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MAN, MATERIAL AND MACHINE: THE TRICYCLE FOR AGRICULTURAL MECHANIZATION

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MAN, MATERIAL AND MACHINE: THE TRICYCLE FOR AGRICULTURAL MECHANIZATION

The Vice-Chancellor,
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Distinguished Members of Senate,
Eminent Scholars and Academic Staff,
My Lord Spiritual and Temporal;
Members of My Immediate and Extended Families,
Invited Guests,
Members of the University Community,
Gentlemen of the Press,
Distinguished Ladies and Gentlemen,
Great FUNAABITES!

Preamble:

"If, I dig with my hands, the crust of the earth, my hands will blister and bleed. If between my hands and the soil, I interpose a spade, then out of the labour of my body, the crust is broken and my hands remain whole". Moreover, "Let a machine be interposed between the man and the spade; the machine labours, the spade cuts, the field is tilled and the man is spared to turn his attention to other tasks, to higher levels of human endeavour". Surely, this is one of the most effective ways to "restore the dignity of man" (Odigboh 1985).

Mr. Vice-Chancellor, Sir,
I am highly honoured, humbled and count it a rare privilege to stand before this great audience to deliver the **51st** Inaugural Lecture of this University, the **Fourth** in the College of Engineering and the **Second** in the Department of Agricultural Engineering.

The dictionary meaning of inaugural is *"concerning inauguration", the verb of which is "to inaugurate" which in turn means to introduce (someone important) into a new place or job by holding a special ceremony, to start (a public affair) with a ceremony; or to be the beginning of something (especially an important period of time).*

An Inaugural Lecture is an essential feature of an academic institution. It is an opportunity for a new Professor to showcase his or her claim to scholarship. It is an occasion of significance in an academic career as it provides a forum to inform colleagues, the academic community and the general public of his/her work to-date including current research and future plans. This Inaugural Lecture series makes an important contribution on the role of the University within the wider community as a forum for public enlightment. I am giving this lecture; three years, four months and seventeen days after attaining the rank of Professor of Agricultural Mechanization of this great institution. Therefore, I am excited to deliver the lecture.

The focus of my research for the past two decades is on the development of agricultural machines that bring convenience to farmers and crop processors. Mr. Vice-Chancellor, Sir, distinguished colleagues, ladies and gentlemen, permit me therefore, to address you on the topic **"Man, Material and Machine: The Tricycle For Agricultural Mechanization"**

1.0 INTRODUCTION

1.1 Man

Man is a triune being. He is a spirit; he has a soul and lives in a body. Man in this context, is an agricultural engineer whose spirit communes with a higher spirit (God) and receives inspiration or revelation which he converts to design and development. His mind or soul, which is the human faculty of reasoning and logic, is trained in science and engineering principles and he applies them to solve agricultural challenges. He uses his physical body or strength as a source of power on the farm.

Man operates essentially like a heat engine, with built-in overload controls or regulators. He converts chemical energy input in the form of food into energy output, part of which is useful for doing work. On the average, a healthy person in temperate climate consumes energy at a sustainable rate of only about 300 W, while in tropical climate, as a result of heat stress, the rate is reduced to 250 W (CIGR, 1999). In another word, man, for the purpose of this lecture, is the inaugural lecturer of today, who has been trained in the field of engineering and is applying the knowledge in the design and development of machines that bring convenience to agriculture.

1.1.1 Engineering

Engineering comes from the Latin word, *INGENIUM* meaning natural capacity and invention. The American Engineers' Council for Professional Development defined Engineering as "The creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behaviour under specific operating conditions; all in respect of an intended function, economics of operation or safety to life and property" as the case may be (AECPD, 1980).

The Professional Engineer by virtue of his fundamental education and training is competent to apply scientific methods and outlook to the analysis and solution of engineering problems. He is able to assume personal responsibility for the development and application of engineering science and knowledge. In due time, he would be able to give authoritative technical advice and assume responsibility for important tasks of his/her branch of engineering (Olorunnisola, 2007).

The branch of Engineering in which I obtained my first, second and third degrees and for which I am recognized by the Council for the Regulation of Engineering in Nigeria (COREN) is Agricultural Engineering. To appreciate the application of Agricultural Engineering principles in this presentation, I will briefly define Agricultural Engineering and briefly outline its functions in the society.

1.1.2 Agricultural Engineering

Agricultural Engineering is a specialized branch of Engineering which deals with the application of Engineering Science and Technology to agricultural production with the aim of reducing complexity and increasing productivity. Agricultural production is faced with a number of challenges and problems, such as, druggery of crops and livestock production; poor storage and processing facilities; efficient management of resources required for production such as land, sufficient water, adequate energy, ideal waste disposal and utilization.

Agricultural engineering combines the basic engineering knowledge from three major disciplines (Civil, Mechanical and Electrical Engineering) and applies it to agriculture. This makes Agricultural Engineering very versatile branch in engineering discipline. It is concerned with the utilization of all branches of engineering science and technology in the art, science and business of crop production, animal husbandry, as well as handling, processing, preservation, storage, manufacturing and distribution of products that feed, shelter and clothe mankind (Lucas and Falade, 1992)

Agricultural Engineering can be divided into six major areas of specialisations, namely: Farm Power and Machinery Engineering, Soil and Water Engineering, Processing or Post Harvest Engineering, Farm Structures and Environmental Control Engineering, Forestry and Wood Product Engineering and Food Engineering. Other areas that are emerging from the specialisations are Amenity (Ecological) Engineering, Mechatronics and Robotics Engineering, Information and Communication Technology, Biotechnology, Renewable Energy and Environmental Engineering (Ajisegiri and Sobowale, 2012).

Farm power and machinery engineering focuses on the design, construction, operation and maintenance of power and machinery systems needed for all aspects of Agricultural Mechanization. The power aspect refers to the development of all prime movers and power sources for all phases of agricultural production, processing and distribution. These include tractors, electric motors, stationary engines, generators, pumps, truck engines, solar energy, wind mills and hydro power systems. The machinery aspect handles the machines used for production, which may or may not be powered by the power units mentioned above, i.e., machines/machineries for land clearing, tillage, planting, tending (weeding and spraying), harvesting and transportation.

Soil and water engineering deals with the harnessing and management of the soil and water resources of the ecosystem. The area include land degradation, soil and water conservation, land reclamation, irrigation technology, land drainage systems, water supply, catchment modeling, hydrology and hydraulics, agricultural waste management and environment. Others include the design, construction, installation, operation and management of engineering structures and machines required in the areas listed above. Some of the structures include: dams, canals, erosion control structures, reservoirs, boreholes, irrigation pumps, etc.

Post harvest engineering deals with all the activities, processes, structures and machines which convert agricultural raw materials (harvested crops) into semi-finished consumer goods. It covers the area of value addition to crops with the aim of converting them to more usable form or extends the storage/shelf life. Specialists in this aspect handle the design, construction, operation and management of machines and structures which carry out the following operations: cleaning, sorting, separation, cooling and drying, size reduction, pelleting, extruding, expelling, refining, extraction, etc. In carrying out all these processes, the material has to be conveyed from one point to the other especially in crop/food processing factories. In this case, machines for conveyance, discharging and packaging are very essential.

Farm structures and environmental control engineering deals with the design and construction of all structures that are used in agricultural production. The structures include farm roads, residential buildings, livestock pens, warehouses for storage and food processing, implement sheds and farm shops, storage structures, holding bays for produce. The other aspect of the option deals with the control of environmental factors in farm buildings such as temperature, humidity, light and air. Agricultural waste management is also an important part of the option and it includes waste treatment and recycling, bio gas production, waste conversion etc.

Food engineering is a specialized area of agricultural engineering which deals with the processes and machineries that are required for processing agricultural products into consumable foods. Areas covered by this option include operation of feed mills, rice mills, flour mills, vegetable oil processing, beverage manufacturing, and confectionary machines for baking and sweet production. In general, it involves the operation and management of food processing facilities and equipment.

Wood products and forestry engineering deals with the machines required for exploiting forest products such as timber and non-timber products. It also handles machinery for afforestation such as loggers, tree fellers/pushers, etc.

Emerging areas in agricultural engineering: The discipline of agricultural engineering is currently undergoing major and important changes as it responds to new developments and challenges. These emerging areas include: Information and communication technology (ICT); Biotechnology; Environmental engineering, Renewable energy, Ecological engineering. Information and communication technology involves the use of computer and communications equipment for data acquisition, machine control, information management, GIS in agriculture, precision farming and simulation of agricultural systems. It enables information on genes, data bank on crops and similar data to be compiled/uploaded on the internet. Biotechnology involves the engineering of biological materials. Applications include gene manipulation, waste recycling, fermentation, vegetable-based fuels, etc. These require specialized equipment such as reactors and sensors. Environmental engineering involves all activities concerned with the conservation of the environment and most of the associated challenges are addressed in this area. Another area is Renewable energy systems. These include the processing and utilization of solar, water and wind energy for agricultural production, processing and handling. New projects in this area have addressed control of animal and that of the environment using solar and wind energy for power generation. Others include alternative bio-fuels for internal combustion engines and optimization of energy systems.

1.2 Material

Material is the substance or substances of which an object is made or composed. Material handling is the art and science of conveying, elevating, positioning, transporting, packaging and storing of materials. Plant materials exhibit some properties that are physical, aerodynamic, mechanical, and thermal in nature. The Yoruba tribe of the South Western part of Nigeria understands the import of engineering properties in material handling and this is exhibited in one of their proverbs, "Ipa ti apa tete, a ko le pa dagunro, nitoripe dagunro o se pa", meaning: there are different approaches of handling different materials (soft or hard; smooth or rough). The physical properties of agricultural materials are those properties that lend themselves to description and quantification by physical means. These properties include the linear dimensions, size, shape, bulk and true densities, porosity, weight and volume. Others are angle of repose, specific gravity, color and coefficient of friction (Peleg and Bagly, 1982).

According to Mohsenin (1986), the mechanical properties of a material describe how it will react to physical forces. It is the aggregate of indexes that characterize the resistance of a material to a load acting on it, the degree to which it will deform under the load and its behaviuor in the process of failure. These occur as a result of the physical properties inherent in each material and are determined through a series of standardized mechanical tests. The knowledge of these properties constitutes an essential engineering data in the design of machines, structures, processes and control, in analysing the performance and the efficiency of a machine, as well as in developing new consumer products (Mohsenin, 1986).

1.3 Machine

The word *machine* derives from the Latin word *machina.* A **machine** is a tool containing one or more parts that uses energy to perform an intended action. Machines are usually powered by mechanical, chemical, thermal, or electrical means, and are often motorized. Historically, a power tool also required moving parts to classify as a machine. However, the advent of electronics has led to the development of power tools without moving parts that are considered machines. A simple machine is a device that simply transforms the direction or magnitude of a force, but a large number of more complex machines exist. Examples include vehicles, electronic systems, molecular machines, computers, television, and radio.

1.3.1 Engineering design

Engineering design is a creative activity undertaken by an Engineer. It is the synthesis, the putting together of ideas to achieve a desired purpose. The designer starts with a specific objective in mind, a need, and by developing and evaluating possible designs, arrives at what he considers the best way of achieving that objective.

1.3.2 Approaches to design.

The are four popular approaches to design and they are meant to reduce complications such as shown in Plate 1, where the viewing angles gave different number of objects and thus causing argument between the viewers. The approaches are:

- **KISS principle**, (Keep it Simple, Stupid), which strives to eliminate unnecessary complications as we had in Plate 1.
- **TIMTOWTDI (**There is more than one way to do it**).**

a philosophy to allow multiple methods of doing the same thing.

- **Use-centered design**, which focuses on the goals and tasks associated with the use of the artifact, rather than focusing on the end user.
- **User-centered design,** which focuses on the needs, wants, and limitations of the end user of the design.

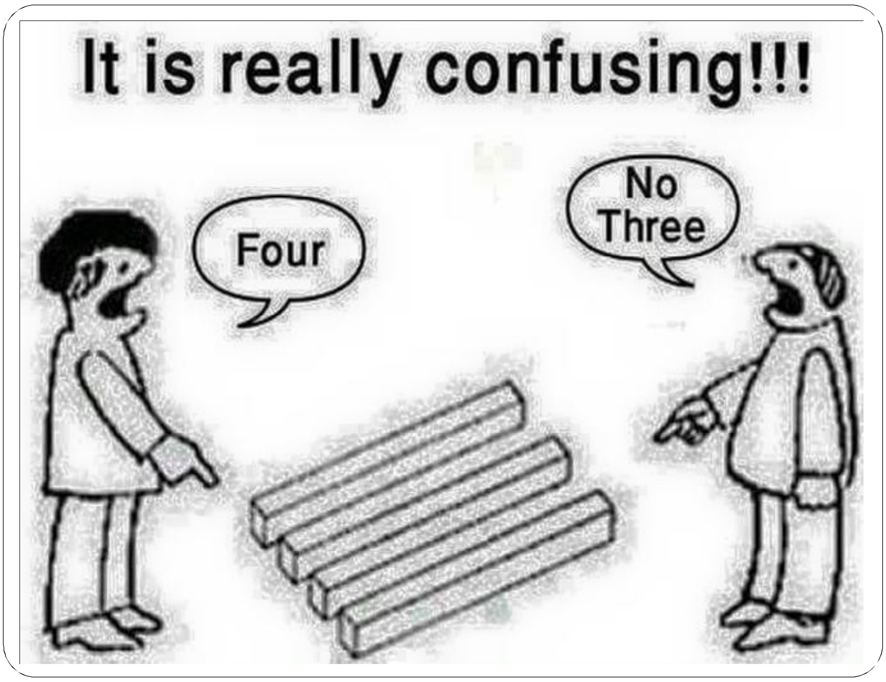


Plate 1: Complications in viewing angles

1.4 Tricycle

A **tricycle**, often abbreviated as **trike**, is a three-wheeled passenger vehicle, usually carrying a single rider. It is a motorized version of the traditional pulled rickshaw or cycle rickshaw (Plate 2). Therefore, man, material and machine are like the three wheels of a vehicle that drive Agricultural Mechanization.

Plate 2: Two different types of tricycles

1.5 Agricultural Mechanization

To mechanize means to use machine to accomplish a task or operation. A machine may be as simple as a wedge or an inclined plane, or as complex as an airplane. Igbeka (1991) defined **Mechanization** as providing human beings with machinery that assists them with the muscular requirements of work or displaces muscular work (Plate 3).

In some fields, mechanization includes the use of hand tools. In modern usage, such as in engineering or economics, mechanization implies machinery more complex than hand tools and would not include simple devices such as an un-geared horse or donkey mill. Devices that cause speed changes or changes to or from reciprocating to rotary motion, using means such as gears, pulleys or sheaves and belts, shafts, cams and cranks, usually are considered machines. After electrification, when most small machinery was no longer hand powered, mechanization was synonymous with motorized machines.

Agricultural mechanization, therefore, is the use of any machine to accomplish a task or operation involved in agricultural activities. It is clear from this definition that agriculture anywhere has always been mechanized, employing a combination of three main sources of power: human, animal and mechanical/engine, giving rise to three broad levels of agricultural mechanization technology (Odigboh, 1999).

Plate 3: The use of machine to accomplish a task or an operation
Source: Dixon, *et al.* (2015)

This is classified as hand-tool technology, (HTT); draft-animal technology, (DAT) and mechanical-power or engine-power technology (EPT), (Plates 4 to 6).

Hand-tool technology is the most basic level of agricultural mechanization, where a human being is the power source, using simple tools and implements such as hoes, machetes, sickles, wooden diggers, etc. A farmer using hand-tool technology can cultivate only about one hectare of land. He cannot do more than that because of certain scientifically established facts. Machinery, for example, multiplies this tiny power (about 0.07 kW) of a farmer into the 70 kW power of a tractor which makes possible the production of food several hundred times more than what a farmer can produce manually. Mechanisation reduces food loss and adds much more nutritional values to agricultural products than they originally had.

Effective crop production requires machines-hand tools, animal-drawn implements and engine-powered equipment. Since machines for crop production represent a substantial capital investment for individual farmers, principles and guidelines are needed for proper selection and machine management to achieve the greatest return.

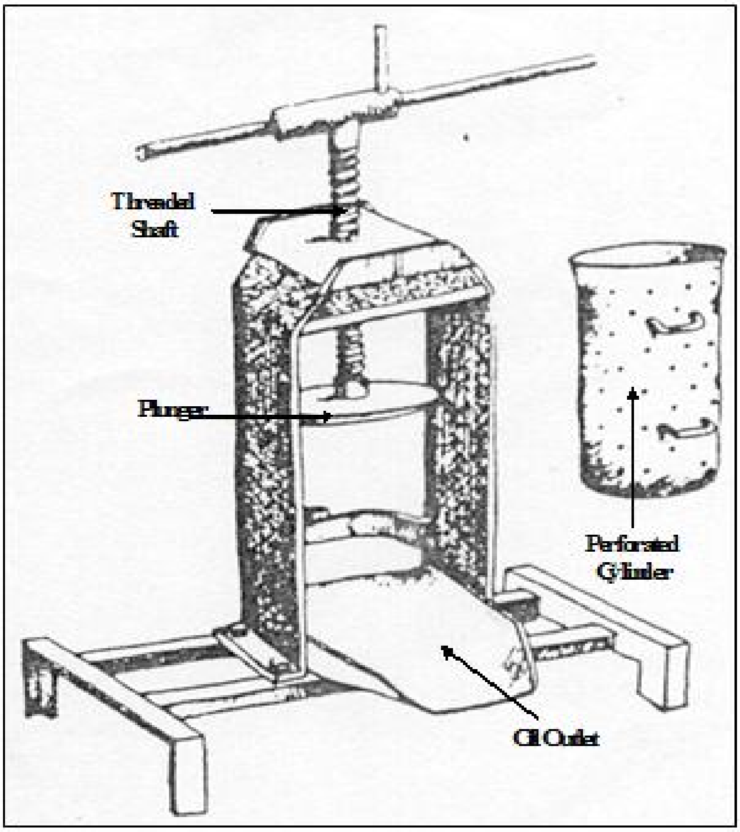


Plate 4: A screw press (Hand-Tool Technology)
Source: UNIFEM (1987)

