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BUILDING A PARADISE IN NIGERIA-THE R&D OPTION FOR SMALL AND MEDIUM SCALE AGRO-ALLIED INDUSTRIES

By

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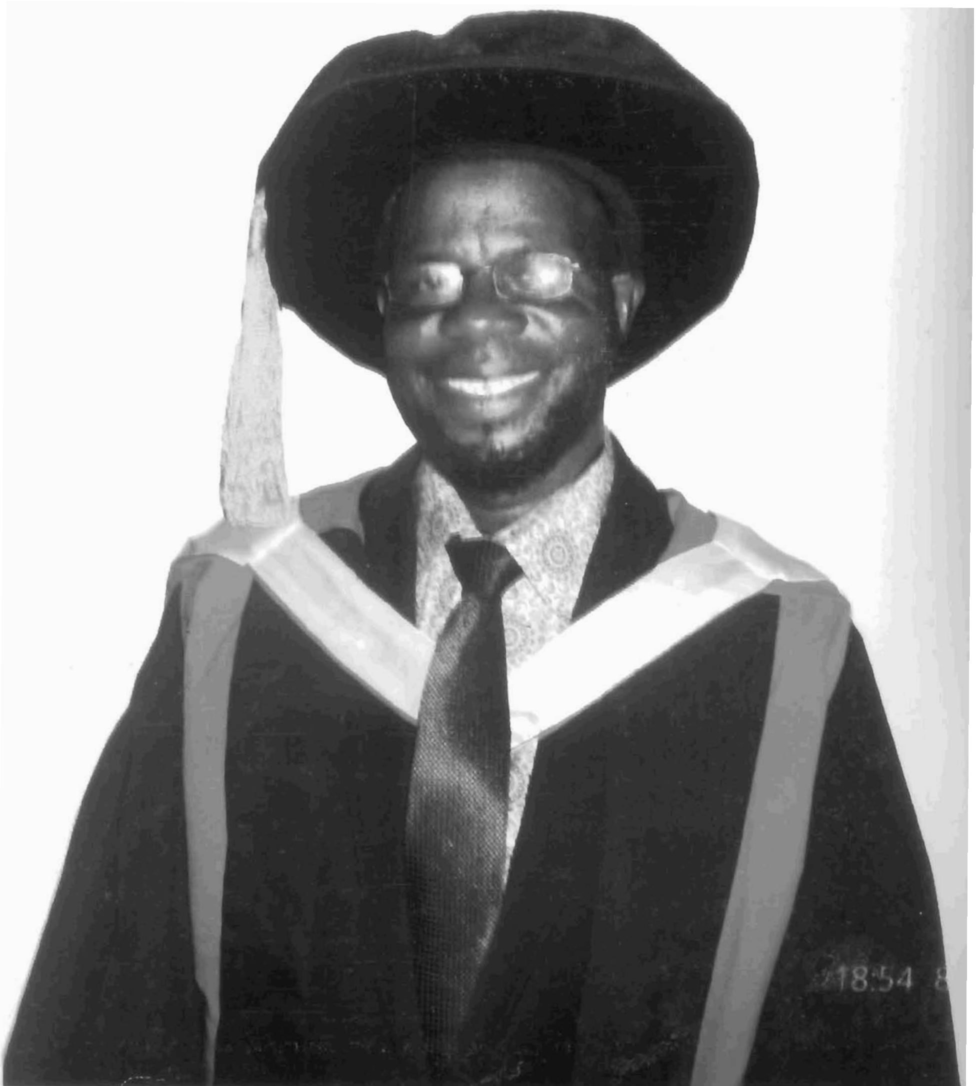

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An Inaugural Lecture Delivered at Oduduwa Hall, Obafemi Awolowo University, Ile-Ife, Nigeria On Tuesday 22nd December, 2015

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Preamble

Mr. Vice Chancellor Sir, distinguished Senior Colleagues, ladies and gentlemen, I give praise and gratitude to Almighty Allah, the Master of knowledge for making it possible for me to stand before you this evening to present the 282nd Inaugural Lecture of this University. The presentation of this lecture which is focused on how to address some challenges the country has been facing for sometime could not have been better than this time. I give glory to God the best Planner and Executor of events for choosing this time for me which is an era of "Change" in Nigeria.

Mr. Vice Chancellor Sir, permit me to say a few words about myself before going into the business of the day. The option to read Agricultural Engineering in this University came out of my volition being the son of a farmer with whom I spent my youthful life before he passed away. May Allah forgive him and admit him to *Al Jannah Fridaos, amin.* There was a serious pressure on me by my secondary school teachers to study Medicine but I initially insisted on studying Chemistry Education because I love teaching as a profession. Later I was lured into Engineering and I saw Agricultural Engineering in the brochure. I was curious to find out about the course and I realised that it is the right profession for me to better the lots of my people on the farm and so I chose to study the course. Also, at graduation, my mission as written by me in the directory for the 1989 graduating set in the Department reads "To contribute immensely to technological development of the country and to become an inventor". With all humility I am happy to say here that the choice of this course of study has enabled me to accomplish the two missions stated above to the best of my ability.

My coming here to join academics was motivated by Prof. Obafemi Olusegun Ajibola who persistently encouraged me to pursue my postgraduate studies in the Department and possibly join the system despite my insistence that I didn't want to continue in my indigent condition which had ran through my primary education to undergraduate days. Without his intervention, I might not have been able to stand before you today presenting this lecture. My Prof. Sir, I am eternally grateful to you.

Introduction

Mr. Vice Chancellor Sir, ladies and gentlemen, Hornby (2010) in his Oxford English dictionary describes paradise as part of the following:

i. **a place or state of perfect happiness:** a place, situation, or condition in which somebody finds perfect happiness;

ii. **Garden of Eden:** in the Bible, the perfect garden where Adam and Eve were placed at the Creation; and

iii. **a place ideally suited to somebody:** a place where there is everything that a particular person needs for his or her interest (*informal*)

Wikipedia (2015) defines paradise as a religious or metaphysical term for a place in which existence is positive, harmonious and eternal. It is conceptually a counter-image of the supposed miseries of human civilization, and in paradise there is only peace, happiness and prosperity. Paradise is a place of contentment, but it is not necessarily a land of luxury and idleness. Paradise is often described as a "higher place", the holiest place, in contrast to this world, or underworlds such as Hell".

The Qur-aan describes paradise as presented in this verse: "Verily, the dwellers of Paradise that Day, will be busy in joyful things. They and their wives will be in pleasant shade, reclining on thrones. They will have therein fruits (of all kinds), and all that they will ask for. (It will be said to them): "Salaam!" (Peace be on you), a Word from the Lord, Most Merciful." [36:55-58] (Ali, 1938).

When everybody has access to the basic needs of life and can sleep peacefully without being scared of loss of its possession, tranquillity is guaranteed and as such there will exist a paradise on earth. A traditional list of immediate "basic needs" has food, water, shelter and clothing as the main items. Many modern lists emphasise that the minimum level of 'basic needs' include not just food, water, and shelter, but also sanitation, education, and healthcare. Nigeria is blessed with abundant human and material resources. However, the optimum and appropriate utilization of

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i. Provision of basic needs of life guaranteed
ii. Creation of employment opportunities
iii. Alleviation of poverty
iv. Reduction of crime rates

Mr. Vice Chancellor Sir, the first inaugural lecture in the Department of Agricultural Engineering of University of Ife (now Department of Agricultural and Environmental Engineering of Obafemi Awolowo University) delivered by Prof. G.A. Makanjuola (Makanjuola, 1977) was titled "Agricultural Mechanisation in Nigeria-The Prospects and Promises". The second was delivered by Prof. M.T. Ige (Ige, 1994) titled "Energy in Agriculture –the Mechanisation Option", the third by Prof. O.O. Ajibola (Ajibola, 2000) was titled "Adding Value to the Farmers' Harvest"; the fourth titled "Making it Rain for the Farmers 'Harvest was by Late Prof. H.O. Fapohunda (Fapohunda, 2002)while the fifth by Prof. M.O. Faborode (Faborode, 2005) was titled "Technology, Life and Living". Obviously the lectures showcased the activities of the Department from inception in identifying technologies for the maximum utilisation of the abundant resources with which the country is blessed. Starting from there, we have taken a few steps forward to discover appropriate technologies (in terms of process lines and machines) and techniques through feedback from utilisation of such technologies by the adopters. Therefore linkage between the laboratory research and field trials was maintained in many cases. I will endeavour to discuss some of the efforts in these regards in this inaugural lecture which happens to be the sixth in the Department.

