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TABLE OF CONTENTS

Editorial Board … … … … … … … … … i

Aims and Objectives … … … … … … … … … ii

Table of Contents … … … … … … … … … iii

Developments in Grain Harvesting Mechanization
O. J. Olukunle … … … … … … … … … 1

Mechanized Tillage Operations in Nigeria: The National Agricultural Land Development Authority Experience
J. C. Adama and B. S. Elesa … … … … … … … ... 14

Effect of Knife Velocity and Compaction on Forage Chopper Cutting Efficiency
S. R. Bello and T. A. Adegbulugbe … … … … … … … 24

Determination of Appropriate Tractor Operator's Height using other Anthropometric Parameters
E. U. U. Ituen ... … … … … … … … … 31

Cleaning Loss Characteristics of a Conventional Stationary Rasp Bar Sorghum Thresher
K. J. Simonyan and A. B. Eke … … … … … … … … 40

Design of a Gari Fryer
O. O. Ajayi and O. J. Olukunle … … … … … … … … 51

Design and Development of Forage Chopper for Silage Making
A. L. Musa-Makama and A. P. Onwualu … … … … … … … 63

Development of a Locally Designed Rice Destoning Machine
K. S. Simonyan, I. S. Emordi and J. C. Adama … … … … … … 74

Validating ACPU Model for Agbogbo Catchment, Ile-Ife Southwestern Nigeria
A.P. Adegede, C.C. Mbajiorgu and O. O. Ogunkoya … … … … … 81

Information and Communication Technology in Extension, Educational Services and Revitalizing Agriculture in Nigeria
A. O. Raji … … … … … … … … … … 90

Guide to Authors … … … … … … … … … 101

DEVELOPMENTS IN GRAIN HARVESTING MECHANISATION

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ABSTRACT

In this study a review of grain harvest machinery is presented in order to bring to focus the past and present state of the art in grain harvesting mechanization and hence influence future trends in grain harvest technology. Grain harvesting mechanisation has come a long way, from the wooded implements employed by the early man, to the sickle, the scythe, the semi-mechanised methods, through the various conventional combines to the modern sophisticated combine harvester. The overall design of the combine harvester witnessed a significant transformation. Automatic controls and adjustments and non-conventional straw walkers that permit higher work rate have been incorporated. The most important improvement however is in comfort and ergonomics: protective structures, hydraulic and electronic controls, and automatic adjustments have made the use of the combine easier and safer for the human operator. Indigenous combines are also being developed in developing countries to avoid the high initial price of importation. It is believed the latter will enhance machine capacity, reduce post harvest losses and promote food security in Nigeria as well as in Sub-Saharan Africa.

KEYWORDS: Development, grain harvesting, mechanisation

1. INTRODUCTION

Combine harvesters introduced in the middle of the 19th century are generally used to harvest grains in developed countries in contrast to manual harvesting methods in the developing countries. Manual harvesting is however labour intensive and also time consuming. Timeliness is important during grain harvesting to reduce losses due to attack by rodents, insects, pests and adverse weather conditions. Thus, mechanical harvesting is important to obtain optimum output and returns during harvesting of grains.

Machines have been developed which can handle one or more unit operations involved in the harvesting of grains. However, the combine harvester is unique as it cuts, transports, threshes, cleans and stores the grain in one operation. Biondi *et al.*, (1996) identified combine harvesters and tractors as the symbol of modern agricultural mechanisation. According to Bosworth (1987) the requirements for the design of a combine include high capacity, compatibility with all types of crops, high cleaning efficiency, good maneuverability, operator's environment, ease of control and good straw recovery for baling. However, most of the extensive work done to date on the development of the combine harvester as reported by Tado *et al.*, (1998) has been done in developed countries. Kutzbach (1998) opined that the high production cost of combine harvesters require further improvement in structural development. In this study, a review of grain harvest machinery is presented as a basis for design of improved and appropriate indigenous combine harvesters.

Man has always tried to simplify the procedure of harvesting through mechanical means. As early as 500 BC, wooded implements were used for stripping ears of corn. The sickle was introduced in 280 BC. The scythe was developed later. The Gallic harvester was the first mobile harvesting equipment and it was introduced around 200 BC. The machine was animal drawn and consists of a wooden cart with a comb for stripping the ears (Griffin, 1973, Nakra, 1990). The McCormick

reaper was introduced in the 1830's and used to mechanize the cutting and gathering of grains. It cut the grain and raked it from the platform into bunches. However, the Moore Hascall harvester that was introduced later performed the basic functions of cutting, threshing and cleaning.

In 1864 and 1886, the Marvin Combine harvester and the Hauser harvester were patented. While in 1889 the steam-powered combine was patented by Daniel Best. The steam engine was mounted on the combine and a large steam tractor pulled the machine through the field. Horse drawn tractor-driven combines were introduced in the 1890's. The typical header width of this machine was 12.80m and the field capacity was between 36.42 and 50.59 hectares per day (Griffin, 1973). Samuel Lane was granted a patent on a machine known as combine harvester thresher in 1928.

Within this period Binders were used extensively to cut and gather small grains Massey Hariss introduced two combine harvesters in 1941 and in 1960 commercial production of combine harvesters began. These combine harvesters, and their components have been described by Kepner *et al* (1978), Shippen *et al* (1987), Jacobs *et al* (1983) and Nakra (1990). Biondi *et al* (1996) reported that over 80% of combines are still in conventional designs. However, there is an increasing demand for increase in output. Thus the width and diameter of the straw walker, sieve areas and the threshing drum have been increased in Europe to accommodate high straw yield of cereals and seed crops.

In North America, the trend is towards the use of axial rotors for threshing and cleaning. However, cylinders, which draw the crop over suitably shaped concave grids, are used in Europe. The latter is adjudged effective regardless of straw condition and moisture content. The new trend of threshing and separating units in Italy positioned a tangentially fed axial threshing and separating rotor behind and parallel with a conventional cutting table. This layout accommodates a large grain tank, disallows all the grains from passing through the whole machine and permits a compact design. A stripper header was developed at the Silsoe research Institute and is now in commercial production. Klinner *et al* (1987) reported the development of the stripper header and the mode of operation. Gale (1995) developed an automatic height control for the stripper header. He concluded that the rate of grain harvesting by conventional combines could be increased by 100% using the new development. Price (1993) discussed the major differences between the conventional cutter bar and the stripper header. The engines of combine harvesters increasingly show greater performance regarding thermal efficiency (from 30% in 1960 to 35% in 1989) at rated speed of 2000 to 2500 rev/min and specific power (from 11kW/dm^3 to 17kW/dm^3) in the same years. The power of the combine engine also increased from 44kW to 130kW. The trend towards more powerful models is very significant for combines and non-conventional ones show maximum power requirements

The work capacity of combine harvesters increased between 1960 and 1989 as can be inferred by the increase in rated power. The Italian type approval data in Biondi et al (1996) shows that the average cutting width increased from 3m in 1960 to about 5m in 1989, but the more powerful models have a cutting width of 6 to 7m. It is evident from the fore going that the overall design of the combine harvester witnessed a significant transformation. Automatic controls and adjustments and non-conventional straw-walkers that permit higher work rate have been incorporated. The most important improvement however is in comfort and ergonomics: protective structures, hydraulic and electronic controls, and automatic adjustments have made the use of the combine easier and safer for the human operator.

1.1 Development of Grain Harvesters

Development of grain harvesters started with the use of manual methods, to the semi mechanized methods, the combine harvesters and the modern combine harvesters with stripper headers and automatic controls.

1.1.1 *Manual Harvesting Methods*

Harvesting of grains is done manually by hand picking pods from plant stem. It could also be done by cutting the crop just below the head using knife, sickle and the scythe. In Africa and especially in Nigeria manual harvesting of grains is very prominent. However, this method is time consuming and labour intensive. Baryeh (1987) reported that losses with manual methods are generally lower than mechanical methods. His results showed that losses for manual harvesting varied from 0.5 to. 16.9% depending on the cowpea variety and method of harvesting. He classified manual harvesting as: pod picking, uprooting and shearing.

Baryeh (1987) conducted a research on these three manual methods and concluded that harvesting rates are generally low for manual harvesting ranging from 0.02 to 0.07 ha/hr, it has a high net yield but time consuming. The major problem of cowpea harvest is that it requires going through the field several times, thus making harvest cost, the major cost of production. After harvest, manual threshing is done using sticks; pounding using a wooden mortar and pestle could also do it. The threshed crop is then tossed into natural breeze and the grains are caught. Thus, the breeze carries the chaff and dust. According to Kaul and Egbo (1985), the man-hours required for these manual methods of threshing and winnowing are variable and depends on crop factors (such as variety and moisture content) and on worker attitude and supervision.

1.1.2 *Mechanical Harvesting Methods*

Baryeh (1987) reported the performance of modified models of cutter conveyor and rotary cutter on cowpea harvesting. He described the cutter conveyor (Fig. 1) as a two row self propelled machine with a 1m adjustable cutter bar, a 3.8 kW gasoline engine, an inclined rubber conveyor belt and a temporary cowpea hopper. The rotary cutter (Fig. 2) consist of a 0.3 m diameter saw at one end of a 55 mm diameter hollow minimum shaft 1.5 m long, a 1 kW gasoline engine at the other end of the shaft and a handle in between these components.

The combine harvester or combined harvester thresher is also known as the mobile threshing machine, because it differs little from the stationary thresher except that a crop is fed into a combine more evenly and continuously as it moves forward. The combine is highly sophisticated and exclusively designed to harvest the grains and other cereals grown today. The combine is unique as it cuts the crops, feeds the crops into the cylinder, threshes the seeds from the seed heads, separates the seeds from the straw, cleans the seeds, and handles the seeds until it is dumped into the truck or trailer for transportation.

Kepner *et al* (I978) reported that direct combining (cutting and threshing in one operation) is the most common harvesting method. Combining from the windrow involves an extra operation (windrowing) as compared with direct combining. It is however advantageous under certain conditions. Heavy windrow may stay in good condition for about 30 days, while in a light windrow; grains may begin to sprout much earlier. The method common in hot, dry climate is spray curing followed by direct combining. In this method a desiccant or a general contact herbicide is applied to kill the top growth. The crop is then direct combined before re-growth starts.

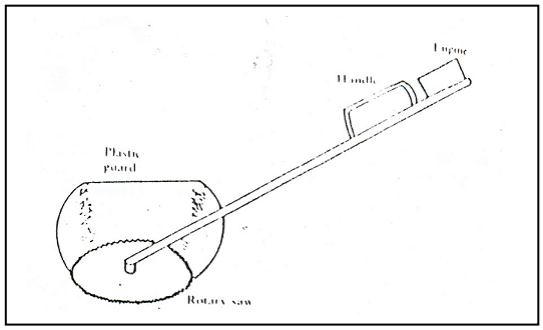


Fig. 1: Cutter Conveyor

Source: Baryeh, 1987

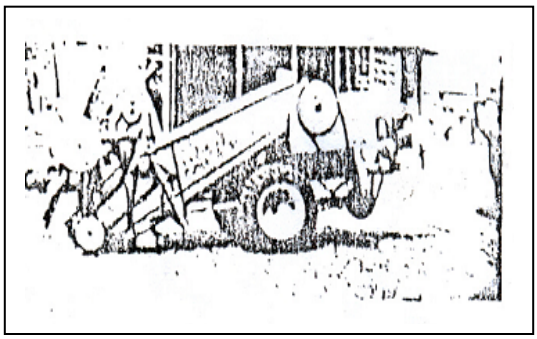


Fig. 2: Rotary Cutter

1.2 Classification of Combine Harvesters

Several types of combine harvesters have been designed and manufactured to meet various needs of grain producers. The selection of combines depends on the crop grown, the terrain, farm size and the capital available. Combine classification is normally done either on the basis of propulsion as self propelled, tractor- drawn and tractor-drawn engine-driven combines or on the basis of crop to be harvested as rice combine, cowpea combine and maize combine. The crop specific combines are also known as special combines. Combines also vary in size and they could be grouped on this basis, as single row, two rows, three rows and so on. The most useful and most prominent among combine types is the self- propelled combine harvester. Combines also differ not only by power source or point of attachment to the tractor but also by the types and arrangements of components. According to Jacobs *et al*, (1983) special combines could be fitted with special headers such as corn headers or other components, which differentiate them from conventional combines. The type of header, width of the header and hence the capacity of the combine can also be used to classify combine harvesters.

1.3 Self-Propelled Combine

The self-propelled combine is the most popular grain-harvesting unit used in modern agricultural production especially in developed countries. These combines are powered by gasoline and provide power for traction and operation of special features attached to self propelled combines which include controls, dials, gauges, air conditioned cabs, heaters, and electronic devices. (Jacob *et al* 1983, Kepner *et al* 1978 and Culpin 1982). The self-propelled combine is easier to manoeuvre and more convenient when opening out the field as it eliminates the back swath. Its weight on the traction wheels also helps when working in wet soil condition and on hilly land (Lovegrove, 1978). According to Culpin (1982), self- propelled combines are well suited for large farms and ranches, but smaller models can be purchased for area where fields are small. For these big machines the relative amount of costs for engine, drive train and drivers compartment on total machine costs decreases. That is the reason why more and more self propelled machine types are on the market. For combines the transition from pull type to self-propelled combines has taken place decades of years ago; especially for smaller plots with numerous plot changes and road transportation, the self-propelled combines won the market. The advantages like optimal technical adaptation to the field operation, good view to the crop intake, infinitely variable hydraulic transmission, good maneuverability and short preparation time led to the introduction of self propelled combines. This trend is particularly obvious for forage harvesters. Pull type and tractor mounted choppers have lost importance. For sugar beet harvest, 6-row harvesters are

further increasing, Bertram (1996). While in France harvesters and loaders are used as tractor-mounted implements, in Germany self-propelled 6-row hopper harvester gained increasing market share in recent years. The big 6-row hopper harvesters have the problem that hopper capacities of the largest harvester are only sufficient for field lengths of approximately 700 m when yields reach 500 to 550 t/ha. Self-propelled harvester loaders are an alternative. They gather the beets from the swath. Another solution is the use of harvesters with an intermediate hopper with a loading capacity of 2 to 14 t. They convey the beets to an ongoing transport wagon, so that stopping in order to change the wagon becomes unnecessary (Knusting, 1998). For potato harvest, self-propelled Harvesters with 2- or 4-rows and hopper capacities up to 5t are on the market, having a performance up to 1 ha/h. However, practical realization of this high performance requires permanent availability of transport wagons and high storage capacity. Self-propelled potato harvesters offer advantages under unfavourable operating conditions. But daily and annual use is limited by the potato quality required for processing. This also affects the costs. In contrast to sugar beet harvest; the costs of self-propelled machines cannot be offset by a higher output (Peters, 1997). Highest engine power but relative low masses characterize the forage harvesters. The combine harvesters show lower engine power but somewhat higher masses. There is a wide range of such carrier vehicles available with relative high engine power and large total mass. They are specially developed for slurry application, but they can be equipped as sugar beet harvester. The success of these machines depends on the necessary preparation times and the overlapping of possible field operations. The performance of the combine largely depends on the header. This was considered as a challenge by researchers over the years. This challenge led to the development of stripper harvesters.

2. DEVELOPMENT OF STRIPPER HARVESTERS

Stripping is a very old harvesting method that continues to challenge design engineers throughout the centuries. The most promising stripping system is the stripper header developed at Silsoe Research Institute in the UK. Tado *et.al* (1998) reported that this stripping system increases combine capacity by 50 - 100% at a lower power requirement through the reduced amount of straw intake. A stripper combine in Australia achieved the highest reported output of 59.6 t/h. However, front-end losses in the stripper combine had been reported to be at least 1% higher than the cutter bar. Laid and tangled crops also attract higher front-end losses in stripper combine. Tremendous progress in modem combine technology has been achieved in the last decade by combine manufactures constantly vying to produce more efficient and ergonomically sound machines through improved threshing and separating systems and on-board computers. Kutzbach (1998) reported that grain capacities of 40 t/h and 60 t/h had been attained with conventional combines and stripper-equipped combines respectively.

The ratio of grain/ non-grain material affects the performance of the combine considerably. The quantity of straw entering the combine reduces combine capacities. One way of reducing straw intake during combine harvesting is to cut the crop as high as possible. Straw could thus be reduced by 50 to 70%, which could result in 50 to 90% increase in field and throughput capacity. The major bottleneck to this method is in the handling of laid crops and over-matured crops with dropping panicles. The principle of stripping presents a bright prospect in mechanical harvesting. The limitations of the stripper harvesters include high shatter losses and poor performance in laid and tangled crops.

The first known stripper harvester was described by the Roman historian Piling around 70 AD. This equipment known as the Gallic vallus (Fig.3) was a simple wooden container with a forward projecting comb mounted on wheels and pushed into the crop by a donkey, stripped grains were raked into a container by an attendant walking along the side of the machine (Quick and Buchele

1978). Klinner *et al* (1987) and Quick and Buchele (1978) reported that, William, Pitt proposed a field-rippling device composed of a rippling cylinder with transverse iron combs, fixed to the back of a cart. The cylinder was driven from one wheel of the cart pushed through the crop by a horse.

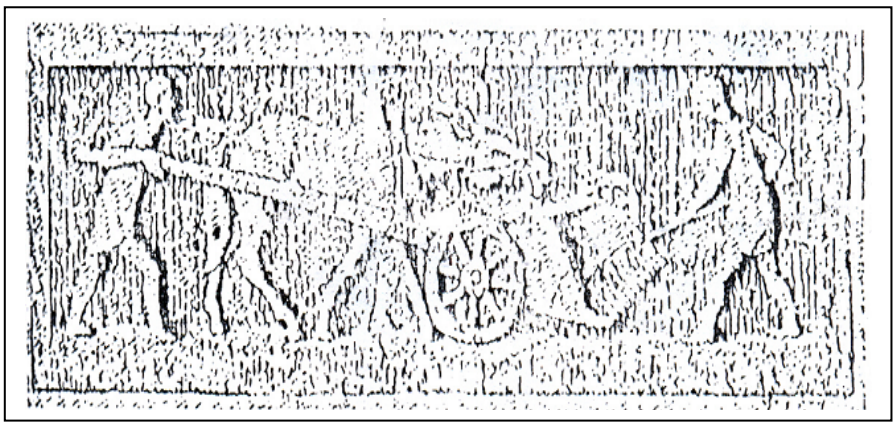


Fig. 3: The Gallic Vallus (Source: Tado *et al.*, 1998)

They also reported an animal pushed stripper by John Bull and John Ridney in Australia consisting of a horizontally projecting, long toothed comb and wooden beaters driven by belts connected to the wheel axles in 1913. Headlie Taylor equipped the Australian stripper with a cutter bar installed under the comb and crop control rotor which facilitated the cutting heads from the straw held by the rotor and comb. Wacker (1984) reported the development of a "standing Grain Thresher" by Badwin C.C. built and tested in 1910. The machine (Fig. 4) had a horizontal stripping rotor powered by a gasoline engine and moved by draught horses. Crop movement over the rotor was initially aided by air blast and subsequently replaced by a moving canvas. Commercial stripper harvesters of different designs were introduced between 1940 and 1975. These include the Wild Harvest Thresher consisting of parallel stripping plates about 500 mm in diameter and mounted on a horizontal spindle, the Poynter stripper harvester that consisted of a comb guiding the crop into the machine for stripping and a threshing concave. The International Rice Research Institute (lRRI) in the Philippines also developed a rice harvester in the late 1960s. Stripping by this machine was carried out on a belt fitted with wire-loop teeth moving parallel to the travel direction of the machine. The major problems of the machine were high shatter losses and poor performance in difficult crop conditions. Chowdhury (1977) reported the design and operation of a power tiller-mounted stripper combine which threshed the ears inside the stripping swath by utilizing the technique of a differential beating action of the spikes attached to a series of vertical shafts arranged in two rows.

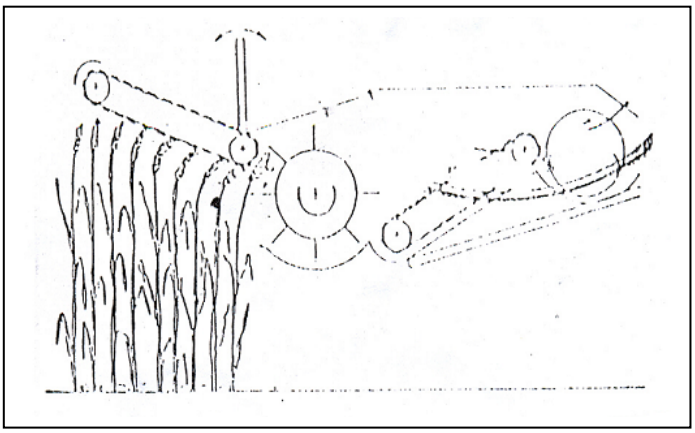


Fig. 4: The Badwin C.C Stripper (Source: Tado *et al.*, 1998)

2.1 The Chinese Stripper

Figure 5 Shows the Chinese stripper developed at the Northeast Agricultural University in Habin. The machine used a transverse mounted belt-type stripper because of a wide variation in height of rice plants in China where rice is direct seeded (Jiang *et al.*, 1991). It is essentially composed of a pickup system for harvesting lodged crop, a drum-type thresher to thresh the standing rice and a pragmatic conveyor system to provide air suction for reducing grain losses. The plants are deflected by fingers on the chain of the pickup and gently pressed further by feeding belt. The panicles are fed into the thresher through the action of the teeth on the threshing drum and air suction from the pragmatic conveyance system. The threshed grain and chaff are conducted through the conduit to the depositing chamber and down to the discharge rotor. The straw is removed by the movement of the separator, while the grain and light chaff fall through the concave to the auger.

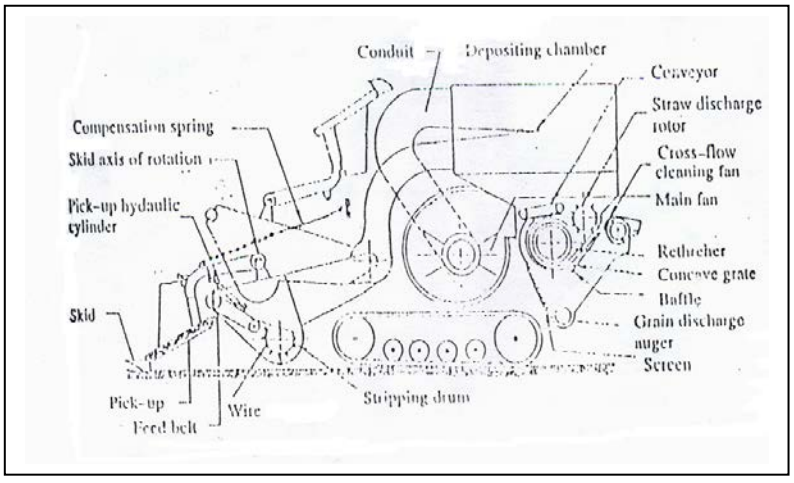


Fig. 5: The Chinese Stripper (Source: Tado *et al*, 1998)

The chaff is blown off by the air stream and clean grain is elevated to the sack.

2.2 The French EC 60 Cereal Stripper

The French EC 60 Stripper is a self-propelled machine for harvesting rice in small and medium-sized field; it is commonly used in developing countries. Development of the machine began in 1982 with field tests on prototypes conducted in France and Africa as reported by Marouze (1989) in Tado *et al* (1998). The stripping technique of the EC 60 stripper (Fig. 6) was based on a longitudinal rotor principle. The stripping mechanism consists of a divider-gatherer system mounted on the front of the machine and a threshing chamber with a drum studded with wire loop. The total width of the machine was 1.70 m but the maximum harvesting width was 0.6m which made the machine unsuitable for larger farm holders. The machine had been reported to harvest at speeds of II km/h in standing crop and 5km/h in laid crops under firm soil conditions Martin (1990) in Tado *et al* (1998).

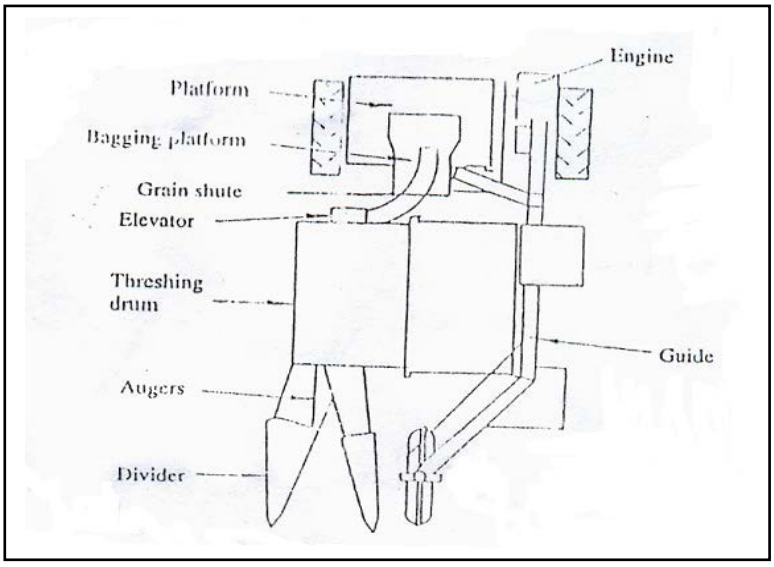


Fig. 6: The French EC Stripper (Source: *et al.*, 1998)

2.3 The Silsoe Stripper

The Silsoe stripper (Fig.7) was reported by Klinner *et al* (1987), Price (1989) and Tado *et al* (1998). The machine uses the transverse rotor principle in which stripping of the crop takes place along the whole length of the rotor arranged transversely to the direction of travel. It consists of flexible arrowhead stripping elements mounted on a horizontal rotor of 540 mm diameter and rotating at 600 to 800 rev/min resulting in a peripheral speed of 17 - 22.7 m/s. The system combs the ear from the stalk leaving most of the straw anchored in the field. The upward rotation of the rotor with respect to the crop enables it to pick up lodged crops. Price (1989) reported the experiments performed with two rigs, a 1.5 m wide tractor mounted field rig and a 300 mm wide laboratory rig to study the stripping process. These led to further improvements on the design based on the result of the laboratory and field tests. Thus it was shown that throughput capacity could be increased from 50 to 100% at loss levels comparable to conventional combines.

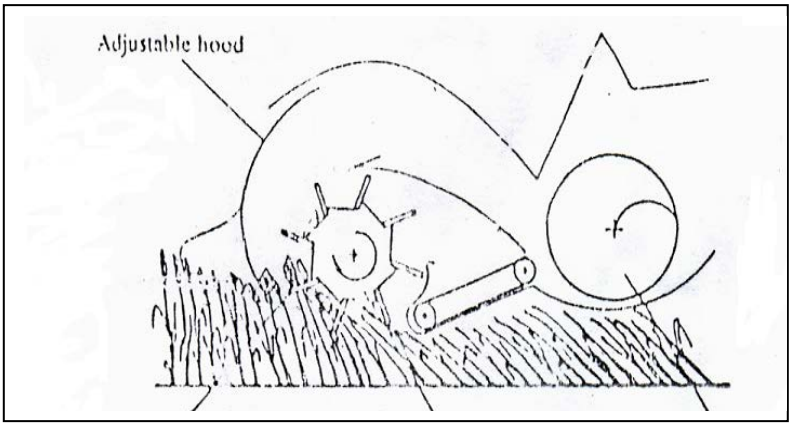


Fig 7: The Silsoe Stripper (Source: Klinner *et al.*, 1987)

It can also effectively harvest lodged crops with good grain recovery particularly in barley. However, the performance of the striper was found to be highly dependent on machine settings such as hood, height and forward speed. In wheat harvesting, the lower edge of the hood has to be maintained at 100 - 150 mm below the crop height to minimize grain losses. Too low rotor speeds result in unstripped grains while too fast rotor speed increases straw intake. Shelbourne Renolds had commenced the commercial production of this retrofit header that may be fitted to any popular make of the combine. Garbers (1987) reported that the standard header shows a linear increase in width over the years, but optional header width increase progressively. The advantage of small header was given as the ability to follow contours and rough fields and on hillside. However the combine output has to be maintained by use of higher ground speed, resulting in vibration. The capacity of the header has been increased by greater diameter and a large pitch of the auger. Retracting fingers throughout the width of the auger ensure trouble free continuous crop intake. Although other systems of crop cutting have been tried, they have not supplanted the reciprocating knife. Further improvement on the cutting mechanism are the use of oil bath knife, making it possible to increase knife oscillation to 550 cycles per minute, and the use of double finger mounting and self sharpening knives. Gale (1995) developed an automatic height control for the stripper header, which improved the performance of the stripper during combine operations.

3. DEVELOPMENT OF INDIGENOUS COMBINE HARVESTERS

This review on grain harvesters shows that a lot of work has been done in the area of grain harvesting mechanisation especially in Europe and America. On the other hand, the cost of modern combine harvesters is a major obstacle to farmers in developing countries. This is a challenge to engineers in developing countries. Some developing countries such as India and Thailand are responding positively to this challenge. Thepent (2009) reported that the rice combine harvester had been introduced to Thai farmers for a long time. However it is very expensive, unsuitable for field conditions and high in technology, the rice combine harvester was not accepted by Thai farmers (Anon, 2006: CIA 2008). However, because of the expansion of industrial sector, labour migrated to other sectors and consequently leaving the agricultural sector short of labour especially in harvest periods. During 1985-1986, the rice combine harvester was developed by local manufacturers. There were about 1500 harvesters made by 30 manufacturers during 1990-1991. The spare parts of harvester were integrated among exported parts, used parts and using axial flow thresher as threshing unit. The hiring rate was about 75-90 US$/ha. The future role of rice combine harvester in Thailand was considered to be based on economic, social

and agricultural production systems (Chimchana *et al* 2008). For the economic aspect, the labor shortage in harvesting, the need in quality improvement of rice and cost reduction lead to the utilization of the rice combine harvester (Tahir *et al*, 2003*)*. For social aspect, due to labour migration most available labour is found to be older persons and children. For agricultural production system, the rice combine harvester was necessary for timely harvesting of upland crop planting as a second crop after rice. In terms of post-harvest loss, the use of combine harvester loss can be reduced when compared with traditional method. The use of combine harvester can be found in the intensive planting areas, from the lower part of the northern region down to the central plain region. The availability of water supply, non-photosensitive varieties, tractors and combine harvesters allow rice farmers in this area to grow 2 to 3 crops per year. There are about 3,000 units of the combine harvester being used in those areas operating on contract basis (ASABE, 1997; IRRI, 2007).

In Africa, especially in Nigeria, research into the development of grain harvesters is in progress (Olukunle, 2002; Ademosun and Olukunle, 2003; Ademosun *et al* 2003). Olukunle (2000) developed an indigenous self-propelled combine harvester for harvesting cowpea and soybean. The machine (Fig.8) had been tested under various crop, operational and machine conditions. The cost of the machine was estimated as ₦450, 000. A full scale 3 row combine harvester of this design would cost ₦1,200,000 as opposed to about 6 million naira for imported combine of similar size .The machine though far from the modern combine harvesters in advanced countries is however appropriate for small farm holders and local farmers. The Stripper Header was observed to be efficient as it stripped the pods from plant stems especially between 100 and 600 rpm. However above 600 rpm the machine beheaded the crop acting more like the conventional cutter bar. The machine field capacity is 0.33 ha/h with an estimated feed rate of 322.22 kg/h. The header also aided the flow of materials into the combine as it throws and blows the materials unto the horizontal conveyor. Losses incurred with the machine were minimal under various crop, machine, and operational conditions.