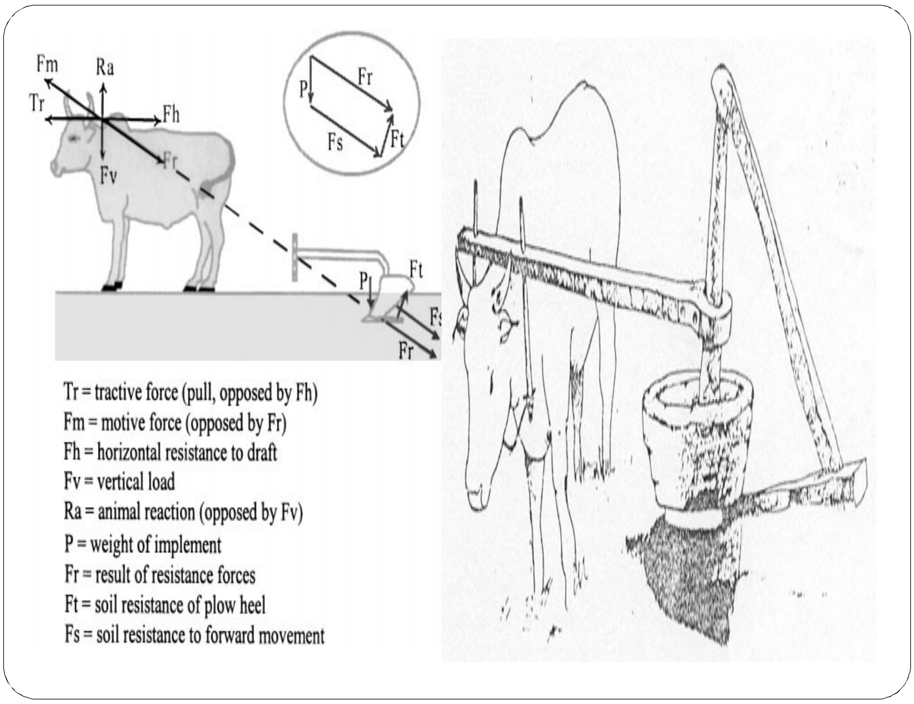


Plate 5: Traditional animal powered plow and oilseed press (Draft-Animal Technology)
Source: UNIFEM (1987)

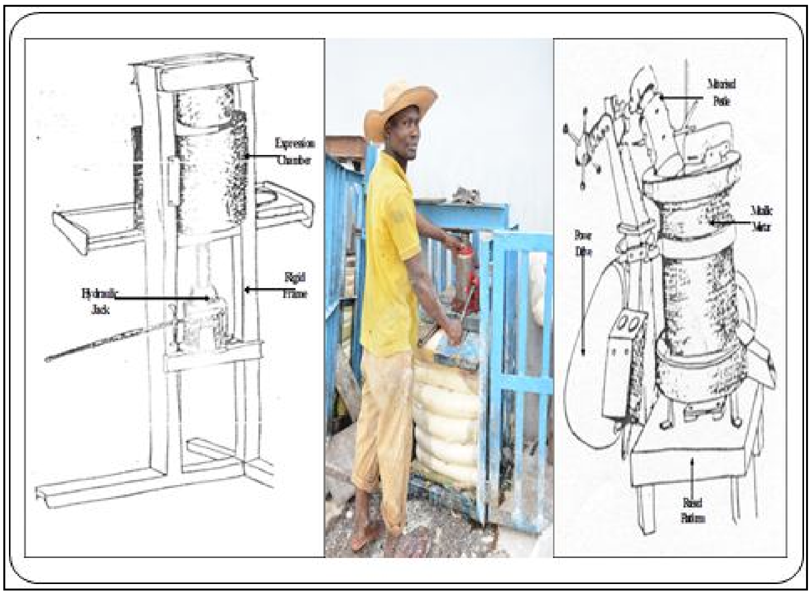


Plate 6: Hydraulic and engine powered press (Mechanical or Engine Power – Technology) Source: UNIFEM (1987)

1.6 Mechanization of post-harvest operations

Post-harvest operations refer to those activities undertaken to transport, process, transform, preserve or store harvested agricultural products in order to enhance their economic value by increasing their nutritional value and availability over time and space and therefore, their price or market value. The relevant activities include such unit operations as threshing, cleaning, sizing, shelling, peeling, grating, cutting, slicing, chipping, grinding, milling, comminuting, cooking, drying, pasteurising, fermentation, handling and transporting. Although some authorities treat threshing together with harvesting (of cereals especially), at the level of operation of small-holder farmers, it is considered more appropriate to treat threshing as a post-harvest operation because the two activities are quite separate (CIGR, 1999).

Naturally, small-holder or peasant farmers form the majority of those who use the human-powered tools and machines, especially the tools for post-harvest operations. Some post-harvest unit operations for certain crops, such as peeling of cassava or extraction of melon (egusi) seeds from the pod, can be performed using only hand tools because viable machines for them, human-powered or otherwise, simply do not exist. In such cases, there is really no choice but to live with the inherent tedium and low efficiency. But because of the nature of the majority of post-harvest operations involved, small-to-medium-scale commercial farmers, and even non-farmers, also use the human-powered tools and especially, machines, to some advantage.

Nevertheless, the fact of the situation is that, given the natural limitations of human-powered machines (tedium, low power, low capacity, and low efficiency), most human-powered machines for post-harvest unit operations have motorized counterparts, powered by electric motors or internal combustion engines. Of course, motorized machines are preferred by small-scale commercial farmers, or by non-farmers who use them mostly to serve peasant farmers, who naturally prefer the custom services to the tedium of manual operation. Nevertheless, there are literally hundreds of food products processed by peasant farmers using hand tools and human-powered machines not found in the literature. Many of them are specific to certain localities outside of which they may not be known even in the same country. As already stated, manual processing of these products is time-consuming and tedious; the conditions prevalent at this level of operation generally are unsanitary and inherently unhygienic, with little attention paid to quality control, making the wholesomeness and quality of the products, perforce, variable and uncertain. Furthermore, new agricultural technology is also expected to help reduce environmental destruction.

2.0 MY RESEARCH CONTRIBUTIONS

My research focus in the past two decades has been on the development of agricultural machines with special emphasis on the study of Engineering Properties of Agricultural Materials and Design of Processing Machines. I have participated in mechanizing the processing of the following fruits, oilseeds, and cereals: oranges (Olayanju, 1997, Olayanju and Ajuebor, 2004); groundnut (Olayanju, 1992; Olayanju *et al,* 2003a), beniseed (Olayanju, 2002; Olayanju *et al.,* 2003b), palm fruits (Olayanju *et al.,* 2002; Akinoso, 2006a; 2006b and Akinoso *et* *al.,* 2008), maize (Olayanju and Asiru, 2003), soybean (Olayanju *et. al.,* 2006a) and cowpea (Aderinlewo *et. al.*, 2011; Ola *et al.,* 2014).

As a Research Engineer at the Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos, I engaged in the development of machines for beniseed (*Sesamum indicum*) processing. As at that time, there was no serious commercial production/ processing of the seed which is one of the mandate crops of the Institute. Processing the seed in this country was expected to add value to it, create employment and eventually lead to the development of production of the oil.

In the light of this, I focused on the development of machines that would assist the small-scale farmers and oilseed processors increase their productivities, and with less drudgery. This was achieved by coming up with a package of low level equipment those farmers and processors can afford. The components of the package would assist in the area of cleaning (Akinoso *et al.,* 2010a) dehulling and debittering (Olayanju *et al.,* 2003c), expelling (Olayanju, 2004; Olayanju *et al.,* 2004a) and filtering of the oil (Olayanju *et al.,* 2004b).

Some of these machines were developed based on some determined physical properties of the seed (Lucas and Olayanju, 2003; Olayanju, 2003a), mechanical properties (Olayanju and

Lucas, 2004) and aerodynamic properties (Olayanju *et al.,* 2009a). Also the effect of moisture content and wormshaft speed on expeller capacity (Olayanju, 2003b), oil and cake qualities (Olayanju, 2003c) and oil recovery from the seed (Olayanju *et al.,* 2006b) were studied.

Further work on the thermal characteristics as related to its drying (Dairo and Olayanju, 2012) as well as modeling, optimization, colour determination and storage of oil expressed from the seed respectively were carried out (Akinoso *et al.,* 2006c, 2006d, 2006e, and 2010b)

The International Department for Food, DFID and Pro-Poor Opportunity Commodity Markets, PrOpCom in 2007 funded a research work on the assessment of the status of small rice threshers in Nigeria (Adewumi *et al.,* 2007, Olayanju *et al.,.* 2009b). As a follow up to the assessment, Olayanju *et al.,* (2009c) and (2009d) developed a thresher and a cleaner for the seed.

The Delta State Oil Producing Area Development Commissiom, DESOPADEC in 2008 funded another research work on cassava multiplication and utilisation (Okuneye *et al.,* 2008). Also, as a follow up to this work, a gari fryer, a cassava pelletiser and a cassava chip dryer were developed (Asiru *et al.,* 2010; Olayanju *et al.,* 2012a, 2012b, and 2012c).

Recent contributions were made in the area of bio – diesel production such as development of an *in – situ* batch equipment for biodiesel production (Dairo, 2011a), provision of useful information on process factors that determine yield of biodiesel from castor oilseed and characterization of biodiesel produced from castor seed (Dairo *et al.* 2011b and 2011c), and jatropha seed (Dairo, 2012a; 2012b) as well as status of bamboo production in Nigeria (Olayanju *et al.,* 2011).

Sir, I hereby proceed to discuss my humble contributions on development of machines for processing **three** of these agricultural commodities – **beniseed, ofada rice and cassava.**

2.1. Production and industrial potentials of beniseed

According to Olowe and Olayanju (2005), beniseed (sesame seed) has a long history of cultivation and utilization in some agricultural zones of the country. The production and utilization scenario of the seed had been that of era of production mainly for exports, to that of limited household processing and utilization, and now to that of medium to large – scale industrial processing coupled with expanded export promotion drives.

The Raw Materials Research and Development Council (RMRDC) commissioned a baseline survey on beniseed, among other agro raw materials in Nigeria. The main objective was to collect information on the crop from the areas of endowment for production, agronomic practices, production level, industrial/specifications for beniseed-based products, indigenous and modern technology available for conversion into these products, historical development, present situation and developmental strategies as well as factors militating against optimal production and utilization of beniseed in Nigeria (RMRDC, 2004).

The survey revealed that beniseed has high economic potentials in Nigeria both as source of raw materials for the vegetable oil industry and as a reliable foreign exchange earner. It was estimated that about 334,685 hectares is currently under beniseed cultivation in Nigeria out of 3.5 million hectares of arable land suitable for its cultivation. The survey report put the National outputs for the year 2000, 2001, 2002, 2003, and 2004 (projected) at 77870.9 mt, 80,478.1 mt, 86980.4 mt, 65776.5 mt and 93250.7 mt, respectively. With these figures, the prospect for local sourcing of beniseed as an industrial raw material in Nigeria was assured. The seed is marketed at both the urban and rural markets .The rural markets are mainly for domestic consumption while the urban markets are controlled by middlemen and buying agents for export trade. Prices are generally lower during the on season compared to off-season.

However, earlier research has shown that beniseed has bitter taste and the hull contains oxalic acid (about 2-3%) which reacts with calcium and thus reduces calcium availability from the seed (Kinsella and Mohite, 1983). Therefore, the Federal Ministry of Science and Technology in 1984 formed an inter-institutional beniseed task force consisting of the Institute of Agricultural Research (I.A.R), Samaru; Federal Polytechnic, Idah; Federal Institute of Industrial Research, Oshodi (FIIRO); Benue Polytechnic and the University of Ibadan (Oresanya, and Koleoso, 1990).

One of the tasks assigned to the body was for FIIRO, Lagos to develop technology and machinery for dehulling and expressing oil from the seed. The Federal Institute of Industrial Research, Oshodi, as reported by Odunfa and Oresanya (1998) has developed a process for cleaning, debittering, dehulling, drying and expressing oil from the seed (Figure 1).

2.2 Physico-mechanical properties of beniseed

The Federal Institute of Industrial Research, Oshodi, as reported by Olayanju *et al.,* (2003c) had developed a mechanical dehuller that can handle up to 10kg of beniseed per batch of 10 minutes. However, there is a need to study the physical and mechanical properties of the seed before the development of oil processing plant and studies of factors affecting oil expression from the seed as well as modeling and optimisation of those factors. A series of experiments were then carried out. The levels and range of independent variables in various studies were selected on the basis of review of literature and preliminary experiments conducted as shown in Table 1.

The knowledge of the physical properties of beniseed like any other biomaterial is fundamental because mechanical, rheological, thermal and other properties depend on them. Therefore, Lucas and Olayanju (2003) determined some of the physical properties of the seed as they relate to mechanical oil expression. The selected properties were major diameter, intermediate diameter, minor diameter, geometric mean size, sphericity, bulk density, true density, porosity and thousand-kernel weight. These were determined at moisture content levels of 5.3, 10.6, 16.1, 22.4, and 28.3 per cent (wet basis).

Raw Beniseeds

↓

Cleaning

↓

Debittering

↓

Hull Separation

↓

Drying

↓

Expelling

Oil	**Cake**
↓	↓
Filtering	Drying
↓	↓
Degumming	Milling/Peletizing
↓	↓
Packaging	Storage

Figure 1: Flow chart for beniseed oil and cake production
Source: Odunfa and Oresanya (1998)

Table 1: Experimental variables and their levels

S/N Quantity Variables	Independent Variables	Dependent	Treatment	Levels	Interval	Replication
1. Spatial	Moisture	Major Diameter,mm	5	5-30	6	50
Dimensions	Content	Intermiadiate Dia,mm				
	%, wb	Minor Diameter., mm				
		Geometric Mean, mm				
		Sphericity, %				
2. Gravimetric	Moisture	Bulk Density, kg/m^3	5	5-30	6	3
Properties	Content	True Density, kg/m^3				
	%, wb	Porosity, %				
		Thousand Kernel Weight, g				
3.Compression	Moisture	Rupture Force, N	3	4 - 8	2	10
Behaviour	Content	Deformation, mm				
	%, wb	Energy, Nm				

Source: Olayanju (2002a)

2.2.1 Size and sphericity of beniseed

The three principal dimensions of two accessions of beniseed namely major, intermediate and minor diameters were determined based on standard procedures. Figure 2 shows the effect of moisture content on the size of Yandev 55 accession of beniseed. The size indices exhibit linear increase with increase in moisture content. This could be due to increase in axial dimensions while gaining moisture. A similar trend was observed for E8 accession. The sphericities of the two accessions as shown in Figure 3 decreased as the moisture content increased from 5.3 to 16.1% and then increased with a further increase in moisture content to 28.3%. The observed trend for the studied accessions could be attributed to the large increase in seed length relative to width and thickness between 5.3 and 16.1% moisture content for the two accessions. The sphericity values of beniseed for the two accessions are within the range 0.52 and 0.55. This falls within the range of 0.32 and 1.00 reported by Mohsenin (1986) for most agricultural crops. As sphericity is nearly constant within the harvest and storage moisture content of 16.1 and 5.3% wet basis, beniseed can be said to exhibit isometric shrinkage during drying. The medium sphericity values for the seed indicate characteristics not that favourable for rolling of seeds to take place and thus have practical implication in the design of processing and storage equipment, especially in handling operations such as conveying and discharge from chutes.

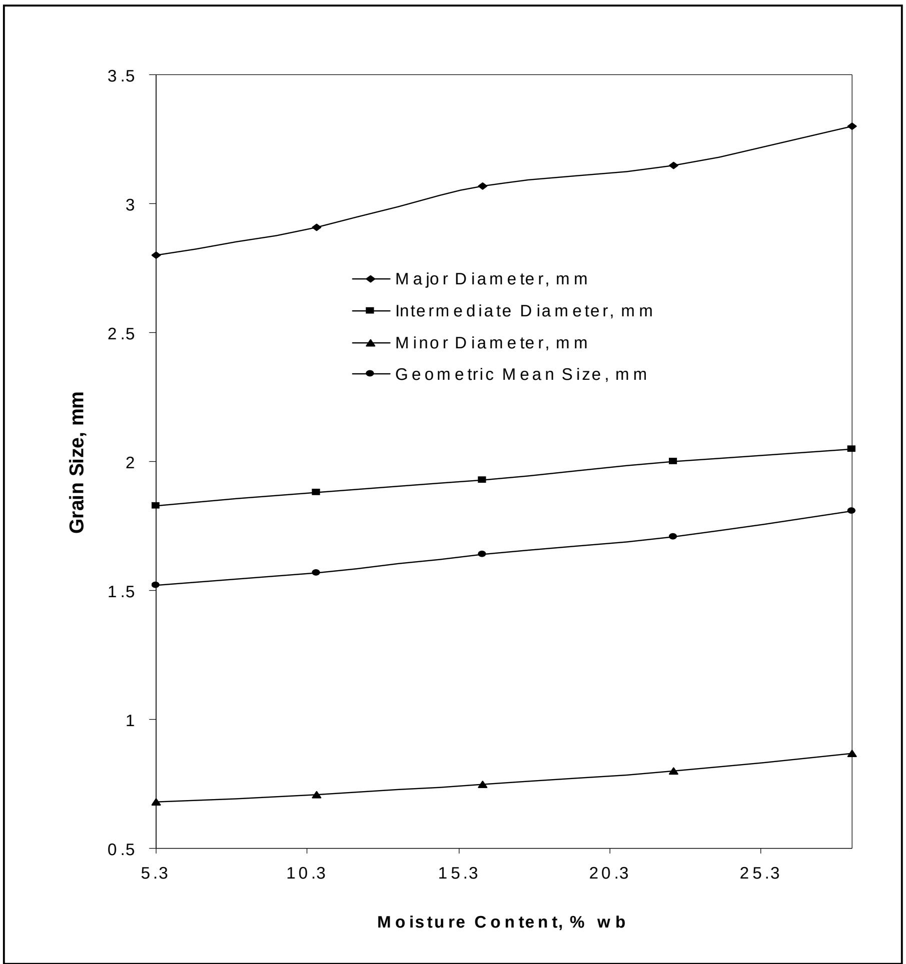


Figure 2: Effect of Moisture Content on the Size of Beniseed
Source: Lucas and Olayanju (2004)

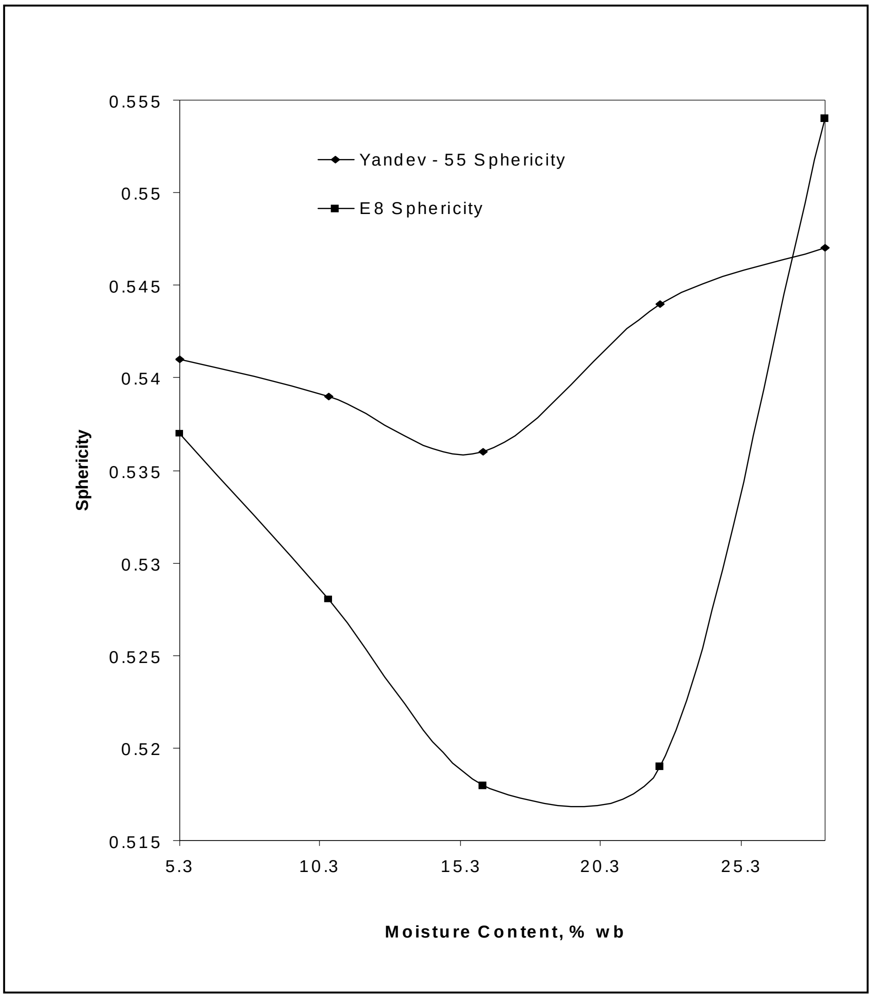


Figure 3: Effect of moisture content on the sphericity of two beniseed accessions
Source: Lucas and Olayanju (2004)

2.2.2. Gravimetric properties

The bulk and true densities of beniseed decreased with increasing moisture content (Figure 4). The reason for the different trends of agricultural products could be that some seeds, on application of moisture, increase in volume much more than the corresponding weight gain and vice versa. Figure 5 shows that the porosity and thousand-kernel weight (TKW) increased with increase in moisture content for the two accessions.

