condensation inside the building. Good drainage should be one of his major concerns too in order to provide a good environment for both husbandman and customers. It is hereby expedient for more research works to be carried out on the effect of environmental factors of livestock buildings considering various animals to add value to the structural designs for efficient production.

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DEVELOPMENT OF SOFTWARE FOR BILLS OF ENGINEERING MEASUREMENTS OF WIND POWER ELECTRICITY SUPPLY TO RURAL AREAS OF NIGERIA

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ABSTRACT

A Software for design of power supply system using wind system was developed. The software has a size of 30.6 MB; it requires a computer of minimum speed of 166 MHz (FOS) and random access memory of at least 64 MB and a hard disk space (HDD) of 40 MB to function well. A windows operating system of at least windows 98 and office application that have Microsoft Access and internet explorer are also required for proper functioning of the software. The software has the advantage of saving information in a database system. It encompasses forms that design and (or) modify the design system. The input required for running the software are the basic design specifications like load, power factor, growth rate and locality name. Additional inputs are average wind speed, air density, system voltage, inverter size, regulator efficiency, charge controller size, statistics factors (scale/shape factor), battery selection and Turbine model. The output of the software shows the required bills of engineering measurements. The software was tested with some hypothetical cases and the bills of engineering measurements were obtained.

KEYWORDS: Bills of engineering measurements, rural areas, software, and wind energy.

1.0 INTRODUCTION

According to World Energy Council and FAO (1999) about 85% of population in developing countries (including Nigeria) live in rural areas and most rural areas in Nigeria lacks electricity supply which is the most easily and commonly available form of energy that could be converted from one form to another. This is due to lack of enough funds by sponsors of rural electrification schemes. Globally, the numbers of rural households with access to electricity have more than doubled in the 1970 –90 periods, this increase just kept up with population growth (WEC and FAO,1999).Early electrification programme focused on extending the grid because it is asserted that decentralized systems do not compete with conventional grid extension. Where grid power is possible and viable there should be no question about providing it. This viability is based on the assumption that there is sufficient generation and transmission capacity.

Rural electrification programs have typically concentrated on connecting rural villages and remote areas to a national grid owned by the power holding company of Nigeria (PHCN). The tendency is to extend the grid incrementally reaching towns and settlements in order of increasing capital costs thus, remote areas with small populations are likely to be the last to receive an electricity supply. By contrast, the cost of installing decentralized system is independent of the status of the transmission and distribution system and thus can decrease the cost of connectivity drastically (WEC and FAO, 1999).

The cost of grid connection to the national grid has increased due to lack of adequate bulk power supply at 132/33 KV level in strategic locations throughout the Federation (NEPA Public Relations Division, 2000) resulting to some 33 KV feeders extended by as much as 350 Km (including tee-offs), which is longer than the recommended length of 150 Km (Yusuf, 2000). Although isolated diesel power stations can provide alternative source of power, there is difficulty in the fuel and spare parts sourcing (Yusuf, 2000) This difficulty experienced in obtaining diesel fuel and spare parts for maintenance and running makes the prospect of using renewable technology options bright since most rural areas are blessed with abundant multiple energy resources.

Wind energy systems convert the kinetic energy of moving air masses into electrical energy by using conventional rotating generators. The maximum power available is directly proportional to the cube of the wind velocity thus performance is very sensitive to the wind speed conditions at prospective sites. Global installed capacity of wind energy systems continues to rise rapidly from 3100 MW in 1993 to about 4800 MW in 1995 (Reddy, Williams and Johansson, 1997). Wind power is initially deployed in industrialized countries but is now growing rapidly in some developing countries e.g. wind capacity in India reaches 970 MW in early 1998 (WEC and FAO ,1999). The cubic relationship of energy availability to wind speed makes it critical to assess wind resources for wisely usage of wind technology. The development of computer-based models to enhance the applicability of meteorological data is facilitating better design decisions.

