JOURNAL OF AGRICULTURAL ENGINEERING AND TECHNOLOGY (JAET)

Aims and Scope

The main aim of the Journal of Agricultural Engineering and Technology (JAET) is to provide a medium for dissemination of high quality Technical and Scientific information emanating from research on Engineering for Agriculture. This, it is hoped will encourage researchers in the area to continue to develop cutting edge technologies for solving the numerous engineering problems facing agriculture in the third world in particular and the world in general.

The Journal publishes original research papers, review articles, technical notes and book reviews in Agricultural Engineering and related subjects. Key areas covered by the journal are: Agricultural Power and Machinery; Agricultural Process Engineering; Food Engineering; Post-Harvest Engineering; Soil and Water Engineering; Environmental Engineering; Agricultural Structures and Environmental Control; Waste Management; Aquacultural Engineering; Animal Production Engineering and the Emerging Technology Areas of Information and Communications Technology (ICT) Applications, Computer Based Simulation, Instrumentation and Process Control, CAD/CAM Systems, Biotechnology, Biological Engineering, Biosystems Engineering, Bioresources Engineering, Nanotechnology and Renewable Energy. The journal also considers relevant manuscripts from related disciplines such as other fields of Engineering, Food Science and Technology, Physical Sciences, Agriculture and Environmental Sciences.

The journal is published by the Nigerian Institution of Agricultural Engineers (NIAE), A Division of Nigerian Society of Engineers (NSE). The Editorial Board and NIAE wish to make it clear that statements or views expressed in papers published in this journal are those of the authors and no responsibility is assumed for the accuracy of such statements or views. In the interest of factual recording, occasional reference to manufacturers, trade names and proprietary products may be inevitable. No endorsement of a named product is intended nor is any criticism implied of similar products that are not mentioned.

Submission of an article for publication implies that it has not been previously published and is not being considered for publication elsewhere. The journal's peer review policy demands that at least two reviewers give positive recommendations before the paper is accepted for publication. Prospective authors are advised to consult the Guide for Authors which is available in each volume of the journal. Four copies of the manuscript should be sent to:

The Editor-In-Chief
Journal of Agricultural Engineering and Technology (JAET)
℅ The Editorial Office
National Centre for Agricultural Mechanization (NCAM)
P.M.B. 1525
Ilorin, Kwara State,
Nigeria.

Papers can also be submitted directly to the Editor-In-Chief or any of the Sectional Editors. Those who have access to the internet can submit electronically as an attached file in MS Word to aponwualu@niae.net; ponwualu@yahoo.com and ifeeolife@yahoo.com. All correspondence with respect to status of manuscript should be sent to the E-mail address.

TABLE OF CONTENTS

THE POTENTIAL OF SAWDUST AS AN INSULATOR IN A DOUBLE WALLED METALLIC SILO

[1]B. A. Adejumo, F. A. Ola, A. A. Odubiyi, A. O. Oyefeso and J. O. Aje
Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso
[1]Author for correspondence: Email: funmibitan@yahoo.com

ABSTRACT

Sawdust is one of the major residues from sawmilling industry. The saw mill sector currently disposes off some of its residues (sawdust, bark and planer shavings) through environmentally incorrect means with only a small amount used as litter in the poultry industry. The major disadvantage in the use of metallic silo for grain storage is the temperature fluctuations within the structure which will results in grains deterioration. The objective of this work is to investigate the potential of sawdust as an insulator in a double walled metallic silo. This is with a view of solving the problems of environmental pollution from the sawmilling industry as well as reducing losses of grain stored in metallic silo. A 350kg double-walled metallic silo was designed and constructed using galvanized iron sheet with sawdust as insulating material between the walls. The silo has a total height of 2.70metres above the ground level with an internal and external diameter of 0.80metres and 0.90metres respectively. The silo consists of four major sections viz – the roof, cylindrical section, conical hopper and foundation. A pre-storage evaluation was carried out on the silo to ascertain the potential of sawdust as an insulator prior to grain storage. Temperature differences between the silo and the ambient as well as along the height were monitored three times daily for a period of thirty days. The result shows a temperature range of 19-40.7^{o}C and 22.5-42.5^{o}C inside the silo and ambient respectively. Statistical analysis revealed significant difference ($p<0.05$) in the temperature range in the silo and ambient during the test period. The double-walled sawdust insulated metallic silo demonstrated some prospects for use in grain storage especially in the reduction of temperature fluctuations within the silo. This in turn will help solve the problems of sawdust disposal in Nigeria.

KEYWORDS: Thermal conductivity, silo, sawdust, temperature, waste.

1. INTRODUCTION

Sawmill industry is very essential in the utilization of wood for both domestic and commercial purposes. Sawdust is the wood waste produced by cutting wood with a saw. The size of the sawdust particles depends on the kind of wood from which the sawdust is obtained and also on the size of the teeth of the saw (Afuwape, 1983). Between 10 and 13% of the total content of a log is reduced to sawdust in milling operations; this depends largely on the average width of the saw kerfs and the thickness of the timber sawed. Sawdust has low thermal conductivity, which ranges between 0.06 to 0.12W/mK. Thermal conductivity of sawdust is a function of the wood specie. The sawmill sector currently disposes off some of its residues (sawdust, bark and planer shavings) through environmentally incorrect means, with only a small amount of sawdust is used as litter in the poultry industry and cooking in sawdust stoves.

Sawdust is readily available in large quantities as wastes in majority of the wood processing industries. It has been proposed that the conversion of sawdust wastes through briquetting process is one of the ways of reducing waste disposal problems in majority of the wood processing industries. Furthermore deforestation which promotes pollution will be drastically reduced if the use of sawdust waste is enhanced. The use of sawmill residues must be carefully analyzed to offer the best technical, economic and environmental alternative. The characterization (quantity, type, chemical and energy analysis) of the residues generated, in addition to the energy needs of sawmills, is essential to determining which technology is more suitable.

Silos are the most commonly used structure for the bulk storage of grains. There are a number of construction materials such as steel, aluminum, concrete, wood rubber, and clay etc used for silo construction. Although silos are the most appropriate modern structures for the bulk storage of grains, their performances are greatly influenced by the materials of construction and the climatic environment where they are used (Mijinyawa, 1999). The metallic silos are the predominant structures used for grain storage in strategic grain reserves in Nigeria due to their large unit capacities which could be as much as 500 tonnes (Talabi, 1996). However in the warm and humid environment prevalent in Nigeria, these silos of temperate region origin though purchased and stocked at very high costs, experience moisture condensation, hot spot development, high temperature fluctuation and caking which results into grain deterioration (Mijinyawa *et al.*, 2007).

The low thermal conductivity of wood products of about 0.12 W/(mK) (Parrish, 1973) and their availability most especially in Southwestern Nigeria encouraged their consideration for use in silo construction (Alabadan, 2002). Mijinyawa (1989) and Alabadan (2006) investigated the potentials of wooden silos in reducing temperature fluctuations. They found that temperature fluctuations obtained within the wooden silos were lower than for those in metal silos. However, the difficulty in making the joints tight in order to eliminate crevices where insects could hibernate constitutes one of its disadvantages. Termites build their tunnels from the soil into the wooden structures leaving the surface untouched which makes it difficult to detect an attack in the early stages (John *et al.*, 1995).

The main objective of this work is to investigate the potential of sawdust as an insulator in a double walled metallic silo due its low thermal conductivity. The double-walled silo will reduce temperature fluctuations between the environment and the silo enclosure thereby reducing the effect of condensation that could lead to deterioration of stored grains. The utilization of sawdust in this structure will help reduce the problems of waste disposal and environment pollutions emanating from the sawmilling industry.

2. MATERIALS AND METHOD

A 350kg double-walled metallic silo was designed and constructed using galvanized iron sheet with sawdust as insulating material between the walls. The silo is located in the experimental field of the Department of Agricultural Engineering, Ladoke Akintola University of Technology Ogbomoso, Nigeria. The silo has a total height of 2.70metres above the ground level with an internal and external diameter of 0.80metres and 0.90metres respectively. The silo consists of four major sections viz – the roof, cylindrical section, conical hopper and foundation (Plate 1). The body of the silo comprises of two cylinders (outer and inner) of diameters 0.90m and 0.80m and length 1.22m and 1.18m respectively. Sawdust was placed in the space (5cm) between the two walls to serve as an insulating material. The silo also has six inspection holes of diameter 0.02m drilled through the silo wall at 0.60m, 1.20m and 1.80m along the height of the silo. It is meant to facilitate easy assessment of the quality of the stored grains and conditions within the structure. Pre-storage temperature measurements were made in order to establish the efficiency of the silo before grains are stored in the structure. The temperature differences between the silo enclosure and the environment where it is located was measured by placing the probe of a thermocouple in each of the inspection probes located on the silo walls and outside the silo for a period of thirty days (1st to 31st October 2009). Temperature readings were taken three times daily at 8:30 am, 12:30 pm and 3:30 pm. Temperature data collected were statistically analysed. A one-way analysis of variance (ANOVA) was carried out to determine differences and Duncan's multiple range tests to separate means.

Plate 1: The Double-Walled Metallic Silo

3. RESULTS AND DISCUSSION

The results show that there are differences between the temperature within and outside the insulated silo as shown in Figure 1. This is an indication that there is resistance to temperature influx into the silo from the outside, which shows that the low thermal conductivity of the sawdust has reduced the heat transfer into the silo. Temperature within the silo was also found to be affected by the time of the day at which readings are taken (Figure 2). Naturally lower temperatures were recorded in the mornings than in the afternoon; this also has direct effect on the temperature within the silo. The result shows a temperature range of 19-40.7^{o}C and 22.5-42.5^{o}C inside the silo and ambient respectively.

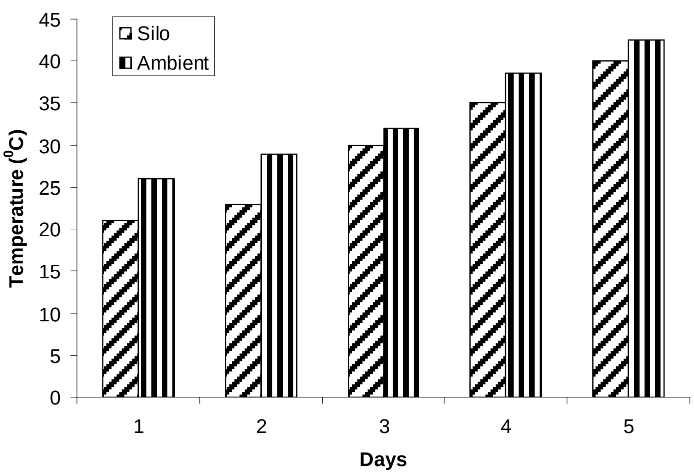


Fig 1: Average temperature within the silo and ambient condition at 3.30pm (1st to 31st October 2009)

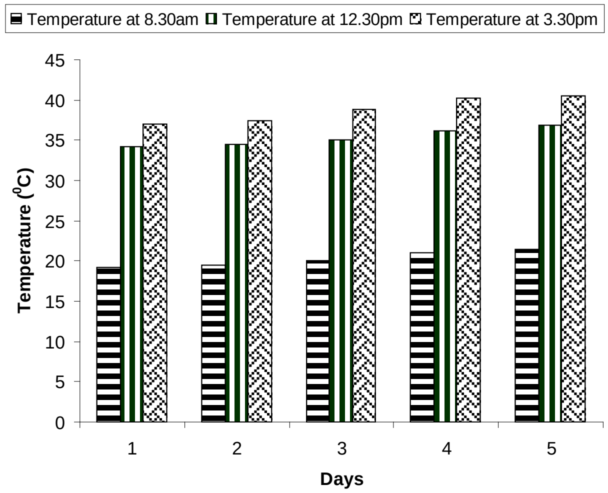


Figure 2: Average temperature variation within silo at different time of the day

The statistical analyses show that there are significant differences between the temperature within the silo and the ambient as shown in Table 1. The Duncan test (Table 2) showed that temperature in the silo at 8.30am is the lowest and the highest at 3.30pm at the ambient. There are no significant difference between the temperatures of the silo at 12.30pm and the ambient at 8.30am. There are however differences in all the temperatures in the ambient and silo from 12.30pm to 3.30pm.

Table 1: Anova for the temperature difference between the ambient and silo

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1365.167	5	273.033	45.585	0.000
Within Groups	143.748	24	5.990		
Total	1508.915	29			

Table 2: Duncan test for temperature variation between the silo and the ambient

	Time	N	Subset for alpha = .05				
		1	2	3	4	5	1
Duncan	Silo at 8.30	5	20.2000				
	Ambient at 8.30	5		24.9000			
	Silo at 12.30	5		27.0000			
	Ambient at 12.30	5			31.2000		
	Silo at 3.30	5				36.4000	
	Ambient at 3.30	5					39.9800
	Sig.		1.000	0.187	1.000	1.000	1.000

There are significant differences in the temperature within the silo as shown in the analysis of variance (Table 3). The temperature increases with the time of the day, with the lowest at 8.30am and highest at 3.30pm (Table 4).

Table 3: Anova for the temperature difference within the silo

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2917.968	2	1458.984	714.566	0.000
Within Groups	85.755	42	2.042		
Total	3003.723	44			

Table 4: Duncan test for temperature variation within the silo

	Time	N	Subset for alpha = .05		
		1	2	3	1
Duncan	8.30	15	20.2600		
	12.30	15		35.3733	
	3.30	15			38.7933
	Sig.		1.000	1.000	1.000

Temperature was observed to increase from the bottom to the upper part of the silo (Figure 3).

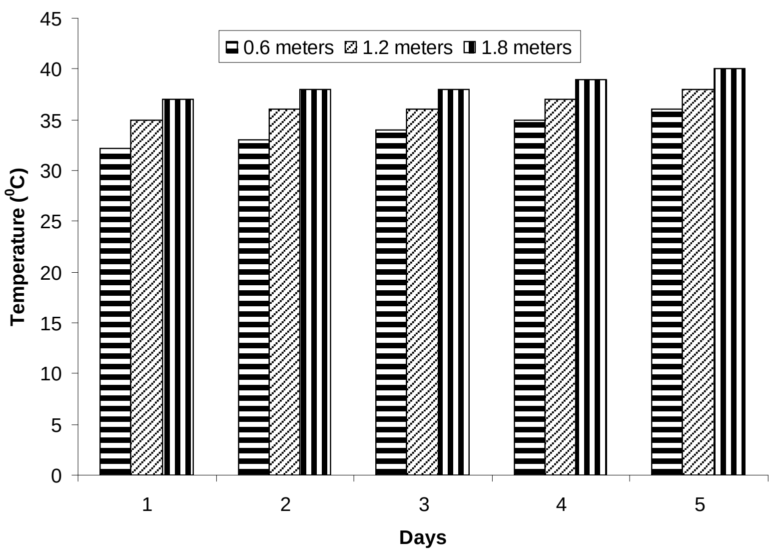


Figure 3: Average temperature within the silo along the height

The analysis of variance showed that there are significant differences in the temperature within the silo (Table 5) with the increase in height. The Duncan test showed that the temperature at the lower part (0.6m) is lower (Table 6) and there is no significant difference between the temperature at 1.2m and 1.8m

Table 5: Anova for the temperature difference with height in the silo

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	18.565	2	9.283	5.674	0.018
Within Groups	19.632	12	1.636		
Total	38.197	14			

Table 6: Duncan test for temperature variation with height in the silo

	Silo height	N	Subset for alpha = .05	
		1	2	1
Duncan	0.6	5	34.0400	
	1.2	5		36.4000
	1.8	5		36.4000
	Sig.		1.000	1.000

4. CONCLUSIONS

The insulated double-walled metallic silo demonstrated some prospects for use in grain storage; especially in the reduction of temperature fluctuations within the silo due to the low thermal conductivity of the sawdust.

REFERENCES

Afuwape F. K. 1983. Design and Testing of a Sawdust Compactor. B.Sc. Thesis, Department Agricultural Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria.

Alabadan B. A. 2002. Modelling the Performance of a Hexagonal Wooden Silo during Storage of Maize (*Zea mays*) *Unpublished PhD thesis*, University of Ibadan, Nigeria

Alabadan B. A. 2006. Evaluation of Wooden Silo during Storage of Maize (*Zea mays*) in Humid Tropical Climate. Agricultural Engineering International: the CIGR E-journal. Manuscript BC 05 013. Vol. VIII. February, 2006

John V. W., Wolfram P. and Fritz H. 1995. Rural Building Course. IT Publication Ltd. London. (1): pp.143 – 144

Mijinyawa Y. 1989. The Use of Wood Products in the Design and Construction of a Grain Silo for the Humid Tropics. Unpublished PhD thesis. University of Ibadan, Nigeria

Mijinyawa Y. 1999. Wood Products for Grain Silo Construction. Journal of Engineering Applications 1(2): 25 – 29

Mijinyawa Y., Lucas E. B. and Adegunloye F. O. 2007. Termite Mound Clay as Material for Grain Silo Construction. Agricultural Engineering International: the CIGR E-journal. Manuscript BC 07 002. Vol. IX. July, 2007

Parrish A. 1973. Mechanical Engineers Reference Book. 11th Edition. Butterworth and Company Publishers, London. pp 2-25

Talabi A. E. 1996. Implementation of National Food Security Programme: Experience So Far. In Proceedings of the National Workshop on Strategic Grains Reserve Storage Programme. Federal Ministry of Agriculture, Abuja. 26th – 28th July. 1996

PRESENT STATUS OF CASSAVA PEELING IN NIGERIA

A. R. Kamal and O. A. Oyelade
National Centre for Agricultural Mechanization (NCAM), Ilorin.
Email: yemioyelade@yahoo.com

ABSTRACT

Cassava (Manihot esculenta Crantz) is a root and tuber crop of the tropics, and is one of the most important sources of energy in the human diet in the tropics. It is also an important staple, food security and cash crop that thrives where most other crops fails. Cassava is a major source of carbohydrate in most developing nations of the world. It can be used as binder in the textile industries as well as in many pharmaceutical and agro allied industries as well as in many pharmaceutical and agro-allied industries. It is a known fact, that cassava processing operation is lobour-intensive requiring lots of energy and power in order to meet up with people's needs which could only be achieved through mechanization. Hence, the objective of this study is to present the present status of cassava peeling in Nigeria.

KEYWORDS: Peeling, cassava, processing, tool, machine

1. INTRODUCTION

Cassava (Manihot esculenta Crantz), is grown mainly in the tropical parts of Africa, Brazil, Malagasy, Indonesia, South India, Phillipines, Malaya, Thailand and China (Ajibola, 2000). Nigeria is the largest producer of cassava in Africa. This became evident from statistics of cassava production quantity reported by Food and Agriculture Organization, (FAO 2000). In the tropical part of Africa, it has become the most important crop in terms of both land area devoted to its production and the proportion it contributes to the human diet. Jeon and halos (1992) stated that 60% of root crop consumption in Africa is accounted for by cassava. Cassava is utilized extensively for human and livestock consumption as well as for other industrial products such as starch. Most of the usages of cassava are in its processed forms while only a small quantity is consumed directly. Cassava is a short-lived perennial tropical shrub growing from about 100 – 350cm tall which is believed to be first domesticated in South America. Its cultivation has spread throughout the humid tropics and subtropics (Rehn and Espig, 1991). Its total production in Africa has increased from 35 – 80 million tonnes between 1965 and 1995 (Hillocks, 2002). Nigeria being one of the African countries in cassava production can process this crop into gari, lafun, pupuru, paki, fufu and cassava grit for direct human/livestock consumption. Cassava starch is an ingredient used for the manufacturing of dyes, drugs, chemicals, carpets and in coagulation of rubber latex (Odigboh, 1983). It could be recalled in the last administration of President Olusegun Obasanjo came up with "Presidential Initiative" to increase production for local consumption and export promotions. More so, a policy was initiated the year 2004 to produce bread in the country with cassava and wheat flours in a ratio of 1:9 in the Nigerian Bakery Industry. Apart from human food, cassava is also used for animal feed and alcohol production (El-sharkawy and Cock, 1987).

Sometimes ago in Nigeria, there was a certain time whereby there was an ever-increasing global demand for cassava chips and pellets particularly from Brazil and China. Cassava can therefore be regarded as a multipurpose crop for man and livestock. Because of the importance of cassava to both human and animal, cassava processing operations in Nigeria deserves serious attention in order to meet the local and international demand of its products. Several operations are involved in the area of cassava processing of which includes operation such as peeling, washing, grating, boiling, parboiling, drying, milling, pressing, sieving, extrusion and frying. Among these operations stated above, cassava peeling remains a serious problem to the cassava processing industries in Nigeria and calls for serious attention. Before the cassava tuber is processed into any of its food and some of its non-food products, it must be peeled. Ideally, and especially in the food industry, the peel must be completely removed without removing the useful tuber flesh. The major cassava peeling problem arises from the fact that cassava roots exhibit appreciable differences in weight, size and shape. There are also differences in the properties of the cassava peel, which varies in thickness, texture, and strength of adhesion to the root flesh. Thus, it is difficult to design a cassava peeling machine that is capable of efficiently peeling all roots from various sources. Indeed the development of a technically and economically acceptable cassava peeling machine is still a challenge.

This paper examines various types of cassava peeling technologies developed so far in the country till date in tackling this bottleneck (cassava peeling) in the area of cassava processing in Nigeria.

2. DESCRIPTION OF CASSAVA PEELING TECHNOLOGIES

Several efforts have been made in Nigeria in solving the bottleneck (cassava peeling) associated with cassava processing in Nigeria. Due to the importance of cassava to both human and animals many manufacturers of cassava peeling machines and cassava peeling tools in Nigeria have been trying their possible best in the country to come up with new technologies in tackling the problem of the most stressful part of cassava processing which has to do with cassava peeling. Presented below are detail reports of some of the cassava peeling tools and machines in the country.

2.1 Cassava Peeling Tool

2.1.1 *IITA Cassava Peeling Tool*

The IITA cassava peeling tool has the capacity of peeling up to 30 kg/hr depending on experience of the user. Some of the advantages of this peeling tool are that it is simple which can be easily fabricated. It provides uniform peeling of the tuber being peeled with minimum peeling loss. It also has easy grip of the tool which provides for maximum safety of the user. Lastly the cassava peeling tool has the advantage of peeling various sizes of cassava tubers. It is easy to maintain by washing and drying after use. Fig. 1 shows the pictorial view of the IITA cassava peeling tool.

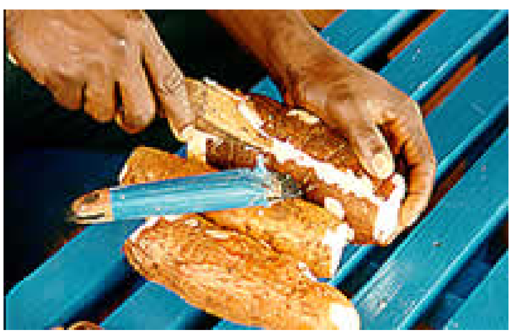


Fig. 1. IITA's cassava peeling tool in operation

2.1.2 *NCAM Improved Cassava Peeling Tool*

The NCAM improved cassava peeling tool has the capacity of peeling up to 45kg/hr which also is a function of the person using it. One of the main features of this cassava peeling tool is that it has a high quality peeling blade and handle made of mild steel. Some of the advantages of this peeling tool are that it is simple which can be easily fabricated. It provides uniform peeling of the tuber being peeled with minimum peeling loss. It also has easy grip of the tool which provides for maximum safety of the user. Lastly the cassava peeling tool has the advantage of peeling various sizes of cassava tubers. It is easy to maintain by washing and drying after use. Fig 2. shows the pictorial view of NCAM improved cassava peeling tool.

Fig. 2. NCAM improved cassava peeling tool

2.2 Cassava Peeling Machine

2.2.1 *PRODA's Cassava Peeling Machine*

The PRODA's cassava peeling machine has the capacity of peeling up to 1500kg/hr of cassava tubers. The word PRODA denotes Projects Development Institute located in Enugu State of Nigeria. Fig.3. shows the pictorial view of PRODA's cassava peeling machine.

Fig. 3. PRODA's cassava peeling machine

2.2.2 *2-Action Zone Peeler*

The 2-Action zone peeler has the capacity of peeling up to 135kg/hr of cassava tubers. For more detail on this machine contact Prof. E. U. Odigboh who is now a retired lecturer at the University of Nigeria, Nsukka. Fig. 4 shows the pictorial view of the 2-Action zone peeler.

Fig 4. The 2-Action zone peeler

2.2.3 *A & H cassava peeling machine*

The A & H cassava peeling machine was one of the initial concept of cassava peeling machine that was designed to have sharp blade end wounded round the rollers of the machine. A & H is a company located in Iwo town located in Osun State. A prototype of this machine is available at NCAM, Ilorin for necessary modification and improvement of the machine which was found to be big and huge in size. Fig.5. shows the pictorial view of the A & H cassava peeling machine.

Fig. 5. A & H cassava peeling machine

2.2.4 *FUTA's Cassava Peeling Machine*

The FUTA's cassava peeling machine was a particular prototype of a cassava peeling machine made of wire brush type has its own peeling device. The machine as reported by the manufacturer has the capacity of peeling up to 8-tonnes/day of cassava tubers. Figure 6 shows the pictorial view of FUTA's cassava peeling machine.

Fig. 6. FUTA's cassava peeling machine

2.2.5 *FATAROY's Cassava Peeling Machine*

The FATAOY's cassava peeling machine is claimed to be one of the latest version of cassava peeling machines in the country. As a result of this one unit of this machine was recently supplied to NCAM, Ilorin for specification and performance test. The machine is made up of five different rollers of which four of the rollers serves as peeling devices made of perforated sheet wounded round the rollers while the last roller serve as the machine's conveyor. The machine performed best at conveyor speed at no load condition of 420rpm to give an average peeling efficiency of 72.21% and tuber losses of 17.37%. Under the condition given above the machine has a capacity of peeling 725kg/hr of cassava tubers at two passes. Fig. 7 shows the pictorial view of FATAROY's cassava peeling machine.

Fig. 7. FATAROY's cassava peeling machine

2.2.6 *FATAROY's Improved Cassava Peeling Machine*

The improved version of FATAROY's cassava peeling presently at NCAM has the same features with the former one sent to NCAM for testing. The improved version is equipped with pneumatics wheels which makes the machine transportable for peeling of cassava from one cassava farm to another. The machine is mounted to the rear end of a tricycle bike. The tricycle here serves a dual purpose, first by transporting the cassava peeling machine to where needed on the farm and secondly by transporting the machine operator and the cassava processors. Figure 8 and 9 show the pictorial views of the improved version of FATAROY's cassava peeling machine and tricycle bike, respectively.

Fig. 8. The improved version of FATAROY's cassava peeling machine

Fig. 9. Tricycle bike used for transporting the cassava peeler through rear mounting

2.2.7 *IITA Cassava Peeling Machine*

The IITA cassava peeling machine was developed in Brazil in order to remove the drudgery involved with cassava peeling operation and also to encourage large-scale processing of cassava in the country. The machine consists of a prime mover and a cylindrical wooden drum which houses the cassava tubers to be peeled. Peeling is achieved through abrasion. The machine has the capacity to peel up to 2000 kg/hr. Fig. 10 shows the pictorial view of the IITA cassava peeling machine.

Fig. 10. IITA cassava peeling machine

2.2.8 *New Developed Cassava Peeling Machine through Collaborative Effort*

The new developed cassava peeling machine was the collaborative effort of IITA, Ibadan; FUTA, Akure; FATAROY, Ibadan; and A & H, Iwo. The machine is a double action/self fed cassava peeling machine which consists of two conveyors arranged in parallel, two rotating and outlets, tuber monitor, a protective hood, frame and transmission system. The machine impacts rotary/linear motion on the tuber, which also makes contact with the peeling brush and thus provides the required peeling effect on the tubers. The machine has the capacity of peeling 1000 kg/hr with 10% and 5% tuber losses and peel retention, respectively. Figure 11 shows the pictorial view of the double action/self fed cassava peeling machine.

Fig. 11. The double action/self fed cassava peeling machine

3. CONCLUSION

The present status of cassava peeling in Nigeria is still on the search for an effective cassava peeler stage. There is need for the encouragement of more collaboration between the governmental and non-governmental organizations in Nigeria in seeing to how this cassava peeling problem that is labour-intensive can fully be addressed by coming up with an effective cassava peeling machine in the country that will peel 100% cassava root with a minimal root loss of less than 0.5%.

REFERENCES

Ajibola O. O. 2000. Adding value to the farmer's harvest: Obafemi Awolowo University Press Limited, Ile-Ife, Nigeria.

El-Sharkawy M. A. and Cock J. S. 1987. Response of cassava to water stress. Plant and Soil 100, 345-360.

FAO 2000. FAO Corporate Documentary Repository, Proceedings of the Expert Consultation on Root Crop Statistics.

Hillocks R. J. 2002. Cassava in Africa. In Cassava: Biology, Production and Utilization. Eds. R.J. Hillocks J. M. Thresh and A.C. Bellolli. Pp 41-54. CAB International, Wallingford.

Jeon Y. W. and L.S. Halos 1992. Innovations for Improved Roots and Tuber Food Processing. In: An Unpublished Training Manual: design Operation and Maintenance of IITA-developed Postharvest technologies. (Eds Y. W. Jeon, L. S. Halos).

Odigboh E. U. 1983. Cassava Production, Processing and Utilization. In. Chan Jnr., H.T. (ed), Handbook of Tropical Foods. Mercel Decker Pub. Inc., 270, Madison avenue, New York. Pp 145-200.

Rehm S. and Espig G. 1991. The cultivated plants of the tropics and subtropics. Verlag Josef Margraf, Germany, 243-247.

INSTITUTIONAL FRAMEWORK FOR AGRICULTURAL MECHANISATION IN BENUE STATE, NIGERIA

T.U. Nwakonobi[1] and A.P. Onwualu[2]
[1]Department of Agricultural Engineering
University of Agriculture, Makurdi, Nigeria
[2]Raw Materials Research and Development Council, Abuja
E-mail: ponwualu@yahoo.com

ABSTRACT

Many agricultural institutions have existed and continuing to exist in different states in Nigeria since independence in 1960. The aim is to improve agricultural production by small scale farmers by providing production inputs that are beyond the famers. This includes mechanization services. But this objective is yet to be realized. This has led to more research efforts being directed towards assessing the level of machinery utilization in these agricultural institutions. To do this, a standard structured questionnaire was developed and administered to various agricultural institutions in Benue State in 2001. Also used was direct physical count and observation. Information was obtained on the level of mechanization, linkages among the institutions providing mechanization services, availability and condition of machinery as well as maintenance facilities, opinion of the workers on how to make the services to be better.

The institutions identified include: Field Monitoring Unit (FMU), Lower Benue River Basin Development Authority (LBRBDA), Benue State Ministry of Agriculture and Natural Resources, Benue State Tractor Hiring Agency (BENTHA), Agricultural Development Company (ADC), Benue State Agricultural and Rural Development Authority (BNARD), National Agricultural Land Development Authority (NALDA), College of Agriculture and University of Agriculture. Most of the institutions surveyed (83.3%) do not have enough shed for their machinery. Half of those institutions have no standard functional and well equipped workshop for maintenance. This accounts for enormous frequent breakdown of machinery (83.3%) recorded in this study. Obsolete machinery, poor maintenance facilities, poor storage and lack of genuine spare parts form the major causes of machinery breakdown. Most of the machinery available in these institutions were in unserviceable condition. Steyr tractors are dominantly used followed by Fiat tractors in the State. Most of the agricultural institutions have linkages with one another for both institutional and technical support.

For these institutions to adequately provide mechanization services to famers they need to be overhauled with respect to funding, provision of facilities and acquisition of new machinery.

KEYWORDS: Agricultural mechanisation, agricultural machinery, tractors, Benue State.

1. INTRODUCTION

In sustained efforts to boost agricultural production in Nigeria, the Federal Government under different regimes had laid serious emphasis on agriculture. According to Odigboh and Onwualu (1994) agriculture and related activities has always been allocated at least 5% of the approved expenditure in the past few decades. This justifiably high emphasis on agriculture has resulted in the establishment of a number of schemes, programmes and institutions for promoting agriculture and related industries. These include the Farm Settlement Schemes, World Bank Assisted Agricultural Development Project (ADP), Tractor Hiring Unit (THU), Operation Feed the Nation (OFN), Green Revolution, Commodity Marketing Boards (CMB), River Basin Development Authorities (RBDA), Federal Department of Agriculture (FDA), Federal Agricultural Coordinating Unit (FACU), Agricultural Input Subsidy Schemes, Tractor and

Implement Assembly Plants, Agricultural Research Institutes, Colleges of Agriculture, Universities of Agriculture, Directorate of Food, Roads, and Rural Infrastructures (DFRRI), National Directorate of Employment (NDE) and National Agricultural Land Development Authority (NALDA), Agricultural Research Council of Nigeria (ARCN), Commercial Agriculture Scheme, Agriculture Credit Guarantee Scheme, National Agriculture Insurance Scheme and Bank of Agriculture (Onwualu et al, 2006; Ani and Onwualu, 2002). Benue State Government has shown similar emphasis through the establishment of some agricultural institutions in the state.

The agricultural institutions that exist in the state (Federal and State Government owned) at present (2001) include: Field Monitoring Unit (FMU), Lower Benue River Basin Development Authority (LBRBDA), Benue State Ministry of Agriculture and Natural Resources. Benue State Tractor Hiring Agency (BENTHA), Agricultural Development Company Ltd. (ADC), Benue State Agricultural and Rural Development Authority (BNARDA) and National Agricultural Land Development Authority (NALDA). There are two educational agricultural institutions – College of Agriculture and University of Agriculture.

In each of the Agricultural institutions, there is an engineering division or department with agricultural mechanization related programmes. The provisions of this type of programme according to Jones (1984) had helped to transform American Agriculture from a situation where one farmer fed 5 people in 1880 to that where one farmer could feed 80 people in 1982. But in the Nigerian situation the case is different as the level of agricultural development is still below expectation in spite of all these programmes in place. Komolafe et al, (1980) noted that the use of machines on the farm can contribute greatly to the well-being of both the producer and the consumer. Crosslay and Kilgur (1983) attributed the potential benefits of mechanization to the farmer as reduced drudgery, increased returns, and reduced costs. Odigboh and Onwualu (1994) reported that the machines used for agricultural production in Nigeria include hand tools, animal drawn implements, two-wheel and four-wheel drive tractors, motorized or mechanically driven post-harvest handling and processing machines, crop storage equipment and pumps for irrigation. Mrema (1993) reported that about 86% of land preparation operations in Nigeria are carried out using such hand tools powered by the human muscle. About 8% of farm operations in Nigeria are carried out using Draught Animal Technology (DAT). According to Musa (1988) animals are used mainly for farm transport and tillage operations. The use of engine powered technology for agricultural production in Nigeria as reported by several researchers (Anazodo et al, 1986, 1987, 1989; Aneke and Ayoola, 1993) is very low.