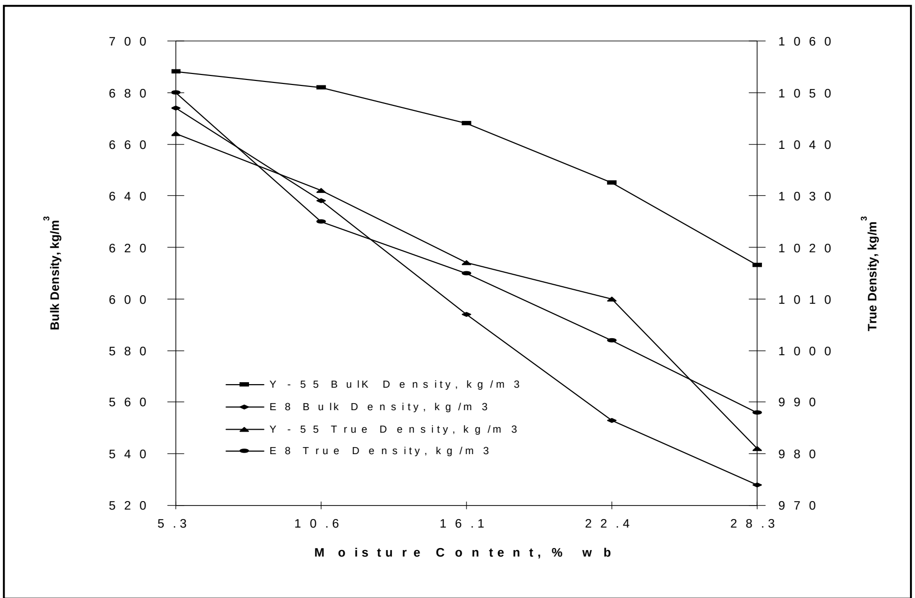


Figure 4: Effect of moisture content on the densities of two beniseed accessions
Source: Lucas and Olayanju (2003)

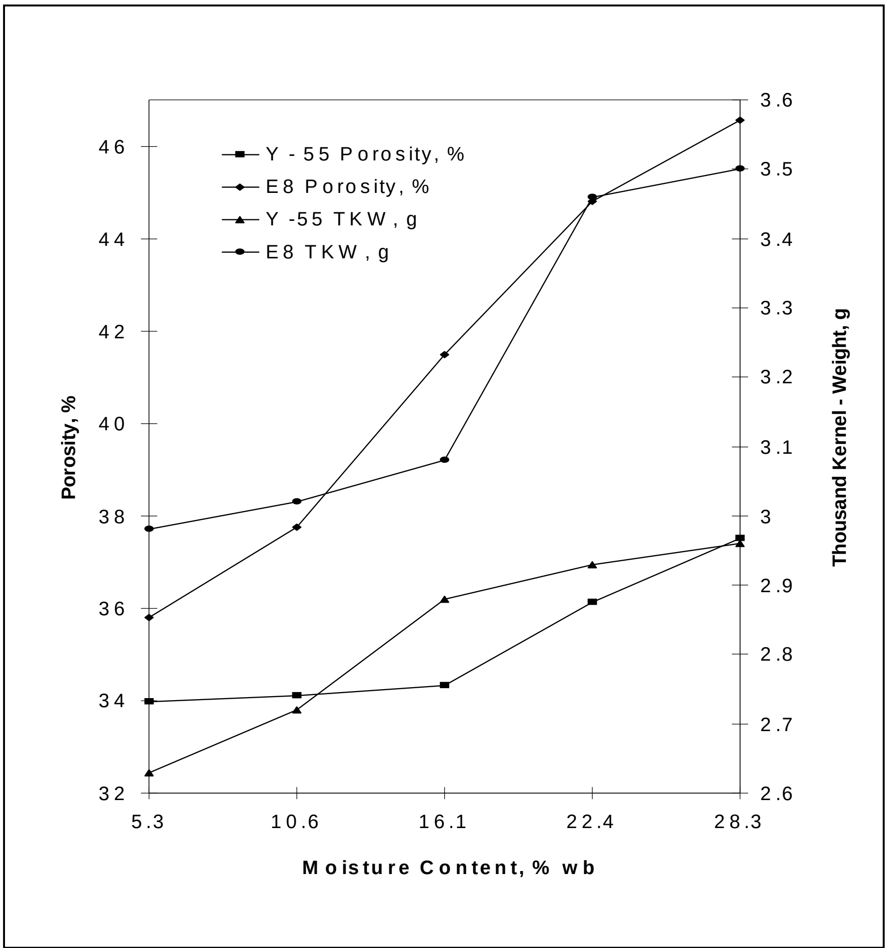


Figure 5: Effect of moisture content on the porosity and TKW of two beniseed accessions
Source: Lucas and Olayanju (2003)

The observation on porosity could be due to large increase in bulk density relative to true density as the moisture content increases for the two accessions. The differences may be attributable to the size and shape of individual seeds at high moisture contents. The E8 accession had higher porosity values than Yandev-55. This could be due to the larger size of the former.

The increase in thousand-kernel weight with increase in moisture content was because increase in moisture content increases the water content (by weight) of the grain leading to an increase in the size of the grain. The maximum values of 1000 - kernel weight for beniseed were 2.96g for Yandev-55 and 3.5 for E8 at 28.3%. The reported values for most of the seeds were very much higher than beniseed in relative comparison.

The result indicates that moisture content has highly significant effect on all the parameters but non-significant on major diameter and sphericity at the 0.05 level (Table 2). The regression equations of moisture content for some physical properties of the seed are shown in Table 3. The bulk and true densities ranged from 528 to 682 kg/m^3 and 981 to 1050kg/m^3 respectively and are negatively correlated with moisture content. The porosity and thousand-kernel weight increased with increase in moisture content and are within the range of 34.52

Table 2: Summary of analysis of variance for the physical properties

Source of variation	Degree of Freedom	Major Dia. (mm)	Inter-mediate (mm)	Minor Dia. (mm)	Geom. Mean (mm)	Sphericity	Bulk Density (kg/m³)	True Density (kg/m³)	Porosity (%)	Thousand Kernel Wt. (g)
Treatment	9									
Accession (A)	1	7.94**	9.15*	1.20 NS	4.51NS	0.40NS	2876**	13.03**	489.73**	974.61**
Moisture Content (M)	4	2.70NS	65.0**	60.0**	20.50**	0.25NS	359.77**	73.567**	19.19**	1471.79**
Interaction (AxM)	4	0.03 NS	0.10NS	0.03 NS	0.05NS	0.30 NS	6.95**	1.03NS	3.62**	0.97NS
Error	490									

*Values represent F – calculated; **highly significant difference; NS – non significant difference
Source: Lucas and Olayanju (2003)

Table 3: Regression equations for some physical properties of beniseed in the moisture content range of 5.3 to 28.3%

Property	Beniseed Accession					
	Yandev 55			E8		
	Linear Regression Equation	R^2	r	Linear Regression Equation	R^2	r
Major Diameter,mm	2.692 + 0.021M	0.989	0.995	3.096 + 0.029M	0.896	0.946
Intermediate Dia.,mm	1.778 + 0.009M	0.998	0.999	1.984 + 0.020M	0.907	0.953
Minor Diameter, mm	0.627 + 0.008M	0.981	0.991	0.676 + 0.010M	0.922	0.961
Geometric Mean, mm	1.444 + 0.012M	0.990	0.995	1.617 + 0.018M	0.962	0.981
Sphericity	0.536 + 0.0003M	0.427	0.653	0.523 - 0.0004M	0.082	0.287
Bulk Density, kg/m^3	0.697 - 0.002M	0.815	-0.922	0.681 - 0.002M	0.908	-0.996
True Density, kg/m^3	1.066 - 0.006M	0.969	-0.966	1.073 - 0.005M	0.906	-0.980
Porosity, %	34.38 - 0.174M	0.920	0.905	36.32 - 0.097M	0.859	0.964
1000 - Kernel Wt., g	2.516 + 0.072M	0.989	0.969	2.865 + 0.072M	0.959	0.979

M - moisture content, % wb; R^2 - coefficient of determination; r – correlation coefficient
Source: Lucas and Olayanju (2003)

2.2.3 Coefficient of static friction on selected structural surfaces

Olayanju (2003d) obtained the static coefficient of frictions of the two beniseed accessions on four structural surfaces namely mildsteel, plywood, concrete and glass. In the case of plywood the direction of movement was parallel to the grain. The surface to be tested was fixed on the tilting table and the beniseeds were poured into a cardboard paper ring of diameter 10cm by 2cm deep until the ring was full. Care was taken to raise the ring slightly so that it did not touch the surface. The table was then slowly tilted by a gentle screwing device until movement of the seeds down mounted against the edge of the tilting table. The tangent of the angle of friction is the coefficient of friction.

Figure 6 shows the effect of moisture content on the coefficient of friction on different structural surfaces for the two beniseed accessions. It was observed that the coefficient of friction decreased from 0.5095 at 5.3% moisture content to 0.4621 at 10.6% moisture content and increased to 0.5392 with a further increase in moisture content to 22.4% for mild steel (normal surface finish). Similar trends were observed for plywood (normal surface finish), concrete (normal surface finish) and glass (plain surface).

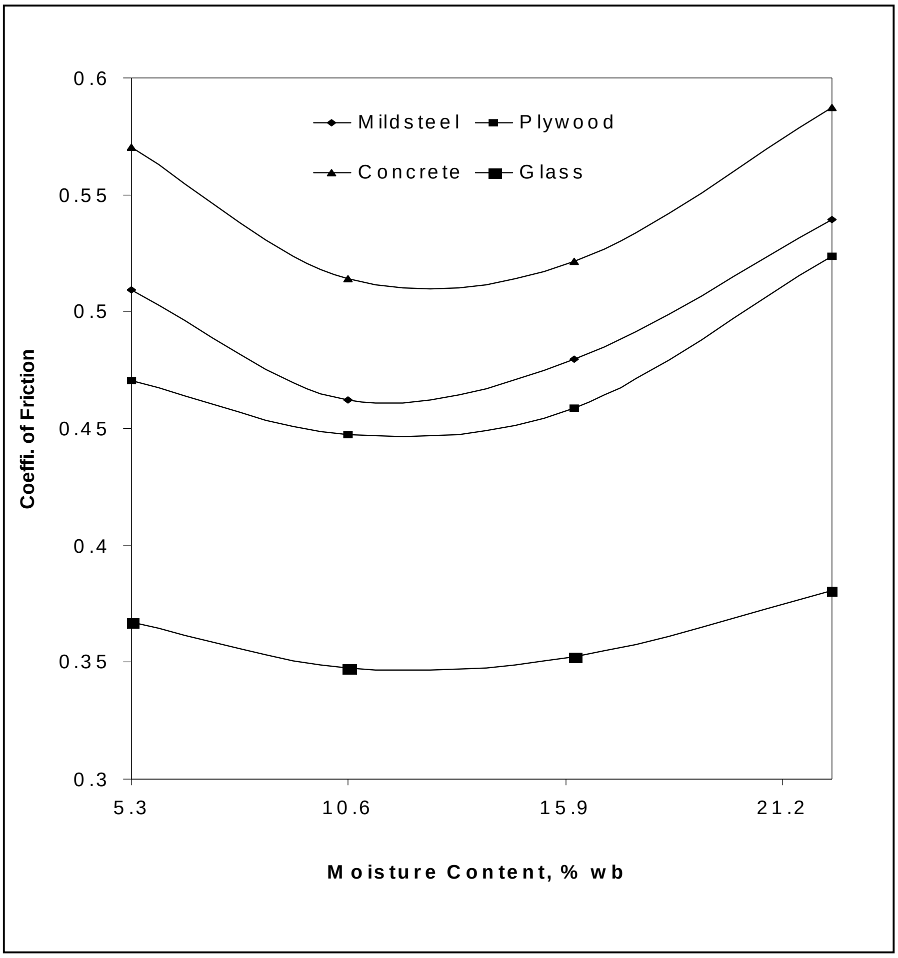


Figure 6: Effect of Moisture Content on the Coefficient of Friction of Yandev 55 Beniseed Accession
Source: Olayanju (2003d)

The coefficient of friction on all the studied surfaces decreased with increase in moisture content from 5.3% to 10.6% and then increased with a further increase in moisture content to 28.3%. Glass has the least values of 0.345 for Yandev55 and 0.323 for E8 at 10.6% moisture content. The values of coefficient of friction for beniseed on mild steel, plywood and concrete do not differ significantly from each other and they are not significantly affected by moisture content. Their values lie between the range 0.41 to 0.58.

These values are within the range of values specified for other seeds and grains as summarized by Mohsenin (1986). This is expected as the seeds have very smooth surfaces. The analysis of variance shows a highly significance difference between the moisture content means for all the structural surfaces but the effects of accession and its interaction with moisture content not significant.

The mean coefficient of friction between beniseed and glass was 0.32 while that on other structural surface lies between 0.45 to 0.59. The effect of moisture content was highly significant on the coefficient of frictions of all the tested surfaces. The static coefficients of friction of beniseed on the selected structural surfaces increased curvilinearly with increase in moisture content. The result showed that glass had the least value of 0.32 while for mild steel, plywood and concrete, frictional coefficients with beniseed were between 0.39 to 0.59 within the 5.3 and 22.4% moisture content. The effect of moisture content was highly significant on the coefficient of friction of all the tested surfaces.

2.2.4 Aerodynamic properties

Some aerodynamic properties of beniseed such as particle diameter, frontal area, terminal velocity and drag coefficients were determined by Olayanju *et al.* (2009a). Terminal velocity of beniseed, the final velocity of a particle in a fluid, was measured by using a vertical air tunnel (Plate 7). It consists of the following components: a frame, wind tunnel, plenum chamber, flow straightener, centrifugal blower, electric motor, pitot tubes and inclined manometer filled with coloured water. The centrifugal fan was mounted on a frame and it provides air current for the equipment. A vertical tunnel which was coupled to the fan is 1200 mm long with 100 mm x 100 mm cross section. An adjustable flap at the top of the fan allows variation of admission of air from the fan into the tunnel. The tunnel was built with mild steel sheet but the front was covered with 2mm thick transparent plastic material for observation. A window was cut at the front of the test section, and below it is a small screen braced to cover the inside of the section. This was to break small eddies behind the vanes and to keep the seed from falling into the chamber (Plate 7).

Air current was monitored in the tunnel with a pitot-static tube mounted inside the tunnel below the product-holding screen. These were two in numbers; the total pressure pilot tube and the static pressure pilot tube. The former is a right-angled bent tube with long arm being 290mm and short arm being 95mm. The static tube is straight with 200mm 2. The diameter of the glass tube is about 10mm. The out ports of the pitot - static tube were connected to the two arms of a - coloured water filled manometer. It is made with a 10mm diameter glass tube inclined at 12^0 to the horizontal. It has a length of 440mm; longer limb 320mm and shorter limb 320mm. The manometer was installed on a – 700mm long, 400mm wide and 12mm thick plywood. Two-holes were drilled at the top of the frame to hold the rubber corks through which manometer limbs passed out. The manometer was connected to the pilot tubes by Ǿ 10mm rubber tubes. A ruler was screwed to the frame below the manometer. This is to aid the reading of the rise of the liquid.

The test equipment was initially ran without any seed while response of the measuring instrument: Pitot – static tube and manometer were observed. The beniseed sample was placed on a mosquito wire netting within the duct and was blown upwards using a centrifugal blower whose speed was controlled by a variable speed motor. The air velocity at which the seed was suspended in the air was determined. Five readings were taken for each observation.

The terminal velocity of beniseed was also computed based on its sphericity. According to the equation proposed by Torobin and Gauvin (1960) as reported by Gorial and O'callaghan (1991); the drag coefficient,

$$C_d = 5.31 - 4.884\varphi \quad (1)$$

for low Reynold's number (with $\pm$ 4% accuracy) where ψ is sphencity of grain with 2000 < Re < 200,000.

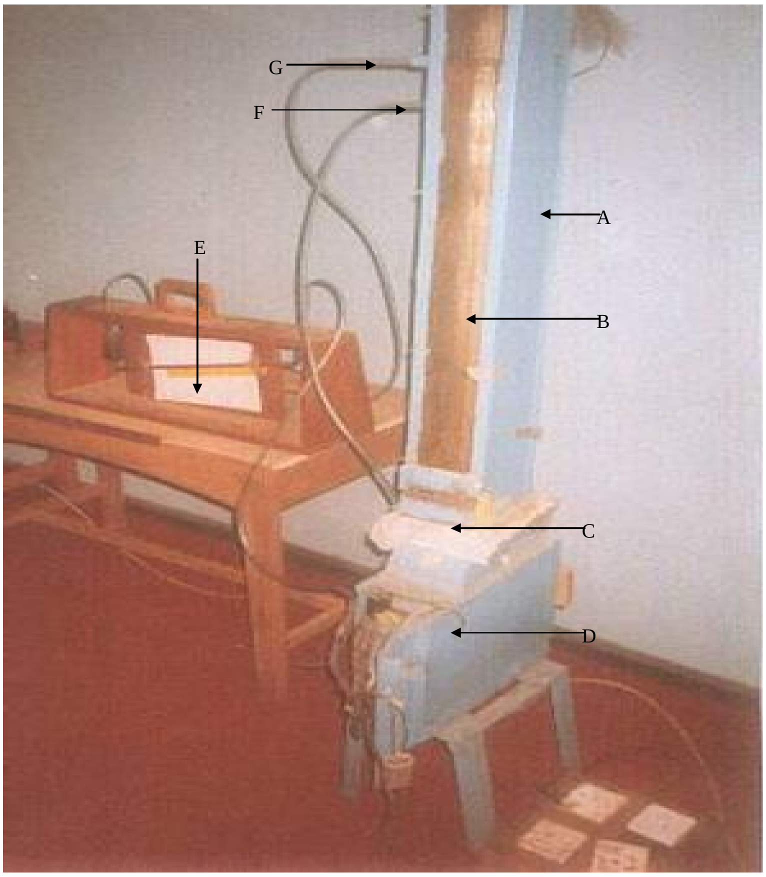


Plate 7: Terminal Velocity Test Equipment

A – Vertical Tunnel; B – Perspex Glass; C – Seed Inlet; D – Centrifugal Blower; E – Manometer; F – Total Pressure Tube; G – Static Pressure Tube
Source: Olayanju *et al.* (2009)

The value of C_D was then used in an equation proposed by Kashayap and Pandya (1986) for calculation of terminal velocity (v_t) as:

$$V_t = \frac{\sqrt{2Mg}}{A_p S_f C_d} \qquad (2)$$

where:

M = Weight of particle (kg

A_P = Projected area of seed, LW (m^2)

C_D = Drag Coefficient

δ_f = Density of fluid (air), (kg/m^3) = 1.150

g = Acceleration due to gravity, m/s^2 = 9.81

Note that density and viscosity of air were assumed constant at the temperature and pressure when the experiment was carried out

A summary of the result obtained for terminal velocity of beniseed using the vertical wind tunnel and manometric displacements for the pitot-static tube is as shown in Table 4. The result of computed terminal velocities using equation based on the sphericity of the seed at different moisture content levels is shown in Table 5. The difference between the mean terminal velocity of 2.0 m/s obtained based on the manometric measurements and 2.6 m/s obtained from computation based on sphericity may be due to human error and turbulence in the air stream. The two results compared favourably well with those obtained for other crops (Perry *et al.* (1985); Koya and Adekoya (1994); Babatunde and Olowonibi, 2000).