Oil Palm Research

Mr. Vice Chancellor Sir, the bulk of my research is on the development of appropriate processing technology for oil palm fruit. Let me say here that when I was born and growing up as a twin, according to the Yoruba culture and mythology, I was assigned to be selling palm oil while my twin-brother was selling kolanut as the businesses that were supposed to keep us from dying. When I grew up, I met my father as an "oil palm climber" (i.e harvester of oil palm fruit) and I had to fall in. My mother was also processing palm fruit using the traditional technology. Therefore I was sandwiched between harvesting and processing of palm fruit because I had to assist my father in harvesting palm fruit, and my mother in processing the fruit at "ebu" (the traditional palm fruit processing centre). My research in palm fruit processing was motivated by the efforts of Prof. Obafemi Ajibola who established the Post harvest Technology Research Group (PHTRG) in the Faculty of Technology in 1996. At that time the group had three major crops viz; oil palm, cassava and rice as the focus for the development of appropriate technologies for processing them. Every member was initially involved in the research efforts focused on the three crops. Later, each researcher had to specialize on a particular crop; and as fate would have it, I chose oil palm. A cursory look at my initial step (as palm oil trader at birth) indicates that I was really destined to be an oil palm man!

Importance of palm oil

The importance of oil palm cannot be overemphasized. Harvesting and processing of oil palm fruit into palm oil yield a lot of by-products on further processing. These include shell, palm kernel oil, palm kernel cake, palm frond and palm bunch which have numerous domestic and industrial applications. Palm oil, the principal product of the crop has a great number of uses. About 80 per cent of palm oil production is destined for human consumption with the balance going to animal feed and to various industries. Palm oil serves as the main cooking oil in Nigeria. In common with all fats, palm oil is a good source of energy and in addition the crude oil provides carotenoids (pro-Vitamin A) and tocopherol or Vitamin E (Babatunde, 1987).

Palm oil is consumed as margarine, as a base vegetable fat, as industrial frying oil and used as several special purpose fats. Margarine takes several forms, namely refined or table margarine, cooking margarine and industrial margarine used for baking. Its crystallization behaviour, particularly its effect on crystallization of fats with which it is mixed, makes palm oil highly valued for the manufacture of table margarine (Tropical Agriculturalist, 1998; Owolarafe, 2007). Tropical Agriculturalist (1998) also reports that the derivatives of palm oil are used world-wide for a wide range of purposes. These include the manufacture of ice cream and confectioneries, soaps, detergent, ink, epoxy resins and animal feeds. Palm oil has long been used as fuel. Report had it that during the Second World War, many engines were driven on by crude palm oil, either pure or mixed with diesel oil. Recent studies show that it is feasible to produce a fuel similar to diesel oil by simple conversion of palm oil to alcohol with methanol or a similar spirit. Thus the demand for palm oil will always be on the increase to meet the immediate domestic consumption and downstream processing into several products. As a green renewable energy source, the sky is the limit for a country that possesses the potential for its production and processing in improving its economy.

State of palm oil production in Nigeria and beyond

World production of palm oil has shown astonishing growth having risen tenfold since 1948. The commodity is now the World's second most important vegetable oil after soyabean (Owolarafe, 2007). Palm oil and soya oil constitute 23 and 29%, respectively, of the total vegetable oil production. The reason for the change in the total World's production of palm oil is due to the fact that oil palm has the highest oil yield per unit area. This is between 5-10 times greater than that for other oilseeds. Owolarafe (2007) reports further that the key to this growth is however found in the Asia where output is more than 80 % of the World's total production.

Between 1920 and 1960, Nigeria was the leading producer and exporter of palm oil (Hartley, 1988). Two decades ago, the product was almost missing on the nation's export lists. In 1991, no shipment was recorded, a trend that continued until in 1995 when about 30 tonnes of the product was shipped by a private exporter (CBN, 1998). There has been no remarkable change in this trend up till now. Indonesia and Malaysia (in that order) now lead the production of palm oil in the whole world. Table 1 shows the current production

Table 1: World Major Producers of Palm Oil: 2002- 2012 ('000 Tones)

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Malaysia	13,180	13,420	15,194	14,800	15290	17567	17259	17763	18211	18202	19000
Indonesia	10,300	11,500	14,000	15,[illegible]00	16600	18000	20500	22000	23600	25900	28000
Nigeria	770	780	790	800	810	820	850	850	850	850	850
Colombia	540	614	647	690	755	780	795	770	750	915	960
Cote D'Ivoire	234	308	340	360	281	289	290	300	300	300	300
Thailand	640	840	760	800	1170	1050	1540	1345	1288	1546	1700
Papau New Guinea	380	380	380	380	365	382	465	478	500	510	530
Ecuador	320	340	340	340	410	405	440	430	460	500	505
Costa Rica	156	190	240	285							
Honduras	165	165	165	165	195	220	250	252	252	252	252
Brazil	110	110	110	110	190	205	230	240	265	275	275

Source: Index Mundi (2015)

trend for the major producers of palm oil. Indonesia and Malaysia produce in million tonnes while Nigeria is still struggling to reach a million tonnes. Currently the country which occupied the premier position has been dropped to the fifth position. Though there has been increase in production within the last few years, Nigeria at present imports palm oil to the tune of about five hundred thousand (500,000) metric tonnes to supplement the local production in order to meet high demand (Index Mundi, 2015). Malaysia and Indonesia produce excess and export a large quantity. It has been reported that the two countries have since some years ago been engaging in the downstream processing of excess palm oil into fuels and chemicals (Leng*et al.*, 1999; Majuski *et al.*, 1997).Thus, palm oil has been the mainstay of the economy of the two countries. Mr. Vice Chancellor Sir, the Nigeria's poor story has been reported to be due to declining productivity of oil palm plantations due to old age, lack of appropriate technologies for palm fruit processing (notably small and medium scales), unfavourable government policies as regards agriculture in general and non-availability of effective extension communication profile. Lack of appropriate technology for the palm fruit processors has been observed to be the major problem facing the palm oil industry and it needs to be addressed (Owolarafe, 2007).

Palm fruit processing and the search for appropriate technology

Palm fruit processing generally involves five basic operations, which are fruit loosening, fruit sterilisation, digestion, oil extraction and clarification. The operations are carried out in all palm fruit processing plants (i.e. small, medium and large) regardless of the size of the plants. The method adopted and the sequence of carrying out the operations distinguishes the different plants from each other. The large-scale plants utilise sophisticated equipment and have all the above listed operations mechanised. The sets of equipment are electronically controlled and are always imported with their spare parts. There is therefore an extremely high investment required. Such plants also need high quality maintenance engineering staff and expensive infrastructural facilities, which are not available in the country. Though there are few of the plants in Nigeria, the technologies being used are beyond the reach of the small and medium scale processors who occupy a major position in palm oil production in Nigeria (Badmus, 1991; Owolarafe, 1999).

As a result, the development of appropriate technologies for the small and medium scale processors has been the concern of many research institutes in Nigeria. There has been a gradual transformation from the traditional process (pit technology) which has low efficiency and low quality oil to an improved process with each of the stages or units involved having distinct features in terms of equipment, oil yield and quality. Notable among these efforts are those of the Nigerian Institute for Oil palm Research (NIFOR), the Post harvest Technology Research Group of Obafemi Awolowo University, Ile - Ife and a host of others.

A lot of work has been done to improve the efficiency of the technologies developed for small and medium scale palm fruit processing, the bulk of which was focused on the modification of process lines for palm fruit handling, the development of new machines and on the evaluation of the technologies so developed (Hartley, 1988; Badmus, 1981 and 1991; Babatunde *et al.* 1988; Owolarafe *et al.*, 1998; Owolarafe *et al.*, 2002a; Badmus *et al.* 2003).

In the new process lines developed for palm fruit processing, attention is being given not only to high oil yield but also to quality with particular emphasis on the hygienic condition of the processing operation.