The low utilization of agricultural machinery in Nigeria has prompted various studies in the past covering different aspects including machinery ownership patterns (Dauda et al, 2010), tractor and equipment hire services (Kolawole, 1972; Akinola et al, 2008; Nkakini and Eguruze, 2009; Haque et al, 2003, Aneke and Ayoola, 1993) and maintenance practices (Jakayinfa et al, 2005; Onwualu, 1996; Onwualu, 1998). These and other studies suggest the need to study the institutions set up by government to deliver mechanization inputs to farmers in order to make them more efficient and hence increase the level of machinery use by farmers. The objective of this study was to investigate how successful the institutions set up by government to provide agricultural mechanization services to farmers in Benue State have been. The study would also provide policy guidelines towards making these institutions to be more efficient.

2. RESEARCH METHODOLOGY

2.1 The Study Area

Benue State is one of the 36 States of Nigeria and located in the north central region of the country. The State lies between Longitude 7o^{O} 32’ and 9^{o} 56’ E and Latitudes 6^{o} 27’ and 8^{o} 11’ N. The State is situated mostly in the Southern Guinea Savanna and has a total land area of about 31,568Km^2 and a population of about 2.78 million people out of which 80 percent are engaged in agriculture (UAM, 1992). The State is bound by Plateau State to the North, Taraba State and the Republic of Cameroun to the East, Enugu and Cross River States to the South and Kogi State to the West.

The climate in Benue State is characterized by its, high variability in terms of amount and distribution of rainfall. The annual rainfall varied from 727mm in 1987 to 1244mm in 1989. The mean annual maximum temperature stands at 33.4^{o}C while the mean annual minimum is at 22.4^{o}C. The potential evapotranspiration is estimated at about 2602mm. The mean annual relative humidity stands at 40.7%. It is usually lowest (13.2%) in January and highest (74.4%) in July. Average sunshine hours and wind speed are 6.0 hours and 1.1m/sec respectively. The topography of Benue State is reported as being made up of extensive undulating plains of generally less than 150m above sea level. These plains slope irregularly towards Rivers Benue and Katsina-Ala and other major Rivers.

The State is covered by three different vegetation namely, the Southern Guinea Savanna, the forest Savanna Mosaic and the flood plain complexes. The State is predominantly covered by the Southern Guinea Savanna Vegetation (90%). The primary occupation of the Benue State people is farming with communities living on the banks of Rivers Benue and Katsina-Ala engaging in fishing as an important secondary occupation. The major crops of the area are yam, rice, cassava, maize and sorghum in that order of priority and hectarage. Other crops of lesser hectarage are soyabean, groundnut, bambara groundnut, sweet potatoes and cowpea. Orange trees in small orchards are common in the area. The commonest domestic animals raised by the people are poultry (local breeds) followed by goats and pigs, cattle rearing is virtually absent.

Benue State was initially created on February 3, 1976 consisting of Tiv speaking, Idoma-Igede speaking and Igala-Base speaking people. The new Benue State came into existence on August 27, 1991 with the creation of additional States when the Igala and Bassa areas were merged to form part of Kogi State. Benue State is administratively grouped into eighteen Local Government Areas namely, Ado. Apa, Buruku, Gboko, Guma, Gwer, Gwer-West, Katsina-Ala, Konshisha, Kwande, Makurdi, Ogbadibo, Oju, Okpokwu, Otukpo, Ukum, Ushongo and Vandeikya. The settlement patterns in the State vary from scattered to nucleated ones and there are large expanses of farmland in between their settlements.

Land acquisition and ownership is by inheritance (NALDA, 1992). This land tenure system does not augur well with large scale farming that favours mechanisation of agriculture.

2.2 Survey Instrument

Questionnaires were developed and distributed to agricultural institutions in the study area to collect the necessary data. The questionnaires were of three parts.

Part A consists of nine (9) questions seeking information on the general opinion of people on the level of mechanization of agriculture in Benue State, the relationships, linkages among various agricultural mechanization institutions, the type of services rendered by each of the organizations, the type of farmers that patronize the services, size of hectarage cultivated and size of livestock produced.

Part B which consists of 18 questions sought general information on the farm machinery/equipment available, their quantity, conditions and management systems, repairs, maintenance facilities available as well as spare parts, causes of breakdown and general problems, irrigation machinery available, source of irrigation water and level of adoption by farmers.

Part C consists of five (5) questions which sought information on the agricultural mechanization policy and the implementation, achievement, problems, and annual turnover of each of the organizations surveyed.

2.3 Data Collection and Analysis

The questionnaires were distributed to all agricultural institutions in Benue State in 2001. In each of the institutions visited, questionnaires were randomly distributed to officers of various ranks and positions which included Agricultural Engineers, Agricultural Officers, Field Supervisors, Technical Officers, Mechanical Superintendents, General Manager, Irrigation Officers, Livestock Supervisors, Mechanics and Tractor Operators. The questionnaires were circulated round the various operational centres of some institutions scattered across the State or at Headquarters of Local Government Area.

The retrieval of the questionnaires was successful as 90% of the total questionnaires distributed were returned for analysis. Information from the questionnaires were extracted and analysed using frequency method and simple percentages.

3. RESULTS AND DISCUSSION

3.1 Institutions Involved in Agricultural Mechanization in Benue State

3.1.1 *Federal Ministry of Agriculture and Natural Resources (FMANR)*

This consists of five different departments created by the Federal Ministry of Agriculture and Natural Resources to monitor different agricultural projects/activities in the State. They also provide such services as land clearing and storage of agricultural products. These departments are: Federal Department of Agriculture (FDA), Federal Livestock Department (FLD), Federal Forestry Department (FFD), Federal Department of Fisheries (FDF) and Agricultural Development Project (ADP).

The existence of these units in Benue State has had remarkable impacts. Some of the impacts so far made include improved agricultural land or soil fertility, controlled soil erosion, controlled pest and diseases of crops and animals as well as produced improved seeds and seedlings.

The major challenges of the units as identified from the field survey include inadequate or non-functional vehicles to supervise the numerous projects in the State, lack of funds, poor sustainability of projects and poor linkages to farmers.

3.1.2 *Lower Benue River Basin Development Authority (LBRBDA)*

This was among the nine(9) River Basin Development Authorities established in 1976 by the Federal Government of Nigeria. Initially they were charged with harnessing, management and exploitation of the country's water resources, providing feeder roads and operating pilot agro-industrial projects. The Authority has recorded numerous achievements since its inception. Some of its achievements include construction of 5 earth dams located at Doma, Naka, Guma, Bokkos and Kwa with capacities of 37.5mcm, 2.5mcm, 6.5mcm, 2.5mcm and 2.6mcm respectively; acquired and developed over 17,000ha of farmland for mechanization, developed irrigation infrastructures in some its farms, drilled about 50 boreholes for rural water supply. Constructed dyke for flood control at Katsina-ala, controlled erosion at Haipeng, Kuru, Ankpa, Ugwalowo and Ayingba. With the introduction of the Structural Adjustment Programme (SAP) by the government, the agricultural mandate of the RBDAs (including LBRBDA) were removed and they were asked to concentrate more on water resources development. This change in policy has led to abandoning of the acquired agricultural machines at the projects site while some have continued to wear in machinery sheds. The old tractors and implements procured by LBRBDA in 1980s have not been replaced. Thus, the major current activities of LBRBDA involve development of both surface and underground water resources through construction of dams, sinking of boreholes, provision of irrigation infrastructure and control of flood and soil erosion in the water sheds.

LBRBDA is faced with a host of problems in carrying out its mandates. These constraints include inadequate funding, untimely release of fund, frequent changes in government policy, obsolete machinery and equipment, lack of spare parts and maintenance, and inadequate qualified and trained staff for mechanized farming.

3.1.3 *Agricultural Development Company (ADC)*

The Agricultural Development Company (ADC) was established in 1977 by the Benue State Government. The company was under the State Ministry of Agriculture and Natural Resources and is charged with the responsibility of promoting agriculture in Benue State, production of crops and livestock, processing and marketing of agricultural products such as livestock feeds. Initially, the company was being adequately funded by the State government making its productivity to be at the peak. At that time, the company generated huge revenue through production of crops, eggs, meat, livestock feed and hatchery. The company was provided with agricultural machinery for its farm operations. The management and day to day running of the company was later handed over to private owners/individuals who maintained it. With this, the State government stopped providing grant and assistance to the company which depends on its outputs for its continuing existence.

The operations of the company began to dwindle since the government had hands-off from aiding it. There is total absence of farming operation as most of the farm machinery are not in good condition and could not be rehabilitated due to inadequate or lack of fund.

At present, the staff that used to be involved in mechanized farming operation have been dismissed, The company could only maintained few livestock and produce feed for up-keep of its livestock while excess is taken to market for sale.

3.1.4 *Benue State Agricultural and Rural Development Authority (BNARDA)*

This organization came into being via Benue State edict No. 7 of 1985. It is a World Bank Assisted Project which became effective in June, 1987. The major role of the project is to increase food production and income of small scale farmers in the State. This is to be effected by rationalizing the current activities of farmers through the re-organisation and commercialization of input distribution system and development of effective unified extension system. This is in relation to crop production, animal husbandry, agro forestry, fisheries and Fadama Development. The project has department of Engineering/Fadama which controls the mechanization aspects. Animals traction, Fadama Development and Agro-processing sub-component of farm mechanization component are recognized (according to the policy of the supervising body, FACU).

BNARDA has the responsibility of providing portable water to Benue rural populace, provide small scale irrigation scheme through Fadama, supply farmers with Agro-input such as fertilizers, pesticides, herbicide and farm machinery/equipment. Some of the achievements recorded so far by BNARDA include training of staff and farmers for animal traction, provision of dry season irrigation for dry season cropping through establishment of tubewells and washbore technique, construction of boreholes and shallow wells for rural water supply, development of seed farms for improved seeds, establishment of linkage with FACU and other agencies and rehabilitation of rural roads for easy transport of agricultural inputs and farm produce.

The targets of BNARDA are yet to be met because of certain draw back such as lack of proper funding for maintenance of broken down machinery, and procurement of much needed implement and equipment, inadequate and lack of trained personnel and technicians.

3.1.5 *Benue State Tractor Hiring Agency (BENTHA)*

This is a parastatal under Benue State Ministry of Agriculture and Natural Resources. It was established in 1988 with the major aim of boosting agricultural production in the State through provision of tractors and implements to farmers (tractorised farming). BENTHA has its tractors distributed across the State with its offices and operational centres located in all the Local Government Areas of the State. Farmers go to the nearest centre or unit to hire tractor. This helps widespread and easy hiring of tractors by farmers who could afford them. The Agency has field officers, maintenance officers, mechanics, tractor operators, revenue clerk in each of these units scattered all over the State. With this, tractor operation and maintenance, general supervision of Field Operation and other management services are carried out by the Agency. The farmers pay in return for the services rendered which may be tillage operation, trailing, hauling or harvesting etc. The price or rate is usually determined and set by the State Government. Usually a tractor is hired at rate of ₦10,000 per day and ₦3,000 per hectare for ploughing, harrowing and ridging.

The Agency has since its inception cultivated and planted over 21,000ha for Benue farmers which has greatly increased their income. The Agency has annual turnover of ₦1.9m, ₦1.4m and ₦1.6m for the year 1997, 1998 and 1999 respectively.

The major problem facing the Agency is that almost all the machinery are obsolete and need to be replaced. But no action has been taken to this effect. The use of old and broken-down tractors/machinery has hindered the effective implementation of policy of BENTHA.

3.1.6 *National Agricultural Land Development Authority (NALDA)*

The National Agricultural Land Development Authority (NALDA) was formally launched in 1992 with the following objectives (NALDA, 1993):

a. Provision of strategic public support for land development,
b. Promotion and support of optimal utilization of the nation's land resources for accelerated production of food and fibre,
c. Encouragement and support of economic size farm holdings and consolidation of fragmented holdings,
d. Encouragement of the evolution of economic-size village settlements,
e. Provision of gainful income and employment opportunities for rural Nigeria,
f. Expansion of productive capacity in agriculture and regaining of exports.

The operations of the Authority spread to most of the States of the Federation and came to Benue State in 1993. The agency has been involved in land clearing, seed bed preparation, supply of agro-input such as fertilizer, seeds for their participating farmers. The Ugamber and Mbagbe Communities in Konshisha LGA of Benue State donated the land for the NALDA farm project. The question now is how far this agency been able to meet the set objectives in Benue State. The only impact NALDA makes is that it makes use of few available tractors and implements to carry out seed bed preparation for interested farmers. As this study was going on (2001) there were indications that the Federal Government was planning to scrap the institution nationwide.

3.1.7 *University of Agriculture, Makurdi (UAM)*

The University of Agriculture, Makurdi was established by the Federal Military Government in January 1988. The University is one of the three Agricultural Universities already existing in the country to disseminate the new agricultural technologies. The general objective of the University of Agriculture, Makurdi is to put in place a properly integrated system of teaching, research and extension toward appropriate technology creation, transfer and utilization in Nigerian Agriculture as a whole and Benue State in particular (Idachaba, 1991).

Among the courses offered by the University is the Engineering courses under four different engineering programmes namely: Agricultural, Civil, Electrical/Electronic and Mechanical Engineering. The programmes aim at producing graduates of outstanding academic qualities with sound practical skills for the transformation of Nigeria's agriculture. The University offers ready services to farmers in areas of short term training, workshops, and extension. The average small-scale farmers are the beneficiaries of the University's research and extension programmes. Both Federal and State Ministries of Agriculture including other related agencies have linkages with the University of Agriculture, Makurdi for institutional and technical support.

3.1.8 *College of Agriculture, Yandev (CAY)*

The Akperan Orshi College of Agriculture, Yandev was first established by the colonial administration in 1926 as farm training centre. It was succeeded by the School of Agriculture established in 1973 by Benue-Plateau State Government. This later became College of Agriculture in 1983. It was finally changed to Akperan Orshi College of Agriculture after Tor Tiv the III in 1991. The mandate of the College is to provide courses of study, training and research in agriculture, and disciplines related to other complementary sciences allied to it. It produces intermediate and junior level manpower training and provides agricultural extension to farmers. The College turns out youths at both National and Higher National Diploma levels. The College is faced with the general constraint of inadequate funding, obsolete facilities and equipment and non-replacement of old and broken down machineries particularly in Agricultural Mechanisation Department.

3.2 Agricultural Machinery in Benue State

Tables 1 and 2 show the total number and condition of agricultural machinery/equipment in agricultural institutions in Benue State.

Table 1: Number of Machinery/Equipment in Agricultural Institutions in Benue State

S/N	EQUIPMENT	INSTITUTIONS						TOTAL
		FMU	BENTHA	LBRBDA	BNARDA	ADC	NALDA	
1.	Bulldozer	-	-	14	4	-	-	18
2.	Graders	-	-	10	1	-	-	11
3.	Pail Loaders	-	-	1	3	-	-	4
4.	Tipping Trailers	-	-	10	4	1	-	15
5.	Tractors	-	146	37	8	1	6	198
6.	Ploughs	-	146	14	5	2	5	172
7.	Harrows	-	146	7	5	1	4	163
8.	Ridgers	-	146	4	4	-	-	154
9.	Planters/Drills	-	-	-	8	1	-	9

10.	Animal Drawn Implement	-	-	-	50	-	-	50
11.	Cultivators	-	-	-	-	-	-	-
12.	Fertilizer Broadcaster	-	-	-	-	-	-	-
13.	Knapsack Sprayers	5	-	-	5	3	3	16
14.	Thresher/Shellers	-	10	-	8	2	-	20
15.	Combine Harvesters	-	-	6	1	2	-	9
16.	Feed Mixers	-	-	-	-	2	-	2
17.	Silo Bins	10	-	-	-	3	-	13
18.	Rice Reaper	-	10	-	-	-	-	10
19.	Dryers	-	-	-	-	1	-	1
	Total	**15**	**604**	**103**	**106**	**19**	**18**	**865**

BENTHA has highest number of tractors and tractor implements while highest number of land clearing equipment are owned by LBRBDA. Only BNARDA has animal draw implement. FMU has least number of agricultural machinery/equipment.

3.3 Breakdown of Agricultural Machinery

3.3.1 *Frequency of Breakdown*

Only 16.7% of the agricultural institutions do not have cases of frequent breakdown while 83.3% experience cases of frequent breakdown during operation. These high cases of frequent breakdown may be attributable to poor maintenance and inadequate shed for machinery storage.

Table 2: Condition of Agricultural Machinery (Number Serviceable/Unserviceable)

S/N	Equipment	Serviceable						Unserviceable					
		FMU	BENTHA	LBRBDA	BNARDA	ADC	NALDA	FMU	BENTHA	LBRBDA	BNARDA	ADC	NALDA
1.	Bulldozer	-	-	9	3	-	-	-	-	5	1	-	-
2.	Graders	-	-	8	1	-	-	-	-	2	-	-	-
3.	Fail Loaders	-	-	1	1	-	-	-	-	-	2	-	-
4.	Tipping Trailers	-	-	10	-	1	-	-	-	-	4	-	-
5.	Tractors	-	46	37	4	1	5	-	100	-	1	-	1
6.	Ploughs	-	33	14	4	2	4	-	113	-	1	-	1
7.	Harrows	-	33	7	2	1	3	-	113	-	-	-	1
8.	Ridgers	-	33	4	4	-	-	-	113	-	-	-	-
9.	Planters/Drills	-	-	-	8	1	-	-	-	-	-	-	-
10.	Animal Drawn Implement	-	-	-	40	-	-	-	-	-	10	-	-
11.	Cultivators	-	-	-	-	-	-	-	-	-	-	-	-
12.	Knapsack Sprayers	-	-	-	5	3	-	-	-	-	-	-	3
13.	Combine Harvesters	-	-	6	-	2	-	-	-	-	1	-	-
14.	Threshers/Shellers	-	10	-	7	2	-	-	-	-	1	-	-
15.	Feed Mixers	-	-	-	-	2	-	-	-	-	-	-	-
16.	Silo Bins	10	-	-	-	3	-	-	-	-	-	-	-
17.	Rice Reaper	-	10	-	-	-	-	-	-	-	-	-	-
18.	Dryers	-	-	-	-	1	-	-	-	-	-	-	-

From Table 2 it is observed that most of the tractors and implements in BENTHA need to be replaced due to their unserviceable condition. The high number of unserviceable agricultural machinery is partly due to unavailability of spare parts, negative attitude of owners of the machinery to maintenance culture and lack of funds.

BNARDA has about 600 pumps for irrigation water lifting and distribution, and provided 750 tubewells/washbores in various locations of Benue State. LBRBDA has built 50 dams, sprinklers, canal systems and pumps for irrigation water supplies and these are distributed all over her areas of jurisdictions.

Irrigation practice is therefore gaining ground in Benue State through the operations of Fadama; though the level of adoption by Benue farmers can still be described as being low.

Table 3 shows the distribution of tractors by make in the Agricultural Institutions. It is observed from Table 3 that Steyr tractor are extensively used followed by Fiat tractors. Steyr tractors are dominant in the agricultural institutions probably due to the fact that they are assembled locally.

Table 3: Distribution of Tractors by Make

MAKE	INSTITUTION					PERCENTAGE (%)
	BENTHA	LBRBDA	BNARDA	ADC	NALDA	
Steyr	78	10	3	-	6	49
Fiat	51	22	3	-	-	38.4
Ford	-	-	-	-	-	-
Massey Ferguson	12	5	1	1	-	9.6
Zetor	5	-	-	-	-	2.5
Iseki	-	-	1	-	-	0.5

3.3.2 *Victims of Breakdown*

Tables 4 and 5 show the victims of frequent breakdown and the causes of such breakdown respectively. The frequency rate of score based on 0 – 10 was used to analyse this.

In the case of frequent breakdown the score range 0 – 4, 5 – 7 and 8 – 10 are described as being low, high and very high respectively. From Table 4, it is clearly seen that victims of frequent breakdown are very high with tractors, plough and harrows.

Table 4: Victims of Frequent Breakdown on 0 – 10 Basis

S/N	Machinery Type	Total Frequency Rate of Score		
		Low (0 – 4)	High (5 – 7)	Very High (8 – 10)
1.	Bulldozers	6	3	-
2.	Tractors	5	2	5
3.	Ploughs	7	1	5
4.	Harrows	6	2	5
5.	Planters	2	2	-
6.	Harvesters	2	3	4

Table 5: Causes of Machinery Breakdown, Frequency Rating Based on 0 – 10

S/N	Causes of Breakdown	Total Frequency Rate of Score		
		Not Likely (0 – 4)	**Likely (5 – 7)**	**Very Likely (8 – 10)**
1.	Careless Operators	11	-	2
2.	Over Usage	4	7	2
3.	Obsolete Machinery	4	2	7
4.	Poor Maintenance Facilities	7	2	5
5.	Poor Maintenance Skill	10	1	1
6.	Lack of Genuine Spare Parts	3	6	4
7.	Poor Storage (No Shed)	4	4	5
8.	Environment (weather)	9	1	3

3.3.3 Causes of Breakdown

The causes of machinery breakdown are mostly due to obsolete machinery, poor maintenance facilities, poor storage and lack of genuine spare parts in that order. Factors such as careless operator, maintenance skills, and usage are less likely to cause breakdown of machinery, obsolete machinery is therefore the commonest problem in all the agricultural institutions in Benue State. This means that substantial part of rehabilitation fund would be spent on purchase of new equipment. Inadequate maintenance facility is also another significant factor.

3.4 Facilities for Use and Maintenance of Agricultural Machinery

3.4.1 *Machinery Storage*

Only 16.7% of the Agricultural Institutions surveyed have enough sheds and 83.3% do not have shelters for all the machinery in their possession. These institutions that do not have enough shed for their machinery experience cases of frequent breakdown of machinery.

3.4.2 *Operators*

About 33% of the Agricultural Institutions do not have enough trained or qualified operators while 67% have sufficient of them. This lack of qualified operators always leads to minor problems of machinery that could be rectified by an operator developing into a major one.

3.4.3 *Spare Parts*

Spare parts are most frequently sourced from local dealers and are generally available with difficulty. Other maintenance facilities are also lacking. This unfortunate situation has resulted in a high number of unserviceable agricultural machinery being found in the agricultural institution.

3.4.4 *Maintenance Workshops*

About 50% of the Agricultural Institutions have standard functional and adequately equipped workshop for carrying out machinery repairs while 50% do not have.

3.5 Services Rendered by Agricultural Institutions

Table 6 shows the various mechanization services as rendered by different agricultural institutions in the State and Table 7 shows the average yearly hectarage cultivated as well as number of livestock owned by these various agricultural institutions.

Table 6: Names and Number of Institutions offering various Mechanisation Services

S/N	Mechanisation Service	Institutions
1.	Land Operation	LBRBDA/BNARDA
2.	Tillage Operation	LBRBDA/BENTHA/BNARDA/NALDA
3.	Planting	LBRBDA/BENTHA
4.	Fertilizer Application	
5.	Spraying	BNARDA/BENTHA
6.	Harvesting	LBRBDA/BENTHA/BNARDA
7.	Processing	ADC/BENTHA/BNARDA
8.	Storage	FDA/ADC
9.	Irrigation	LBRBDA/BNARDA

Peasant farmers are the most beneficiary of these services. They are the target group of the most of the agricultural institutions whose objective are towards improving their productive capacity. This, generally, is to increase agricultural production in Nigeria since they constitute the greatest percentage of the Nigeria’s farming population.

Table 7: Average Yearly Size of farm Cultivated and Number of Livestock in various Agricultural Institutions in Benue State

Institution	Average size, ha	Number of Livestock				
		Poultry	Pigs	Goats	Cattle	Rabbits
BENTHA	5,000	-	-	-	-	-
LBRBDA	10,000	-	-	-	-	-
BNARDA	1,000	10,000	1,000	-	-	1,000
ADC	-	10,000	<500	<500	<200	<200
NALDA	1,000	-	-	-	-	-

Table 7 indicates that only ADC and BNARDA engage in livestock production and ADC is no longer involved in any form of farm operations. Total average yearly size of farm cultivated by all the Agricultural Institutions involved is 17,000ha. This is very low and indicates that most farmland in the State is still being cultivated by traditional method. This may be attributed to the inadequate number of farm machinery being available at these institutions.

3.6 Policy Implications of the Study

1. Most agricultural institutions in the State have mechanization component in them but are not fully operational. There is the need to make these components to be more effective through appropriate programmes towards providing services to the farmers in a timely manner.
2. Most of the machinery/equipment at the disposal of the agricultural institutions in Benue State are obsolete and unserviceable. There is the need for a sustained policy towards continuous acquisition of new machines every year and preventive maintenance of existing ones.
3. Old age, poor storage, lack of genuine spare parts and maintenance facility have been found to be the major cause of machinery breakdown in the agricultural institutions in the State.

4. It is observed that the services of these institutions are not being patronized adequately by peasant farmers. This is because of the high cost of hiring tractors which is ₦10,000.00 per day from BENTHA and other agencies. About ₦30,000.00 per ha is charged for each farm operation such as ploughing, harrowing and ridging.
5. Inadequate funding of these institutions has resulted in their abysmally low performance.

It is therefore recommended that:

i. No new agricultural institution should be created or established in the state until the existing ones are properly funded and managed.
ii. The existing ones should be activated, rehabilitated and adequately funded to enable them meet up the set objectives.
iii. A programme of servicing and maintenance of agricultural machinery operated by these institutions be considered.
iv. All the obsolete machinery should be scrapped and replaced with new ones.
v. Benue State Government should set up a farm machinery/spare parts sales depot in the State to cater for the immediate needs of these institutions.
vi. Maintenance facilities and machinery sheds should be adequately provided in these institutions.
vii. Agricultural Engineers should head the various mechanization departments so as to properly direct the activities of the institutions towards mechanization of agriculture in Benue State.
viii. Agricultural mechanization policy of these institutions must be clearly defined towards improving the level of agricultural production of rural and peasant farmers in the State.
ix. A state summit on mechanization is advocated. This summit will bring stakeholders together to come up with a new policy on mechanization in the state. The stakeholders include state owned agricultural institutions, federal owned agricultural institutions, non-governmental organizations, development partners, large scale farms, commodity associations, machinery dealers and the small scale farmers themselves.

4. CONCLUSIONS

The study has shown that in Benue state there are at least 11 government owned Agricultural Institutions providing mechanization input services to small scale farmers in the state. In terms of numbers, this was found to be adequate. Using relevant indices, it was found that: the number of agricultural machinery available is inadequate to serve all the farmers, the facilities for optimum operation and maintenance of the machines owned by these institutions are inadequate and hence the institutions have not able to provide optimum service to the farmers. For these institutions to succeed in providing optimum services to farmers a number of reforms have to be implemented. These include adequate funding, acquisition of more machinery, training of operators and mechanics, provision of more maintenance workshops, spare parts and machinery sheds. A new policy on adequate provision of mechanization inputs by these institutions should be formulated to ensure synergy of operations and optimum performance. In this respect, a state summit on mechanization of agriculture is advocated.

REFERENCES

Akinola, A. A. 1987. Government Tractor Hire Service Scheme as a Tractorisation Policy in Africa: The Nigerian Experience. Agricultural Administration and Extension 25 (2): 63 – 71.

Ani, A.O. and Onwualu, A. P. 2002, Agricultural Mechanization: a pre-requisite for food security in West Africa. Proceedings, International Conference on Food Security, WASAE, Abuja. Pg 252-274.

Anazodo, U. G. N., Abimbola, T. O. and Dairo, J. A. 1986. Agricultural Machinery Inventory. Type and Condition in Nigeria (1975 – 1985). A National Investigation Survey Report. FDA, Lagos.

Anazodo, U. G. N., Abimbola, T. O. and Dairo, J. A. 1987. Agricultural Machinery Use in Nigeria. The Experience of a Decade (1975 – 1985). Proc. NSAE 11:406 – 429.

Anazodo, U. G. N., Abimbola, T. O. and Dairo, J. A. 1989. Perspective Plan for Agricultural Development in Nigeria (1989 – 2004). Agricultural Mechanisation Study Report, FACU, Ibadan.

Aneke, D. O., Ayoola, G. B. 1993. Farm Tractor Utilisation and Distribution in Benue and Plateau State of Nigeria. NAMA Newsletter. Vol. I No. 3. Dec. 1993 pp 51 – 56.

Anyanwu, A. C., Anyanwu, B. O., and Anyanwu, V. A. 1982. A Textbook of Agriculture for School Certificate (4th Edition). African Pub. Ltd. Singapore. Pp 24 – 30.

Crossley, P. and Kilgour, J. 1983. The Economic of Small Farm Mechanisation.

Dauda, S. M., Agidi, G. and Shotunde, M. A. 2010. Agricultural Tractor Ownership and Off Season Utilisation in Ogun State.

FAO, 1980. Farm Management Research for Small Farmer Development FAO Agricultural Services Bulleting No. 41, 58pp. Food and Agriculture Organisation (FAO), Rome.

Gefund, J. O. and Otchere, E. O. 1989. Draught Animal Power Research and Development in Nigeria. Proc. Of the First National Workshop on Draught Animal Power Research and Development in Nigeria. NAPRI. ABU, Zaria, Nigeria.

Haque, M. A., Bobboi, U. and Arku, A. Y. 2003. A Comparative Analysis of Tractor Use in Borno State of Nigeria, Arid Zone Journal of Engineering Technology and Environment. 3: 22 – 26.

Idachaba, F. S. 1991. Calendar. University of Agriculture, Makurdi (1988 – 91). Ige, M. T. (1979). Appropriate Mechanisation System for Agriculture

Irtwinge, S. V. and Akubuo, S. V. 1990. Animal Draught Technology in Nigeria Small Farms: A challenge in the 1990s. Paper Presented at the 14th Anual Conference of the Nigeria Society of Agricultural Engineers (NSAE). University of Agriculture, Makurdi.

Jekayinfa, S. O., Adebiyi, U. A., Waheed, M. A., and Owolabi, O. O. 2005. Appraisal of Farm Tractor Maintenance Practices and Costs in Nigeria. Journal of Quality in Maintenance Engineering. 11 (2): 152 – 168.

Jones, T. O. 1984. Future Technologies and Systems for Agricultural Equipment Agricultural Electronics – 1993 and Beyond. Vol. 1. Field Equipment Irrigation and Drainage. ASAE Pub. 8 – 84. ASAE St. Joseph MI 905 – 965, pp. 9 – 21.

Kaul. R. N. 1990. Agricultural Mechanisation in Africa: An Overview. In Comsec (1990). Report of an Expert Consultation on Agricultural Mechanisation in Commonwealth Africa. Commonwealth Secretariat, London.

Komolafe, M. F., Adegbola, A. A., Are, L. A. and Ashaye, T. L. 1980. Agricultural Science for West African Schools and Colleges (2nd Edition) Oxford University Press, Ibadan, Nigeria.

Kolawole, M. I. 1972. Economic Aspects of Tractor Contracting Operations in Western Nigeria. Journal of Agricultural Engineering Res. 17 (4): 289 – 294.

Mrema, G. C. and Mrema, M. Y. 1993. Draught Animal Technology and Agricultural Mechanisation in Africa. NAMA Newsletter 1 (2); 12 – 33.

Mrema, G. C. and Odigboh, E. U. 1993. Agricultural Development and Mechanisation in Africa: Policy Perspectives. Network for Agricultural Mechanisation in Africa (NAMA) Newsletter I (3); 11 – 50.

Musa, H. L. 1978. Donkey Mechanisation: A Supplementary Power Source for Agricultural Production. Paper Presented at the Conference of the Nigeria Society of Agricultural Engineers, August 28 – 31, 1978, ABU, Zaria.

Musa, H. L. 1979. Traditional Tillage Operations and Development and Use of Drawn Equipment Proc., Appropriate Tillage Workshop. Institute for Agricultural Research, Zaria.

Musa, H. L. 1988. Animal Power Utilisation in Nigeria. Paper Presented at the Pastoralism Conference, National Animal Research Institute, ABU, Zaria.

Munzinger, P. 1982. Animal Traction in Africa German Agency for Technical Cooperation (GTZ), West Germany.

NALDA, 1992. Design and Formulation of State Agricultural Projects: Information and Instructions to Consultants.

NALDA, 1993. National Agricultural Land Development Authority (NALDA). Blue Print NALDA. The Presidency, Abuja.

Nkakini, S. O. and Eguruze, B. V. 2009. Farm Tractor Utilisation for Various Agricultural Operations. Journal of Agricultural Engineering and Technology, 17 (2): 44 – 56.

Odey, S. O., Adinya, I. D., Oniah, M. O., and Nsor, M. E. 2008. Effective Tractor Utilisation for Agricultural Mechanisation in Central Cross River State, Nigeria. Global Journal of Engineering Res. 7 (1): 37 – 42.

Odigboh, E. U. 1990. Engineering Challenges and Strategies for the 1990's Agricultural Mechanisation Issues and Options Invited Paper in Proc. of NSE Annual Conference, pp. 145 – 154. Hill Station Hotel, Jos 12 – 15 Dec., 1990.

Odigboh, E. U. 1991. Continuing Controversies in Tillage Mechanisation in Nigeria. Journal of Agric. Science Technology 1 (1) 41 – 49.

Odigboh, E. U. and Onwualu, A. P. 1994. Mechanisation of Agricultural in Nigeria: A Critical Appraisal. JAT 2 (2), 1 – 58.

Onwualu, A. P., Akubuo, C.O. and Ahaneku, I.E. 2006. Fundamentals of Engineering for Agriculture. SNAAP Press and Publishers, Enugu. ISBN 978-036-133-2 397 pgs.

Onwualu, A. P. 1996. Sustainable Strategies for Prevention of Premature Failure of Agricultural Machinery and Tools in a Distressed Economy. Proceedings, National Workshop on Appropriate Agricultural Mechanization Under the UNDP Agricultural Mechanization Sub-Programme. pp 222-234.

Onwualu, A. P. 1998. Strategies for rehabilitation and maintenance of unserviceable agricultural tractors and implements in Nigeria. Proceedings, National Training Workshop, AMMOTRAC, Akure. pp 56-73.

UAM, 1992. Design and Formulation of Mbagbe/Ugambe Small Holder Agricultural Project in Benue State.