Wind power is technologically ready to be deployed as a major option for providing electricity to the grid. Wind is an intermittent energy source and thus not particularly well suited to provide reliable power in rural areas isolated from a multi-resources grid. Some sort of energy storage is required typically lead-acid battery, which have high capital costs and limited life. However, in good resource areas wind turbines are cheaper per KW than the principal alternative photovoltaic. Site specific analysis is required to determine the most appropriate technology mix but it is not unusual to find that a combination of wind turbine(s) and photovoltaic power, perhaps supported by a diesel generating set provide the most economical technology mix for a given load(WEC and FAO ,1999).

Globally, Nigeria is located within low to moderate wind energy zone (Ojosu and Salawu, 1990). According to Francis (2002), Ojosu and Salawu did the most comprehensive nationwide study on wind energy availability and potential in Nigeria in 1989. The study used Data on Wind speeds and directions from

the Nigerian Meteorological office, Oshodi near Lagos. From the study four different wind zones/regimes were identified (Francis, 2002). The estimated maximum energy obtainable from a 25 m diameter wind turbine with an efficiency of 30% at 25m height is about 97 MWh/year for Sokoto a site in the high wind speed regions, 50MWh/year for Kano, 25.7 MWh/year for Lagos and 24.5 MWh/year for Port Harcourt (Francis, 2002).

A few windmills were installed in the northern States in the 1960's. In Badagry, there is a propeller type windmill employed for pumping water for use of a large portion of the town's population. The Gear type models were installed in most parts of Katsina State. In different surveys of the old installations conducted by UAC – T & E, UNDTCD and Sokoto Polytechnic, it was found that most of the above wind mills failed because of inadequate maintenance. A number of wind powered water pumps have been installed in some northern states, notably at Goronyo in Sokoto State, Kedada in Bauchi States and in Katsina State. At present, a 5 KW pilot wind turbine/generator is under tests at Sayya Gidan-Gada village in Sokoto State. The performance so far is satisfactory (Ojosu and Salawu, 1990; Francis, 2002).

Design, planning, and bills of engineering measurements presentation are not only time consuming but are also error prone. This indirectly leads to high labour cost and delay. Therefore software which can perform the design, planning, and bills of engineering measurements presentation can reduce the labour cost and time requirements.

Information could be very cumbersome and time- consuming to obtain but the computer could make information readily accessible if the data is stored in a retrievable form. This easy accessibility of information can assist in planning, thus sponsors of rural electrification could utilize their resources better and more efficiently.

This work aims at studying the viability of using wind energy sources to expand access to energy in rural areas, and in developing a computer program (software) which will assist in designing power supply to rural areas in Nigeria using wind energy.

2.0 DESIGN SYNTHESIS AND ANALYSIS

2.1 Design Concepts

The design analysis is based on the general specification as given in the regulations and recommendations of International Electro technical Commission (IEC) and the laws of the Federation of Nigeria (Gongola State Rural Electrification Board, 1980).

2.2 Wind Energy System Design

Complete wind power system including a wind turbine, tower, and related equipment such as batteries are called wind energy conversion systems (William and Rose, 1965). Wind turbines designed to generate electricity are known as wind turbine generators (WTG).

2.3 Wind Electric System

There are two broad classifications of wind-electric systems: Stand-alone and Grid connected (William and Rose, 1965; Wind Energy Manual, 2005).

2.3.1 Stand Alone Systems

Stand – alone systems act as completely Independent Power Sources. Onsite battery banks store electrical energy for use during low periods. Stand-alone system consists of a turbine, voltage regulation, batteries and inverter. Figure 2.1 depicts a

schematic diagram of an isolated wind-electric system.