In the course of searching for appropriate methods, two distinct methods have emerged with the aim of achieving high extraction efficiency of good quality oil. These methods are described by the following flow charts. The first method (Fig. 1) has low extraction efficiency and the oil quality is bad. The free fatty acid (FFA) is above 10%. Apart from this, the process is time-consuming while the manual fruit loosening is tedious. The second method (Fig. 2) includes the use of press for extraction. The extraction efficiency is above 70% but the long fruit fermentation time induces high free fatty acid.

An improved method recommended for small scale is shown in Fig. 3 as the third method (Ajibola, 2000). The oil quality is better and the extraction efficiency is 80%. The short time of fermentation and the introduction of improved press and clarifier improved oil quality and oil recovery, respectively. The following machines are required for this new method:

i. A Cutting Platform for cutting of palm fruit bunches into quarters
ii. A Stripper for fruit loosening
iii. A Steriliser for cooking the fruit
iv. A Digester in line with the capacity of the Steriliser
v. A Press of adequate capacity
vi. A Clarifier for clarifying the crude oil produced
vii. A Nut/fibre Separator for separating nut from the cake.

The capacity of the plant is about 1 tons of fresh fruit bunches per hour

For the medium scale processors, a machine that combines digestion and press extraction (digester-screw press) is being introduced, and as such, this will increase the rate of processing. The extraction efficiency of the system is about 87%. The capacity is 5 tons of fruit per hour. The flow process is shown in Fig. 4.

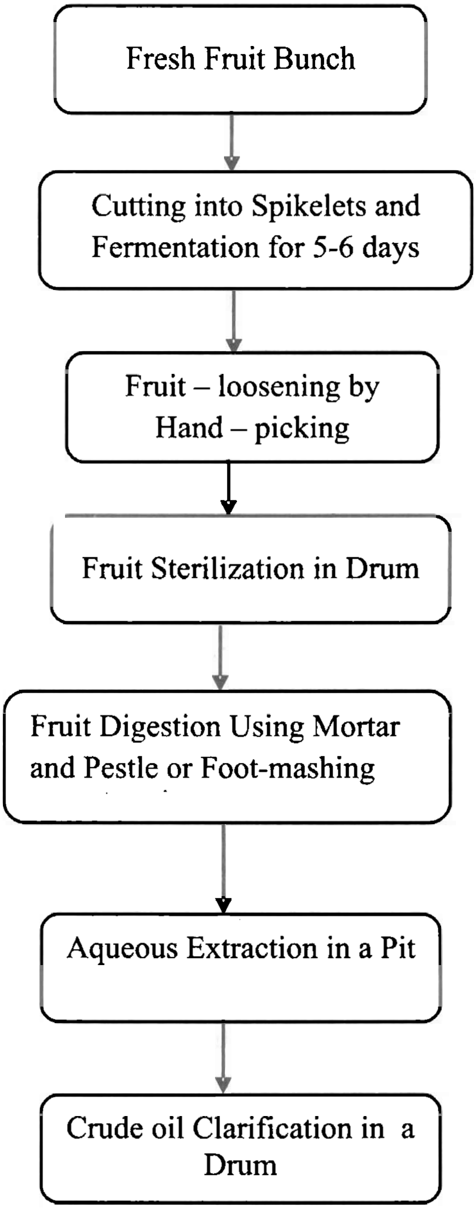


Fig. 1: Flow chart of first method of palm oil extraction (traditional method)

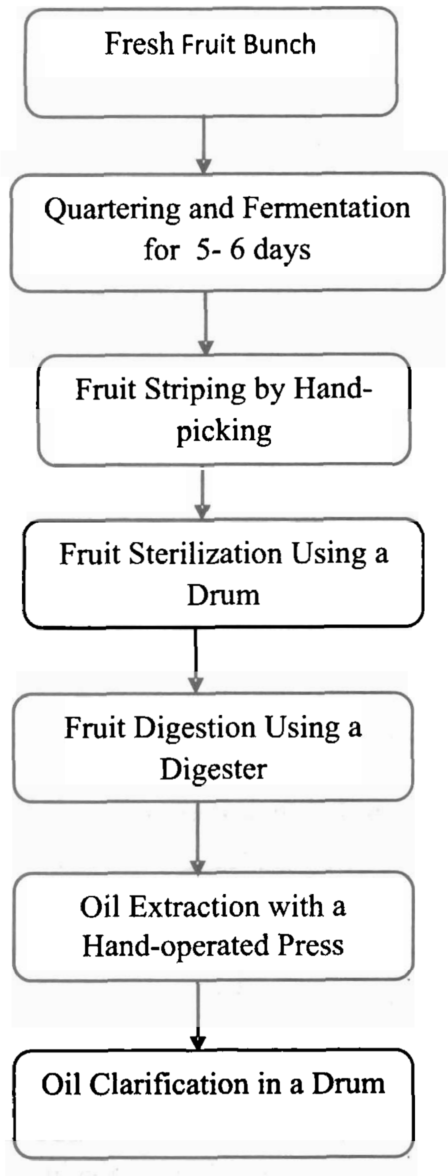


Fig. 2: Flow chart of second method of palm oil extraction (showing some level of improvement)

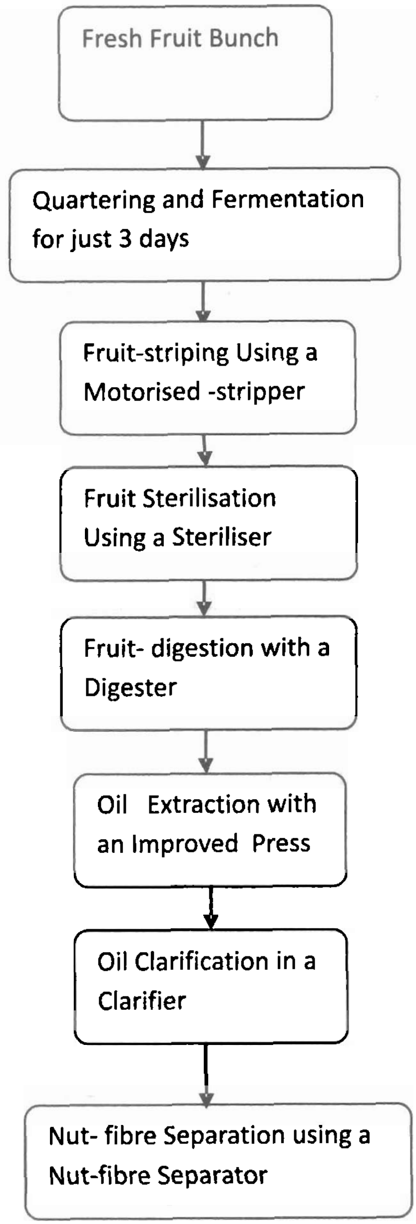


Fig. 3: Flow chart of third method of palm oil extraction (recommended for small scale)

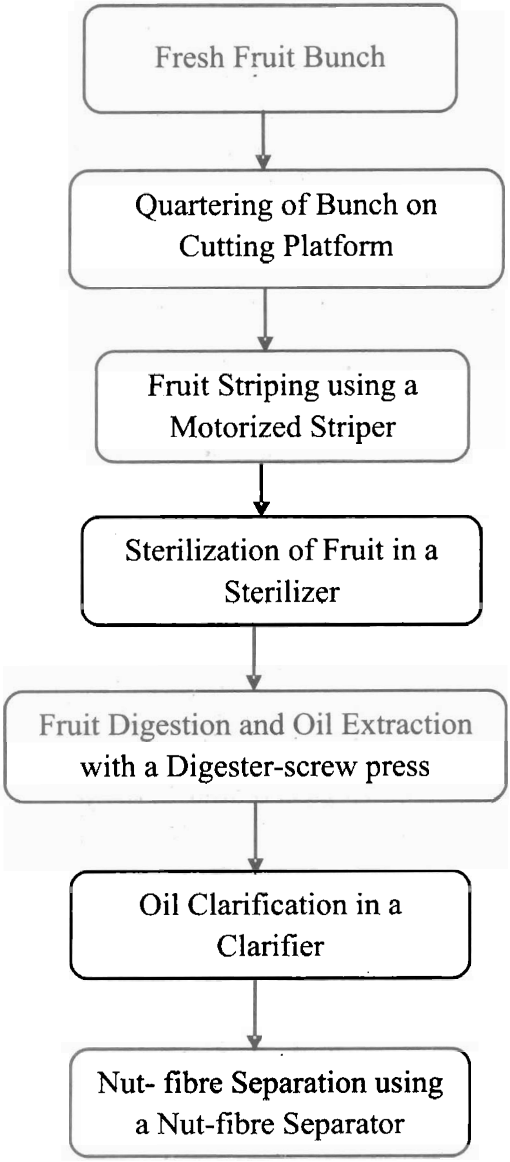


Fig. 4: Flow chart of recommended process line for medium scale palm oil extraction plant

Oil palm fruit sterilisation technology

Sterilisation of palm fruit is one of the key unit operations in palm fruit processing. This is a heat-rendering operation involving steaming of fruits. The operation aids loosening of fruits from the bunches and digestion operation by softening the fruit mesocarp for an efficient maceration. The operation functions as heat-treatment and moisture adjustment. Increase in sterilization temperature and time (bringing about increase in heat-treatment and moisture conditioning) has been found to increase oil yield from palm fruits (Babatunde, 1987; Owolarafe *et al.,* 2002a). Steriliser is the equipment used for this operation and it is available in different capacities. In the traditional palm fruit processing, sterilisation is done arbitrarily, ranging from one and half hours to eight hours. Plate 1 shows the traditional sterilisation method while Plate 2 shows the improved steriliser for small scale processing.