DEVELOPMENT OF AN AUTOMATIC FISH FEEDER

C.C. Anyadike[1], M. Eze[1] and G.N. Ajah[2]
[1]Department of Agric and Bioresource Engineering, University of Nigeria, Nsukka, Nigeria.
chi4jessy@yahoo.com
[2]Department of Electronic Engineering, University of Nigeria, Nsukka, Nigeria.
ajah.genesis@gmail.com

ABSTRACT

This paper gives a concise and comprehensive description on the design and construction of a simple automatic fish feeder. The design was realized using inexpensive locally sourced materials. The system was grouped into two major units; the construction of the feeder and automating of the feeder. The feeder discharges pelleted fish feed into a pond or tank at specified time interval with minimal human intervention. The programmed time was 2:1 (2mins to open valve and 1min to close valve).The timing intervals could be reset by the use of the push buttons while the display unit shows the set time. Two different time intervals were set, first one determines the time of opening and discharging feed while the second determines how long the valve stays closed. The feeder discharges 240g of pelleted feed in 120seconds. The design eliminates human error to a very reasonable extent, protect the feed and ensure that feed is supplied to the aquatic environment at desired times and reduces operational cost of manual feeding.

KEYWORDS: Fish feed, aquaculture, automatic feeder.

1. INTRODUCTION

Fish has always been an important part of the diet of Africans; but until recently, fish has been largely harvested from the wild. Total fish output in African nations, such as Nigeria and Egypt, continues to grow at accelerating rates as aquaculture (fish cultivation) become part of many rural agricultural enterprises. This has been encouraged by expansions of *NGO* developmental activities in aquaculture, improved aquaculture production technologies, recognition of over exploitation of natural fisheries, and increased nutritional requirements of rapidly growing populations. These factors combine to make aquaculture an economically attractive agricultural production alternative in sub-Saharan Africa. According to Quansah *et al* (2007) aquaculture provides economic opportunities, which include contribution to food security and poverty alleviation through employment and income generation.

Fish requires high quality nutritionally balanced diet for their growth and attainment of market size within the shortest possible time. Fish feed is therefore very crucial to the development and sustainability of aquaculture, especially in the rural areas (Gabriel *et al*., 2007). Fish feed represents more than 50% of the variable costs in growing fish, feeding is therefore the largest operational cost of growing fish in aquaculture. Labour and feeding equipment contribute to the total cost of feeding aquacultural crop; hence the choice of feeding equipment which depends on factors such as type and life stage of fish, type and size of feed, size of the operation, available labor and the type of culture system need careful analysis to ensure successful and profitable fish culture. Delivering the feed to fish at the right time, in the correct form, and in the right amount is necessary for optimal growth and profitability.

The rapid development of aquaculture in recent years has led to the development of new techniques and methodologies. These have intensified all stages of the production process. At the same time, the need for a new approach to farm management including automation of several production steps had became apparent (Lee, 2000). Several examples of computer based systems used in aquaculture already exist for monitoring of abiotic parameters (Lee, 1995), feeding in cages (Kadri and Blyth, 1997), fish sorting (Zion *et al*., 2000), and for simulation and decision support (Ernst *et al*., 2000). On the other hand, research of the biological bases of aquaculture showed that success of larval or rearing depends upon meeting the corresponding metabolic demands of the fingerling at different stages of their development (Guyot de la Hardrouye`re, 1994). At the beginning of exogenous feeding, foraging activity is limited by swimming capacity which is not fully developed (Kentouri, 1985) and hence food availability is critical for survival. Continually meeting the metabolic demand is crucial for fish larvae, which have a higher metabolism and require a long photophase with continuous feeding (Papandroulakis *et al*., 2001a). This cannot be achieved using the classic methods of feed administration by personnel due to human and logistic limitations.

Although several automated feeding systems exist in developed countries, none have been developed for larval rearing in Nigeria. The cost of importing some of these machines into the country has limited its use in our communities.

Hence the objective of this work is to design and fabricate an automatic fish feeder that will be suitable for small scale aquacultural production. The feeder which is aimed at delivery feed at the required time and desired quantity will minimize feed losses, and drudgery involved in manual feeding.

2. MATERIALS AND METHODS

2.1 Major Components

In meeting with the objectives of this work, the components used in fabricating the automatic fish feeder were cheap and locally sourced. The major components were as follow:

Feedbin: This is the first section of the system designed to hold the fish feed, protect it from degradation due to moisture and other environmental factors.

Discharge chute: This is a channel with steep slope for easy conveyance of feed from the feedbin to the discharge valve.

Discharge valve: This is a section of the system known as the Gate. It is automated and opens at timed intervals in order to meter fish feed into pond. The duration and frequency of opening and closing of this valve determines the amount of feed discharged from the chute.

Electronic circuitry: this is where automation takes place. The circuit comprises of electronic elements put together to achieve the required design specifications. Amongst other components, is the micro-controller; the “decision maker” of the unit. It controls the timing of the valve (opening and closing of the valve) by processing a set of instructions.

Power: The system can be powered by means of direct current (dc), which would employ the use of batteries or by alternating current (ac) which would mean powering the system directly from the mains. For this work, mobility and versatility were taken into consideration hence, the choice of dc. This makes the system battery operated.

2.2 Design of the Automatic Fish Feeder

A lot of factors were considered in the design of the system. These include:

Feed metering: This is the primary design consideration; the system is supposed to be able to discharge a particular quantity of feed at specific times. There is provision for increasing and decreasing feeding rate depending on size of pond/fish.
Availability of materials: the components were sourced from materials that can be found locally.

Operating environment: the system is such that it has to be used outdoors, hence it has been designed to function under sunny, rainy and humid conditions without causing any damage to its content (feed).

Ease of operation: the machine is easy to use, taking consideration of the technical status of the users.
Source of power: Since it is outdoor portable equipment, it requires a mobile power source.

Other factors considered include: ease of maintenance, efficiency, and resilience of the equipment.

2.3 Design Parameters/Analysis

a. Determination of Angle of Repose for Feed Material

There are two angles of repose:
Static angle: this is the angle of friction taken up by a granular solid about to slide upon itself. Dynamic angle: angle of friction that arises in all cases where the bulk of the material is in motion (i.e. movement of solid discharging from a bin).

The angle of repose (56^o) adapted for this work is the dynamic angle of repose.

b. Determination of Bulk Density of Feed Material

Weight of feed was determined using an electronic weighing balance. Volume of feed material was obtained with a measuring flask and the density was 0.635kg/m^3

c. Feed hopper Design

The hopper can be of any size as far as the base fits into the rim of the discharge chute. The size largely depends on the quantity of feed that should be adequately held, as desired. In this paper, the feed hopper of 0.216m^3employed was made of plastic with a lid (to protect its content).

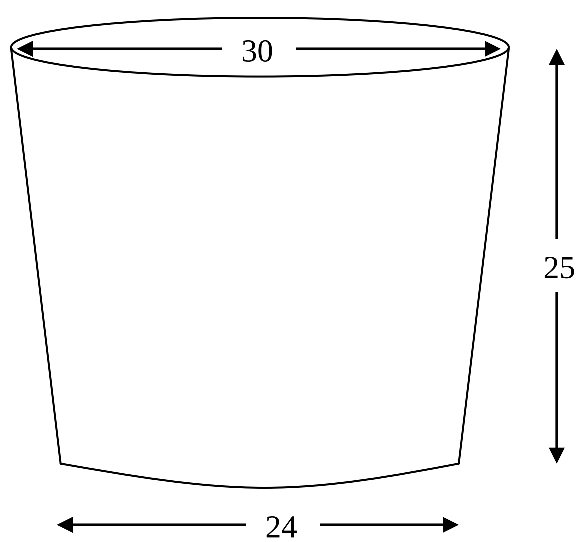


Fig 1: Feed hopper (all measurements in cm, diagram drawn to scale)

d. **Discharge Chute**

This is designed from a gauge 18 galvanized metal sheet to prevent rust - and wear conditions. It also contributes to the entire weight of the system in order to prevent it from being upturned easily by wind. The design of the chute was done, taking into consideration the angle of repose with +5 clearance. This will facilitate easy flow of the feed.

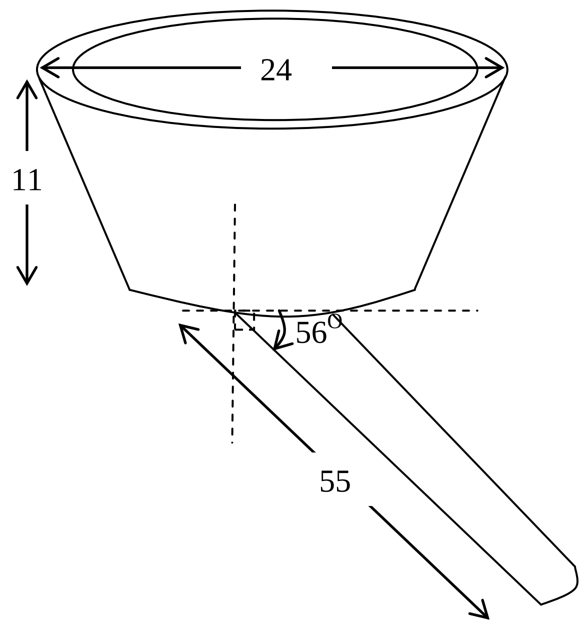


Fig 2: Discharge chute (all measurements in cm)

e. Circuit Design

The circuit was designed using simple and available electronic components available in the open market. Basic electronic components used are:

1. Micro-controller
2. 7-segment display
3. 5V regulator
4. 2MHz crystal oscillator
5. 12V relay
6. S474S14 Schnutt Inverter
7. Transistors (C945)
8. Light Emitting Diodes (LEDs)
9. Resistors
10. Printed Circuit Board (PCB)
11. Vero board
12. Push buttons
13. Capacitors
14. Diodes

There are three basic units in the circuit:

- Power supply unit: supplies the unit with power to perform its electronic functions.
- Processing unit: this is where all the decisions and instructions are processed which automates the gate.
- Load unit: This is the output unit. There is a digital display that shows a timer counter, and the load which is the automatic valve of the valve.

The block diagram below illustrates the electronic system.

Fig. 3: Block diagram of circuit.

Power Supply Unit (PSU)

The function of power supply unit is to convert the power provided from the mains into useable power for the electronic components in the circuit. This type of power supply unit is the regulated linear supply. The advantage of this type of supply is that it is cheap, simple and effective. The output voltage has negligible ripple, very small load regulation, and high reliability, thus making it an ideal choice for use in this system. The power supply unit was designed to deliver up to 12V ± 0.25V to run the circuit efficiently. The circuit diagram is as shown on figure 4.

Components used in designing the power supply unit are listed below.

- 240V – 25V step down transformer: steps down voltage from 240v to 25v
- Bridge Rectifier:: turns AC into pulsating DC
- Filter Capacitors: smooth the output reducing its ripples
- 7805 regulator: produces a nearly constant output voltage

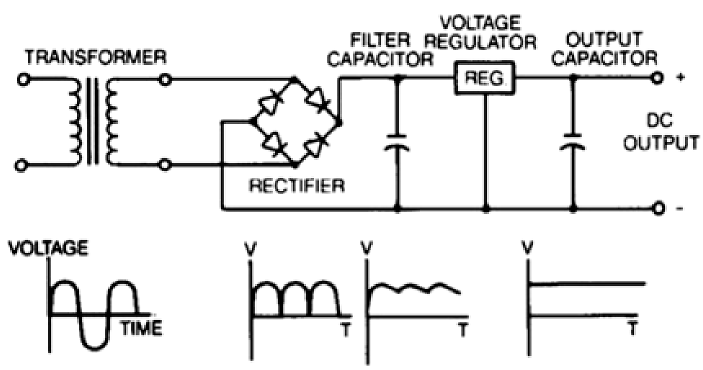


Fig 4: Circuit diagram of power supply unit

The Processing Unit

The processing unit is made up of an electronic circuitry with the Intel 8051 chip as the processor. The 8051 micro-controller was the suitable choice of processor for this system due to it availability and required features. The Features included in 8051 based microcontrollers include built-in reset timers with brown-out detection, on-chip oscillators, self-programmable Flash ROM program memory, bootloader code in ROM, EEPROM non-volatile data storage, extra counters and timers, in-circuit debugging facilities, more interrupt sources, and extra power saving modes, amongst others. This means that the micro-controller can be programmed to count time, reset time and can also be reprogrammable.

The 8051 programme (see Figure 5) was written in C language. The instructions programmed into the chip, was for time delay, to achieve a 2:1 open and close time interval i.e. 2 minutes to open discharge valve and 1 minute to close. The chip processes the instructions and sends it to the actuators in form of electric signals which opens and closes the valve.

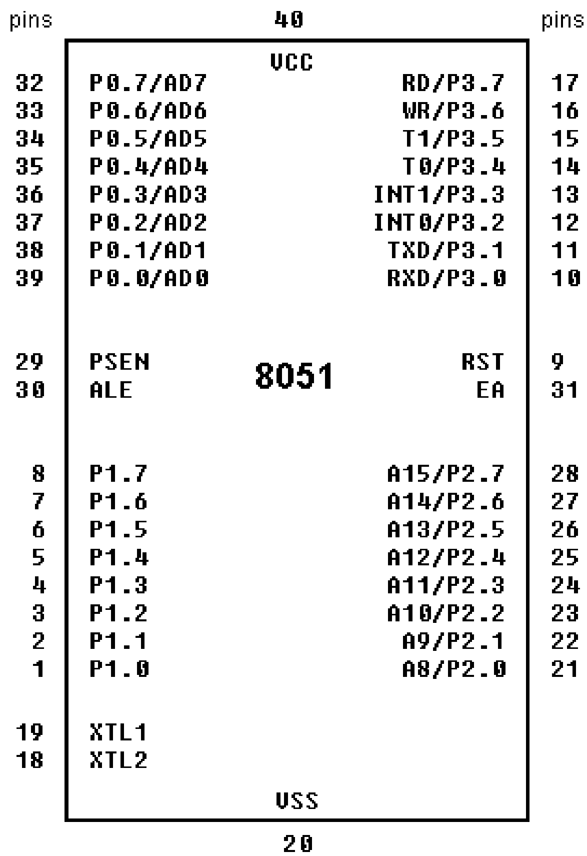


Fig. 5: Diagram of 8051 microcontroller showing all pin-outs

The valve door is controlled by an actuator that convert electronic signals to electromagnetic. Hence, when the microcontroller sends electric signals to open the valve door, the actuator demagnetizes thereby releasing valve door. When signals are sent to close valve door, the actuator magnetizes and attracts the door, closing it.

2.4 Description and Operation

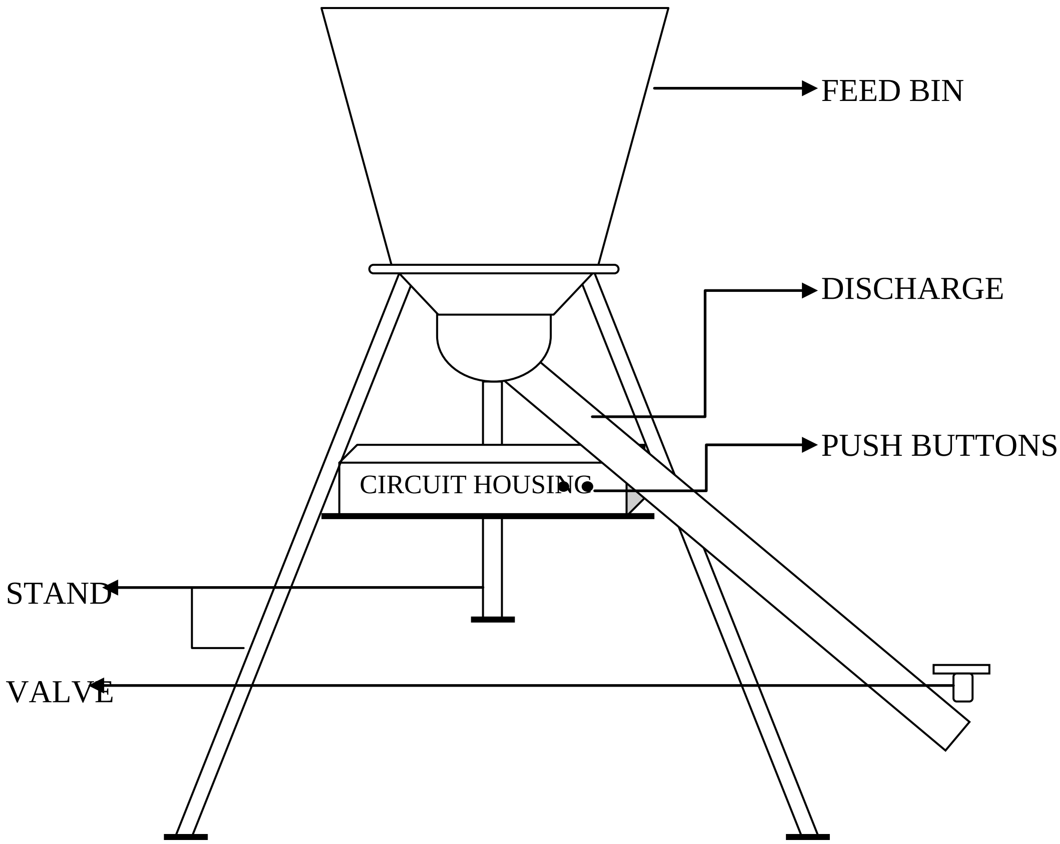


Fig 6: Diagram of the automatic fish feeder

Above is a well labeled diagram description of the system.

- The hopper is filled with feed as desired
- The system is powered on
- Once powered, the system discharges feed according to the previously programmed time. The timing intervals could be reset by the use of the push buttons while the display unit shows the set time. Two different time intervals were set, first one determines the time of opening and discharging feed while the second determines how long the valve stays closed.
- The system continues working until the time interval is altered or the system is shut down.

3. TESTS AND RESULTS

After the assembly and coupling of the automatic fish feeder, it was first tested without any feed material to determine the workability. To determine the quantity of feed delivered at different time interval of times, apparatus used was conical flask, stop watch and a weighing device.

Procedure:

The hopper was filled with pelleted fish feed and the automatic fish feeder was powered. Using the buttons, the time was set to 2:1 (2mins to open valve and 1min to close valve). The stop watch was at same time activated.

The table below shows the discharge rate at different time intervals.

Table 3.1. Time and Quantity of Feed Discharged

S/N	Intervals of opening (sec)	Duration of opening (sec)	Quantity of feed discharged (g)
1	120	60	240
2	60	30	128
3	30	15	89
4	15	8	40
5	8	4	20

4. CONCLUSION

Based on the results of the performance, the following conclusions were drawn: the machine performs adequately for discharging the pelleted fish feed, the machine efficiency is comparable to what is obtainable in other similar designs. The throughput of the feeder should be increased so that larger quantities can be discharged per unit time so as to be used for commercial ponds. The modified machine should be commercialized so as to increase yield and reduce drudgery involved in manual fish feeding.

REFERENCES

Ernst D. H., J. P. Bolte and S. S. Nath. 2000. AquaFarm: simulation and decision support for aquaculture facility design and management planning. Aquacultural Engineering 23, 121–179

Gabriel U.U., O. A Akinrotimi, D. O. Bekibele, D. N. Onunkwo and P. E. Anyanwu 2007. Locally produced fish feed: potentials for aquaculture development in subsaharan Africa. African Journal of Agricultural Research Vol. 2(7), pp. 287-295.

Guyot de la Hardrouye`re, E., 1994. Passage de l’endotrophie a`l’exotrophie chez la larve de daurade, Sparus aurata, soumise a` diffe´rents re´gimes alimentaires: e´volution du complexe vitellin, du foie et de l’intestin. The`se de Doctorat, Universite´ des Sciences et Techniques du Languedoc, Montpellier II, p.126.

Kadri S., Blyth, P.J., 1997. The Aquasmart adaptive feeding system: a tool for studying the feeding patterns of cultured fish and optimising fish farm production. In: Houlihan, D., Kiessling, A., Boujard, T. (Eds.), Voluntary Food Intake in Fish, p. 15.

Kentouri M., 1985. Comportement larvaire de 4 Sparides me´diterrane´ens en e´levage: Sparus aurata, Diplodus sargus, Lithognathus mormyrus, Puntazzo puntazzo (Poissons te´le´oste´ens). The`se de doctorat e`s Sciences, Universite´ de Sciences et Techniques du Languedoc, Montpellier, p. 492.

Lee P. G. 1995. A review of automated control systems for aquaculture and design criteria for their implementation. Aquacultural Engineering 14, 205–227.

Lee P. G., 2000. Process control and artificial intelligence software for aquaculture. Aquacultural Engineering 23, 13–36.

Papandroulakis N., P. Divanach, M. Kentouri. 2001. Enhanced biological performance of intensive sea bream (Sparus aurata) larviculture in the presence of phytoplankton with long photophase. Aquaculture 204, 45–63.

Quansah E. J, G.L. Rochon, K. Kwamena, Q. P.U.S. Amisah, M. Muchiri, C. Ngugi. 2007 Remote Sensing Applications for Sustainable Aquaculture in Africa 1-4244-1212-9/07/$25.00 ©2007 IEEE page 1255 – 1259

Zion B., A. Shklyar, I. Karplus. 2000. In vivo fish sorting by computer vision. Aquacultural Engineering 22, 165–179.

ELECTRO PERMEABILITY OF ALFALFA LEAF

S. I. Oluka[1], T. Gachovska[2], M O. Ngadi[2] and R. S. V. Raghavan[2]
[1]Department of Agricultural & Bioresource Engineering,
Enugu State University of Science and Technology, Enugu, Nigeria
ikeoluka@yahoo.com
[2]Department of Bioresource Engineering, McGill University, Canada

ABSTRACT

Due to its higher proteins and energy per hectare than other crops, as well as its usage as feed for animals and food for humans, considerable attention has been drawn to the expression of juice and preparation of protein from alfalfa plant. Structural arrangement of alfalfa leaf indicates that the leaf cell walls and the plasma lemma as well as the intercellular spaces and stoma are such that they act as natural barriers to the escape of proteins. These necessitate that the structural barriers must be disrupted to permit full and efficient juice and protein extraction. In this study, alfalfa juice was extracted, using coupled Pulsed Electric Field (PEF) application and mechanical pressing.

Fresh Alfalfa mash were electro pulsed through a high voltage generator at the electrical field of 2.5 kV/cm, capacitance of 1μF, and electric pulse number of 200. The PEF treated alfalfa mash and mechanically expressed at the moisture content of 81.04% and pressure range of 0.5 – 4.0 Mpa using an Instron Universal Testing Machine. The quantity of juice yield, impedance level and damage degrees of the alfalfa were measured.

Results indicate 39.26%, 32.53%, 30.81%, and 28.92 % increase in juice extraction at 0.5, 1.0, 2.0 and 4.0 Mpa respectively. Average impedance before and after PEF treatments were 117.07 and 60.77. The damage degree was 1.94, indicating 94% electroplasmolysis of the alfalfa cells. Energy due to juice extraction decreased in the PEF-treated samples. Pore displacement of the alfalfa mash after pressing was higher in the treated than the untreated samples indicating that electroplasmolysis of alfalfa leaf could enhance juice extraction process.

1. INTRODUCTION

Forage crops are generally known to produce more proteins and energy per hectare than other crops (Koegel and Straub, 1996). This has prompted considerable research in the expression of juice and preparation of protein from leafy crops (Knuckles and Kohler, 1982). Alfalfa, as a major source of forage for animals has long history of predominance (Whitney et al., 1975). Studies have indicated that as much as 60% of the plant's held water could be removed along with most of the protein and that the pressed cake as dewatered forage retains enough protein for adequate animal forage requirement (Pirie, 1971).

The high protein and low fiber content of alfalfa leaf protein have made it highly desirable as feed ingredients for monogastric animals, swine and as a functional food (Savoe and Beauregard 1991; Knuckles and Kohler, 1982). In addition, while the alfalfa sprouts could be consumed by humans, the juice is widely used as food supplement. A whole green leaf protein concentrate from alfalfa has been shown to cure symptoms of kwashiorkor - the protein deficiency disease (Olatunbosun et al, 1972). In their study on the functional properties of alfalfa leaf protein concentrate, Knuckles and Kohler (1982), observed that alfalfa leaf protein concentrate absorbed at least 20% more oil than soy protein, and that emulsions formed with 2% alfalfa protein solutions and oil were stable and had the consistency of mayonnaise.

Different methods such as heating (Rao & Lund, 1986), pressing (Duran & Nunez-Arenas, 1988), osmotic drying (Aguilera & Stanley, 1999), high pressure (Basak & Ramaswamy 1998), microwave (Deng & Zhang, 2002), supercritical fluid extraction (Rozzi *et al*., 2002), freezing (Tsuruta et al. 1998), alkaline breakage (Ponant, *et al* 1988), enzymatic treatment (Saulnier & Thibault 1999) or combination of them have been used to increase the degree of plasmolysis of plant tissue. Pulsed electric field has been proposed as a pretreatment for fruit (Bazhal *et al* 2001) and vegetable (Bouzrara & Vorabiev, 2000; Geulen *et al* 1994).

A study of the alfalfa leaf for juice extraction indicates that the arrangement of the leaf cell walls and the plasma lemma as well as the intercellular spaces and stoma are such that they act as natural barriers to the escape of proteins. The primary objective of the juice extractor is to obtain high yield with maximum productivity, high quality as well as minimum energy expenditure. These necessitate that the barriers posed by the leaf and cell structures must be disrupted to permit juice and protein recovery (Schwartzberg et al., 1978).To disrupt the leaf and cell wall structures for more juice and protein recovery require a shift from the conventional mechanical method of pressing untreated alfalfa leaf (Savoe *et al*, 1991; Sinha *et al*, 2000; Bazhal *et al*, 2001).

Pulsed Electric Field (PEF) application, also known as electro pulsation, is a non thermal processing technology to gain access to the cytoplasm for cell structural disruption. Guelen *et al*, (1994) observed that juice extraction from PEF treated carrot mash increased from 62- 75%. A combination of the mechanical expression (pressure) and PEF treatment has been used to enhance juice yield from beet (Bouzrara and Vorobiev, 2000) and carrot (Knoor *et al*, 1994). The objective of this work is to study juice extraction from fresh alfalfa leaf by coupled PEF application and mechanical pressing.

2. MATERIALS AND METHODS

Essentially, the materials and apparatus consist of fresh alfalfa leaves and stems cut from the McGill, Macdonald campus farm, Canada; a laboratory pressure cell with a cylindrical cavity, a filter and an elastic seal; an Instron Universal Testing Machine with a cylindrical press and a PEF generator.

The fresh alfalfa stems with leaves were sorted, cleaned and comminuted to obtain a homogeneous mash using a laboratory food blender. The moisture content of the mash was measured using the oven method and found to be 81.04 % w. b. The mash was kept in a closed container prior to juice extraction to prevent loss of moisture.

The alfalfa mash was properly mixed before every experiment to obtain a homogeneous mixture.

The experiments were done in three phases namely PEF treatment of the alfalfa mash; mechanical pressing of the alfalfa mash and the measurement of electrical impedance of the alfalfa mash.

In the PEF treatment, a pulsating high voltage generator, shown diagrammatically in Fig. 1 was used to provide the pulsed electrical field. A variable autotransformer (Power stat Type 3PN116C, The Superior Co Bristol, USA) was used to supply voltage to the circuit. The input voltage was regulated by the autotransformer to obtain a pulse frequency of 1 Hz. The voltage was then transformed by a high voltage transformer (Model 62159A, Apotex Imaging Inc., Canada) and rectified by high voltage diode. The 24 resistors (Renfrew 6 ½ CE 100 KΩ; 100W), connected in series were used to limit current that passed through the capacitor C (Plastic capacitor Inc. 1μF). The initial treatment voltage supplying the treatment chamber depended on the distance between the spheres of discharger, ℓ_{sph} (mm). The discharger was made from 15 mm diameter stainless steel spheres. The break voltage V_0 was calculated using Equation 1 (Armyanov *et al* 2001):

$$V_0 = 4.85\ell_{sph}^{0.75} \quad (1)$$

The voltage applied to the treatment chamber was registered with a high voltage probe (Tektronix, P6015A) connected to a digital oscilloscope (Agilent, 54621A).

The PEF treatment parameters were: electrical field E = 2.5 kV/cm, capacity of discharged capacitor 1μF and pulse number 200.

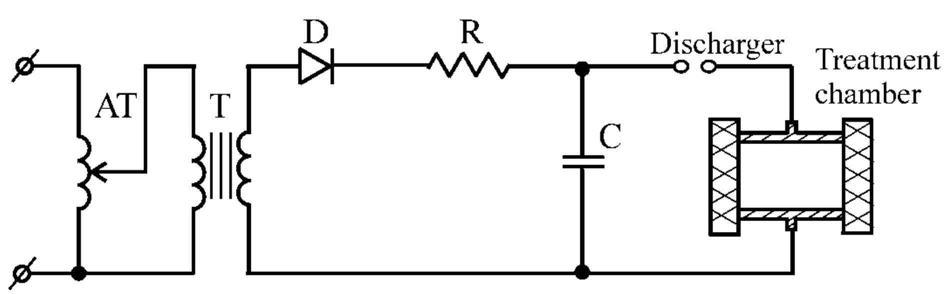
2.1 Juice Extraction

Fresh alfalfa mash weighing 40 g was filled into the cylindrical cavity of the pressure cell. The juice extraction experiment was setup in a treatment chamber as shown in Figure 2. Constant pressure was applied, using the Instron Universal Testing Machine (Series IX Automated Materials Testing System 1.16) until all the juice were drained and collected. Three repetitions were performed at the pressures of 0.5, 1, 2 and 4 MPa; crosshead speed 25.4 mm/min /sample and rate of 5 points/second.

2.2 Measurement of Electrical Impedance of the Alfalfa

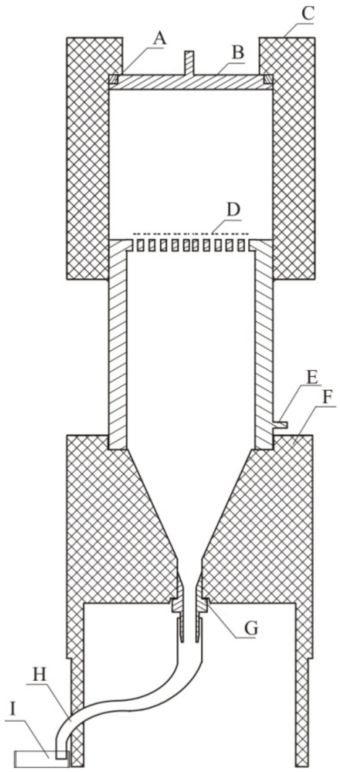
Electrical impedance of the alfalfa mash was needed to determine the level of damage or the "damage degree" of the alfalfa plant tissue after PEF treatment. The damage degree of a plant tissue is an important index that indicates the effectiveness of PEF treatment as it shows the level of electro-plasmolysis in the plant. Figure 2 shows the setup of the treatment chamber. Alfalfa mash was placed into the plastic cylinder (C). The cylinder (E), with perforated base and the stainless steel base (B) were used as electrodes for PEF treatment as well as electrical impedance measurement of the fresh alfalfa mash. The measurement, which was done at the frequency of 1 KHz, was made by connecting base (B) and cylinder (E) as shown in Fig.2, to the RLC measuring meter, which indicates the impedance level at each stage of measurement. The measurements were done before and after PEF treatment of the mash. For the untreated samples, the impedance was measured before and after pressing while in the case of the PEF treated samples, impedance was measured before treatment, after treatment and after pressing.

Figure 1: Electrical circuit for PEF treatment of alfalfa



Auto transformer (AT), transformer (T), diode (D), capacitor (C), résistor (R)

Figure 2: Treatment chamber – piston cylinder



After the impedance measurements, the damage degree of the fresh alfalfa mash was determined using equation 2 (Klimov, *et al*. 1970, Savchuk, 1971 and Sinyuhin, 1967):

$$S_d = \frac{Z_0}{Z} \qquad 2$$

Where S_d is damage degree, Z_0 - impedance before PEF treatment, Z - impedance after PEF treatment.

3. RESULTS AND DISCUSSIONS

The results of the experiments are as presented in Table 1and Figures 1 to 7.

Table 1 and Fig. 7 show the results of juice yields after mechanical pressing at different pressures for the PEF treated and untreated alfalfa samples. There is noticeable difference in the juice yield between the treated and untreated samples. From Table 1 the difference is as much as 39.34% increase in juice yield at 0.5 MPa and 31.65% at 4.0 MPa. These compares with the works of Bouzrara and Vorobiev (2000) on beet juice; Knorr *et al*. (1994) on carrot. It was observed that, although increase in pressure resulted to increase in the quantity of juice extracted, the percent increase reduced as the pressure increased. This correlates earlier results on pore displacement and bulk density.

The results of the measurement of impedance after juice expression are presented in Fig.3. From Fig. 3, it is easily observable that as mechanical pressure on the alfalfa mash was increased, there was a corresponding increase in the impedance. However, the increase was more pronounced in the untreated than the treated alfalfa mash samples. It was also observed that pressure increased the impedance as well as the alfalfa juice yield. As more juice yields occurred, the mash got drier. The dryness of the mash decreased the electrical conductivity of the material, resulting to the increase in the impedance of the mash. The initial impedance $\bar{Z}_0$ has a mean of 117.07 with standard deviation of 13.06 and estimate standard error of 4.35%. After treatment, the impedance $\bar{Z}$, decreased to a mean of 60.77 with standard deviation of 9.3 and estimate standard error of 3.1%.

It was observed that the impedance of the untreated mash increased after juice expression unlike the case of the treated samples. This could be explained from the understanding that as the pressure increased, the impedance also increased for the untreated samples. For the PEF treated samples, impedance before pressing was higher than that after juice expression. PEF treatments in this case led to better compression of the mash which increases the conductivity of the residue. Higher pressure on the treated samples, led to the increase in impedance, because the residue became dryer as more juice was extracted.

The damage degree was calculated using equation 2 to be 1.94 with standard deviation of 0.2 and estimated standard error of 0.07%. The calculated damage degree indicates that 94% electroplasmolysis of the alfalfa cells was achieved.

The difference between Z_0 and Z was due the fact that during the experiments, there were variations in the interfacial electrical contact between the electrodes and the alfalfa mash due to pore spaces and rough edges of the mash. Regarding the damage degree of the plant tissue, this parameter does not depend on the contact between the electrodes and the alfalfa mash. Rather it was dependent on the basic parameters of the generator such as voltage and capacity of the discharged capacitor (Armyanov *et al.* 1999). Initially, the impedance of the treatment chamber immediately before discharge of the capacitor is negligible compared to the impedance of the discharger (switch) and could be ignored. This means that the damage degree of the plant tissue would not depend on the variance of the impedance of the treated mash.