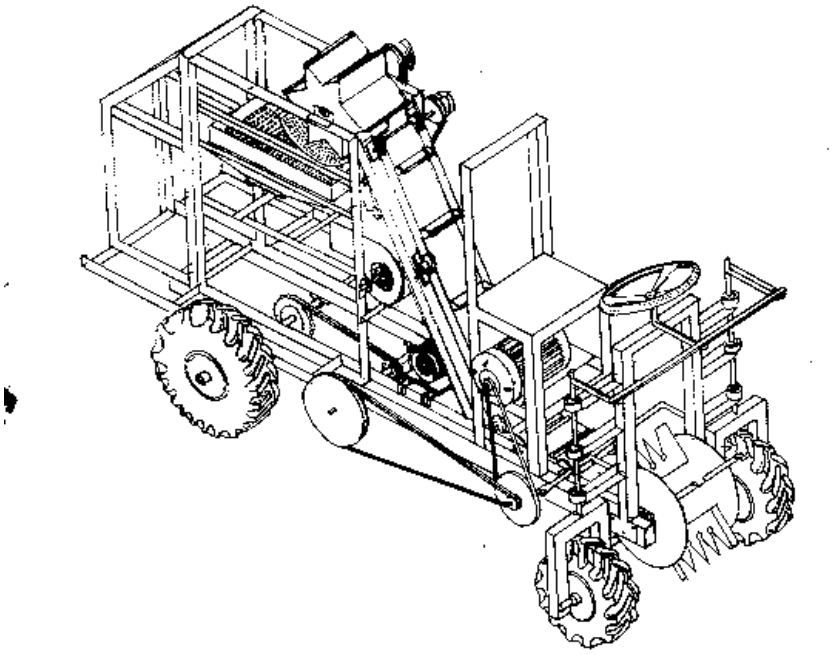


Fig 8: The indigenous self-propelled Combine Harvester (Olukunle, 2000)

4. CONCLUDING REMARKS

Grain harvesting mechanisation has witnessed a significant transformation through which the combine harvester has evolved. The width and diameter of the straw walker, sieve areas and the threshing drum have been increased in Europe to accommodate high straw yield of cereals and seed crops due to increasing demand for increase in output. In North America, the trend is towards the use of axial rotors for threshing and cleaning. However, cylinders, which draw the crop over suitably shaped concave grids, are used in Europe. The latter is adjudged effective regardless of straw condition and moisture content. The new trend of threshing and separating units in Italy positioned a tangentially fed axial threshing and separating rotor behind and parallel with a conventional cutting table. This layout accommodates a large grain tank, disallows all the grains from passing through the whole machine and permits a compact design. A stripper header was developed at the Silsoe Research Institute (Cranfield University, UK) and is now in commercial production. The engines of combine harvesters increasingly show greater performance regarding thermal efficiency (from 30% in 1960 to 35% in 1989) at rated speed of 2000 to 2500 rev/min and specific power (from 11kW/dm^3 to 17kW/dm^3) in the same years. The power of the combine engine also increased from 44kW to 130kW. The trend towards more powerful models is very significant for combines and non-conventional ones show maximum power requirements.

The work capacity of combine harvesters increased between 1960 and 1989 as can be inferred by the increase in rated power. It is evident from the fore going that the overall design of the combine harvester witnessed a significant transformation. Automatic controls and adjustments and non-conventional straw-walkers that permit higher work rate have been incorporated. The most important improvement however is in comfort and ergonomics: protective structures, hydraulic and electronic controls, and automatic adjustments have made the use of the combine harvesters easier and safer for the human operator.

In Africa and other developing countries efforts should be made to develop indigenous combine harvesters or to adopt/adapt imported technology. The initial cost of the combine harvesters is however very high, this requires further structural development. In developing countries, farmers find it difficult to adapt imported combines to local conditions. Thus, In addition to training, development of appropriate indigenous combine harvesters would be necessary to meet the ever-increasing demand for grains. Generally, combine harvesting is a destructive test, as the vegetation is terminated through the harvesters passage through the field, this in many cases leads to reduction in crop yield particularly for crops such as cowpea where there exists mixture of ripe and unripe pods on the same plant. Thus, research which would make selective harvest of matured grains possible should be encouraged.

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MECHANIZED TILLAGE OPERATIONS IN NIGERIA: THE NATIONAL AGRICULTURAL LAND DEVELOPMENT AUTHORITY EXPERIENCE

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ABSTRACT

One of the cardinal objectives of the Federal government of Nigeria is to ensure sustainable production of food and fibre to satisfy both domestic and external demands. To achieve this objective, these governments have formulated a number of policies, strategies and programmes. The objective of this paper is to present a study undertaken to review the mechanized tillage component of the National Agricultural Land Development Authority (NALDA). Results showed that the authority owned and managed 201 tractors, 178 disc ploughs, 177 disc harrows, 164 disc ridgers, etc: and in 1998 farming season alone, the authority nationwide ploughed 11,600 hectares, harrowed 23,100 hectares and ridged 5300 hectares using mechanized equipment, thus generating 23,546,500.00 million naira. The study further revealed that the authority subsidized tillage by more than 67%. This increased the financial efficiency of farmers in Enugu state from 151.41% to 391.26%. The paper is recommending that programmes with similar mandates be established and adequately funded at all levels of government in this country.

KEYWORDS: Tillage, mechanization, agriculture, land, development**.**

1. INTRODUCTION

Tillage is the process of modifying the state of the soil by mechanical means in order to provide conditions that are favourable to root penetration, and hence overall crop performance while preventing the deterioration of the land through soil compaction soil loss, nutrient loss or erosion (Abraham, 1984; Anazodo, 1986b). The objectives of tillage according to Anazodo, 1988 and Onwualu et al, 2006, are to:

- Develop a good soil structure which will give a desirable seed bed or root bed
- Destroy weeds which will compete with crops for moisture, nutrients and sunlight
- Reduce soil erosion
- Prepare land for irrigation
- Incorporate commercial fertilizer, lime or other soil amendments into the soil through mixing and even spreading
- Relief drudgery inherent in traditional tillage operation
- Bring more land under cultivation

Mechanized tillage is a component of agricultural mechanization and agricultural mechanization is the use of mechanical devices or systems to replace human muscle in all forms and at any level of sophistication in agricultural production, processing storage etc in order to reduce human

drudgery, improve timeliness and efficiency of various farm operations, bring more land under cultivation, preserve the quality of agricultural produce, provide better rural living condition and markedly advance the economic growth of the rural sector (Anazodo, 1986a; Onwualu *et al*, 2006).

Nigeria is a country with land surplus economy. She has a land area of 924000 sq km (FMARD, 2004). 70% of this area is cultivable and capable of supporting one or more forms of agricultural production (Idike, 1990).There are streams, lakes and rivers running across the different ecological zones. To ensure increased food and fibre production to satisfy both domestic and external demands the Federal and governments of Nigeria have formulated and implemented policies, strategies and programmes aimed at realizing the objectives. Some of these approaches have agricultural mechanization particularly mechanized tillage as their cardinal objectives. Some of the approaches are, the National Agricultural Land Development (NALDA). the Equatorial Guinea Returnee programme, the Farm Settlement Scheme, Operation Feed the Nation, Accelerated Food Production Project, Agricultural Development Project, the National Directorate of Employment, Directorate of Food Roads and Rural Infrastructure, the National Poverty Eradication Programme National Centre for Agricultural Mechanization, Tractor and Equipment Hiring Units, Family Economic Advancement Programme and the latest Food Security Programme. The formation, operation, achievement, problems, etc of these institutions have been discussed extensively by various authors (Taylor, 1981; Ijere, 1991; Odigboh and Onwualu, 1994; Onwualu, *et al*, 2006, FMAWR, 2008).

The objective of this paper is to present a study conducted on mechanized tillage activities of the National Agricultural Land Development Authority (NALDA).

2. THE NATIONAL AGRICULTURAL LAND DEVELOPMENT AUTHORITY (NALDA)

NALDA was established in 1992 to facilitate the optimal use of the nation's land and human resources to uplift the quality of rural life, vide a programme to address the chronic problem of low levels of utilization of abundant farm land and rural labour resources and the high cost of land development (NALDA 1992).

2.1 The Structure

The authority had three organs at the three tiers of government. These are: a board of Directors and management at the national level, State Advisory and State Directorate at the States level and a project implementation and advisory panel at the Local Government level.

2.2 Programme

The authority operated eight technical programmes with six departments as shown in table 2.1.

Table 2.1 Programmes and Sub Programmes of NALDA

Programme	**Sub programme**
Planning Coordination and Monitoring	Programme and Project plan; Technical Consultancies; Field Operation, Monitoring and Evaluation
Land Resources Inventory and Planning	Project Site and Land Characterization; Soil Survey and Mapping Farm Erosion and Fertility Status Survey Farm Layout Design
Land Development	Cadastal Survey and Mapping; Bush Clearing and

	Seedbed Operations, Farm Parcellation; Procurement and Maintenance of Agricultural Machinery.
Farm Infrastructural Development	Farm Workshop Sheds, Farm Stores, Residential Quarters, Farm Offices and Farm Roads, Culverts and Bridges
Soil Conservation and Fertility Management	Environmental Impact Assessment; Flood and Erosion Control; Soil Fertility Maintenance and Management Sustainable Farming Promotion
Cooperative/Extension Services	Routine Extension Services. Development and Dissemination of Production Technologies; Women and Youths Outreach Activities.
Agricultural Production and Post Harvest Services	Production, Procurement and Distribution of Input; Livestock Integration; On Farm Adaptive Research Diagnostic Survey and Farm Management Processing Support Services; Quality Control and Monitoring Services, Agricultural Finance and Recovery. Small Scale Investment Promotion.
Programme Documentation and Data Bank	Management Information System; Library and Publication, Fairs and Exhibition

Source: NALDA, 1992.

The departments that existed in the authority which implemented the above programmes are:

- Finance and supplies
- Personnel Management and General Services
- Engineering Services
- Extension and Agro services
- Land use Planning and Management
- Planning Research and Data Bank.

3. DISCUSSION

3.1 Machinery Procurement and Distribution

The authority procured and distributed farm machinery to states directorate for field operations. The categories of machinery distributed are tractors, disc ploughs, disc harrows, disc ridgers, mouldboard plough, bund former ditcher, tipping trailer, rotary slasher, power saw, Pto air compressor, water browser, etc. The machinery types and distribution as distributed to states are present on Table 3.1. From the table, as at 2000, the authority had 201 tractors, 178 disc ploughs, 177 disc ridgers, 80 tipping trailers, 23 rotary slashers, 55 power saw machines, 16 Pto air compressor and 11 water bowser.

Table 3.1: List of Tractors and Implements Inherited by Department of Rural Development from Defunct NALDA

State	No. of Tractors	Number of Implements										
		Disc plough	Disc harrow	Disc ridger	M/B plough	Bund former	Ditcher	Tipping trailer	Rotary slaher	Stihl c/saw	Pto compressor	Water Bowser
Abia	1	1	1	1	1	1	1	1	-	3	-	-
Adamawa	8	8	7	6	-	2	2	3	1	-	1	1
A/Ibom	2	2	2	1	-	2	2	2	1	1	-	-
Anambra	2	2	2	2	-	2	2	2	1	-	-	-
Bauchi	7	6	5	5	-	1	2	2	-	-	1	1
Bayelsa	1	1	1	1	-	1	1	1	1	-	-	-
Benue	5	4	4	4	1	2	2	3	1	-	1	1
Borno	7	7	6	6	2	2	2	2	-	-	1	1
C/River	4	3	3	2	-	2	2	2	1	2	-	-
Delta	2	2	2	2	-	2	2	2	1	-	-	-
Ebonyi	3	3	3	2	-	2	2	2	1	-	-	-
Edo	3	3	3	4	1	2	2	2	1	-	-	-
Ekiti	5	4	4	4	1	1	1	1	1	-	-	-
Enugu	3	3	3	3	-	1	1	1	1	-	-	-
FCT	6	6	6	5	-	2	2	2	1	-	-	1
Gombe	7	7	6	6	-	1	1	2	-	-	-	-
Imo	3	2	2	2	1	2	2	2	1	-	-	-
Jigawa	10	8	9	8	1	2	2	4	-	-	1	1
Kaduna	8	8	7	7	1	2	2	3	-	-	1	-
Kano	8	8	7	7	1	2	2	3	-	-	1	1
Katsina	10	9	8	8	1	32	5	1	-	1	-	1
Kebbi	8	8	7	7	1	2	2	2	1	-	1	1
Kogi	6	5	5	5	-	2	2	3	1	-	1	1
Kwara	7	7	7	8	1	2	2	3	1	2	1	-
Lagos	5	4	4	4	-	2	2	2	1	-	-	-
Nassarawa	6	6	6	6	1	1	1	1	-	-	-	-
Niger	6	6	5	4	1	2	2	3	-	-	1	-
Ogun	3	3	2	2	-	2	2	2	1	-	-	-
Ondo	4	3	3	3	1	1	1	1	1	1	-	-
Osun	3	3	2	2	-	2	2	2	1	-	-	-

Oyo	5	4	4	4	1	2	2	2	1	-	-	-
Plateau	11	10	10	8	1	1	1	3	1	-	1	1
Rivers	2	2	2	1	-	1	1	1	1	4	-	-
Sokoto	8	5	7	6	3	1	1	1	-	-	1	1
Taraba	8	8	7	6	-	3	2	3	1	-	1	1
Yobe	7	5	6	6	-	2	1	2	-	-	1	1
Zamfara	7	4	7	6	2	1	1	1	-	-	-	-
Total in place	201	178	177	164	23	63	62	80	25	14	16	10
	-	-	-	-	13	-	1	-	-	41	-	-
TOTAL	**201**	**178**	**177**	**164**	**36**	**63**	**63**	**80**	**25**	**55**	**16**	**11**

Source: Elesa, 2003

3.2 Farm Machinery Management

The country was zoned into 5 and the Authority entered into machinery service agreement with 3 reputable companies to inspect and effect major repairs on farm machinery. The companies are Steyr Nig. Ltd., UTC and Green Fingers (Gana, 1999). For routine repair and maintenance, funds were made available to State Directorates at the beginning of each farm season for that purpose, Table 3.2 gives details of funds sent to Enugu State Directorate for 1998 farming season. From the table, a total of N290, 000.00 was sent for field operation, routine services and maintenance and implement rehabilitation.

3.3 NALDA as a Strategy to Relief Drudgery in Tillage Operation

Figure 1 show the drudgery associated with hand tool technology, one of the problems NALDA was addressing before it was scrapped.

In the Authority's enclave farms, the following operations were fully mechanized; ploughing, harrowing and ridging. Table 3.3 presents area ploughed, harrowed and ridged in each State and Federal Capital Territory. From the table, for the 1998 farming season alone, a total of 11,600 ha were ploughed, 23,100 ha were harrowed and 5,350 ha were ridged. The fund generated within the year amounted to ₦23, 546, 500.00.

Table 3.2: Funds, Released to Enugu State Directorate for Machinery Maintenance for 1998/99 Cropping Season

Purpose	**Amount, ₦**
Field operations (Fuelling Lubrication, Oil, etc)	160,000.00
Routine Service and Maintenance	74,000.00
Rehabilitation of Tractors	-
Rehabilitation of implements	56, 000.00
Total	**290,000.00**

Source: NALDA, Enugu State, 1998.

Table 3.3: Field Operations in States and FCT and Revenue for 1998 Cropping Season.

	Operations carried out			**Soil textural class**	**Revenue, ₦**
States	**Ploughing**	**Harrowing**	**Ridging**		
Abia	100	100	-	Medium	126,500.00
Adamawa	100	100	-	Heavy	165,000.00
	300	750	250	Medium	756,250.00
					921,250.00
Akwa Ibom	200	200	-	Medium	253,000.00
Anambra	200	200	-	Medium	805,750.00
Bauchi	300	700	350	Medium	805,750.00
Bayelsa	100	100	-	Heavy	165,000.00
Benue	100	100	-	Heavy	165,000.00
	300	700	200	Medium	698,500.00
					863.500.00
Borno	300	300	-	Heavy	495,000.00
	300	1000	350	Medium	937,750.00
					1,432,750.00
Cross river	100	100	-	Heave	165,000.00
	200	400	-	Medium	341,000.00
					506,000.00
Delta	100	200	50	Medium	206,250.00
Ebonyi	100	100	-	Heavy	165,000.00

Edo	100	100	50	Medium	162,250.00
Ekiti	250	300	50	Medium	374,000.00
Enugu	200	250	5	Medium	310,750.00
FCT	200	200	100	Medium	325, 500.00
Gombe	500	1000	300	Light	825,000.00
Imo	100	200	-	Medium	170,000.00
Jigawa	300	300	-	Heavy	495,000.00
	300	1000	150	Medium	794,750.00
					1,289,750.00
Kaduna	200	200	-	Heavy	330,000.00
	400	1,000	200	Medium	913,000.00
					1,243,000.00
Kano	200	200	-	Heavy	330,000.00
	500	1,000	200	Medium	995,500.00
					1,325,500.00
Katsina	500	1,250	250	Medium	1,141,250.00
Kebbi	200	600	250	Light	508,750.00
	150	200	-	Medium	211,750.00
					720,500.00
Kogi	150	150	-	Heavy	247,500.00
	300	500	100	Medium	539,000.00
					786,500.00
Kwara	400	1,000	250	Medium	948,750.00
Lagos	100	150	-	Medium	148,500.00
Nassarawa	300	300	-	Heavy	495,000.00
	200	500	150	Medium	492,250.00
					987,250.00
Niger	100	100	-	Heavy	165,000.00
	300	500	200	Medium	610,500.00
					775,500.00
Ogun	100	150	50	Medium	184,250.00
Ondo	150	200	50	Medium	247,500.00
Osun	100	150	50	Medium	184,250.00
Oyo	100	150	50	Medium	184,250.00
Plateau	600	1,500	400	Medium	1,441,000.00
Rivers	100	100	-	Heavy	165,000.00
Sokoto	300	1,500	250	Light	871,750.00
Taraba	300	300	-	Heavy	495,000.00
	300	1,000	200	Medium	830.500.00
Yobe	300	1,250	250	Light	748,000.00
Zamfara	500	1,500	250	Light	962,500.00
Total	11,600	23,100	5,350	-	**23,546,500.00**

Source: NALDA 1999

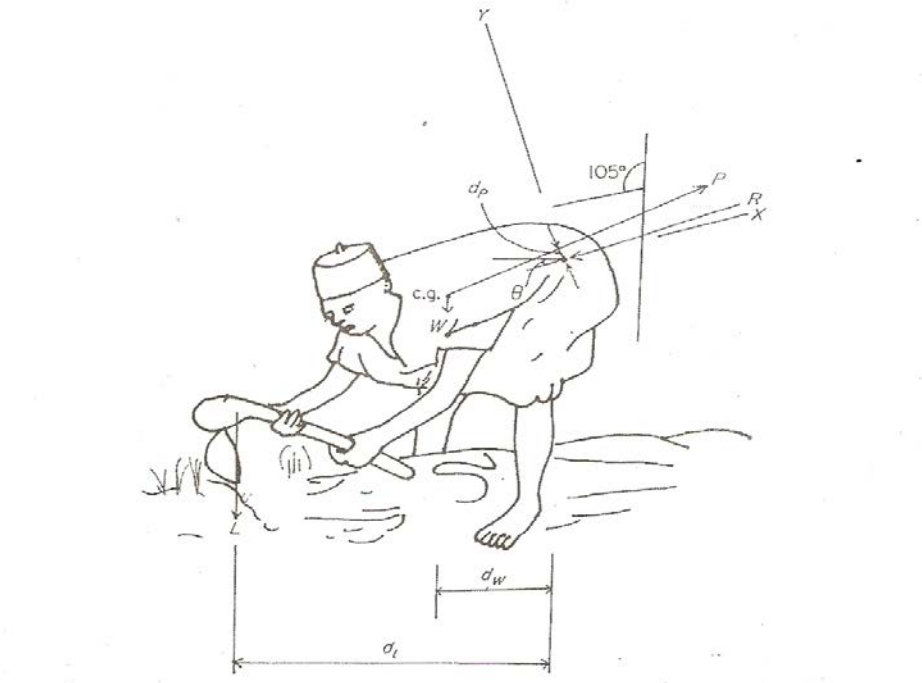


Fig 1: A hand tool user tilling the soil. P, R and W are forces acting on his spine, evidence of drudgery associated with hand powered agriculture.
Source: Nwuba, 2009.

3.4 Subsidy on Tillage Operation

The change per hectare for various tillage operations by NALDA and private fire services is presented in Table 3.4. From the table for different soil classifications, the authority subsidized tillage operations to more than 67%.

Table 3.4: Soil Classification, Private Charge Rates and NALDA Charging Rate for Different Tillage Operations

Operation	Soil Classes	Private Charging Rate, ₦/ha	NALDA Charge Rates, ₦/ha
Ploughing	Heavy	6,166.62	1,980
	Medium		
	Light		
Harrowing	Heavy	2,752.96	900
	Medium	2,202.37	720
	Light	1,835.31	600
Ridging	Heavy	5,138.85	1,710
	Medium	3,854.14	1,290
	Light	3,083.31	1,020

Source: Gana, 1999

3.5 Further Justification for NALDA Intervention in Tillage Operations in Nigeria.

The production cost estimates for performing various maize production operations using hand powered and mechanically assisted system for NALDA service and private hire service, was done elsewhere (Adama *et al*, 1998). For the same rate of agronomic inputs the total cost of maize production per hectare was calculated to be N31,700 for hand powered system, N20,450 for private machinery hire system and only N13,701.50 for NALDA assisted mechanical system. These gave financial efficiencies of 151.41%, 234.72% and 391.26% for the three systems.

3.6 The Problem

In January 2000, the authority was scrapped by the government of the day and its services transferred to the Department of Rural Development of the Federal Ministry of Agriculture and Rural Development.

4. CONCLUSIONS AND RECOMMENDATION

The following conclusions could be drawn from the study:

i. NALDA was the only government agency involved in direct mechanized tillage operation for different categories of farmers in Nigeria
ii. The authority nationwide provided subsidy of up to 67% on mechanized tillage operation
iii. NALDA provided a marginal relief to drudgery inherent in farm operations in the country

It is recommended that for sustainable food security, government at all levels should set up an agency with similar mandates in the country.

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EFFECT OF KNIFE VELOCITY AND COMPACTION ON FORAGE CHOPPER CUTTING EFFICIENCY

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ABSTRACT

A forage chopper developed at the Federal College of Agriculture, Ishiagu Ebonyi State, Nigeria to reduce lengths of freshly harvested vegetables for palatability and to ease domestic stress of vegetable chopping with kitchen knife during cooking. The effects of forage compaction density (change in specific volume) and knife velocity were studied to determine the relationships between changes in specific volume, specific weight (density), and knife velocity and energy requirements during cutting. Effect of specific volume and knife velocity on cutting of test samples at different moisture contents determined for Telfaria (*Ugu*) at 75% and for Spinach (*Ẹfọ*) at 55% w.b. shows that increasing the energy of compaction increases the volumetric weight and cutting efficiency of the machine. Maximum volumetric weight of 1.56 mm^3/g and 1.70mm^3/g were obtained during compaction of 0.50kg of Telfaria (*Ugu*) at 75% and Spinach (*Ẹfọ*) at 55% w.b. respectively.

KEYWORDS: Chopping, velocity, specific volume, compression chamber, forage, efficiency.

1. INTRODUCTION

Compaction and chopping have been proposed as a means of reducing volume and weight or increasing density to increase the efficiency of forage harvesting or cutting operations (Cifuentes and Bagnall, 1976; Bagnall, 1980; Mathur and Shing, 2000; Shailendra *et al.*, 2004). The literatures indicate that three types of choppers; flywheel, flail and cylindrical had been used for agricultural forage chopping and published data suggest that power loss due to water resistance and mechanical losses are high in flail cutters but the accuracy of cutting was not acceptable. (Shailendra *et al.*, 2004).

Two stages are distinguished in the cutting process which involves preliminary compaction of the material until a pressure is reached at which the material under the cutting edge yields; while the second stage concerns the motion of the cutting edge in the material. High density packaging of unconsolidated agricultural materials such as forage enables more efficient mechanical handling. The compressibility of forage materials depends mainly on the plant species and moisture content, but the length and orientation of the strands also have a certain effect. These variables influence greatly the initial volumetric weight, γ_0 of the material. Moisture content has the greatest effect in pressure-volumetric weight relationship for various hay species Sitkei, (1986).

Cutting of agricultural material is one of the most frequent operations carried out during agricultural technological processes, and is applied always during harvesting, separation and subsequent communition of plant components. Various deformations often occur in the material during cutting, depending on the form of cutting edge and the kinematics of the process. Products may be cut individually or in bundles depending on the type of material and the technological process.

The cutting effect produced by a 2-blade rotor, fixed and moving sharp edges has been particularly found to be suitable for the preliminary size reduction and homogenization of soft to medium-hard, dry, moist or wet materials (Retsch, 2006). An effect of cutting velocity on energy requirement investigated for green maize stalk having a 63% moisture content, 70cm^2 cross sectional area, 4mm knife thickness and 25˚ sharpening angle with 80µm edge thickness indicates a decrease in energy requirements with increase in cutting velocity and the proportion of useful cutting work reaching 95% (Sitkei, 1986). Energy requirement to cut alfalfa stalks as a function of increase in their thickness increases with increase in specific cutting resistance from 0.041-0.046 daNm cm^{-2} have also been reported and result indicate that the cutting resistance of younger plants is significantly lower than that of older plants by as much as one-half (Sitkei, 1986). The range of knife velocity corresponding to the minimum cutting energy requirement obtained for cutting the stalk base is close to the 2.65 m/s speed obtained by Prasad and Gupta, (1975) for cutting maize stalk base.

2. MATERIALS AND METHODS

2.1 Instrumentation

The test apparatus (Chopper) shown in (Fig.1) was originally designed and fabricated at the engineering Programme of Federal College of Agriculture, Ishiagu Ebonyi State Nigeria. The machine consisted of two compartments which include; compression chamber and the cutting edge. The compression chamber is made up of the pressure plate, the feeder mechanism and the chamber measuring (184x100x95) mm^3. It has a wooden base on which other wall plates were attached. The feeder plate (push plate) is connected to a screw-nut shaft supported by ball bearings. The knife disk and the crank are attached to one end of the shaft.



Fig.1: Chopper used for the test

When the crank is turned, the screw-nut converts the rotational motion of the shaft to translational movement in the feeder plate which feeds the knife. The pressure plate has dimension (184x95x2) mm^3 and it is attached to a screw jack for compression purposes. The knife assembly consists of two blades sandwiched between two disks and held in place by four screw nuts. Each knife has a length of 120mm, 120µm thickness and a sharpening angle of 25°. It has a curved shape with a width of 30mm at the stalk. There is a housing to shield the moving knife blades from injuring people. The entire assembly is mounted on a table edge when in use.

2.2 Experimental Procedure

Freshly harvested samples of telfaria, (*Ugu)* at 75% moisture content and Spinach (*Ẹfọ*) at 65% moisture content were randomly sourced at Eke Ishiagu local market for the test. Each sample was washed to remove grit (Robinson *et al.*, 1977) and the fibrous parts of the stalk trimmed off. Equal quantity of each sample by weight of (50g) were laterally packed into the compression chamber and compressed through a compression distance of 45mm (preliminary compression distance where all the air voids has been eliminated (Faborode and Callaghan, 1989). The material is further compressed stepwise by 5mm and the density and cutting velocities determined for each sample. The efficiency of cut is evaluated based on the amount of energy exerted in cutting.

2.3 Density Measurement

All density measurements were based on weight to volume ratio (Mohsenin and Zaske, 1976; Shailendra *et al*, 2004). Volume was determined from the thickness of the compressed material in the compression chamber and the constant cross-sectional area. Density was determined from the geometry of the compression chamber and the initial material weights.

Density = weight/Volume (Kg/m^3) (1)

This method was found to be more acceptable and accurate and less time-consuming than the ASAE S269.2 Standard.

2.4 Work Done in Feeding

At the beginning of compaction, the relative compression load acting on the material is assumed to be the weight of the pressure plate. The work done in pushing the compressed material toward the cutting edge is expected to overcome the compression work and frictional forces. This work is provided by the push plate driven by a screw - nut arrangement. *Torque*: The torque T produced by the rotating arm is transmitted to the push plate through the screw and is evaluated by the relation given.

3. RESULTS AND DISCUSSION

3.1 Compaction-Density Behaviour

Under compression, the load pressure on forage increased as the density increases until the maximum compression load is reached, which is determined at the vertical height of the push plate. The pressure exerted by the plate during compaction was determined through calculations to be $191.65N/m^2$. The material is compressed through a distance l = (75-45) mm and the density of material determined at an interval of 5mm. Fig. 3, shows the graph of the variation in specific volume and compaction length/thickness of the two samples. The average reduction in specific volume of samples led to an increase in volumetric weight (density) of samples.

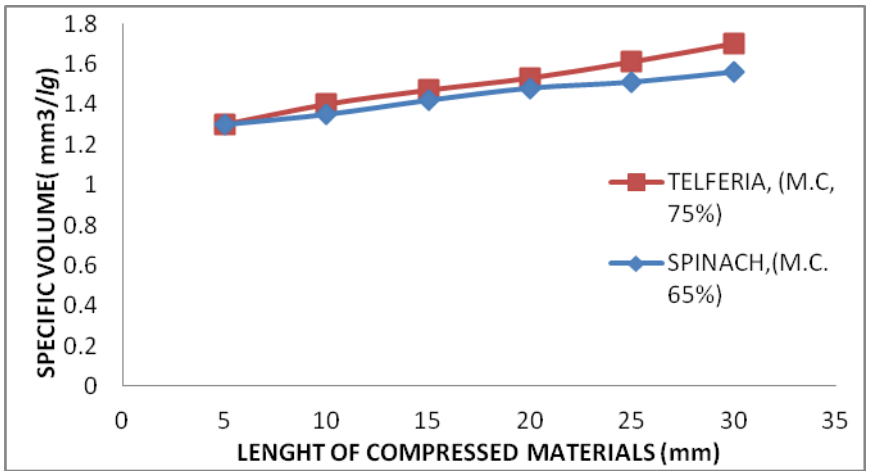


Fig. 3: Relationships between the specific volume and compaction

With an increasing preliminary compaction length, the proportion of useful cutting force is increased, and a greater effort (increase in cutting force) is required to cut material thus the specific energy consumption must increase. The analysis of variance indicates that the specific volume has a significant effect on knife speed at 97% confidence level.

3.1 Moisture Content Relationship

At high moisture content, less energy is required to attain certain initial density during compaction. The difference between the two curves for the samples represents the amount of energy dissipated in compression.

3.3 Density - Energy Relationship

It has been shown that as the compaction energy increases, there is a reduction in volume and increase in density weight of material under compression (Segun, 2010). Fig. 4 show the energy required to compress each sample at different moisture contents. The initial density was in the same range when compressed with the same pressure. However, the compaction energy represented by the area under the curves was much less for the high moisture Telferia (75% w.b.) compared to the energy necessary to compress the same quantity of spinach (*Efo*) at low moistures.

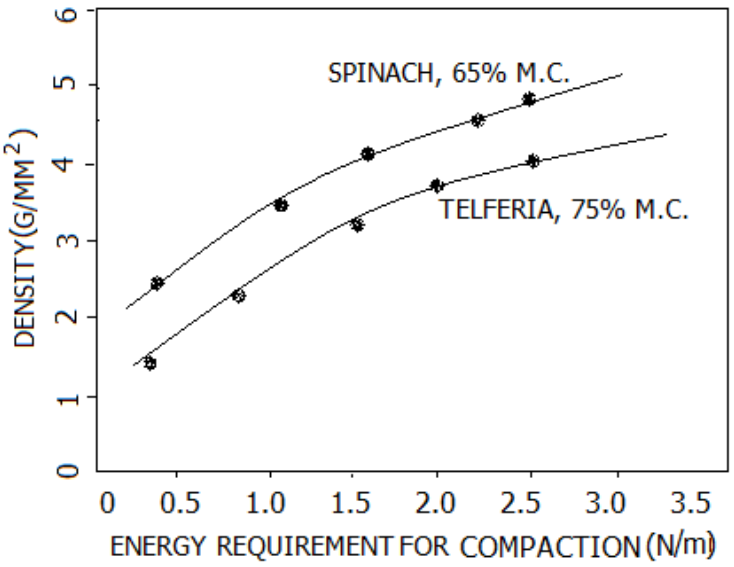


Fig.4: Energy requirements for compaction

The figure also shows the influence of the moisture content in relation to the final density. The differences between the curves indicate the amount of energy dissipated in compression to the final volume. It can thus generally be concluded that energy requirement to compress high moisture material is less than same material at lower moisture content thus confirming the result of Mohsenin and Zaske, (1976)

3.4 Knife Velocity - Cutting Energy Relationship

Fig. 5 presents the requirement for the materials under test. It shows that the cutting energy requirements decreased with increase in knife velocity up to a minimum, beyond the minimum values the energy increased with increase in knife velocity for both samples. The initial decrease in cutting energy at knife speeds higher than 0.84m/s was explained by the fact that at lower velocities, impact force was too small to sufficiently cut the bundle. These results agreed with those of (Yiljep and Mohammed, 2005) and (Gwani, 1986) for cutting sorghum and maize stalks although the result did not obtain the minimum value for the cutting energy requirement and the corresponding knife speed.