Vital values of some aerodynamics properties of beniseed had been established. The particle diameter and frontal area of beniseed increased from 1.52 to 1.78 mm and 1.77 to 2.49 mm^2 for Yandev 55; 1.74 to 2.18 mm and 2.38 to 3.73 mm^2 for E8, respectively as the moisture content increased from 5.3 to 28.3%. The respective terminal velocities decreased from 3.05 to 2.74 m/s and 2.80 to 2.48 m/s for Yandev 55 and E8 within the studied moisture content levels. The measured and computed average values of terminal velocity for beniseed are between 2.0 to 2.7 m/s. Increasing the moisture content from 5.3 to 16.10% increased the drag coefficient from 2.67 to 2.70 and 2.74 to 2.78 for the two accessions respectively. The effect of moisture content on beniseed was highly significant (p = 0.8) on the terminal velocity.

2.2.5 Mechanical properties of beniseed

Olayanju and Lucas (2004) determined mechanical properties of the seed. These are the force applied, the deformation sustained and the energy required to rupture and express oil from the seed. Compression tests were performed on beniseed kernels using Monsanto Universal Testing Machine (Plate 8). The testing conditions for the Instron Machine were loading range 0 - 500N; chart speed – 50/mm; Crosshead speed – 1.5mm/mm. The procedure used by Braga *et al.* (1999) was followed. Ten samples, each of the two beniseed accessions in both dehulled and undehulled form and at three moisture content levels of 4.1, 5.3 and 7.7% wet basis were used for the test.

Each seed was placed between the compression plates of the tensonometer. The seed was compressed at a constant deformation rate of 1.25mm/min. The applied force at rupture and oil - point and their corresponding deformations for each seed sample was read directly from the force-deformation curve. The mechanical behaviour of beniseed was expressed in terms of force required for maximum strength of the seed, energy required to deform the seed to initial rupture and the seed specific deformation. The rupture force was determined as the force on the digital display when the seed under compression makes a clicking sound. Each process was often completed whenever the break point of the positioned seed is reached.

The result indicates that the seed accession, pre-conditioning method and moisture content levels have significant effects on the applied force, specific deformation and energy characteristics of beniseed at the 0.05 level. Figure 7 shows the variation in force required to rupture and to reach the oil-point of individual kernels and their corresponding deformations. The bioyield point in the force deformation curves denote the seed rupture point and this point was determined by a visual decrease in force (Point A) as deformation increases. The oil-point indicates the threshold force (Points B) and corresponding deformation at which the oil emerges from an oilseed kernel when pressed mechanically.

Table 4: Measured terminal velocity of beniseed using vertical tunnel

Serial No	Inclined length L, 10^{-3}(m)	Actual length $h_w = L\sin\theta$, 10^{-3}(m)	Height of air ha = hwdw/da, 10-3(m)	Terminal velocity Vt = 2/gha, (m/s)
1	1.1	0.23	0.19	1.95
2	1.2	0.25	0.21	2.02
3	1.1	0.23	0.19	1.95
4	1.1	0.23	0.19	1.95
5	1	0.21	0.17	1.84
6	1	0.21	0.17	1.84
7	1.2	0.25	0.21	2.02
8	1.1	0.23	0.19	1.95
9	1.2	0.25	0.21	2.02
10	1	0.21	0.17	1.84
11	1.1	0.23	0.19	1.95
12	1.1	0.23	0.19	1.95
13	1.2	0.25	0.21	2.02
14	1.4	0.29	0.24	2.18
15	1.1	0.23	0.19	1.95
16	1.1	0.23	0.19	1.95
17	1.2	0.25	0.21	2.02
18	1.2	0.25	0.21	2.02
19	1.2	0.25	0.21	2.02
20	1.1	0.23	0.19	1.95
21	1.2	0.25	0.21	2.02
22	1.1	0.23	0.19	1.95
23	1.1	0.23	0.19	1.95
24	1.6	0.33	0.28	2.33
25	1	0.21	0.17	1.84
26	1.1	0.23	0.19	1.95
27	1.2	0.25	0.21	2.02
28	1.2	0.25	0.21	2.02
29	1.4	0.29	0.24	2.18
30	1.2	0.25	0.21	2.02
31	1.4	0.29	0.24	2.18
32	1.1	0.23	0.19	1.95
33	1.5	0.31	0.26	2.26
34	1	0.21	0.17	1.84
35	1.1	0.23	0.19	1.95
36	1.6	0.33	0.28	2.33
37	1.1	0.23	0.19	1.95
38	1.1	0.23	0.19	1.95
39	1.2	0.25	0.21	2.02
40	1.1	0.23	0.19	1.95
41	1	0.21	0.17	1.84
42	1.1	0.23	0.19	1.95
43	1.5	0.31	0.26	2.26
44	1.1	0.23	0.19	1.95
45	1.2	0.25	0.21	2.02
46	1	0.21	0.17	1.84
47	1.1	0.23	0.19	1.95
48	1.1	0.23	0.19	1.95
49	1.6	0.33	0.28	2.33
50	1.1	0.23	0.19	1.95
Mean	1.176	0.2452	0.2036	2.0018
Maximum	1.6	0.33	0.28	2.33
Minimum	1	0.21	0.17	1.84
Std. Deviatio	0.159795788	0.031959158	0.028696867	0.127642517

θ = Manometer's angle of inclination = 12 deg; δ_w = Density of manometer's fluid (water) = 1000kg/m ;
δ_a = Density of air at room temperature = 1.2kg/m ; **g** = Acceleration due to gravity = 9.81m/s

Source: Olayanju *et al.* (2009a)

Table 5: Computed terminal velocity of beniseed based on sphericity

Serial No	Particle Size (LBT)1/3 (mm)	Sphericity	Particle Weight (mg)	Projected Area (mm2)	Drag Coefficient	Terminal Velocity (m/s)
1	1.06	0.48	2.13	0.88	2.96	3.65
2	1.12	0.47	2.36	0.99	3.03	3.60
3	0.99	0.44	2.21	0.77	3.17	3.85
4	0.96	0.45	2.25	0.72	3.13	4.03
5	1.04	0.47	2.55	0.85	3.00	4.04
6	1.08	0.50	2.42	0.92	2.88	3.87
7	1.20	0.48	2.38	1.13	2.98	3.40
8	0.89	0.40	2.01	0.62	3.37	3.96
9	0.90	0.37	2.23	0.64	3.48	4.06
10	0.87	0.41	2.00	0.59	3.33	4.06
11	1.35	0.61	2.03	1.43	2.34	3.15
12	1.24	0.57	2.52	1.21	2.55	3.66
13	0.91	0.42	2.04	0.65	3.26	3.97
14	0.96	0.40	2.01	0.72	3.36	3.67
15	0.93	0.43	2.37	0.68	3.20	4.22
16	0.88	0.41	2.43	0.61	3.33	4.43
17	0.99	0.45	2.04	0.77	3.14	3.72
18	1.01	0.46	2.07	0.80	3.07	3.71
19	0.85	0.40	2.02	0.57	3.38	4.15
20	0.85	0.39	2.51	0.57	3.40	4.61
21	0.97	0.44	2.20	0.74	3.17	3.92
22	0.95	0.44	2.22	0.71	3.17	4.02
23	0.94	0.44	2.33	0.69	3.18	4.15
24	1.02	0.39	2.03	0.82	3.42	3.45
25	0.96	0.44	2.11	0.72	3.19	3.87
26	0.72	0.61	2.45	0.41	2.33	6.50
27	1.26	0.57	2.21	1.25	2.52	3.39
28	0.85	0.39	2.46	0.57	3.40	4.57
29	0.97	0.45	2.21	0.74	3.11	3.97
30	0.97	0.42	2.31	0.74	3.27	3.95
31	0.90	0.43	2.03	0.64	3.21	4.03
32	0.94	0.43	2.01	0.69	3.19	3.85
33	0.93	0.46	2.22	0.68	3.06	4.18
34	0.99	0.43	2.41	0.77	3.19	4.00
35	0.96	0.45	2.17	0.72	3.13	3.96
36	0.99	0.41	2.38	0.77	3.29	3.92
37	0.99	0.43	2.23	0.77	3.20	3.85
38	1.04	0.44	2.15	0.85	3.17	3.61
39	0.99	0.45	2.03	0.77	3.12	3.72
40	0.98	0.41	2.34	0.75	3.29	3.93
41	0.90	0.41	2.34	0.64	3.29	4.28
42	1.04	0.47	2.53	0.85	3.04	4.00
43	1.00	0.44	2.53	0.79	3.17	4.08
44	0.96	0.53	2.23	0.72	2.74	4.29
45	1.14	0.45	2.22	1.02	3.13	3.37
46	0.96	0.42	2.43	0.72	3.26	4.10
47	0.92	0.45	2.29	0.66	3.13	4.24
48	0.96	0.41	2.26	0.72	3.32	3.92
49	0.98	0.45	2.16	0.75	3.10	3.89
50	1.09	0.43	2.51	0.93	3.19	3.71
Mean	**0.99**	**0.45**	**2.25**	**0.77**	**3.14**	**3.92**
Maximum	**1.35**	**0.51**	**2.55**	**1.43**	**2.81**	**6.50**
Minimum	**0.72**	**0.61**	**2.00**	**0.41**	**2.33**	**3.15**
Std. Dev.	**0.12**	**0.52**	**0.17**	**0.01**	**0.27**	**0.58**

Source: Olayanju *et al*. (2009a)

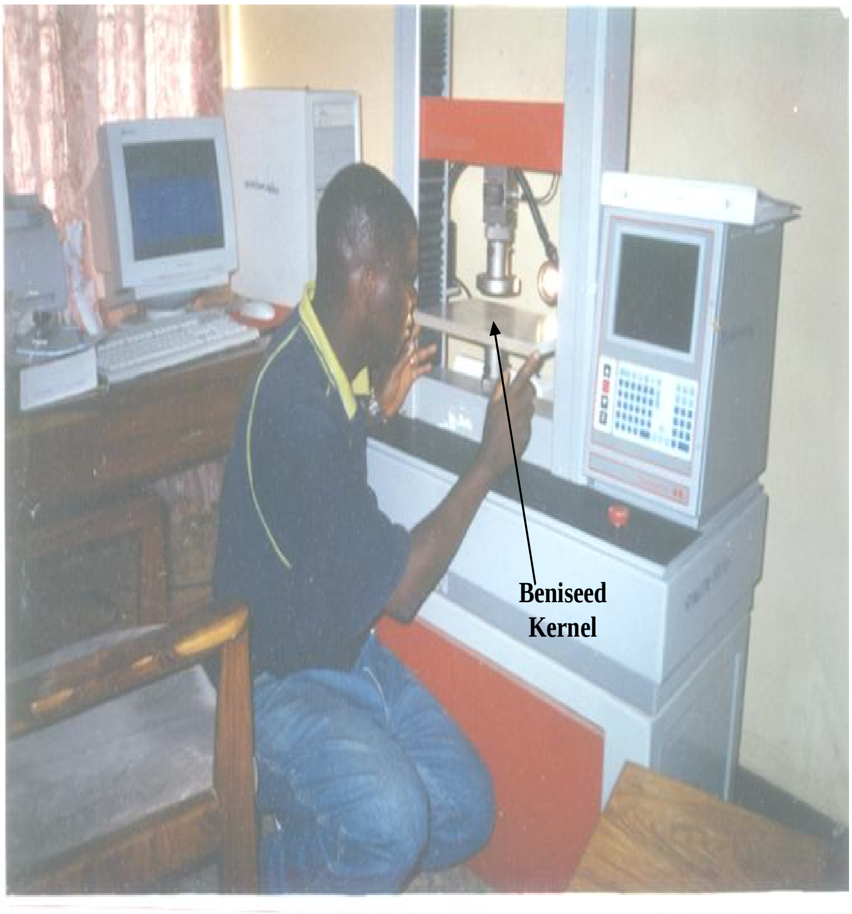


Plate 8: Beniseed Kernel under Compression Loading
Source: Olayanju and Lucas (2004)

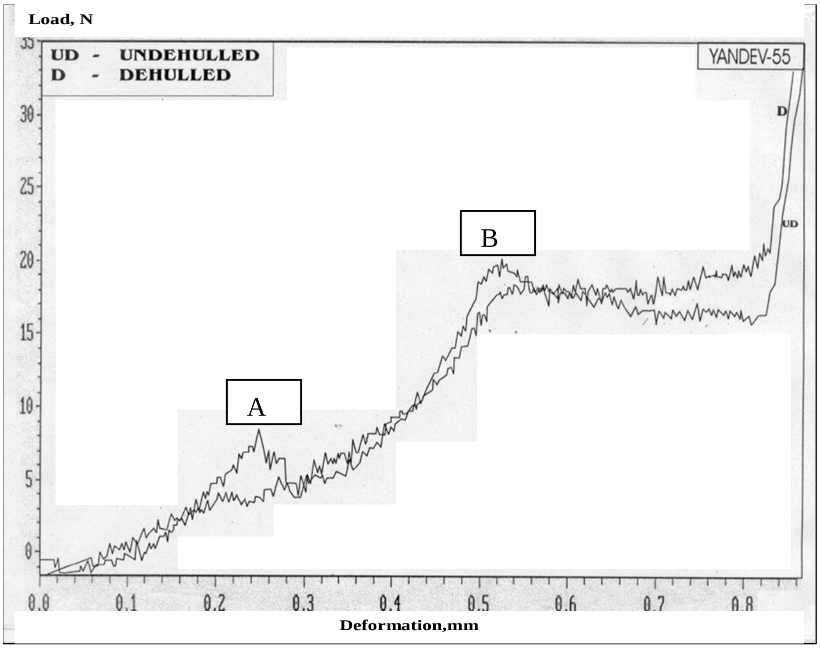


Figure 7: Load Deformation Curve of Individual Beniseed
Source: Olayanju and Lucas (2004)

The force required to rupture and express oil from undehulled Yandev – 55 accession is greater than for undehulled E8 accession. At rupture (Point A), the values are 10.9 and 9.4N, respectively, while at oil point (Point B) the respective values are 20.4N and 18.4N. However, for dehulled seeds, the values for Yandev-55 and E8 are 8.7 and 9.0N for rupture and 18.6 and 20.8N for oil point, respectively. The corresponding deformations follow a similar trend with values ranging between 0.123 to 0.494mm and 0.46 to 0.54mm for rupture and oil-point, respectively..

It was also observed that the mean values of all the characteristics were higher when the seeds were dehulled than when left undehulled. This may be due to the fact, when the seed has been dehulled and dried, it shrinks and becomes hard, thus requiring a higher force, longer distance and more energy to deform and rupture the seed. Changes in moisture content also affect the force-deformation behaviour of the seed. The interactions of all the factors showed significant effect on all the characteristics. Braga *et al.* (1999) also reported that the compression position and moisture content affect the rupture force, specific deformation and energy requirement of macadamia nut.

The summary of the results obtained on the investigated physical and mechanical properties of beniseed at storage moisture of 5.3% (wet basis) is as shown in Table 6.

Table 6: Some determined physico – mechanical properties of two beniseed accessions

Beniseed Accession Property	Yandev 55 Benue Origin	E8 Kano Origin	Mean
Major Diammeter, mm	2.8	3.3	3.05
Intermediate Diameter, mm	1.83	2.13	1.98
Minor Diameter, mm	0.68	0.75	0.715
Geometric Mean Dia. (Size), mm	1.52	1.74	1.63
Sphericity (Shape)	0.54	0.54	0.54
Bulk Density, kg/m^3	688	674	681
True Density, kg/m^3	1042	1050	1046
Porosity, %	33.97	35.81	34.89
Thousand Kernel Weight, g	2.63	2.98	2.805
Coeff. of Friction on Mild Steel	0.51	0.41	0.46
Terminal Velocity, m/s	3.05	2.79	2.92
Rupture Force, N	7.73	8.92	8.325
Expression Force, N	29.4	28.3	28.85
Deformation, mm	0.23	0.17	0.2
Energy Required, mJ	0.7	0.6	0.65

2.3 Assessment of some oil expellers

Modern oil expellers have been imported and are presently in use in Nigeria. However, there is need for modifications and local production of these in order to eliminate or reduce the problem of shortage of spare parts, maintenance personnel and the cost of importation. Many local fabricators have attempted to develop expellers without recourse to the design specifications, which are vital inputs in the development of oil expellers. This has invariably led to the development of expellers with low oil recovery and high residual oil in cake.

An investigation into the design specifications of some oil expellers manufactured or presently in used in Nigeria was carried out by Olayanju *et al.* (2004a). The investigated parameters were machine capacity, power requirement, wormshaft speed, worm pitch, flight height, flight width, helix angle, barrel diameter and barrel length (Figure 8). The data obtained were utilised in the design of a soft seed oil expellers as most locally fabricated ones had no design basis and are not effective with soft seeds.