The results of the mash pore displacement after pressing the alfalfa mash are presented in fig.4. Pressure increase led to increase in displacement for both the untreated and treated samples. There was a noticeable difference in mash pore displacement between treated and untreated samples as pressure increased until at 2.0 MPa, after which the increase remained approximately gradual as shown in figure 4. The explanation is that as the pressure increased, more yield occurred and the mash got drier and the mash pore displacement became higher. The higher pore displacement observed in the treated than the untreated mash could be attributed to the PEF treatment of the plant cells. Table 1 showed that the difference was as much as 10.74% at 0.5 MPa and 7.27 % at 4.0 MPa.

Figure 5 compares the bulk densities of both the treated and the untreated samples. It shows that the bulk density of the treated samples decrease with pressure while that of the untreated samples were rather increasing as pressure were increased. Similarly, Table 1 shows that the bulk density of the treated samples was higher than those of the untreated with as much as 10.54 % at 0.5MPa and 0.85 % at 4.0 MPa. These could be attributed to the PEF treatment which disrupted the cell structure thereby facilitated higher compression and more pore displacement of the PEF treated mash.

Table 1: Percent increase in juice yield; mash pore displacement and bulk density of PEF treated and untreated Alfalfa plant.

Pressure MPa	Juice Yield (treated)	Juice Yield (untreated)	% increase	Displa-cement (treated)	Displa-cement(un treated)	% increase	Density (treated) Kg/m^3	Density ´untreated) Kg/m^3	% increase
0.5	10.31	7.4	39.34	26.7	24.11	10.74	1.0279	0.9299	10.54
1	13.67	10.31	32.53	27.98	25.47	9.85	1.0153	0.9447	7.47
2	15.68	11.98	30.82	28.97	26.87	7.82	1.0088	0.9825	2.68
4	17.34	13.17	31.65	29.66	27.65	7.27	1.0086	1.0001	0.85

The process of the electroplasmolysis of the Alfalfa plant tissue after PEF treatment reflected in the amount of energy required in alfalfa juice expression as indicated by Figure 6. The result, generated through Instron tests, showed that at the same pressure, more energy was needed to obtain same quantity of juice yield from the untreated samples than the PEF treated samples. This is attributable to the break-up or disruption of the cell structure of treated samples through the PEF treatment, which hitherto has not been the case with the untreated samples.

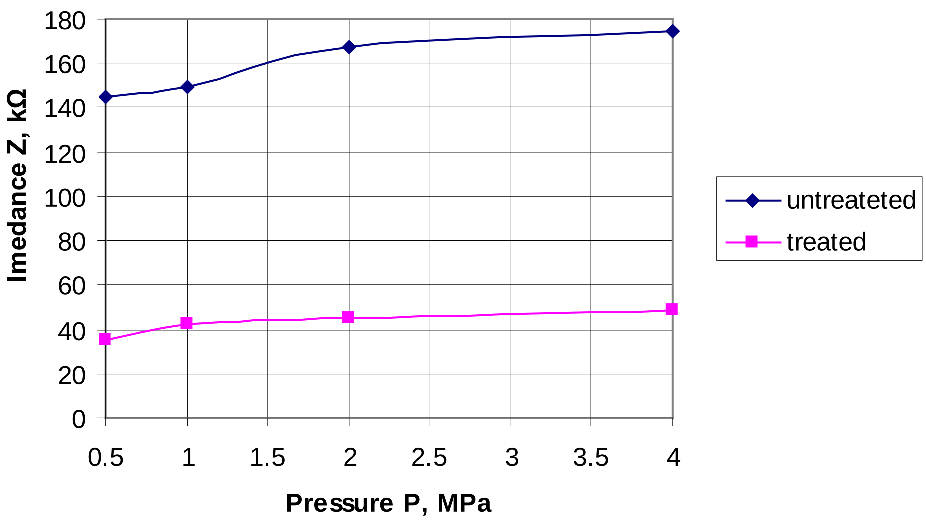


Figure 3: Impedance – mechanical pressure relationship for PEF treated and untreated Alfalfa mash

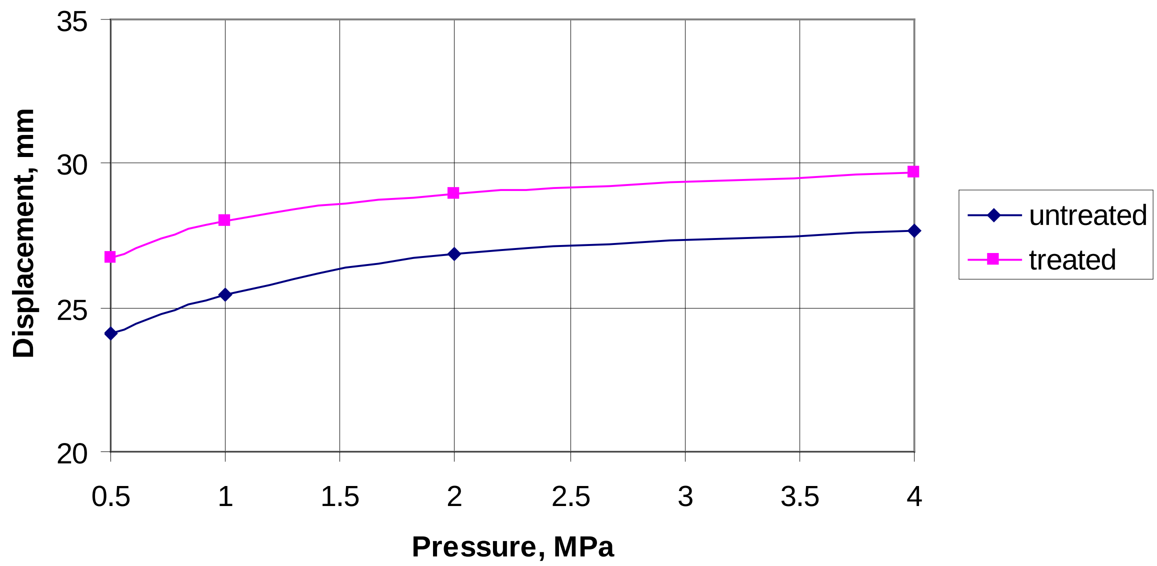


Figure 4: Alfalfa mash-pore displacement after mechanical pressing at varying pressures for PEF treated and untreated alfalfa mash.

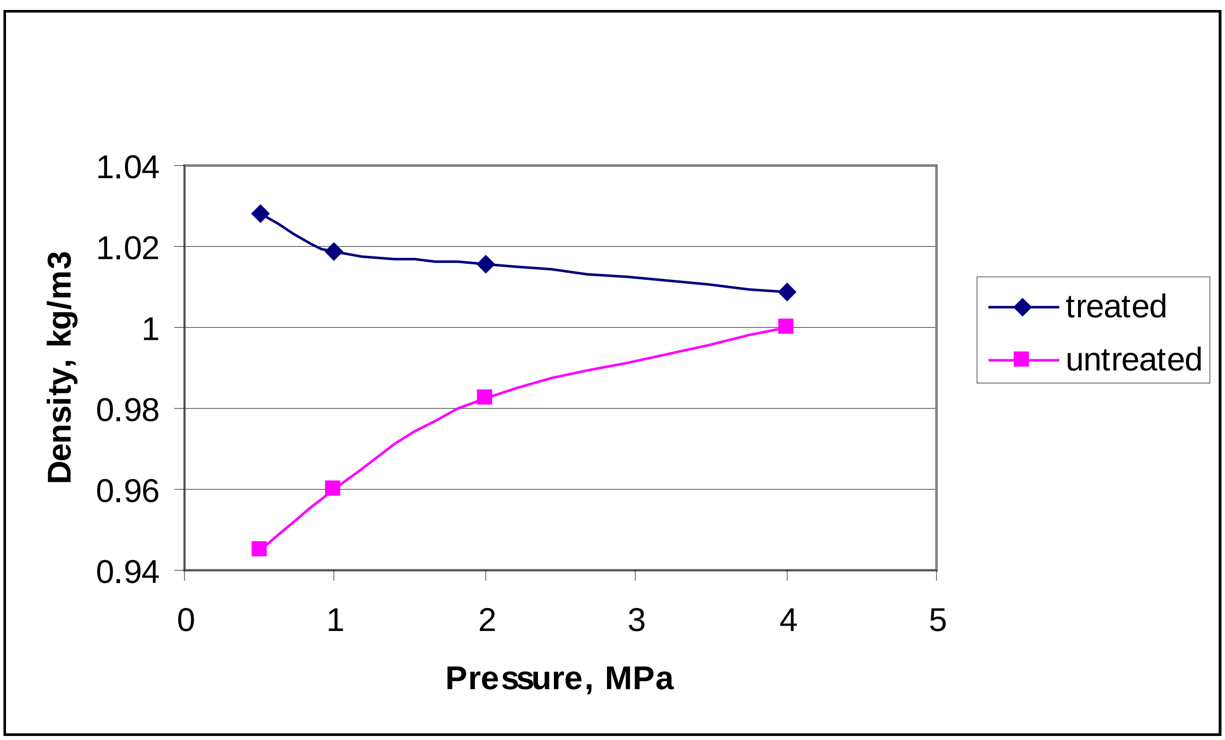


Figure 5: The bulk densities of PEF treated and untreated alfalfa mash at varying mechanical pressures.

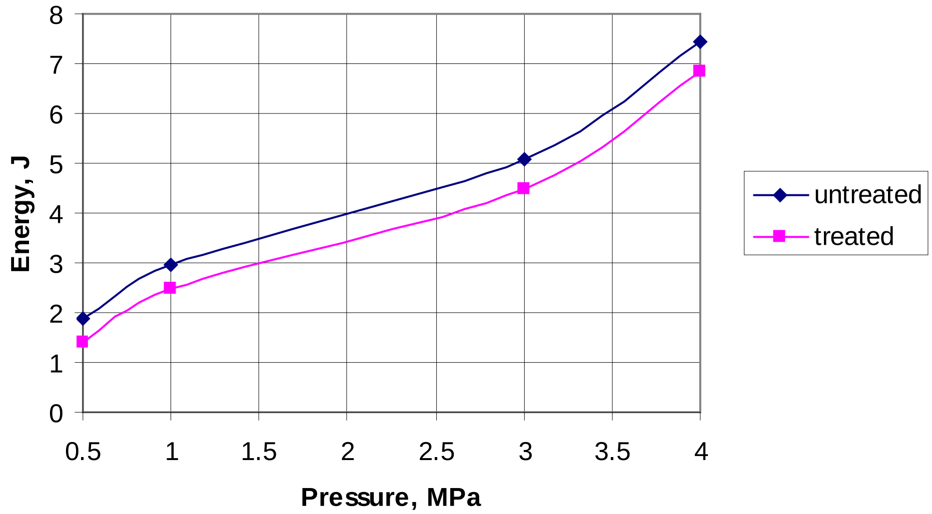


Figure 6: Comparison of the energy requirement of PEF treated and untreated alfalfa using mechanical pressure.

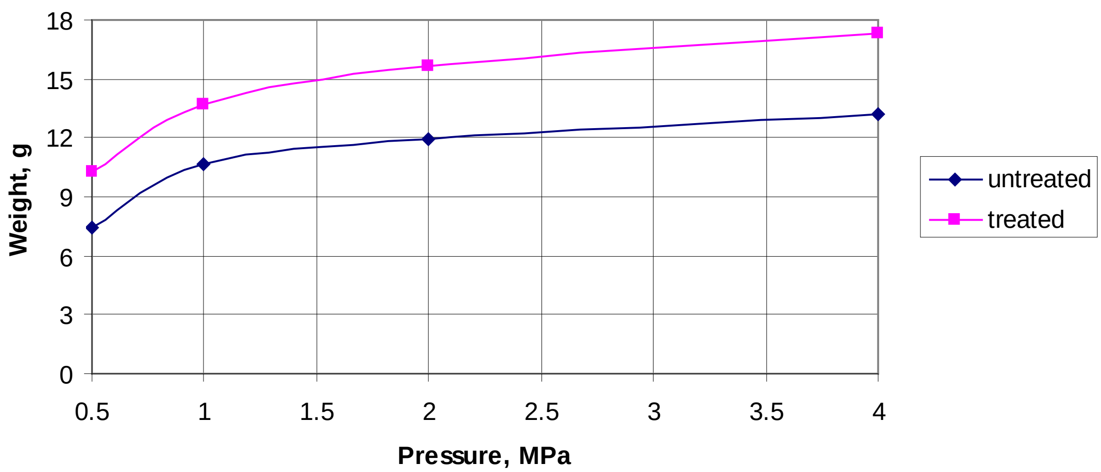


Figure 7: The juice yields for the PEF treated and untreated alfalfa samples.

4. CONCLUSION

Mechanical pressing increases the impedance of alfalfa mash. The increase was more pronounced in the untreated than the treated alfalfa mash samples. At the electrical field of 3.0 kV/cm, capacitor of 1μF and pulse number 200, 94% electroplasmolysis of the alfalfa cells was achieved. The bulk density of the treated samples was higher than those of the untreated with as much as 8.81% at 0.5MPa and 0.87% at 4.0 MPa. These could be attributed to the PEF treatment which disrupted the cell structure thereby facilitated higher compression and more pore displacement of the PEF treated mash.

REFERENCES

Aguilera J. M. and Stanley D. W. 1999. Microstructural principles of food processing and engineering, Aspen Publishers, Gaithersburg.

Armyanov N. K.; Gachovska, T. K.; Stoyanova; T. M., Kiryakov, D. B. 2001. Electric spark equipment for treatment of tobacco leaves. Scientists Conference of Technology, Security and Ecology, VelikoTarnovo, Bulgaria

Basak S. and Ramaswamy H.S. 1998. Effect of high hydrostatic pressure processing (HPP) on the texture of selected fruits and vegetables. Journal of Texture Studies, 29, 587–601.

Bazhal M., Lebovka N. and Vorobiev E. 2001. Pulse electric field treatment of apple tissue during compression for juice extraction. Journal of Food Engineering, 50, 129-139.

Bouzrara H. and Vorobiev E. 2000. Beet juice extraction by pressing and pulsed electric fields. International sugar journal, 102, 194 -200.

Deng Y. and Zhang W. 2002. Study on methods of lycopene extraction. Modern chemical industry. China 22(2), 25-28.

Duran J. M.; A. Nunez – Arenas. 1988. Extraction of Alfalfa (Medicago Sativa L.) Juice by two types of press and at three stages of growth. *Crop Research*, 28: 111-

Geulen M.; Teichgreber, R.; Knor, D. 1994. Zellaufchluβ durch electrische Hochspannungsimpulse. ZFL, 45 (7/8), 24-27

Knorr D., Guelen W., Grahl T. and Sitzmann W. 1994. Food application of high electric field pulses. Trends in Food Science & Technology. Vol.5, 71-75

Knuckles, B.E; Kohler, G.O. 1982. Functional Properties of Edible Protein Concentrates from Alfalfa. Journal of Agric & Food Chemistry. 30, 748-752.

Koegel R.G; Straub, R. J. 1996. Fractionation of Alfalfa for Food, Feed, Biomass and Enzymes. Transactions of ASAE 39 (3), 769-774

Olatunbosun D.A; Adedevok, B.K; Oke, O.L. 1972. A new source for the management of Protein calorie malnutrition in Nigeria. Nigerian Medical Journal, 2, 195-199.

Pirie N.W. 1971. In Leaf Protein: its agronomy, preparation, quality and use. International Biological Programmes. Oxford: Blackwell Scientific Publications.

Ponant J.; Foissac, S. Esnault, A. 1988. The alkaline extraction of sugar beet. Zuckerindustrie, 113(8), 665-676.

Rao M.A.; Lund, D.B. 1986. Kinetics of thermal softening of food – a review. Journal of Food Processing and Preservation, 10, 311–329.

Rozzi N. L; Singh, R. K. Vierling, R.A., Watkins B. A. 2002. Supercritical fluid extraction of lycopene from tomato processing byproducts. Journal of Agric & Food Chemistry. 24;50(9):2638-43.

Saulnier L.; Thibault J. F. 1999. Ferulic acid and diferulic acids as components of sugar-beet pectins and maize bran heteroxylans. Journal of the Science of Food and Agriculture. 79(3), 396 – 402.

Savoe P. and Beauregard, S. 1991. Potential of Forage juice extraction from macerated alfalfa mats. Transactions of ASAE 34(4): 1604-1608.

Schwartzberg H.G and Fafard, D.M 1978. Expression of Alfalfa Juice – Yield Determining Factors. Paper No. 78-1523 presented at the winter meeting of the American Society of Agricultural Engineers.

Sinha S; Sokhansanj, S; Credar, W.J; Yang, W; Tabil, L.G; Khoshtaghaza, M.H;Patil, R.T. 2000. Mechanical dewatering of chopped alfalfa using an experimental piston-cylinder assembly. Canadian Agricultural Engineering, Vol. 42(3) 153-156.

Tsuruta T., Ishimoto, Y.; Masuoka, T. 1998. Effect of glycerol on intracellular ice formation and dehydration of onion epidermis. Annals of the New York Academy of Sciences 858, 217–226.

Whitney L. F.: Cook, R.W; Rosenau, J. R. 1975. Viscosity of Alfalfa Juice. Paper No. 75-6520 presented at the winter meeting of the American Society of Agricultural Engineers.

DEVELOPMENT AND PERFORMANCE EVALUATION OF MOTORIZED CASSAVA MASH SIFTER

S. R. Samaila, O. A. Ogunjirin and M. M. Olowonibi
National Centre for Agricultural Mechanization,
PMB 1525, Ilorin, Kwara State, Nigeria.
roysformi@yahoo.com, ntslola@yahoo.com

ABSTRACT

A motorized cassava sifter was developed and evaluated. The sifter was powered by a 3.41kW petrol engine; the overall dimension of the machine is 1117 x 1045 x 500 mm. Test results showed that the sifter has sifting efficiency of 90% at sifting speed of 450 rpm with an output capacity of 132.78 kg/h at a moisture content of 40%. Particle sizes of the sifted mash ranged from 0.378 to 0.38 mm while the fineness modules was 1.91 the machine is affordable and adequately manageable therefore recommended for the small scale cassava processor.

KEYWORDS: Development, cassava, sifter, motorized.

1. INTRODUCTION

Cassava is one of the most important food crop grown in tropical Africa, because of its efficient source of food energy, all year-round availability and tolerance of extreme environmental stresses making it suitable for farming [IITA, 1989]. Cassava consists of 60 –70% water, processing it into a dry form reduces the moisture content and thus makes the product easier to transport. Processing is also necessary to eliminate or reduce the level of cyanide in cassava to 5mg (or less) per 100g for low- cyanide cassava or 10mg (or more) per 100g for high cyanide cassava varieties. [IITA, 1989]. Thus, improving the palatability of the food products.

Approximately two-thirds of the cassava used in Africa for food is eaten after traditional processing, usually at the farm or village level. The processing method comprises combination of some of the following activities: peeling, boiling, steaming, slicing, grating, soaking, fermenting, pounding, frying, pressing, sifting and drying. Such traditional processing is carried out mainly by women and it requires high labour input and it is time consuming (especially the peeling, grating and sifting processes). Thus high processing losses are sometime incurred while the processors are exposed to health hazards. Unhygienic processing condition may contaminate the resulting products as in the case of sifted cassava mash using local sifter (raffia made sieve) [IITA, 1990].

Traditionally, cassava roots are processed by various methods into different products and used in diverse ways. Therefore, improvement of post harvest processing techniques for cassava would greatly decrease labour, increase efficiency, productivity, increase income and standard of living for cassava farmers, and cassava processing entrepreneur. It would also enhance the shelf life of the products and make their transportation easier, improve marketing opportunities and upgrade their nutritional value.

Cassava sifting is one of the unit operations in the processing of cassava tubers into gari. But with the advent of motorized cassava sifting large percentage of dewatered grated cassava are still been sifted manually using local sieves made from palm frond.

Pulverisation of pressed mash/sieving of dewatered mash i.e. sifting of dewatered mash is necessary to achieve efficient heat transfer during frying. Obafemi Awolawo University, (OAU 1998) Ife research group reported that in Osun and Ondo States, manual sieving method is still dominant (84.6%). In motorized sifting (15.4%), 66.7% uses the grater and 33.3% uses the mechanical shaker. They also reported that the mechanical shaker is unreliable thus some processors still sieve the pulverized mash with raffia sieve after grating the cassava, this is because the grater does not remove the fibre but only achieve further size reduction.

The raffia sieve has a major problem in the sifting positions because it requires bending and stretching which result in aches and pain on the back of the person carrying out the sifting operation. Improvement in processing and increase in the production of gari is one of the Presidential initiative on cassava for export. The government is expecting to hit 50M tones per annum in cassava production from year 2002-2010 (Attah, 2000).

Therefore with the year 2002 Presidential directive to meet the set target, the NCAM developed motorized cassava mash sifter to eliminated the drudgery and danger associated with the use of raffia sieve.

The objective of this study is to develop an efficient motorized cassava mash sifter that would increase gari production with a multiplier effect on the earnings for the farmers and processors.

2. DESIGN FEATURES

The pictorial and exploded view of the developed rotary cassava mash sifter is as shown in Figure 1 and 2. The details of the component parts are as follows: -

Fig. 1: Pictorial view of NCAM Cassava mash sifter

LEGEND
A - Top cover
B - Hopper
C - Metering device
D - Pulley
E - Pillow bearing
F - Central shaft
G - Shifting brush
H - End cover I
I - Main frame
J - Sieved mash outlet
K - Prime mover seat
L - Chaff outlet
M - End cover II
N - Sifting net
O - Seal
P - Hopper lid

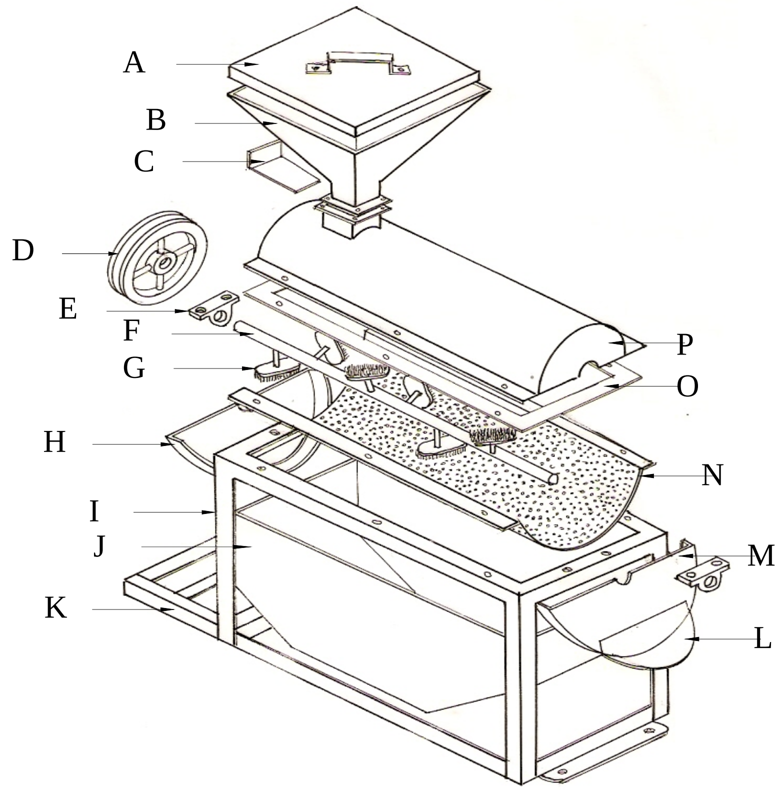


Fig. 2: Material flow of NCAM cassava mash sifter

The Frame
The frame was made of an angle iron with length, width and height of 990, 500 and 80 mm respectively.

The Hopper
This was made of galvanized iron sheet with the following dimensions 60 x 360 x 360mm. It is trapezoidal in shape. At the base of the hopper to the concave cover is a stopper made of flat-galvanized iron sheet with dimension 150 x 50 mm and bent at an angle 45^0 upward to serve as the handle. This is slotted in and out through a clearance of 2 mm between the hopper and the upper concave cover. It serves as a regulator for the flow of the cassava mash into the sifting chamber.

Concave Cover
It was made of galvanized iron sheet of gauge 1.5 mm, concave in shape with length and width of 800 and 400 mm respectively. The top cover encloses the sifting unit while the hopper is connected to the top cover with bolts and nut.

The Sifting Unit
It was made of a shaft of 980mm x 25 mmØ. On the shaft are 16mm alternatively, arranged on the rods are bristles rubbing brushes that does the pulverization. There are also spikes in between the first two brushes, these assist in breaking the cassava mash lumps.

The Sieve
The sieve was gauge 1.5mm thick stainless steel and concave in shape with a dimension of 800 and 400 mm respectively it is perforated in regular size of 2 mm Ø. There is a rubber seal in between the upper

concave cover and the concave sieve this prevents cassava mash been sieved escaping from the sifting chamber.

The Outlet

The outlet was made from a stainless steel material and rectangular in shape with dimension of 830, 480 and 250 mm respectively, it tapers from height 250mm downward. The outlet is below the concave sieve.

Residue Outlet

This was made of galvanized iron sheet of gauge 1.5 mm. It is welded to the main frame and residue from the sifted cassava mash passed through it into the collection trough.

Collecting Trough

It was made of stainless steel sheet of gauge 1.5 mm and dimension 830 x 480 x 750 mm. This is where the residues from the sifting chamber are being collected.

2.1 Operation of the Machine

The machine was designed based on the concept that sifting action is achieved by rubbing the cassava mash on two surfaces (The sifting unit and the sieve). There is a clearance of 1.5 mm between the sieve and the sifting unit.

When the prime mover is energized to propel the shaft, cassava mash is introduced through the hopper at the upper concave cylinder. A stopper, situated in between the neck of the hopper and upper concave cylinder regulates the flow of cassava mash into the sifting chamber. As the mash flows down by gravity into the sifting chamber through the spaces in between the alternately arranged brushes, the lumps are broken down by the rods and this is further robbed on the sieves by brushes. The particles of sifted mash that are of the same sizes as the sieves passes through while bigger ones which are the ungrated cassava root parts and fibres are retained.

Cassava fibres and parts of cassava root that were not properly grated are conveyed as residue by the brushes which also act as an auger into a collecting trough.

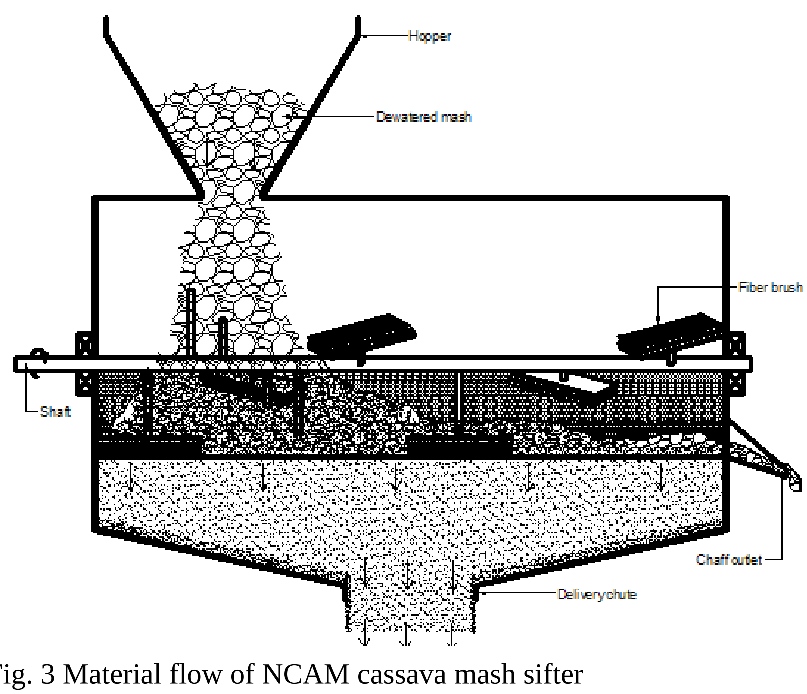


Fig. 3 Material flow of NCAM cassava mash sifter

2.2 Performance Test

Test Methodology

The NCAM motorized cassava sifter was tested at varying speed between 340-500 rpm using a 3.41 kW petrol engine. Some 15kg of cassava mash in three replications at pre-determined moisture content was prepared for each test. Result from the motorized sifter was compared with that of manual and traditional sifting. The following parameters were measured:

a. Time of feeding (T)
b. Time of sifting (T)
c. Weight of sifted mash (kg/h)
d. Weight of residue (kg/h)

After sifting, sample of sifted mash from each method was analyzed in order to determine the particle size and fineness modulus using the Tyler sieves analysis method. At the end of the test analysis the following were calculated.

a. Throughput T_p *(kg/h):* This determines the input capacity of the sifter and it is expressed as:

$$T_p(kg/h) = \frac{W_1}{T} \quad (1)$$

Where W_1 = Initial weight of the cassava mash (kg)
T = Time of sifting (min)

b. Output Capacity *(kg/hr)* Qc: This determines the quantity of cassava mash sifted per hour and is expressed as

$$Q_c(kg/h) = \frac{W_2}{T} \quad (2)$$

Where Q_c = Output Capacity *(kg/hr)*
W_2 = Weight of sifted cassava mass (kg)
T = Time of sifting (min)

c. Sifting Efficiency (%): This determines how efficiently the Cassava Sifter is sifting and is expressed as:

$$E_f(\%) = \left(\frac{W_2}{W_1}\right) \times 100\% \quad (3)$$

Where E_f (%) = Sifting efficiency
W_2 = Weight of Sifted cassava mash (kg)
W_1 = Initial weight of Cassava mash (kg)

d. Finess Modulus FM: This shows the uniformity of the sizes of the sifted cassava mash and is calculated by the equation:

$$FM = \sum\left(\frac{Pecentage\ materials\ retained\ \times pan\ No.}{100}\right) \quad (4)$$

(Source: Henderson and Perry)

e. Particle size analysis (mm): This is done to determine the sizes of the particles produced from the sifter and is indicated by a modulus number FM and is calculated using the equation:

$$D_m = 0.0041 \times 2.54(2)^{FM} \qquad (5)$$

(Source: Henderson and Perry)

3. RESULT AND DISCUSSIONS

The test was conducted at operating speeds of 340, 450 and 500rpm respectively using cassava mash samples of 40, 46, and 48% m.c. wb in line with IITA/UNICEF 1990.

At 450 rpm and 48% M.C. (wet basis) the machine has the highest output capacity of 132.35 kg/h and sifting efficiency of 90%. As the speed of the sifter increases from 340 to 450 rpm the output capacity increases it then decreases as the speed increase to 500 rpm. It implies that some of the mash that were supposed to be sifted has been conveyed along with the residue because the operating speed was too high for the sifting unit to adequately sift the cassava mash thus leading to decrease in quantity of cassava mash sifted.

The test result was compared with manual and traditional (local) sifter at the same varying moisture content (wet basis) 40, 46 and 48%. The manual sifter has a capacity of 70.85 kg/h while local sifter has 28.29 kg/h. The local sifter has the highest operating time of 30.26min followed by the manual sifter with 12 minutes and the motorized sifter has the least sifting time of 6.10 minutes as shown in Tables 1, 2 & 3.

Table 1 Average Performance Evaluation Indices of NCAM Motorized Cassava Mash Sifter

Speed of prime mover (rpm)	Speed of sifter (rpm)	Moisture content of cassava mash (%)	Weight of cassava mash W_1 (kg)	Time of sifting T (MIN)	Weight of sifted cassava W_2 (kg)	Weight of residue W_3 (kg)	Input capacity (kg/h)	Output capacity (kg/h)	Sifting efficiency (%)	Particle size of sifted mash (mm)	Fineness modulus (FM)
2000	340.00	40.00	15.00	6.32	13.00	0.89	142.45	123.42	86.67	0.38	1.91
2500	450.00	40.00	15.00	6.10	13.50	0.95	147.54	132.78	90.00	0.38	1.91
3000	500.00	40.00	15.00	6.00	13.10	0.90	150.00	131.00	81.33	0.38	1.91
2000	340.00	46.00	15.00	7.00	12.82	1.80	128.21	109.77	85.47	0.38	1.91
2500	450.00	46.00	15.00	6.60	12.90	2.83	136.36	117.27	86.00	0.38	1.91
3000	500.00	46.00	15.00	6.50	12.10	1.60	138.89	112.04	80.67	0.38	1.91
2000	340.00	48.00	15.00	7.23	11.48	1.70	130.44	100.00	76.53	0.38	1.91
2500	450.00	48.00	15.00	6.88	11.81	2.95	130.98	102.70	78.33	0.38	1.91
3000	500.00	48.00	15.00	6.80	11.20	3.30	132.74	99.12	74.67	0.38	1.91

Value are means of three replications

Table 2: Average Performance Evaluation Indices of Manual Sifter

Moisture content of cassava mash (%)	Weight of cassava mash W_1 (kg)	Time of sifting T (MIN)	Weight of sifted cassava W_2 (kg)	Weight of residue W_3 (kg)	Input capacity (kg/h)	Output capacity (kg/h)	Sifting efficiency (%)	Particle size of sifted mash (mm)	Fineness modulus (FM)
40	15.00	12.00	14.17	0.80	75.00	70.85	94.47	0.37	1.92
46	15.00	12.20	14.00	0.85	73.89	68.97	93.33	0.37	1.92
48	15.00	12.50	13.60	1.20	72.12	65.39	90.63	0.37	1.92

Value are means of three replications

Table 3 Average Performance Evaluation Indices of Local (Rafia Made) Sifter

Moisture content of cassava mash (%)	Weight of cassava mash W_1 (kg)	Time of sifting T (MIN)	Weight of sifted cassava W_2 (kg)	Weight of residue W_3 (kg)	Input capacity (kg/h)	Output capacity (kg/h)	Sifting efficiency (%)	Particle size of sifted mash (mm)	Fineness modulus (FM)
40	15.00	30.26	14.23	0.93	29.76	28.29	94.87	0.40	0.70
46	15.00	31.20	13.90	1.00	28.85	26.73	92.67	0.40	0.70
48	15.00	32.00	13.00	1.02	27.42	23.77	86.67	0.40	0.70

Value are means of three replications

The particle size analysis showed that the sizes of sifted cassava mash obtained from the motorized sifter is 0.38 mm and fineness modulus is 1.91 while that from manual sifter is 0.37mm, 1.92 fineness modulus and that of local sifter is 0.4 mm and 0.70 for particle size and fineness modulus respectively. Fig. 4 showed the output capacity of the motorized cassava mash sifter at varying moisture contents.