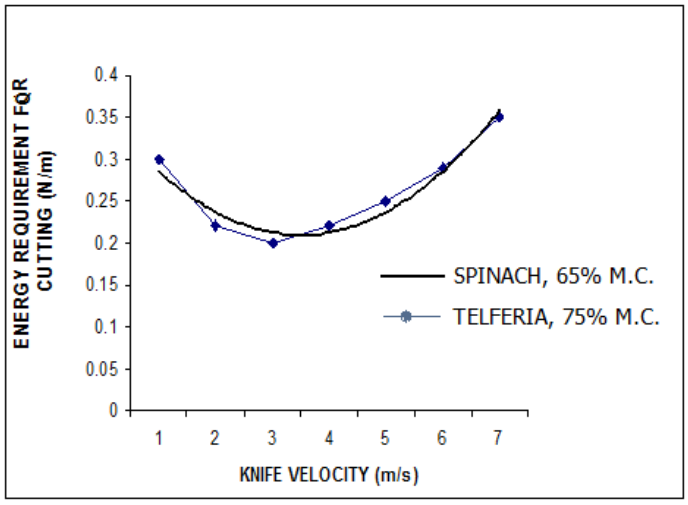


Fig. 5: Relationship between knife velocity and cutting energy

The average reduction in specific volume and compaction at different speed is shown in Fig 5. The trend of curves shows that the reduction in specific volume increased the knife speed and efficiency of cut (Shailendra *et al.*, 2004) and there after decreased. This may be attributable to lesser contact between the knife and the material, thus reducing crushing at high speed. There is also a linear relationship between the knife speed and the feed rates. Analysis of variance shows that the combined effect of feed rate and knife speed on specific volume was highly significant.

4. CONCLUSION

The effect of specific volume and knife velocity on cutting of forage crops at different moisture contents; Telfaria (Uwu) at 75% and Spinach (Efo) at 55% w.b., shows that increasing the compaction energy increases the volumetric weight and cutting efficiency. Maximum volumetric weight of 1.56 mm^3/g and 1.70mm^3/g were obtained during compaction for 50g of Telfaria (Uwu) at 75% and Spinach (Efo) at 55% w.b., respectively. The effect of knife velocity on observed cutting efficiency (physical observation) indicated an improvement in the cutting efficiency with increase in knife velocity.

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DETERMINATION OF APPROPRIATE TRACTOR OPERATOR'S HEIGHT USING OTHER ANTHROPOMETRIC PARAMETERS

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ABSTRACT

Many tractor operators and potential tractor operators were subjected to anthropometric measurements of body segments. The legs, hands, trunks, foot lengths and palm widths were measured. Also, pelvic, elbow, knee and foot angles were determined. The various body segments, at standing position, were plotted against height of the operator in a regression relationship. The hand or upper limb (UL) from shoulder to fingers had the highest correlation with a correlation coefficient (R) of 0.9124. This was followed by the leg or lower limb (LL), from pelvic to foot with correlation coefficient of 0.8012. The foot length was also observed to correlate with the height of the operator. The worst relationship was exhibited by the trunk, with a correlation coefficient of 0.2755.Also in sitting and driving positions on the tractor, the straight distances from the shoulder to hand controls were taken as arm reaches and from pelvic to foot controls as foot reaches of the tractor. The measured hand and foot reaches of the farm tractor used were substituted in the regression equations for the operator's height in relation to the upper and lower limbs to obtain the height of the operator suitable for operating the farm tractor using the controls. Substituting an arm reach of 62cm for hand brake of Ford6610 tractor in the upper limb equation gave a height of the operator to be 1.56 meters. By this means, an appropriate operator can be chosen. Thirdly, the body angles measured in the sitting position and plotted against height of the operator, showed that the pelvic angle (Pa), had the highest correlation but with a negative gradient. Other limb angles such as the knee angle (Ka) the foot angle, also had negative gradient. It was the elbow angle that related positively but poorly with the height of the operator.

KEYWORDS: Tractor operator's height, body segment, arm-reach, foot-reach, correlation.

1. INTRODUCTION

The design of modern machinery is complex, involving multidisciplinary or systems approach, "the human factors". Thus psychology, industrial engineering, anthropology, physiology and ergonomics are considered in the human factors approach (Huchingson, 1981).

Human factors specialists may be either primarily concerned with research to generate human factors data or concerned with the implementation of human factors data into the systems or work place design (McCormic, et al; 1983). Most works in human factors data involve body dimensions measurements, otherwise called anthropometry.

Anthropometric data are used to ensure that the machine or the environment fits the operator whenever he has to interact with it .Today, the data are also used to calculate parameter values during the human model generating (Yao, et al, 2008) The overall stature is an important determinant in the design of some facilities such as room size, door height or the cockpit dimensions. The size of the pelvis and buttocks limit the size of hatch openings or seats. The size of the hand determines the dimensions of controls and supportive stanchions. Details of arm reach will enable the positioning of controls at appropriate distances (Orbone, 1982; Hertzbeng and Burke, 1971; Purcell, 1980; Stikeleather, 1981)

The dimensions of the reach envelope around an operator can be used to locate controls so that seated operators can operate them without having to lean forward away from the backrest or twisting the trunk, and standing operators can operate them without forward, backward or sideways inclination of the trunk. The reach envelope is a circular track round the operator subtended by a radius which is a straight distance from the seated operator to the control (Bridger, 1995). This can be from the shoulder to the hand controls for arm reaches and from the pelvic to the foot controls for foot reaches.

It is a known fact that body dimensions and shapes of persons in a certain population can be widely distributed due to slight genetic differences (Orbone 1982). Therefore, there may be wide disparity when it comes to different tribes or races. This means that machines and equipment imported and which are designed from data generated from people in developed countries, may not therefore, be very suitable to an average operator from a developing country. For this reason, there is need for researchers to generate human factors data in developing countries. This will help in the selection of imported equipment for a particular tribe, race or region or it may help in the eventual design and construction of some equipment for use in that region. Bassi (1988) has shown that anthropometric data are needed in the production of suitable local Agricultural hand tools.

The design of a farm tractor is different from those of automobiles. Considerable attention in human factors engineering is given to the design of operator's platform and the shape and colour coding of lever handles are somewhat standardized as to location and mode of operation (Huchingston, 1981). Clearance of various locations is necessary to provide access to and from the workplace. Proper workplace dimensions in relation to the seat are important for ease in grasping and operating controls. Anthropometric data are used to properly design the operator's workplace to meet visibility and clearance needs. Two functional considerations in the design of the workplace for tractor operator are visibility and clearance, and they are related to the operator's anthropometric and biomechanical characteristics (Liljedahl *et al*, 1989).

Considering the current worldwide marketing of many given tractor models, the designer needs to consider the use of ethnic anthropometric data. This research is in response to this need. It is important now because many African countries, including Nigeria, are massively importing farm tractors to mechanize farms and produce more food to reduce hunger. Many tractor operators will be employed and this work is to generate anthropometric data for the selection of suitable tractor operators.

Body segments measurements of people of different heights were to be taken when standing on a platform. Measurements of arm-and foot reaches as well as the body segment angles were also to be taken when sitting on an idling farm tractor. Correlation relationships were to be established between the body segments and the heights of the people, tractor operators and potential tractor operators.

2. METHODOLOGY

The participants in the research were selected from Ekpri Nsukara village, near Uyo, where the Ministry of Agriculture Engineering Workshop is situated. They included short, moderate and some very tall people, 5^{th}, 50^{th} and 95^{th} percentiles.

Their heights were taken while standing on a platform. Dimensions of other segments of the body, the trunk, arm, hand, leg, foot length, foot width, palm width, etc; were also measured.

They were again allowed to sit on a farm tractor, (Ford 6610) with their two hands on the steering wheel and their right feet resting lightly on the accelerator pedal. The engine was running at idling speed. The tractor seat was adjusted backwards to maximum position. While in that position, the various leg and hand angles were measured with a protractor. The limb angles in the sitting position measured included the foot angle (F_a), the knee angle (K_a), the pelvic angle (P_a) and the elbow angle (E_a). The distances from the sitting

operator to the different hand and foot control devices were measured as arm and foot reaches respectively, as they made contact with the controls.

For the hand controls (arm reaches) the distances from the shoulder to the different hand control devices were measured as they held these controls. The straight line distance was measured. Such a distance could form a radius round the operator, the reach envelope the distances were taken at minimum and maximum positions of the controls. The average for the distances were taken.

For the foot control devices (foot reaches) the straight distance from the pelvic of the seated operator to each foot control was taken both at zero or minimum position and at fully depressed or maximum position. A straight distance was taken and this could form a radius round the operator. Since the seat was fixed and the measurement was not taken through the thigh and leg, the height of the operator did not influence this distance, the foot reach. Therefore, hand and foot reaches may only differ due to tractor make or model.

The 37 persons selected for the study constituted good representatives of the local population because their heights were reflected. Some of them had the same height and this reduced the total different heights in the study to 21. In such cases, the average value for the body segment was recorded for that height. The various body segment data were plotted against the height of the operator. The data were also subjected to statistical analysis.

3. RESULTS AND DISCUSSION

TABLE 1: ***Average Dimensions of limbs and angles for various Heights of persons.***

S/N (n)	Height (m)	Freq.	Trunk (m) 1	Lower limb Thigh + leg (Leg control) (m) 2	Upper limb Arm + hand (Hand Control) (m) 3	Foot length (m) 4	Foot width (m)	Palm width (m) 5	Foot angle °	Knee angle °	Pelvic angle	Elbow angle °
1	1.52	1	0.43	0.84	0.60	0.24	0.11	0.11	93	58	128	135
2	1.55	2	0.48	0.89	0.64	0.24	0.10	0.113	96.5	67.5	124	135.5
3	1.56	1	0.49	0.97	0.62	0.25	0.11	0.105	93	111(60)	116	150
4	1.58	2	0.49	0.96	0.65	0.25	0.10	0.098	92.5	64.5	122.5	142.5
5	1.59	2	0.47	0.90	0.66	0.25	0.115	0.11	93.5	64	130	150
6	1.60	2	0.46	0.99	0.69	0.27	0.11	0.10	88.5	57	125	137.5
7	1.61	1	0.45	0.93	0.72	0.26	0.10	0.10	95	62	130	132
8	1.62	1	0.44	1.00	0.70	0.26	0.10	0.115	91	53	122	150
9	1.63	1	0.44	0.95	0.69	0.24	0.10	0.112	91	68	130	150
10	1.64	1	0.46	1.00	0.71	0.28	0.11	0.11	92	55	125	125
11	1.65	4	0.48	0.95	0.67	0.27	0.11	0.11	91	55.5	114.5	154
12	1.66	4	0.45	0.99	0.67	0.27	0.11	0.11	95.3	60.00	114.3	150
13	1.67	1	0.52	0.91	0.67	0.26	0.115	0.11	90	63	120	150
14	1.70	3	0.48	1.02	0.73	0.27	0.11	0.11	96.7	68.7	105.3	135.
15	1.71	3	0.49	1.04	0.75	0.28	0.11	0.11	96	60	118	141
16	1.72	1	0.47	1.05	0.71	0.28	0.11	0.10	96	62	110	150
17	1.73	2	0.49	1.02	0.73	0.30	0.11	0.113	93	67	107.5	133
18	1.74	2	0.49	1.08	0.74	0.28	0.11	0.11	94	58	114	151
19	1.77	1	0.49	1.06	0.84	0.27	0.10	0.11	94	56	130	135
20	1.78	1	0.46	1.07	0.84	0.28	0.11	0.112	85	45	110	135
21	1.87	1	0.47	1.20	0.87	0.29	0.112	0.114	88	71(55)	114	152
n =21	_33.451 H=1.59	= 37		= 18.87 Mean = 0.90	14.90 Mean = 0.71							

TABLE 2: Some hand and foot control reaches of Ford 6610 tractor.

A. Hand Controls (Arm reach, shoulder to control unit).

Hand throttle		Steering (centre) (m)	Low gear (m)	High gear (m)	Hand brake (m)	Hydraulic control (m)		Light knob (m)	Fuel cut off (m)	PTO lever (m)	Horn (m)	Ignition key	Levelling lever	
Min. Pos.	Max Pos.					Min Pos.	Max Pos.						3pt. min	3pt. max
		0.55	0.66	0.61	0.69	0.60	0.68	0.61	0.60	0.66	0.66	0.65	0.60	0.77

B. Foot Controls (Foot reach = waist to control unit).

Brake Pedal (m)	Clutch Pedal (m)	Foot throttle (m)
0.88	0.69	0.80

Table 1 shows the dimensions of body segments against the heights of the operators at a standing position. The angles of the bending limbs were measured at sitting and driving posture on a farm tractor. The respondents represented the approximate heights of the people of the local community, Ekpri Nsukara, near Uyo in Akwa Ibom State of Nigeria. Thus, the shortest range, 5^{th} percentile is represented by the top part of the Table while the tallest range representing 95^{th} percentile is indicated at the bottom of that Table. The middle portion shows the average heights of people in the community, 50^{th} percentile.

Table 2A shows the hand control reaches from the shoulder of the operator to the hand controls. These distances differ according to the make and model of the farm tractor. The ease with which an operator reaches the hand control depends on the length of his hand (shoulder to palm).

Table 2B shows the foot control reaches, from the pelvic to the foot controls such as the clutch, brake and throttle pedals.

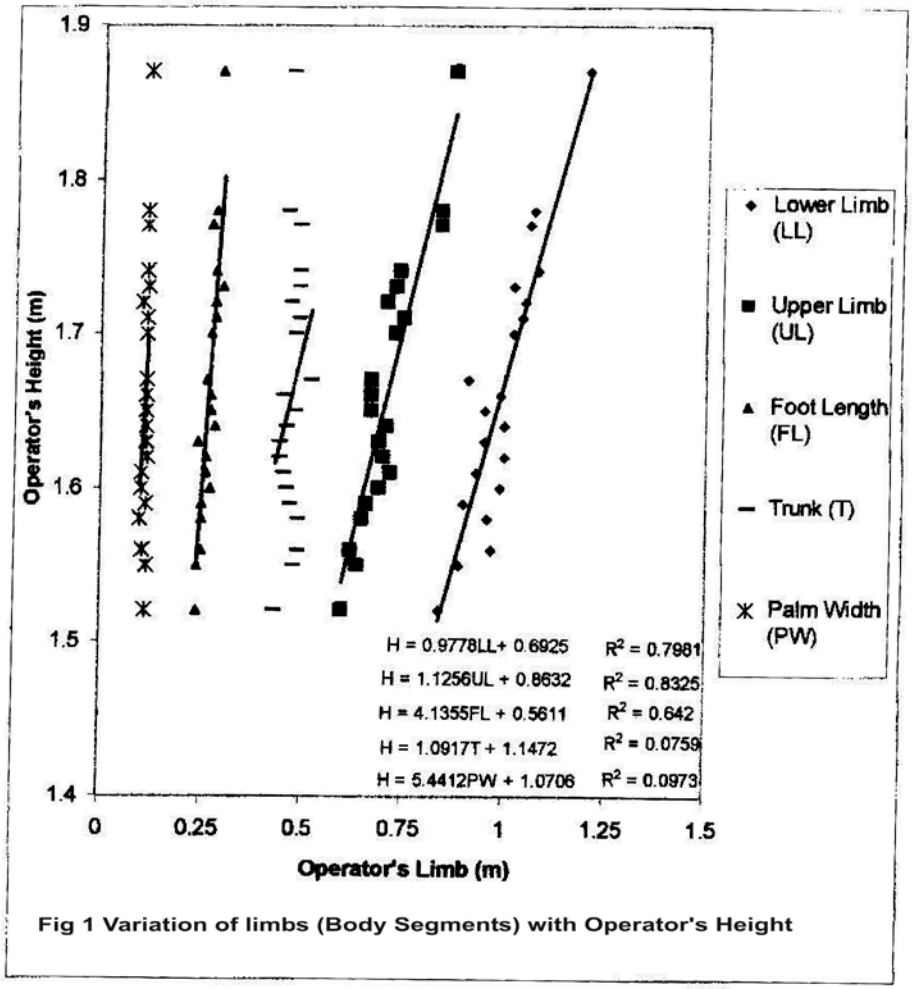


Fig 1 Variation of limbs (Body Segments) with Operator's Height

Figure 1 shows graphs of body segments mainly the limbs, plotted against the height of the operator. Linear regression equations relating the body segments to the height are also indicated. Adams (1989) reported of such analysis. Park, et al (1999) also showed a similar linear regressional relationship between the weights and volumes of body segments and the whole body weights and body volumes, respectively, for different ages and sex of Korean people. The limbs considered here are as follows:

(i) **Upper Limb (UL):** The upper limb (shoulder to fingers) otherwise called arm reach in this work is highly correlated with the height of the operator as indicated by an R value of 0.9124. This value is greater than the tabular R value at n-2 degrees of freedom at both 5% and 1% ∞ levels of significance. The correlation equation is given by:

$$H = 1.1256\,UL + 0.8632, \quad R^2 = 0.8325 \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where H = height of the operator (m)
UL = upper Limb (m)

(ii) **Lower Limbs (LL):** The lower limbs (pelvic to foot control) or foot reach is also highly correlated with the height of the operator. The correlation is given by the equation;

$$H = 0.9778LL + 0.6025, \text{ (m)}, \qquad R^2 = 0.7981 \ldots\ldots\ldots(2)$$

In this equation, the calculated R, 0.8012 is greater than the tabular R at n-2 degrees of freedom at both 5% and 1% ∞ levels of significance.

Thus, these two limbs (UL and LL) vary directly with the height of the operator. The implication of this high correlation is that they can be used with the appropriate regression equations to predict the height of the operator.

Farm tractors of different makes and sizes have different hand and foot controls. The operator should have adequate arm-and foot-lengths in order to operate the machine effectively. For example with the same tractor used, it was found that the longest arm-reaches were 0.60m, 0.77m and 0.69m for fuel cut off, leveling lever and hand brake, respectively (Table 2). To select an operator for this high clearance tractor, he should have an arm-reach of about 0.77m and substituting this figure in the regression equation of upper limb (UL) gives an operator's height of 1.75m. In the same vein, the longest foot-reaches were 0.88m, 0.69m, 0.70m for brake pedal, clutch pedal and foot throttle, respectively. Substituting the figure, 0.87m in the appropriate lower limb (LL) regression equation gives an operator's height of 1.55m. From the two results, it was observed that the foot reach regression equation gave a slightly lower height of the operator, which is within the reach of an average operator height. This confirms the fact the upper limb is more correlated than the lower limb as indicted by the higher correlation coefficient, R= 0.9124., and then higher height of the operator generated.

Seats in modern machines are adjustable so as to enable the operator sit properly and adjust his legs. The important points of considerations in the location of controls are the ease of reach and maximum force that can be exerted on it during pulling or pushing.

Dupuis (1957), found that the maximum force that can be exert by pulling is at about 57 to 66cm forward from seat reference point and this span is said to define the location of a lever control (such as hand brake), if pulling force is to be reasonably high. From Table 2, nearly all hand control positions are in this range of distance from the operator's sitting position. Table 1 also shows that even the shortest man in that study has his upper limb adequate to handle these hand controls when sitting on the tractor. Therefore, for effective pulling of the hand controls, the arm reach of the operator should be about 61cm on the average and his height from the regression equation should be about 1.55m.

But for very tall people their upper arms may be 0.85m. In such a case, the operator will hold the controls with a bending elbow which may not exert maximal force. Also, if the arm-reach of the operator is 50cm, his height as obtained from the regression equation of upper limb, will be 1.43m.With this height, the operator may not be able to perform well. Hence the minimum upper limb of the operator should not be less than 55cm or operator's height of 1.48m.

(iii) **Foot Length (FL)**

$$H = 4.1355FL + 0.5611 \qquad R^2 = 0.642 \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

The foot length was found to be highly correlated with the height of the operator. The correlation coefficient calculated was found to be greater than the tabular R at both 5% and 1% ∞ levels of significance. Therefore, the equation relating the foot length with the height of the operator can be used in predicting the height of the operator from his foot length. Hence the foot length of the operator is directly proportional to his height.

In some machines where precision in required for foot controls or pedals e.g. (aeroplanes), there is need for reasonable foot length. This may account for selecting tall people as pilots. This measurement is also needed to determine the size of foot wears.

(iv) **Trunk (T)**

$H = 1.0917T + 1.1472$, $R^2 = 0.0759$ ……(4)

The height of the trunk of the body will help an operator who is seated to have an overall view of the machine environment. From Fig. 1, it is observed that the trunk of the body is poorly correlated with the height of the body. The calculated 'R' is less than the tabular 'R' at both 5% and 1% ∞ levels of significance at n-2 degrees of freedom. The non-correlation can further be observed from Table 1 where some of the shorter operators have higher trunk dimensions. Therefore the trunk of the operator is not directly proportional to his height. However, disparity in trunk height with the height of people is small.

(v) **Palm Width (PW)**

$H = 5.4412\ PW + 1.0706$ $R^2 = 0.0973$ ……(5)

From Fig.1, it could be been is seem that palm width is not proportional to the height of the operator, with a poor correlation between them. Therefore, a short operator can have a wider palm and can have full grip of the control knob.

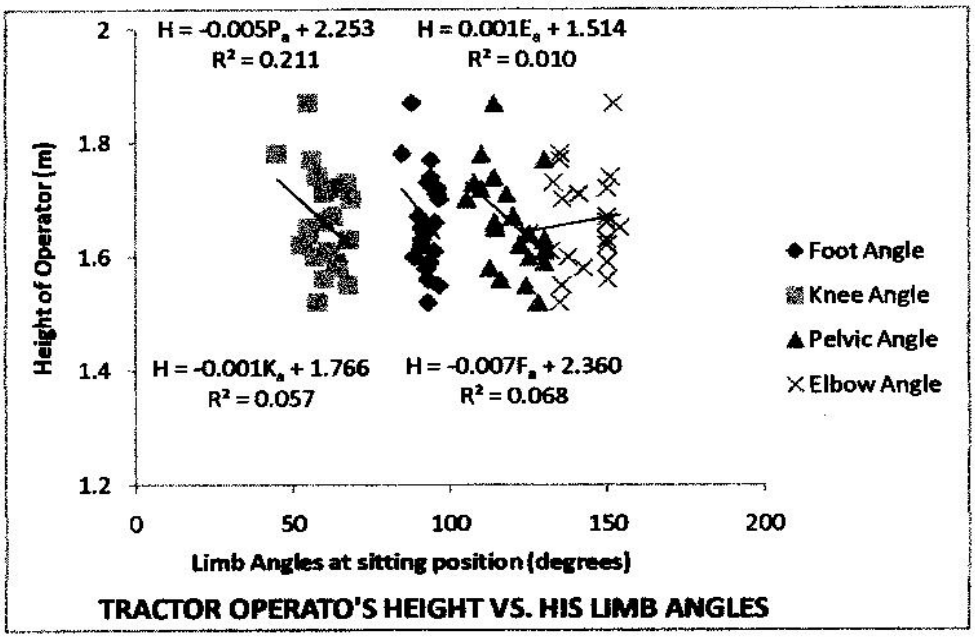


Fig.2 Tractor Operator's Limb Angles Versus Height

Figure 2 shows graphs of angles of bending limbs at driving position plotted against the height of the operator. The linear regression equations showing the relationship between the height of the operator and the limb angles are also shown.

(i) **The knee Angle (Ka)**

$H = -0.001k_a + 1.766$, $R^2 = 0.57$……..(6)

The knee angle has a negative gradient in the linear regression equation. Therefore it is inversely related to the height of the operator. This means that when a tall operator sits on the tractor, he bends his knee angle which becomes smaller than when a short person is sitting. The sitting position may adversely affect the performance of a tall operator. The linear relationship is poor and insignificant and as such the height of the operator cannot be said to positively affect the knee angle in a sitting or driving position.

(ii) **Foot Angle (F_a)**

$H = -0.007F_a + 2.360$, $R^2 = 0.068$……..(7)

The foot angle is also poorly correlated with the height of the operator. The linear regression equation has a negative gradient showing that the foot angle is inversely related to the height of the operator in a sitting position. If the bending foot angle of very tall operator is too small, he may experience some discomfort.

(iii) **Pelvic Angle (P_a)**

$H = -0.005P_a + 2.253$, $R^2 = 0.211$……..(8)

The gradient of the linear regression equation is negative, the linearity is significant. The relationship can be described as fairly correlated with the height of the operator but in the opposite direction. This also shows that the pelvic angle becomes smaller with tall operators which may indicate an uncomfortable sitting position.

(iv) **Elbow Angle (E_a)**

$H = -0.0011E_a + 1.514$, $R^2 = 0.010$……..(9)

The linear regression equation has a positive gradient showing it is directly related to the height of the operator. But the correlation in extremely poor and so the elbow angle cannot be said to be affected by the height of the operator in a sitting position.

4. CONCLUSION

The performance of a farm tractor operator can be directly affected by his height. This is because the upper limbs (arms) lower limbs (legs) and the foot length are found to be linearly related to his height. Therefore the taller the operator, the more ease with which he handles the hand and foot controls. However, the upper limb which has the highest correlation coefficient is preferred in predicting the operator's height.

Suitable potential tractor operators' heights can be selected by choosing the proper height determined from the appropriate linear regression equation when the arm-and foot-reaches of the farm tractors are known. With the ford 6610 tractor used in this work, and with other high clearance tractors, it was found that good tractor operators can be of the height of 1.55m and above for ease of foot control devices manipulations.

It has also been found that the body trunk and palm width of an operator are not directly related to his height. Therefore, these two segments of the body cannot be used in determining the proper height of the tractor driver.

The knee, foot and pelvic angles are inversely related with the height of the operator but the elbow angle is positively related.

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CLEANING LOSS CHARACTERISTICS OF A CONVENTIONAL STATIONARY RASP BAR SORGHUM THRESHER

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ABSTRACT

The effect of some crop and machine parameters such as straw bulk density ranging from 35 to 38 kg/m^3, feed rate ranging from 480 to 680 kg/h, sieve oscillation frequency ranging from 6 to 12 oscillations per seconds and threshing cylinder speed ranging from 3.56 to 5.66 m/s on the cleaning loss of a conventional stationary rasp bar sorghum thresher was explored. Results showed that there was an increase in cleaning loss with increase in straw bulk density, threshing cylinder speed and sieve oscillation frequency. At low parameters combination values, cleaning loss was 9.73 % while at high combination values, the cleaning loss was high, 54.44 %. The optimum combination for loss minimization was cleaning parameter with air speed 5 m/s, sieve oscillation frequency 6 oscillations per seconds and feed rate 543 kg/h.

KEYWORDS: Cleaning loss, feed rate, moisture content, speed, sieve oscillation frequency, density,

1. INTRODUCTION

Threshing of grains in the developing countries has been predominantly manual involving beating the plant heads with sticks at different spots in or near the farm. Occasionally, the threshing points may be bare ground, tarpaulin spread on hard surface in the field, stony or rocky areas or abandoned roads near farms. Sometimes harvested heads are transported to the homestead and are threshed using sticks, mortar and pestle or in a bag with special sticks. These processes are slow, laborious with high potential of contamination with debris and stones, susceptible to internal and external damage and give very low output (Asota, 1996). These have led to losses which occur during threshing due to spillage, incomplete removal of grains from heads, damage to grain and contamination with sands and stones. Choudhury and Kaul (1979) noted that 6-8 % of grains being manually winnowed is lost in the chaff. Odigboh (2004) gave post harvest losses estimate in Nigeria to be up to 25%.

One approach at meeting increasing demands for food supplies is by reducing heavy losses of food grain at the post harvest stage (FAO, 1979). Kays (1991) reported that the total cost of losses which occur during post harvest phase is substantially greater that that incurred during the production phase. Characterizing the losses during cleaning process is essential to arriving at the most appropriate compromise to obtain optimum conditions that will reduce losses. Asota (1996) reported that lack of consumer demand for quality product, lack of awareness of losses that could be saved economically and conveniently and lack of reward for good quality threshed products are some of the factors impeding the development of efficient threshing machines. Also proper understanding of the post harvest processes of sorghum will help to readily make the crop available at right quantity, quality and prices. This study explores the effect of some crop and machine parameters on the cleaning loss of a conventional stationary rasp bar sorghum thresher.

2. MATERIALS AND METHODS

2.1 The Test-Rig

The test rig used for the study is shown in Figure 1. It consists of the frame, the hopper, the threshing unit, the sieve, the reciprocating mechanism, the blower and collecting tray. The collecting tray was 100 cm long divided into eight (8) compartments of equal distances of 11 cm each as done by Kutzbach (2003) and Rothaug, *et al*. (2003). The grains in each compartment were collected manually separately for analysis. A 3.75 kW (5 hp) petrol engine was used to prime the threshing, sieves and blower units. The specifications of the sorghum thresher are listed in Table 1.



Figure 1. Side view of the sorghum thresher testing rig.

Table 1. Parameters of the sorghum thresher test rig

Parameter	Dimension, m
Overall length	1.474
Overall width	0.386
Overall height	1.323
Effective threshing cylinder diameter	0.140
Effective concave diameter	0.310
Sieve dimension	0.735 x 0.300
Sieve amplitude	0.05
Blower-major diameter	0.460
Blower- minor diameter	0.350
Blower- width	0.300
Blower-throat	0.150
Blower blades dimension	0.160 x 0.120
Sieve inclination	0^0(horizontal)
Air direction	0^0(horizontal)
Cylinder – concave clearance	0.015

Threshing Unit: Threshing unit carried out the actual removal of grains from sorghum heads. It comprised threshing cylinder and concave.

(a) Threshing cylinder is a bar type consisting of a cylinder 140 mm diameter with length of 320-mm. 6 numbers 20 mm by 20 mm angle iron were inverted and welded equi -distant on the outside diameter of the cylinder to give an overall cylinder diameter of 175 mm. A 600 mm shaft diameter 25 mm passed through the center of the cylinder. The threshing cylinder weighed 10.01 kg (karl kolb D 6072).

(b) Concave was formed into a basket using flat bars 4 mm thick and 10 mm diameter iron rods. Concave had a semicircular diameter of 310 mm. The threshing cylinder concave clearance was the same and fixed throughout the test at 15 mm at the inlet, 3 mm at the middle and 7 mm at the outlet.

Sieve: The sieve scalped, removing larger material particles and trash out. There were two sieves, arranged horizontally and carried in separate racks one above the other, reciprocating as a unit. The sieve racks have adjustable inclinations. There are four (4) supporting hangers of the sieve carrier assembly. The reciprocating motion of sieves is transmitted from an eccentric by a pair of connecting rods at each side of the machine. The upper and the lower sieves remove the larger than grain constituents. Grains and chaff passed through sieve holes cross flow the air current, which removed lighter than grain particles. Distance between the sieves was 150 mm. Sieve constructed from 16 gauge (1.6mm) metal sheet, was dimensioned 935 mm long and 300 mm wide. Sieve hole diameters are 6.5 mm and are readily removable whenever it is necessary. Four hitch pins; two at each side suspend the sieves. The sieve racks have adjustable tilt angle.