In order to obtain information on the design specifications of vegetable oil expellers, correspondences were made to manufacturers of oil expellers and oil processors within and outside the country (Plate 9). The addresses of some of these individuals and organisations are as shown in Table 7. The requested parameters were based on the theoretical capacity of an expeller with single flight in feed section. This was given by Varma (1998) as:

$$Q = \pi DN \cos\alpha (P \cos\alpha - e)H \quad (3)$$

where; Q = volumetric oil flow rate, m^3/s
D = mean diameter of screw, mm
N = rotational speed of wormshaft, rpm
P = worm pitch, mm; H = flight height, mm
e = flight width, mm; a = helix angle, degree

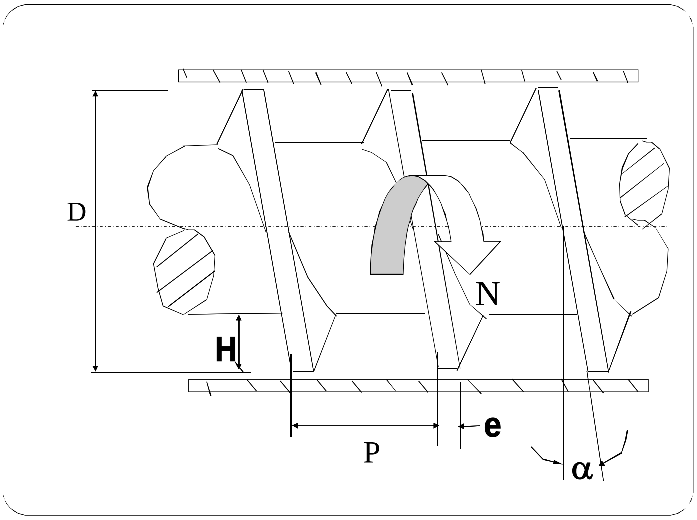
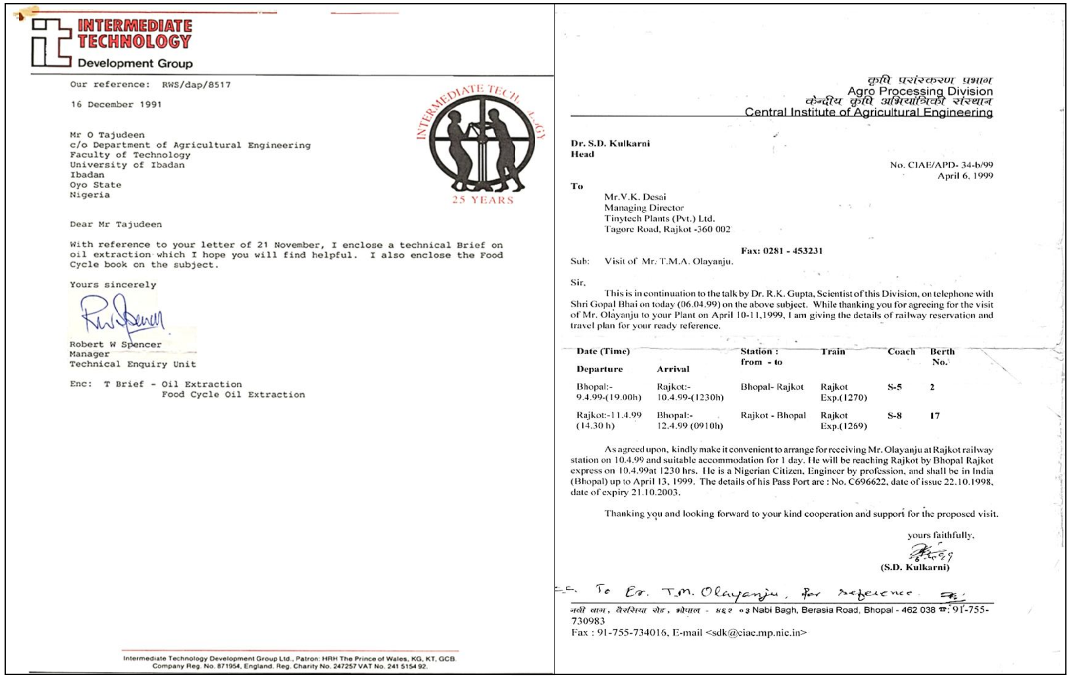


Figure 8: Some design parameters of oil expellers
Source: Olayanju *et al*. (2004a).



INTERMEDIATE TECHNOLOGY
Development Group

Our reference: RWS/dap/8517

16 December 1991

Mr O Tajudeen
c/o Department of Agricultural Engineering
Faculty of Technology
University of Ibadan
Ibadan
Oyo State
Nigeria

Dear Mr Tajudeen

With reference to your letter of 21 November, I enclose a technical Brief on oil extraction which I hope you will find helpful. I also enclose the Food Cycle book on the subject.

Yours sincerely

Robert W Spencer
Manager
Technical Enquiry Unit

Enc: T Brief - Oil Extraction
Food Cycle Oil Extraction

Intermediate Technology Development Group Ltd., Patron: HRH The Prince of Wales, KG, KT, GCB.
Company Reg. No. 871954, England. Reg. Charity No. 247257 VAT No. 241 5154 92.

कृषि प्रसंस्करण प्रभाग
Agro Processing Division
केन्द्रीय कृषि अभियांत्रिकी संस्थान
Central Institute of Agricultural Engineering

Dr. S.D. Kulkarni
Head

No. CIAE/APD- 34-b/99
April 6, 1999

To
Mr.V.K. Desai
Managing Director
Tinytech Plants (Pvt.) Ltd.
Tagore Road, Rajkot -360 002

Fax: 0281 - 453231

Sub: Visit of Mr. T.M.A. Olayanju.

Sir,

This is in continuation to the talk by Dr. R.K. Gupta, Scientist of this Division, on telephone with Shri Gopal Bhai on today (06.04.99) on the above subject. While thanking you for agreeing for the visit of Mr. Olayanju to your Plant on April 10-11,1999, I am giving the details of railway reservation and travel plan for your ready reference.

Date (Time) Departure	Arrival	Station : from - to	Train	Coach	Berth No.
Bhopal:- 9.4.99-(19.00h)	Rajkot:- 10.4.99-(1230h)	Bhopal- Rajkot	Rajkot Exp.(1270)	S-5	2
Rajkot:-11.4.99 (14.30 h)	Bhopal:- 12.4.99 (0910h)	Rajkot - Bhopal	Rajkot Exp.(1269)	S-8	17

As agreed upon, kindly make it convenient to arrange for receiving Mr. Olayanju at Rajkot railway station on 10.4.99 and suitable accommodation for 1 day. He will be reaching Rajkot by Bhopal Rajkot express on 10.4.99at 1230 hrs. He is a Nigerian Citizen, Engineer by profession, and shall be in India (Bhopal) up to April 13, 1999. The details of his Pass Port are : No. C696622, date of issue 22.10.1998, date of expiry 21.10.2003.

Thanking you and looking forward to your kind cooperation and support for the proposed visit.

yours faithfully,

(S.D. Kulkarni)

c.c. To Er. T.M. Olayanju, for reference.

नबी बाग, बैरसिया रोड, भोपाल - ४६२ ०३ Nabi Bagh, Berasia Road, Bhopal - 462 038 फ: 91-755-730983
Fax : 91-755-734016, E-mail <sdk@ciae.mp.nic.in>

Plate 10: Correspondences on different oil expeller design specifications

Source: Olayanju (2002)

Table 7: Some manufacturers of small - scale oil expellers and oil processors

S/N	Name and Address	S/N	Name and Address
1.	Techo Quip Ltd. Techno Industrial Estate 15, Olushola Ikare Street Alake Bus Stop P. O. Box 5323, Ikeja, Lagos	2.	Indev Ltd. 3/5 Adebambo St. Obanikoro, Lagos Tel. 964498
3.	Chidi Aguba Nig. Ltd. 55, Western Avenue Surulere, Lagos	4.	Nucleus Ventures (Nig.) Ltd. Ariwoola House Opp. Olona Motors, Polytechnic Road, P. O. Box 19910, U. I.
5.	Ultra Unique Eng. Ltd. 36/38 Winners way, Off Basorun MKT Orita Basorun, Ibadan	6.	Nova Technologies Ltd. Ajibode Bus Stop, U.I., Ojoo Road Ibadan Tel (02) 8103960
7.	Lawod Metals Ltd. 9, Alekuwodo Road Okefia, Osogbo. Tel: 035 – 232241	8.	Tiny Tech Plants Tagore Road, Rajkot 360 000 2 India Tel: 91 – 281 477466
9.	Marthias Reinartz Neuss Industrie Str. 14, England Tel: 0482 – 29864	10.	Simon Rosedowns Ltd. CannonStreet, Hull, P.O.Box 100950 Fed. Rep. Germany
11.	International Institute of Tropical Agriculture (IITA)	12.	Akin Tech, Iyana Ipaja, Lagos.

The received information was collated and briefly summarised in Table 8. All the investigated parameters except wormshaft speed increased with the increase in machine capacity (Figure 9). The power requirement, barrel diameter and barrel length were in the range 2.25 to 11.25 kW, 60 to 90 mm and 234 to 680 mm, respectively, while the wormshaft speed decreased from 120 to 22 rpm, as the machine capacity increased from 30 to 180 kg/h. The worm pitch, flight height, flight width, and helix angle varied from 25 to 75 mm; 12.5 to 25 mm; 6.25 to 12.5 mm and 10 to 25 degrees, respectively, depending on the type of oilseeds and the required capacity.

Most of the studied expellers have continuous helical threads with constant root diameter and constant worm pitch with restrictions while few have interrupted helical threads revolving concentrically within stationary cylindrical barrels, which usually have axially arranged slots through which oil flows out. These have been improved upon by utilising six worms of different pitches with one of them being in the reverse direction (Olayanju, 2002).

The worm flight design is such that the material does not wrap around more than 320^0. This leaves an axial gap in the flight that enables the compressed material to slide in either direction relative to velocity generated by worm pitch. This also balances the pressure over a group of worm section and reduces the tendency of material to lock in, individual section and rotate with the shaft. In the reverse worm set-up, one of the original worms in the middle of the shaft is replaced by another worm of similar dimensions but with flight running in the opposite direction i.e towards the feed end. Due to the pressure created by the reverse worm, the oil flows out of the oil – solid matrix through the holes in the cage bar.

All the studied expellers have identical cone mechanisms and compression ratios in the order of 5, which indicate that the basic design features of most of the expellers are similar. The analysis of the data from Table 8 also indicates that over 75% of the investigated expeller had capacity below 75 kg/h, which shows a trend towards the manufacture of small capacity expellers. The expressed cake has 5 – 18% (w/w) residual oil, depending on the type of oilseed and operating conditions (Rosedown, 1990; Desai, 1998).

Table 8: Design specifications of some small - scale oil expellers

Name	Capacity, kg/h	Power reqd., kW	Wormshaft speed, rpm	Barrel dia., mm	*Noof bars Barrel length, mm	Overall dimen-sion, L, B, H (mm)	Total weight kg
Table oil expeller (S)	30	2.25	-	58	*16	1060, 530, 890	203
Mini 40 oil expeller	40	2.25	120	62	234	760, 450, 550	250
Table oil expeller (Du)	40	3.75	-	69	*18	1060, 530, 890	208
Infant oil expeller	40	3.75	45	73	406	1625, 700, 1145	440
Table oil expeller (De)	50	3.75	-	78	*20	1140, 550, 960	230
Table oil expeller	55	3.75	-	80	*22	1140, 550, 960	255
Baby oil expeller (No 1)	56	5.60	33	-	610	2083, 610, 1370	1000
Baby oil expeller (SOL)	60	5.25	35	-	-	1880, 610, 1370	1000
Baby oil expeller (SDG)	72	7.5	22	-	-	2753, 1066, 2051	2400
Baby oil expeller (No 2)	83	7.5	-	89	686	2436, 1066, 2055	1500
Tiny tech oil expeller	100	7.5	-	124	*24	1960, 460, 500	1200
Young oil (S)	180	11.25	22	126	762	2250, 1060, 2220	2500

Analysis of the data indicates that over 75% of the expellers had capacity below 75 kg/h. All the parameters with the exception of wormshaft speed increased with the increase in machine capacity. The power requirement, barrel diameter and barrel length increased from 2.25 to 11.25 kW, 60 to 90 mm and 234 to 680mm respectively while the wormshaft speed decreased from 120 to 22 rpm, as the machine capacity increased from 30 to 180kg/h. The worm pitch, flight height, flight width, and helix angle varied from 25 to 75 mm; 12.5 to 25 mm; 6.25 to 12.5 mm and 10 to 25 degrees respectively depending on the type of oilseeds and the required capacity. A trend towards the manufacture of small capacity expellers was established from the results.

In general, the type of expeller depends on the power applied per kg of material being crushed, the types of barrel, the form of expeller's feed end, the form of choke section and worm configuration.Vital values of some design parameters of relevance to oil expeller development have been established. This would assist our local fabricators and engineers to come up with a comprehensive design that will eventually lead to the development of improved and efficient oil expellers.

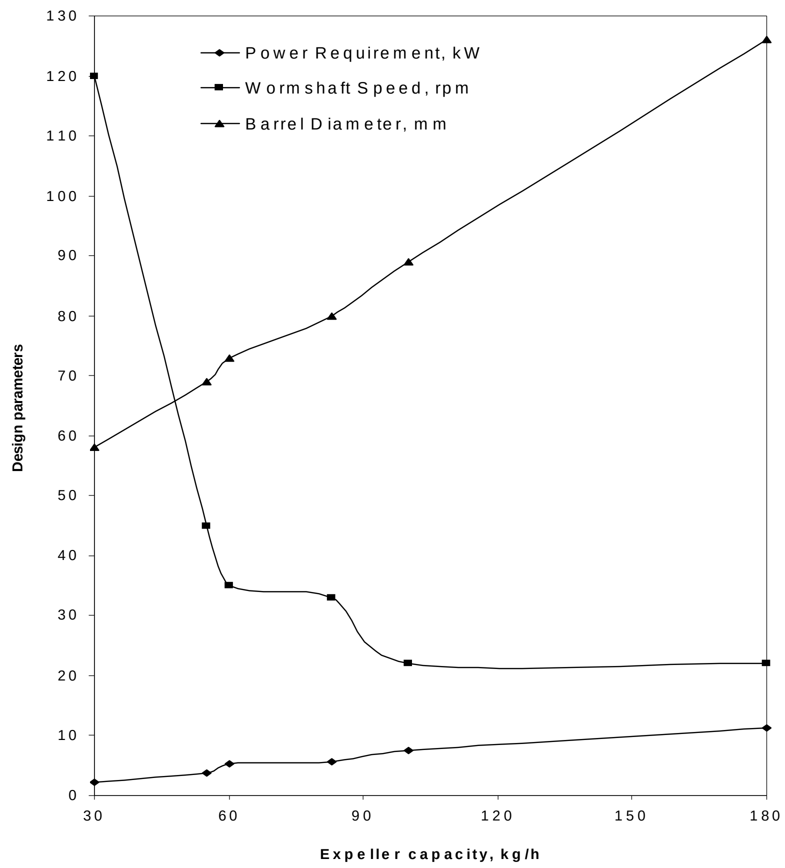


Figure 9: Expeller capacity as a function of power requirement, wormshaft speed and barrel diameter
Source: Olayanju *et al.* (2004a)

2.4 Development of a beniseed oil expeller

Commercially, beniseed oil is produced either by extraction or expression. Extraction method is not suitable for cottage scale level because of the expensive solvent involved; the problem of separating the chemical used from the oil; and the fact that extraction might result in devaluation of the seed. Therefore, expression method is preferred. Khan and Hannah (1983) described expression as the process of mechanically removing liquid out of solid containing liquid by the use of equipment such as plate presses, hydraulic presses and expellers. Plate and hydraulic presses are much more laborious, time consuming and less effective than screw presses/expellers (Oresanya and Koleoso, 1990; NCRI, 1995). An expeller is therefore preferred. However, most available expellers could not perform effectively with beniseed because of its small size. Therefore, Olayanju (2002) developed a special expeller for the seed.

2.4.1 Expeller's design capacity

The theoretical capacity of an expeller with single flight in feed section was given by equation 3 and the following specifications were obtained:

Required Capacity, Q_R = 100 - 125kg/h Inner Diameter of Chamber, D_c = 50 – 100mm
Length (Chamber) to Diameter Ratio, L/D_c = 1:1 to 10:1

Length of Chamber at Feed Section, L_F = 0.1 to 0.5L

Length of Chamber at Compression Section, L_C = 0.1 to 0.5L

Length of Chamber at Discharge Section, L_D = 0.1 to 0.5L

Helix Angle of Worm, $\alpha = 10$ – 20degrees Worm Pitch, $P = \pi D \tan\alpha$

Worm Depth, H = 0.5P + 0.25mm Worm Thickness, e = 0.37P

Compression Ratio, C = 1:1 to 5:1 Wormshaft Speed, N = 22 – 120rpm

A computer program in basic language was written to evaluate the design capacity based on the above and the following iterative values were used in running the program:

π = 3.142; D = 87mm; α = 13degrees; N = 70rpm $P = \pi D \tan\alpha$ = 3.142 * 87 * tan 13 = 62.5;

H = 0.2P + 0.25mm = 0.5 * 50 + 0.25 = 12.75; e = 0.5H = 0.5 * 12.75 = 6.38

Output Derivable

Capacity, Q = 5603493mm^3/min = 5.603 x 10^6 mm^3/min Volumetric flow rate, Q = 0.37m^3/h for single start in 2 passes. Mass flow rate, m = Q ϱ = 256.78kg/h for average bulk density of 694kg/m^3 = 128.39kg/h in a single pass

This can be taken as 125kg/h considering all losses in material and machine operation, which translates to 1 metric tonne/ day.

2.4.2 Forces Acting on Screw Thread

The two main forces acting on the screw thread are those required to translate and compress the beniseed charge and the frictional force resulting from the screw's motion.

The wormshaft has six worms, each of which is subjected to pressure due to compression of beniseed kernels. This pressure increases from a minimum value at the feed end to a maximum at the discharge end. Consider a portion of the wormscrew as shown in Figure 10, under the static condition, the direction of elemental load, K on the unit length of the thread will be normal to the thread surface along line AO.

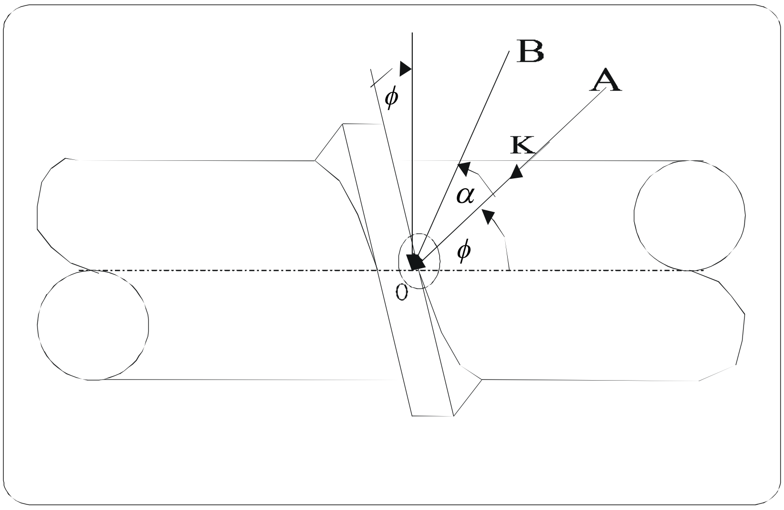


Figure 10: Forces acting on screw thread
Source: Olayanju (2004)

When the screw is rotated so that the load is moved, the line of action AO will be rotated through the angle of friction, Φ to BO. For equilibrium of forces, resolving the force BO vertical and horizontally, the component parallel to the axis of the screw, is given as

$$W = K\cos(\alpha + \phi) \tag{4}$$

Similarly, the component perpendicular to the axis of the screw.

$$F = K\sin(\alpha + \phi) \tag{5}$$

$$\frac{F}{W} = \frac{K\sin(\alpha + \phi)}{K\cos(\alpha + \phi)}$$

then,

$$F = W\tan(\alpha + \phi) \tag{6}$$

The friction angle,

$$\phi = \tan{-1}(\mu_s) \tag{7}$$

where: m_s = coefficient of static friction = 0.486 (Olayanju, 2003d)

$$\phi = \tan{-1}(0.486) \cong 25°$$

W is the axial force required to expel a great deal of the oil at the oil-point and has been determined to be 28.8N on the average. Based on the average size of beniseed (1.70mm) about 100 seeds were crushed at the considered feed end portion. Therefore a force of 2.88KN would be required to express the oil.