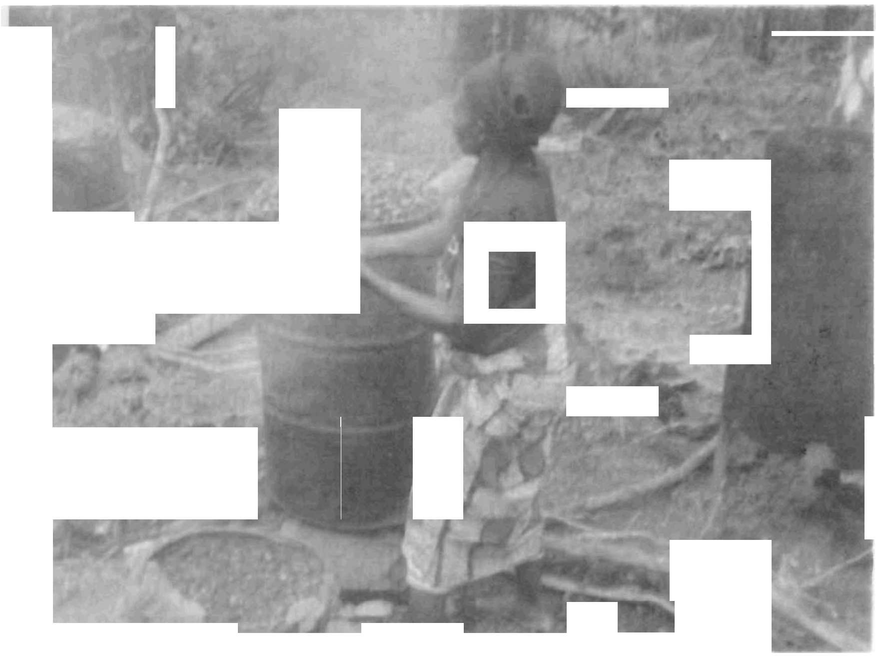


Plate 1: Traditional method of sterilising palm fruit using drum

Plate 2: Improved Sterilisers for palm fruit

Towards improved palm fruit stripping technology

Mr. Vice Chancellor Sir, another key unit operation in palm fruit processing is fruit-stripping. Manual fruit stripping of fruit is tedious, time-consuming and hazardous. In the traditional method of fruit stripping, harvested bunches are usually cut into spikelets and fermented for about a week followed by manual handpicking (Taiwo *et al.*, 2000). Fermentation aids fruit-stripping but impairs oil quality. Increase in fruit fermentation time beyond 3 days has been reported to raise the free fatty acid (FFA) content of oil (Owolarafe *et al.*, 2002a; Owolarafe *et al.*, 2002b). To reduce processing time and improve the quality of oil, bunches are cut into quarters in some centers, heaped for about 5 to 7 days and subjected to manual stripping using axe and planks to remove the fruits from the quarters (Badmus, 1991). However, the oil produced from the fruit contains FFA in the range of 5 – 10%

which is not acceptable in most Nigerian industries and the World market.

Prompt processing of bunches as the case in large scale plants is the best practice but for the fact that the technology being utilized is expensive and beyond the reach of the Small and Medium Scale (SMS) processors who occupy a major position in the Nigerian palm oil industry. In the large scale plants, whole fresh fruit bunches (FFB) are usually sterilized for between 45 and 60 minutes in modern mills using steam of about 3 to 5 bars generated from a boiler (Badmus, 1991; Hussain *et al.*, 2003). However, steam at atmospheric pressure adopted for sterilization of fermented fruits in small scale processing plants is not adequate for sterilization of bunches. An alternative process line developed was the cutting of bunches into spikelets, the sterilization of the spikelets at atmospheric pressure and the stripping of fruits from the spikelets. A hand-operated stripper was developed to handle the sterilized spikelets. Though the stripping (threshing) efficiency of the stripper was 72% (Owolarafe *et al.* 2002b), evacuation of the spikes after stripping was a bit difficult. This was found to be due to clogging resulting from the interlocking of the spikes. Hence the use of quarters seems promising as far as the discharge of the quarters is concerned. Thus a stripper for palm fruit quarters was designed, fabricated and evaluated for its performance in one of our studies. In achieving this, an earlier design for spikelets was modified and adapted (Owolarafe *et al.*, 2011a). The stripper consists of a main shaft (supported by bearing at both ends), carrying a revolving perforated cage, hopper, discharge chute for fruit, an outlet for empty quarters and a standing frame. The performance evaluation was carried out by determining the effect of quarter's sterilization time, quarter's fermentation days and shaft speed on the efficiency of the stripper. A set of palm fruit quarters was sterilised (for 2, 3 and 4 hours) subjected to stripping at the same operational speeds of 30, 45 and 60 revolution per minute (rpm), respectively. Another set of palm fruit quarters were subjected to fermentation (for 3, 5 and 7 days) and stripped in the stripper at operational speeds mentioned above. The stripping efficiencies and throughputs were btained at the combination of these factors.

efficiencies and throughputs were obtained at the combination of these factors. The results show that increase in sterilization time (in the range of 2 to 4 hours) increased the threshing efficiency and throughput of the stripper. Also increase in fermentation duration (in the range of 3 to 7 days) yielded a corresponding increase in the stripping efficiency and throughput of the stripper. However, increase in the speed of rotation from 30 to 60 rpm gave a decrease in the efficiency and an increase in throughput of the stripper for both fermented and sterilized palm fruit quarters. It was found that the highest threshing efficiencies (64.5% and 97.1%, for fruit sterilized at 4 hrs and fruit fermented for 7 days, respectively) were obtained at 30 rpm. The highest throughputs for sterilized fruits and fermented fruits were 456.0 kg/hr and 1665.1 kg/hr, respectively. From this study, it may be inferred that the motorized palm fruit stripper will be useful for small and medium scale processing of palm fruits and hence assist in the development of the palm oil industry and the economy of the country. Fig. 5 shows the exploded view of the palm fruit stripper while Table 2 shows the different parts of the stripper.