Reciprocating Mechanism: Quick return mechanism was used to translate rotary motion of engine to a reciprocating motion of sieves. There were 4 adjustable arms, which transferred reciprocating motion to the sieves. The reciprocating mechanism was attached to the lower sieve having the crank radius of the rotating arm 50 mm. The stroke of reciprocation was 100 mm. The length of the connecting rod was 575 mm. The reciprocating mechanism exerts force on the particle in the horizontal and vertical directions.

Blower: A centrifugal blower driven via pulley and vee belt by the prime mover generated air stream. Blower propelled air continuously by aerodynamic action and consisted of housing and blades. It blow air stream in between the two sieves with air current aiding in lifting up straw and stalk on the upper sieve. It comprises of an impeller, which rotates in a scrolled (spiral) shaped casing. The housing was spiral shaped with a major diameter of 460 mm and minor diameter 350 mm while the width was 300 mm. The inner diameter for air inlet was 220 mm with provision for regulation of the air opening through gates. The throat of the blower housing was 150 mm. There were 4 straight paddle blades dimensioned 160 by 120 mm bolted to a 25 mm diameter shaft. A simple flat radial blade was bolted to the central spider. This type of blade is capable of operating satisfactorily in a dusty environment because of the self-cleaning characteristics (Osborne and Turner, 1967; Ige, 1978).

Grain collector: The cleaned grain that passed the sieves was collected for analysis. The collector was 1000 mm long divided into eight compartments of equal distances of 110 mm each as done for alfalfa by Mkomwa (1988). Grains in each compartment were collected separately for analysis.

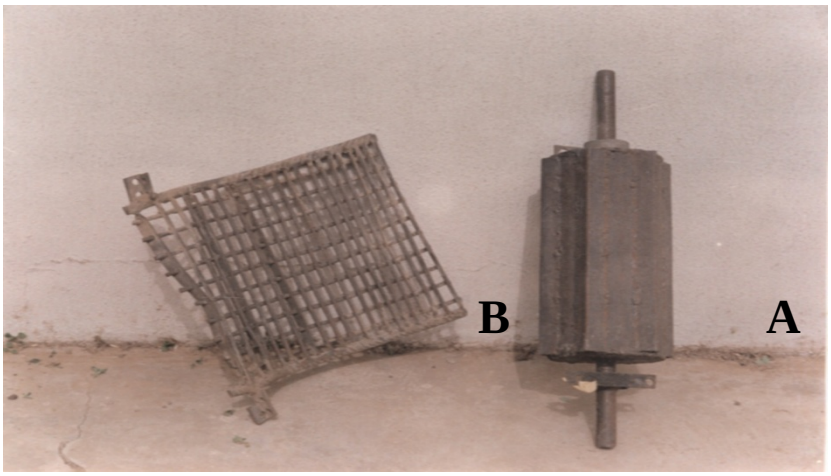


Figure 2**:** Threshing cylinder (A) and concave (B)

2.2 Test Sample

Sorghum variety, SAMSORG 17 (SK 5912) was selected as test crop for the experiment. The same sorghum variety was used throughout the experiment to eliminate varietal differences effects due to contamination. The seed was obtained from the sorghum multiplication unit, Plant Science Department, Institute for Agricultural Research, Ahmadu Bello University, Zaria.

2.3 Parameters Measured

2.3.1 ***Moisture Content***

Moisture content of samples was determined using the procedure detailed by Henderson *et al.* (1997). The samples were dried at 130^0C for 18 hours (ASAE, 2003). The weight loss of the samples was recorded and the moisture in percentage determined. This was replicated three times. The moisture content was calculated as:

$$MC_{wb} = \frac{W_i - W_d}{W_i}.100 \qquad 1$$

where

MC_{wb} = moisture content, wet basis, %.
W_i = initial weight of sample, kg.
W_d = dried weight of sample, kg

2.3.2 ***Measured Machine Parameters***

i. Time

Crop feeding and threshing times in seconds were measured with stopwatch. A stopwatch (Precista max 60, d =15) was used to determine the air velocity in meters per minute.

ii. Shaft Speeds

A tachometer (Smith Industrial Division, London HW2, max 50,000 rpm, d=1 rpm) was used to determine the speed of threshing cylinder shaft, blower shaft and sieve shaft.

iii. Air Velocity

Air velocity from radial blade centrifugal fan was determined using anemometer (Pruufschein Fur Anenometer, L-Nr, 3010/112546). The anemometer was placed in the air stream.

2.3.3 ***Determined Machine Parameters***

i. Feed rate:

Feed rate was computed as weight of crop fed into machine per unit time (hr).

ii. ***Bulk Density of Samples***

A rectangular container dimensioned 210 by 145 by 72 mm was used. The sample, which filled the container, was weighed using electronic mettler balance (Sarturious 2355, maximum 160g, d = 0.001d). The bulk density of the samples were determined using the method given by Mohsenin(1980) using the relation:

$$\beta = \frac{m}{v} \qquad 2$$

Where:
m = mass of grain, chaff or straw, kg
v = volume of container, m^3.

iii. Linear Velocity:

For a rotating shaft with speed n and pulley of radius r

$$V = \frac{2\pi rn}{60} \qquad 3$$

In which n is speed in revolutions per minute

iv. Sieve Oscillation Frequency

The sieve oscillation frequency, α, was obtained from eqn 4

$$\alpha = \frac{N}{t} \qquad 4$$

where :
N = the number of reciprocation
t = the time in seconds

v. Cleaning Loss (C_L):

$$C_L = \frac{G_i}{G_w} x100 \qquad 5$$

where
C_L = cleaning loss, %.
G_w = weight of grain at input, kg.
G_i = weight of grain at the chaff outlet, kg.

2.4 Data Analysis

The method of regression analysis as described by Gomez and Gomez (1984) was used to describe the relationships. General Linear Model (GLM) procedure of Statistical Analysis System (SAS, 1989) was used to analyze the data.

3. RESULTS AND DISCUSSION

The performance of the thresher in terms of cleaning loss characteristics was evaluated. Cleaning loss is the quantity of sorghum grain blown out with trash effluent during the cleaning process.

3.1 Effect of Straw Bulk Density

Figure 3 shows the effect of straw bulk density on cleaning loss. There was generally an increase cleaning loss with increase in straw bulk density. There was an initial decrease in cleaning loss from 11 % at 35.3 kg/m^3 to 9.9 % at 36 kg/m^3 respectively then increased up to 54 % cleaning loss at 38 kg/m^3. The relationship between the cleaning loss and straw bulk density is given by the equation.

$$C_L = 14613 - 811.46\beta_s + 11.27\beta_s^2 \qquad 6$$

where

β_s =straw bulk density, kg/m^3

The coefficient of determination R^2 is 0.82. When the straw bulk density increases, the material on the sieve forms a dense mat, which may reduce the grain penetrating through the straw thereby increasing the amount of grain that is discharged from the sieve as chaff. The segregation and separation model has been modeled using the convection and diffusion model which describes the physical processes involved in grain penetrating the mog layer. The stochastic vertical grain movement is combinations of constant sinking movement (convection) and random scattering (diffusion) (Kutzbach, 2003). The dense straw therefore may be impeding the penetration of grains causing it to be dropped with the chaff at the end of the sieve. Hollatz and Quick (2003) reported static pressure build up under heavy mat of grain and mog on chaffer and sieve. The heavy mat of material tends to plug the openings causing much of the grains not to penetrate the chaffer and is dumped out of the machine onto the ground. The result in the study agreed with this assertion. Srivastava *et al* (2006) published that higher straw density reduces separator capacity.

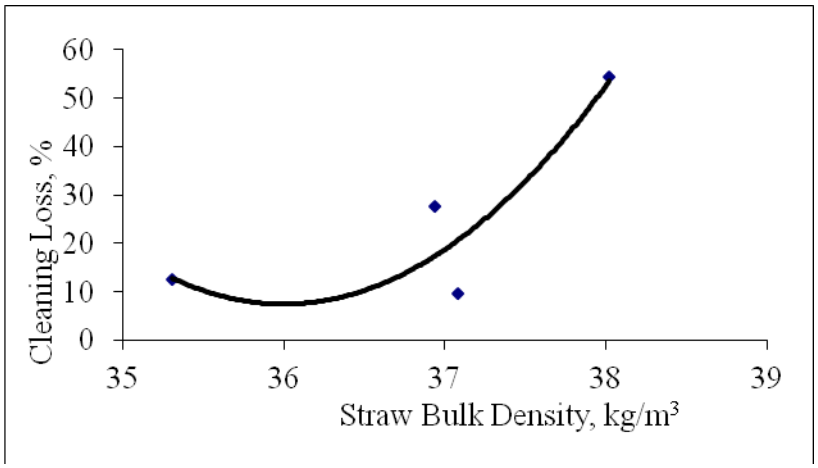


Figure 3. Effect of straw bulk density on cleaning loss

3.2 Effect of the Speed of Threshing Cylinder

The effect of speed of threshing cylinder on cleaning loss is shown in figure 4. There was an increase in cleaning loss with increase in threshing cylinder speed within the range 3.56 and 5.66 m/s. When the speed of threshing cylinder was 3.56 m/s, cleaning loss was 9.73%, which increased to 54% when the threshing cylinder speed was 5.66 m/s. The equation describing the relationship between cleaning loss and speed of threshing cylinder is given by

$$C_L = 222.28 - 110.63\ V_t + 14.305\ V_t^2 \qquad 7$$

where

V_t = threshing cylinder speed, m/s

The coefficient of determination R^2 is 0.99. Increasing the speed of threshing cylinder increased impact on materials introduced to concave to be threshed, which is all discharged on sieves in fine minute particles to be cleaned. This increased load intensity on the sieve, which causes matting thereby reducing the chances of grain passing through mixture mass to the sieve holes for cleaning across the air current. A similar experience was explained by Hollatz and Quick (2003) for wheat by reporting that overthreshing occurs when the grain and mog are pulverized to finer particles. And they noted that overthreshing occurs as the cylinder speed increases thereby causing a marked rise in losses.

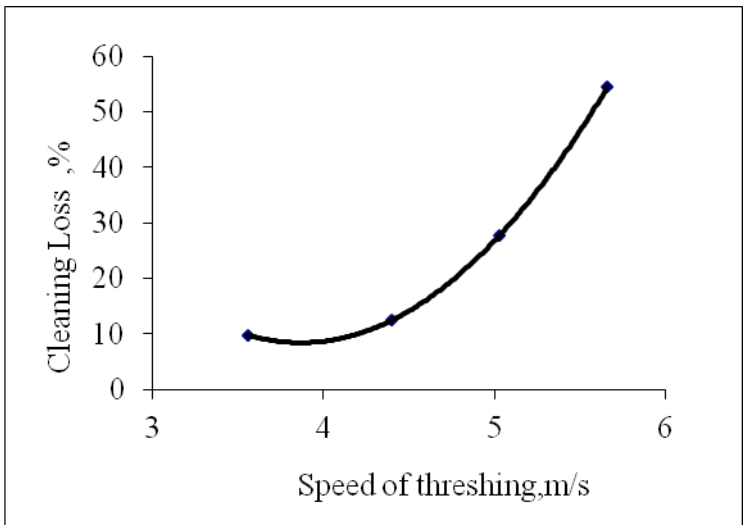


Figure 4. Effect of speed of threshing cylinder on cleaning loss

3.3 Effect of Sieve Oscillation Frequency

The effect of sieve oscillation frequency on the cleaning loss is presented in Figure 5. There was an increase in cleaning loss with increasing sieve oscillation frequency from 6 to 12 oscillations per seconds. At 6 sieve oscillations per second, cleaning loss was 9.73 % but at 12 sieve oscillations per second, cleaning loss increased to 54 %. The relationship between the cleaning loss and the sieve oscillation frequency is given by the equation:

$$C_L = 72.57 - 19.46\ \alpha + 1.50\ \alpha^2 \qquad 8$$

where

α = sieve oscillation frequency, oscillations per second

The coefficient of determination R^2 is 0.99. Srivastava, *et al.*, (2006) reported that frequency and amplitude

determines the level of acceleration imparted on the crop. This according to them determines the agitation level that will give the least resistance for grain separation. Increasing sieve oscillation frequency allows less resident time for the materials to be separated to stay on the sieve not allowing it to pass through the sieve holes. Also, as material is about passing through the hole, oscillating sieve may impinge force on grain materials, thereby imparting away as cleaning loss.

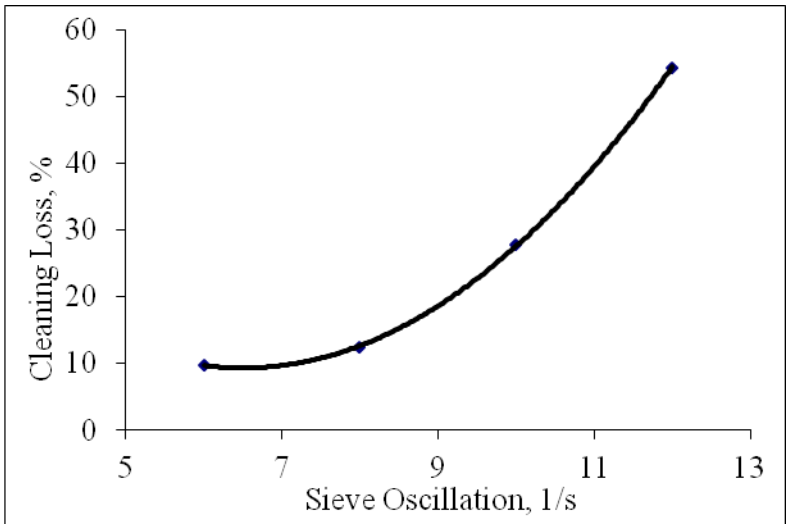


Figure 5. Effect of sieve oscillation frequency on cleaning loss

3.4 Effect of Feed Rate

The effect of feed rate of materials to be cleaned on cleaning loss is given in Figure 6. There was an increase in cleaning loss with increasing feed rate within the range of 480 kg/h and 680 kg/h. When feed rate was 480 kg/h, cleaning loss was 10 % and when feed rate was 680 kg/h cleaning loss increased to 54 %. The equation describing the relationship between the cleaning loss and feed rate of material is given by

$$C_L = 441.69 - 1.6743Fr + 0.0016\,Fr^2 \qquad 9$$

where

Fr= feed rate, kg/h

The coefficient of determination is 0.99. The increase in cleaning loss with feed rate may be due to load intensity on the sieve, which results in matting on sieve with material other than grain blocking sieve holes, thereby increasing grain cleaning loss. Lee and Winfield (1969) reported that at high feed rate, material particles are no longer supported aerodynamically, which forms a mat on sieve, increasing grain losses. Similar results were reported recently by Hollatz and Quick (2003) and Wacker (2003) for wheat. Srivastava et al (2006) published that increasing mog feed rate of crop increases grain losses exponentially.

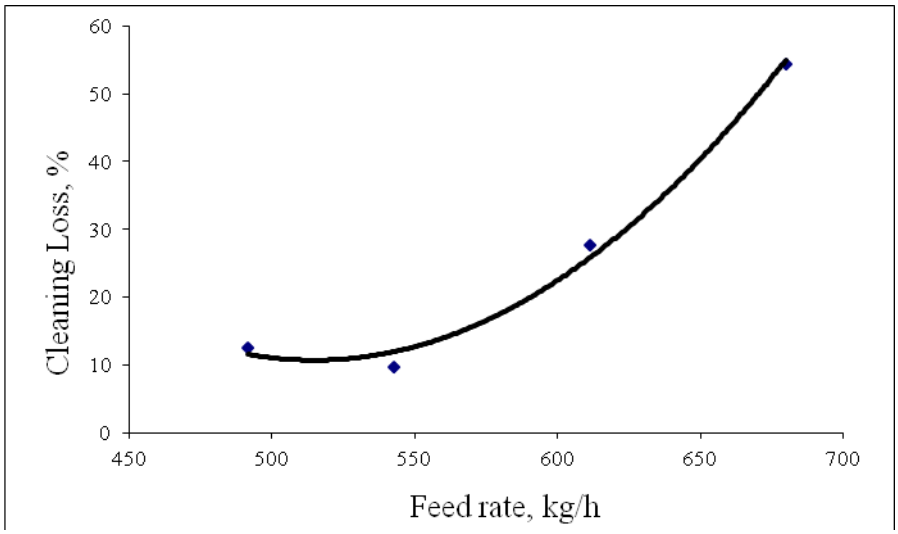


Figure 6. Effect of feed rate on cleaning loss.

3.5 Effect of Cleaning Parameters Combinations on Grain Cleaning Loss

The effect of cleaning parameters combination on cleaning loss is given in Figure 7. Cleaning parameter combination 1 represented by histogram 1 involved air speed 5.00 m/s, sieve oscillation frequency 6 oscillations/sec and feed rate 543 kg/h. Cleaning loss was 9.73%. When combination was air speed 8.67 m/s, sieve oscillation frequency 8 oscillations /sec and feed rate 491 kg/h, represented by histogram 2. Cleaning loss was 12.48 %. Histogram 3 represent cleaning loss for combination having air speed 9.33 m/s sieve oscillation frequency 10 oscillations /sec and feed rate 611 kg/h. Cleaning loss was 27.73 %. Cleaning parameter combination represented by histogram 4 involved air speed 9.67 m/s, sieve oscillation frequency 12 oscillations / sec and the feed rate 680 kg /h, cleaning loss was 54.44%. It can be observed that there is an increase in the grain cleaning loss with increase in the cleaning parameters values. At low parameters combination values, cleaning loss was 9.73% while at high combination values, the cleaning loss was high, 54.44%. A lot of sorghum grain materials and chaff are thrown away at high parameter combinations. The optimum combination for loss minimization was cleaning parameter 1 with air speed 5 m/s, sieve oscillation frequency 6 oscillations per seconds and feed rate 543 kg/h.

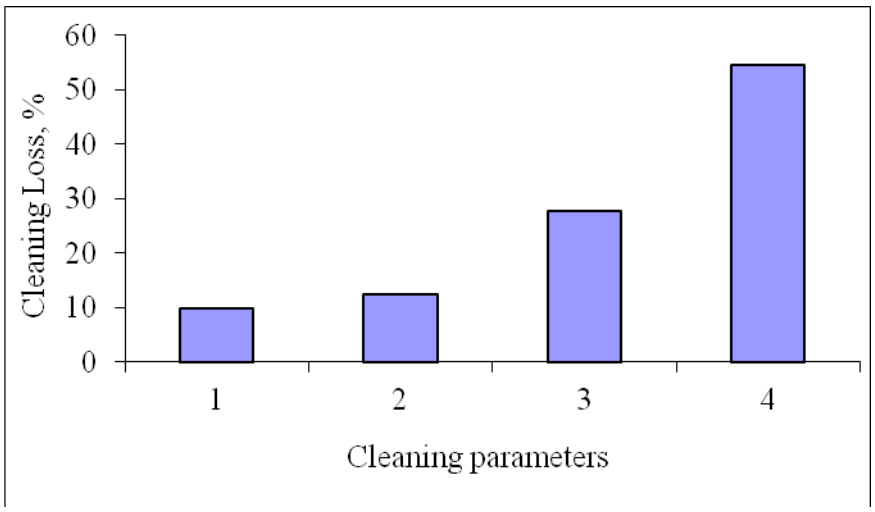


Figure 7. Effect of cleaning parameters on cleaning loss

4. CONCLUSIONS AND RECOMMENDATIONS

The effect of some crop and machine parameters such as straw bulk density, feed rate, sieve oscillation frequency and threshing cylinder speed on cleaning loss of a conventional stationary rasp bar sorghum thresher were explored. Results showed that

i. Cleaning loss increased with increase in straw bulk density, threshing cylinder speed, and sieve oscillation frequency.

ii. The optimum combination for loss minimization occurred with air speed 5 m/s, sieve oscillation frequency 6 oscillations per seconds and feed rate 543 kg/h.

iii. The sieve characteristics in terms of length, width and angle of inclination influence on cleaning loss should be explored in another study.

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DESIGN OF A GARI FRYER

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ABSTRACT

Gari a dry granular, fermented product of cassava is widely consumed across West Africa, Central Africa and in some parts of North and Southern Africa. It can be consumed directly without cooking. The, processing of cassava into gari is largely done manually. However some of the unit operations have been mechanized, though peeling and frying are yet to be fully mechanized. In this paper, a machine for gari frying was designed, fabricated and tested. The major components of the machine include the hopper, base fryer, drum-auger conveyor, frame, heating chamber, shaft, charcoal plate, and discharge outlet. The machine is powered by a three-phase (20 rpm – 100 rpm) 1.5kw electric motor (variable speed reduction gear motor) connected to the mains through a control box which controls the movement of the auger conveyor; forward, stop and backward. Charcoal was used as a source of heat energy required for the gari frying. The performance characteristics of the machine, that is, functional efficiency and throughput capacity evaluated at an optimum operating speed of 20 rpm were 71.4% and 20.4 kg/hr respectively. The product (i.e gari) obtained during the test was fit for human consumption. It has a pleasant colour, texture, smell and taste. The two main aims of frying gari (called garification) were achieved, that is the safe cooking and the reduction of moisture content (MC) to a storage level. The machine can be used by the small and medium scale farmers and it can complement emerging mechanized methods of cassava processing which include; Washing, Peeling, Grating, Dewatering, and Sieving. It has low maintenance cost, reduced drudgery, save labour, save time and eliminates smoke during frying operation.

KEYWORDS: Design, gari fryer, functional efficiency, throughput capacity.

1. INTRODUCTION

The operations involved in the preliminary processing of the various forms of products from cassava include washing, peeling and size-reduction, drying and milling. The sequence of these operations commences soon as the roots are harvested. This is because cassava roots deteriorate within few days after harvest and the rate of deterioration varies between cassava varieties (Wenham, 1995) . Cassava damage after harvest is aggravated when tubers are bruised and then they rapidly become of little value for consumption or industrial applications (Agbetoye, 2003). Cassava consists of high percentage of water, processing it into dry form by reducing the moisture content and will enhance preservation and convert it into more durable and stable product. Gari is a processed fermented product from cassava and is consumed in Nigeria as well as in most countries of the West African Coast and in Brazil. The preparation of gari from cassava has traditionally been done according to local and rudimentary processing techniques. The unit operations involved in gari processing (called garification) involves sorting, peeling, washing, grating fermentation, dehydration, sifting, frying and packaging. Various machinery have been designed to aid the large scale processing of cassava. They include graters (Akinyemi and Akinlua, 1999); peeling machines (Olukunle and Atere 2009); dewatering, sifters and pulverizers for dried cassava mash and gari fryers (Odigboh, 1983) Agbetoye et.al, (2006).

Drying solid means the removal of some amount of water or other liquid from the solid material to reduce the content or residual liquid to acceptable low values. It is usually the final step in a series of processing and handling operations and the product from a dryer is often ready for final packaging. There are three major

industrial methods of removing moisture from solid materials as reported by Jackson and Lamb, (1981). These are by subjecting it to a high velocity stream of heated, low humidity air (air drying) or by placing it on a heated surface and allowing evaporation of moisture into the surrounding atmosphere (contact drying), or by subjecting it to a low pressure heating source (vacuum drying). Cassava has about 60% water content while final gari is between 10-15% (Odigboh and Ahmed, 1982).

The basic principle of frying gari is that of moisture removal from the fresh mash, repetitive pressing, scrapping and stirring over a hot surface until the moisture reaches an acceptable level when the gari could be store. Heat is applied via the trough to the mash for the evaporation of its moisture. This is accompanied by the gelatinization of the starch granules, toasting and eventually drying of the mash. Effectiveness of these processes depends on the mash initial moisture content, frying time, frying temperature and quantity of mash introduced into fryer. Gari frying, though a dehydrating process, is not a straightforward drying process. It is not possible to produce gari from cassava pulp by just passing heated air through it. The product from such an operation would be dried cassava pulp or granules and not gari. Gari frying is a simultaneous cooking and dehydrating operation. The product is first cooked with the moisture in it and then dehydrated.

The heat intensity during frying affects the quality of the product. The moisture content of dewatered and sieved cassava mash is normally between 35 to 50% which has to be reduced to around 12% after the frying operation. In the local technique, the initial frying temperature is relatively low so as to avoid the formation of many lumps or caking. As the moisture content reduces and most of the small lumps developed, would be broken down by constant pressing and agitation. The temperature is increased in order to further cook to a safe level and dehydrate the product. The colour and taste of gari can then be enhanced by adding a few drops of palm oil. At the end of the frying operation, the product is still hot and a little bit damp. It is then left to cool and dry in a cool dry shade.

Igbeka (1995) reported that the best quality gari is obtained by local technique but it is time consuming, uncomfortable and lends itself to health hazard on the part of the operator. Developments in the processes and equipment have been more on the accurate simulation of the local technique. Therefore, in developing any mechanized gari fryer the following features have to be considered as basic requirements: 1. A continuous process operation leading to mass production of moderate capacity. 2. A regulated temperature mechanism which ensures simultaneous cooking and dehydration, without roasting, to desired moisture content after a specific period. *3.* A mechanism that provides both stirring and lump breaking actions so that uniform cooking and dehydration in the entire mass is ensured and the desired texture produced. *4.* An arrangement of paddles so as to produce a conveyor effect which will give the product a forward movement during the process. Mechanized fryers are not within the reach of the rural farmers who are the main producers of gari in al1 the gari-producing countries including Nigeria. Commercialized models are for large-scale producers while the developed prototypes by the universities and research institutions which could have been within the reach of the small scale farmers are not available in the market. Efforts should be made to mechanize the garification operation for large scale processing without loosing sight of improving the local method. The improvements in garification should be in the areas of ergonomics (Sitting position, comfortable work environments and health hazards). Igbeka (1993), carried out studies on the ergonomics of Nigerian women in gari frying. The factors investigated were the comfort, fatigue and arm-reach of the operators as they affected the efficiency of operating three types of traditional gari fryers. It was found that the sitting posture and exposure to excessive heat were the twin factors that affected the arm-reach and comfort of the operator, respectively. Improved designs that reduced heat and changed the sitting posture were found to increase efficiency.

1.1 Review of Existing Gari Fryer

Historically, frying of gari starts from a shallow earthenware, aluminum or cast iron container set on tripod stones and fuelled by burning firewood. Other forms of dryers consist of clayed water pot which are cut into

two-halves longitudinally and set into a specially prepared fire place that is meant for the purpose. The burning firewood also supplies the heat required for the frying. Stirring is done with carved wood or calabash or broom (IITA, 1990). A lot of attempts have been made at improving the process of frying gari over the traditional methods of using open clay pots mounted on wood fire. The IITA (International Institute of Tropical Agriculture) model is a circular pan, made of cast iron and is smaller than the normal traditional pan in diameter but has more depth. The pan sits on a circular oven which has a chimney and can use either dense rice husk or wood shavings as fuel. RAIDS (Rural Agro-Industrial Development Scheme) Ibadan, Nigeria developed a fryer suitable for a small scale production of gari. The frying pan is made from cast iron which sits on an elevated oven fireplace with a chimney. This consists of a rectangular metal tray measuring 1.2m by 2.4m and 3mm thick to fry gari with a side gate for discharging fried gari. The gari is fried in batches and manual stirring is employed and operated by two persons.

The Project Development Agency (PRODA), Enugu, Nigeria developed a commercial gari fryer which can be used by four to six women simultaneously. The system consist of a frying pan of large projected area 2.75m^2 that forms the top part of a rectangular cabinet-like structure and four fire-place chambers lie immediately below the frying pan, each separated from its neighbour by paddles which deflect the hot gasses to the bottom of the pan as reported by Kwatia (1986).

The UNN (University of Nigeria, Nsukka) model was designed by Odigboh and Ahmed (1982), to simulate the village manual frying operations. The equipment has a semi-circular 1.7 m long frying trough of 0.57 m diameter mounted at an inclination variable from 0 to 20^0 to the horizontal. Sixteen spring-loaded paddles are attached to a 1.75 m long shaft also mounted axially in a way such as to locate the paddles inside and in permanent contact with the trough. The paddles overlap and are angled relative to the axis of the trough to act as a sort of conveyor. They are driven by an electric motor through several speed reducers and linkage arrangements. As the gang of paddles oscillate through 180^0 at 40 reversals per minute sieved cassava mash is automatically metered into the trough, once in a cycle of the to and fro motion. Swinging to one direction, the paddles press the mash against the hot surface of the trough while in the opposite direction; they scrape, stir and move it slightly forward to the exit end of the trough.

The UNIBADAN (University of Ibadan) model (Igbeka and Akinbolade, 1986) is a continuous flow fryer which is an improvement and modification of the UNN model. Power supply to the fryer could be either a petrol engine or fire wood and operate at 15 rpm.

Previous efforts in this area are commendable; however, this operation is still largely done by manual methods. The truth is that this method cannot cope with the emerging mechanized methods being utilized for other processing operations. There is need to produce a machine that will work at the same rate with other operation in gari processing and improved the quality of the product. The manual method of frying gari involved a lot of energy and time. Therefore a prototype machine for gari frying was developed.

1.2 Existing Theories of Drying

McCabe *et al*., (1986) reported that two major drying rates could be said to be responsible for the process of gari frying, these are constant and the falling drying rates.

Drying rate at constant period (Rc) is described as:

$$R_c = h/\lambda (T_a - T_s) \quad \text{..... (1)}$$

Where

h= coefficient of heat transfer, w/m^2k

T_s= surface temperature of the mash at equilibrium, ^{o}C

T_a= air temperature at drying condition, ^{o}C

λ= latent heat of evaporation of water, kJ/kgK

The falling rate period is the period when water in the pores of granulous materials is being dried up as described by Keey (1972), this immediately follows the constant period which can also be computed using the equation below:

$$F_r = M_{ev}/A_t \quad \ldots\ldots (2)$$

$$M_{ev} = M_o kg - M_c kg \quad \ldots\ldots (3)$$

$$Vol = (W_o - M_o kg)/\rho \quad \ldots\ldots (4)$$

$$Area = Vol/L \quad \ldots\ldots (5)$$

Where

F_r = falling rate
M_{ev} = moisture evaporated
A_t = area of the mash, m^2
Vol = volume of the mash, m^3
ρ = density of the mash, kg/m^3
L = mash thickness, mm
M_o(kg) = initial moisture content in kg/kg
W_o = initial weight of the mash, kg
M_o = initial moisture content in % db
M_c(kg) = critical moisture content in kg/kg
M_c = critical moisture content in % db

Jackson and Lamb (1981) stated that the total time for drying a given quantity of cassava mash is:

$$t_T = \frac{M_s}{AF_c}\left[\left[(M_o - M_c) + M_c Ln\frac{M_c}{M_f}\right]\right] \quad \ldots\ldots (6)$$

Where,

t_T = Total time for drying, min
M_s = Mass of solid, kg
A = Drying area, m^2
F_c = Drying rate at critical period, kg/s
M_o = Initial moisture content, %
M_c = Critical moisture content, %
M_f = Final moisture content, %

2. METHODOLOGY

2.1 Design Considerations.

In the design of the gari fryer, the following requirements were considered:

i. Higher capacity compared to traditional method of gari frying.
ii. Reduction in drudgery involved in the traditional methods of gari frying.
iii. 25% cheaper in production cost compared to imported machines of similar capacity
iv. Locally sourced materials for fabrication.
v. Strength of materials should withstand the forces acting in the various components parts of the machine.
vi. Physical properties of the materials with high heat transfer would be required
vii. Simplicity and flexibility of the machine should suit the targeted users.
Viii. Choice of materials should be such as will reduce power required by the machine.
ix. Renewable energy would be used for the frying operation.

x. Low cost of maintenance compared to imported machine.
xi. Stainless steel would be selected to ensure product quality

2.2 Design Features

Special design features of the machine include:

i. Drum-Auger Conveyor

One of the special features in the gari fryer developed was the drum-auger conveyor (figure 1) which consists of the drum of 2 mm galvanized metal sheet rolled to form a cylindrical shape; it was of diameter 280 mm and 1480 mm long. The auger was welded to the drum with a flight of 105 mm and pitch of 210 mm. Stainless twisted wire brush of height 40 mm were attached to a paddle-like metal plate of 80 mm X 60 mm which was also welded at an angle of 45^0 round the drum to press the gari against the base of fryer as well as breaking the clods that formed during gelatinization.

ii. Upper Clogs

The moisture content may increase due to condensation near the air (vapour) exit. The perforation at the upper chamber (cover) of the trough as shown in figure 2, served as exit for vapour during frying operation thus preventing formation of vapour condensation at the surface.