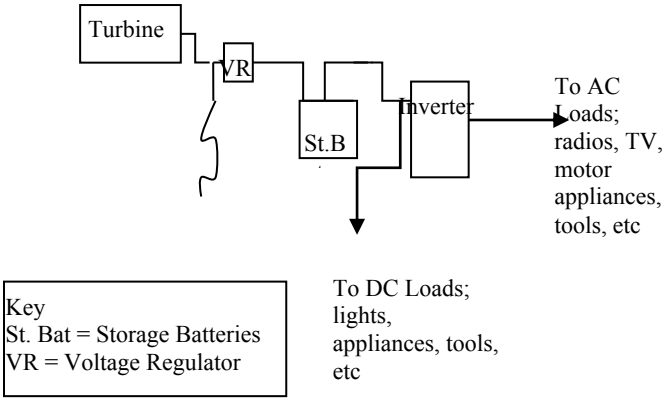


Figure.2.1 an Isolated Wind Energy Conversion System

2.3.2 Grid Connected Systems

Grid connected systems produce electricity identical in frequency and voltage to utility supplied electricity that is they are synchronized with utility lines. Grid interconnected wind systems do not have onsite energy storage systems and are inoperable when the utility grid is not energized. A regulator always controls the battery charging DC voltage. During periods of little or no wind, the utility company supplies power to augment onsite electrical demand that cannot be met by the wind system. Excess electricity obtained when the wind power output is greater than the electrical demand, is fed back through the utility grid.

Basically, two kinds of utility grid-interconnected wind systems exist.

1) Synchronous inverter systems or variable – speed constant frequency (VSCF) Systems.

2) Induction generator or constant – speed constant- frequency systems.

The solid-state synchronous inverter convert various DC voltage electricity into AC voltage electricity at the same frequency as the Grid line and requires 50 or 60Hz frequency to operate.

2.4 Wind Characteristics

Some of the most important wind characteristics pertaining to wind power applications include: average wind speeds; yearly, seasonal, and daily wind speed variations, local terrain effects, height effects on wind speed; sitting considerations and using statistical models to describe wind behaviour (William and Rose, 1965; Wind Energy Manual, 2005).

Analysis of wind data is not within the scope of this work. So, wind data should be analysed first. Wind characteristics will be considered as an input required for the software.

2.4.1 Wind Speed Variation with Height

Wind speed varies with height above ground surface. Wind speed is also affected by the type of surface over which the wind blows. The wind speed profile curves can be determined for various surfaces with the following formula (William and Rose, 1965; Wind Energy Manual, 2005; Ojosu and Salawu, 1990).

$$V_2 = V_1\left(\frac{h_2}{h_1}\right)^{\alpha} \quad \text{.....2.1}$$

Where V_1 = known (reference) average wind speed at a reference height,

V_2 = unknown speed at a second height,

h_1 = reference height,

h_2 = new height and

α = height correction exponent (surface roughness factor).

2.5 Statistical Models

To accurately predict the total yearly energy a wind turbine will produce at a given site the wind speed distribution must be determined. It is important to derive the

expected probability distribution of the site's wind speed. In order to know the effective or probability of the number of hour in a year for various range of velocity, the following relations are used to calculate the values for each of the distribution models (Asok, 1991; Katsoulis and Metaxas, 1992).

For Weibull,

$$T(V) = 8760.\exp\left(-\left(\frac{V}{C}\right)^{K}\right) \quad \text{.....2.2}$$

For Rayleigh,

$$T(V) = 8760.\exp\left(-\frac{1}{2}\left(\frac{V}{\sigma}\right)^{2}\right) \quad \text{.. .. ..2.3}$$

For Exponential.

$$T(V) = 8760.\exp\left(-\left(\frac{V}{C}\right)\right) \quad \text{….....2.4}$$

Where V = average wind speed (m/s),

σ = standard deviation,

C and K = scale and shape parameters of the Weibull probability distribution function.

According to Asok (1991), the wind speed probability distribution could be used to evaluate the followings:

i. The capacity factor for a particular wind turbine generator used in producing any form of energy.

ii. The probability for the wind speed to lie in a certain Interval or duration especially when the speed is above the cut in speed of the turbine.

iii. The mean wind power density.

2.6 Operating Characteristics of Wind Machines

Since the turbine would be selected from available turbines based on operating characteristics, there is a need to define such operating characteristics.

a) Cut-in-speed: This is the minimum wind speed at which the blades will turn to generate usable power.

b) Rated–speed: This is the minimum wind speed at which the wind turbine will generate its designated rated power. The output of most machines levels off above the rated speed.

c) Cut–out–speed: This is the upper level wind speed limit at which the wind turbines cease power generation and shut down.