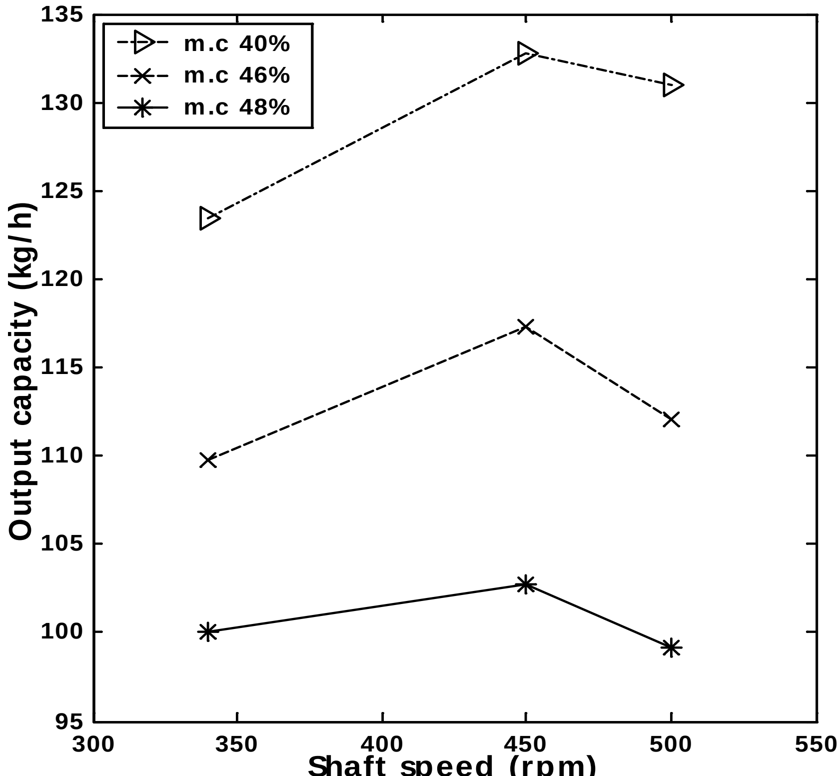


Fig. 4: Effect of shaft speed on performance of the sifter

4. CONCLUSION

The motorized cassava sifter was observed to perform efficiently at all the sifting speed when compared with manual and local sifter. However, the highest sifting efficiency of 90% was obtained at sifting speed of 450 rpm and at moisture content of 40% which is within the range of the recommended moisture content required for sifted cassava mash before frying into gari (IITA/UNICEF, 1990).

The value of the output capacity obtained is very high which indicated that more of the cassava mash being sifted and subsequently recovered. The particle size of the sifted mash obtained is 0.388mm which is within the particle size range as those of the local gari processors (0.4 mm). The sifting machine performance increases as the moisture of the dewatered cassava mash reduces. The motorized sifter is therefore considered appropriate for small, medium, and large scale farmers that may want to go into gari processing.

REFERENCES

Attah A. B. 2002. A memorandum submitted to the Hon. Minister of Agriculture and on Rural Development on Presidential initiative on cassava production and export project summary 2002-2009.

Henderson S. M. and Perry R. L. Agricultural Process Engineering; 3rd ed AVI Pub. Co. Connecticut; 1980, Pg. 130 – 138.

IITA 1989. Cassava processing and utilization. International Institute of Tropical Agriculture Research Briefs. Sept. 1989. Pg. 1.

IITA/UNICEF 1990: Cassava in Tropical Africa A reference manual. Pg.87

OAU IFE 1998. Capacity and Agro-Processing, Technology Needs of woman in Osun and Ondo State - survey report by post-harvest technology research Group, Faculty of Technology. Obafemi Awolowo University (OAU) Ile Ife, Osun State.

THE RESPONSE SURFACE EFFECTS OF TEMPERATURE, TIME AND THICKNESS OF SLICES ON WEIGHT LOSSES OF COCOYAM (*colocasia esculenta)* DURING DRYING

U. J. Etoamaihe
Department of Agricultural Engineering
Michael Okpara University of Agriculture Umudike,
P.M.B. 7267, Umuahia Abia State
jeto50@yahoo.co.uk

ABSTRACT

Fresh cocoyams (Colocasia Esculenta) harvested from a farm in Michael Okpara University of Agriculture Umudike were peeled and diced into cuboids of size thicknesses 5mm, 10mm and 15mm respectively. The diced cocoyam slices were dried in trays in an oven (Uniscope SM9023 laboratory oven) at three arbitrarily selected temperatures of 60^0C, 80^0C and 100^OC. The slices were weighed with Furi electronic balance before oven drying and removed from the oven after every 30mins, reweighed and quickly put back to the oven to continue the drying process. This process was allowed to continue till 90mins. Drying of cocoyam slices is influenced by thickness of slices, drying temperature and time of drying. The most significant effect, being the thickness of the cocoyam slices being dried. The next most significant effect was the interaction between the thickness of slice and the drying time., the linear effect of thickness of slices, the interaction of temperature and time of drying and the interaction of thickness of slices and time of drying had significant effects on weight losses of the slices ($P<0.05$). Also the quadratic effects of the thickness of the cocoyam slices were significant. The experimental, variables of temperature of drying, thickness of slices and time of drying accounted for 92.9% of the variation in the response (weight losses) observed during drying of cocoyam slices.

KEYWORDS: Cocoyam slices, drying, weight losses, response surface.

1. INTRODUCTION

Two common species of cocoyam grown around the world are *Xanthosoma Sajitifolium* and *Colocasia Esculent*a. *Colocasi* originated from Southeast Asia while *Xanthosoma* originated from tropical America, (Cobley and Steole, 2001). It is a perennial tropical plant primarily grown as a root vegetable for its edible starchy corm and as a leafy vegetable and is considered a staple food in Africa, Oceanic and Asian cultures(www.newagrico 2006).Cocoyam can be grown in paddy fields or in upland situations where watering is supplied by rainfall or by supplemental irrigation. Like most root crops, cocoyam does well on deep, moist or even swampy soils where the annual rainfall exceeds 250 cm. The crop attains maturity within six to nine months of planting. For better storage, the crop is harvested after the leaves turn yellow (www.wikipedia 2010).The plant is inedible when raw and considered toxic due to the presence of calcium oxalate crystals, typically as raphides. The toxin is minimized by cooking, especially with a pinch of baking soda. It can also be reduced by steeping cocoyam roots in cold water overnight. Calcium oxalate is highly insoluble and contributes to kidney stones, gout, or rheumatoid arthritis. It has been recommended to take milk or other calcium rich foods with cocoyam. Cocoyam leaves also must be handled with care due to toxicity of the leaves, but are completely safe after cooking (Kolchaar, 2006).

Cocoyam corms contain high levels of digestible starch as well as substantial amounts of protein, vitamin C, thiamine, riboflavin and diacin . Nigeria is presently the world's largest producer of cocoyam, with 40% of the total production. Most of the Nigerian cocoyams are grown in the Southeastern part of the country (Onwueme, 2002). There has been a steady increase in the production of cocoyams in Nigeria as reported by the National Bureau of Statistics (2006), however cocoyam is a crop that had received least research attention and featured least at all Nigerian National Development Programmes .

Once harvested cocoyam corms are prone to deteriorate if not properly stored. To ensure safe storage over a much longer period without the risk of losses from rotting, the corm must be dried. Chipping or slicing the corm into smaller units before drying has an added advantage of reducing the drying time of the processed cocoyam, also during prolonged drying more spoilage is recorded in whole corms when compared to sliced ones.

2. MATERIALS AND METHODS

Fresh cocoyams (*Colocasia Esculenta*) harvested from a farm in Michael Okpara University of Agriculture Umudike were peeled and diced into cuboids of size thicknesses 5mm, 10mm and 15mm respectively with a kitchen knife. The diced cocoyam slices were dried in trays in an oven (Uniscope SM9023 laboratory oven) at three commonly used drying temperatures of 60^0C, 80^0C and 100^OC. The slices were weighed with Furi electronic balance before oven drying and removed from the oven after every 30mins, reweighed and quickly put back to the oven to continue the drying process. This process was allowed to continue till 90mins. The weight losses between successive readings were obtained as;

$$W_L = W_1 - W_2 \quad \text{(gms)}$$

Where W_L=weight losses between successive readings. W_1 = initial weight of slice (gms)
W_2 = weight of slice after 30 mins(gms)

2.1 Design of Experiment

Response Surface Methodology, (RSM) was used in the design of the experiment. Cornell (2005), reported that RSM uses quantitative data from appropriate experimental designs to determine and simultaneously solve multivariate equation, graphically represented as response surfaces which can be used in three ways;

(i) to describe how the test variable affect the response.
(ii) to determine the inter- relationships among the test variables on the response
(iii) to describe the combined effects of all the test variables on the response. A three factor, three level central composite design of RSM was used in this study. This design is suitable for exploration of quadratic response surfaces and construction of a second order polynomial model thus helping in optimizing the process using a small number of experimental runs, Sopa *et al* (2008). A total of 16 experimental runs were used. The nonlinear model of the R S M is:

$$Y = bo + \sum_i biXi + \sum_i biiXi^2 + \sum \sum_{iK(k \angle j)} bjkXjXk$$

Where Y= response variable
bo= intercept
Xk, Xj, Xi = independent variable.
bii, bjk, bi= regression coefficients of the model.

The experimental design, regression analysis and response surface graphs were carried out with Matlab 7.1 software.

3. RESULTS AND DISCUSSIONS

3.1 Results

In the experimental RSM procedure, the three factors and coding used are shown in Table 1, while the 16 experimental runs and observed response values are shown in Table 2.

Table 1: Variables in the RSM Design

	Low	Medium	High
Independent variables	-1	0	+1
(i) Temperature ^{0}C (X_1)	60	80	100
(ii)Thickness of slice (mm)X_2	5	10	15
(iii)Time (mins)X_3	30	60	90
Dependent variable (response)			
(i)Weight Loss (g m)Y			

Table 2: Experimental Data and Observed Response Values for the RSM

Runs	Temp ^{0}C (X_1)	Thickness (mm) (X_2)	Time (mins) (X_3)	Weight loss (gm) Y
1	-1	-1	-1	0.11
2	-1	-1	1	0.09
3	-1	1	-1	1.24
4	-1	1	1	0.54
5	1	-1	-1	0.31
6	1	-1	1	0.18
7	1	1	-1	2.41
8	1	1	1	0.82
9	-1	0	0	0.21
10	1	0	0	0.34
11	0	-1	0	0.12
12	0	-1	0	0.11
13	0	0	-1	0.34
14	0	0	1	0.06
15	0	0	0	0.21
16	0	0	0	0.22

Table 3: Estimated Regression Coefficients for Weight Losses

Model	Coefficients	T-Stat	P-value
Constant)	0.054	1.665	0.147
Temperature	.181	1.525	0.178
Thickness	.672	5.516	0.001
Time	-091	-578	0.584
Temp * temp	.113	.766	0.472
Temp * thickness	.158	1.172	0.286
Temp * time	-.331	-2.545	0.044
Thickness * thickness	.378	2.691	0.36
Thickness * time	-.539	-4.466	0.004
Time * time	-.007	-.055	0.958

R: 0.964, R-square: 0.929, Adjusted R: 0.824, Std Error: 0.25838

Table 4: Anova for Weight Losses of Cocoyam Slices during Drying.

Model	Sum of squares	Df	Mean square	F-value	P-value
Regression	5.279	9	0.587	8.786	0.008*
Residual	0.401	6	0.067		
Total	5.680	15			

* Significant (P<0.05)

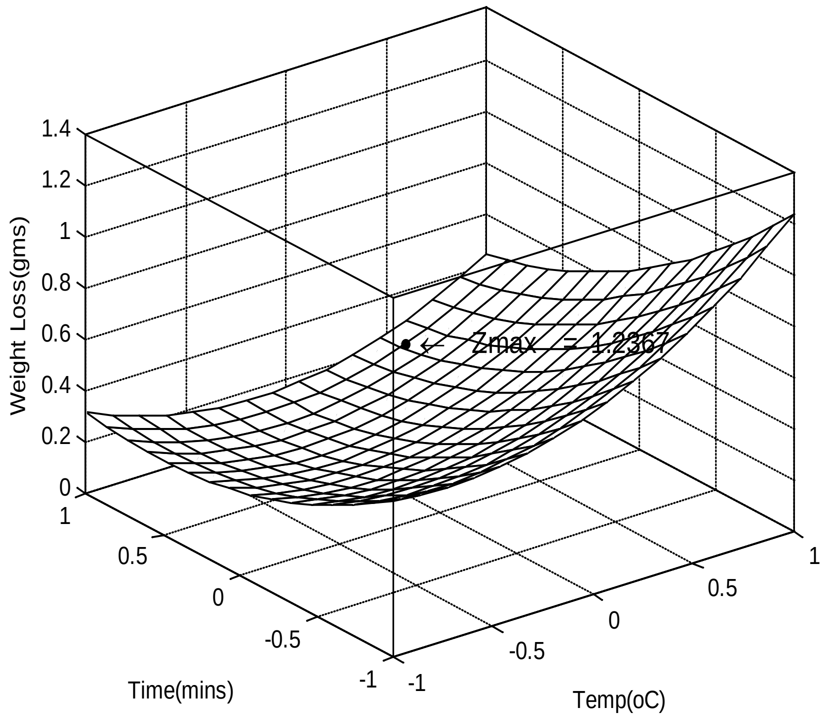


Figure 1. Response Surface Curves of the Effects of Temperature and Time of Drying of Cocoyam Slices on the Weight Losses

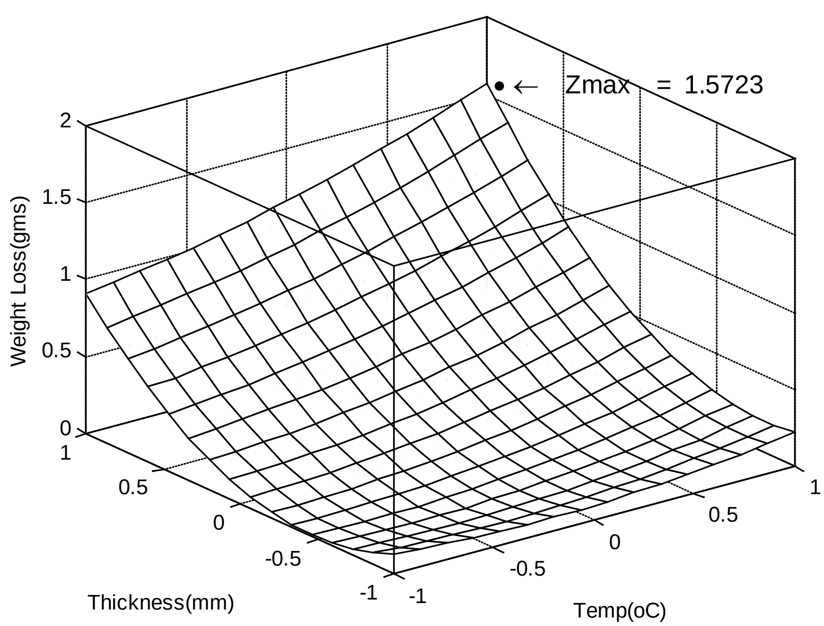


Figure 2. Response Surface Curves of the Effects of Temperature and Thickness of Cocoyam Slices on the Weight Losses during Drying

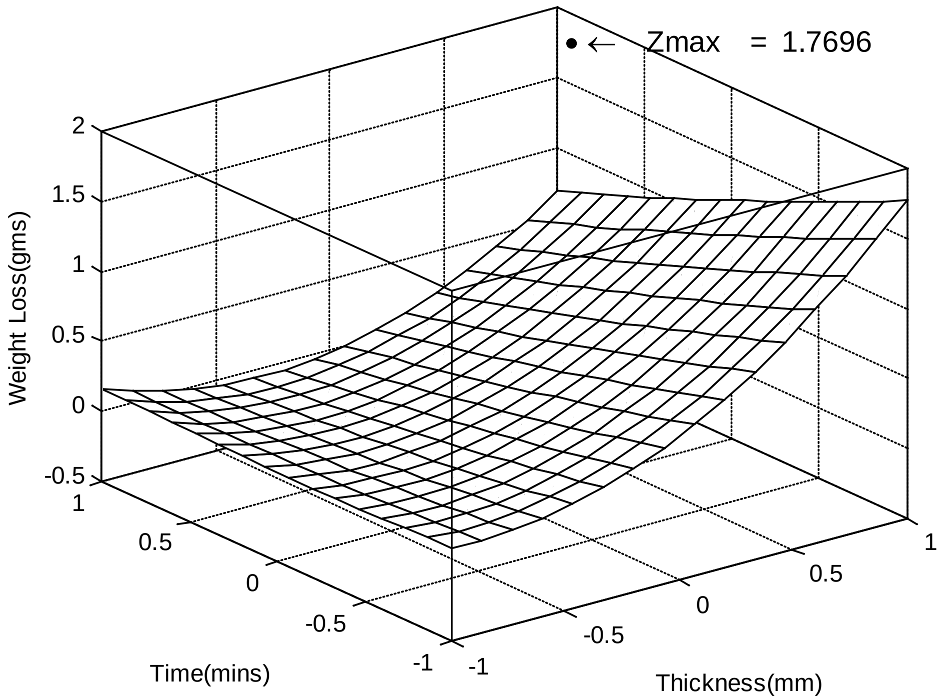


Figure 3. Response Surface Curves of the Effects of Thickness of Cocoyam Slices and Time of Drying on the Weight Losses

3.2 Discussions

From the response surface plots Figure 1, the weight losses in the slices increased with temperature and thickness of slices having a maximum value of 1.5723gms at drying temperature of 100^0C and thickness of 5mm. Also from figure 2 the weight losses in the slices decreased with time but increased with temperature having a maximum of 1.2357gms at drying temperature of 100^0C and time of 30minutes. Also from fig 3, the weight losses of the slices during drying increased with the thickness of the slices but were nearly constant over time, having a maximum value of 1.7696gms with 15mm thick slice and at a time of 30minutes.

The effects of the experimental variables on the weight losses of cocoyam slices during drying are shown in Table 3. The (i) linear effect of size, of cocoyam chips, (ii) the interaction of temperature and time of drying, (iii) the interaction of size of cocoyam slices and time of drying and (iv) the quadratic effects of the size of the cocoyam slices, all had significant effects on the weight losses of cocoyam slices during drying ($P<0.05$). The experimental variables accounted for 92.9% of the variation in this response. The analysis of variance in Table 4 showed that the variables had significant effects ($P<0.05$) on the weight losses of cocoyam slices during drying.

4. CONCLUSION

Drying of cocoyam is influenced by thickness of slices, drying temperature and time of drying. The most significant effect, being the thickness of the cocoyam slices being dried. The next most significant effect was the interaction between the thickness of slice and the drying time.

REFERENCES

Cobley L. S. D. and Steole W.H. 2001. An Introduction into Botany of Tropical Crops. 5th ed Longmans 142-148.

Cornell J. A. 2005 How to Apply Response Surface Methodology Revised edn Macmillan Publishers 335-375.

Doku E. U. 1989. Strategies for Progress in Cocoyam Research. In Proceedings of First Triennial Symposium. International Society of Tropical Root Crops. African Approach 8-12 Sept., Ibadan Nigeria 227-230.

Kolchaar K. 2006 Economic Botany in the Tropics. Macmillan India

National Bureau of Statistics 2006 Annual Abstract of Statistics Federal Republic of Nigeria 298-299.

Onwueme I. C. 2002. The Tropical Tuber Crops. John Wiley and Sons Publishers New York.

Sopa C.; Juntanee U., Commueng W.; Thavachi T. and Jatuphong V. 2008 Amphoteric starch in Simultaneous Process Preparation with Box-Behnken Design for Optimal Conditions. Amercian Journal of Applied Sciences 5(11): 1533-1542.

www.newagrico 2006 Samoa:New Agriculturist Online.Accessed June 12, 2006.

www.wikipedia 2010 Taro.Accessed 4th January 2010.

SOIL BIN INVESTIGATION OF THE EFFECT OF WIDTH OF TINE AND RAKE ANGLE ON DRAUGHT AND SOIL DISTURBANCE OF SANDY CLAY LOAM SOIL

S. I. Manuwa
Department of Agricultural Engineering, School of Engineering and Engineering Technology,
The Federal University of Technology, Akure, Nigeria,
E-mail: sethimanuwa@yahoo.com

ABSTRACT

Published articles and relevant data are scarce on soil bin investigations and the design of soil engaging implements under Nigeria soil conditions. In this study, three different model plane tillage tines designated T1, T5 and T20 (1, 5, and 20 cm wide respectively) were tested under indoor soil bin conditions. The effects of tool dimensions, forward speed and rake angle on draught force and soil disturbance were studied and evaluated. It was observed that draught increased with an increasing rate with the width of tine. The increase was also affected by the forward speed. Draught force varied quadratically with forward speed and similarly with rake angle. The relationship was developed from multiple regression analysis with coefficient of determination ranging from 0.964 to 0.995. Values of specific draught ranged from 4.44 to 12.90, 6.08 to 12.50, and 8.05 to 15.62 N/cm for tines T1, T5 and T20, respectively at forward speed of 1.0 m/s and 10.0 cm operating depth. The highest specific draught of 38.91 N/cm was observed with tine T5 at forward speed of 2.5 m/s and 15 cm operating depth. Soil disturbance patterns were observed, evaluated and analyzed.

Some parameters of soil disturbance increased with increase in tine width and speed, others decreased. Rupture distance (f) ranged from 11.0 to 13.8, 20.0 to 23.0, 25.5 to 36 cm for T1, T5 and T20, respectively. Soil throw (TDW) ranged from 6.5 to 47 cm, maximum width of soil cut (Wfs) from 4.5 to 36.0 cm, ridge-to-ridge distance (RRD) from 4 to 33 cm, height of ridge (hr) from 0.9 to 6.0 cm, and after plough depth (df) from 1.5 to 6.5 cm. The study provides relevant data in the design of soil engaging implements.

KEYWORDS: Tillage tools, operational parameters, rake angle, draught, forward speed, soil disturbance parameters

1. INTRODUCTION

The availability of data relating to draught requirements is an important factor in selecting tillage implements for a particular farm situation. Farm implements designers and consultants use draught and power requirement data of tillage implements in specific soil conditions to determine the size of tractor required. Many studies have been conducted to measure draught and power requirements of tillage implements for various soil conditions (Oni et al., 1992; Grisso et al., 1996; Onwualu and Watts, 1998; Mamman and K. C. Oni, 2005; Manuwa and Ademosun, 2007; Manuwa, 2009 . Grisso et al (1996) reviewed the work reported by different researchers in measuring draught and power requirements of the most common tillage implements. The ASAE standards (1994) provide mathematical expressions for draught and power requirements for tillage implements in several soil types.

Draught required to pull a tillage implement is a function of implement width, operating depth, and the speed at which it is pulled. Draught also is affected by soil conditions and the geometry of the tillage implement (Upadhyaya et al, 1984). It has been widely reported that the draught forces on implements increase significantly with speed and the relationship varies from linear to quadratic (Grisso et al, 1996). Harrigan and Rotz (1994) proposed a simple function for a range of soil conditions to model tillage draught under general conditions, where draught per unit width or cross-sectional area of the tilled zone is a function of soil type and the forward speed at which the implement is pulled.

All the draught data presented in the ASAE Standards (1994) and the data presented by Harrigan and Rotz (1994) were based mostly on USA lands. Presently, there is a shortage of data available on draught requirements of agricultural implements and tools operating on the soils of Nigeria. This is a point of great concern since the data are necessary and essential for the proper design of tillage implement and tools and for appropriate matching of the implements and tools with their power sources, and the selection of the optimum operating conditions.

Soil disturbance parameters are important in soil tillage dynamics studies in several aspects such as incorporating manure and organic residues and protection of soil from water and wind erosion (Liu and Kushwaha, 2006).

The objective of this study therefore was to determine the effects of implements and operational parameters on draught and soil disturbance of model tillage tines and to model the relationships after regression equations.

2. MATERIALS AND METHODS

The study was conducted in the soil Tillage Dynamics Laboratory of the Department of Agricultural Engineering, The Federal University of Technology, Akure, Nigeria. The soil was a sandy clay loam composed of 54% sand, 21% silt and 25% clay in the first 23 cm layer from the top and 52% sand, 17% silt and 31% clay in the lower layer of 22 cm. The organic carbon ranged from 0.87 to 1.41%.

The Soil Tillage Dynamics Equipment consisted of an indoor soil bin 9.0 m long, o.85 m wide, filled with 0.45 m soil, a soil processing trolley, a tool carriage, a power transmission system. A tool-mounting frame for the depth and angle adjusting mechanism was fabricated and was mounted on the tool carriage. The soil tillage dynamics equipment included a spring of dynanometer (load meter) for measuring draught of tillage tools. Full details of the soil tillage dynamics equipment is presented in Manuwa (2002).

Other accessories include a bush recording penetrometer (CP20 ultrasonic) for measuring cone index of the soil and core soil samplers for measuring soil bulk density and moisture content.

Three different tillage tines were used for the test. The widths of the tines were 1 cm (T1), 5 cm (T5) and 20 cm (T20). These tines were classified as very narrow tine, narrow tine and wide tine respectively, cut from mild steel sheet with plate thickness of 8.0 mm. Each tool had a bevel angle of 15^0.

The soil – processing trolley was used for processing the soil in the bin mechanically in order to achieve uniform soil condition as desired for test run throughout the soil bed. For all the experiments the soil moisture content was maintained at about 11.5% (db) and a mean cone index at about 500 kPa.

For the influence of speed on draught, two treatments of rake angle (45^0 and 90^0) were used but the depth was fixed at 150 mm. The forward speed was varied. For the influence of rake angle on draught, three treatments of depth were considered (50, 100 and 200 mm) while the speed was fixed at 1.0 m/s (3.6 km/h) but the rake angle was varied. After the soil processing was over, the test tool was mounted on the tool bar and the desired depth and rake angle were selected. The draught of the tools was measured with the aid of the load meter. Average values of at least three replicates were taken for each treatment.

Immediately after each experimental run, the profilometer was placed in position and the vertical members adjusted to acquire the shape of the surface profile of the soil resulting from the tillage. Care is taken to ensure the two extreme points coincides with undisturbed soil surface, from this a datum from which measurements are taken is established. When the rods corresponding to the transect to be measured have been adjusted, the instrument was then carefully lifted from its stand and place on its side on a large graph sheet. The rod tip was located on the graph sheet thus, tracing surface profile of the resulting soil disturbance. The soil disturbance parameters are illustrated in Fig. 1

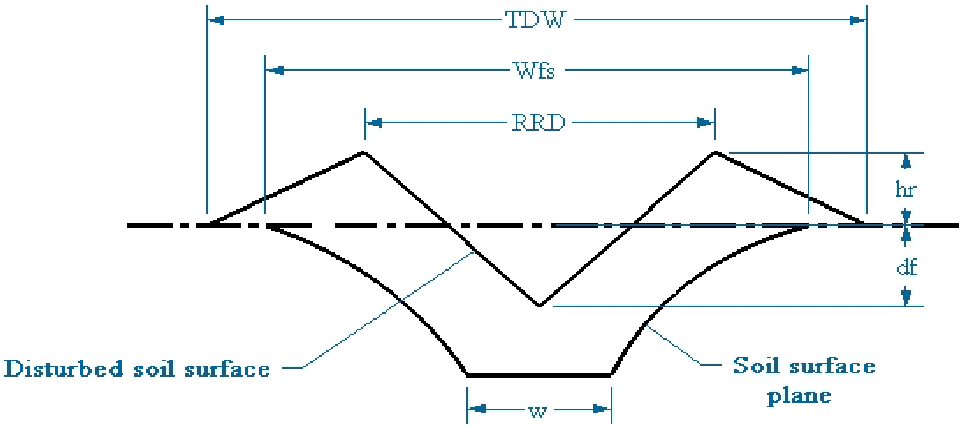


Figure 1. Parameters used to define soil disturbance of a single tillage tool: maximum width of soil throw (TDW); maximum width of soil cut (Wfs); ridge-to –ridge distance (RRD); height of ridge (hr); furrow depth (df); tool width (w).

3. RESULTS AND DISCUSSION

3.1 Effect of Width of Tine on Draught

Effect of implement dimension/width on draught at 35 mm depth is shown in Fig. 2. The variation of draught with tine width was also observed at greater depths of 70, 150 and 200 mm (figures not presented here in).The trend showed that draught increased at a decreasing rate with tine width. The increase was also affected by the forward speed since higher draught values were obtained at higher speed. The forward speed V1, V2 and V3 were 0.28, 1.0 and 2.5 m/s, respectively. Quadratic models best fit the data points with very high R^2 values. These relationships agree well with the work reported by Hettiaratchi and Reece (1974), O' Callaghen and Farrelly (1964).

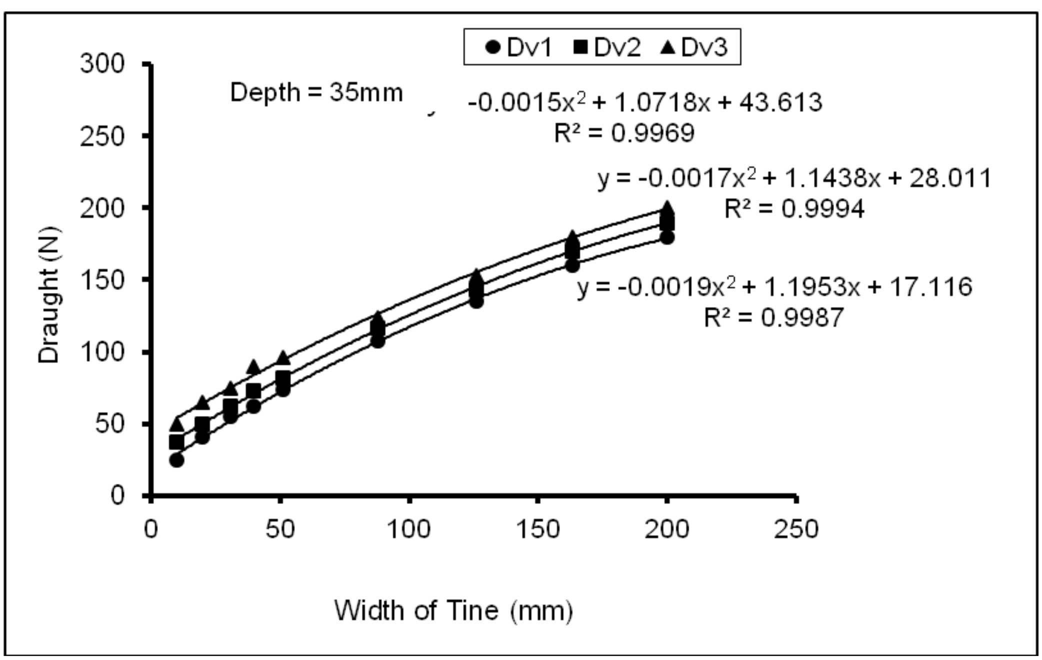


Figure. 2. Effect of width of tool on draught of tillage tines at operating depth of 35 mm.

3.2 Effect of Rake Angle on Draught

The effect of rake angle, α on draught, D of the tillage tines is presented in Figs 3 to 5. The mean values of the data were subjected to multiple regression analysis and the best relationship that fitted the data was a quadratic model of the form:

$$D = A\alpha^2 + B\alpha + k \quad (1)$$

where, A, B and k are regression coefficients in figs 3 to 5. The levels of depth of operation were 50, 100 and 200 mm respectively. The forward speed and moisture content were held constant at 1.0 m/s and 11.5% (db) respectively; the cone index was in the range of 500 to 600 kPa. It was observed that draught increased quadratically with increase in rake angle, and the draught requirement of the tines increased in ascending order of magnitude: DT1, DT5 and DT20. The R^2 values of the models range from 0.9691 to 0.9949, which shows that the models are good for accurate prediction. The findings here agree well with the work reported by Spoor (1969), Gupta et al (1989) that the tine rake angle has a large effect on the draught force. Draught increased slowly from 30^0 to 50^0, above 50^0 however, the rate of increase was very rapid. This means that for minimum draught, rake angles of less than 50^0 should be used providing that tines set at this inclination will do the job satisfactorily. The specific draught of tines T1, T5 and T20 at rake angle of 45^0, 1.0 m/s speed, 100mm depth and 11.5% mc were 4.40, 5.58 and 8.23 N/cm. Under this same conditions, the specific draught at 90^0 rake angle were 12.90, 12.50 and 15.62 N/cm.