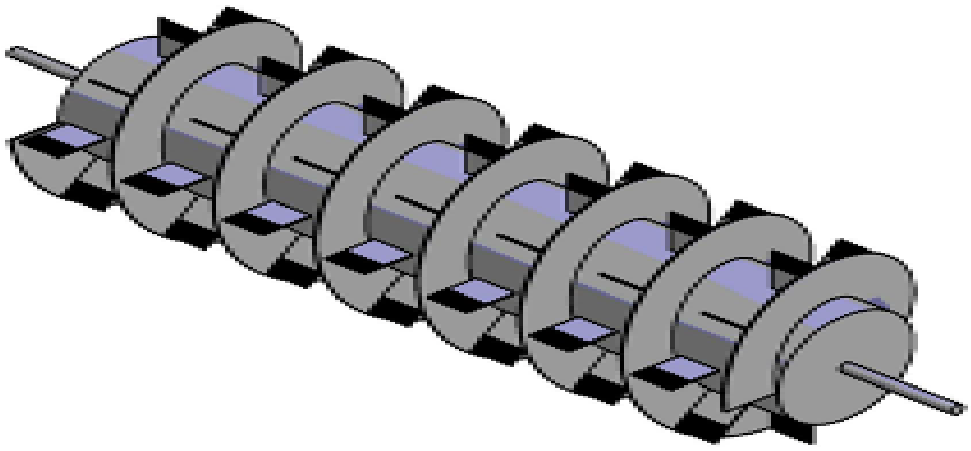


Fig. 1: Drum-auger conveyor

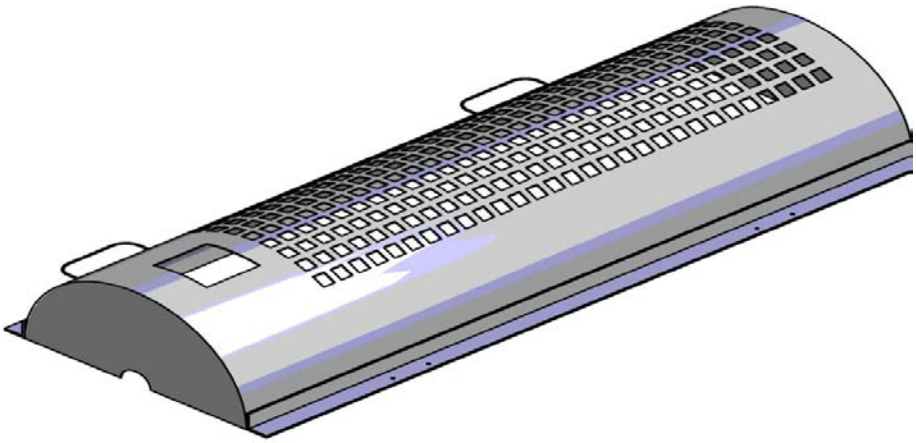


Fig. 2: Upper Chamber

iii. **The Heating Chamber**

A charcoal plate was fabricated from mild steel plate of 5 mm thickness. It was of dimension 1620 mm and 590 mm placed 150 mm below the base fryer. The perforation was to allow the passage of air to blow the burning coal and for the passage of ashes from the burnt coal. The coal served as a source of heat energy required for the gari frying. The heating chamber was constructed using asbestos as heat insulating material around the rigid support of the machine as shown in the exploded view (figure 5). This help in minimizing heat loss by convection and radiation. The coal should generate enough heat needed for the cooking and frying of the cassava mash in the frying chamber.

iv. **Control Box**

A control box as shown in figure 3 was another special feature that allow for movement of the auger conveyor in the forward and the reverse direction. It was also to stop the motion of the auger when necessary. It contained two contactors (for forward and reverse movement), a three-way switch (forward, stop and reverse) and an overloaded relay.



Fig. 3: Control Box

v. **The Prime Mover**

The electric motor chosen was a reduction gear motor of variable speed (20 rpm to 100 rpm). The size of the motor choosing from the design calculation was 1.5 kw (2 Hp).

2.3 Other Design Features

Some other design features of the machine are described below:

i. **The Hopper**

The Hopper was pyramidal in shape and situated at the right top hand side of the machine. It is the inlet in which the dewatered and sifted cassava mash was admitted into the frying chamber.

ii. **The Frying Chamber**

The frying chamber of the gari fryer consists of the base fryer, auger conveyor, upper chamber as shown in figure 5. The base fryer which was in shape of a dissected cylinder in which if the cover is placed will make a complete cylinder shape. The base fryer was fabricated from 2 mm thick galvanized metal sheet. The auger conveyor consists of the drum (2 mm galvanized metal sheet rolled to form a cylindrical shape), it is of diameter 280 mm and 1480 mm long. The auger was welded to the drum with a flight of 105 mm and pitch of 210 mm. Stainless twisted wire brush were attached to a rectangular metal plate of 80 mm X 60 mm which was also welded at an angle of 45^0 round the drum to press the gari against the base of fryer as well as breaking the clods that formed during gelatinization. The upper chamber was made from galvanized sheet and perforated to serve as exit for vapour during frying operation thus preventing formation of vapor condensation at the surface. The upper chamber was attached to the base fryer with hinge. The shaft of 25 mm diameter and 1940 mm long, made from mild steel was chosen from the design calculation to drive the drum, it was supported by pillow bearing and constantly lubricated for maintainability. There was a clearance of 5 mm between the auger flight and the base fryer.

iii. **The Discharge Outlet**

This is the point where the fried cassava mash (gari) was collected. It was welded to the left side of the base fryer and was also made from 2 mm thick galvanized metal sheet plate.

iv. **The Machine Frame**

The frame was the mounting support of all the components of the machine. Therefore, while it was desirable to minimize the weight of the frame, it should be sufficiently strong and rigid. The frame was fabricated by marking out different dimensions which were cut and welded into the rigidly fixed support called frame. The frame was made from angular bar mild steel of 45 mm by 45 mm and 5 mm thick.

v. **Machine Overall Conceptual Design**

The isometric view of the machine is shown in figure 4. The exploded diagram of the machine is also shown in figure 5. The Machine was conceived as an indigenous gari fryer which complements other machines used in gari processing operation. The drum-auger conveyor moves the cassava mash poured into the base fryer through the hopper in the forward and reverse direction by the help of control box until the gari of acceptable final moisture content and save for human consumption was obtained at the exit. Figure 6 shows the photograph of the fabricated fryer with its internal structure.

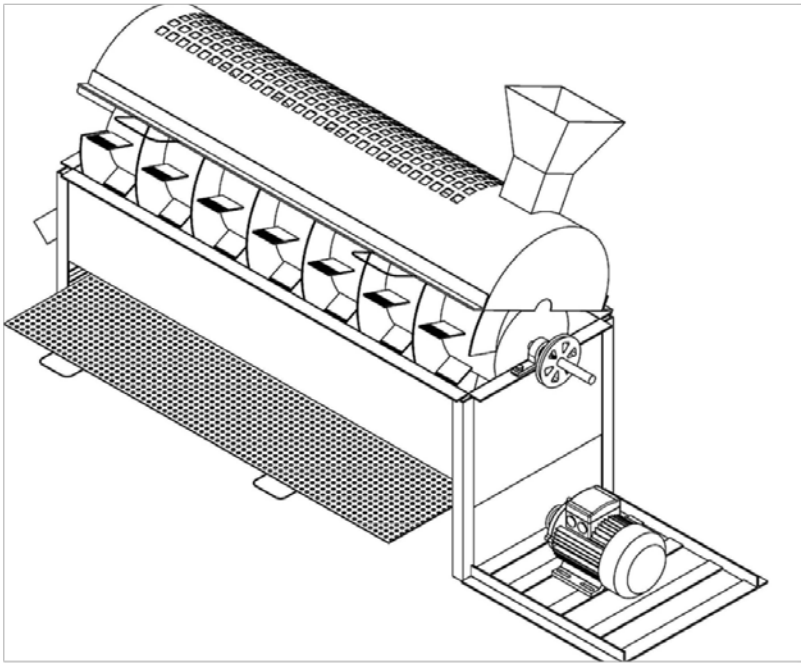


Fig. 4: Isometric view of the machine

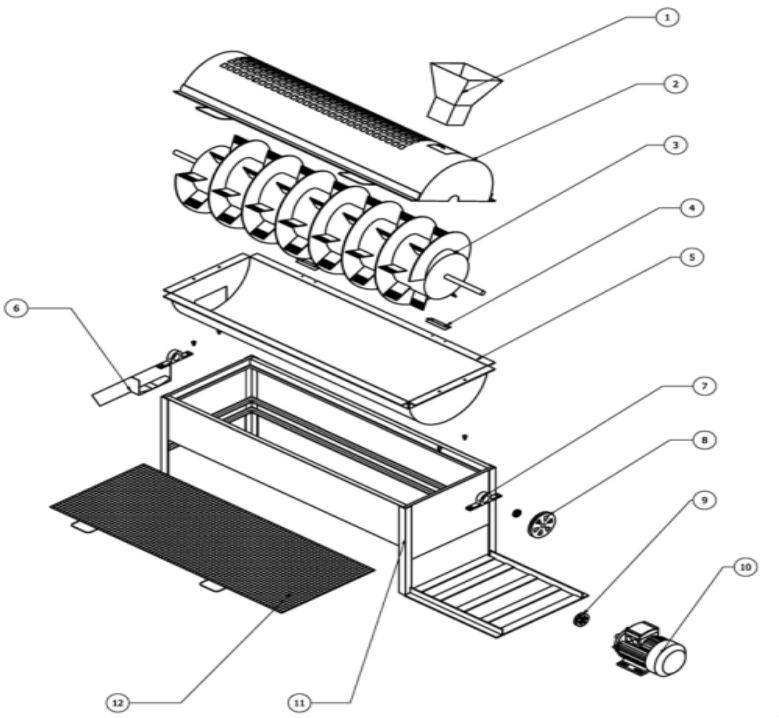


Fig. 5: Exploded view of the gari fryer showing the component parts

Legend: 1, Hopper; 2, Upper chamber; 3, Drum-auger conveyor; 4, Hinges; 5, Base fryer; 6, Outlet; 7, Bearing; 8, Shaft pulley; 9, Motor pulley; 10, Electric motor; 11, Frame; 12, Charcoal plate



Fig. 6: Photograph of the machine (Inner Structure)

2.4 Design Analysis.

The design analysis was carried out to determine the parameters necessary for the selection of appropriate grade and size of materials for the fabrication of the various machine components.

The power, P in KW required to operate the gari frying machine was estimated using equation:

$$P = m\left(\frac{2\pi N}{60}\right)^3 r^2 \quad \text{..... (7)}$$

(Hannah and Stephens, 1999)

Where;
m = mass of rotating components
N = number of revolution of the drum per minute
r = radius of gyration

The power requirement of the machine from the designed calculation is 1.2775KW. Thus a motor of 1.5KW (2Hp) was used to drive the machine.

The shaft driving the drum-auger conveyor was designed based on maximum direct stress of 1.2 x 10^8 Pa using ASME code equation

$$d^3 = \frac{16}{\pi S_s}\sqrt{(M_b K_b)^2 + (M_t K_t)^2} \quad \text{..... (8)}$$

$K_b = Combine\ shock\ and\ fatique\ applied\ to\ bending = 1.5$
$K_t = Combine\ shock\ and\ fatique\ applied\ to\ torsion = 1.5$
$M_t = Maximum\ torsional\ moment, Nm$
$M_b = Maximum\ bending\ moment, Nm$
$S_s = Allowable\ shear\ stress\ for\ shaft\ without\ keyway, \frac{N}{m^2}$

d = required shaft diameter, m

The diameter of the shaft was determined as 0.2434 m. Thus 0.25 m standard diameter shaft was selected.

2.5 Performance Test

2.5.1 *Sourcing and Preparation of Test Sample*

The dewatered cassava mash was purchased at a local gari production factory in Shagari village, Akure after a series of operations on the cassava tubers which include peeling of the tubers,

washing, grating, dewatering, fermentation and sifting. The moisture content of the sifted mash was determined by oven dried method. A known mass (using a digital weighing scale to determine the mass) of the mash is placed in an oven at 110^0 for 8 hours. The final weight was taken when the product has cooled. The moisture content was obtained in the wet basis as:

$$M_c = \frac{W_o - W_f}{W_0} \quad X\ 100\% \quad \ldots\ldots (9)$$

Where;

M_c = Moisture content (wet basis), %
W_o = Weight of wet mash, kg
W_f = Weight of dried mash, kg

A bag of charcoal used as source of heat energy for the frying operation was also purchased in Akure market.

2.5.2 *Operation of the Fryer developed*

Frying cassava mash from original moisture content to final moisture content was carried out by pouring the cassava mash of known moisture content and mass intermittently through the hopper into the fryer.

The base fryer was being heated using charcoal as a source of energy and the temperature was determined through the use of probe thermometer. The heat supplied reduced the moisture of the cassava mash, cooked the mash (gelatinization) and also dried the cooked mash.

The cassava mash gelatinizes while being moved over the heated surface of the metal trough and the gelatinization occurs at a temperature between 60^0C and 65^0C. The stainless wire mesh fixed to the auger drum rotating on the axis of the drum sweep the gelatinizing mash from the trough wall to prevent sticking and burning and also break the lumps that formed during gelatinization. The auger move the mash to and fro through the length of the base fryer with the help of the control box connected to the electric motor.

Several parameters influenced the time required to reduce the moisture content of the cassava mash to the desired moisture content of the product (gari). These include:

i. The frying temperature.
ii. The system dimension.
iii. Quantity of mash introduced.
iv. Initial moisture content of cassava mash.
v. Speed of the prime mover.

The extent of drying depends on the temperature and the length of time of the mash in the fryer.

2.6 Performance Criteria

Test parameters that were measured in evaluating the performance of the machine are throughput capacity and functional efficiency.

Throughput capacity was defined as the ratio of the quantity of gari collected from the machine to the time taken.

$$T_c = \frac{W_s}{T} \quad \ldots\ldots\ldots\ldots (10)$$

Where;

T_c = Throughput capacity, kg/hr
W_s = Weight of gari collected, kg

T = Time taken for frying, hr

The functional efficiency was defined as a percentage of the product output to the material input.

$$E_f = \frac{W_f}{W_i} \quad X\ 100\% \ldots\ldots \quad (11)$$

Where;

E_f = Functional efficiency, %

W_f = Weight of gari obtained, kg

W_i = Weight of mash introduced into the fryer, kg

3. RESULTS AND DISCUSSION

The performance of the machine was satisfactory during the preliminary tests. Gari obtained from the test was fit for human consumption. The characteristic flavour of gari during the frying process was achieved. It has a pleasant colour, texture, smell and taste. The machine can be used by the small and medium scale farmers and it can complement emerging mechanized methods of cassava processing which include; Washing, Peeling, Grating, Dewatering, and Sieving. This design reduced drudgery, saved labour, time and eliminated smoke during frying operation.

3.1 The Effect of Variation in Operation Speed on the Rate of Drying of Cassava Mash

The result of preliminary performance test reveals the effect of the auger speed on the drying rate of cassava mash as shown in figure 7. At auger speeds of 80 rpm and 100 rpm and after a period of 21 minutes, the product obtained was not properly cooked and the final moisture content was between 16.5% and 17.8 % from an initial moisture content of 41.2%. This moisture was higher than the safe moisture for storage of gari (6.0 to 10.0%). However, the speed of 20 rpm, 40 rpm and 60 rpm gave product (gari) of final moisture content 10.02%, 12.60% and 13.91% respectively at the same period of frying. The Optimum operating speed with this design was in the range of 15 to 20 rpm. The UNN model developed by Odigboh and Ahmed (1982) and that of UNIBADAN model designed by Igbeka and Akinbolade (1986) operate at 40 reversals per minute and 15 revolution per minute respectively. Major problems associated with mechanized gari frying have being the formation of lumps and inability to produce products similar in quality to gari obtained during manual frying. This design eliminated these constraints through the incorporation of abrasive brush operating at the same speed with the auger. The result is production of gari with variation in fineness of particles depending on the brush speed. The possibility of a to and fro motion of the auger permitted sufficient residence time in the frying chamber which enhanced the production of gari of good quality similar to products obtainable during manual frying.

3.2 The Effect of Mash Quantity Feed into the Machine on the Rate of Drying

The quantity of cassava mash in kg introduced into the frying chamber affected the frying process considerably. The final moisture content obtained from the cassava mash of 5 kg, 7.5 kg and 10 kg fed into the machine were 11.5%, 11.8% and 12.4% respectively (figure 8). This shows that the higher the quantity of mash introduced into the fryer, the higher the final moisture content at the same period of frying. At the eighteenth minute of frying, the moisture content of 5 kg mash was 12.0 % which was even lower than that of 10kg mash (12.4%) at the twentieth minute of frying. Other factors which may influence the final moisture content and hence the quality of the product inlude ability of the mechanical process to simulate the basic unit operations in the manual process and exposure of final product to open air for natural dryaeration. Introduction of dry and wet cassava mash in the ratio 1:10, 2:10 and 3:10 produced variation of quality product in a descending order.

3.3 Throughput Capacity and Functional Efficiency of the Machine

The mass of the product obtained (gari) and its final moisture content at twenty first minute of frying were 7.14 kg and 12.4% from 10 kg cassava mash and initial moisture content of 41.2% respectively using optimum operating speed of 20 rpm. Hence the throughput capacity of 20.4 kg/hr and functional efficiency of 71.4% was obtained.

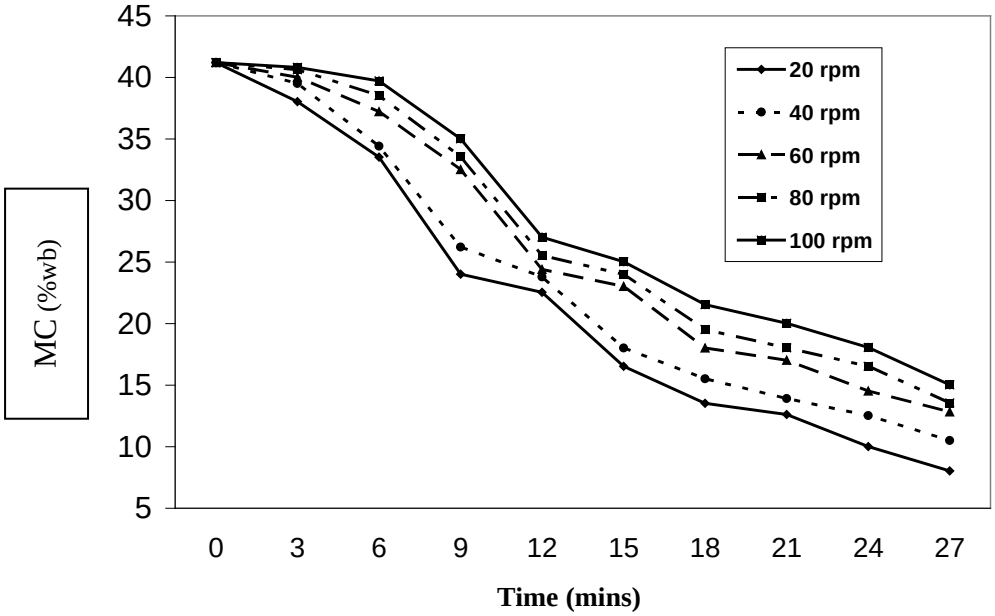


Fig 7. Effect of Auger Speed and Time of operation on the frying rate of Cassava Mash.

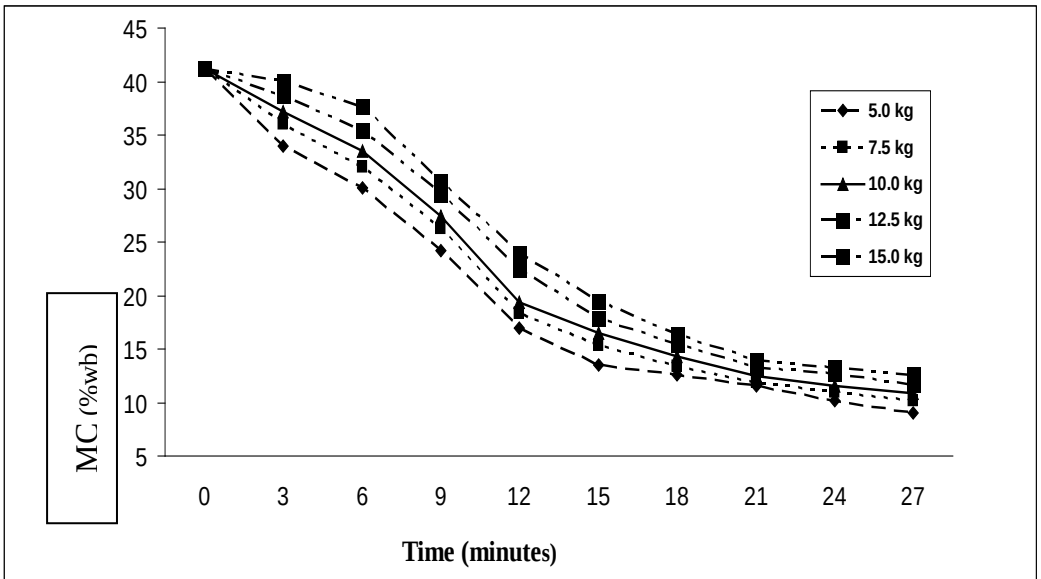


Fig. 8: Effect of Feed Rate on the Frying Rate of Cassava Mash

4. CONCLUSION

A machine for frying dewatered and sifted cassava mash has been designed, fabricated and evaluated for performance. The performance of the machine was satisfactory during the preliminary

tests. The characteristic flavour of gari during the frying process was achieved. It has a pleasant colour, texture, smell and taste. The machine can be used by the small and medium scale farmers and it can complement emerging mechanized methods of cassava processing. The optimum speed of the machine was 20 rpm which gave the throughput capacity and functional efficiency of 20.4kg/hr and 71.4% respectively. The machine uses coal as a source of heat energy and quality product (gari) was obtained. It reduced drudgery, saved labour, save time and eliminated smoke during operation.

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DESIGN AND DEVELOPMENT OF FORAGE CHOPPER FOR SILAGE MAKING

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ABSTRACT

A forage chopper required to chop forage for silage making has been designed and fabricated. It consist of a solid circular shaft, a cutting unit which is made of six (6) bar-knives mounted on a circular disc (flywheel), a cylindrical housing, a hopper and a discharge outlet which are all carried on an angle iron frame 0.9m high. It utilizes 3kW electric power to drive a 0.3m diameter shaft on which the cutting unit is carried and rotate at a constant speed of 1450rpm via a V-belt- pulley drive mechanism. The machine has a capacity of 2.85 kg and a cutting speed of 91.1rpm. Forage crop is fed through $0.1m^3$ rectangular hopper in a perpendicular direction to the rotation of the cutting knives. The forage is chopped and discharge through a 0.25m diameter discharge sprout sited at the base of the cylindrical housing which encloses the shaft and cutting unit. The machine has been tested and found to cut forage to about 20-25mm length at a rate 0.801kg/sec, with an efficiency of 42.38%. This is a remarkable improvement over manual chopping of forage. Chop size was more uniform and the feeding device protects operator's hand. The length of chop can be varied by varying the speed of the cutting unit, the number of cutting blades (by 1) or by adjusting the length of the cutting knife. The machine will find usefulness in the mechanization of livestock feed processing into silage for storage particularly in Northern part of Nigeria where the availability of forage for livestock is seasonal. The forage chopper will also enhance silage making for intensive zero grazing livestock farming and management.

KEYWORDS: Forage, silage chopping efficiency, chopping rate

1. INTRODUCTION

Forage is a group of plants which are consumed by livestock and are often grown for that purpose. Forage can be grazed directly on the land or harvested and fed to livestock in different forms which include hay, soilage, and silage. Goats, Sheep and Cattle are greatly dependent on forage while poultry and swine have small percentage of their feed from forage (Machin, 2000). Livestock can be either grazed directly or forage is cut to make silage which is fed to livestock. In most parts of Nigeria especially the north, livestock farmers suffer from low quality and non-availability of forage for cattle during the dry season. Thus most livestock are free ranged or grazed. This sometimes results into communal /neighborhood clashes. The lack of forage during dry season results into nomadic migration, as well as high cost of livestock products such as meat, milk, cheese and so on. The tropic and sub-tropic climatic conditions favour the production of forage crop to meet the demand of the growing livestock farming industries. One factor which tends to limit intensive production of forage crop is proper processing into feed which primarily involve chopping of forage.

Silage is a form of forage feed which is made during raining season (when the grass is in excess of grazing) and fed to livestock during winter. The silage is made under naturally produced acidic conditions which effectively pickle the grass. Silage has been reported to be more palatable, of higher nutritive value and usually preferred by livestock to hay (Bolsen, 1995). Over the last several decades, two primary factors have contributed to the increased production of silage in North America. First, silage-making is much less weather dependent than hay-making. Some forage such as corn or sorghum can be direct cut. After mowing, most other forages can be adequately wilted

for silage production in less than 24 hours. This greatly reduces the risk of weather damage to the forage crop. Secondly, production of silage has been relatively easy to mechanize. This makes the practice quite attractive to large-scale livestock enterprises, particularly those that are based on confinement feeding (Anon, 2010).

The first process in silage making is chopping of the forage. This is quite important in the production of silage which has remain a difficult problem to livestock farmers especially women who perform most of the house hold labour devoted to animal feeding especially in zero-grazing animal enterprise.

Zero grazing livestock production is labour intensive. Traditionally, farmers chop forage with sharp edge knife or machete into small pieces. This method is tedious, time consuming, dangerous to the person chopping and has low output. Forage processing for animal feeds requires chopping, ensilaging and storage then feeding to animals. The high labour demand and forage scarcity for dry season feeding means that available forage must be efficiently processed and preserved. The production of silage has been relatively mechanized over the years in developed countries thus making practice quite attractive to large –scale livestock enterprises especially those who are involved in zero-grazing.

Mechanized forage choppers and cutters are mostly imported into developing countries to eliminate problems of manual chopping. Such choppers include the fine chop cylinder machine fine chop (flywheel) chopper and double-chop forage choppers. These imported devices are sophisticated, costly and require skill to be able to operate and maintain especially by women whose role within the livestock sector has increased as they perform most of the farm labour related to feeding animals. However the efficient production of good silage depends on precision chopped forage which usually requires relatively high financial investment in heavy machine such as forage harvesters for harvesting and chopping. A manually operated labour saving device was also developed in Uganda by the National Agricultural Research Organization (NARO), in 1999 (Liesa, 2000), to make the task of animal feed production less arduous. It must be noted, however, that each country has its own crops, level of engineering capability and needs; hence introduction of labour saving technology as solution to developmental problems must involve building a machine which suits the local requirement (Brain 1986).

Labour saving chopping device such as this forage chopper is needed in developing countries like Nigeria. Just as it is needful to mechanize the livestock industry, there is also a great need to mechanize the process of livestock feed production both for direct consumption and storage purposes to meet the protein demand of the every-growing population of Nigeria. In view of this, a less sophisticated forage chopper for silage making is needful and has been designed and developed. This paper describes the design and performance tests of the chopper.

2. DEVELOPMENT OF THE FORAGE CHOPPER

2.1 Description of the Machine

The machine consists of basically 3 units, the hopper and casing, the cutting unit (flywheel and knives) and the drive system as shown in Figs 1, 2 and 3. All these are mounted on an angle iron frame. The shaft is carried on ball bearings which sit on the frame at both ends. The entire machine assembly is powered mechanically via a belt –pulley drive mechanism linking the power source. The 6 cutting knives are made from mild steel bars (4mm thick which are carried on a flat mild steel wheel).

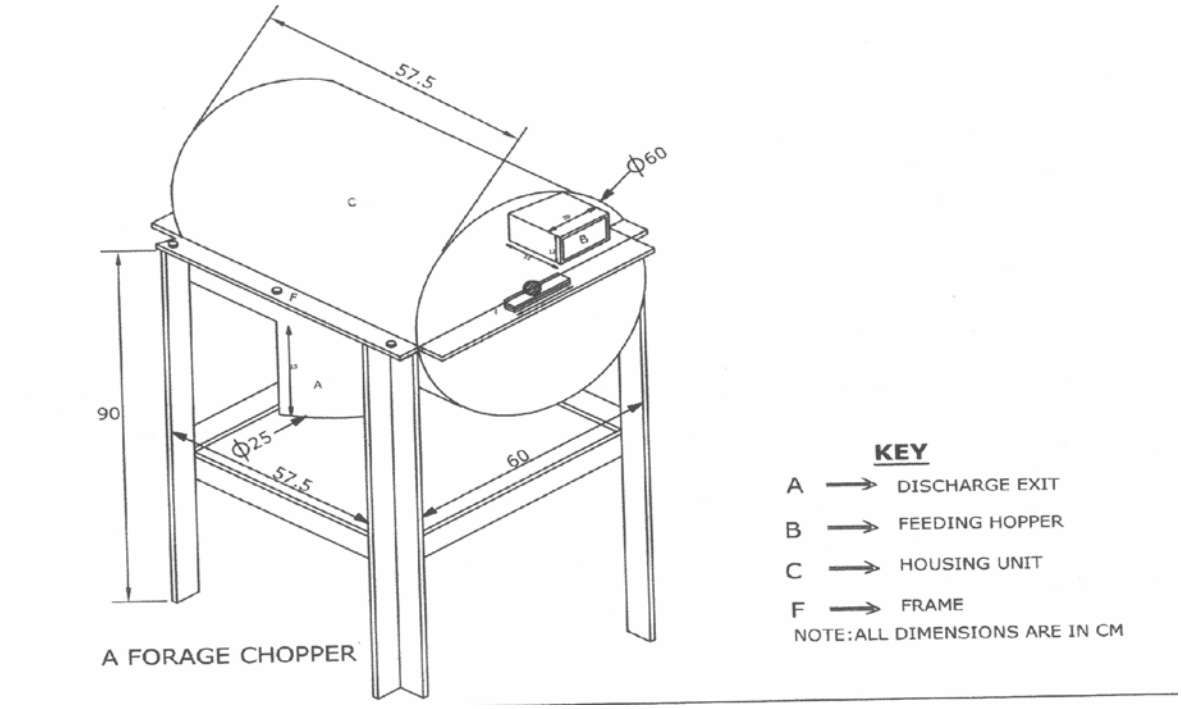


Figure 1: 3-Dimensional View of the Forage Chopper

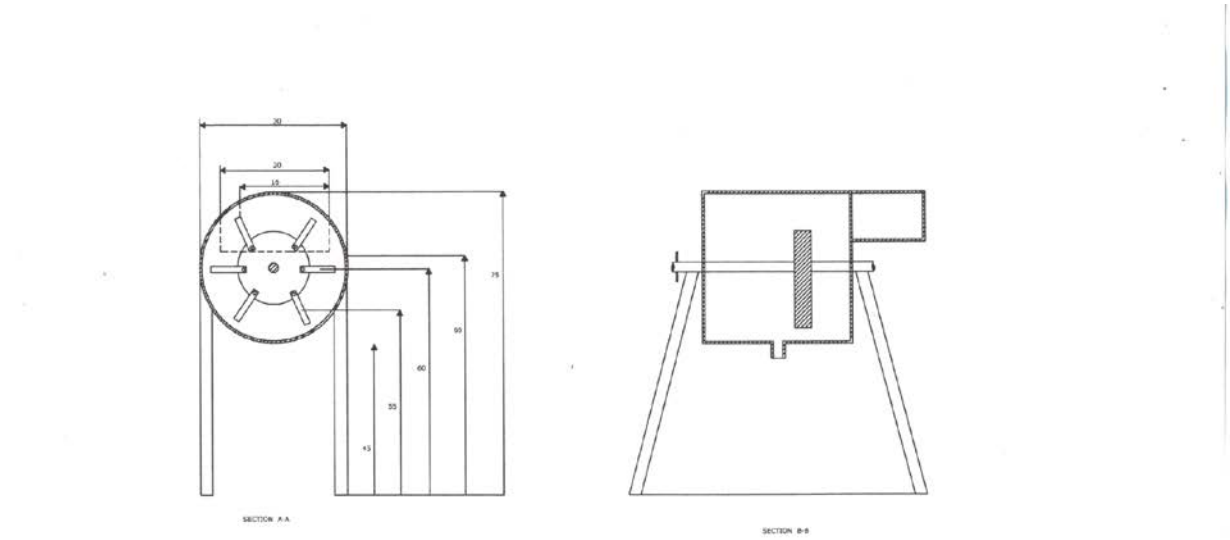


Figure 2: Sectional View of Forrage Chopper

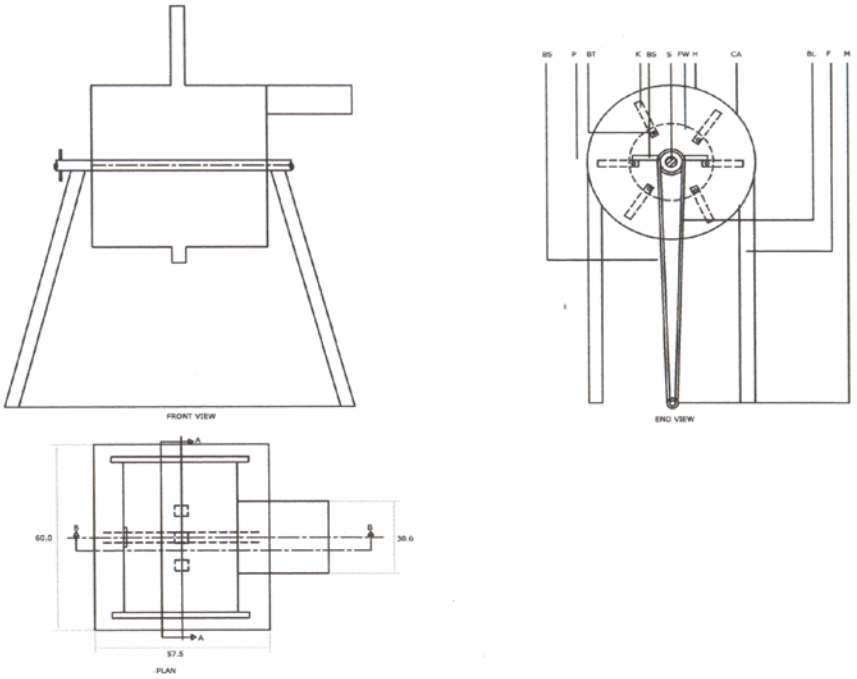


Figure 3: Projections of the Forage Chopper

2.2 Design Considerations and Calculations

In the design of the forage chopper, basic engineering considerations such as power requirement, velocities torque, speed and size of drove mechanism, stresses on shaft, cutting size and speed of culling units were duly considered. The component parameters, specifications and careful selection of materials as well as construction of parts were established following careful review of technical literature on the subject.