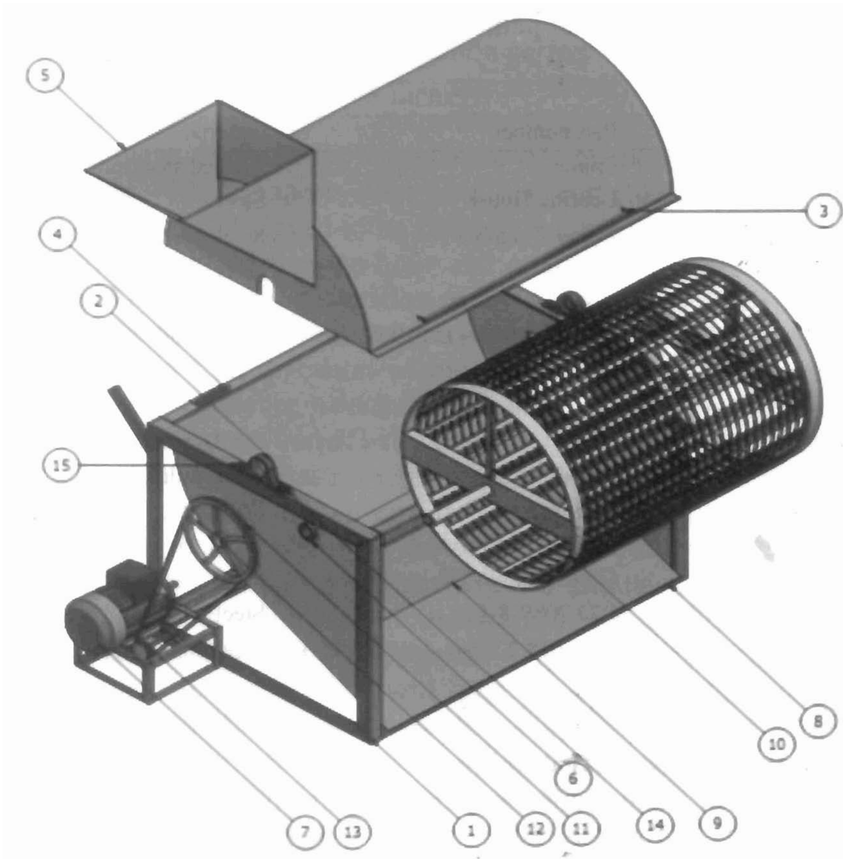


Fig. 5: Exploded view of palm fruit stripper for quartered- bunches

Fig. 5: Exploded view of palm fruit stripper for quartered- bunches

Part list			
Items	QTY	Part number	material
1	1	Frame	Welded steel mild
2	2	Bearing House	Steel
3	1	Upper Chamber	Steel, Mild
4	2	Hinge	Steel
5	1	Hopper	Steel, Mild
6	2	CSN 02 4645 – B 71908	Steel, mild
7	1	AC Motor	
8	1	Lower Chamber	
9	1	Sheet	Steel, mild
10	1	Stripping Wheel	Steel, mild
11	1	V-Belt	Rubber
12	1	Grooved Pulley 1	Steel
13	1	Grooved Pulley 2	Steel
14	12	ISO 7089-8-140 HV	Steel mild
15	8	Ansi b18.2.3.5m – m8 x 1.25 x 30	Steel, mild
16	8	ISO 4033 – M8	Steel

Palm fruit digestion technology

Digestion of palm fruit, another key unit operation in palm fruit processing is a size reduction and a wet communition process carried out in a digester. It is an important operation necessary to facilitate oil extraction and it involves subjecting fruits to random motion by the movement of the digester arms through the fruit load. Vibration is induced in the mesocarp tissue and this prepares the materials for subsequent oil expression. This process is described as impulse rendering (Babatunde, 1987).

The degree of fruit maceration (impulse rendering) determines to a large extent the effectiveness of oil extraction operation and hence the oil yield. The method (horizontal or vertical) also affects the oil yield. The vertical digester has been found to be more efficient than horizontal digester (Babatunde, 1987). It has been difficult to ascertain the time required for adequate digestion of well sterilised palm fruits. In the traditional method which involves the use of pestle and mortal and foot-mashing, digestion period is arbitrary and based on the texture of the resulting mash as physically observed and felt between fingers. As a result, palm fruit digestion may take several minutes depending on the experience of the operator/processor. Babatunde (1987) reports that using a vertical and horizontal digester, oil was observed to be flowing from mash produced from palm fruit sterilised for one hour and one and a half hours when digested for 3 mins using digestion speed of 100 rpm and 175 rpm. He notes further that it was difficult to categorically state or suggest the time for palm fruit digestion within the limit of the experimental factors used. However, research into microstructural analysis of sterilisation and digestion of palm fruit at different times (Owolarafe and Faborode, 2008) has revealed that optimum time sterilisation of palm fruit and digestion of sterilised palm fruit are 60 minutes and 5 minutes, respectively. Fig. 6 shows the micrograph of palm fruit sterilised for 60 minutes and digested for 5 minutes indicating that there is complete rupture of the cell wall to enable oil flow out of inter-kernel voids during expression. Therefore sterilising fruit beyond the time specified will induce waste of energy and sterilisation loss while digestion for more than 5 minutes will result in oil loss from the digester.

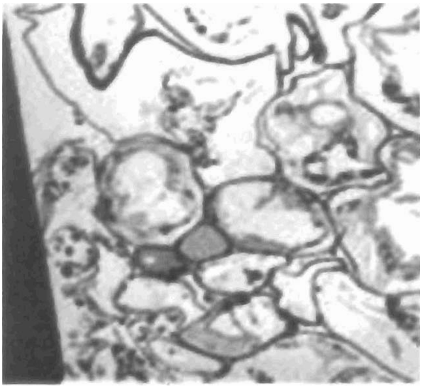


Fig. 6: Transmission electron micrograph of a section through palm fruit sterilised for 60 minutes and digested for 5 minutes (Rupturing of cell wall observed, complete loss of cellular architecture). Magnification: 1200

Oil extraction technology

Oil extraction involves the separation of oil from the mash. This is achieved either by aqueous or mechanical extraction. The aqueous extraction involves agitation of mixture of water and the mash to create turbulence, hence forcing the crude oil out in form of emulsion, and this is scooped off. The method is common with those who utilise the traditional pit technology (Plate 3). In mechanical expression, it is achieved through the use of hydraulic or screw press. The screw press has been found to be more efficient than the hydraulic press in terms of oil yield (Hartley, 1988). However the former has a higher initial and maintenance cost. The hydraulic press being used by processors also have the setback of the hydraulic system breaking down frequently. A modified screw press in form of press and basket was developed and found effective and has efficiency of about 60%. However most processors still prefer to use the pit technology owing to the fact they have been addicted to the system of aqueous oil extraction through the pit technology.

Plate 3: Traditional pit technology system showing the processor scooping oil and removing the fibre from inside the pit.

The Nigerian Institute for Oil Palm Research (NIFOR), Benin City, our collaborator in Oil Palm Research has developed some sets of Small Scale Processing Equipment (SSPE) that take care of all the unit operations in the small and medium scale processing of oil palm fruit. These sets of equipment were evaluated from 1997 to 1998 under the National Agricultural Research Project by the author. The result indicated that the digested–screw press which combines both digestion and pressing operations has high extraction efficiency (about 89%) and can be included in the technology profile for small and medium scale processors (Owolarafe, 1999; Owolarafe *et al.*, 2002a). However, many small and medium scale processors could not afford the price of the complete set.

Realising the high cost of screw press coupled with the resistance to change by processors, an aqueous extraction system which simulates the traditional wet system was designed (Owolarafe *et al.* 2007a). The aqueous extraction was tested with small scale processors in a village (Abagboro, Ile-Ife). The system (Plate 4) which has extraction efficiency of about 72% was an improvement over the pit technology and also has considerable level of hygiene and is less hazardous as compared to the traditional pit technology where the processors have to enter into the pit. However, an oil loss of 28% is considerable and efforts were also made to design improved devices for the palm oil extraction. A manual system that combines the efforts of screw and hydraulic was thus developed (Owolarafe *et al.*, 2009) to improve the extraction efficiency. This system (Plate 5) with extraction efficiency of about 87% compares well with the output of the digester-screw press earlier developed in NIFOR. Due to its low throughput (1.5 tons fresh fruit bunch/hr), it is only suitable for small scale processors. This press was exhibited by the University in 2010 and 2012 editions of the Nigerian Universities Research and Development Fair (NURESDEF) held at the University of Nigeria, Nsukka and Federal University of Technology, Minna, respectively.