2.4.3 Power requirement

The power input to the expeller is used to convey and heat the material for oil expression. The power drive mechanism incorporates the use of a reduction gear motor of ratio 12 to 1. This is coupled to the expeller shaft by pulley and belts arrangement. The chosen speed for the expeller N_e is 45rpm

$\therefore$ the angular speed, $\omega_e = \dfrac{2\pi N}{60}$ (8)

The power input to the expeller can be computed as given below:

$$P_e = T\omega_e \qquad (9)$$

The input parameters are, π = 3.142; W = 28800N; N = 70rpm; ϕ = 25^0; $\alpha = 10^0$; R = 0.037m while the output parameters are; Expulsion Force, F = 13.65 KN; Torque, T = 504.9 Nm; Angular velocity, ω = 7.33 rad/s; Power Requirement, P = 3.7 kW. This power input to the expeller is utilized to heat the material, to convey the material for oil expression. To give allowance for power used in driving wormshaft and pulleys, a-5 hp electric reduction gear motor with a speed of about 140 rpm is chosen.

2.4.4 Machine Construction

The designed expeller consists of seven main parts namely: the feeding assembly, the expression barrel, the worms and wormshaft assembly, the cone mechanism, the power transmission unit, the oil and cake troughs and the main frame (Plate 11). Six worms of different pitches were fitted on the main shaft. The fifth worm is in the reverse direction to enable proper squeezing of the cake before discharge. The worm flight design, along pressure and discharge section is such that the material does not wrap around more than 320^0. This leaves an axial gap in the flight that enables the compressed material to slide in either direction relative to velocity generated by worm pitch (Plate 12).

The expression chamber is made of twenty wear resistant bars arranged longitudinally to form a circular barrel with slots between them for oil drainage. The chamber is split into two halves. The top carries the hopper at the extreme right while the bottom part is welded to the frame for rigidity. The split parts are bolted together. The unit is driven by a 3 kW gear-reduction electric motor (Plates 13 and 14). Two units of the expellers were procured by the Family Economic Advancement Programme (FEAP) and one unit by the Raw Materials Research and development Council (RMRDC) Abuja in the year 2000 and 2004 respectively.

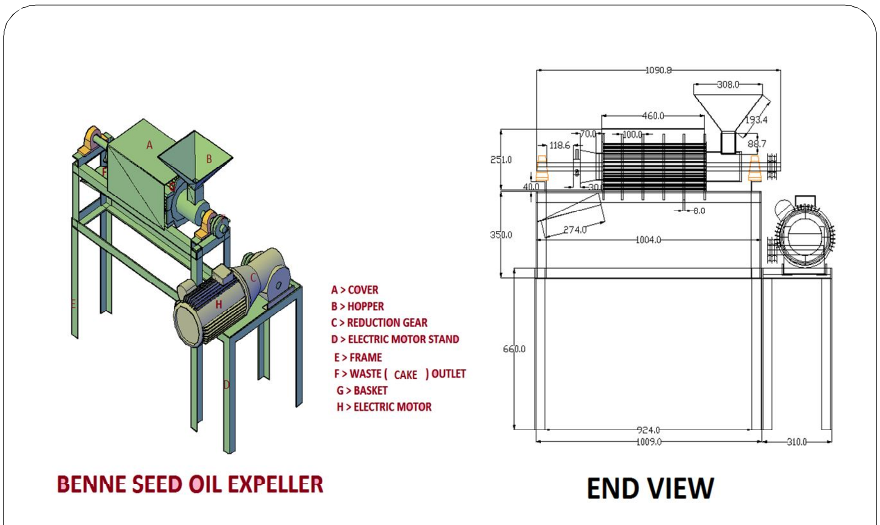


Plate 11: Isometric projection and front view of the oil expeller. Source: Olayanju (2002)

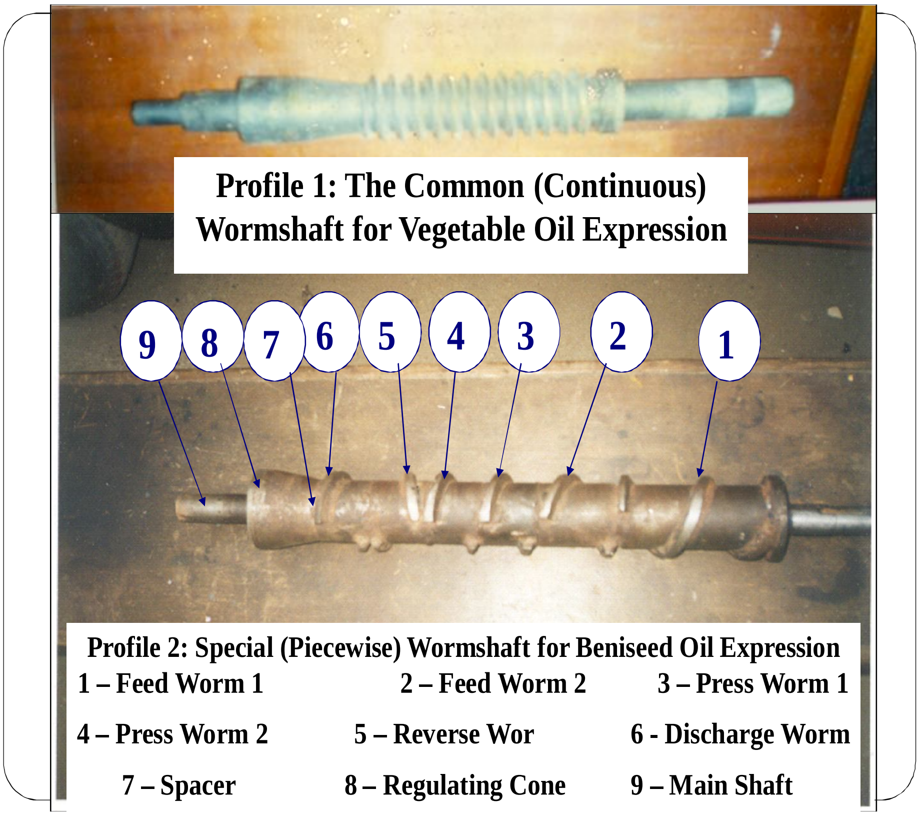


Plate 12: Worms and wormshaft assembly
Source: Olayanju (2002)

Plate 13: Performance evaluation of FIIRO developed oil expeller.
Source: Olayanju (2002)

Plate 14: Inspection of the FIIRO developed oil expeller by the supervisory Ministry of Science and Technology.
Source: Olayanju (2002)

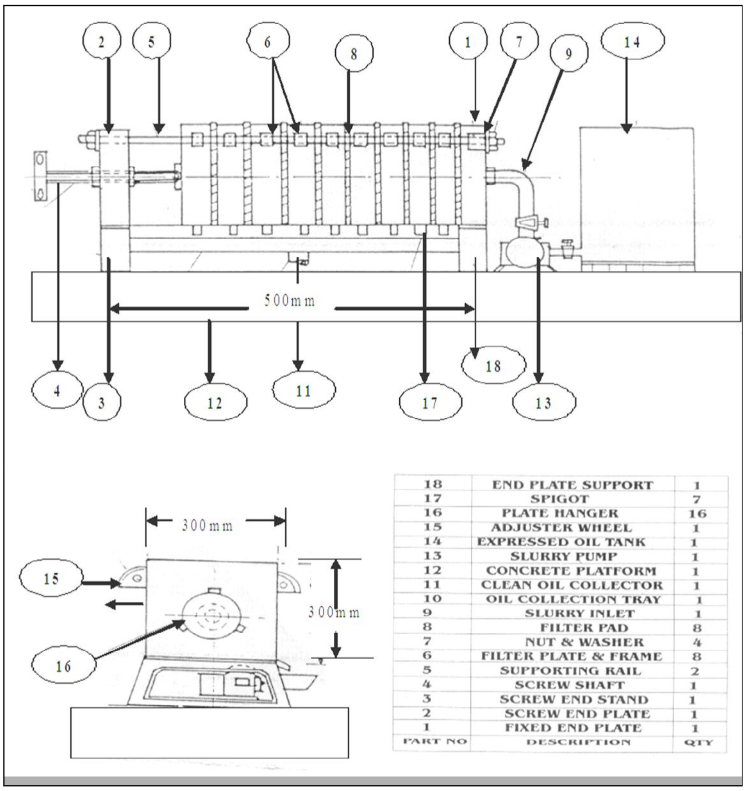
2.5 Development of an oil filter press

Olayanju *et. al.* (2004b) developed a vegetable oil filter press for clarifying mechanically expressed oil from oil - bearing seeds such as beniseeds, groundnuts, melon and palm kernels. The press is made of 6 solid square plates and 6 hollow square frames of dimensions 300mm x 300mm x 25mm cast, machined and packed in alternating arrangement on a steel framework. A selection of grades of filter media is utilized (Figure 11). The equipment is driven by a gear pump through a – 1.5kW electric motor. The design output of the press is 80 litres of raw oil per hour.

The filter press is made of nine main components viz.; the filter plates, the end plates, the filter cloth, the screw shaft and follower, the operating handle, the standing frame, the filter pump drive and the piping materials. A – 1.5 kW electric gear pump forces the oil into the press. The filtration chamber is made of 12-filter plates (6 solid and 6 Hollow) cast, machined and arranged on a framework (Figure 12). Each solid plate has grooves on its surfaces for oil drainage after passing through the filter cloth. The filter plates was cast and the border had a thin - central portion, the surface of which is in the form of ridges or designs in relief, between which the oil can flow in spite of the pressure. This tends to force the cloth against the plate. There are 6 of them in all each having dimension - 300 x 300 x 25 mm3 (Plate 15).

The frames have similar machined borders but their interiors are opened. They are supported by two steel bars, which also serve as cross braces and absorb tensile force produced between the two end members by the pressure exerted in closing the press. There is an electric motor and a gear pump coupled together with the aid of sprockets and chain. There are six taps on the filter plates discharging oil into a longitudinal trough through which the clear filtered oil is removed. Each face of every plate is covered with a filter cloth to create a series of cloth-walled chambers into which slurry can be forced under pressure.

In operation, vegetable oil slurry is pumped from a tank into the chamber where it is to be filtered. The oil flows down the grooved surfaces of the plates and is drained through an outlet channel in the base of each plate. A layer of cake builds up on the cloths until the space between the plates is filled (Plate 16). The press is then dismantled at a pressure of about 5atm and the cloth is cleaned ready to begin another cycle. Plate 18 shows the oil and cake produced by the filter press.



18	END PLATE SUPPORT	1
17	SPIGOT	7
16	PLATE HANGER	16
15	ADJUSTER WHEEL	1
14	EXPRESSED OIL TANK	1
13	SLURRY PUMP	1
12	CONCRETE PLATFORM	1
11	CLEAN OIL COLLECTOR	1
10	OIL COLLECTION TRAY	1
9	SLURRY INLET	1
8	FILTER PAD	8
7	NUT & WASHER	4
6	FILTER PLATE & FRAME	8
5	SUPPORTING RAIL	2
4	SCREW SHAFT	1
3	SCREW END STAND	1
2	SCREW END PLATE	1
1	FIXED END PLATE	1
PART NO	DESCRIPTION	QTY

Figure 11: Orthographic view of the developed oil filter press

Source: Olayanju *et al.* (2004b)

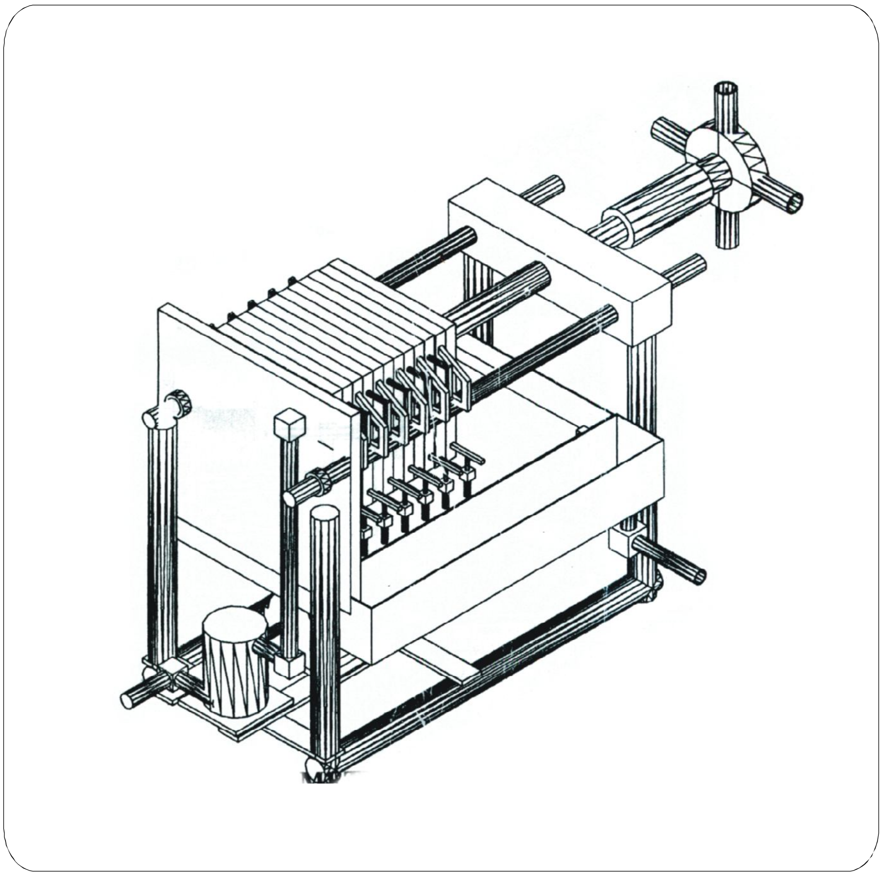


Figure 12: Isometric view of the developed oil filter press
Source: Olayanju *et al.* (2004b)

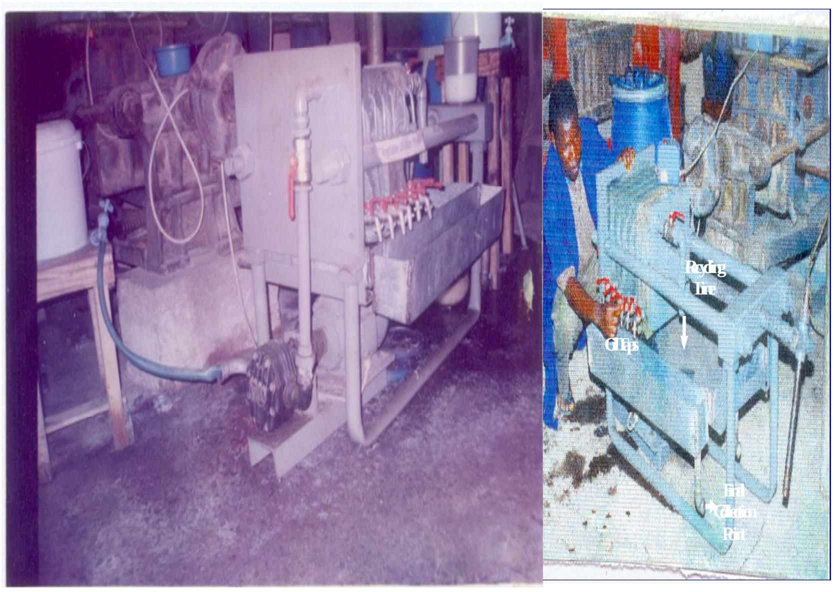


Plate 15: The fabricated oil filter press from different views
Source: Olayanju *et al.* (2004b)

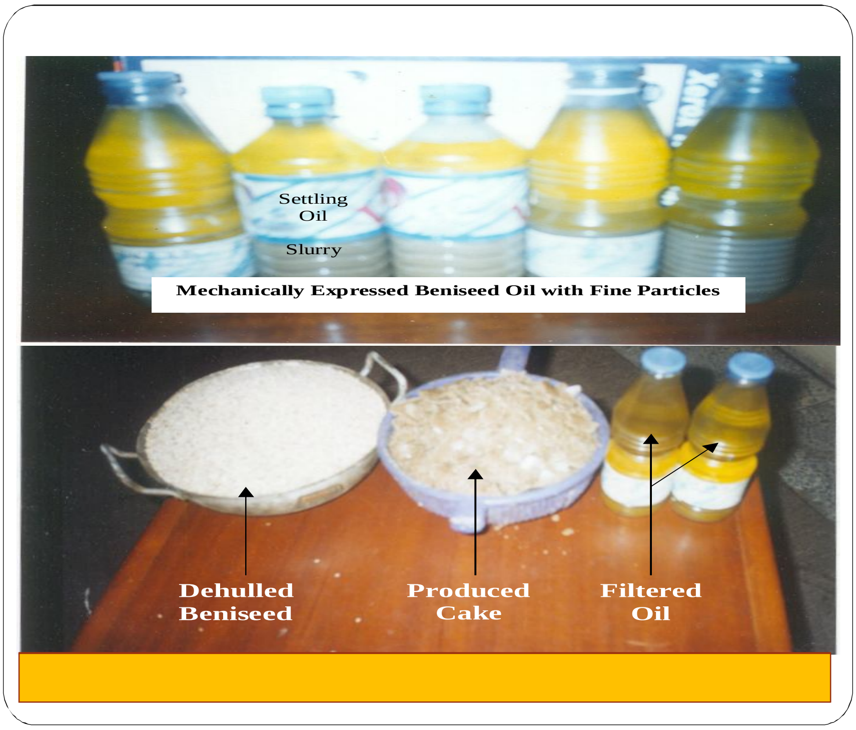


Plate 16: The oil and cake produced by the expeller and the filter press
Source: Olayanju *et al.* (2004b)

2.6 Performance evaluation of the oil expeller

2.6.1 Effect of moisture content and machine speed on capacity

Beniseed contains about 42-54 % quality oil, 22-25 % protein, 20-25 % carbohydrates and 4-6% ash. This composition varies with genetic and environmental factors. Olayanju (2003b) studied the effect of machine wormshaft speed and seed moisture content on the capacity of a cottage-scale oil expeller using two beniseed accessions-Yandev 55 and E8. The machine capacity increased from 9.98 to 11.88 kg/h and 8.91 to 11.52 kg/h, respectively, for the two accessions as the moisture content increased from 4.1 to 5.3% wet basis at wormshaft speed of 30 rpm. A further increase in moisture content to 10.3 % decreased the capacities to 10.50 and 9.65 kg/h, respectively. This was a general trend for all the wormshaft speeds (45, 60, and 75 rpm). The capacity of the expeller was highly affected by wormshaft speed, moisture content and seed accessions. It was found to be greater at lower levels of wormshaft speed and moisture content. The maximum capacities of 13.22 and 12.08 kg/h were obtained at wormshaft speed of 60 rpm and 5.3% moisture content for Yandev 55 and E8, respectively.