2.2.1 ***Power Requirement***

The machine is design for available power input unit of 5.0 horse power (electric motor). The available power for ensilaging using 80% assumed efficiency is calculated as 3kW using the expression.

$$\eta = \frac{P_o}{P_i} \times 100 \qquad 1$$

where P_o is power output and P_i is power input.

2.2.2 Velocities of Engine Shaft

The linear and angular velocities as well as torque were calculated from

$$\omega = \frac{2\pi N_1}{60} \qquad 2a$$

$$N = \omega \times r \qquad 2b$$

$$P = T\omega$$

where ω is angular velocity (rad/sec), N_1 is speed of engine (rpm), r is this linear velocity (m/sec), T is the torque (N-mm), P is the power available(kW).

The angular velocity of the machine shaft was found to be 303.687 rad/sec; the engine torque was 9878N-mm.

2.2.3 *Drive Mechanism*

The belt drive consists of driving and driven pulleys. The speed of the driving pulley was 2900rpm.using a speed ratio of 2, the speed of the driven pulley was calculated using the equation.

$$V_1 = \frac{D_1 N_1}{60} \quad 3a$$

$$V_2 = \frac{D_2 N_2}{60} \quad 3b$$

$$U = \frac{N_1}{N_2} \quad 3c$$

(Titherington and Rimmer, 1980) where N_1 is speed of engine, N_2 is speed of driven shaft, U is the speed ratio V_1 and V_2 are peripheral velocities.V_1 was determined to be 7.56m/s. The size of the driven pulley was calculated as 10cm using the equation

$$\frac{N_1}{N_2} = \frac{D}{d} \quad 3d$$

where d is the diameter of driving pulley and D is diameter of driven pulley.

2.2.4 *Belt Tension*

The belt tensions in belt were calculated for V_1 and V_2 respectively using the expressions. (Redford,1973; Kurmi and Gupta 1995)

$$P = (T_1 - T_2)V$$
$$(T_1 - T_2)V = 10T_2 - T_2 \quad 4$$

The pull p_1 on a rotating shaft is the sum of all T_1 and T_2 acting on the body and is calculated as 483.63N.

2.2.5 *Design of Shaft*

The rotating parts of the forage chopper are mounted on a shaft which must provide a constant rotary motion for the cutting knives which are carried on a flywheel. The shaft considered for satisfactory performance is to be rigid enough while transmitting load under various operating conditions. To achieve this, a solid circular shaft was considered for analysis of combined torsional and bending stresses.Since the shaft will be subjected to torsional stress and high vibration, adequate calculation is made to determine the correct nominal allowable stress, bending stress and torsional stress. For solid shaft having little or no axial load, the diameter is given by: (Hicks 1995; Desmond 2007; Benham and Warnock 1980).

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad 5a$$

where M_t = torsional moment, M_b = bending moment, K_b = combined shock and fatigue applied to bending moment (1.5), K_t = combine shock & fatigue applied to torsional moment (1.0), and Ss =allowable stress.

2.2.6 *Stress Calculation*

Using the values of mechanical properties of mild steel (0.05 -0.3% carbon) direct stress on shaft which is the same as the working stress which the shaft can carry under working condition is expressed by Desmond, (2007) as

$$\sigma_d = \frac{\sigma_{ultimate}}{f_s} \quad 5b$$

σ_d was calculated as 71.66MN/m^2 for a factor of safety of 6. The safe load the shaft can carry is determined as 51.54 kN from the equation

$$\sigma_d = \frac{Force}{Area} \quad 5c$$

Strain (ε) is determined as 0.000358 from the expression

$$\varepsilon = \frac{Stress}{E} \quad 5d$$

while an extension, x of 0.000025m is calculated from $x = \varepsilon L$ where L is the original length of shaft, m.

The angle of twist was determined using the equation below (Anon, 2007).

$$\theta = \frac{TL}{GJ} \quad 6$$

where T is the torque, N-m; L is the length of shaft (m), G is the modulus of Rigidity (GN/m^2) and J is the polar second moment of area $J = \frac{\pi \times d^2}{32}$ (Anon, 2007)

2.2.7 *Principal Stresses*

For a solid circular shaft such as used herein which is acted upon by both bending moment M and torque T, the maximum bending and shear stresses at the outer surfaces are given as shown in figure 1 below.

The maximum bending and shear stresses occur at the outer surfaces of the shaft and are given by

$$\sigma_x = \frac{32M}{\pi d^3} \text{ and } \tau_{xz} = \frac{16T}{\pi d^3} \quad 7a$$

The stress components at points A, B and C are described as maximum tension at point A, zero at B and maximum compression at C are shown in figure 4. The maximum principal stress and principal maximum shear stress obtained are 617.27MN/m^2 and 430.0 MN/m^2 respectively as given by Desmond, (2007).

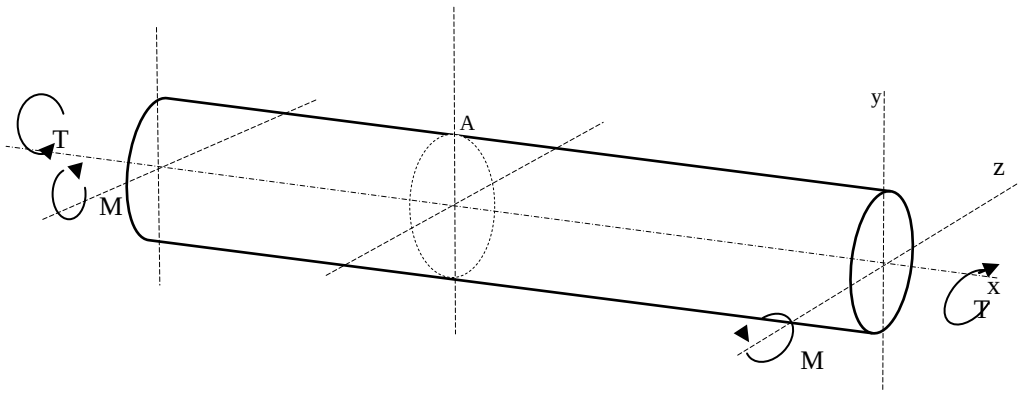


Fig.4: Stress component of the solid shaft

$$\sigma_{\max} = \left(\tfrac{1}{2}\sigma_x + \tfrac{1}{2}\sqrt{\sigma_x^{\,2} + 4\tau_{xz}^{\,2}} \right) \quad 7b$$

Where σ_x is ultimate tensile stress τ_{xz} is the ultimate shear stress. The principal maximum shear stress is given as

$$\tau_{\max} = \frac{1}{2}\sqrt{\left(\sigma_x^{\,2} + 4\tau_{xz}^{\,2}\right)} \quad 7c$$

Pure bending moment M and Torsional stress value was calculated using the equations 7d-7f below

$$\sigma_x = \frac{32M}{\pi d^3} \quad 7d$$

M = $\sigma_x Z$ where Z is defined as $Z = \frac{d^3}{32} \Rightarrow M = \frac{\sigma_x \times \pi d^3}{32}$ 7e

$$\tau_{xz} = \frac{16 \times T}{\pi d^3} \quad 7f$$

An equivalent bending moment for a maximum principal stress was determined as given by the equation

$$M_B = \frac{1}{2}\left(M + \sqrt{M^2 + T^2}\right) \quad 7g$$

The bending stress was calculated from the expression

$$\sigma_B = \frac{M32}{\pi d^3} \quad \text{or } \sigma_B = \frac{MY}{I_{XX}} \qquad I_{XX} = \frac{\pi \times d^2}{64} \quad 7h$$

Y is the distance from the centriod where bending could occur. Given that *Y* =0.01513m, the value of bending stress calculated was 916.5MN/m^2.

2.2.8 *Design of Shaft Key*

The key on the shaft will encounter a tangential force calculated from the expression Anon(2007)

$$F_k = \frac{T}{r} \quad 8$$

Where F_K is the tangential force, r is the shaft radius and *T* is the torque. The resultant area is 0.00008m^2. The shear stress on the shaft key is 15.20kN/ m^2

2.2.9 Design of the Cutting Unit

The chopping unit of the forage chopper consist of a weighted circular rotating disc on which the cutting knives are spirally arranged. It provides the cutting knives with the compressive force needed along with shear force to achieve cutting. The resistance that will be encountered during chopping results into loss of energy.

$$hp = \frac{EN}{33{,}000} = \frac{E}{t \times 550}; E = \frac{1}{2}MV^2 \quad 9a$$

where *E* is the total energy impacted on the flywheel, J; t is the time per stroke, in seconds. For power input of 5hp, the total energy on the flywheel is 27500J and the corresponding cutting time per knife =10seconds.

The weight and mass of the flywheel is calculated from the relationship given by Gopinath and Mayuram (2009)

$$W = \frac{E}{CD^2n^2} \quad 9a$$

where *C* is a speed reduction constant given as 0.0001180 for 15% reduction.

The total force F_w acting on the flywheel is the sum of the tensions T_1on the tight side of the belt and T_2 acting on the wheel

$\frac{T_1}{T_2} = 10$ (Khurmi and Gupta, 1979) T_1 = 439.7N, and $T_2 = \frac{P}{V} \div 9$ where *V* is the linear velocity of the flywheel. For solid disc of steel plate stacked on a through shaft like that of a forage chopper a high speed is required the speed is related to stress by (Redford,1973) expressed as

$V = \sqrt{10 \times \sigma}$. 9c

σ is the tensile strength of the material in lb/in^2 =19000lb/in^2 =1.310kN/mm^2. The centrifugal tension on the flywheel and is related the mass of the flywheel by $T_c = M\omega^2$. This gives the calculated

weight of the flywheel as approximately 58.8N. The corresponding diameter of the flywheel using equation 10 is 0.362m.

From the force and the torque, $T = Fx$. the thickness of the knife (x) is calculated to be 3.96mm (approximately 0.004m) The total mass of cutting unit is 15.08kg, and the mass of each cutting knife is determined as 1.51kg using the equation

$$F_C = M\omega^2 r \qquad 9d$$

where M, is the total mass of the cutting unit, r is the radius of rotation.. The length of the cutting knife which is calculated from the known mass of the knife is 8.50cm =0.085m.

2.2.10 Design of Machine Housing

The area of the casing relates to the maximum tensile strength of the material and the force on the machine by the expression

$$\sigma = \frac{Force}{Area} \qquad 10a$$

$$A = 1.083 = 2\pi rL \quad \Rightarrow 1.083 = 2\pi \times 0.3L$$

The length of the casing is approximately 0.575m and the calculated as 1.083m^2.

The hopper is the unit through which forage is fed into the cutting knives mounted on the flywheel. Dimension of chopper is calculated based on the capacity selected, density of forage. Using a capacity of 3.8kg per batch (i.e. mass of forage) and designing for ¼ of capacity, the equivalent volume of 0.01m^3 is obtained from expression

Bulk density = $\rho_b = \frac{Mass}{Volume}$ 10b

The calculated dimensions are length = 0.25m, width= 0.20m and depth= 0.12m.

2.2.11 ***Calculation of Cutting Rate***

The cutting speed is given as

$$N_C = \frac{2\pi N_2}{100} \qquad 10c$$

where N_2 is the speed of the cutting shaft. N_C=91.11rpm. Mass of forage in hopper = 2.85kg**.** Cutting rate is calculated to be 1.87kg/sec and the diameter of the discharge or outlet end was calculated as 0.25m

2.2.12 ***Other Components***

Ball bearing used was selected based on its ability to be easily maintained and lubricated, high load bearing capacity per bearing width, low friction and heat generation, high speed, support of radial load and appreciable axial load on either or both direction of rotation. The frame of the machine is constructed from mild steel angle iron. The legs are arranged spirally to ensure high resistance to vibration. The frame also provides a seat for the ball bearing and casing along with holding the entire unit firmly under operating and idling conditions. The frame has a height =0.9m, length = 0.65m and breath =0.575m. The frame also carries four (4) cross- bars in- between the legs to provide adequate support and rigidity. A summary of results of design calculation is shown in Table 1 while the Bill of Engineering Qualities is shown in Table 2.

Table 1: Summary of Results of Design Calculations

Parameter	Value
Speed of electric motor	2900rpm
Speed of Machine driven shaft	1450rpm
Diameter of the driven pulley	10cm = 0.01m
Shaft of diameter	32.5mm =0.0325m
Selected Shaft diameter	32mm =0.032m

Length of shaft	700mm = 0.7m
Diameter of Flywheel	0.362m
Thickness of the knife	3.96mm = 0.004m
The length of the cutting knife	8.50cm = 0.085m
Cutting Rate	1.87kg/sec
The area of casing	$1.083m^2$
Volume of Hopper	$0.01m^3$
Diameter of the discharge or outlet end	0.25m

Table 2: Bill of Engineering Measurement and Evaluation

S/N	Material	Specification	Quantity	Unit Cost ₦	Total Cost ₦
1	Metal Sheet	Galvanized Iron sheet Guage18	1 sheet	4,500.00	4,500.00
2	Solid Shaft	Mild Steel 32mm Φ 1 m length	1	2,000.00	2,000.00
3	Angle Iron	Mild Steel 50x50x5	2 length	1,200.00	2,400.00
4	Flat bar	Mild Steel 50mmx5mm	¼ length	1,200.00	1,200.00
5	Pulley	Cast Iron100mm & 50mmΦ	1 each	500.00	1,000.00
6	Bearing	Ball Bearing 6204Z	2	500.00	1,000.00
7	Drive Belt	Rubber, A-type 8mm thickness	1	350.00	350.00
8	Fasteners	Mild Steel Bolts and 10mm Φ	1½ doz	600.00	900.00
9	Electrodes	Cast Iron, Gauge 12	1 Pack	1,000.00	1,000.00
10	Prime mover	Electric Motor 5hp	1	20,000.00	20,000.00
11	Transport & others			2,000.00	2,000.00
12	Sub-total				36,350.00
	Labour(15% Sub-total)				5,452.50
	Total Cost				41,802.50

2.3 Construction and Evaluation of the Forage Chopper

The components of the forage chopper were fabricated using locally available materials which were properly selected to meet the engineering requirements of the machine. Each component was fabricated according to designed dimensions and assembled such that parts such as the casing, frame, knives bearing seats and discharge unit were joined and or held in place using bolts and nuts. The shaft ends were machined to dimensions to fit into the ball bearing and the pulley at both ends. The frame iron bars were cut to dimension and joined together using bolts and nuts.

The cylindrical casing was formed using electric arc welding after cutting the sheet and rolled using the bending machine. Holes were drilled on the lower side of the casing to hold it on the frame by means of bolts and nuts. The action/cutting unit, (flywheels and knives) and bearing were arranged and mounted on the shaft which is set on the bearing seat. The bearing seat is mounted on the frame by means of bolts and nuts.

2.4 Operational Principle

The petrol engine of 5.0 hp through a V-belt- pulley arrangement is connected to the shaft. The shaft rotates the flywheel- knives arrangement. The rotation of the shaft via the pulley transmits power to the cutting knives through the flywheel. Thus, as the shaft rotates, the knives rotate in the same direction and cut the forage which is introduced directly into it through the hopper. The chopped forage is discharged through the discharge sprout at the base of the cylindrical casing.

2.5 Performance Tests

Field tests were conducted to ascertain the performance of the machine hence facilitate necessary modification that would lead to perfection. A sample of 2.85 ± 0.05kg of freshly harvested grass crop of about 60cm tall was weighed using weighing scale. The machine was operated for 15 minutes to

allow it stabilize the operational speed, and then the grass was fed into the machine via the hopper. The time taken to chop the material was recorded at the operating speed while the chopped forage was collected in a container of predetermined weight and then reweighed to determine the weight of the chopped grass collected i.e. the output. The length of randomly selected quantity of the chops was measured to determine average length of the chopped forage. The chopping efficiency (CE) was determined as:

CE = $\frac{W_f}{W_c} \times 100$ where CE is the Chopping efficiency, W_c is the total weight chopped, and W_f is the total weight fed in. The chopping rate was determined as $C_R = \frac{W_c}{t_c}$ where t_c is the chopping time in seconds. The experiment was replicated 10 times.

3. PERFORMANCE EVALUATION RESULTS

The results of field test carried out shows that forage is chopped at the rate of 0.801kg/sec into lengths of between 20 and 25mm. The machine chopping efficiency was 42.38%. The ability of the chopper to cut or chop forage for silage making is enhanced by its features such as the rotating knives, flywheel and the V-belt-pulley arrangement. This arrangement transmits power and conveys cutting action which leads to size reduction. The power transmission system which allows for speed variation by changing pulley size also makes chopping action easier. Safety and efficiency were critically taken into consideration in the design. The cutting knives are adequately protected to prevent access by hand during feeding of forage.

The constructed forage chopper has been found to be effectively less tedious, faster and safer in the chopping of forage grass crops for animal feed. The length of the chops can be varied by varying the speed of flywheel or number of blades on the flywheel by 1 and by varying the length of the cutting edge of the blade. The efficiency of the machine can be increased with a little modification particularly of the speed. The performance is a remarkable improvement over manual chopping since chopped size was more uniform. Therefore it can be used by rural livestock farmers particularly women for carrying out the first operation in the process of silage for animals, an aspect of livestock feed processing that has been generally carried out manually.

The machine will find its place of importance in the mechanization of livestock feed processing and storage particularly in the northern part of Nigeria where forage for livestock are not readily available all through the year. It is cheap and since the cost of production is low it is affordable. The availability of a forage chopper will also enhance silage making for intensive livestock farming and management.

4. CONCLUSION

A simple motorized forage chopper has been developed. The machine has a capacity of 0.8 kg/sec and is capable of chopping forage to 20-25 mm at an efficiency of 42.38%. The machine can contribute significantly towards mechanization of forage production in Nigeria.

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DEVELOPMENT OF A LOCALLY DESIGNED RICE DESTONING MACHINE

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ABSTRACT

A rice destoning machine operating on mechanical principles of reciprocating and vibrating sieves was developed. The developed machine was tested in terms of the rice separation efficiency, stone separation efficiency, tray loss and impurity level after separation. The result showed an average of 74.2 %, 70 %, 25.8 % and 16 % for rice separation efficiency, stone separation efficiency, tray loss and impurity after separation respectively for Zaria rice variety. The developed machine has the promise of solving the problem of stone infestation usually encountered in locally produced rice.

KEYWORDS: Rice destoning, rice cleaning, rice technology.

1. INTRODUCTION

Rice is one of the most important staple foods for human race (Hawkworth, 1985) ranking third after wheat and maize in production worldwide. Nigeria has ecologies suitable for the production of different rice varieties which can be harnessed to boost rice production to meet domestic demands and even produce a surplus for export (Anonymous, 1997). The cultivable land for rice is spread over major ecologies – upland, inland or shallow swamp and tidal mangrove or swamp. Nigeria accounts for about half of the 840,000 hectares of land under rice cultivations in West Africa (Kanayo, 2004).

There has been several of government programmes since 1974 aimed at encouraging and boosting local rice production in Nigeria such as National Accelerated Food Production Project (NAFPP), Agricultural Development Project (ADP), Operation Feed the Nation (OFN), Back to Land Programme (BLP), Directorate of Food, Road and Rural Infrastructures (DFRRI), Better Life Programme for Rural Women (BLP), National Agricultural Land Development Agency (NALDA). Despite, all these programmes, local rice production has not kept up with the local consumption demands, consequently the continued importation of rice in Nigeria (Singh et al, 1997).

Harvesting and post harvest handling methods of local rice encourage the presence of contaminants such as stones, sticks, chaff and sand (Ogunlowo and Adesuyi, 1999). Traditional methods of removing contaminants include handpicking (sorting and separation of stones from rice manually) and floatation (submersion of rice in water and allowing the stones to settle at the bottom while the rice is carefully scooped). These methods are tedious and time consuming. The demand for foreign rice in Nigeria had been attributed to the prevalence of contaminants in locally produced ones (Koya and Adekoya, 1994).
Destoning operation is to eliminate stones mixed with either paddy or milled rice. It is possible to separate agricultural products using the or a combination of the following methods: screening, pneumatic, fluidization and floatation. In the recent years, research and developmental efforts are aimed at solving this problem with different levels of success (Oguoma, *et al*., 1992; Ogunlowo and Adesuyi, 1999). Oguoma et al (1992) published that the separation of sand and stones from rice can be achieved by exploiting the difference in the dimensional characteristics of rice and stones. They further reported that rice has three dimensions - length, width and thickness. The length and thickness are the longest and shortest dimensions respectively.

The production and adoption of locally produced rice destoner by the farmers will improve the quality of domestically produced rice, while the foreign exchange used in purchasing foreign rice will be saved and used for other purposes. Above all, further improvement, development and

commercialization of the destoning machine will not only create jobs for the teaming population of young graduates but it will also create wealth for the nation. The objective of the study is to develop a prototype rice destoning machine using locally available materials.

2. MATERIALS AND METHODS

2.1 Design Considerations

The following factors were considered in designing the destoning machine

i. The static and dynamic stresses due to direct and eccentric loading in the shaft design and choice of materials.
ii. The component supports were designed to carry the total weight of all the oscillating and vibrating sieves.
iii. The designs of the eccentric shaft and crankshaft were based on suitable velocity requirement for vibrating and oscillating sieves to produce the desired result for destoning.
iv. To achieve a more rigid joint and effective assembly, fillet welding and bolts and nuts were used to secure some movable elements.

Component Design

The component of the destoning machine was designed using relationships given by Khurmi and Gupta (2007):

Crank Speed of Reciprocating Sieve

$$N_1 D_1 = N_2 D_2 \quad (3)$$

Where N_1 is speed of driver pulley, rpm; D_1 is diameter of driver, cm; N_2 is speed of driven pulley, rpm and D_2 is diameter of driven pulley, cm.

N_1= 1440 rpm, D_1= 100 cm, D_2 = 450 cm

$$N_2 = 1444 \times \frac{100}{450} = 320 rpm$$

Determination of Torque

$$T = \frac{P \times 60}{2\pi N} \quad (4)$$

Where T is torque, Nm; P is power transmitted, W and N is speed, rpm.

$$P = 3.7 kW$$

$$N = N_2 = 320 rpm$$

$$T = 3.7 \times 10^3 \times \frac{60}{2\pi} \times 320 = 110.4 Nm$$

Equivalent Twisting Moment

$$T_e = \sqrt{(K_m \times M)^2 + (K_t \times T)^2} \quad (5)$$

Where T_e is equivalent twisting moment, K_m is combined shock and fatigue factor for bending equals 1.5, M = maximum bending moment, Nm and K_t is combined shock and fatigue factor for torsion equals 1.0.

$$= \{(1.5 \times 7.0 \times 10^3)^2 + (1.0 \times 110.4 \times 10^3)^2\}^{\frac{1}{2}} = 110.9 \times 10^3 Nmm$$

Equivalent Bending Moment

$$M_e = \frac{1}{2}(K_m \times M + T_e) = \frac{\pi}{32} \times \delta_b \times d_s^3 \quad (6)$$

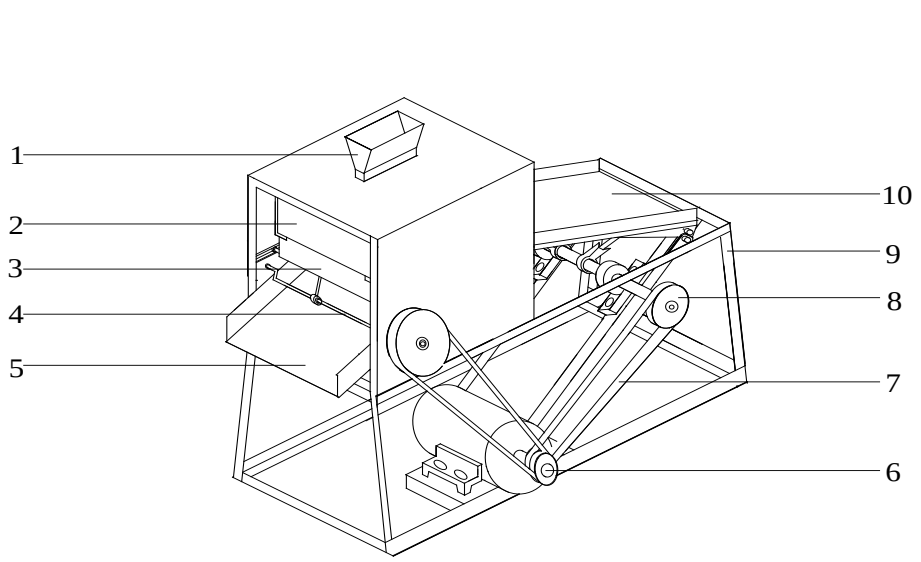
Where M_e is equivalent bending moment, Nm, δ_b is maximum bending stress and d_s is shaft diameter, m.

$$M_e = \frac{1}{2}(1.5\times 7.0\times 10^3 + 110.9\times 10^3) = \frac{\pi}{32}\times 56\times 10^6 \times d_s^3$$

d_s = 22.3 mm

2.2 Description of the Destoner Component Parts

The destoning machine separates by mechanical means only using reciprocating and vibratory sieves. Figures 1 and 2 give the isometric and orthographic drawings while figure 3 shows the picture of the developed destoner respectively.



1 Hopper
2 Reciprocating sieve
3 Sieve tray
4 Crank shaft
5 Stone tray
6 Prime mover
7 V-Belt
8 Pulley
9 Frame
10 Vibrating sieve

Figure 1. Isometric Drawing of the Developed Rice Destoner

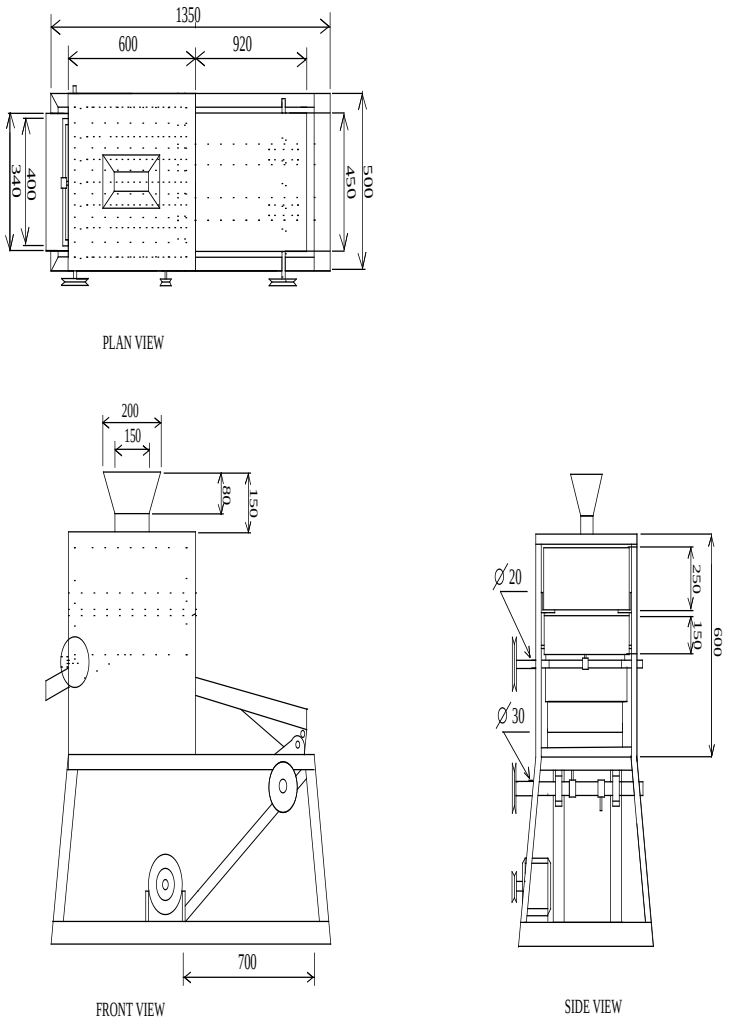


Figure 2. Orthographic Drawings of the Developed Rice Destoner



Figure 3. The developed rice destoning machine

Reciprocating Sieve- The reciprocating motion of this sieve is produced by a crankshaft. The crankshaft consists of a shaft diameter 30 mm, crankpin diameter 20 mm, left and right crank web diameter 30mm. It has a connecting rod mechanism which derives its torque from an electric motor (3.7 kW, 1440 rpm) which drives a sieve tray with sieve sizes of about 2 mm. The unit consists of a sieve tray 350 by 450 mm. The sieve tray is guarded by sheet metal on the sides to prevent rice spillage. The sieve tray is inclined at an angle 37^0 more than the angle of repose of rice 35^0 (Ogunlowo and Adesuyi, 1999). This is to enable easy flow of the rice during the reciprocatory motion of the sieve.

Vibratory Sieve –The product from the reciprocating sieve is discharged on the vibratory sieve. The eccentric mechanism and arrangement of the shaft enabled the vibration. The vibratory sieve causes agitations of the mixture of rice - stone making the stone to gravitate downwards thereby passing through the fine sieve while the rice remains on top. The vibration is caused by a shaft with diameter 30 mm which drives both the tray arm and destoning arm connected to it by means of a bearing with eccentric mechanism weighing 0.65 kg.