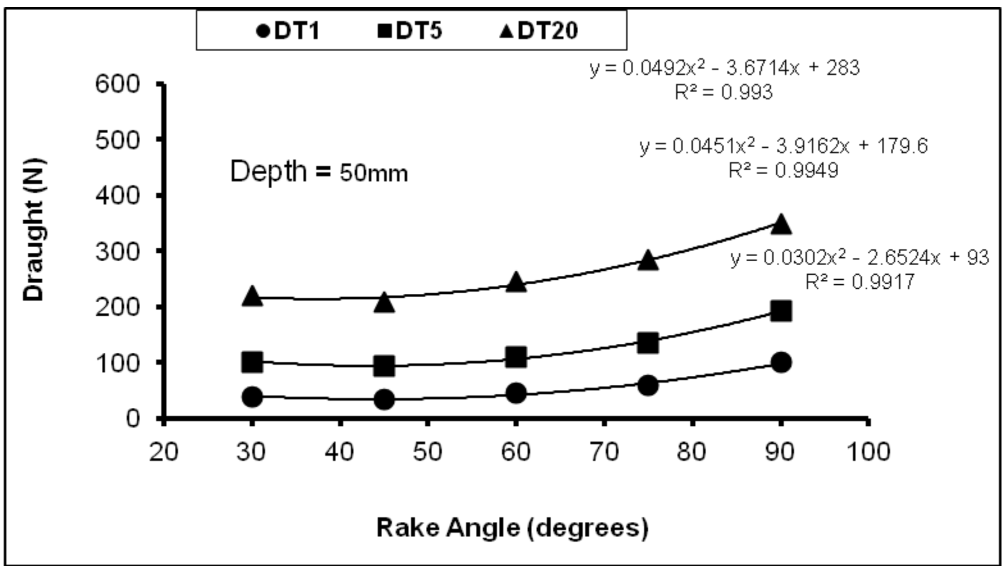


Figure 3. Effect of rake angle on draught of tines at 50 mm depth

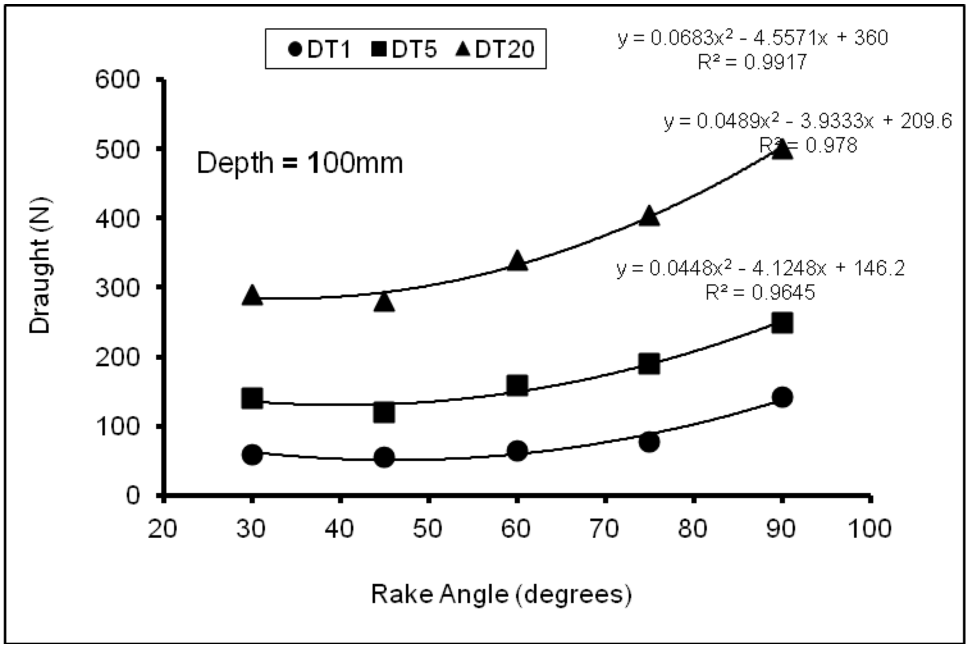


Figure 4. Effect of rake angle on draught of tines at 100 mm depth

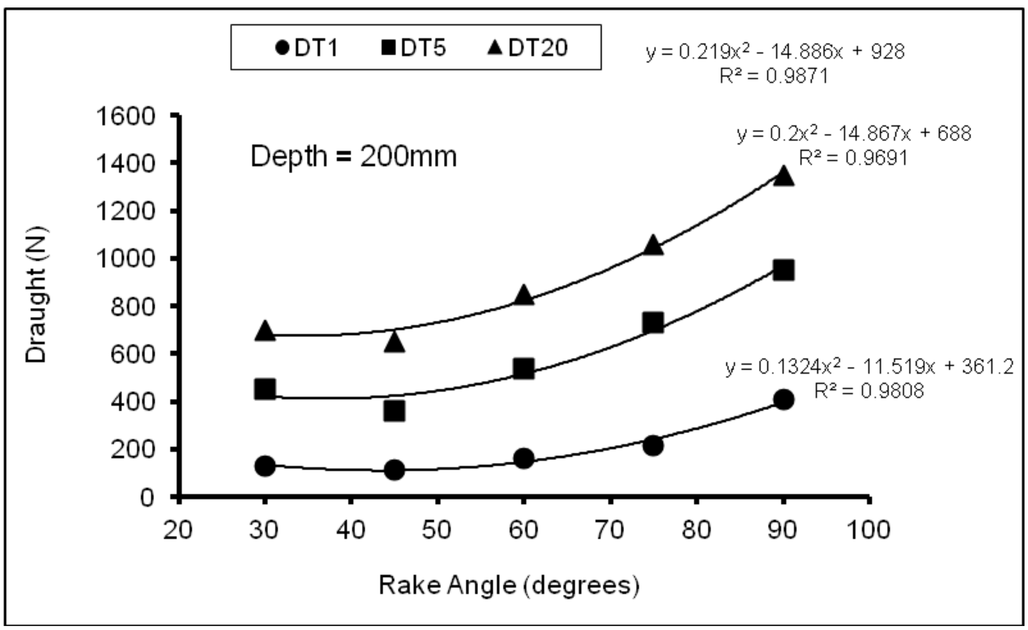


Figure 5. Effect of rake angle on draught of tines at 200 mm depth

3.3 Effect of Speed on Draught

The variation of draught, D with increase in forward speed V of the tillage tines is shown in Figs 6 and 7. The mean values of the data were subjected to multiple regression analysis. The best relationship that fitted the data was a quadratic regression model of the form:

$$D = a S^2 + b S + C \qquad (2)$$

where, a, b and c are regression coefficients and constant.

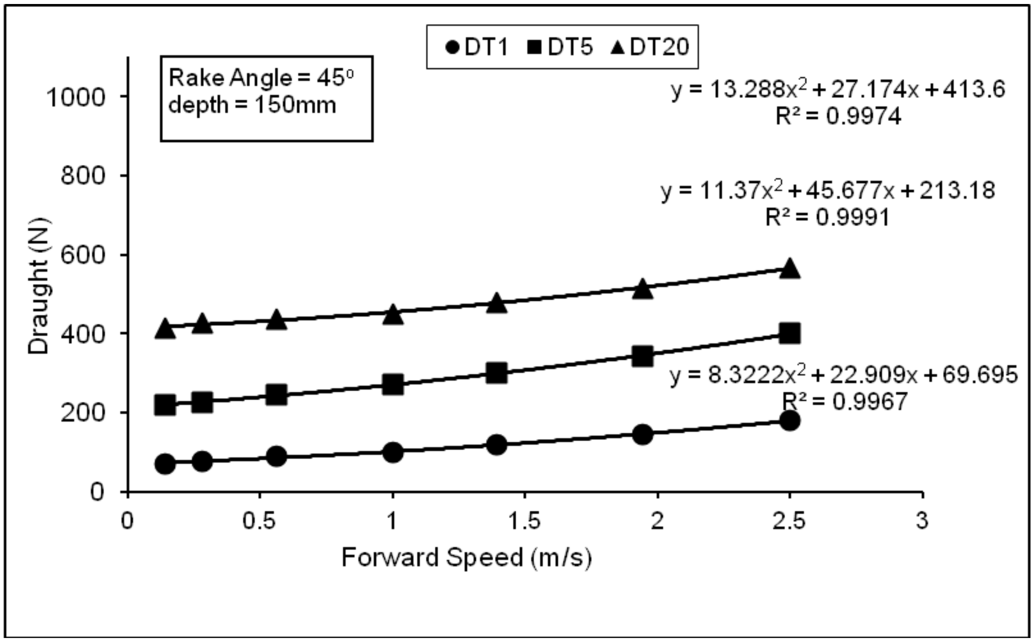


Figure 6. Effect of speed on rake angle of tillage tines at 150 mm depth and 45^0 rake angle

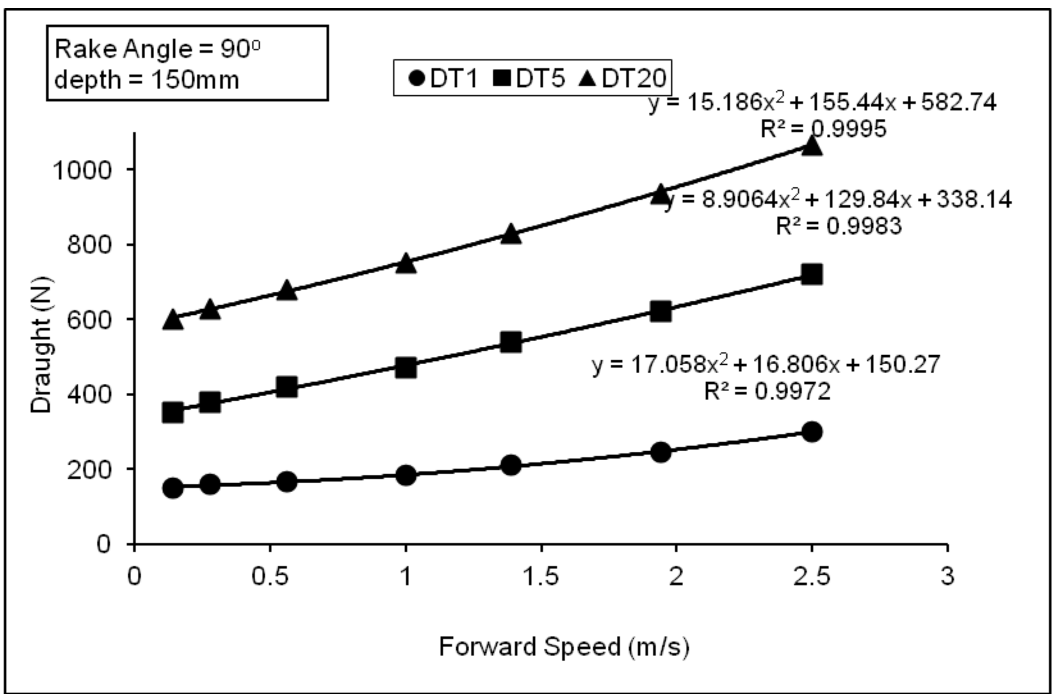


Figure 7. Effect of speed on rake angle of tillage tines at 150 mm depth and 90^0 rake angle

In the two treatments presented in figs 6 and 7, depth of operation and moisture content were held constant at 150 mm and 11.5% (db) respectively. In fig 6, the rake angle was held at 45^0 while it was 90^0 in fig 7. For both figures, draught increased with speed at an increasing rate. The quadratic model that best fitted the relationships was similar to that reported by Collins et al (1978), Koolen and Kuipers (1983) for arable soils and similar tillage tools. The result also agreed with the non-linear trend reported by Oni et al. (1992). It also agrees well with the findings that draught force is a function of the speed and the square of speed reported by Onwualu and Watts (1998).

These results also show that draught increases with increase in rake angle by about 44% to 114% within the range of soils conditions used and tools. It was also observed that draught increased with the width of tines. The specific draught of the tines T1, T5 and T20 ranged between 21.4 and 36.7, 27.6 and 38.1, 24.2 N and 32.9 N/cm respectively in the range of soil conditions considered. It can be seen that the models are very good and could be used for accurate prediction due to the very high values of R^2 (coefficient of Determination).

3.4 Effect of Rake Angle on Soil Disturbance of Tillage Tines

It is seen in this Table 1 that the rupture distance decreased as the rake angle increased in the range of 30^0 to 90^0. The width of the disturbed area: the total disturbed width and the width of crescent remained fairly constant (that is small increases recorded) with change in rate angle. However, there was a slight increase. These trends were also reported by Spoor (1969).

Table 1. Effect of Rake Angle of Implement on Soil Disturbance at forward speed (1.0 m/s), operating depth (10.0 cm) and moisture content (11.5% (db))

Parameters of Soil Disturbance (cm)	T1			T5			T20		
	Speed (m/s)			Speed (m/s)			Speed (m/s)		
	0.56	1.0	2.5	0.56	1.0	2.5	0.56	1.0	2.5
RRD	4	8	9.5	13.5	15	17	22	18	31
WC (Wfs)	4.5	8.5	10.5	14.5	17	18.5	23	31	32.5
TDW	6.5	11	12.5	23	2.9	32.5	34	40	42.5
d_f	1.5	4.5	6	3.5	5	5.5	2.5	3	3.5
h_r	0.9	1.5	2.8	3.0	4.5	5	1.8	2.5	2.8
f	12.0	12.5	13.0	21.5	22	23	25.5	26	26.5
Draught, N	165	182	300	420	470	720	680	750	1068
Specific Draught, N/cm	36.66	21.41	28.57	28.96	27.6	38.91	29.56	24.19	32.86

Table 2. Effect of forward Speed of Implement on Soil Disturbance at 90 degrees rake angle, operating depth (15 cm) and 11.5% (db) moisture content

Parameters of Soil Disturbance (cm)	T1			T5			T20		
	Rake angle, degree			Rake angle, degree			Rake angle, degree		
	30	45	90	30	45	90	30	45	90
RRD	12	10.5	9	16	14.5	13.5	37	33	30
WC (Wfs)	13.5	12.5	11	23	21.5	20	36	34	32
TDW	21	19.5	17	33	31	27.5	47	45	43.5
d_f	4.5	5	6.5	4.5	5	5.5	2.5	3	3.5
h_r	3	2.5	1.5	6	5.5	4.5	4	3.5	3
f	13.8	12.5	11	23	21.5	20	36	34	32
Draught, N	60	55	142	140	120	250	290	280	500
Specific Draught, N/cm	4.44	4.40	12.90	6.08	5.58	12.50	8.05	8.23	15.62

Experimental results show that ridge spacing (RRD), ridge height (hr) decrease with increase in rake angle (Table 1) but increase with forward speed (Table 2). However, furrow depth increased with tillage speed, tool width and rake angle. The maximum width of soil throws (TDW) decrease with rake angle (Table 1) but increase with forward speed (Table 2).

4. CONCLUSION

In all the treatments, a significant increase in draught was observed for all the three tillage tines. Draught forces of the tines were significantly affected by forward speed and more by rake angle. Draught force varied quadratically with forward speed and also with rake angle in sandy clay loam soil**.** Inter-ridge spacing, height of ridge decrease with increase in rake angle but increase with forward speed. Furrow depth increased with tillage speed, tool width and rake angle.

The maximum widths of soil throw (or soil redistribution) decrease with rake angle but increase with forward speed. The study provides some useful data for the design and operation of soil-engaging tools. The models established are good for predictive purposes under similar soil and implement conditions.

ACKNOWLEDGEMENTS

The author is grateful to the Senate and management of the Federal University of Technology, Akure for sponsoring a Research Grant No. (URG/MINOR/98/105) which partly funded this study.

REFERENCES

ASAE standards 1994. Agricultural Machinery Management Data. ASAE, St. Joseph, Michigan, U.S.A.

Collins, N. E; Kemble, L. S. and Williams, T. H. 1978. Energy Requirements for Tillage on Control Plain Soil. ASAE Paper No. 78 – 1517, St. Joseph, Michigan, American Society of Agricultura Engineers.

Grisso, R. D; Yasin, M; and Kocher, M. F. 1996. Tillage Implement Forces Operating in silty clay loam. Transactions of the American Society of agricultural Engineers, 39(6): 1977 – 1982.

Gupta, P. D.; Gupta, C. P. and Pandey, K. P. 1989. Performance Evaluation of Wide Cutting Tillage

Tools of Different Geometry for Dryland Farming. Soil and Tillage Research, 14: 145 – 162.
Harrigan, T. M. and Rotz, C. A. 1994. Draught of Major Tillage Seeding Equipment. American Society of Agricultural Engineers, Paper No. 94 – 1533, St. Joseph, Michigan, U.S.A. pp 21.
Hettiaratchi, D. R. P. and Reece, A. R. 1974. The Calculation of Passive Soil Resistance. Geotechniques. 24: 289 – 310.
Kooken, A. J. and Kuipers, H. 1983. Agricultural Soil Mechanics, Springer – Verlag, New York: 171 – 280.Requirements in Western Canada. ASAE. Paper No. 84 – 1027, St. Joseph, Michigan; ASAE.
Liu, J., R. L. Kushwaha, 2006. Modeling of soil profile produced by a single sweep tool. Agricultural Engineering International: the CIGR Ejournal. . PM 06 008. Vol. VIII. May, 2006
Mamman, E. and K. C. Oni. 2005. Draught performance of a range of model chisel furrowers. Agricultural Engineering International: the CIGR Ejournal. .PM 05 003. Vol. VII. November 2005.
Manuwa, S. I. 2002. Development of an Equipment for Soil Tillage Dynamics and Evaluation of Tillage Parameters. Unpublished Ph. D. Thesis, Department of Agricultural Engineering, Federal University of Technology, Akure, Nigeria.
Manuwa, S. I. and O. C. Ademosun 2007. Draught and Soil Disturbance of Model Tillage Tines Under Varying Soil Parameters. Agricultural Engineering International: the CIGR Ejournal.Manuscript PM 06 016. Vol. IX. March, 2007.
Manuwa, S. I. 2009. Performance evaluation of tillage tines operating under different depths in a sandy clay loam soil. Soil and tillage research, 103: 399- 405.
O'Callaghan, J. R. and Farrelly, K. M. 1964. Cleavage of Soil by Tined Implement. Journal of Agricultural Engineering Research. 9 (3), 250 – 270.
Oni, K.C. Clark, S.J. and Johnson, W.H. 1992. The effects of design on the draught of under cutter-sweep tillage tools. *Soil Tillage Research, 22:* 117-130.
Onwualu, A.P. and Watts, R.C. 1998. Draught and vertical forces obtained from dynamic soil cutting by plane tillage tools. *Soil Tillage Research*, 48: 239-253.
Spoor, G. 1969. Farm machine design engineering Vol. 3: 22 – 25.
Spoor, G. 1969. Design of Soil Engaging Implements. Journal of Farm Machine Design Engineering, 3
Upadhyaya, S. K; Williams, T. H; Kemble, L. S. and Collins, N. E. 1984. Energy Requirement for Chiseling in Coastal Plain Soils. Transactions of the American Society of Agricultural Engineers, 27(6): 1643 – 1649.

DESIGN AND DEVELOPMENT OF AN ACTIVE SOLAR DRYER WITH ADJUSTABLE AIR FLOW RATES FOR AGRICULTURAL PRODUCTS

[1]Ikejiofor M. C. and [2]Okonkwo W. I.
[1]National Root Crops Research Institute, Umudike
[2]National Centre for Energy Research and Development,
University of Nigeria, Nsukka
[1]mauikejiofor@yahoo.com; [2]ifeanyiwilfred@yahoo.com

ABSTRACT

The need to utilize effectively the abundant solar energy in drying of agricultural products is the major consideration in the design and development of an active solar dryer. The dryer has 4 main sections: The solar collector, heat storage unit, drying chamber and air outlet unit with the following dimensions 160cmx95cmx10cm, 85cmx65cmx35cm, 95cmx75cmx70cm and 41cmx41cm respectively. Also, the dryer has a suction fan with adjustable air flow rates which helps to increase the flow of the exhaust air. Performance of the dryer was evaluated with respect to its capacity, drying rate and quality of the dried root / tuber crop products: cassava, yam, sweet potato, cocoyam, ginger and turmeric in their chip forms of 3mm thick. Test results show that the minimum drying period of 8 - 11 hours was obtained using the solar dryer and the suction fan at the suction rate of 27.29m^3/s, as compared with the drying period range of 24 – 29 hours obtained when the solar dryer was used alone, and also 42 – 50 hours obtained when the open un- controlled sun drying method was used. The results also indicate that the value of the relative humidity within the drying chamber was lower when the suction fan was used.

KEYWORDS: Design, development, solar dryer, adjustable air flow rates, agricultural products.

1. INTRODUCTION

Drying refers to the removal of moisture from agricultural products until the moisture content of the product is in equilibrium with the surrounding air usually 12 to 14 percent moisture wet basis (Hall, 1957). Solar drying is an improvement to the traditional sun drying method. Solar dryers have the principal advantage of using solar energy which is a free, available and limitless energy source that is also non- polluting (Igbeka, 1980). Solar dryers fall into two broad categories: Active and passive. Active dryers require an external means like fans or pumps to speed up the rate of air flow. Either air or liquid collectors can be used to collect the sun’s energy. Passive solar dryers use natural means radiation and convection to heat and move the air. The passive dryers can be divided into direct and indirect models. A direct passive dryer is one in which the product is directly exposed to the sun’s rays. In the indirect passive dryer, the sun’s rays do not strike the product to be dried. In this system, drying is achieved indirectly by using air collector that channels hot air into a separate drying chamber. Arinze (1985) has successfully designed a commercial solar dryer for maize and other cereals that has been found suitable for the northern part of Nigeria.

In 1980, the design and evaluation was reported for a solar dryer with a reflector / concentrator type of collector in which shelled maize and sliced plantain were dried (Igbeka, 1980). This dryer was also used to dry other crops. Later, a flat- plate collector was used to heat air for drying maize on cob and sliced okro (Igbeka, 1982), and this dryer was modified as a solar dryer /storage system by Araonye (1984) with very satisfactory results. All these dryers have problem of low air flow through them, because air is circulated by natural convection. Also, solar dryers are subject to daily, seasonal variations and other climatologically factors. Drying cannot be continuous throughout the day. The drying depends on the rate of solar radiation, time of the day, season and also the humidity of the environment.

Solar dryers require heat storage systems that can store solar energy so that drying can continue during periods of low sun radiation and also fan or pump to speed up the rate of air flow.

The objective of the work is to design and develop an active solar dryer with adjustable air flow rates using suction fan, and also to evaluate the effect of the enhanced air flow rates in the solar crop drying system.

2. MATERIALS AND METHOD

The design of the solar dryer was carried out, followed by the fabrication of the dryer in the Engineering Research Workshop of National Root Crops Research Institute, Umudike. The following materials were used: mild sheet, angle iron, aluminium absorber plate, glass transparent cover, perforated trays, hinges, aluminium frame, metal handle, bolts and nuts, pebbles, switch and suction fan. The machine / tools used include: welding, grinding / cutting, drilling, vice, hand file, spanner, hand saw, hand drill, plier and other hand tools. Evaluation of the solar dryer was carried out considering the following parameters: collector and drying chamber temperature / relative humidity, capacity, drying rate and quality of the dried products. The following root / tuber crop products: cassava, yam, sweet potato, cocoyam, ginger and turmeric were used for the testing. These products were prepared in chip forms of 3mm thick using chipping machine. Moisture content of the products used was determined by oven method. Omega RS-232 data logging thermometer was used for measurement of temperature both in the collector area, heat storage unit and the drying chamber. It was also used in measuring the ambient temperature. Also, dry/wet bulb hydrometer was used in measuring the ambient / drying chamber relative humidity. The solar radiation data on the test dates was obtained from the Meteorological unit of NRCRI, Umudike. The data was obtained using Gunn- Bellani pyranometer.

2.1 Description of the Solar Dryer

Figure 1 below shows the active solar dryer. The solar dryer has four main sections: The solar collector, heat storage unit, drying chamber and the air outlet unit.

2.2 The Solar Collector

The collector is a flat plate type having dimension of 1.60mx0.95mx0.10m with glass transparent cover. The absorber of the collector was made of aluminium sheet that was painted black. The base and sides of the collector are insulated with glass fiber with cover made of mild steel sheet. Provision for air entrance into the collector was in front of it and the dimension is 0.05mx0.60m. This air inlet can be closed during periods of low sun radiation. The collector was connected to the floor of the drying chamber through the base. The collector has slope of $7^{o}C$ which is an approximation of 6^{o} 52'N at Nsukka location. The air gap between the absorber and the transparent cover of 4cm was used.

2.3 Heat Storage Unit

The dimension of the heat storage unit is 0.85m x 0.65m x 0.35m. Sized coarse pebbles of average diameter 0.35m were used. Pebbles were considered because of its high specific heat of $0.88KJ/Kg^{o}K$. The pebbles volumes were calculated to be $0.19337m^3$. The sides and base of this unit are insulated with glass fibre to minimize heat loss from it.

$$\text{Heat Stored} = mCp_1\Delta T$$

Where, m is the weight of pebbles; Cp_1 is the specific heat of pebbles; and ΔT is the difference between storage temperature and the lowest feasible temperature.

2.4 The Drying Chamber

The drying chamber has the dimension of 0.95m x 0.75m x 0.70m, and is covered with a transparent material to allow direct solar radiation on the products. It consists of 3 detachable perforated metal screens for spreading of the product in thin layer. Perforated screen was used so that heated air can pass through it to the product easily. The dimension of the perforated tray is 0.95m x 0.75m and each can hold up to 20kg of the product / batch. There is handle and provision for opening of the chamber from one side for easy monitoring / removal of the products during and after drying. Heated air from the collector will pass through the floor and heat storage unit to the drying chamber.

2.5 The Air Outlet Unit

The air outlet unit has the dimension of 0.41m x 0.41m. This unit enclosed the suction fan, having speed of 1550rpm. The suction fan which can be adjusted to three different flow rates was used to increase the amount of air flowing through the dryer by speeding the flow of the exhaust air.

$$\text{Air flow rate of the suction fan } m^3/s = \text{Area of the air outlet opening} \times \frac{2\pi \times N}{60}$$

Where N is the fan speed in rpm
Π = Constant (22/7)

2.6 Design Considerations

A covered plate collector consisting of glass transparent cover with front air entrance and aluminium absorber sheet (painted black) was chosen to maintain high incident radiation on the collector surface. The collector's area that will provide the desired rise in temperature of 25^{o}C was determined. Also, the slope of 7^o which is an approximation of latitude of 6^{o}52'N at Nsukka location was used. Aluminium sheet was considered because of its high specific heat of 0.896KJ^{o}K. The base and sides of the collector and heat storage unit were insulated in order to reduce heat loss. The collector was connected to the floor of the drying chamber through the base for easy spreading of heated air from the collector to the drying chamber. The dryer has heat storage unit to store heat for use during period of low sun radiation. The upper part of the drying chamber containing the drying trays was made of transparent cover for direct solar radiation on the products. Also, detachable perforated metal screen were used for spreading of the products so that air can pass through them easily. Each tray has dimension of 0.95m x 0.75m to hold up to 20kg of the products in thin layer spread of about 6mm height. The air outlet chamber enclosed the suction fan with adjustable flow rates. The fan was used to increase the amount of air flowing through the dryer by speeding up the flow of the exhaust air.

2.7 Design Calculations

2.7.1 Determination of the Collector Area

To determine the collector area required for the expected rise in temperature of 25^{o}C, the total incident radiation on the tilted collector surface, Ht was calculated first. The values of H_t, H_B and H_{BN} were calculated from Hsieh (1986).

$$H_t = H R \quad (1)$$

Where H, is the total radiation on the horizontal surface, and R is the total radiation tilt.

$$H = H_B + H_d \quad (2)$$

Where H_B is the beam incident on a horizontal surface and H_d, is the diffuse radiation.

$$H_B = H_{BN} \sin\alpha \quad (3)$$

Where H_{BN} is beam radiation at normal incidence and α, is the altitude angle.

$$H_{BN} = Ae^{-B\sin\alpha} \quad (4)$$

The values of A, B and C for the month of march are 1185.34W/m2, 0.156 and 0.071 respectively (Hsieh, 1986).

To calculate the altitude angle, α

$$\alpha = \arcsin(\sin L \sin \delta + \cos L \cos \delta \cos h) \quad (5)$$

L, is the latitude value of 7^o and h, is the hour angle δ, is the solar declination.

The solar declination δ, for any day can be calculated approximately by the equation

$$\delta = 23.45 \sin \frac{360}{365}(284 + n) \quad (6)$$

Where n, is the day of the year.

Hour angle, h = + 1/4 (number of minutes from local solar noon) (7)

Where the + sign applies to afternoon hours and – sign to morning hours.

Also, diffused radiation $Hd = CH_{BN}Fa$ (8)

Where Fa, is the angle factor which has the value of 1.0 for horizontal surfaces and 0.5 for vertical surfaces.

To calculate for the total radiation tilt, R

$$R = \frac{H_B}{H} R_B + \frac{Hd}{H}\left(\frac{1+\cos S}{2}\right) + \partial g\left(\frac{1-\cos S}{2}\right) \quad (9)$$

Where R_B is the beam radiation tilt factor
S = The surface tilt angle

$$R_B = \frac{\cos(L-S)\cos\delta\cos h + \sin(L-S)\sin\delta}{\cos L \cos\delta \cos h + \sin L \sin\delta} \quad (10)$$

$\partial g = 0.2$ ie assuming ground reflectivity of 0.2

The total radiation on the tilted surface, Ht is then calculated as:

$$H_t = H R$$

2.7.2 Area of the Collector

The area of collector, Ac is given by the Hottel Whiller equation (Agbo, S.N et al, 2005) as:

$$Ac = \frac{Qu}{€ \, Ht} \quad (11)$$

Where, Qu is the collector useful energy gain; € is average efficiency of flat plate collector and Ht is the total incident radiation on the tilted collector surface.

The collector useful energy gain, $Qu = MCp\Delta t$ (12)

Where M, is the mass flow rate of air and Cp, is the specific heat capacity of air at 300^oK and Δt is the desired rise in temperature. According to Akani (1990), the mass flow rate of air per unit collector area is

0.0408Kg/s. Also the value of Cp at 300^{o}K from Appendix (Hsieh, 1986) is 1.0057KJ/Kg^o.The average efficiency, € of flat- plate collectors at Nsukka ranges between 73% to 81% (Ezeike, 1986), considering € = 80%.

In the design, the collector internal dimensions are 0.95m width and 1.6m length, giving the area of 1.52m^2. This area is greater than the calculated area of 1.406m^2. It also agrees with the recommendation of Sayigh (1979) that the maximium area of a collector should be 2m^2.

3. RESULTS AND DISCUSSION

Test results on the test dates indicate that the temperature in the collector ranged from a minimum of 31^{o}C at 7am to a maximum of 76^{o}C at 2pm. Also, the temperature in the drying chamber ranged from a minimum of 30^{o}C at 7am to a maximum of 59^{o}C at 2pm, while the corresponding range of ambient temperature was between 25.2^{o}C to 36.7^{o}C. The average relative humidity of the drying chamber also indicates minimium value of 26% at 2pm and maximum value of 90% at 7am, while the ambient relative humidity range was 41% to 96%. It was also observed that the days during which the suction fan was used had lower values of relative humidity that when the solar dryer was used alone. The figure 2 below shows that test with the open un- controlled sun drying method which serves as the control took maximium of 50 hours and minimium of 42 hours to dry the products to moisture content of 12%. It also shows that using the solar dryer (SD), the drying period reduced to the range of 24 to 29 hours. The figure finally indicates that using the solar dryer (SD) and the suction fan (SF) at the three different flow rates gave minimum drying period of 8 to 11 hours. Fig. 3 also shows the moisture content graph of the cassava product using different drying methods: Open sun drying (TD), Solar dryer alone (SD) and Solar dryer with suction fan at three different flow rates of 22.89, 25.09 and 27.29m^3/s which were represented as (SD+SF1), (SD+SF2) and (SD+SF3) respectively.

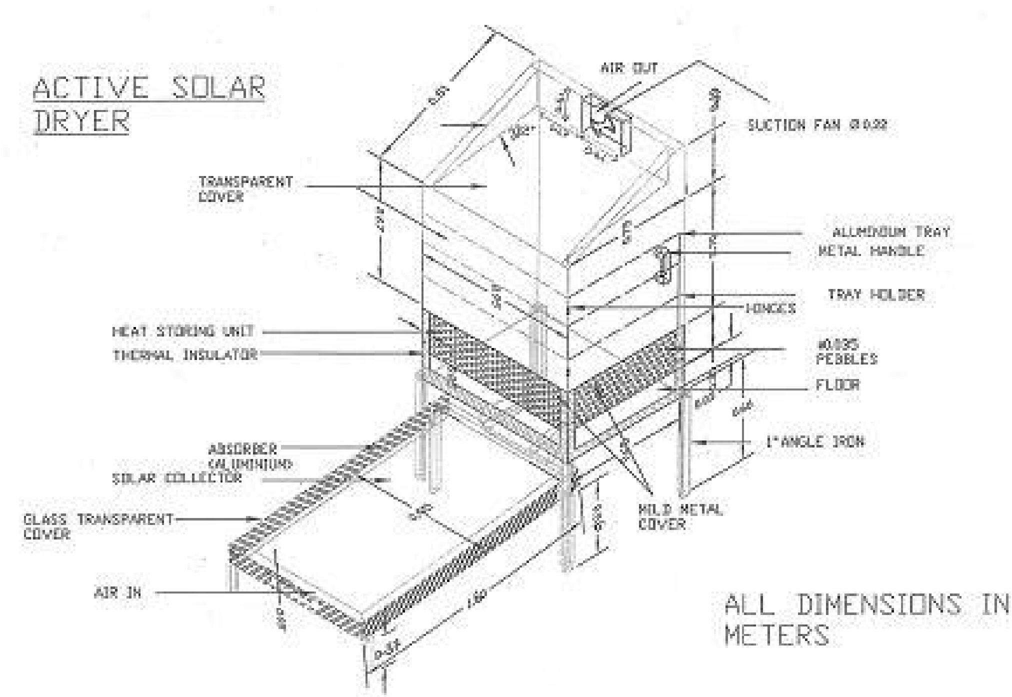


Fig. 1: The Active Solar Dryer

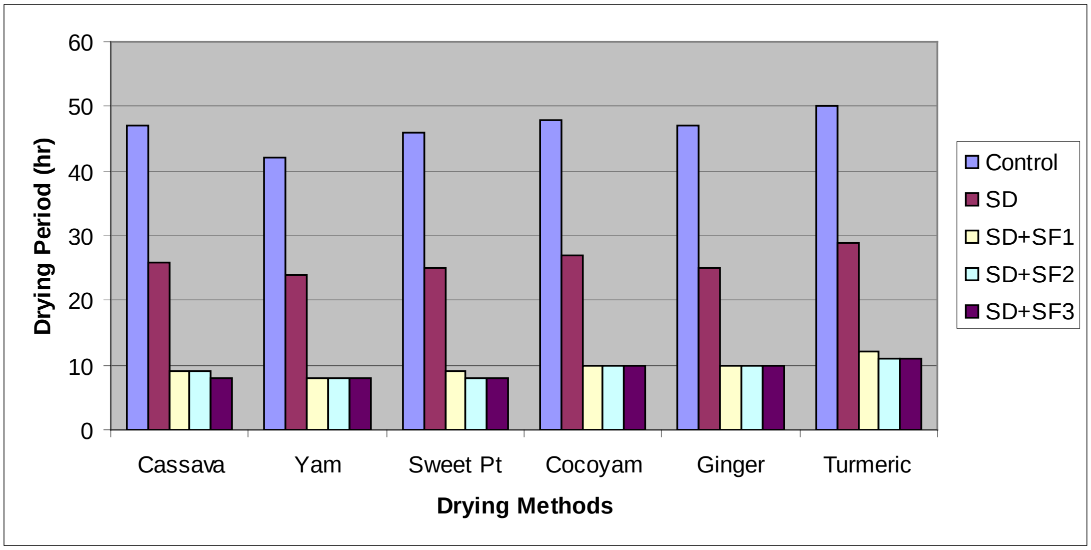


Fig. 2: Drying Periods (hours) versus Drying Methods using six different products

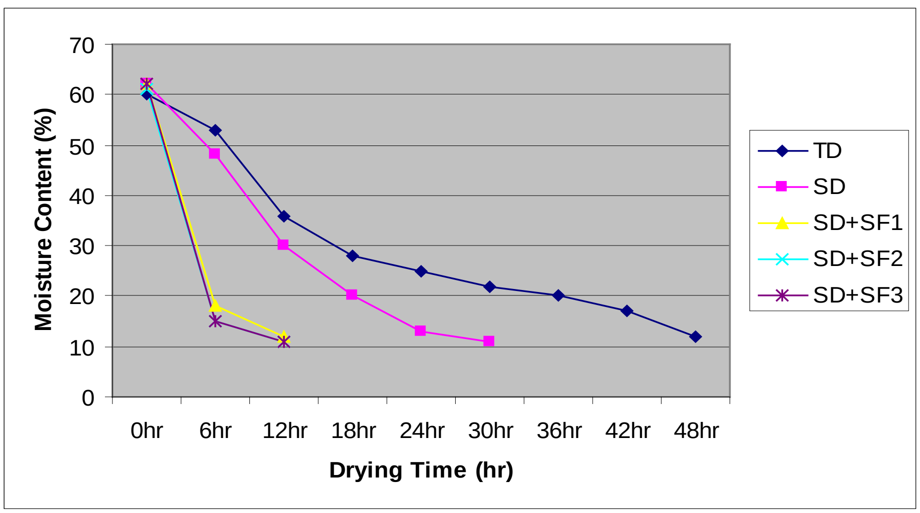


Fig. 3: Moisture content (%) of cassava versus drying time (hr) using different drying methods

4. CONCLUSIONS

The results of the experimental tests on solar dryer indicate that solar dryer incorporated with suction fan which can be adjusted to different air flow rates performed very satisfactorily in drying various root/ tuber crops and other agricultural products. The test also indicates that the suction fan helps to reduce the relative humidity within the drying chamber and therefore increases the efficiency of the solar dryer. The solar crop dryer has considerable advantages over the open un- controlled sun drying method in terms of faster drying rate, quality of product and handling convenience. Over 50% savings in time can be achieved by using the solar crop dryer as against the open un- controlled sun drying method. The solar crop dryer can be made in various sizes, depending on farmers' need and capital availability.