2.6.2 Effect of moisture content and machine speed on oil and cake qualities

Olayanju (2003c) stated that for processing two sesame seed accessions, Yandev 55 and E8, in an oil expeller, a wormshaft speed of 45 rpm and 5.3% seed moisture content (wet basis) gave the best oil and cake qualities. Akinoso *et al*. (2010) investigated effects of initial moisture content, roasting duration and temperature on initial Peroxide Value (PV) and Oxidative Stability (OS) of un-refined beniseed oil using response surface methodology. The recorded minimum and maximum PV were 3.9 and 15.4 meq/kg, respectively. Peroxide value increased with increasing moisture content and reduced with increasing roasting duration. Within the studied range, 13 h was the minimum OS recorded while maximum were 63.3 h. Mean of the data was 38.37 ± 16.02. Using the conversion factor of one hour of an active oxygen hour as being equivalent to 15 days; the expressed oil in its present form will retain its quality for a maximum period of $2^1/_2$ months. Rise in roasting temperature and duration increased the oxidative stability, a reverse was observed with initial moisture content. High moisture content reduced the quality and storage life while heat treatment increased both the initial quality and storage life of the mechanically expressed oil. Storage is one of the identified factors that influence usage of oil. Akinoso (2006c) established the shelf –life of un-refined sesame oils. Organoleptic evaluation technique was applied. Best grade after 6 months of storage was 8.9 (good) while least grade was 4.9 (moderate). It is obvious that quality grade of oil declined with duration of storage.

2.6.3 Effect of moisture content and machine wormshaft speed on oil recovery

Olayanju *et. al*. (2006b) studied the effect of machine wormshaft speed and seed moisture content on oil recovery from the expelled seed. The oil recoveries from the two accessions increased from 37.56 to 70.62 and 33.70 to 64.85% respectively as the wormshaft speed increased from 30 to 45rpm at 4.1% moisture content (wet basis). A further increase to 75rpm decreased the respective oil recoveries to 40.23 and 38.79%. This was a general trend for all the studied moisture contents. The maximum filtered oil recoveries of 79.63 and 74.28% of the expressable oil were obtained for Yandev 55 and E8 respectively from a-one pass crushing. These values were obtained at 45rpm and 5.3% m.c. The statistical analysis shows that only wormshaft speed and its interaction with moisture content have significant effect on the oil recovery.

2.6.4 Optimization of beniseed oil recovery

Akinoso *e. al*. (2006d) established the degree of influence of moisture content, duration and temperature of roasting on oil expression from this crop using an oil expeller. Effects of these parameters were used to develop model equations, optimize oil yield and quality. Four levels, each of moisture content, roasting duration and temperature were used for the experiment, giving a total of 64 samples. Expressed oil was recorded as yield while free fatty acid, oil impurity and color were the criteria used in determining oil quality. Data were analyzed, employing multiple regression technique to generate mathematical models. Oil yield was maximized while free fatty acid; color and impurities were kept at acceptable levels. Mean oil yield, free fatty acid, impurity and color were 34.78%, 2.57%, 0.22% and 6.7 respectively. The optimum moisture content, roasting duration and roasting temperature were 4.6%, wet basis, 13.0minutes and 124.2^{o}C respectively. These combinations gave 50.4% oil yield, 1.1% free fatty acid, 0.1% oil impurity and 6.2LUY. Error in prediction is not significant at P>0.05. Expression of beniseed at the obtained optimum parameters guarantees high yield and good quality virgin oil.

2.6.5 Modelling of beniseed oil colour

A 3-factor experimental design was used to determine the influence of moisture content, roasting duration and temperature on beniseed oil colour (Akinoso *et al*., 2006e). The data obtained were used to develop prediction model for the oil colour. Coefficient of determination R^2, probability of prediction F, and analysis of variance technique were employed to authenticate the adequacy of the model. Colour intensity increased with increase in moisture content, roasting duration and seed temperature. Rated by lovibond unit, the oil colour varied from 5.8 to 8.3 yellow and 2.3 to 3.4 red. Therefore the three parameters investigated had significant effects on the oil colour. Coefficient of determination, R^2 at 95 % confidence level and Probability of prediction F, were 0.93 and 0.77 respectively. Estimated error of $\pm$ 0.2 is envisaged while applying the model for predicting beniseed oil colour.

2.6.6 Economic evaluation of beniseed

Oyeku *et al*., (2006) carried out the economic evaluation of beniseed oil production based on annual plant capacity of 1,500 tonnes (i.e. raw beniseed at 100% capacity utilization) with production taking off in year 1 at 60% capacity utilization and this increased gradually to 80% capacity utilization in the fifth year. The Return on Investment and Return on Equity in year one were determined as 14.56 and 18.45% respectively. The Internal Rate of Return is above 50%. This is greater than 20% which is the cost of fund. The Net Present Value (NPV) at 25% is positive i.e N10, 226,540.00. The payback period and the discounted payback period are 1.6 and 2.4 years respectively. Also, the Net Profit to sales and the Capital Turnover Ratio are 7.5 and 5.8% respectively in year one. The Debt Servicing Coverage Ratio (DSCR) showed a gradual increase from 2.2 to 4.4 from the first to the fifth year of operation. The breakeven point in year one is 41%. All these economic indices attest to the viability of the project.

The developed oil expeller and filter press have won awards at the National Design Competition (2004) and National University Research and Development Fairs (2004 and 2005).

2.7 Ofada rice threshing in Nigeria

2.7.1 Assessment of ofada rice threshers

Adewumi *et al*., (2007) assessed rice thresher designs and products available within Nigeria and neighbouring countries. The project was funded by DFID/PrOpCom. The impetus for the study is the concern that low and poor quality of local rice in Nigeria may be due, in important measure, to lack of good threshers. Like many others in Nigeria, the rice production system is labour intensive. There is minimal mechanization and this is mostly at the level of land preparation. The reconnaissance work was carried out in Five Local Government Areas in Ogun State, Erin – Ijesha in Osun State, Igbimo in Ekiti State; Abakaliki in Ebonyi State, Makurdi in Benue State as well as Kura - Kano and Tundun Wada areas of Kano State.

Olayanju *et al.,* (2009b) stated that access to appropriate threshing machines will give a big boost to rice product development and marketing in the Ofada and Kura-Kano rice production areas by reducing the physical drudgery of manual threshing (Plate 17) and speeding up the process of threshing. Since paddy rice is often piled in the field to dry and await threshing, more rapid threshing will reduce the exposure to harsh weather (with risk of loss from mould and shattering before arriving at the threshing location), birds, livestock and other sources of predation. It will also limit the amount of contamination and breakage of the grains thereby increasing product quality and competitiveness in the market. It was found that most farmers in Ogun state had no threshers nor the opportunity to borrow one. Therefore a stakeholder workshop was held in Ogun State. Based on the farmers' evaluation and assessment of existing rice threshers displayed by Research Centres/Universities, local fabricators and some organization within and outside Ogun State. The workshop recommended three prototype small threshers that are pedal and petrol engine driven.

Plate 17: Manual rice threshing in Ogun state

Source: Adewumi *et al.* (2007)

The National Centre for Agricultural Mechanization, NCAM pedal operated thresher (Plate 18) was recommended for those with farm hectarage of less than 2. For threshing freshly harvested rice at very high moisture content, the IITA/ WARDA small plot spike-tooth thresher (Plate 19) which has a threshing capacity of about 100 kg/h was found to be appropriate for the small – scale farmers provided some little modifications in the area of capacity and mobility were carried out while the multi-crop thresher (Plate 20) of the Federal College of Agriculture (FCA), Ibadan with a capacity of about 250 kg/h was recommended for those with farm hectarage of more than 5ha. The study concluded that:

- The average quantity of rice threshed by rice farmers during the production season under consideration was 300 kg while the manual threshing capacity was 30 kg per hour.
- The provision of affordable threshing machine will reduce drudgery, increase efficiency in rice threshing, quantity of rice threshed and the level of profitability.
- The quantity of rice threshed can also be increased with increase in the income of rice farmers (to meet the financial requirement for purchase of threshing machines) and reduction in the labour cost.
- Like many other farm production systems in Nigeria, the rice production system is labour intensive. There is minimal mechanization and this is mostly at the level of land preparation.

Plate 17: NCAM pedal operated thresher
Source: Olayanju *et al*. (2009b)

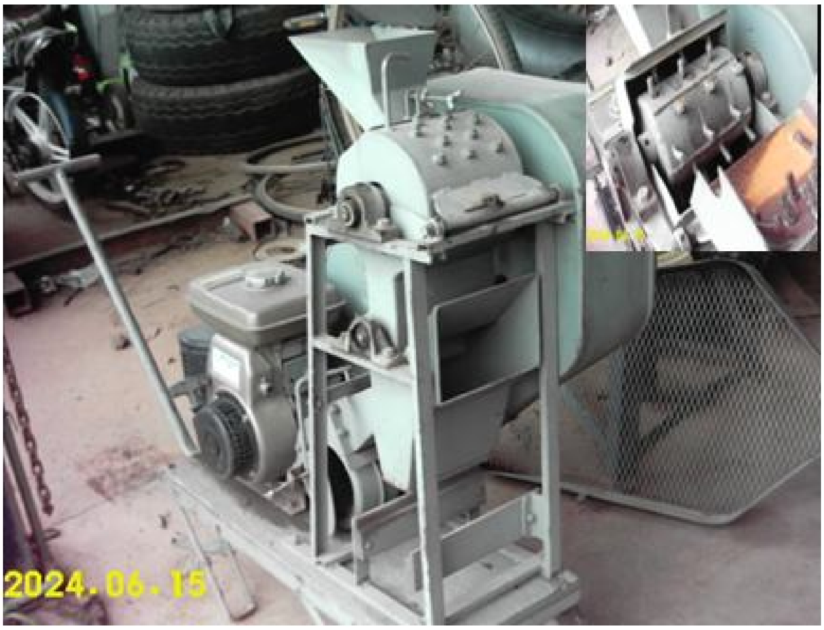


Plate 18: IITA/WARDA plot thresher (In set: The multi -spike drum)
Source: Olayanju *et al*. (2009b)

Plate 19: FCA, Ibadan multi crop thresher
Source: Olayanju *et al*. (2009b)

2.7.2 Development of an ofada rice thresher

Olayanju *et al*. (2009c) developed an axial flow spike toothed manually operated rice thresher (Plate 20) based on the recommendations of Adewumi *et al*. (2007) and Olayanju *et al*. (2009a). It has a capacity of 25kg/h. The length of spike is 50mm and 5mm in diameter. The performance of the thresher was evaluated in terms of threshing efficiency. The cylinder –concave clearance was fixed at 3:1 and 3:0.8 at the front and rear respectively throughout the test.

The performance of the thresher was evaluated in terms of threshing efficiency (Plate 21). The cylinder –concave clearance was fixed at 3:1 and 3:0.8 at the front and rear respectively throughout the test. Results showed that decreasing the feed rate increases the threshing efficiency irrespective of the feeding pattern. Threshing efficiency decreased with increasing sieve oscillations and threshing cylinder speed. Feeding patterns affect the separation efficiency. Grain wastage was observed to decrease with increasing feed rate while increasing sieve and straw walker oscillations increased wastage.

Plate 20: The developed rice thresher in operation
Source: Olayanju *et al.* (2009c)

Plate 21: Testing of the fabricated rice thresher
Source: Olayanju *et al.* (2009c)

2.7.3 Development of an ofada rice cleaner

Cleaning is a pre-requisite operation in Ofada rice production. The Federal Produce Inspection Service (FPIS) enforces FAO prescribed grades and standards recommended by International Commodities Board for cleaning of grains especially those intended for export (Hockman, 1998). They observed that an average 50kg bag of ofada rice in Nigerian markets contains average of 10 % foreign materials which include; oversize materials like leaves, sticks and stems; undersize materials such as sand and dust; same size material like hulls, empty shell of grains and stone. Ofada rice that failed to meet international standard were rejected for export.

Olayanju *et al.* (2009d) modified a designed beniseed air-screen cleaner to handle ofada rice (Plate 22). The machine employs the use of a set of two vibratory screens of different apertures depending on the seed accessions and a blower powered by a 3Kw electric motor to remove unwanted materials from the seeds (Plate 23).

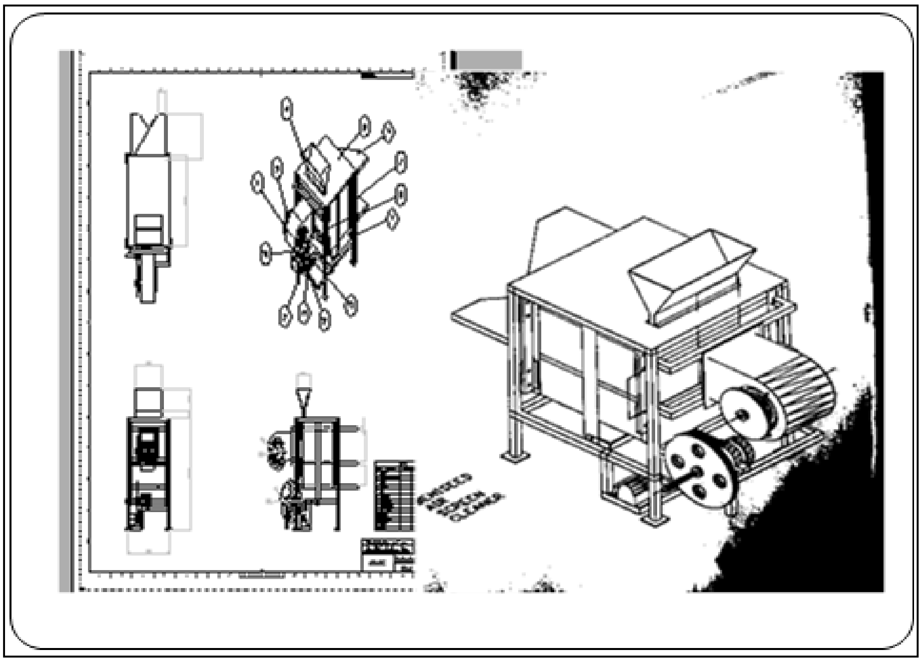


Plate 22: AutoCAD view of the modified seed cleaner
Source: Akinoso *et al.* (2010)

Plate 23: The modified grain cleaner in operation
Source: Olayanju *et al*. (2009d)

2.8 Development of improved cassava processing plant

2.8.1 DESOPADEC cassava utilisation project

Okuneye *et al.* (2008) carried out a baseline survey of cassava multiplication and utilisation project in Delta State. The project was sponsored by the Delta State Oil Producing and Economy Commission (DESOPADEC). It was observed that Cassava production is still carried out by manual labour using local simple farm implements such as hoes and cutlasses in most parts of the state. There is a general absence of mechanized facilities to the local farmers who constitute the majority of the producers.

Cassava roots were processed at household and cottage levels in the rural areas of the state. Processing at these levels involved mainly the production of garri, fermented and unfermented flour, as well as fufu for both domestic use and the market. Production of wet cassava starch was also observed at low levels.

The survey showed that cassava was mainly cultivated as an intercrop in small holding farms (about 87%) owned by peasant farmers in the villages. An average of 0.1 to 0.8 ha of the farms is cultivated per community. Medium holding farms constitute about 10%, while large scale farms of cassava mono crop make up 3% of the farms in the state.

The processing of cassava roots into 'gari', flour and fufu are done by traditional methods handed down through time as cassava was adopted as food by the people. The process of cassava into gari, involved peeling grating (mashing) – dewatering/fermentation – sieving – frying – packaging. The process for production of flour involve peeling – cutting into pieces – sun drying – milling – sieving – packaging (for unfermented flour); peeling – cutting – steeping (soaking in water) and fermentation – (mashing) – sun drying – milling – sieving – packaging (for fermented flour).

The process for fufu production is similar to fermented flour production except that the sun drying is omitted and the mash dewatered after sieving. Fufu was normally sold as wet mash although modern methods for producing odourless fufu flour were adopted. The exact estimate of the annual requirements of the processed cassava roots could not be ascertained from the questionnaire returned due to the absence of standard measures. However, the estimated 30 million tonnes produced could be taken as that processed into different products. There was no indication of processing cassava root into chips and pellets for animal feeds in the state. Likewise, processing of cassava to value added products like alcohol, dextrins, glue, sweeteners, monosodium glutamate (MSG), modified starch, etc were yet to be done in the state.

Processors usually obtain the supply of their cassava root tubers direct from the producers (farmers), or from the open market, while a good number of them got from their own farms. The demand for the tubers by the processors is in most cases met by the supply. However, market forces, transportation costs, and low pricing of the roots discourage the producers from embarking on larger scale production. Production is also limited by the drudgery of using local implements and manual labour for cultivation as well as soil degradation by erosion, desertification and oil pollution in different parts of the country. The equipment and machinery used by the processors are mainly sourced locally.

2.8.2 Development of an improved gari fryer

'Gari' is a creamy white granular flour with slightly fermented flavor and slightly sour taste made from fermented gelatinized fresh cassava tubers. It is widely known and used as staple food in Nigeria and West African countries. It is consumed in different forms; it is consumed principally as a main meal but sometimes taken as a snack. Garification or frying is the most critical unit operation in Gari Production and it determines the quality of the final product in gari. Local gari frying method has been a tedious and cumbersome process for gari producers over the years, across the gari producing zones of Nigeria. Our women face the hazard of direct heat from the frying system using charcoal in the process of producing gari.

Although there are some moderns machines, there is need to improve on them.

Olayanju *et al.* (2012a) developed a fryer which consists of a frying pan, a charcoal tray, aeration pipe with bellow, support/ stand and the discharge mechanism (Plate 24). It has a capacity of 2kg of cassava cake per batch of 15 minutes. The frying tray is rectangular in shape with dimensions 1000mm x 430mm x 50mm with 2mm thickness. Four supports are provided at each corner of the frying tray. The charcoal tray is made of two boxes of dimensions 400mm x 380mm x 25mm. it is perforated using 8mm drill for passage of ashes. The boxes are open at the end. One handle each is attached to the end of the tray for easy handling.

The advantages of this improved village model/ local gari fryer over the existing traditional fryers are the introduction of bellow for uniform distribution of heat, the attachment of a tilting device for easy discharge of the finished product, the use of castrol wheel for easy movement of the fryer from place to place, the use of charcoal, which is a cleaner fuel than firewood and the insulation of the wall of the fireplace for heat conservation (Plate 25).