The destoning arm weighs 3.9 kg consist of a shaft with a hammer at one end pivoted to the frame of the machine to enable the motion be transmitted by the eccentric mechanism from the other end. This was arranged to produce counter vibration with the tray arm by setting its motion opposite the tray arm for balancing and stability.

The tray arm weighs 1.8 kg, consists of a shaft which is pivoted to support the tray at an angle of inclination of 35^0 at one end and the other end connected to the shaft with eccentric mechanism to aid vibration.

The sieve tray is suspended by the tray arm consists of sieve dimensioned 750 x 450 mm with sieve size of 2.5 mm.

2.3 The Principle of Operation of the Destoning Machine

The rice destoning machine was designed to separate rice from stone. The admixture (mixture of rice and stone) was fed through the hopper into the reciprocating sieve which allows stones smaller than the rice to pass through. Any stone that is larger than the diameter of the sieve size (2 mm and above) will fall along with the rice onto the vibratory sieve. The vibratory sieve sends the stones in the opposite direction of the flow of clean rice so that the cleaned rice will not be mixed with separated stone. The clean rice is collected at the lower part of the inclined sieve.

2.4 Test Procedure

Tests were carried out to evaluate the performance of the machine. Five different samples of Zaria rice variety and sand respectively were taken and weighed. Each corresponding samples were mixed and the mixture weight taken (Table 1). It is noteworthy that the proportion of stones mixed with the rice for the sake of testing the machine is unrealistic practically; the weight of rice to stone is in ratio 2:1. The rice –stone mixtures were introduced into the destoning machine. The time taken for separation was recorded. The quantities of cleaned rice and separated stones for all treatment were recorded and the machine capacity determined.

The performance of the machine was evaluated using the relationship given by Ogunlowo and Adesuyi, (1999)

i. Impurity Level after separation (IML_{AS}), percent

$$IML_{AS} = \frac{M_{scr}}{M_{cr} + M_{scr}} \times 100 \qquad 7$$

ii Tray Loss (TL), percent

$$T_L = \left(1 - \frac{M_{cr}}{M_{rm}}\right) \times 100 \quad 8$$

iii. Rice Separation Efficiency (RSE), percent

$$RSE = \left(\frac{M_{cr}}{M_{rm}}\right) \times 100 \quad 9$$

iv. Stone Separation Efficiency (SSE), percent

$$SSE = \left(1 - \frac{M_{scr}}{M_{sm}}\right) \times 100 \quad 10$$

Where M_{cr} is the mass of clean rice, g; M_{sm} is the mass of stone in admixture, g; M_{rm} is the mass of rice in admixture before separation, g and M_{scr} is the mass of stone in clean rice after separation, g.

3. RESULTS AND DISCUSSION

The result of the test carried out to evaluate the performance of the developed destoner is given in Table 2. The result showed an average of 74.2 %, 70 %, 25.8 % and 16 % for rice separation efficiency, stone separation efficiency, Tray loss and impurity after separation respectively for Zaria rice variety. The rice separation efficiency obtained was lower than 82.18 % rice separation efficiency obtained by Ogunlowo and Adesuyi, (1999). The tray loss and impurity level after separation were however higher than 17.82 % and 9.43 % obtained by Ogunlowo and Adesuyi, (1999).

Table 1. Result of the Performance of Developed Destoner

S/No	Weight of Rice, g	Weight of Stone, g	Weight of Rice and Stone mixture, g	Weight of Stone Separated, g	Weight of Rice Separated, g
1	1000	500	1500	350	650
2	1000	500	1500	325	700
3	1000	500	1500	310	800
4	1000	400	1400	300	810
5	1000	400	1400	310	750

Table 2: Performance Evaluation of Destoner for 5 Replications.

S/N	Impurity level after separation, %	Rice Separation Efficiency, %	Stone Separation Efficiency, %	Tray Loss, %
1	19	65	70	35
2	20	70	65	30
3	19	80	62	20
4	11	81	75	19
5	11	75	78	25
Average	16	74.2	70	25.8

4. CONCLUSIONS AND RECOMMENDATIONS

A rice destoning machine operating on mechanical principles of reciprocating and vibrating sieves was developed. The developed machine was tested in terms of the rice separation efficiency, stone separation efficiency, tray loss and impurity level after separation.

The result showed an average of 74.2 %, 70 %, 25.8 % and 16 % for rice separation efficiency, stone separation efficiency, tray loss and impurity after separation respectively for Zaria rice variety.

The developed machine has the promise of solving the problem of stone infestation usually encountered in locally produced rice.

5. Recommendations include:

1. There should be proper selection of sieve size for any variety of rice to be destoned.
2. There should be a speed adjustment mechanism by changing pulley sizes to regulate the speed as may be required for any operation.
3. There should be addition of fan for the machine to both destone and clean the rice.

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VALIDATING ACRU MODEL FOR AGBOGBO CATCHMENT, ILE-IFE SOUTHWESTERN NIGERIA

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ABSTRACT

Agricultural Catchments Research Unit (ACRU) model was developed by the former Department of Agricultural Engineering, now School of Bioresources Engineering and Environmental Hydrology, of the University of Natal in South Africa. It is a model in which the fields of applied engineering and water resources are integrated with agrohydrology in terms of the forcing functions and responses of the various components which make up the natural terrestial hydrology system (Schulze *et al.*, 2004). Three years streamflow, rainfall, minimum and maximum temperature, relative humidity, evaporation, and other climatic data were obtained for Agbogbo catchment at the Obafemi Awolowo University to calibrate the ACRU model for the catchment. A Digital Elevation Model of the catchment was also generated to provide other required data input for the model. Streamflow control parameters were adjusted in calibrating the model for the 1st hydrologic year (April 1987–March 1988). After which the same values of these variables were used in validating the model for the two subsequent hydrologic years (April 1988–March 1990). Chi-square goodness-of-fit test conducted at 5% significance level showed that there is no difference between the observed and the predicted streamflows. Values of 0.786 and 0.782 were obtained when Nash–Sutcliffe model efficiency coefficient was computed to determine the predictive power of ACRU model for Agbogbo catchment. A comparison of the simulated and observed hydrographs of for the catchment shows that ACRU Agrohydrologic Model overestimated streamflow for the catchment for the 2nd and 3rd hydrologic years. However, the similarity in the timing of the occurrence of peaks for the observed and simulated hydrographs shows that with some parameter adaptation and the availability of continuous long-term data, ACRU model can be modified for reliable streamflow prediction for Agbogbo catchment.

KEYWORDS: Agrohydrology; unguaged catchments; streamflow; calibration and validation

1. INTRODUCTION

With increasing population and industry, the demand for water has increased prodigiously thereby imposing a higher efficiency in the planning and management of water resources. With streamflow accounting for only 0.006% of freshwater resources (Gleick, 1996), realistic and accurate streamflow forecasts have become an essential tool for water resources planning and management (Hobson, 1997).

The availability of high-speed computers has resulted in a widespread use of computer models in the analysis and prediction of hydrologic variables for research as well as for practical design and management purposes. These models vary greatly in type and complexity, from simple computer implementations of methods previously based on manual calculations to attempts to solve the non-linear partial differential equations describing surface and subsurface flow processes that require much computation.

Hydrological models have been developed to improve our understanding of surface runoff generated from complex watersheds, make efficient and cost effective quantitative estimates of water resources of unguaged catchments and to plan, design, operate and manage water related structures.

Our ability to predict the hydrology of streams in future climates depends in part on our ability to model present circumstances. The comparison of observed to modelled streamflow provides insight

into model performance and the ability to predict hydrologic attributes that might be of interest in future scenarios and extreme events (Whitfield *et al.,* 2003).

To guage how well simulations perform requires rigorous assessment, and setting benchmark against which to measure success. Model validation is essential to the interpretation of simulation results. It illuminates under what circumstances a model reproduces events accurately and under what circumstances it performs unsatisfactorily. Validation is also critical to the improvement of models; the modelling community cannot improve models if it does not know how, where, and when they fail (Gordon *et al.,* 2004)

The justification for this study is informed by the following considerations:

- The need to make efficient and cost effective quantitative estimates of water resources of ungauged catchments.
- The need to apply models to planning, design, operation and management of water related structures (e.g. dams, reservoirs, drainage, irrigation etc.).
- The need for improved understanding of and to provide insights into the actual (physical, chemical and/or biological) processes involved in the catchment.

The model selected for the simulation was the ACRU (Agricultural Catchment Research Unit) model, which has been developed in South Africa over the past 15 years and is still undergoing further development and refinement (Smithers *et al*., 1997). ACRU is a physical conceptual agrohydrological model which generally operates with a daily time step. The model simulates all major processes of the hydrological cycle which affect the soil water budget and is capable of simulating, *inter alia*, streamflow volume, peak discharge and hydrograph, reservoir yield, sediment yield, crop yield for selected crops and irrigation supply and demand.

Outside of South Africa, Lesotho and Swaziland, the ACRU model has been applied in Zimbabwe (Butterworth et al., 1999; Makoni, 2001), Eritrea (Ghile, 2004) and further afield in the USA (Martinez et al., 2008) where the model was expanded to accommodate the flatwoods of the southeastern United States, and more recently in New Zealand (Kienzle and Schmidt, 2008; Schmidt et al., 2009) and Canada (Forbes et al., 2010). The authors acknowledge the difficulty in applying the ACRU model in developing countries where climatic, soils and land use data are not always readily available.

The objectives of the study are to:

- Calibrate the ACRU Agrohydrological Modelling System for the Agbogbo catchment with data obtained for the first hydrological year (April 1987 – March 1988).
- Use the calibrated model to simulate streamflow for the two subsequent hydrological years (April 1988 – March 1990).
- Test for validity of ACRU in Agbogbo catchment by comparing simulated and observed streamflow data with appropriate statistical tests.

2. MODEL DESCRIPTION

Agricultural Catchments Research Unit (ACRU) model was developed by the former Department of Agricultural Engineering, now School of Bioresources Engineering and Environmental Hydrology, of the University of Natal in South Africa. It is a model in which the fields of applied engineering and water resources related hydrology are integrated and interlinked with agrohydrology in terms of the forcing functions and responses of the various components which make up the natural terrestrial hydrological system (Schulze *et al.*, 1994). ACRU is a physical-conceptual rainfall-runoff model that simulates stormflows and baseflows explicitly, with a modification enabling the simulation of throughflow (New, 2002).

The ACRU model is a multi-purpose and multi-level integrated physical conceptual model that can simulate streamflow, total evaporation, and land cover/management and abstraction impacts on water resources at a daily time step. ACRU is highly versatile with potential applications ranging from streamflow simulation, to crop yield estimations, irrigation estimations, risk analysis etc. It has been mostly applied in the temperate and humid parts of South Africa and has been frequently used for

assessing the impacts of various land use modifications, specifically commercial afforestation (Hugh, 2002).

The ACRU modelling system is made up of a number of discrete, but interlinked components. The linkages and components are illustrated in Fig 1.

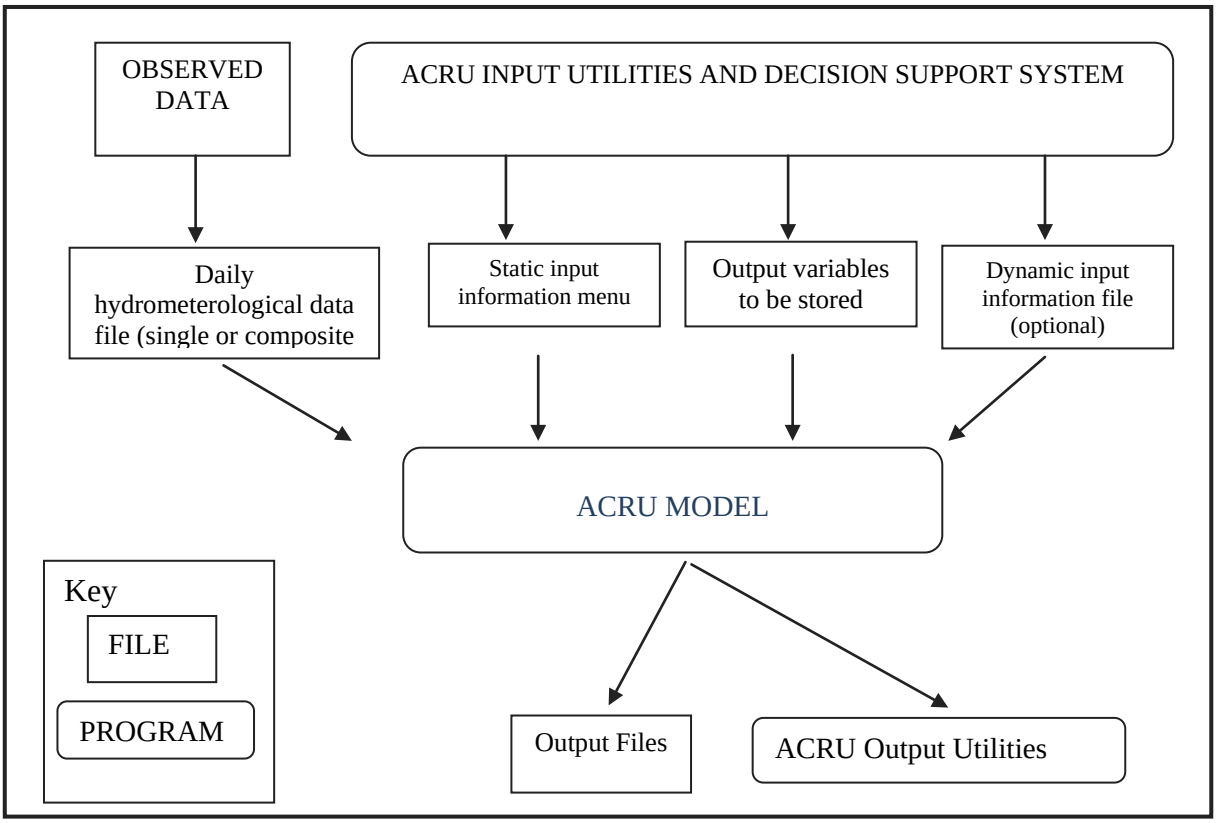


Fig. 1 Components and Linkages of ACRU Modelling System (Smithers *et al*, 1994)

The minimum daily input requirements are precipitation and potential evaporation. Parameter values for evapotranspiration, soil moisture budgeting and runoff generation are also required. ACRU simulates soil moisture in a vertical, two-layer soil column. Incoming rainfall is subject to interception by vegetation depression storage. The remaining rainfall infiltrates the upper soil horizon, and subsequently, moisture in excess of drained upper limit (that is field capacity) drains to the subsoil horizon. Similarly excess water in the subsoil horizon drains, either laterally as throughflow to the stream channel, or vertically to a groundwater store. Evapotranspiration occurs from both the topsoil and subsoil horizon, and is a function of potential evaporation (A-pan), leave area and soil moisture availability. When soil moisture is not a limitation, evapotranspiration occurs at the potential rate, but decrease linearly with increasing water stress once a critical fraction of plant-available water is reached.

Surface runoff and infiltration are simulated using a modified form of the SCS equation (Schmidt and Schulze, 1987), *viz.*

$$Q = (P_n - cS)^2/[P_g + S(1 - c)] \qquad \text{(eqn 1)}$$

Where:
Q is the runoff depth; P_n is the net daily rainfall (i.e. gross rainfall P_g, less canopy interception, plus contributions from impervious areas); S is the potential maximum retention (a function of soil texture and antecendent soil moisture); and c is the coefficient of initial abstraction.

ACRU employs the continuity equation in routing flow through reservoirs (Smithers and Caldecott, 2004). The equation written in finite difference form is expressed as:

$$S_{n+1} - S_n = (I_n + I_{n+1})\Delta t/2 - (Q_n + Q_{n+1})\,\Delta t/2 \qquad \text{(Eqn 2)}$$

Where:

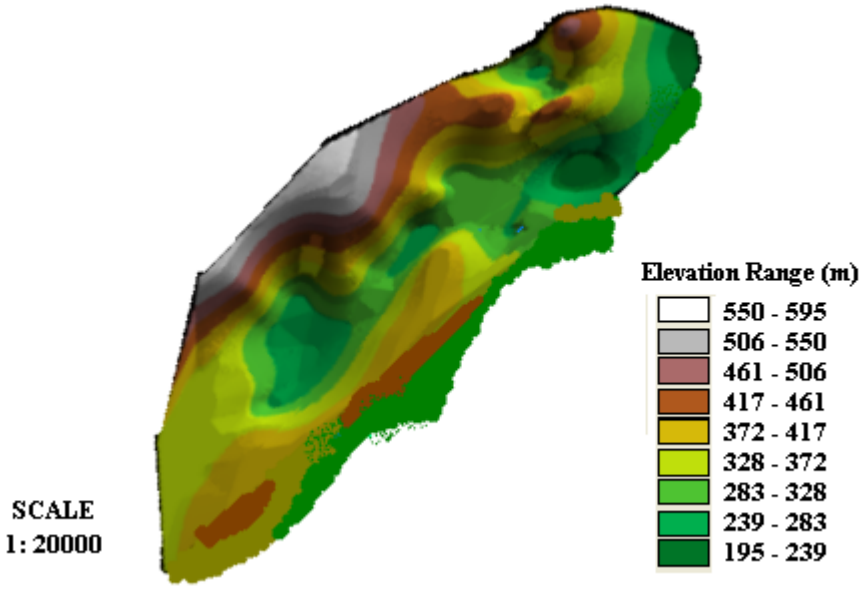
S_n = channel or temporary storage (m^3) at time increment = n
I_n = inflow rate ($m^3.s^{-1}$) at time increment = n
Q_n = outflow rate ($m^3.s^{-1}$) at time increment = n
Δt = routing period (s).

The subscripts (n) and (n+1) refer to the number of increments in time interval Δt. To route a hydrograph through a non-linear reservoir, the storage, outflow relationship and the continuity equation (Eqn 2) are combined to determine the outflow and storage at the end of every time step.

$$(2S_{n+1})/\Delta t + Q_{n+1} = I_n + I_{n+1} + (2S_n/\Delta t - Q_n) \qquad \text{(Eqn 3)}$$

3. CATCHMENT DESCRIPTION

Agbogbo catchment (Fig 2) of Ile-Ife, a city in Southwest Nigeria is at the intersection of Latitude $7^0$32'N and Longitude $4^0$32'E (Ogunkoya, 2000). Agbogbo stream has a basin area of 0.4 km^2 and a perimeter of 3630.8m that is underlain by the Pre-Cambrian Basement Complex bounded by elongated inselbergs. Soil in the drainage basin reflect the underlying geology and is shallower than 2m. The climate in the drainage basin consists of two seasons: the dry season, extending from November to March, and the wet season, from April to October. Temperatures in the dry season range from a night-time mean of 21^0C to a day-time mean of 30^0C and is covered mainly by farms planted to a variety of tropical food and tree crops (Ogunkoya, 2000).



(Scale 1:20000)

Fig. 2 DEM of the Catchment Showing Stream Outlet

4. RESEARCH METHOD

Rainfall data for Agbogbo catchment was collected using the Dines tilting syphon rain recorder while the current meter was used to obtain streamflow data. The rainfall-runoff charts, and other hydrometerological data obtained from Geography Department, Obafemi Awolowo University Ile-Ife, Nigeria, were interpreted into daily rainfall amounts before being formatted into the ACRU single format data input. The digital elevation model of the catchment developed from the contour map of Agbogbo catchment also provided other data required to calibrate and validate the ACRU model. Only charts for three continuous years (January 1987 to March 1990) were used in this study. The stream discharge obtained for the catchment was derived using the rating relationship between water level measurement (stage) and discharge. Ogunkoya (2000) established this relationship for the Agbogbo catchment as follows:

$$LogQ = -2.60 + 3.21 logH \quad \text{(eqn 4.1)}$$

where,

Q = discharge (l/s)

H = Water level (cm)

The monthly total discharge for years 1987, 1988, 1989 and 1990 (Fig. 3) were thus obtained using equation 4.1 after taking stage measurements at the stream outlet.

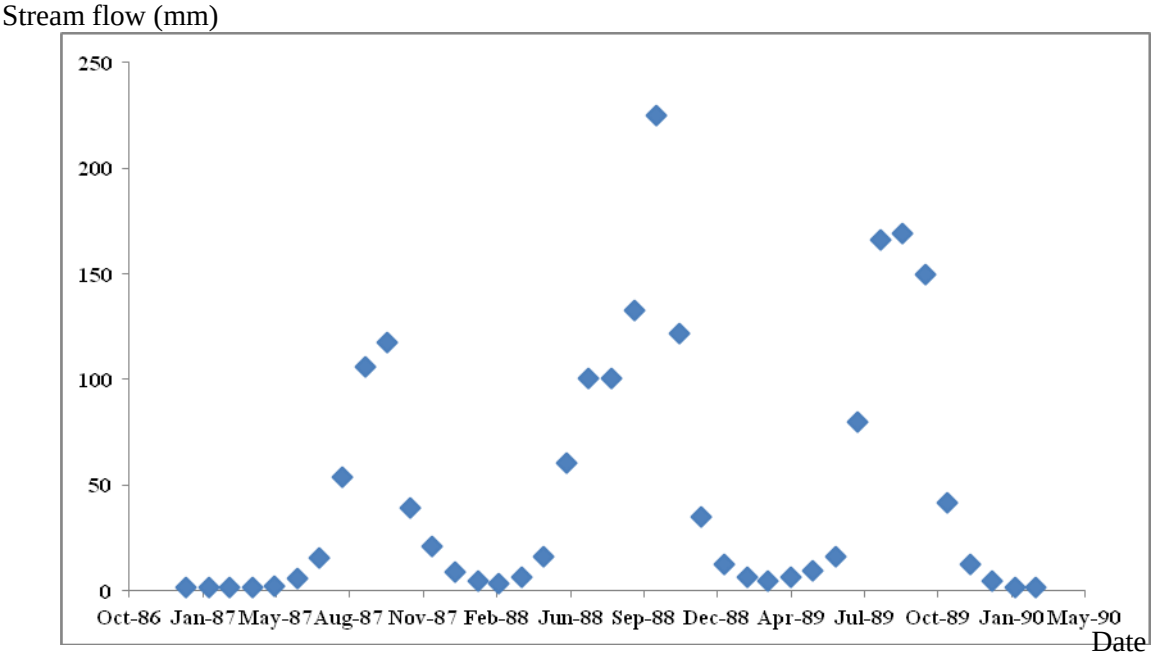


Fig. 3: Streamflow Hydrograph for Agbogbo Catchment

Pre-calibration comparison between the hydrographs of the measured (observed) and the simulated (modelled) streamflow was obtained as given in Fig. 4.

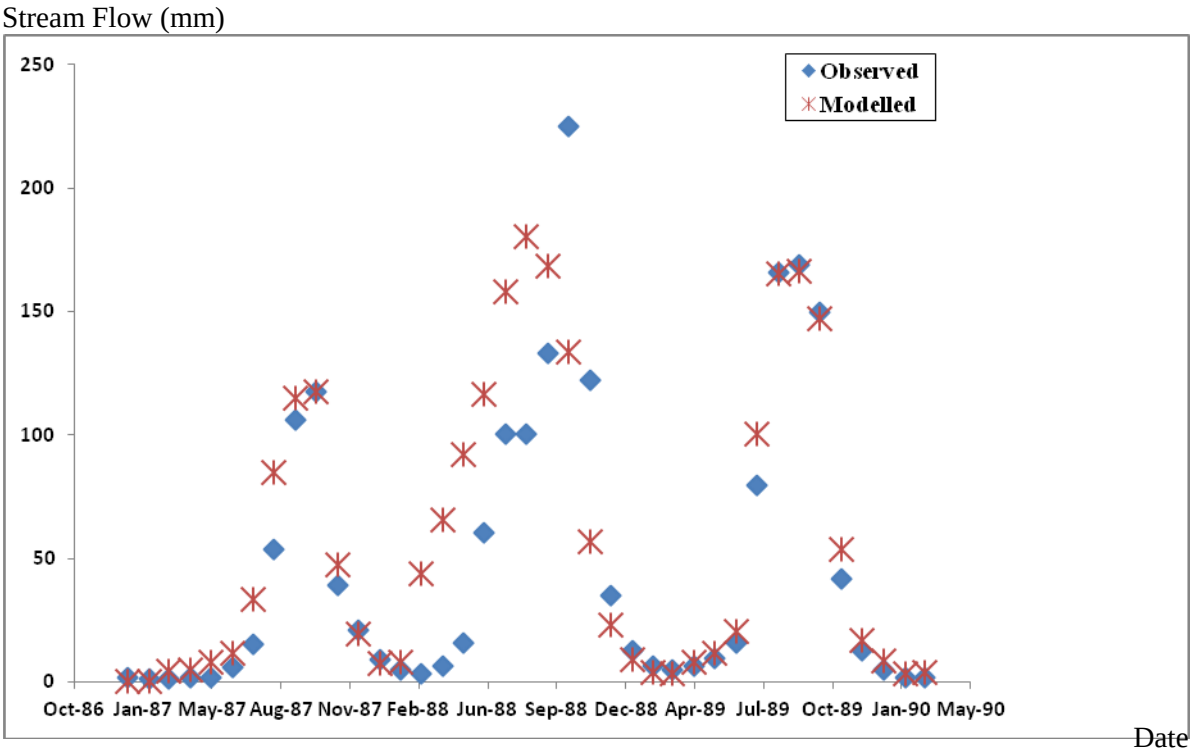
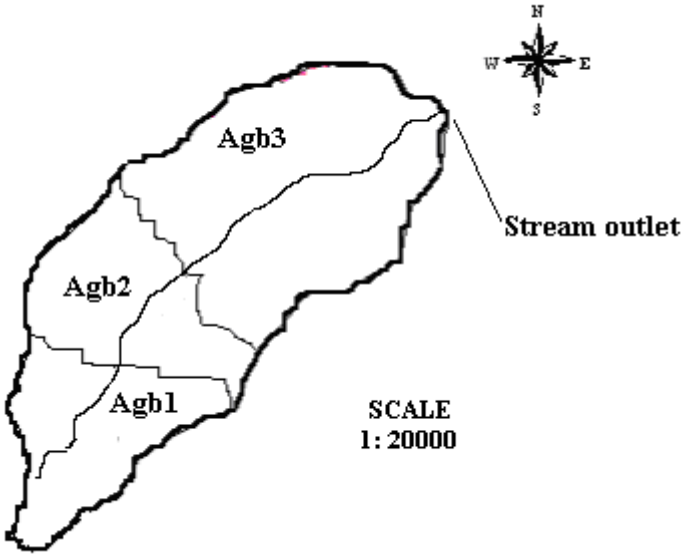


Fig. 4: Pre-Calibration Comparison of Observed and Simulated Hydrographs

Streamflow control variables (stormflow response fraction, coefficient of baseflow response fraction and effective depth of soil from which stormflow generation takes place) were used to calibrate the model by adjusting these parameters to achieve reasonable agreement between the predicted and observed streamflow for the 1st hydrologic year (April 1987 – March 1988). By reasonable agreement is meant an order of magnitude correspondence between the simulated and the recorded series, which is consistent within the duration of an event (Mbajiorgu, 1995). After several simulations, the values of the streamflow control variables that provide the closest match and similarity in the hydrographs of the simulated and the observed streamflows for the 1st hydrologic year were used in simulating flows for the 2nd and 3rd hydrologic years i.e. April 1988 – March 1989 and April 1989 – March 1990 (Fig. 6).

Agbogbo catchment was divided into 3 subcatchments (Agb1, Agb2 and Agb3) with areas 0.1, 0.1, and 0.2km^2. Streamflow is routed from the topmost subcatchment (Agb1) down through Agb2 to the stream outlet (at which point discharge measurements were taken) at Agb3 (Fig 5).



Scale 1:20000

Fig. 5: Sub-catchments Configuration of Agbogbo

5. SIMULATION RESULTS

After the calibration run (April 1987 – March 1988), ACRU Model over-predicted streamflow (Fig. 6) for the two successive hydrologic years (April 1988–March 1989 and April 1989–March 1990). The timing of the peaks for the observed and simulated streamflow during the simulation run however coincide which demonstrates that the model is sensitive to changes within the catchment. Chi-square distribution was used to test the goodness-of-fit between the observed and the simulated streamflows at 5% significance level (95% confidence level). The test showed that there is no significant difference between the simulated and the observed streamflow for the 2nd hydrologic year (April 1988 – March 1989) and third (April 1989 – March 1990) hydrologic years. The Nash–Sutcliffe model efficiency coefficient (Nash *et al*., 1970) which is a measure of the predictive power of hydrological models and defined as;

$$E = 1 - \frac{\sum_{t=0}^{T} (Q^t_o - Q^t_m)^2}{\sum_{t=0}^{T} (Q^t_o - \overline{Q}_o)^2}$$

was also used to compare the observed discharge (Q_o) and the modeled discharge (Q_m) at time t. The model efficiency coefficient E was obtained to be 0.786 for the 1st hydrologic year (April 1988 to March 1989) and 0.782 for the 3rd hydrologic year (April 1989 to March 1990).

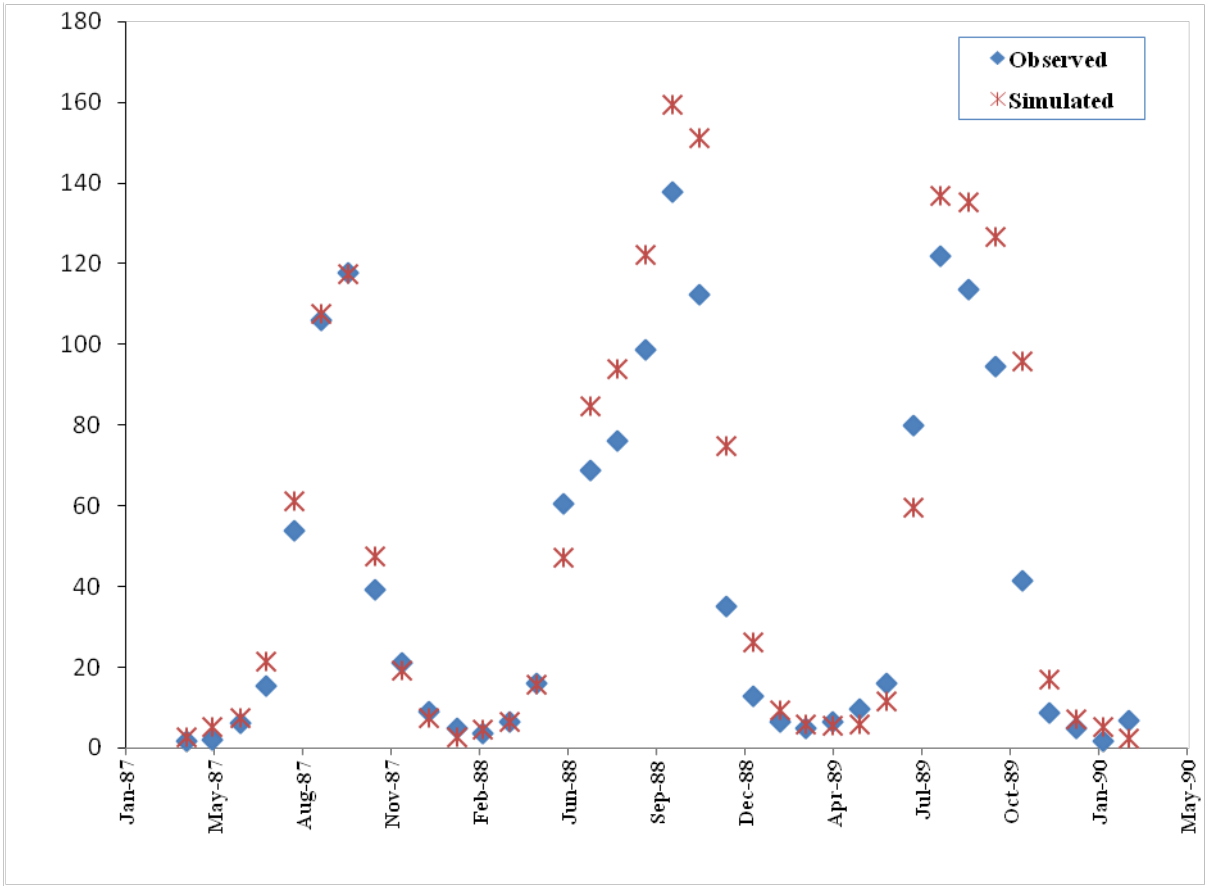


Fig. 6: Comparison between Simulated and Observed Hydrographs after Calibration

6. CONCLUSIONS

Data obtained from the field and those generated from a Digital Elevation Model of the catchment were used in modelling streamflow for Agbogbo catchment. The simulation of streamflow with the available 3 years data shows that ACRU Agrohydrologic Model slightly overestimated streamflow for the catchment for the two later hydrologic years after calibrating the model for the first hydrologic year. Chi-square distribution and Nash–Sutcliffe Model Efficiency Coefficient shows reasonable agreement between the simulated and the observed streamflows. The similarity in the timing of the occurrence of peaks for the observed and simulated hydrographs shows that with some parameter adaptation and the availability of long-term (≥ 10 years) data, ACRU model can be modified for reliable streamflow prediction for Agbogbo catchment. The 3-year duration of the data used for this study (which were the only complete set of data available at the time this study was conducted) is a limitation to the validation exercise.