REERENCES

Agbo S. N. *et al*. 2005. Solar water heating for resident university students. Nigerian Journal of Solar Energy, Vol. 15, Pg 85 – 92.

Akani E. 1990. Soil type natural convention solar dryers. A Conference Paper Presented at the 14th Annual Conference of the Nigerian Society of Agricultural Engineers, University of Agriculture, Markurdi. 12 – 15 September, Pg 22.

Araonye A. O. 1984. Design, fabrication and testing of the solar dryer. University of Ibadan, Nigeria. Bsc. Project Report.

Arinze E. A. 1985. Design and performance evaluation of large scale natural convection solar crop dryer. Paper presented at the National Solar Energy Conference of Solar Energy Society of Nigeria, Enugu, Nigeria.

Ezeike G. O. I. 1986. Development and performance of a triple – pass solar collector and dryer system. Energy in Agriculture, vol. 5, Pg 1- 20.

Hall C. W. 1957. Importance of crop drying. Drying farm crops. Agricultural Consulting Associates, Inc. Ohio. Pg 4.

Hsieh J. S. 1986. Solar Energy Engineering. Prentice. Hall Inc., Englewood Cliffs, New Jersey.

Igbeka J. C. 1980. Solar energy utilization for rural agriculture. International Symposium on Solar Energy Utilization, London, Ontario.

Igbeka J. C. 1982. Flat plate solar collector / dryer. Department of Agricultural Engineering, University of Ibadan, Nigeria. Unpublished research report.

Sayigh A. M. 1979. The Technology of flat- plate collectors in solar energy conversion. An Introductory Course. Editors: A.E. Dixon and J.D. Leslie. Pergamon Press. Pg 101 – 124.

DEVELOPMENT OF A COMBINED GARI POST GRINDER SIFTING MACHINE

[1]Adejumo B. A. and [2]F. A. Ola
[1, 2] Department of Agricultural Engineering
Ladoke Akintola University of Technology,
Ogbomoso, P.M.B 4000, Nigeria.
[1]funmibitan@yahoo.com, bolanleadejumo@yahoo.com

ABSTRACT

Sifting is an essential process in the production of gari which is one of the major products of cassava in Nigeria. It is necessary to sift before and after garification to remove oversized grain fractions. It is particularly important to sift after frying to remove the bigger grains so as to make it more attractive and to increase the market value of the product. A combine gari post grinder-sifting machine was designed, constructed and tested with the aim of easing the problem of sifting and grinding of oversized grains after the garification process. The test results showed that the machine has a highest sifting capacity of 28.2 kg/hr with sifting and grinding efficiencies of 85.5 and 84.0% respectively. A minimum and maximum loss of 12.8 and 27.3% of gari grains respectively were observed during the performance test. The sifting efficiency decreases with increase in loading of the machine while the grinding efficiency increase with loading. The machine could be adapted to handle other low bulk density materials such as yam flour, ground spices and other powdery products. The machine can easily be dismantled and it's operational and maintenance procedure is simple.

KEYWORDS: Gari, Grinder-sifter, grinding, sifting, efficiency

1. INTRODUCTION

Cassava (*Manihot esculenta Crantz*) is a short lived perennial tropical shrub growing from about 1.0 to 3.5m tall, and is believed to be first domesticated in South America. Its cultivation has spread throughout the humid tropics and subtropics (Rehm and Espiq, 1991). The total production of cassava in Africa has increased from 38 to 80 million tons between 1965 and 1995 (Hillocks, 2002). Cassava is an important source of energy to man and animals, it is easy to propagate and also has ability to tolerate drought and yet maintain yield. Cassava can be processed into varieties of food for man among which are *gari, fufu/akpu, starch, abacha, tapioca, kpokogari* and *lafun* (cassava flour) among the rural dwellers (IITA, 2005). The importance of cassava as a cheap source of calorie intake in human diet especially in the tropical areas of Africa, Asia and Latin America cannot be overemphasized. It serves as a source of carbohydrate in the production of animal feed (chips and pellets) and industrial raw materials such as starch and alcohol as reported by Agbetoye (1995); Agbetoye, (2003); Kawano (2000); Ali and Ogbu (2003). Cassava starch is also an important ingredient in the manufacture of dyes, drugs, chemicals, carpets and in coagulation of rubber latex. Cassava which has been previously regarded as a poor man's food is increasing in industrial and economic potential (Agbetoye, 1995). In fact there has been a revenue generation projection of about $100million from cassava in Nigeria by 2005 (Ali and Ogbu 2003).

1.1 *Gari*

Gari is a granulated, white or yellowish product - depending on production methods. It has 10 to 15% moisture content that permits a long conservation period in normal atmospheric conditions (Bencini, 1991). It has a high swelling capability and can absorb up to 4 times its volume in water. It is a popular diet eaten in many flavors:

1. In sugared water with groundnuts.

2. Transform into thick paste with hot water and eaten with a variety of sauces of vegetable, meats, fish etc.
3. As supplement to beans' preparations and a variety of sauces.

The proximate composition of a typical village *gari* in Nigeria as reported by Quenum, 2004 consists of 81.8% weight of carbohydrate, 14.4% water, 1.4% crude fiber and 0.9% crude protein. The main consumption area in Africa covers Nigeria, Benin, Togo and Ghana. The other actual Africa's consumption markets (Niger, Burkina Faso, Ivory Coast, Guinea, Chad, Gabon, Congo, and Cameroon) are marginal. In the main consumption area, 80% of the populations eat *gari* on a daily basis (together with maize flour in Benin and Togo). The remaining portion of the populations (20%) eats *gari* twice per week, with the intake per person and per day averaging 100 grams (Quenum, 2004). *Gari* is the finished product obtained by artesian or industrial processing of cassava tubers (*Manihot esculenta Crantz*). The processing consists of peeling, washing, grating of the tubers, followed by fermentation, pressing, sifting and roasting. *Gari* is presented as grains of variable granule size. Its ability to store well and its acceptance as a convenience food are responsible for its increasing popularity in urban areas of West and Central African (IITA, 1990 and FAO, 1990).

1.2 Processing of Cassava into *Gari*

The processing of cassava into gari consists of various unit operations (Figure 1). Fresh cassava roots are peeled, washed and grated. The grated pulp is put in sacks (Jute or polypropylene) and the sacks are placed under heavy stones or pressed with a hydraulic jack between wooden platforms for 3-4 days to express excess liquid from the pulp while it is fermenting. Fermentation imparts an acidic taste to the final product. The dewatered and fermented lumps of pulp are crumbled by hand and most of the fibrous matter is removed. The remaining mass is sieved with traditional sieves (made of woven splinters of cane) or iron or polyethylene mesh. After being sieved, the fine pulp is then roasted in an iron pan or earthen pot over a fire. If the sieved pulp is too wet, it takes longer time to roast resulting in a finished lumpy product with dull colour. Palm oil may be added to prevent the pulp from burning during roasting and to give a light yellow colour to the *gari*. When palm oil is not added, a white *gari* is produced. Palm oil contains substantial quantities of vitamin A; yellow *gari* is 10-30 percent more nutritious therefore more expensive than white *gari* (Quenum, 2004).

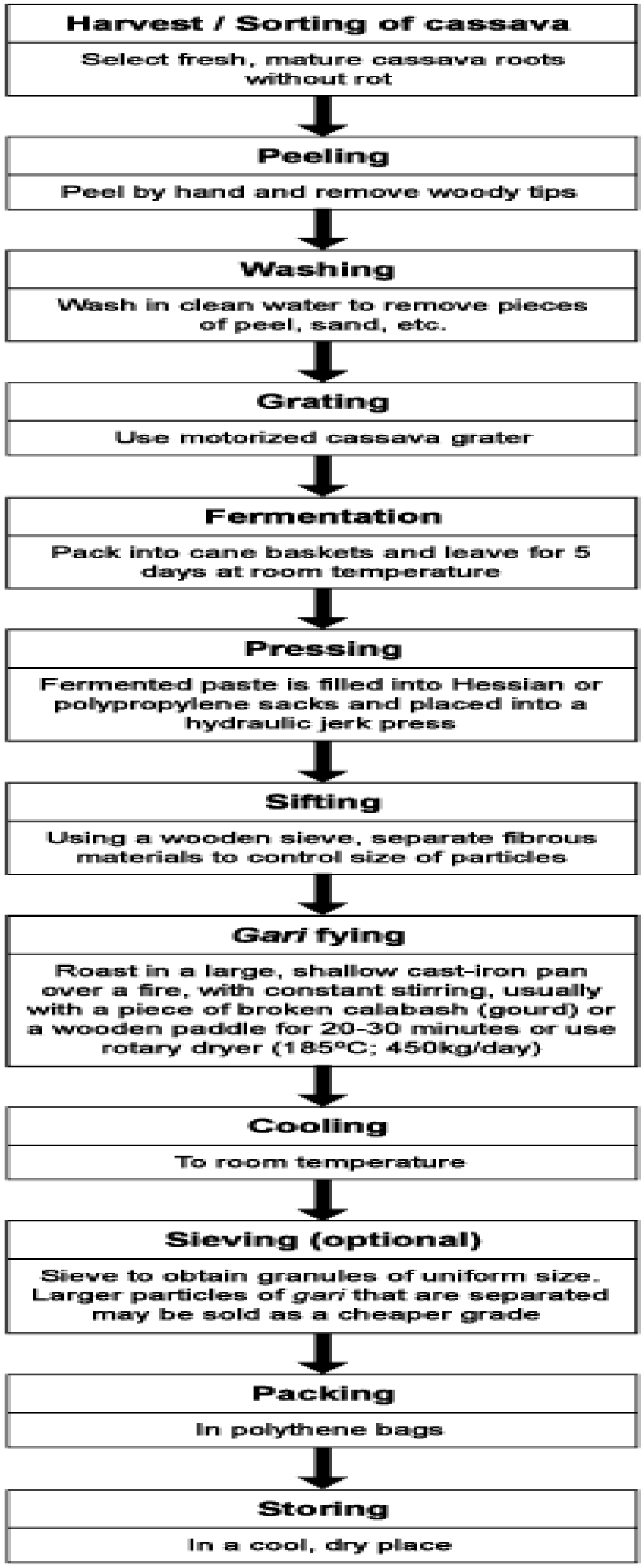


Figure 1: Processes for production of *gari* (*source: IITA, 2005)*

The *garification* or conversion rate of fresh roots into gari is 15-20 %. This value varies with cassava varieties, time of harvesting, age of plant and other environmental factors. *Gari* is very popular in Nigeria and less so in Cameroon, Benin, Togo, Ghana, Liberia, and Sierra Leone. In Brazil, this method is used for the production of "*farinha de madioca"*. The processing of *gari* from cassava has been reported by many authors as a labour demanding operation with women and children being the major producers. There is no single machine designed yet for the production of gari from fresh cassava tubers in Nigeria. However there are mechanized cassava grater and manually operated dewatering presses of various capacity, while peelers, washers, fryers and sievers are at various developmental stages. Onwueme (1978) stated that in traditional setting, only very simple hand equipment is employed in the production of *gari* like the manually operated cassava grater. The poor processing quality of *gari* emanates from the difficulty experienced in the manual processing operations (Nweke, *et al.*, 1994). The processing of cassava into *gari* is energy, time and labour consuming (Francis, 1984) and the processing is almost entirely performed by women at the house hold level or at a central location such as a village or town market place. It is estimated that at least 45% of labour requirement are accounted for by peeling and sifting.

Sifting of *gari* is also important before frying to ensure uniformity in particle size. The uniform size of particles will ensure uniform roasting during *garification* process. The final product as well must be uniform in size so as to attract good market value. The final product *gari* is also sifted after frying to separate it into chaffy, medium and coarse size particle, the sifting is necessary in order to remove the bigger grain *gari* and to make it more attractive and acceptable to the consumers. The finer grain *gari* sells at a higher price while the bigger grains are sold at a lower price. In most cases, the producer still have to grind the bigger grain *gari* and sell to avoid loss as well as to increase profit.

1.3 Classification of Gari

The particle size of *gari* ranges from below 50 μm (fine) to over 200 μm (coarse) (FAO/WHO, 1991). In practice, the quality of *gari* is judged by the degree of coarseness and moisture content (Bencini, 1991). Free–flowing, granular meal and creamy–white color (or yellow if palm oil is added) are the attributes of good *gari*. *Gari* can be classified according to their particle sizes. Gari is classified as extra-fine, medium, coarse and unclassified fractions. The finer particle grain *gari* attract good market value while the coarse grain has lesser value and are less attractive. The extra-fine *gari* will pass through a 0.50mm sieve and at least 40% by weight shall pass through a 0.25mm sieve while the coarse grain *gari* will all pass through a 2mm sieve and a maximum of 40% by weight will pass through a 1.25mm sieve as described in Codex standard for *gari* Stan 151 – 1989 as reported by FAO/WHO, 1991 shown in Table I.

Table I: Classification of Gari

S/N	Description	Limit	Method of Analysis
1.	Extra-fine gari	Min: 100% by weight shall pass through a 0.50mm sieve and MIN: 40% by weight shall pass through 0.25mm sieve.	ISO 2591, test sieving. The sieves used are AFNOR sieves with square mesh.
2.	Fine – grain gari.	MIN: 100% by weight shall pass through a 1mm sieve and max: 40% by weight shall pass through a 0.5mm sieve.	
3.	Medium grain gari	MIN: 100% by weight shall pass through a 1.25mm sieve and max: 40% by weight shall pass through 1.00mm sieve.	
4.	Coarse grain gari.	MIN: 100% by weight shall pass through a 2mm sieve and Max: 40% by weight shall pass through a 1.25mm sieve. Buyer preference.	
5.	Unclassified gari		

Source: FAO/WHO, 1991

During the *garification* process, it is observed that some factors influence the quality and acceptability of the *gari* produced in terms of particle size. These factors are the frying temperature, moisture content of dewatered pulp, frequency of stirring, and skill of the producer. If the moisture content of pulp is high; and the frying temperature is too high, the result will be a lumpy finished product. If the stirring frequency is very low, a lumpy product will result as well. However it is impossible to get a uniform particle size in the final product during a *garification* process, there is always variation in particle size due to the above stated factors. This makes the sifting of the *gari* inevitable by the producers, to make the product attractive and improve its market value. The bigger *gari* grain or lumps are milled if in large quantity (which attracts extra cost of milling) or thrown away as waste in most cases. The design of a combine *gari* post grinder-sifting machine will assist the producer to solve this problem by both sifting and grinding the bigger grain *gari*. This machine will help in reducing time wastage and drudgery in *gari* production. This work was carried out with the aim of solving the problem of extra labour requirements and economic losses associated with *gari* production through the development of a *gari* post grinder-sifting machine.

2. MATERIALS AND METHODS

2.1 Preliminary Investigation

Seven samples of gari were collected from different gari processing centre in Ogbomoso town Oyo State, Nigeria. The particle size of the *gari* was determined using British standard sieves. The result of the particle size analysis was used to determine the sieve aperture of the machine, to enhance the production of quality *gari* that will be attractive and acceptable.

2.2 Assembly of the Machine

The various basic parts of the machine are as shown in Plate 1. The machine consists of the hopper, sieving unit, grinding unit, electric motor mounted on a frame. All the necessary joints are carefully done using the right joining method and materials. Some component parts were joined with bolts and nuts, while others were welded with the right filler material.

2.3 Operation of the Machine

The complete machine assembly as shown in Plate 1 is powered by an electric motor bolted to a slotted table which aids the tensioning of the belt. Apart from the pulley of the driver (electric motor) the machine has two additional pulleys one is double groove and the other a single groove. The electric motor pulley drives the double groove pulley while this in turn drives the single groove pulley of the grinding machine. The double groove pulley is keyed to camshaft which runs parallel under the sieve trough. The cam is always in direct contact with the sieve trough base. Hook attachment are incorporated at mid-point of sieve trough and the frame top, this allow the fixing of extension to keep the trough in constant contact with cam during operation. From the cam the sieving unit receives the power which results in the reciprocating motion that makes the gari to fall into the chamber and pass out through the outlet.

Plate 1: Assembly Diagram

2.4 Performance Test

The machine was tested at various loadings ranging from 1.0 to 10.0 kg. The quantity of gari for each loading levels were weighed and recorded. This was poured into the sieving unit and properly spread out. The machine was operated until the gari was completely sieved with the oversized gari grains falling into the grinder. The time taken for sifting and grinding to be completed was noted and recorded. The samples collected from both sieve and grinding machine was weighed and recorded. These procedures were repeated for other loading levels. The performance criteria of the machine that were evaluated are sifting capacity (SC), sifting efficiency (SE), grinding efficiency (GE) and total loss.

The sifting capacity is the rate at which the machine sieves the gari poured on the sieve and was calculated:

$$SC = \frac{M}{t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where:

SC	=	Sifting capacity (Kg/hr)
M	=	Mass of gari loaded into the sieve (kg)
T	=	Time for the sifting to be completed (hr)

The sifting efficiency (SE) is defined as the percentage mass of fine gari separated after sifting and is calculated as

$$SE = \frac{M - C}{M} \; X\, 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where:

SE	=	Sifting efficiency (%)
M	=	Mass of gari loaded into the sieve (Kg)

C = Mass of bigger gari grain that falls into grinder (Kg)

Grinding efficiency is defined as the percentage by mass of bigger gari grain that falls into grinding machine over output of gari from the grinding machine, and is calculated as:

$$GE = \frac{Output}{Input} \qquad \text{……………………………………………… (3)}$$

Where:

GE = Grinding Efficiency (%)
Output = Grinded gari (Kg)
Input = Bigger gari grain that fall into grinding machine (Kg)

Total loss of gari grain during the operation is the difference between the mass of gari loaded and the sum of the mass of sieved gari and the collected fine grain gari from the grinder

$$Total\,loss = \frac{m+c}{M}\ X\,100 \qquad \text{…………………………………. (4)}$$

Where:

m = Mass of sieved gari (Kg)
c = Mass of bigger gari grain (Kg)
M = Mass of gari loaded into the sieve (Kg)

2.5 Statistical Analysis

The data obtained were subjected to statistical analysis using SPSS 15.0 statistical packages. A one-way analysis of variance (ANOVA) was carried out to determine differences and Duncan's multiple range tests to separate means.

3. RESULTS AND DISCUSSION

3.1 Preliminary Investigations

The results of the preliminary investigation that was carried out are as shown in Table 2. The result reveals that out of 100kg of gari produced in any of the seven processing sites surveyed in Ogbomoso, Nigeria; about 57 to 60kg is of coarse grain gari which attract lesser market value.

Table 2: Sieve Analysis of Gari Samples Collected at Different Processing Centers

	Percentage by weight of *gari* grain retained on each sieve sizes					
Sample No	2.35mm	2.0mm	0.85mm	0.43mm	0.25mm	0.18mm
1	-	-	23.50	29.60	47.10	-
2		18.60	56.70	11.70	6.70	1.80
3	6.30	6.7	59.30	16.70	10.6	1.80
4	4.80	60.30	34.80	-		
5	1.8	3.3	32.20	16.00	6.80	2.70
6			68.10	15.30	13.70	12.90
7			60.00	24.70	12.90	2.20

This makes the sifting of the gari inevitable by the producers to make the product attractive and improve the market value, thereby increasing the profit of the producer.

3.2 Performance Evaluation of Machine

The sample used for the machine test is as shown in Plate 2, the particle size distribution of the sample used consists of 62.4% oversized grain gari when sieved using a sieve size opening of 0.707mm. The gari samples collected at the sieve and grinding outlets are as shown in Plate 3. The analysis of variance and separated means of the machine performance in terms of the sifting efficiency, sifting capacity, grinding efficiency and total loss are as presented in Table 3 and Table 4 respectively. The results showed that the machine loading has significant effect ($p<0.05$) on the sifting efficiency, sifting capacity, grinding efficiency and total loss (Table 3). The sifting efficiency decreases with loading while the sifting capacity and grinding efficiency increases with loading (Table 4).

Plate 2: Gari sample before sifting/grinding

(a)

(b)

Plate 3: Gari samples collected from (a) Sieve Outlet (b) Grinding Machine

Table 3: The Analysis of Variance for the Performance of the Post-Grinder Sifting Machine

		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Sifting efficiency	Between Groups	2114.535	9	234.948	1346.872	0.000
	Within Groups	3.489	20	0.174		
	Total	2118.024	29			
Sifting capacity	Between Groups	506.073	9	56.230	1519.739	0.000
	Within Groups	0.740	20	0.037		
	Total	506.813	29			
Grinding efficiency	Between Groups	2552.652	9	283.628	309.638	0.000
	Within Groups	18.320	20	0.916		
	Total	2570.972	29			
Total loss	Between Groups	444.073	9	49.341	1022.621	0.000
	Within Groups	0.965	20	0.048		
	Total	445.038	29			

Table 4: The Separated Means of the Performance of the Post-Grinder Sifting Machine

Sample Weight (Kg)	Sifting Efficiency (%)	Sifting Capacity (%)	Grinding Efficiency (%)	Total Loss (%)
1	85.5[g]	15.2[a]	65.0[b]	14.0[b]
2	80.1[f]	16.7[b]	69.0[c]	15.5[c]
3	64.1 [e]	19.5[c]	54.4[a]	27.3[i]
4	64.1 [e]	20.4[d]	79.0[d]	12.8[a]
5	63.5e [e]	21.5[e]	80.0[de]	15.2[c]
6	62.0[bd]	22.6[f]	80.0[de]	16.0[d]
7	62.2[d]	24.7[g]	81.0[df]	17.5[e]
8	61.3[bc]	25.5[h]	82.0[fg]	18.2[f]
9	60.8[a]	27.2[i]	83.0[gh]	18.8[g]
10	60.2[a]	28.2[j]	84.0[h]	19.2[h]

Figure 1 shows the relationship between gari loading and machine performance. The sifting efficiency decreases sharply from 1kg loading to 3 kg loading then remained almost linear up to 10kg loading. This may be due to the clogging of the sieve aperture. The highest and lowest sifting efficiency of 85.5 and 60.2% were observed at 1 and 10kg loadings respectively. The sifting capacity increases steadily with increase in loading from 15.2 to 28.2Kg/h at 1 to 10kg respectively.

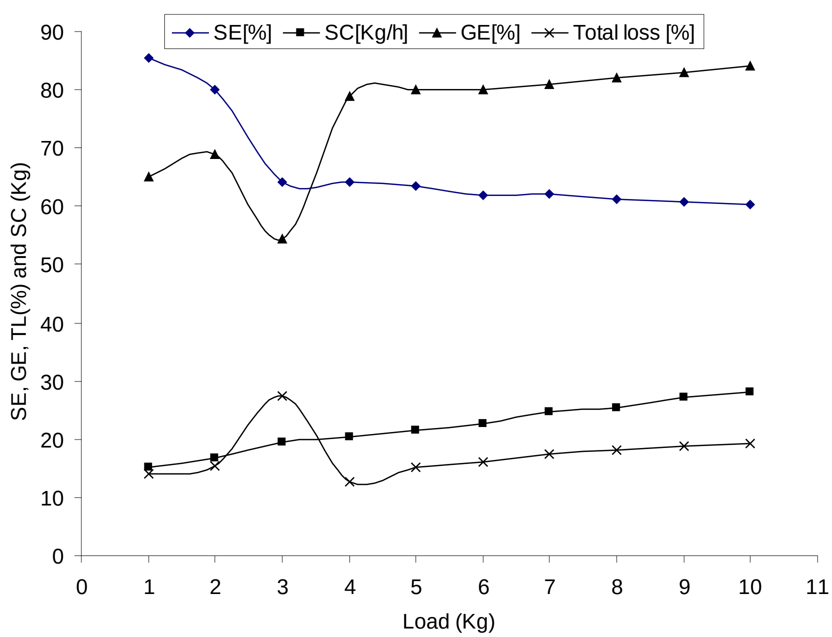


Figure 4: The relationship between loading and machine performances

Where;
SE = Sifting efficiency (%)
SC = Sifting capacity (Kg/h)
GE = Grinding efficiency (%)

The grinding efficiency decreased initially from 1 to 3kg loading, before increasing sharply from 4kg loading and then increased steadily up to 10kg loading. The lowest grinding efficiency of 54.4% was observed at the 3kg loading and the highest of 84.0% at the 10kg loading. The decrease in sifting efficiency and subsequent increase in grinding efficiency is as a result of the increase in quantity of oversized gari grains present in the samples which are retained on the screen that eventually overflows into the grinder. The highest total loss of 27.3% was observed at the 3kg loading, it decreased to 12.8% at 4kg loading and then increased up to 19.2% at 10kg loading. The higher total loss recorded at lower loading is probably due to the vibrating speed of the screen compared to the weight of the gari samples loaded resulting in more gari grain lost during the operation. These results are in agreements with the report of Agbetoye and Oyedele (2005) on the development of a dual powered gari sifter.

4. CONCLUSIONS

A machine capable of being electric motor-operated has been designed, fabricated and tested. Based on the performance evaluation of the machine, it can be concluded that modern method of sieving gari can be done more conveniently than the traditional method. The machine could be adapted to handle other low bulk density materials such as yam flour, ground spices and other powdery products. The machine can easily be dismantled and its operational and maintenance procedure is simple.

REFERENCES

Agbetoye L. A. S. 1995. Mechanics of Cassava Lifting. Unpublished Ph.D thesis, Silsoe College, Cranfield University, Bedford, United Kingdom pp. 280.

Agbetoye L. A.S. 2003. Engineering challenges in developing indigenous machinery for cassava production and processing proceedings of annual conference of the Nigerian Society of Engineers.

Agbetoye L. A. S. and Oyedele, O. A. 2005. Development and testing of dual-powered Gari Sifter. Proceedings of the Nigerian Institution of Agricultural Engineers. 27: 192-198.

Ali Y. and Ogbu C. 2003. Cassava export Ogbeh's team returns from research for markets in: The punch, Edited by Azubuike Ishiekuene, Tuesday 16th September, 2003. pp. 5

Bencini M. C. 1991. Post–harvest and processing technologies of African staple food. A Technical Compendium, FAO Agricultural Service Bulletin 89. Rome: FAO.

FAO (Food and Agriculture Organization) 1990. Roots, tubers, plantains and bananas in human nutrition. Food and Agricultural Organisation of the United Nations, Rome Italy, Pp 59-64

FAO/WHO 1991 Food standard programme. Codex Alimentarius Commission XII, supplement $,FAO, Rome Italy

Francis, O. F. 1984. A Study of Problems involved in Traditional Processing of Cassava into Gari with Reference to Mechanization in Ibadan. Unpublished HND Thesis Report, I.A.R. And T Ibadan. Pp 2.

Hillocks A. G. 2002. An Introduction to tropical food science, Canada, Johnwilley.

IITA International Institute of Tropical Agriculture 1990: Cassava Tropica Africa: International Institute of Tropical Agriculture,Ibadan, Nigeria pp 87, 98, 95.

IITA 2005. The uses of Cassava. Published by the Integrated Cassava Project of the International Institute of Tropical Agriculture.

Kawano K. 2000. Cassava as a source of animal feed and income generation of Agriculture, Kobe University, Japan 24(1): 123 – 124.

Nweke F. I., Dixon A. G. O., Asiedu A. and Folayan S. A. 1994. Cassava varietals needs of farmers and the potential for production growth in Africa, pp 231:89.

Onwueme I. C. 1978. Utilization of fresh cassava and gari. The Tropical Tuber Crops. 2nd edition. John Willey and Sons Limited, Chester. Pp 145 – 149.

Quenum B.M. 2004. Investment and business planners Africabiz 1(61) Africabiz online.

Rehm T. J. and Espiq B. C. 1991. Agriculture and Economic Development in Africa, Decal.

TRACTOR AND TRACTOR OPERATOR CHARACTERISTICS AND CONDITIONS IN THE EASTERN AND GREATER ACCRA REGIONS OF GHANA

Edward A. Baryeh
Agricultural Engineering Department, University of Ghana, Legon, Accra, Ghana.
bar4zone@yahoo.com, eabaryeh@ug.edu.gh

ABSTRACT

Agricultural tractor operator characteristics and conditions were studied using questionnaires. It was found that 4.7%, 16%, 52%, 28% and 4% of tractor operators were below 30 years, from 31 to 40 years, from 41 to 50 years, from 51 to 60 years and over 60 years respectively with 40% having primary or no education and 60% with secondary education. Fifty five percent had been operating tractors for 11 to 20 years. The tractors had an average age of 15 years with engine power from 20 to 100 kW. All the tractors were used for land preparation and transportation. The study revealed that 40% of the tractors studied were Massey-Ferguson, 30% were Farmtrac and the rest were other European and Asian made tractors. The study further indicated that 66% of the tractors studied were bought new, 58% had good headlights, 66% had working turn signal lights, 46% had good parking lights, 48% had working brake lights, 68% had good tyres, 60% had good brakes, 40% had PTO shaft protector guards, 76% had mounting steps, 64% had good bodies and 54% had good seats. None of them had operator cabin cover and 53.3% had good dashboard lights. The operator workplace dimensions were adequate and levers, pedals and controls were conveniently located in 92% of the tractors. Tractor noise levels were found to be above European Community limits. The noise when ploughing at a speed of 6.5 km/h ranged from 97.5 to 106.2 dB(A) for engine power range of 20 to 100 kW. This noise range and tractor vibrations are high enough to affect operator health and hearing. Maintenance and repair were irregular due to lack of education, information and money. This together with the high tractor average age results in environmental pollution and accident prone tractors.

KEYWORDS*:* Tractor, operator, maintenance, training, noise, safety, health, controls, accident

1. INTRODUCTION

Agricultural tractors in Ghana are bought new or used (second hand) and they do not have maintenance books. Hence the maintenance history is often unknown making it difficult to assess the actual tractor condition. Sometimes maintenance is neglected due to ignorance, lack of resources and absence of maintenance workshops within the immediate vicinity of the farmstead.

Good safety practice in product production and farm machinery operation and regular maintenance reduce farm machinery accidents and extends machine life. According to Whitney (1988) cleaning and periodic maintenance of tractors is very essential in enhancing their service life, while Bukhari *et al* (1987) posited that if due attention is not given to proper and timely repair and maintenance of a tractor, it will naturally not give the desired service. The Agricultural Training Board (1985), Hammer (1991) and Mufti *et al* (1989) have given tractor accident statistics in the United Kingdom, Germany and Pakistan respectively. Statistics for tractor accidents due to tractor condition are however, not readily available in most developing countries including Ghana. Nevertheless, it is believed that the accident situation may be worse than in the industrialised countries due to the high percentage of illiteracy and poverty in developing countries compared to the industrialised ones.

Many farms in Ghana are small and family owned and run. Tractors owned by individuals are operated by owners, owner's relatives or hired operators, while those owned by farming companies, organizations and cooperatives are operated solely by hired operators. Tractors comprise old and new ones. Tractors that are old and not well maintained may be dangerous on the road and farm and unsafe for the operator and other road users. If the operator's seat and workplace are uncomfortable and tractor controls are not within operator's reach, he/she will perform below optimum, incur excessive stress and fatigue resulting in possible increase of accidents and loss of money. Operators may also be exposed to harsh climatic conditions like heat, noise, exhaust gases and vibrations, subjecting them to stress, premature fatigue, accidents and occupational diseases. According to Hornick (1961) and Baryeh *et al* (2003), environmental conditions like temperature, relative humidity and dust seriously affect the performance of tractor operators.

Tractor conditions in Ghana have not been studied extensively. The study presented here utilised questionnaires to survey tractor operators' and tractor characteristics and working conditions in the Eastern and Greater Accra Regions of Ghana. The survey will alert the Government, agro-industrial companies, schools, farmers and other stake holders about present tractor and tractor operator conditions and what to do to improve the conditions.

2. MATERIALS AND METHODS

The study was conducted on 150 tractor operators and 90 tractors in the Eastern and Greater Accra Regions of Ghana. Data was obtained using a two part questionnaire. The first part was composed of close-ended questions on the personal characteristics of the tractor operators covering age, gender, marital status, education and training in tractor operation. The second part comprised open-ended questions on the tractors they operate. The questions covered tractor characteristics (like make, type, engine power, year of registration, main dimensions); utilization characteristics (like type of operation, type of maintenance, work duration, main repairs carried out); conditions of tyres, lighting system, brakes, controls (like steering wheel, levers, pedals); safety conditions and protective devices; noise level and operators' comfort (like seat, reach of controls, access and exit conditions). Open-ended questions were used on the tractors because they allowed follow-up questions to obtain detailed or specific responses.

Tractor engine idling, moving and ploughing operation noise levels were determined using Quest Technologie Impulse Sound Level Metre model 2700 with 20 to 140 dB(A) range, equipped with model OB-50 octave filter set. Noise levels were measured 1 m from the tractor engine and at the operator's ear. Steering tests were conducted using a Hoffmann dynamometer steering wheel. Breaking tests were achieved by measuring the distance covered by tractor before coming to a stop from a speed of 5 km/h on a firm untarred ground after brake application.

3. RESULTS AND DISCUSSION

3.1 Characteristics of the Operators

Ten percent of the operators were found to be tractor owners, 28% were relatives of tractor owners and the rest were hired operators. Hence the majority of the tractors were operated by hired operators. About a fifth of the hired operators were hired by farming companies, while the rest were hired by individual farmers. Some of the operators are relatives of tractor owners because most farms are family owned. None of the operators was female.

Table 1 shows some personal characteristics of the operators. The table indicates that seven of the operators were below 30 years of age, 34% were from 31 to 40, 50% were from 41 to 50, 10% from 51 to 60 and 2 above 60 years. The highest percentage of operators was those from 31 to 50 years because younger people are not interested in farming, do not have enough savings to buy a tractor, and are often not credit worthy to borrow from financial institutions to purchase tractors. People below 30 years are often working, schooling or unemployed. All the operators were married with 3 to 8 children.