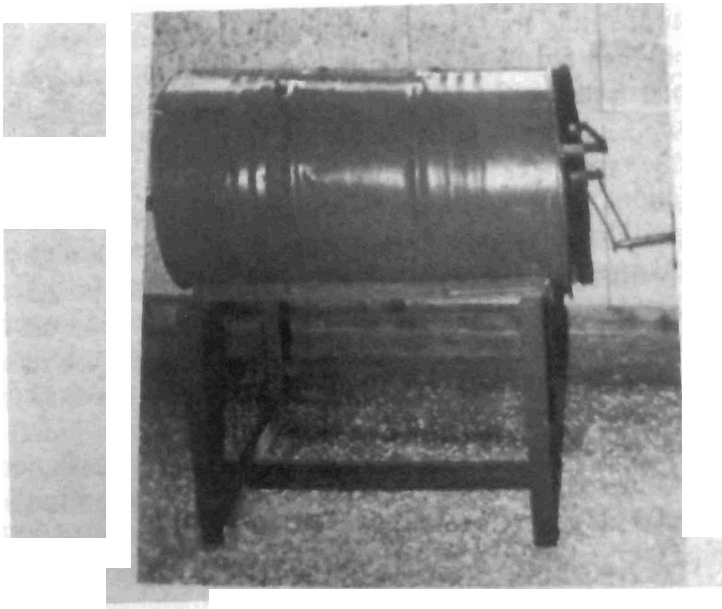


Plate 4: Aqueous oil extraction system

Plate 5: Screw hydraulic press

Palm oil clarification technology

Clarification of oil is a refining process in the palm fruit processing that is carried out to reduce the amount of impurities (water, dust and cellular matter from mesocarp). The technology adopted in the traditional method is usually an open drum with no accessories. Crude palm oil is poured manually into the open drum and cooked for several hours before the hot oil is scooped manually using small metal bowl. The women involved in this operation are proned to a lot of heat hazard and many times result in accidents in form of burns. A system that reduces the drudgery and hazard was designed in NIFOR (Badmus, 1991). The system is made of a drum equipped with long tail funnel that admits crude oil into the drum, an oil bucket through which the clarified oil is collected in the drum, an oil discharge pipe and sludge drain pipe. Owing to the low through put of the design reported by Badmus (1991), I and one of my colleagues in the University here, revised the design and a better small scale clarifier was developed (Owolarafe and Adetan, 2012). Three oil buckets were incorporated into the new design and synchronised with crude oil supply and sludge collection (Plate 6). The advantage of this new design over the earlier design is that the throughput is higher (almost three times the initial design). Mr. Vice Chancellor Sir, I am pleased to mention here, that this clarifier was also exhibited by the University in the 2012 edition of the Nigerian Universities Research and Development Fair (NURESDEF) held at the Federal University of Technology, Minna.

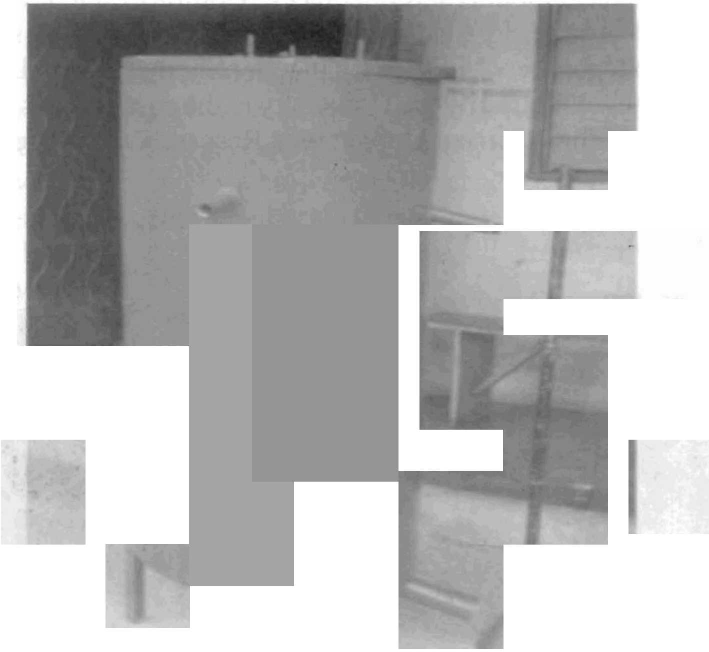


Plate 6: Picture of the new clarifier

Palm nut/fibre separation technology

Palm nut/fibre separation is an important post-palm oil extraction operation that ensures that the co-products of palm fruit processing are made available. This operation is still carried out manually using wet separation techniques where aqueous palm oil extraction system is used, or by shearing with knife and hand where presses is used. The two manual methods are characterised by low throughput and health hazards. Mechanical devices available for use by small scale processors are not as efficient as required. A palm nut/fiber separator (Plate 7) was designed by me and other collaborators (Owolarafe *et al.*, 2012a) taking into consideration the properties of the materials to be separated. The machine which consists of a hopper, cake-breaking compartment equipped with breaking arms, screw auger for conveyance of the nut, screen for separation of the fiber and discharge chutes for nuts and fiber has separation efficiency of about 79% which is quite close to that used in large scale mills. It is also my pleasure to report here Mr. Vice Chancellor Sir, that this is also one of the machines exhibited by the University in the past editions of (2012 and 2013) of the Nigerian Universities Research and Development Fair

Plate 7: The nut/fibre separator

Special palm oil production

Though the modified small scale technology for palm fruit processing was found efficient and effective, the production of special palm oil (SPO) still remains a mirage at this level of processors. SPO is the palm oil of high quality with free fatty acid (FFA) less than 3% and moisture content less than 1%. This grade of palm oil is the best for food processing industries and is usually on high demand by the large scale food and allied processing industries.

To obtain SPO, fresh fruit bunches (FFB) have to be processed within 24 hours but the current technology cannot handle this. FFB requires steam at high pressure for them to be adequately sterilised to achieve substantial fruit recovery and oil extraction. Steam at this condition can only be produced by a boiler, and the absence of this technology is a missing gap in the small scale technology profile. Boilers being utilized by large scale plants (mostly imported) are usually expensive and beyond the reach of small scale processors. To bring the processors to the level of production of SPO, a small scale boiler was developed in one of our studies. In achieving this, the properties of the palm fruit wastes to serve as the fuel for the boiler were first determined at different conditions (Salako *et al.*, 2009). The boiler (Plate 8) consists of four components, namely furnace, boiler drum, water and fire tubes which were designed based on the quantity of steam required to process 0.25 ton ffb/hr (i.e. 150 kg/hr). The furnace was double-walled with the inner wall made of kaolin brick (pure white clay) while the outer wall was made of clay laterite. Performance evaluation of the boiler using different biomass fuel samples indicates that highest steam production of 17.99 kg/min and maximum boiler efficiency of 79.6 % could be achieved (Salako *et al.*, 2014). The study concludes that the boiler developed using adequately-prepared locally-available materials, has the potential to be incorporated into the small scale palm fruit processing technology profile, and has the capacity to supply the steam requirement in the plant, thereby bridging the identified gap in the small scale palm oil process line. The boiler which has been undergoing modification to improve its efficiency has already been exhibited too in the past editions of NURESDEF.

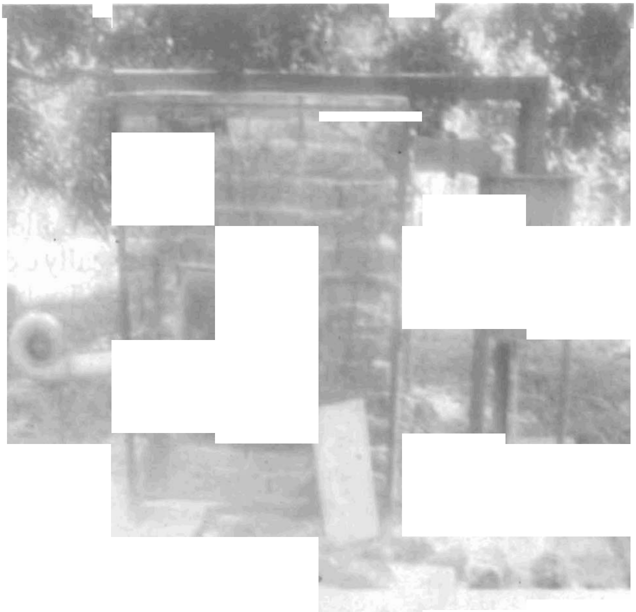


Plate 8: Picture of the water-in-tube and fire-in-tube boiler

Optimisation of palm oil extraction

A considerable research has also been carried out to optimise the design of most of the machines development for palm fruit processing. This involved characterisation of palm fruit materials as well as modelling of palm oil extraction. Owolarafe *et al.* (2007b) and Owolarafe *et al.* (2007c) carried out a macro-structural characterisation of oil palm fruit at different sterilisation and digestion times. The true density of fruit sterilized for 0 to 90 min decreased from 996 to 987 kg/m^{3}while the bulk density decreased from 611 to 577 kg/m^3. The density ratio decreased from 61.5 to 58.5 while the porosity increased from 38.6 to 41.5%. For the sterilised and digested fruit, the true density increased from 806 to 913 kg/m^3 with increase in sterilisation time from 30 to 90 mins and duration of digestion from 5 to 15 mins. The bulk density also increased from 538 to 688 kg/m^3 within the same range of sterilisation and digestion. The fracture resistance and fruit bruising pressure of the palm fruit decreased from 1446 to 318 N and 2.34 N/mm^2 to 0.79 N/mm^2, respectively, when the fruit was sterilised for 0 to 90 mins. These results were used in the modelling of the fruit sterilisation and digestion operations for the optimisation of the overall palm oil extraction process.