Plate 24: The developed gari fryer
Source: Olayanju *et al.* (2012a)

Plate 25: Testing of the developed gari fryer
Source: Olayanju *et al.* (2012a)

2.8.3 Development of a cassava chip dryer

Traditionally, chip production involves the simple technique of cutting peeled or unpeeled cassava roots into smaller pieces and allowing the pieces to dry. Sun drying is the most common and acceptable drying technique, but this is not hygienic, slow and of poor quality. Olayanju *et al.* (2012b) developed an agro-waste fired cassava chip cabinet tray dryer. It can be adapted to dry other agricultural product. It consists of a drying tray, a charcoal section, tray holder, heat distribution pipes, bellow, castrol wheel and support. It has a capacity of 3kg of cassava chips per batch of 15 to 20 mins. The tray is rectangular in shape with dimension 300 x 200 x 30 mm^3. Four supports are provided at each corner of the drying tray which serves as the tray holder (Plate 26). The charcoal section is made of 2 boxes with dimension of 300 x 100 x 150 mm^3.

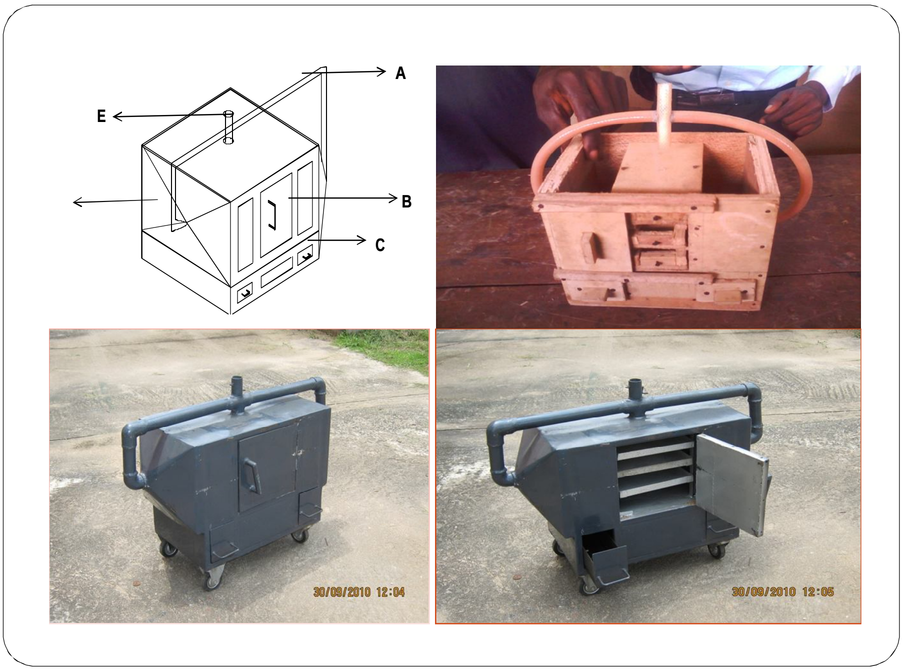


Plate 26: Development of a cassava chip dryer
Source: Olayanju *et al.* (2012b)

The heat from the drying medium (hot air) to the food product is transferred by convection. The convection current passes over the product and not through the product. It is suitable for dehydration of fruit and vegetables. Above the charcoal section are pipes connected in series in which one side connected to a bellow which gives the other side hot air for drying to commence. At the two sides of the dryer are the heat distributors which ensure proper distribution of heated air to the drying section. The special features of this dryer includes the introduction of a bellow, the separation of charcoal section from the drying section and the use of castrol wheel for easy movement from one place to another (Plate 27).

Plate 27: Testing of the developed chip dryer
Source: Olayanju *et al.* (2012b)

2.8.4 Development of a cassava pelletiser

Cassava pellet is an unfermented dried cassava product obtained by compressing raw dried cassava chips under appropriate processing conditions resulting in the formation of dried, bulky product suitable for the animal feed industry with an average length of 3 cm. Pellet production was stimulated by the need to improve the uniformity in the shape and size of cassava chips required by the users and animal feed producers. In addition, during transportation, loading and unloading of chips, dust generation caused serious air pollution, placing pressure on the importers in Europe to improve the nature of cassava products handled by the ports. Production of pellets involves pressing chips and extrusion through a large die.

The heat and moisture in the chips help in the formation of pellet like shaped product known as soft pellets. Later process developments involved grinding of chips followed by steam extrusion. This process produces strong pellets upon cooling. These types of pellets are known as hard pellets. Olayanju *et al.* (2012c) developed a prototype pelletiser for variety of food products. It has a barrel of 20mm diameter and a special wormshaft length of 300mm rotating at a speed of 70rpm through a 0.75kW electric gear reduction motor (Plates 28 and 29). The throughput was estimated as 15kg cassava flour per hour.

The machine converts the powder from the chips into hardened, moulded cylindrical shapes of about 2-3cm long and 0.4 – 0.8 cm in diameter which are uniform in appearance and texture. The efficiency of the machine in terms of pellets from cassava flour as influenced by wormshaft speed and moisture content was evaluated. The maximum efficiency of 86% was obtained from a – one pass crushing. This value was obtained at wormshaft speed of 70rpm and moisture content of 10% and are in agreement with what obtained for other pellets.

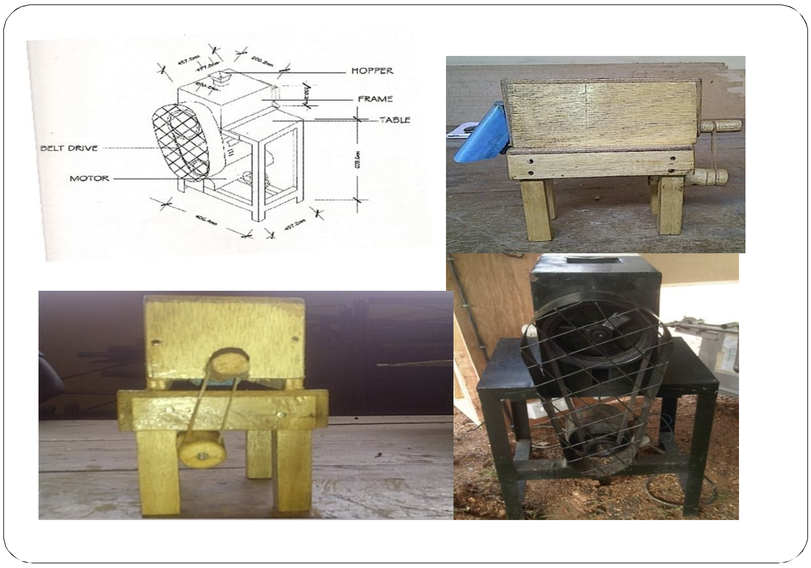


Plate 28: Development of a Cassava Pelletiser
Source: Olayanju *et al.* (2012c)

Plate 29: The internal features of the pelletiser
Source: Olayanju *et al.* (2012c)

2.8.5 Adaptation of some mechanical tillers for weeding cassava farms.

Weed control is one of the most difficult tasks in agriculture, accounting for a considerable share of the cost involved in agricultural production. Farmers generally express their concern for effective weed control measures to arrest the growth and propagation of weeds with a view to increase yield. Chemical method of weed control is more prominent than manual and mechanical methods. However, its adverse effects on the environment, farmers, the community and eventually, the consumers are making farmers to consider and accept the use of mechanical methods of weed control. Manual weeding is common in Nigerian agriculture but it is labour intensive and very slow though very efficient. The use of mechanical weeder will not only reduce cost and improve the output; it will reduce drudgery and make the operation more attractive due to the ergonomic considerations during weeding. This will resultantly increase production.

It is against this background that the Cassava Weed Control Project of the International Institute of Tropical Agriculture (IITA) invited some Nigerian Engineers to modify and test some imported tillers in order to adapt them for weeding cassava farms. Results of the initial field test, showed that the machines had frequent clogging with different types of grasses, density and high depth of cut of about 9 cm capable of causing damages to cassava roots. This shows that the machines may be good for tilling or normal weeding. Therefore, the tines of the machines were modified to accommodate additional blades at the centre of the tines, metallic plates and cups around the swindles and a wheel at the middle of the support for effective traction and stability (Plate 30). The field test of the modified machines showed a reduced depth of cut, less

Plate 30: Modification of the imported tillers
(Source, Diallo *et al.,* 2015)

Plate 31: Testing of the adapted cassava weeders
Source: Diallo *et al.* (2015)

clogging and little or no significant damage to the roots or ridges (Plate 31). The modifications were incorporated in all the fourteen imported tillers. Thereafter, they were distributed to IITA stakeholders on weed control project. Our University (FUNAAB) is a beneficiary of two of these modified machines.

2.9 Production of machine teaching aids

Mr. Vice Chancellor, Sir, three Academic Staff of this University (The Late Engr. M. Aina, Dr O.U. Dairo and Professor, then Dr. T.M.A. Olayanju) attended a Bamboo Technology Training Course held in Hangzhou, China, between June and August, 2011. One of the class activities was the production of a model grain cleaner using bamboo (Olayanju *et al*., 2011). The development has led to the production of many machine teaching aids by our design students (Plate 32) and these have

Plate 32: Development of machine teaching aids by our students

been exhibited in Conferences, Workshops and Agricultural Fairs (Plate 33).

Plate 33: Presentations of the developed teaching aids at FUNAAB Agricultural Fair

3.0 CAPACITY BUILDING FOR DESIGN AND DEVELOPMENT OF AGRICULTURAL MACHINES

Many countries in Africa have over the past three decades established agricultural machinery and implements manufacturing and assembly factories. Some of these have been set up with multi-lateral or bilateral donor assistance often on a turnkey basis and relying on imported technologies. These have often been large or medium scale operations and in most cases have relied on imported CKD kits and raw materials.

Parallel to these medium and large scale enterprises, are also numerous facilities for repair, fabrication and manufacturing of agricultural machinery and implements set up by individual entrepreneurs, usually operating on a small scale level. At the lowest end of these types of enterprises in the machinery and farm implement development sector are the local fabricators and blacksmiths. According to Okuneye and Olayanju, (2008) these small scale enterprises operate in the informal and formal sectors, usually, employing one to two people and often less than ten employees, do not enjoy any government, or credit facilities, and struggle on their own to provide key services to farmers and agricultural machinery and implement owners. Their contribution to the national economy is not recognized in most cases, and in some cases they are not supported by the official organs of state.

The raw materials available in Nigeria such as agro-allied or solid minerals have peculiar characteristics and qualities which only the local engineers can discover and adapt to meet their design needs. A lot of manufacturers of equipment based in Europe, Asia and America are not aware of the peculiar nature and characteristics of our resources. Often they make their design consideration based on their own resources without considering the difference in the nature of our resources. A typical example that readily comes to mind is the use of palm oil processing plant from Malaysia. While it is common knowledge that Malaysia has advanced technologically in oil seed processing, many of their plants do not work well in Nigeria. This is because they are designed for the softer species of palm oil whereas Nigeria has abundance of both hard palm kernel nuts that grow wild and the soft ones, grown through oil palm estates.

The indigenous design engineers and fabricators therefore have the task of ensuring that process equipment and plants must be built to meet peculiarities of our local raw materials in addition to such factors as efficiency, ruggedness, reliability, maintenance, heat generation, life span, safety, robustness, ergonomics, visual appeal scalability, compatibility, cost of design, manufacture and operation, availability of spare parts, user friendliness. Most of our equipment are fraught with problems of engineering designs, materials selection, durability, reliability, maintenance, safety, efficiency in terms of output, crude and poor finishing of equipment and plants, etc. One of the critical factors attributed to the poor performance of this equipment is the limited application of process engineering design calculation in the fabrication (Adewumi, 2012).

A gallup survey conducted by the RMRDC in 2003 reaffirmed this problem to be a national phenomenon as most of the locally fabricated process equipment in the country were not based on detailed engineering design calculations and drawings. It is, therefore, not surprising that the industrial projects embarked on, even by the Council could not meet their targeted goals. It is for these reasons that designers of process equipment must have a thorough understanding of the basic application of engineering design coupled with raw materials characteristics before embarking on the fabrication of process equipment.

In the current global drive to improve quality and production efficiency, understanding basic concept in engineering design of process equipment and machinery for conversion of agricultural and mineral raw materials into finished goods cannot be over emphasized. For the products of local manufacturers of process equipment and machinery to be integrated into meaningful activities of national economy and acceptance in foreign markets, a deliberate plan must be evolved for continuous improvement of the product design, quality of products, good finishing of products, material selection, cost reduction, product flexibility, etc.

A properly designed process plant and equipment will function efficiently, thereby increasing capacity utilisation and industrial growth. The effect of such growth will be reflected in improved living standard, employment generation, maximum utilisation of local raw materials and foreign exchange earnings.

The approach of equipment fabrication by "trial and error" has not encouraged investors to patronise Nigerian made equipment and process plants, which has hampered the industrialization pace of the country, especially the SME's. As the importance of good engineering design for fabrication of durable, efficient and robust process plants and equipment cannot be over emphasised, adequate basic understanding of engineering design concept is the backbone of any good fabrication of plants and equipment. We all know that the level of accuracy of the design parameters determines the viability, durability and profitability of the process plants and equipment.
As we are now aware, the design and fabrication of process equipment and plants involve a wide variety of skills and thus, if the overall design is to be successful a close team-work is necessary among the various groups of engineers working on

different phases of a process plant project. It is my belief that relevant documents should be produced to serve as reference materials for the academic, research institutions, industry, indigenous engineering firms, policy makers, and other users as yseful tools for their operations.

The absence of this fundamental capacity has been responsible for Nigeria's under-development as well as her unfortunate membership of the club of the poorest fifty nations of the world (Nnadi, 2003). This is inspite of the valuable resources and talent potential within the country. We have to address the challenge of our lack of capacity in the areas of design and industrial manufacturing technology especially as the country is beginning to appreciate the need to pay attention to the non-oil area of the national economy. Besides, the universal warnings have always been clear and consistent - manufacture or perish.

3.1 The way forward

As the nation begins to gear up towards the (non-oil) and manufacturing phase of her industrial development, the need to draw attention to the role of **good engineering design practice** has not only become urgent but extremely crucial. Considering our near-zero potential in this area as regards availability of skilled manpower (at the low, intermediate and high levels) we cannot afford any further delay in our capacity building efforts. This deficiency had been partly responsible for the very poor quality (and poor performance) of most of the locally made industrial machinery, equipment and other technical items. Realizing that education and training form the fundamental factors in capacity building and manpower development, it becomes very important to plan a special design awareness programme which must take into account such basic deficiencies as:

(a) Low graphic literacy level, which is nationwide.
(b) Neglect of technical education as clearly demonstrated in the sub-standard nature of our technical colleges.
(c) Absence of qualified/experienced technical teachers and instructors at all levels of technical education.
(d) Absence of manufacturing technology infrastructure.
(e) Near-zero emphasis on standards (both the National Standards and ISO Standards).
(f) Low computer literacy efforts essential for appreciation and adoption of modern Computer-aided-graphics and design techniques like CAD etc.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Mr. Vice-Chancellor, Sir, Distinguished Scholars, Ladies and Gentlemen, while showing immense appreciation for the precious time you all have sacrificed for this lecture, the conclusions and recommendations to be drawn are multifaceted.

If we desire the equitable structure of society free from any kind of exploitation, it is essential that the means of production must be in the hands of the people which should be managed by them, controlled by them and also owned by them. This is possible only if technology of production is decentralized at very small scale level-almost at home or cottage scale level. One of the most striking virtues of such decentralized cottage level technology is that it creates self reliant and self supporting society that can completely protect itself from the external economic forces.

Therefore, for man, material and machine to be the effective wheels of a tricycle that will drive agricultural mechanization, the following recommendations are proposed:

A. For the NATION:

i. Research should be geared seriously toward developing machines and plant for secondary processing of our crop and animal materials to final products. Researches must be end-user-driven and applied so that such products will no longer stay forever in the laboratories.

ii. Promotion of local engineering capability in the design and fabrication of process equipment and machinery for processing of local raw materials.
iii. Infusion of engineering design concepts into engineering practice in Nigeria, so as to enhance standard and quality of locally fabricated process equipment and machinery.
iv. A medium of interaction among the academia, industry and government establishments on the need to inculcating engineering design concepts in the fabrication of process equipment and plants for sustainable industrial development should be created.
v. The Government through the Federal Ministry of Science and Technology should provide incentives and create a conducive environment that will translate science and technology to an efficient engineering practice in Nigeria.
vi. Encouraging and enhancing the efforts of the government institutions such as NCAM, PRODA, FIIRO and FUNAAB in promoting the fabrication and production of processing machine/equipment. These institutions need to be further strengthened to enable them carry out large-scale production of these equipment even at commercial level. The institutions should also be empowered to provide short- term refresher training programmes for the local fabricators to enable them be in tune with modern equipment production and maintenance and to produce more durable and efficient equipment.

B. For FUNAAB

i. The College of Engineering of this University cannot be fully established and developed without her own state-of-the-art building and facilities such as Design Offices, Universal Testing Machine (UTM), Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), highly Advanced Computer Numerically Controlled (CNC), Milling Machine, Heat Treatment facilities, Machine and Fabrication Workshops with a complete tool room, Forging and Foundry and more Laboratory Testing Equipment.
ii. The Community based Farming Scheme (COBFAS) of the University has come to stay.. However, there is need to restructure the scheme to accommodate other programmes of the University such as Agricultural Engineering and Food Technology.. This will take the scheme to its phase II of post harvest operation and value addition of products from the scheme and eventual upgrading to commercial research centre as we have in other parts of the world.

C. For COLENG

i. Our research focus should be relevant to specific national needs and the University focus on Agriculture.
ii. We should be more involved in the development and maintenance of the infrastructural facilities of the University.

5.0 ACKNOWLEDGEMENTS

"I returned and saw under the sun, that the race is not to the swift, nor the battle to the strong, neither yet bread to the wise, nor yet riches to men of understanding, nor yet favour to men of skill, but time and chance happeneth to them all" Ecclesiastes 9:1(NKJV)). I give thanks to the Almighty God for His abundant mercies and unfailing love for me and my loved ones. I am where I am today by His grace and I give Him all the glory.

OUR VICE-CHANCELLORS

I appreciate all the former Vice-Chancellors of this University: Prof. 'Nimbe Adedipe, Prof. J. Okogie, Prof. I. F. Adu, who appointed me, Lecturer I and reappointed me, Senior Lecturer; Prof. I. Adamson, Prof. O. O. Balogun, who promoted me to Readership Position and Prof. O. B. Oyewole, the incumbent Vice Chancellor, who promoted me, Professor of Agricultural Mechanization. Mr. Vice Chancellor, Sir, thank you for your mentorship, especially as the Director of RESDEC when we won two consecutive Awards from NURESDEF in 2004 and 2005. I have learnt quite a number of useful lessons by my interactions with you.

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COLENG FAMILY

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To God be the Glory
Great things He hath done
So love He that world that
He gave us His Son
Who yielded His life
an atonement for sin
And, opened the life gate
that all may go in

Chorus:
Praise the Lord, Praise the Lord
Let the earth hear His voice
Praise the Lord, Praise the Lord
Let the people rejoice
Oh, come to the Father,
through Jesus the Son
And, give Him the glory
Great things He hath done.

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