Table 1. Characteristics of Tractor Operators

Age (years)	Number	Percentage
Below 30	7	4.7
31 – 40	51	34
41 – 50	75	50
51 – 60	15	10
Above 60	2	1.3
Total	150	100
Education	Number	Percentage
None	15	10
Primary	45	30
Junior secondary	78	52
Senior secondary	12	8
University	0	0
Total	150	100

Ten percent of the operators were illiterates, 30% had primary school education and 52% had junior secondary school education. Most people with senior secondary education proceed to some tertiary institution for further studies rather than entering into the agricultural industry. None of them had university education. The operator educational level was thus generally low. Furthermore, only 22% and 16% had formal tractor operation and service management training respectively. These account partly for the infrequent maintenance and repair of tractors. The rest learnt to operate tractors privately on their farms. In contrast, Balasankari and Saloke (1999) have stated in a study in India that only 12.5% of operators were trained in the use and maintenance of tractors. Twenty eight percent of the operators had operated tractors for less than 10 years, 55% for 11 to 20 years and 17% for 21 to 30 years.

3.2 Characteristics of the Tractors

All the tractors studied had Diesel engines. Sixty six percent were bought new and the remaining 34% were bought second hand (used). Ninety percent were insured contrary to studies in Botswana which revealed that all the tractors were not insured (Baryeh and Rakine, 2003) although in both countries the law requires tractors to be insured. The popular make of tractors were Massey-Ferguson (40%) and Farmtrac (30%). Ford and John Deere made up 12%. The remaining 18% were tractors from China, Japan and India. This trend is reflected in the fact that Massey-Ferguson and Farmtrac have dealers who sell and service these makes locally, so operators do not travel long distances to buy or service them. The age and power characteristics of the tractors are displayed in Figures 1 and 2. The average age was 15 years and 21.3% were over 20 years. Those from 5 to 10 years accounted for 22.7% and 11 to 15 years was 35.3%. Only 6% and 4% were less than 5 years and more than 35 years old respectively.

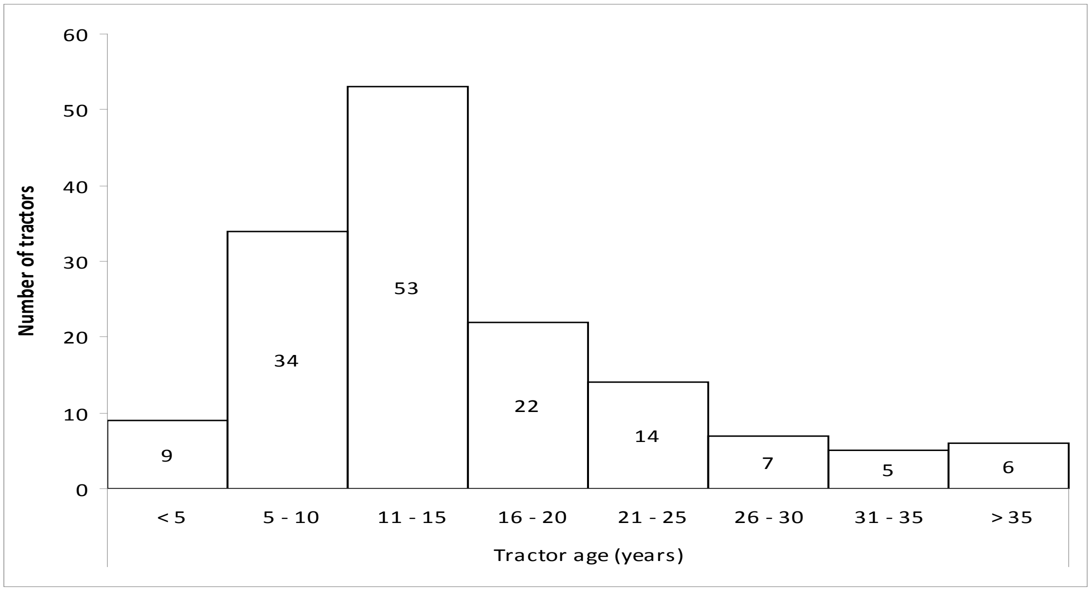


Figure 1. Tractor number variation with tractor age

The management of old tractors is often uneconomical and they may be dangerous on the roads and unsafe for the operators and other road users, mainly because of deterioration of their performance (Febo and Pesena, 1995). The power ranged from 20 to 100 kW with 76% having 20 to 59 kW and only 4% having more than 79 kW. All of them were duly. Since the machines are used off the highway some of the operators did not think it was necessary to license them although it is against the law not to license them. This is not advisable and careless because accidents occur on the farm and off the highway too, and it could occur during the few times they are on the highway. According to Shippen *et al* (1987), each year there are many farm accidents on or about farms when people are killed or injured due to carelessness, ignorance and lack of proper maintenance of farm machinery. Hammer (1991) has also reported that 34% of all tractor accidents in 1988 in Germany were off the farm.

All the tractors were used for land preparation and transportation of farm products to markets or storage centres. In addition, 28% were used for planting and 12% for the dangerous and illegal activity of transporting people. The average time used for land preparation and planting per day was 6.8 hours. Cultivation was done by 38% of the operators who had cultivating equipment, while the others hired them. Fifty two percent of the tractors were hired out to farmers who did not own tractors. Most of the tractors were used during the farming season. Outside this season they are mostly idle or used for transportation. The machines were generally found to be underutilised. Tractors in Botswana and other developing countries have also been found to be underutilized (Patrick *et al*, 2002).

Other characteristics were as follows:

- Number of forward and reverse gear speeds ranged from 6 to 8 and 1 to 3 respectively
- Maximum forward speeds ranged from 20 to 40 km/h
- All the tractors had PTO rotational speed of 540 rpm
- Eight percent had mechanical brakes while 92% had hydraulic brakes
- All the tractors had hydraulic steering
- All the tractors had mechanical hand brakes
- All of them had open operator cabin with no air conditioning

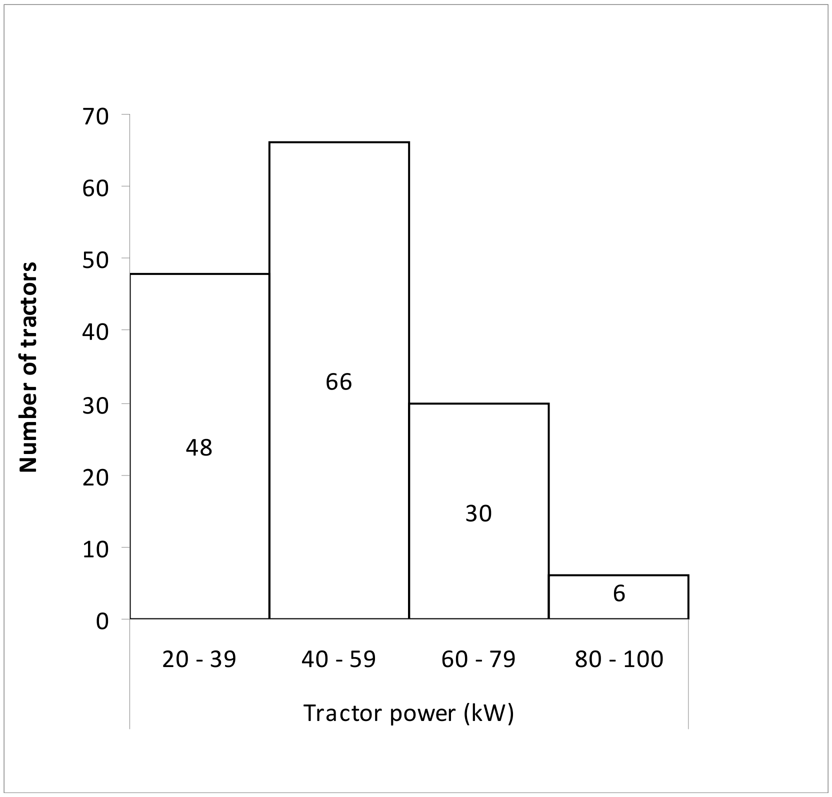


Figure 2. Number of tractors against tractor power

3.3 Condition of the Tractors

Table 2 displays the lighting condition of the tractors. The headlight, turn signal light, parking light, brake light and dashboard light are shown in the table. A Likert scale of 1 to 5 is used for the table with 1 = very good, 2 = good, 3 = moderate, 4 = poor and 5 = very poor. Sixty percent of the tractors had very good or good headlights, while 18% had poor or very poor ones; 40% had very good or good turn signal lights, while 30% had poor or very poor ones; 66% had very good or good parking lights, while 26.6% had poor or very poor ones; 60% had good or very good brake lights and the rest had moderate to very poor ones; 55.3% had very good or good dashboard lights, while 14.7% had moderate ones and the rest had poor or very poor ones. Some of the dashboard lights had varying degrees of dimness. Some headlights were dim, had no high and low beams, had cracked glass cover or had no glass cover. Some of the other lights also had no glass cover or cracked cover plates.

Table 2: Lighting conditions

Type of lighting	1	2	3	4	5
Headlight	42(28%)	48(32%)	33(22%)	15(10%)	12(8%)
Turn signal light	21(14%)	39(26%)	25(30%)	24(16%)	21(14%)
Parking light	30(20%)	36(24%)	44(29.4%)	27(18%)	13(8.6%)
Brake light	33(22%)	57(38%)	24(16%)	21(14%)	15(10%)
Dashboard light	45(30%)	38(25.3%)	22(14.7%)	15(10%)	30(20%)

1 = very good; 2 = good; 3 = moderate; 4 = poor; 5 = very poor.

In general 22% to 30% had unsatisfactory lighting despite the presence of regulations making it compulsory for tractors to go for road worthy test once a year. Poor lighting conditions make the machines prone to accidents and hazardous for operators. Some operators do not pay much attention to these because they operate mostly away from the highways and they ignorantly think they are saving money by not replacing bad lights. The tractors with bad lighting systems were generally over 20 years old.

Table 3 displays tractor age and the presence or absence of lights. The figures on the table show the numbers of tractors with or without certain lights. It reveals that the tractor lighting condition generally deteriorated with increase in age. It also shows that in some cases, the tractors did not have certain lights. The absence of lights were more common with machines that were over 21 years old, while those that were 20 years old or less had most of the lights. The table reveals that 86.6%, 80%, 79.3%, 72% and 74% had headlights, turn signal lights, parking lights, break lights and dashboard lights respectively. Tractors would not have poor lighting systems if they were maintained regularly. Poor lighting conditions were mainly due to neglect and lack of education and money. Poor lighting contributes to poor safety and increased hazard for operators and pedestrians.

Table 3. Presence and Absence of Lighting

Tractor age (years)	Headlight		Turn signal light		Parking light		Brake light		Dash-board light	
	P	A	P	A	P	A	P	A	P	A
Less than 5	9	-	9	-	9	-	9	-	9	-
5 - 10	22	2	32	2	34	-	30	4	31	3
11 - 15	53	-	50	3	48	5	45	8	53	-
16 - 20	18	4	19	3	17	5	18	4	14	8
21 - 25	10	4	8	6	7	7	5	9	2	12
26 - 30	5	2	2	5	2	5	1	6	1	6
31 - 35	2	3	-	5	1	4	-	5	1	4
Over 35	1	5	-	6	1	5	-	6	-	6
Total	130	20	120	30	119	31	108	42	111	39

The tyre conditions were reasonably good because 69% were in very good and good conditions, while 20% were in poor and very poor conditions. The rest were moderate. Tyres with at least 75% of original lug height remaining on them were classified as very good and good. Those with 25% or less of the original lug height remaining were classified as poor and very poor. The increase of tyre wear with hours of work was linear. Tyre wear also increased with tractor age but in a non linear manner. This agrees with findings by Febo and Pessena (1995) working on some Italian tractors.

Sixty eight percent of the tractors had very good and good brakes, while 24% had poor and very poor brakes. Tractors with very good and good brakes stopped within 2 m from a speed of 6.5 kmh^{-1} when brakes were applied. Those with poor and very poor brakes stopped in 4 m or more under the same conditions. The rest had moderate brakes. Fourteen percent of the tractors had no brake pedal locking devices to ensure even braking and simultaneous brake application of left and right wheels. Those with poor and very poor brakes were over 20 years old, while those with very good and good brakes were less than 15 years old. Some of the tractors with poor or very poor brakes had the brake locks completely missing or broken. These were again found on tractors that were over 20 years old. Poor and very poor brakes are also hazardous to both operators and pedestrians.

Eighty eight percent of the tractors had PTO shaft protector guards on them. Out of this, 86% were in good condition and the rest were either cracked or twisted. Those without guards did not have them at the time of second hand purchase.

Mounting and dismounting steps were found on all the tractors except six. All those with mounting steps had one or two steps between the ground and the platform for the feet. About 18% of those with mounting and dismounting steps had twisted or cracked steps. Four of those without mounting steps were not provided with steps by the manufacturer because of the tractor size, while the remainder had their steps broken. The distance between the ground and the step was 47.5 to 55.8 cm with a mean of 51.8 cm for those with one step. The distance between the step and foot platform was 15.6 to 21.4 cm with a mean of 18.5 cm, while the width of the step was 13 to 20 cm with a mean of 15.2 cm. Those with two steps had the first step between 51 and 56 cm with a mean of 53.8 cm, and the second step was 78.5 to 82.6 cm with a mean of 82.2 cm above the ground with an inter-step distance of 25 to 32 cm with a mean of 27.5 cm. The width of the steps was between 14 and 19 cm with a mean of 15.5 cm. Location of steps is very crucial in reducing mounting and dismounting accidents. Hammer (1991) has reported that 49% of tractor accidents in 1985 in Germany were related to mounting and dismounting. Operators often jump off tractors without mounting and dismounting steps when dismounting and sometimes run into accidents. Some of them even jump down when the tractor is equipped with mounting steps. Hammer (1991) further posited that the height of the first step above the ground should not exceed 40 cm and the interstep distance should lie between 12 and 30 cm to enhance safety and reduce accidents. The length and width of steps ranged from 21.5 to 36 cm with a mean of 26.8 cm and 10.5 to 22 cm with a mean of 14.2 cm respectively. It has been suggested that the length of the steps must be at least 40 cm (Hammer, 1991).

None of the tractors had a cab for the operator. Operators were therefore exposed to the scorching sun, dust, exhaust gases and noise. Tractors in most African countries do not have operator cab, while in the industrialized countries the majority of tractors are furnished with cabs (Baryeh, 1982). It was found that 56% had good bodies, 26% had slight body dents and 18% had poor or very poor bodies (with some rusty and/or torn bodies). Those with very good or good bodies were less than 16 years old, while those with poor or very poor bodies were over 18 years old. Nonetheless, 80% had good mud guards. The very poor and poor mud guards were rusty, cracked or torn.

All the seats had vinyl covering. Seat adjustment was not working in 15% of the tractors mainly due to rust and lack of lubrication. Most of them had been operated by the same operator for several years so they did not need to be adjusted. It was found that 48% had very good or good seats, 32% had moderately good seats with patches or stitches and the rest had very poor or poor seats which were torn with bits of the seat filling material (plastic foam) missing or sticking out. Tractors with poor or very poor seats were over 20 years old, while those with very good and good seats were less than 15 years old. The seat dimensions ranged from 42 to 47.5 cm in width with a mean of 45 cm and 32 to 40 cm in depth with a mean of 35 cm. The back rest dimensions ranged from 25 to 35 cm in height with a mean of 30 cm and 37 to 46 cm in width with a mean of 40 cm. According to Gite and Yadav (1989) the dimensions of seats and location of controls are useful in designing tractor workplace. The location of controls should be such that they are accessible to the operator from his safety and comfort viewpoint (Arude *et al,* 1999). Seventy six percent had good steering while 24% had steering with some backlash. Levers, pedals and controls were good in 90% of the tractors while 10% had worn out or stiff pedals and pedals which exhibited some play. The older tractors were in the category with poor levers and pedals. Such poor or very poor pedals were found in old and non-regularly maintained tractors. All the tractors had levers and pedals in place contrary to the findings of Febo and Pessina (1995) in which 8 out of 96 tractors studied in Italy had some levers and pedals of some important controls reduced to stumps.

The operator workplace dimensions are displayed in figure 3 and table 4. The table gives the minimum, mean and maximum values of the dimensions shown in figure 3.

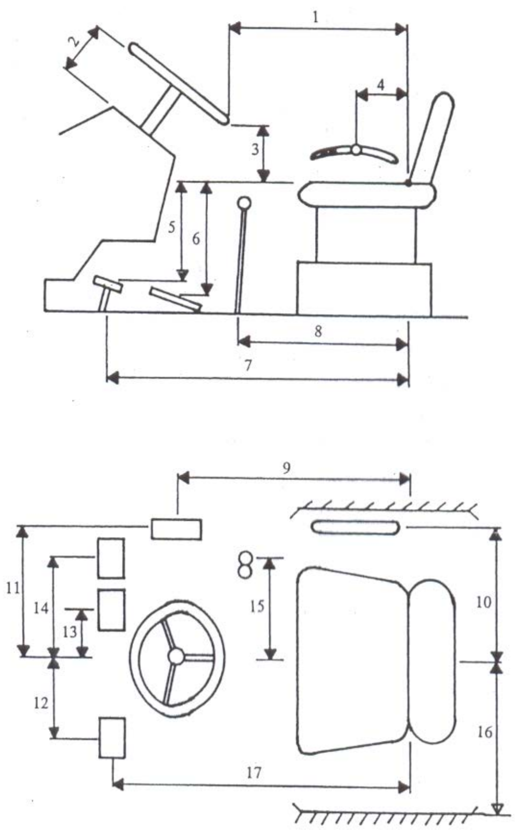


Figure 3: Dimensions of operator workplace and location of controls

Table 4. Dimensions of Operator Workplace

Dimension	Measured (cm)			ISO limits (cm)	
	Minimum	Average	Maximum	Minimum	Maximum
1	51.0	62.3	72.0	57.5	67.5
2	8.0	15.3	18.5	5.0	-
3	15.0	18.5	20.2	np	Np
4	16.0	18.0	23.0	np	Np
5	39.0	41.0	55.0	np	Np
6	44.0	47.0	52.0	np	Np
7	53.0	72.0	84.0	np	Np
8	48.0	68.0	75.0	np	Np
9	57.0	68.0	83.0	np	Np
10	33.0	38.0	45.0	-	40.0
11	28.0	36.3	45.0	-	40.0
12	24.0	27.8	36.0	7.5	30.0
13	15.0	22.2	24.0	7.5	-
14	26.0	28.0	35.0	-	30.0
15	0.0	2.0	8.0	-	35.0
16	44.0	45.0	48.0	45.0	-
17	65.0	74.0	90.0	np	Np
Steer	35.0	36.5	48.0	np	Np

np = not provided

The dimensions have been compared, where possible, with the International Standards Organisation (ISO) standards 4252-4253. The mean dimensions compare favourably with the provided ISO standards. They also compare favourably with values reported by Arude *et al* (1999) for some Indian tractors. About one third of them also agree with results reported by Febo and Pessina (1995) for some Italian tractors. These do not, however, correlate with tractor age. There is a difference of 21 cm or more between the maximum and minimum values of dimensions 1, 7, 8, 9 and 17. The rest have disparities of less than 17 cm. The distances for the gear levers from the operator's seat were 10 to 15 cm with a mean of 13 cm. There were two levers with 20% located beside the seat, 30% in front of the seat and 50% between the operator's legs. Steering wheel diameter varied from 35 to 48 cm with an average of 36.5 cm. Steering column angle with the horizontal varied from 55^0 to 65^0 with a mean of 61.5^0 which compares reasonably well with the average of 62.8^0 reported by Arude *et al* (1999). The steering wheels of 56% of the tractors required an effort of 30 to 70 N to turn when the mass on the steering axle is 1.5 t because of age and irregular or lack of maintenance. In comparison, a new tractor requires a force of 25 to 40 N for the same mass on the steering axle (Febo and Pessena, 1995). The operator workplace was generally spacious enough. Steering wheel, hydraulic lever, brakes, clutch and accelerator lever were generally conveniently placed in 92% of the tractors. The remaining 8% had some of these pedals and levers located too close to the central longitudinal plane of the machine.

Tractor noise level variation with tractor power for various conditions is displayed in figures 4. The figure also displays the noise levels of new tractors and the EC limits for comparison. The second hand (used) tractor noise level for both stationary and moving tractors were always higher than those of new tractors. The used tractor noise levels for stationary and moving situations vary linearly from 90.4 to 89.4 dB(A) and 91.6 to 94.5 dB(A), respectively as the tractor power changes from 20 to 100 kW. When the tractor is ploughing, it changes linearly from 98.6 to 104.1 dB(A) for the same power range. These levels are a bit higher than those reported by Febo and Pessena (1995) but compares with those reported by Pazzona and Murgia (1993) both on Italian tractors. All noise levels recorded in the study are above the EC limits and normal hearing levels. Hence prolonged tractor operation may affect the hearing of operators. Figure 5 displays tractor noise as a function of age. It reveals that tractor noise increases with tractor age. The increase is gentle up to 15 years for ploughing noise and then increases more rapidly with increase in age thereafter.

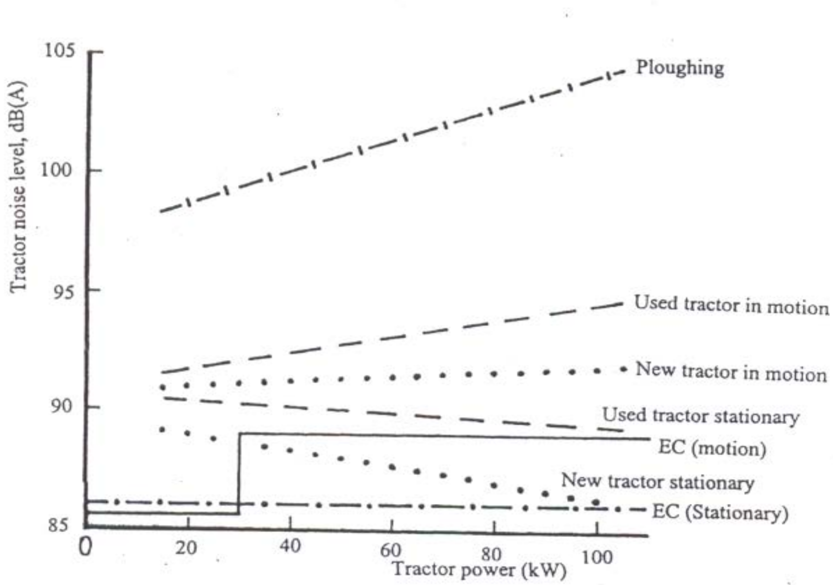


Figure 4: Tractor noise level variation with tractor power (new tractor noise level copied from Febo and Pessina, 1995)

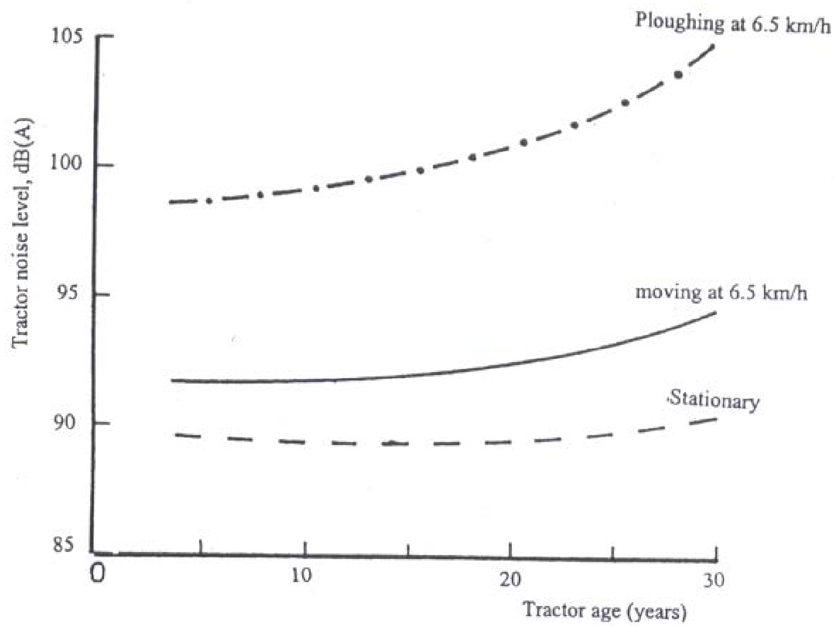


Figure 5: Tractor noise level variation with tractor age

All the tractors had good batteries. Seven tractors had faulty starters. The study revealed that 78% of the tractors were serviced at home or on the farm by tractor owners or operators. The remainders were serviced at the dealers' or tractor garages. Servicing was however irregular. Those serviced at home or on the farm are mostly owned by individuals, while those serviced at the dealers' or tractor garages are mostly company owned. The servicing at home or on the farm involved mainly the change of engine oil. Oil and air filters were not changed regularly mainly due to ignorance. Therefore servicing at home and on the farm was inadequate. Servicing at the dealer's or tractor garages was better done. Studies in India show that 45% of the farmers do tractor repair and maintenance at the dealer's garage[8]. Servicing frequency was, however very erratic in 86% of the tractors due to lack of education, information and money. Tractor owners and operators did not attach much importance to servicing, or could not write down servicing dates and schedules in order to follow them. Lack of money, education and information made them do the minimum maintenance that will enable the tractors to function. This made them neglect regular care and maintenance of tractors and the devices fitted to prevent accidents or guarantee efficient ergonomic performance. Some even left tractors running until they quit before attending to them. Other researchers have also found uneducated and very lowly educated farmers to be negligent with machine maintenance and servicing (Taiwo, 1987; Bhutta *et al*, 1997). It was found that 48% had oil leakage around the engine and oil sump. All such btractors were over 12 years old. Most of the older tractors without such oil leakage had had their engines overhauled. The most frequently repair problems encountered were those related to the ignition switch, starter, injection pump, cooling system and engine in descending order of frequency. These problems were more common with machines that were over 15 years old.

4. CONCLUSION

The characteristics of 150 tractor operators and conditions of 150 tractors in the Eastern and Greater Accra Regions of Ghana have been studied using questionnaires and interviews. The study has shown that most of the tractor operators are over 31 years old and they have little or no education. The physical, mechanical and electrical conditions of the tractors were found to be generally very good or good for tractors which were less than 15 years old and poor or very poor for tractors which were over 20 years old. Poor and very poor conditions of tractors were mainly due to lack of maintenance of tractors, lack of education of operators and poor financial situation of some tractor owners. Dimensions of operator workplace were generally good and pedals, levers and controls were conveniently located in 90% of the tractors. Tractor noise was generally above EC limits. This investigation may be extended further to find out the frequency of tractor accidents and the relation of accidents to tractor maintenance.

REFERENCES

Agricultural Training Board 1985. How to make the most of your tractor. Intermediate Technology Publication.

Arude V. G., Tewari V. K., Pacharne DT 1999. Location of controls and operator activities in Indian tractors. AMA 30(3):19-22.

Balasankari P. K., Saloke V. M. 1999. A case study of tractor utilisation by farmers, Coimbatore District, India. AMA 20(3):14-18.

Baryeh E. A. 1982. Mechanising West African agriculture. Approtech 5(4)**:**79-85.

Baryeh E. A., Mazwiduma P. J., Koloka O. A. 2003. Hazard assessment of tractor operators engaged in food production in Botswana. Food, Agriculture & Environment 1(3&4)**:**295-299.

Baryeh E. A., Raikane O. B. 2003. Farm tractor conditions in Botswana. AMA 34(3)**:**61-66.

Bhutta M. S., Tanveer T., Awan H. M. 1997. Technical skill of tractor operators – a case study in Multan, Pakistan. AMA 28(1)**:**18-22.

Bukhari S., Ali N. M., Baloch J. M. 1987. Factors affecting repair and maintenance costs of farm tractors. AMA 18(3):29-32.

Febo P., Pesina D. 1995. Survey of the working condition of used tractors in Northern Italy. J Agric Eng Res 62:193-202.

Gite LP, Yadav BG 1989. Anthropometric survey for agricultural machine design. Applied Ergonomics 20(3)**:**191-196.

Hammer W. 1991. Safe access to farm tractors and trailers. J Agric Eng Res 50**:**219-237

Hornick R. J. 1961. Effect of tractor vibration on operators. Agric Eng 42(12)**:**696-697.

Mufti A. I., Majid A., Ahmal S. I. 1989. Farm accidents in Pakistan. AMA 20(1)**:**73-77.

Patrick C., Baryeh E. A., Tapela M. 2002. Agricultural tractor ownership and off-season utilization in the Kgatleng District of Botswana. AMA 33(3)**:**65-69.

Pazzona A., Murgia L. 1993. Estimation of noise-induced hearing impaired risk in sheep dairy farming. J Agric Eng Res 55**:**107-112.

Shippen J. M., Ellin C. R., Clover C. H. 1987. Basic farm machinery. Pergamon Press, Oxford.

Taiwo, A. A. 1987. Agricultural machinery inventory, type and condition in Nigeria, 1975-1985. AMA, 20(4):36-42.

Whitney, B. 1988. Choosing and Using Farm Machines. British Library Cataloguing in Publication Data, pp 221.

GUIDE FOR AUTHORS

Publication Schedule: The Journal of Agricultural Engineering and Technology (JAET) is published annually by the Nigerian Institution of Agricultural Engineers (NIAE), A division of the Nigerian Society of Engineers (NSE).

Manuscript: The manuscript should be typed double spaced on A4 paper (216mm x 279mm) on one side of the paper only, with left, right and top-bottom margins of 25.4mm. The original and three copies are required for initial submission. The paper should not exceed 20 pages including Figures and Tables.

Organization of the Manuscript: The manuscript should be organized in the following order; Title, Author's name and address including E-mail address and telephone number; Abstract; Keywords; Introduction; Materials and Methods; Results and Discussion; Conclusion; Notation (if any); Acknowledgements; References. The main headings listed above should be capitalized and left justified. The sub-headings should be in lower case letters and should also be left justified. Sub-sub headings should be in italics. All headings, sub-headings and sub-sub-headings should be in bold font. Headings and sub-headings should be identified with numbers such as 1; 1.1; 1.1.1 etc. For the sub headings, the first letter of every word should be capitalized.

Title: The title should be as short as possible, usually not more than 14 words. Use words that can be used for indexing. In the case of multiple authors, the names should be identified with superscripted numbers and the addresses listed according to the numbers, e.g. A. P. Onwualu[1] and G. B. Musa[2].

Abstract: An abstract not exceeding 400 words should be provided. This should give a short outline of the problem, methods, major findings and recommendations.

Keywords: There should be keywords that can be used for indexing. A maximum of 5 words is allowed.

Introduction: The introduction should provide background information on the problem including recent or current references to work done by previous researchers. It should end with the objectives and contribution of the work.

Materials and Methods: This section can vary depending on the nature of the paper. For papers involving experiments, the methods, experimental design and details of the procedure should be given such that another researcher can verify it. Standard procedures however should not be presented. Rather, authors should refer to other sources. This section should also contain description of equipment and statistical analysis where applicable. For a paper that involves theoretical analysis, this is where the theory is presented.

Results and Discussion: Results give details of what has been achieved, presented in descriptive, tabular or graphical forms. Discussions on the other hand, describe ways the data, graphs and other illustrations have served to provide answers to questions and describe problem areas as previously discussed under introduction.

Conclusion: Conclusion should present the highlights of the solutions obtained. It should be a brief summary stating what the investigation was about, the major result obtained and whether the result were conclusive and recommendations for future work, if any.

Notation: A list of symbols and abbreviation should be provided even though each of them should be explained in the place where it is used.

References: Follow the name-date system in the text, example: Ajibola (1992) for a single author; Echiegu and Ghaly (1992) for double authors and Musa et al. (1992) for multiple authors. All references cited must be listed in alphabetical order. Reference to two or more papers published in the same year by the same author or authors should be distinguished by appending alphabets to the year e.g. Ige (1990a, 1992b). All references cited in the text must be listed under section "References". For Journal, the order of listing should be author's name, year of publication, title of paper, name of journal, volume number, pages of the article: for books, the author's name comes first followed by the date, title of book, edition, publisher, town or city of publication and page or pages involved. Examples are as follows:

Journal Articles: Ezeike, G. O. I. 1992. How to Reference a Journal. J. Agric Engr and Technology. 3(1): 210-205

Conference Papers: Echiegu, E. A. and Onwualu A. P. 1992. Fundamentals of Journal Article Referencing. NSAE paper No 92-0089. Nigerian Society of Agricultural Engineers Annual Meeting, University of Abuja, Abuja – Nigeria.

Books: Ajibola O. 1992. NSAE: Book of abstracts. NSAE: Publishers. Oba. Abakaliki, Nigeria.

Book Chapter: Mohamed S. J., Musa H. and Okonkwo, P. I., Ergonomics of referencing. In: E. I. U. Nwuba (Editor), Ergonomics of Farm Tools. Ebonyi Publishing Company, Oshogbo, Osun State, Nigeria.

Tables: Tables should be numbered by Arabic numerals e.g. Table 3 in ascending order as reference is made to them in the text. The same data cannot be shown in both Table and Figure. Use Table format to create tables. The caption should be self explanatory, typed in lower case letters (with the first letter of each word capitalized) and placed above the table. Tables must be referred to in the text, and positioned at their appropriate location, not at the end of the paper.

Figures: Illustrations may be in the form of graphs, line drawings, diagrams schematics and photographs. They are numbered in Arabic numerals e.g. Figure 5.m. The title should be placed below the figure. Figures should be adequately labeled. All Figures and photographs should be computer generated or scanned and placed at their appropriate locations, not at the end of the paper.

Units: All units in the text, tables and figures must conform to the International System of units (SI)

Reviewing: All papers will be peer reviewed by three reviewers to be appointed by the Editors. The editors collate the reviewers' reports and add their own. The Editor-In-Chief's decision on any paper is final.

Off Prints: A copy of the journal is supplied free of charge to the author(s). Additional reprints can be obtained at current charges.

Page Charges: The journal charges a processing fee of N1000 and page charges are currently N500 per journal page. When a paper is found publishable, the author is advised on the page charges but processing fee (non refundable) must be paid on initial paper submission. These charges are subject to change without notice.

Submission of Manuscript: Submission of an article for publication implies that it has not been previously published and is not being considered for publication elsewhere. Four copies of the manuscript and N1000 processing fee should be sent to:

The Editor-In-Chief
Journal of Agricultural Engineering and Technology (JAET)
C/o The Editorial Office
National Centre for Agricultural Mechanization (NCAM)
P.M.B. 1525, Ilorin, Kwara State
Nigeria.