In another study, Owolarafe *et al.* (2008a) carried out investigation on the effect of processing conditions such as sterilization time, digestion time and expression pressure on the yield and quality of hydraulically expressed crude palm oil. Palm fruits were collected, cleaned and sterilized for 30, 60 and 90 mins. The fruits were then digested for 3, 5, and 10 mins and later pressed with pressures of 0.5, 1 and 1.5 MPa for constant pressing time of 5 mins. The results show that increase in sterilization time from 30 to 90 mins, digestion time from 3 to 10 mins and expression pressure from 0.5 to 1.5 MPa generally increased oil yield. The highest yield of oil of 35% was obtained at the sterilization time of 60 mins, digestion time of 10 mins and expression pressure of 1 MPa. The solid impurity content of the oil (as a measure of crude palm oil quality) at 30 and 90 mins sterilization was observed to be generally high. The solid impurity at 60 mins sterilization time was, however, observed to be low. Increase in digestion time and expression pressure increased the solid impurity at all sterilization times.

Furthermore Owolarafe *et al.* (2008b) developed a mathematical model for expressing palm oil using the properties of the fruit and based on previous work on seed-oil expression. Linearisation of the theoretical model developed was carried out by using empirical expressions for flow parameters such as permeability, viscosity and pressure–porosity relationship. The linearized model is in form of equation 1 below. The general equation developed was solved numerically using Mat Lab. An expression relating oil yield and porosity was obtained as equation 2. The model was validated by comparing the experimental and predicted oil yield recovery at combinations of sterilisation time (30, 60 and 90 mins), digestion time (3, 5 and 10 min) and expression pressure (0.5, 1.0 and 1.5 MPa). The result indicates that generally, both the measured and predicted oil recovery increased with increasing sterilisation time digestion time and expression pressure. The model had an overall deviation between the predicted and measured values of about 5% which is found acceptable. Fig.7 shows a typical plot from the model on variation of the porosity (a function of oil expressed) with pressure and radius of the cage, indicating that the pressure decreased radially from the cage centre towards the outer radius while Fig. 8 shows a typical relationship between predicted and experimental data of oil yield.

$$-\frac{\partial \varepsilon}{\partial t} = -\varepsilon + \frac{A_1}{r}\left(\frac{1}{r}\frac{\partial \varepsilon}{\partial r} + \frac{\partial^2 \varepsilon}{\partial r^2}\right) \quad (1)$$

$$Y = \frac{\rho_{oil}(\varepsilon_0 - \varepsilon_t)}{\rho_T} \quad (2)$$

(where ε is porosity, t is time and r is radius of the cage while subscripts 0 and t represent at time zero and time t, respectively).

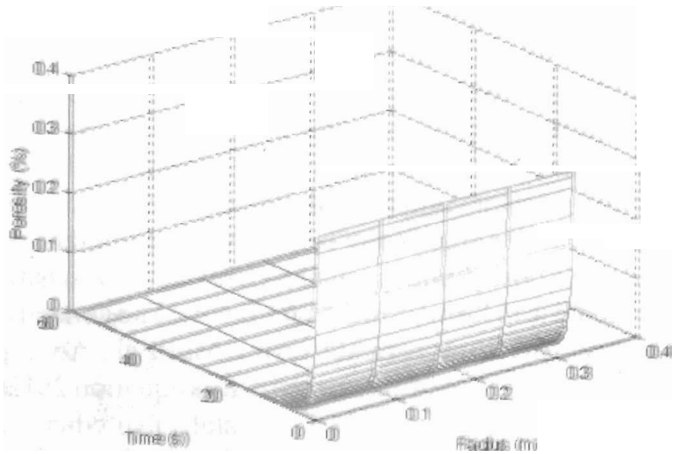


Fig7.: Variation of porosity with time and radius at sterilisation time of 60 mins, digestion time of 10 mins and pressure of 1.5 MPa (ε_0 = 0.3086)

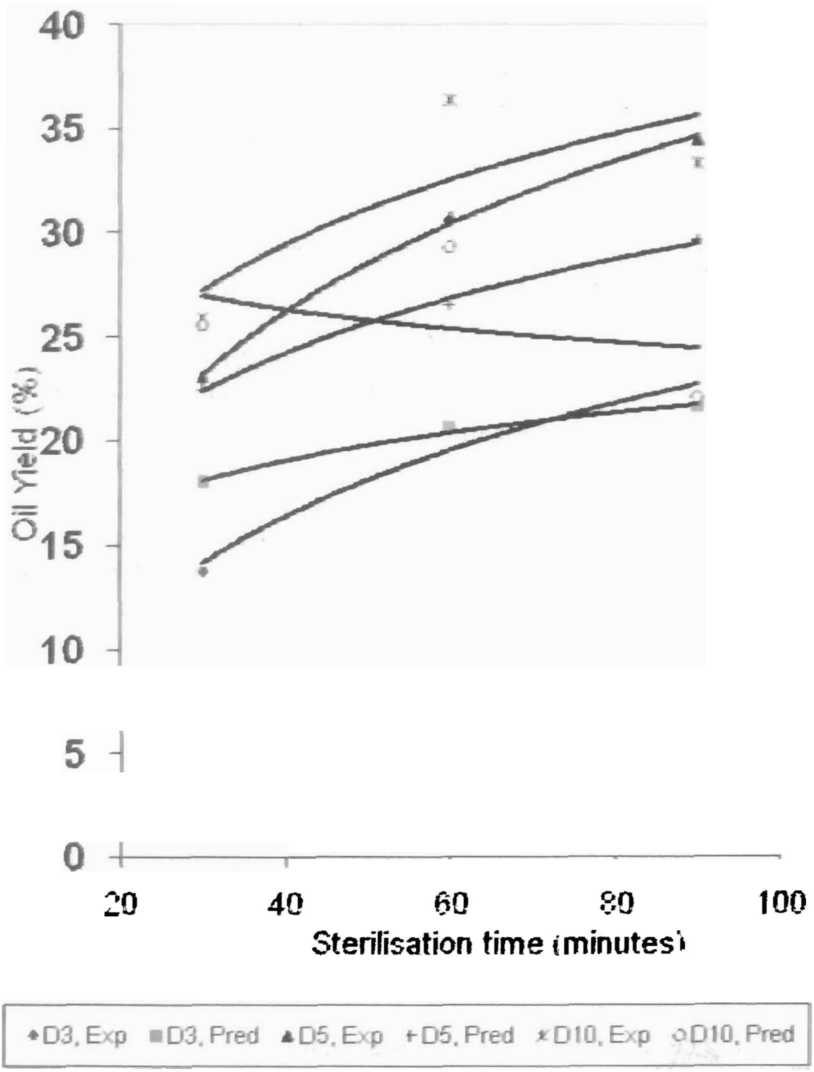


Fig. 8; Experimental and predicted oil yield at pressure of 1.5 MPa
D3- digested time of 3 minutes; D5- digestion time of 5 minutes
D10- digestion time of 10minutes; Exp- experimental, Pred- predicted

In verifying this further, an attempt was made to investigate the effect of increase in size of cage from 80 to 150 mm at sterilisation time of 90 minutes and digestion time of 10 minutes. The oil yield was also observed to increase as pressure increases from 0.5 to 1.5 MPa, and cage diameter from 80 to 120 mm but decreases as the diameter was increased to 150 mm

In synchronising the macro and micro structural analyses, it means, theoretically that whatever the starting porosity is, the target is to attain minimum final porosity at the end of the pressing operation such that the volume of the inter-kernel voids is drastically reduced. This is an indication that most of the oil has been extracted. Therefore the bigger the difference between the initial and final porosities of the cake the greater the quantity of oil extracted. Processing conditions that attain this with due regards for oil quality should be watched. However it is difficult to get the final porosity to be zero even in seed-oil expression where process materials (i.e seeds) of uniform texture are used. In palm oil extraction, the situation is different in the sense that the process material is a fruit, which, after pre-pressing operation, results in non-homogenous mixture of nut, fibre and oil, all embedded in the matrix. The solid component consists of the fibre and nut, and the liquid portion, namely the oil. The hard sub-component of the solid is the nut which is usually preserved for kernel oil and therefore guarded against cracking.