2.7 Wind System Design Calculations

Energy output (Whr/day) is given by (William and Rose, 1965):

$$E = 24 \times \eta_S A.V^3 \quad \text{…….……2.5}$$

Where η_s = efficiency of system,

A = swept area of rotor (m^2),

V = daily average wind speed.

To determine the number of batteries required for the daily load, the owner must decide how many days of reserve that is desired. Storage batteries must be capable of operating the load during periods of little or no wind, without any electricity generated by the turbine. To determine the number of batteries required, the designer must know how much energy the batteries can store (energy capacity) and compare that to the daily load and desired reserve. Batteries are normally rated in amp-hours instead of watt-hours. The number of batteries required can be calculated from the following formula (Kaszeta and Garrett, 2000):

$$N_{bat} = \frac{W_{hrl} \times R_{days}}{E_{cbat}} \quad \text{……...2.6}$$

Where W_{hrl}= Watt-hours required by load,

R_{days}= Days reserve,

E_{cbat}= Energy capacity per battery (watt-hours).

By using the Ampere – Hour method battery capacity required is given by (Aliyu, 2005):

$$B_c = \frac{AH_C \times R_{days}}{D_{max} \times T_f} \quad \text{……...……2.7}$$

Where D_{max} = Maximum depth of discharge

T_f = Temperature correction factor.

Number of batteries in parallel required is given by (Aliyu, 2005):

$$NB_p = \frac{B_c}{B_r} \quad \text{..……2.8}$$

Where B_r = rated battery capacity.

Number of battery in series required is given by (Aliyu, 2005)

$$NB_S = \frac{V_{ns}}{V_{nb}} \quad \text{……2.9}$$

Where V_{nb} = Battery nominal voltage.

Then, Total number of batteries is (Aliyu, 2005):

$$N_{bat} = NB_p \times NB_S \quad \text{.. ..…….2.10}$$

Power in watts is given by:

$$P = \frac{1}{2}\eta_S \rho_a A V^3 \quad \text{…….……..2.11}$$

Where ρ_a = density of air.

3.0 SOFTWARE DEVELOPMENT AND TESTING

This work employed the use of the windows operating systems (windows 98, windows 2000 and windows XP). It also employed the use of the following application software.

i. Microsoft Access.

ii. Microsoft Visual Basic 6.0.

iii. Install Shield.

Microsoft Visual Basic 6.0 is an integrated windows-hosted development tool for basic programming , it allows creation of a new windows application, make modification to it, compile it, run it and debug it all within a single environment called the developer studio. This environment was used to develop the necessary source code for this work. It was selected because it is the favourite programming environment (Steven, 1998).

3.1 Algorithm Considerations

Since the computer program is an engineering analysis its algorithm was based on the conventional engineering approach. The requirements of the system are to be known first and it is based on these requirements that the system is to be analysed.

The algorithm of the program was:

- Start and Show Main Menu.
- Select from Menu.
- Based on selection go to File, Design, Administrator, Report or Help.
- If File, select Exit to end the program. Return to Main Menu or End.
- If Design, select New to design a new system or select Modify to modify an already designed work. Return to Main Menu.
- If Administrator, select User Password to select type of User and input password. Return to Main Menu.
- If Report, select Report to view/print the bills of quantity of already design work or select Price of Materials to view/print Prices of Materials, Return to Main Menu.
- If Help, select About Program to know brief information about the program or select Help Content to open Help content files. Return to Main Menu.

Figure 3.1, shows the main program flowchart.