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INFORMATION AND COMMUNICATION TECHNOLOGY IN EXTENSION, EDUCATIONAL SERVICES AND REVITALISING AGRICULTURE IN NIGERIA

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ABSTRACT

Access to information is of great importance in the development of agriculture among the predominantly peasant farmers in the developing countries where there has been a wide gap in the extension of information on Agricultural technology and services to the rural areas. In Nigeria accessibility to ICTs in the rural areas is growing at a fast rate with the introduction of some new technologies which have removed the problems of location in access. This has assisted in the extension of information on new technological development for agricultural practices. A review of the developments and effects in the rural settings are highlighted and recommendations made on steps necessary to reduce the rural-urban movement.

KEYWORDS: Information, communication, technology, extension, agriculture.

1. INTRODUCTION

Agriculture is an engagement of cardinal importance to any nation; be it developed, developing or underdeveloped for food, fibre and foreign exchange earnings. Technological advancements have played a very great role in the development of agricultural practices globally. In recent years, a new set of challenges to agricultural production and management activities are emerging in developing countries especially Nigeria. The production and processing of food are done mostly by small scale farmers and processors who constitute 80% of the population of the country. These are scattered in small rural settings across the country.

Nigeria is the largest geographical unit in West Africa occupying a land area of 923, 768 square kilometers between longitude 30^{o} and 150^{o} East, and latitude 40^{o} and 140^{o} North. The two main vegetation zones, the rain forest and savanna zones, as well as the wet and dry seasons are indicators for a fertile zone which makes the country an agrarian nation. At the start of the 1960s, the basis of the Nigerian economy was a well-diversified agricultural sector that supported 75 percent of the population, 78 percent of exports and supplied the people with 94 percent of their food. (World Bank, 1996). However, a new development pattern gradually emerged (over the years) as agriculture began to stagnate giving way to rapidly growing oil and manufacturing industries.

The development led to a shift in the pattern of industrialization, from the processing of agricultural products for export, to simple raw materials import substitution; as well as the emergence of petroleum extraction as a leading growth sector (Aigbe, 2006). However, from the mid-1960s growing regional tensions and the identification of the political parties with rent seeking, ethnic interests with the ensuing civil war caused major losses of production. Again, there was a sharp decline in foreign exchange earnings and government revenues attributable to the loss of all on-shore production of oil while foreign exchange was rationed during the war years with a series of increasingly stringent direct and indirect controls (Obayelu and Ogunlade, 2006). This period marked the sharp end to the ever thriving agricultural business.

Information dissemination, support and educational services on agricultural and rural development were fully supported and implemented by the government of the federation during the agricultural boom. It should be recognised that information dissemination is a fundamental element of any rural development programme. The rural areas are often characterised as information-poor. It is generally believed that any information that is not communicated cannot be said to exist. However

communication of information is not a panacea for the removal of constraints to rural agriculture but when accompanied with vision, hard work, patience, persistence, great courage and above all trust, it does bring new understanding and resources for all involved. Given the fact that information revolution brought about globalisation, information utilisation or application is believed to hold the solution to the challenges of globalisation in whatever form it is manifested. Efficient information dissemination remains the key to bridge the gap between the developed and underdeveloped countries (CTA, 2000).

With this in mind, information application is worth exploring as an important factor in the revitalization of the dwindling agriculture in the developing countries especially Nigeria. This paper provides a current review of ICT applications in agriculture and suggestions on how to improve access by rural farmers.

2. AGRICULTURE AND INFORMATION UTILISATION IN NIGERIA

In Nigeria, bridging the information gap and extension of information on Agricultural services and introduction of new techniques through educational services to farmers by utilising electronic technology. This started with the introduction of wired radio (radiofusion) in the 1950's to 1970's and then the transistor radios followed by battery operated television boxes in the towns and villages. This assisted in educating the farmers and also as a form of relaxation after a hard labour during the day through programmes on extension services on agricultural production, processing and economics normally relayed in the evenings. This is because the farmers would have gathered in the village squares after a whole day of labour relaxing under the trees, enjoying the cool evening and later the moonlight. It is pertinent to note that dissemination of information to the farmers have not grown beyond this level, in reality it has gone worse with the biting economy making it difficult for most peasant farmers to afford the simple transistor radios.

The development of agricultural operations in Nigeria has witnessed the introduction of various agricultural programmes which include Operation Feed the Nation in 1977, Green Revolution 1980, Agricultural Development Programmes, Fadama, LEEMP and many others in recent times. These programmes have come and gone or remained inactive with the series of military and civilian governments in the country. They came with agricultural extension and educational services meant to enlighten the farmers through information utilization on improved and best practices. Some have survived but have impacted very little on the development. The political situations in the country have also affected the impact the over fifteen Agricultural Research Institutes in Nigeria have on farmers and other agricultural stakeholders. The knowledge, research outcome, programme objectives and technologies are expected to be implemented by way of information through extension systems (the "carriers and teachers" of information) for further adaptation and delivery to farmers and other stakeholders in agriculture (the "users" of information) (George *et al*., 2002).

Information dissemination on agricultural services are still carried out through direct contact i.e. visits by the agricultural extension and education officers, agricultural engineers and other professionals through the intervention of the Government's Agricultural Development Programme (ADP), Non-Governmental Organisations (NGO) and other international bodies. The means of getting information through periodic half hour extension programmes on the media (radio and television) have remained the major source of updating farmers and processors on new technologies. This is often met with power problems which if available, i.e. the rural electrification, having been extended to such rural area, may be erratic. This reduces the source to only the radio which can be powered by batteries. Most of these and other poverty alleviation programmes in Nigeria are through telephone and radio with other commonly used traditional media including print, video, television, films, slides, pictures, drama, dance, folklore, group discussions, meetings, exhibitions and demonstrations (Munyua, 2000). The use of computers or the Internet is still restricted to very few people living in urban centres. However the potential to broaden and enhance access to information and communication resources for remote rural areas and poor communities are possible through the use of ICT.

Obayelu and Ogunlade (2006) observed that little empirical evidences of the benefits of ICTs in Nigeria are found in literature though there is a great potential for ICTs as tools for enhancing people's daily lives by increasing access to information relevant to their economic livelihood. The fast rate of development of the mobile telephone, the Global System Mobile (GSM) has only helped in a

small way. This is because the telecommunication industries are profit oriented businesses and extension of services to rural areas with low population has not been given priority except in places which are located near very important highways where the network services are critical for people plying on the highways. Braimah and King (2006) stated that it was becoming clear that no country can ignore the ICT revolution and its application to all sectors. They noted that ICT is expected to equip the populace with the requisite technical skills and entrepreneurship for industry as well as the service sectors.

2.1 Information and Communication Technology

Information utilization and application has gone beyond direct contact, one-one or one-many as is generally practiced in extension and educational services. The information revolution has brought about globalization and its utilisation and application is believed to hold the solution to the challenges of globalisation in whatever form it is manifested. However in the developing countries, the situation of information flow among the actors and agricultural stakeholders is at its lowest while the developed countries have gone to the level of application of technology in information dissemination. The use of ICTs in development is therefore not new but has assumed a new prominence when the United Nations and G8 group of industrialised countries flagged off ICT for Development (ICTD) as a global development priority in the year 2000.

Information and Communication Technologies (ICTs) are the set of tools, equipment, applications and services that are used to produce, capture store, process, disseminate and exchange information. Currently ICT is taken as any electronic means of capturing, processing, storing and disseminating information (Duncombe and Heeks, 1999) while others define it as purely a tool for "computerizing" processes or purely Internet-based communications. It is often referred to as Information Technology (IT) or Information System/Science (IS) by those who believed any information that is not communicated is non-existent. Therefore, the word communication is superfluous.

ICT can be categorized into four groups based on the history of usage. These are

1. Very Old ICTs: These are as old as the earth. Examples include artifacts and natural objects, stone tablets, animal skin and leaves. These are used right from the time of creation through the Stone Age until the start of civilization. It is however interesting that it is still in use among a number of primitive tribes and some peasant agricultural workers till date.
2. Really Old ICTs: These are printed matter, books, newspapers and serials
3. Old ICTs: These are the electronic media tools such as radio, television, land-line, telephones and telegraph
4. New ICTs: These are the modern day microelectronic tools such as computers, satellites, wireless one-on-one (mobile), the Internet, e-mail and multimedia.

Currently Information and Communication Technologies (ICTs) are largely micro-electronic networks, embodying complex hardware and software, linked by a vast array of technical protocols. Currently, these are in the form of a global, regional, national and local network of computers and micro computers. The global network of computer is what is referred to as the internet. Today the computer is a synonym for information processing technology. Network of computers are linked by wired or wireless connection through ground equipment known as Very Small Aperture Terminals (VSAT) via satellite or through network of undersea and inland optical fibre cables linking the continents and countries.

The optical fibre cables transmit information by converting electronic signals to light signals hence transmitting at or close to the speed of light. The SAT3 is one of the cables linking Nigeria with the European, Middle East and Asian countries as shown in Figure 1. The SAT3/WASC/SAFE cable system is indeed a technology and commercial breakthrough of unparalleled significance for Africa. It is a historic achievement made possible by the participation of thirty six nations, the majority of the landings being in African states, offering a faster, more efficient trading channel between the continent and international markets. The undersea cable system costing more than US$600 million

will operate for the next twenty five years. This results in much of the revenue it generates being ploughed back into the continent. This is a major departure from the current scenario, where many African countries rely on foreign operators to route their international traffic which results in revenue (generated in Africa) leaving Africa. The other cables are Main1, Glo1, West African Cable System (WACS). These cables will in the nearest future replace expensive and low speed VSAT currently being used by all the developing countries for internet connection.

This project will help bridge the digital divide between Africa and the developed nations and all the role-players will enjoy the access to knowledge brought about by the information revolution that has already had such a dramatic impact in the West, Europe, and the Far East. It will bring the people of Africa the fast, efficient and affordable communications they need for sustained development and progress (SAT3/WASC/SAFE, 2008)

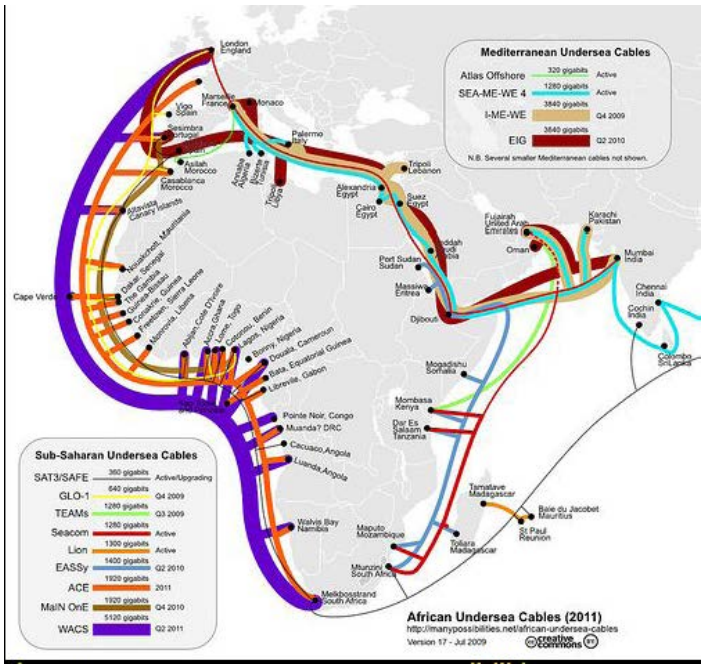


Figure 1. African Undersea Optical Fibre Cable Network (Sources: Song, 2009)

Internet which is the major component of ICT had the greatest impact on the society when compared with all the technologies that had evolved over centuries. The rate of adoption of the Internet exceeds that of all technologies before it (Adeya and Oyelaran-Oyeyinka, 2002). It took the least number of years on record to spread to 25% of the world population becoming popular in 1991 and within seven years became a popular and global technology for information communication (Jasmon, 2004). This is in comparison to the now popularly used electricity, automobiles, and airplanes which spanned through 46, 55 and 64 years from 1873, 1886 and 1903 respectively (Figure 2).

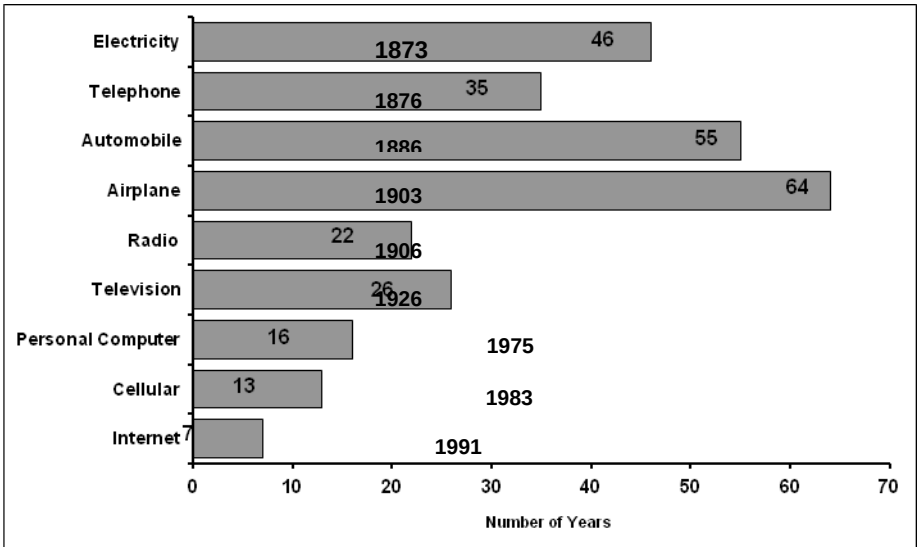


Figure 2. Spread of New Technologies. Showing year of invention/introduction and number of years to spread to 25% of world population.
(Source: Jasmon, 2004).

Recent years have seen an increase in the use of ICTs especially in form of the internet in almost every sphere of life, even in developing countries. Internet connectivity rose from 19 countries in 1996 to 53 in 1999 (Mundy and Sultan, 2001). Only 15 countries which included Congo, Eritrea and Somali operated with less than 64kbps bandwidth in 1996 while Somalia, Libya and Mauritania were still on dial up e-mail system by the year 2000. In 2006, African users constituted only 3% of the world usage and this grew to 3.5% in 2008 and 3.9% in 2009. It is interesting to note that this constitutes the fastest growing usage worldwide, being a growth of 628% and 1392% (after middle east 1648%) compared to the usage in the year 2000 as at 2006 and 2008 respectively (Table 1).

Table 1. World Internet Usage

	2006		2008		2009	
World Regions	% of World Usage	Usage Growth 2000-2006 (%)	% of World Usage	Usage Growth 2000-2008 (%)	% of World Usage	Usage Growth 2000-2009 (%)
Africa	**3.0**	**625.8**	**3.5**	**1,031.2**	3.9	1,392.4
Asia	35.2	231.2	39.5	406.1	42.6	545.9
Europe	28.9	196.3	26.3	266.0	24.1	297.8
Middle East	1.8	479.3	2.9	1,176.8	3.3	1,648.2
North America	21.5	113.7	17.0	129.6	14.6	134.0
Latin America/Caribbean	7.9	370.7	9.5	669.3	10.3	890.8
Oceania / Australia	1.7	141.0	1.4	165.1	1.2	175.2
World Total	**100.0**	**198.1**	**100.0**	**305.5**	100.0	380.3

Source: Internet World Stats (2008)

The world usage in terms of the number of users as at 2006 is presented in Table 2 while the African top ten users are presented in Figure 3 showing that the users have grown to over 44 and 55 million users in 2008 and 2009 respectively from 30 million in 2006. Despite these fast growth rates in the number of users, Africa's bandwidth consumption was second to Asia the least as at 2006 (Table 2). This indicates that the supposed users have only been using the internet for browsing and e-mailing activities while the other general and commercial activities have still not incorporated the internet. The interest shown by the African and Asian countries (especially Nigeria being one of the two taking the lead in Africa, Figure 3) in this technology, for information, is worth commending and therefore should be explored in the development of agriculture. Other issues which include establishment and

development of the necessary infrastructures to derive the maximum benefit, sustainability and how the rural communities can optimise the benefits of ICT for development need to be addressed.

Table 2. Internet users and bandwidth consumption in 2006

Region	User (Millions)	Bandwidth (Mbps)	Consumption (%)
USA	230	1000	66.7
Europe	310	375	25.0
Asia	390	2	0.1
Africa	30	13	0.9
Others	105	110	7.3
World	**1075**	**1500**	

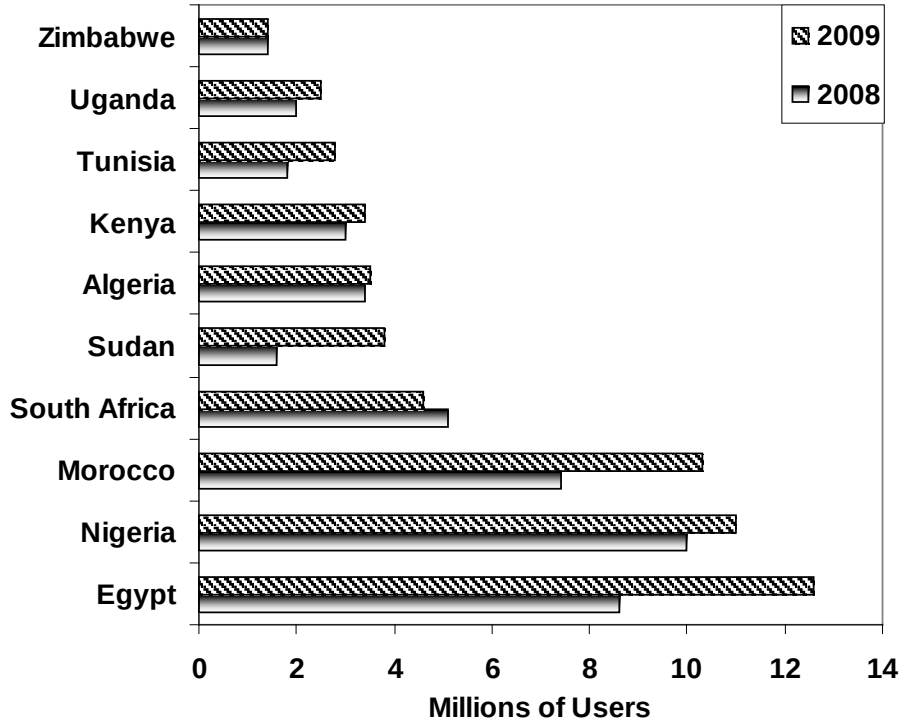


Figure 3. Top Internet Countries in Africa.
(Source: Internet World Stats, 2008 and 2009)

2.2 Available ICT Facilities

There are a number of ICT facilities useful in information management, utilization and dissemination in agricultural practices. These include Radio, Television, Video, Computer (CD-ROM, DVD, Video CD etc), Phone/GSM and Internet (Web (www), Web chatting, E-mail, Tele/audio conferencing, Voice over Internet Protocol (VoIP), Digital and Satellite TV, Electronic Library Resources). Each of these and their usefulness in agricultural information dissemination are discussed.

Wireless Communication: Radio, Television and Telephone

Wireless communications make use of electromagnetic waves to send signals across long distances. Radio is the term used for the portion of the electromagnetic spectrum in which waves can be generated by applying alternating current to an antenna. Radio, television and wireless links infrastructures are useful as backbone for wide area network for rural and sub-urban farming/agricultural communities in developing countries. This, as stated earlier, has been used and still in use extensively in agricultural extension services. The means of getting information through

periodic half hour extension programmes on the media (radio and television) have remained the major source of updating farmers and processors on new technologies. The use of other wireless voice technologies such as GSM and CDMA are well beyond the reach of most of the communities in the developing world for data transfer but useful in voice transfer.

Television and Video – Their additional visual with audio utility for teaching and instruction, can be used to give the appropriate content for effective dissemination of agricultural information for the various actors and stakeholders in agricultural development agenda in the country. It is also a medium for advertisement to promote products.

Computers and CD-ROM – The computer is the main tool for information storage, processing and retrieval as well as internet access. Digitised documentation of activities can also be made available on CDs, DVD and VCDs for access through computers and other electronic devices. Tele and video conferencing through computers connected to the internet can also be used to teach and introduce stakeholders to agricultural practices in other locations.

Phone/GSM – these are cabled and wireless telephoning systems for communication among the personnel and beneficiaries which can also be used to link the internet with modest investment given the prevalent teledensity growth rate of the sector in Nigeria. The coverage of the GSM and CDMA systems which can be up to the remotest farm level makes wireless telephoning a very important tool. Communication has been made easy with the easily affordable wireless telephones in rural and village markets where agricultural materials and processed food materials are exchanged at regular intervals.

The Satellite - The NIGERIA-SAT1 launched in 2004 which is a disaster monitoring/management satellite is also a useful ICT tool in agriculture. Its capability to monitor desert encroachment, flooding in coastal and internal waterways, forest fires and migration as well as animal count in national parks are of importance in revitalization of these aspects of agriculture. The NIGCOM-SAT1 launched in 2006 is a communication satellite meant to bridge the communication gap between Nigeria and other developing countries as a result of the high cost associated with the countries link to other satellites. This is expected to improve access and reduce unit cost of satellite communication within the country. Access to satellite television stations broadcasting educational programmes on agricultural practices could be a good source of information for the stakeholders in agriculture. Best practices and 'how to' programmes and documentaries are sources of information for improved practices. Telecommunications costs are also expected to reduce if the telecoms operating companies have direct connection to local satellite. It is disheartening to note that the status of the NIGCOM-SAT1 is not clear as of now.

The Internet - The World Wide Web is a free and open medium for exchange of information in form of data, voice, video and other means. It is open to all and contains enormous information on various subjects. It could be a static page or an interactive page in the form of a portal where submission of information, management of databases, forms and applications can be obtained, completed or transmitted without the need to travel long distances. It contains abundant Library Resources in the form of electronic books, journals and other publications. Local resources can also be made available on the web. It is also a medium of projecting images and quick confirmation of status can be made on web pages.

E-mail is a fast means of communications for sending electronic messages in the form of data through the cyberspace. The ability to send a broadcast message i.e. to multiple recipients at a time makes it a good source of information exchange. Web-Charting is another form of instant messaging which requires the parties communicating to be connected to the internet at the same time. Issues of importance needing immediate attention could be discussed online.

WiMax is a technology for broadband wireless access networks. With a signal distribution range of up to 48km from a base station, it has since inception been considered as a potentially excellent technology for last mile distribution in Africa particularly as wireless deployment are non-existent in many instances and are costly to establish owing to the limitations of demanding terrain. The non-line

of sight capabilities of WiMax has reduced the required number of base stations and greater coverage. Also WiMax's has full mobility when devices such as phones PDAs and laptops are equipped with integrated WiMax chipsets. This will facilitate the next step for hotspots and migration of these so-called hotzones with larger coverage areas in the kilometers instead of meters. This will give users high speed mobile access in the remotest places without duplication of infrastructures. This is a potentially useful technology especially in Nigeria where there are associated problems with location, management, maintenance and security of transmitting and repeater stations.

3. CURRENT LEVEL OF APPLICATION OF ICTS IN AGRICULTURE IN DEVELOPING COUNTRIES

In Ghana and Mali, ICT have helped women group in increasing production and getting markets for their products (CTA, 2007). In Ghana, CTA reported a women listening club using ICT to access information on the production of healthy vegetables. Members of the group are trained in the use of mobile phones and local radio to access agricultural information. In Mali, the Kari and ICT projects were launched by the Women Shea butter Producers Cooperative with support from the International Institute for Communication and Development (IICD) and the Malian Association for the Promotion of Young People. Their activities include compilation of electronic directory of shea butter buyers, computerizing the cooperatives accounting system and conquering new markets for shea butter using the internet.

Many young people are put off by farming as they see it as too much hard work for too little profit, but technology can be used to improve earnings and give the agricultural sector a fresh appeal in the eyes of the new generation (CTA, 2006). This spurred the women group in Suriname in the Caribbean to try and make agriculture attractive to young people by offering training in basic ICT skills, e-commerce, organic farming, agri-business and agro-processing. They observed that ICTs are attractive tools for young people that can help give agriculture an extra glow of innovation, as well as an extra kick to small agribusinesses for young people to know that there is good money to be made in agriculture.

The assistance of the International organizations, the NGO's and other bodies at rescuing the situation of digital information divide between Africas remote places and the other global areas is very necessary. Although it should be noted as observed by Aigbe (2006) that Communication is not a panacea for the removal of constraints to rural agriculture but when accompanied with vision, hard work, patience, persistence, great courage and above all trust, it does bring new understanding and resources for all involved. It can generate committed farmers in the community who are better disposed to working and understanding one another while bridging cultural and economic differences.

In Nigeria, the Global Citizen Journey, an NGO, demonstrated the practicability of these in November 2005 when Members of this organization traveled to the riverine communities in the Niger Delta region of Nigeria to build the first friendship library in the region. The library, stocked with books (including agricultural books), computers, video and DVD players and soon to be provided Internet access, is fast translating into a gateway for receiving and communicating with the world. The Global Citizen Journey's visit has also opened up windows of agricultural opportunities after the journey, a web based yahoo group has been formed to continue the networking. New communication channels are opening up for the rural agriculture in these communities, thus offering means for bridging the gaps between rural farmers and agriculture information. Despite technological advancement in Information and Communication Technology all over the world, the rural populace of Nigeria still continue to have limited access to information. Establishment of tele and internet centres in the locality and rural settings by the Local Governments will possibly create access points to stakeholders in agriculture.

Ofuoku *et al*. (2007) found that the level of adoption of mobile phones among poultry farmers in Delta state, Nigeria was about 53 percent and this was found to be significantly dependent on the level of education of the farmers. The technology was used for exchange of information by over 63% of the farmers on issues that are related to health problems, request for drugs, sources of feed and drugs, request for attention of veterinarians, poultry products marketers, current prices of inputs/outputs and information about meetings. The reasons for adoption were listed as mobile savings quality assurance

of reaching the receivers at all times, flexibility/carrier quality and faster access to other stakeholders. However, running cost and instability of the network are listed as the constraints.

3.1 ICT Application in Agriculture and the Nigerian Rural Settings

It has been established that the majority of the stakeholders in agriculture in Nigeria who need information for agricultural development are in the rural areas, but it is disheartening to note that, as stated, in most rural settings in Nigeria, the access to the information cyberspace is still at near zero level. Information on agricultural services is still through direct contact by extension services officers. However the other stakeholders in agriculture i.e. the researchers, extension workers, the private sector and the NGOs have one form of access to the ICTs. The need therefore arises on how to bridge the gap of the information divide.

3.2 The Role of Government and the Private Sector

An effective use of ICT in agriculture requires the provision of necessary infrastructures within the reach of the large rural populace. Government effort towards this, though not only channeled for agriculture, includes the approval of a National IT Policy and implementation in April 2001, with the establishment of the National Information Technology Development Agency (NITDA), charged with the implementation responsibility. The policy recognised the private sector as the driving engine of the IT sector. Emphasis is to be laid on development of National Information Infrastructure Backbone (NIIB) as well as Human Resources Development. The policy recognised agriculture as one of the areas of attention for IT adoption. The Policy stated that the nation shall use IT to re-engineer agriculture for the purposes of maximizing food production, improving food self-sufficiency and security, increasing output for industrial raw material utilization, providing employment, economic growth, and minimising environmental abuse and degradation. (National IT Policy, 2001). It also recognized that IT will be used to facilitate the establishment of an agricultural information system to provide support for planning, production, storage, and distribution of horticultural crops, livestock, and fisheries products as well as Create IT awareness for all types of farmers at all levels nationwide. The extent to which these has been implemented and their impacts on the rural populace are not very clear.

Nigerian Communication Satelite-1 (NIGCOMSAT-1) launched in 2006, expected to cover Africa and Europe, is intended to bridge the digital divide, and the Nigerian economy into the information age. Nigerian Government has also invested heavily and announced the National Rural Telephony Programme (NRTP) The introduction of the GSM in the millennium is also another step by the Nigerian Government in improving communications at the rural level. It is, however, interesting to note that not all these projects have achieved the set objectives especially on the rural and agricultural coverage.

The launching of the Cassava Initiative for export in Nigeria in 2002 has resulted in increased production of cassava and processing into a number of products for export. This also led to increased activities of the cassava growers association. However, processors who require large quantities of cassava are faced with the problem of availability of cassava in small quantities from small and medium scale farmers spread over a large area of a region. The associated cost of transportation in locating these farmers to be able to meet their daily factory requirements has made some of the processing operations uneconomical in addition to inadequate raw materials. The existence and management of a database of members of the growers association available online with associated information through the media will reduce the effort and costs associated with the effort to gather raw materials. Trips to collect or organisation of market places for cluster of farmers to market their products can be made easier with the use of these ICT tools.

3.3 Benefits of ICTs in Agriculture

The introduction and use of ICTs in agriculture will enable the stakeholders at all levels access to adequate information on production, processing, storage, marketing and new techniques without distance and cultural barriers. Access to information, essential social facilities which are comparable

with the urban centres will reduce the rural urban drift and stimulate interest in agriculture. Access to information on current prices and international trade, product requirements and standard right at the farm will promote products that are of international standard ready for marketing domestically and for export. ICT is a driving force for improved research and is currently known to be heavily used by researchers and all over the world. Its provision and application by Agricultural Research Officers, NGOs and other information generators in Nigeria will keep them at the level comparable with other nations globally.

3.4 Limitations to the use of ICT in Agriculture

The major driving force for the utilization of ICT and accessing all the ICTs at both the providers and the audiences' end, is power supply. The other limitations are the literacy levels of the end users i.e. the farmers and some other stakeholders in agriculture and rural areas as well as the high cost of acquiring the necessary equipment. Cost of equipment for newly introduced technology and systems are always high in developing countries. The providers of information being mostly researchers, the NGOs and others may also be faced with the problem of the language of presentation across the multi-ethnic settings common in developing countries. Analysing and understanding information posted through data transfer could also be a limiting factor for farmers and the rural populace. Provision of the necessary infrastructures by both the public and private sectors also require heavy investment, although it is a worthy venture. The solutions to most of these are dependent on an organised sector, especially the government.

4. CONCLUSIONS AND RECOMMENDATIONS

It is generally recognised that improved communication and information access are directly related to social and economic development. A measure that will make rural living and involvement of youth and old in agriculture, at all levels of rural society, is the ability to access critical information and to communicate their needs. This will create conducive environments in the rural settings that are comparable to urban setting as a result of easy to use and affordable essential facilities for information access. There is therefore a need to explore the use of the available infrastructures on the fastest growing technology in the developing countries, the ICT, and provide adequate infrastructures necessary for the access and dissemination of information on agricultural services.

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