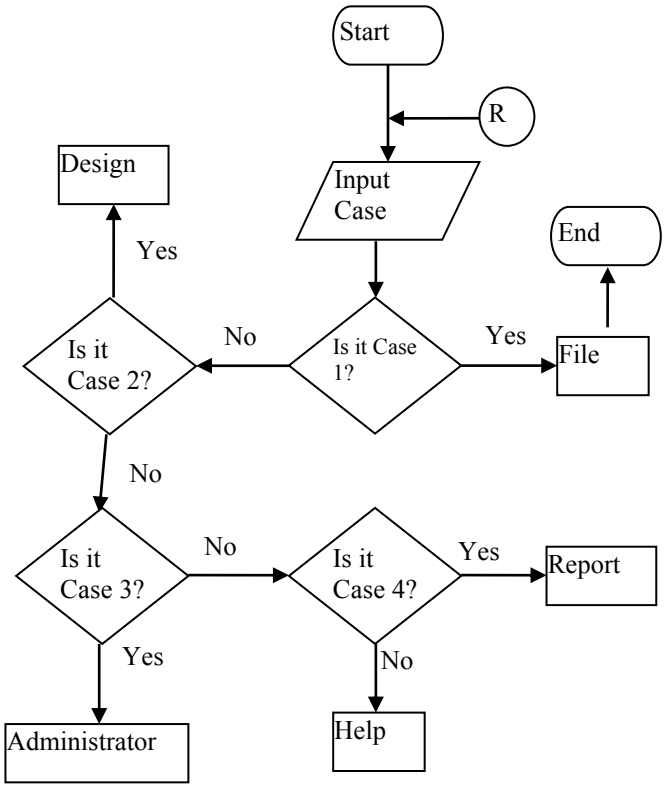


Fig.3.1 Main Program Flow Chart

The algorithm of Design (New) was:

- Input general requirements to design wind system.
- Calculate available wind hours using statistical data inputted.
- If stand-alone type of system design batteries, inverters and charge controllers.
- If grid connected or no back up required calculate power from turbine model selected.
- Design for street lighting if required.
- Continue with design and calculate all required materials.
- Store result if required.
- Generate Report if required.
- View Report and print if required.
- Return to main menu.

The algorithm of Design (Modify) was:

- Select locality from available localities (already designed work).
- Open and re modify data.
- Do same as Design (New).
- Save and Return to Main Menu.

The algorithm of Administrator. (User Password) was:

- Select type of User.
- Input name and password.
- Confirm Password.
- Save and Return to Main Menu.

The algorithm of Report (Design Report) was:

- Select locality from Database (already designed work).
- Select type of bills of engineering measurements.
- View/Print the Report.
- Return to Main Menu.

The algorithm of Report (Prices of materials) was:

- Select type of Material.
- View/Print the Report.
- Return to Main Menu.

The algorithm of Help (Help Content) was:

- Show Help files available.
- Select a file.
- View/Print the file.
- Return to Main Menu.

3.2 Main Features of the Software

The software is a menu-driven computer based program. It is a very robust and powerful data handling system for the design of rural electric power connection using wind. The use of the software is however not restricted to the design, it can also modify a design and store it. It is a comprehensive package designed to be user-friendly it is composed of many forms folders/files.

These forms are discussed below.

frmAbout: This form gives brief information about the software and the computer.

frmAdministrator: This form checks and allows the administrator to be able to add/modify the database.

frmDesignWork: This form is the one responsible for the design. In essence, it is the most important form. It comprises of many frames and commands that do specific things.

frmStartUp: This form gives the user the opportunity to select what he wants to do.

frmClose: This form shows the user that he has end the program.

frmTurbine: This form gives the user the opportunity to store turbine models and their specification.

pop_design_estimate: This is a form that allows the user to select design to show it bills of engineering measurements.

pop_save: This is a form that allows the user to select type of design to save.

pop_Modify: This form allows for modification of already designed work. It is a link to the database so that when a design is selected it can display the already used parameters which could be modified

3.3 Program Execution

To run the Software, click on windows <Start Menu> on the task bar, then <Programs> then the Wind Energy Software. It can also be run by double clicking the Wind Energy icon on the Windows Desktop if the programme shortcut already exists there. The program can run for the first time on the computer after installation. The installation CD can install automatically because it is auto run.

4.0 VALIDATION AND DISCUSSION

The input required for running the software are the basic design specifications like load, power factor, growth rate and locality name. Additional inputs are average wind speed, air density, system voltage, inverter size, regulator efficiency, charge controller size, statistics factors (scale/shape factor), battery selection and Turbine model (see figure 3.2).

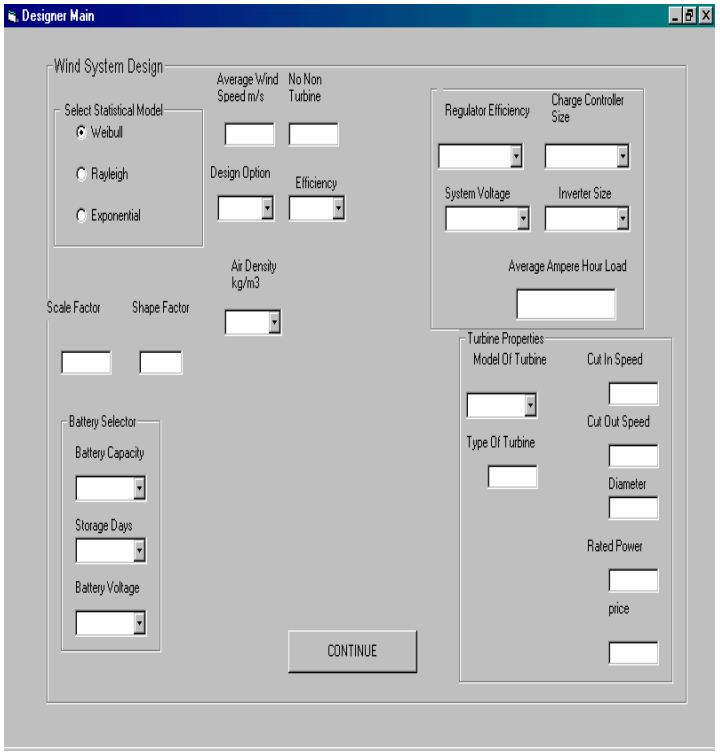


Figure 3.2. Input Requirements.

The output of the software is showing the required bills of engineering measurements (see figure 3.3).

Figure 3. Output Sample.

The first test problem was a case of a grid connected system of a known solution. The town was already designed for a grid connection. The bills of engineering measurements obtained from the software of the consumer service and the low voltage medium line are compared with the actual bills of measurements (see Table 1).

Table 1. Comparison of Bills of Engineering Measurements.

S/no	Materials	Actual Design Cost (₦)	Software Design Cost (₦)	Variation
1	Low Voltage Medium Line	4,499,581.20	4,532,626.00	0.73%
2	Consumer Service	245,015.00	245,015.00	0.00%
3	Street Lighting	278,615.50	283,450.00	1.74%

Actual Design cost Obtained from Ministry of Rural Infrastructure and Community Development Headquarters Yola, Proposed Electrification of Old Loko Bills of Quantity, 2001.

The comparisons of the bill of engineering measurements from the software indicate that the variation is 0.73% for low voltage line. While in street lightings a variation of 1.74% exists and no variation is obtained for the consumer service.

4.1 Limitation of the Software

Computers cannot exercise judgement or common sense so cannot handle any contingency other than those specified by the programmer. Thus intermediate solutions are beyond the specified limits. Technical support is included in the software so that when problems occur communication is facilitated between the user and the programmer for necessary updating of the software.

5.0 CONCLUSION

Wind Energy can be used to expand rural communities' access to electricity supply. The Software designed has the capability of designing, planning, and bills of engineering measurements presentation of wind power supply to rural communities. This software will help rural electrification sponsors to determine the cost of projects. It will also assist in reducing time required for design, analysis and report production and this entails that rural electrification sponsors using it can be more effective in their decisions.

The software has a size of 30.6 MB; it requires a computer of minimum speed of 166 MHz and Random Access Memory of at least 64 MB and a hard disk space of 40 MB to function well. A windows operating system of at least windows 98 and office application that have Microsoft Access and internet explorer are also required for proper functioning of the software.

The software designed also has the facility that will help in documentation since design is saved in a database. When modification is required it can also be done with ease.

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