During palm oil extraction, as the volume of the voids reduces, the nuts move closer with the fibre in between them and acting as a cushion. Nut-to-nut contact will induce cracking thereby exposing the kernel contents and contaminating the oil. Depending on the level of sterilisation and digestion operations, fine fibre may also be expressed out at this stage. Therefore, in the choice of optimal processing conditions, while bigger difference between the initial and final porosities indicate maximum oil yield extracted, processing conditions that reduce the chance of nut-cracking should be sought. This is where the result of the micro-structural characterisation by Owolarafe and Faborode (2008) is useful as earlier presented. Minimal sterilisation (that prevent nut cracking) and minimal digestion (that ensures non-fine fibre particles) that guarantees high yield of oil are very important to preserve oil quality. Also pressure less than 1.50 N/mm^2 (i.e 1.50 MPa) as contained in the macro-structural characterisation (Owolarafe *et al.*,2007b) should be used. Maintaining the temperature at about 55°C at the digestion and pressing stages will assist in attaining the objective of higher extraction efficiency. Whichever residual oil that is left in the cake could be extracted through solvent extraction or washing with hot water.

African Locust Bean and Appropriate Processing Technology

Mr, Vice Chancellor Sir, African locust bean (*Parkia biglobosa*) has a variety of uses which can be grouped as domestic, medicinal, and nutritional. The most important part of the plant is its seed, which is a grain legume, the bean is usually processed to form a strong-smelling food condiment/flavouring agent in the entire Savannah region of West Africa. The condiment is called *Dawadawa* in Niger, Northern Nigeria and Ghana; *Iru* in Southern Nigeria; and *Soumbala* in Burkina Faso, Mali, Cote d'Ivoire and Guinea. My research on locust bean was informed by the visit of one of our inlaws who claimed to have some dexterity in the processing of locust bean to the local condiment but complained of the tedious operations involved. As a result, the unit operations were reviewed and some interventions were outlined and gradually developed.

Depulping is one of the processing operations required to produce the condiment above. At present, the depulping of locust bean is still done manually. The seeds obtained after shelling are surrounded by the yellowish powdery pulp. The seeds together with the pulp are placed in a basket or a locally fabricated screen, usually a perforated calabash known as "Ajere". The pulp is removed manually without damaging the seeds. This method is not only tedious but also time-consuming. A machine which works on the principles of agitation and abrasion was developed by us for depulping the locust bean (Owolarafe *et al.*, 2010). The machine (Plate 9) comprises the hopper, depulping chamber equipped with paddle, screw conveyor, screw-housing and a discharge chute. These components are mounted on a standing frame. The machine which is powered by a 2 hp electric motor, has an efficiency of 83% and a throughput of 20 kg/hr as against the manual method which has 2 kg/hr.

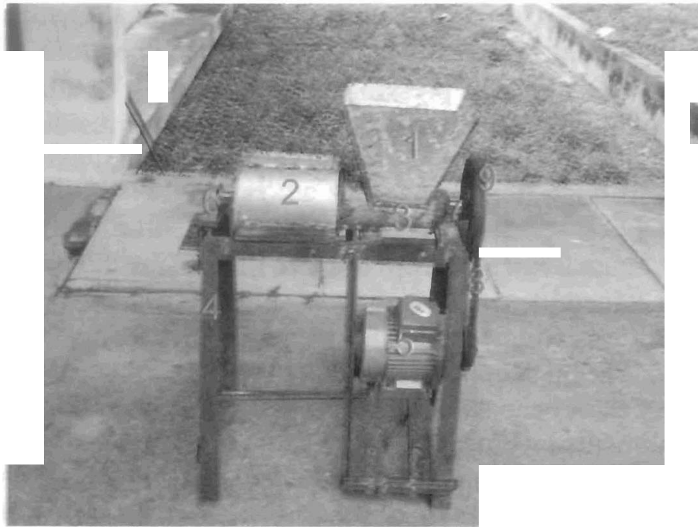


Plate 9: Locust bean depulping device

After depulping of locust bean, the bean extracted is processed to obtain the condiment (*iru*). Traditionally the bean is first boiled for 8 to 10 hours using firewood as fuel. This initial stage of processing makes the process time-consuming and degradation of the seeds also results in the process. Locust bean is dehulled by mashing the boiled seeds with bare feet near the riverside or in a mortar and pestle. If a mortar is used some clean sand may be added to ease the removal of the hull. The process of ridding the edible seeds from the hull in locust bean processing is implied as separation. The separation process is carried out locally using the principle of buoyancy or by using a screen, most often a perforated calabash referred to in Yoruba as *'Ajere'*. Proximity to water supply is required and for this reason the process is carried out in a stream. The undehulled beans are also freed by washing. Several attempts have been made to develop separate machines for each of the processing operations notably boiling, dehulling and separation (Adewumi and Igbeka, 1993). Apart from the fact that the devices are not as effective as expected, intensive handling involved in the use of each of the machines prolongs the whole process and hence results in low throughput.

A machine (Plate 10) that combines three of the processing operations steaming, dehulling and separation was developed by me and other collaborators (Owolarafe *et al.*, 2013a). The machine consists of a pressure-cooking pot (as the cooking device) mounted on a separate stand and equipped with lifting mechanism to facilitate discharge of contents, a hopper made of mild steel sheet, the dehulling unit made of screwed shaft and abrasive barrel, a conical-shaped separating section equipped with paddles (all made of aluminium material) and a standing frame to support the whole arrangement. The new machine which is hand-operated has dehulling and separation efficiencies of 82% and 79%, respectively, and a throughput of 5 kg/hr. There is provision for motorisation of the machine and this will improve the efficiencies as well as the throughput.
Mr. Vice Chancellor Sir, I wish to say here again that the two processing machines were also exhibited by the University in the past editions of NURSDEF.

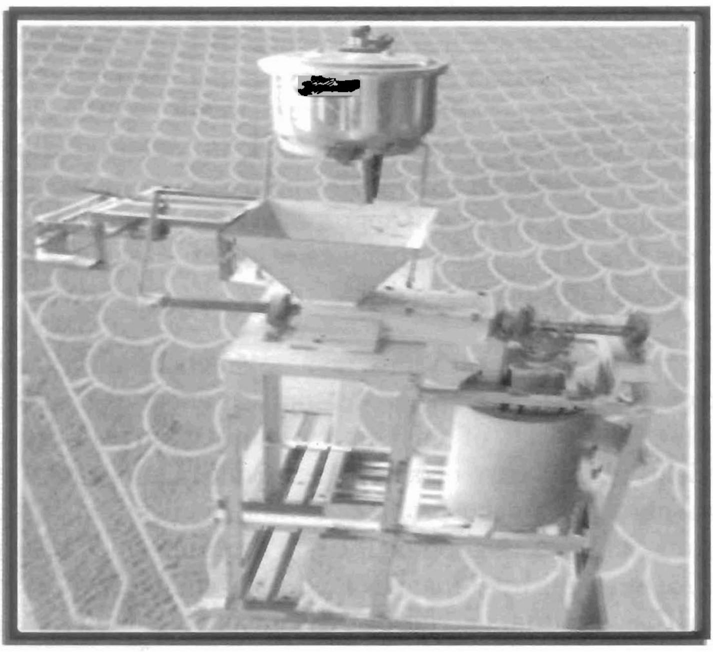


Plate 10: A locust bean steaming, dehulling and separation machine.

Okro Processing Technologies

Mr. Vice Chancellor Sir, this is another area where I carried out comprehensive participatory research in an effort to better the lots of the small and medium scale processors. Okro is a vegetable crop that belongs to the genus *Abelmoschus*, family *Malvaceae* and has two main species: *Abelmoschusesculentus* (L.) Moench. and *Abelmoschuscaillei* (A. Chev.) Stevels (Siemonsma, 1982). It originates probably from East Africa and is today widely distributed in the tropics, subtropics and warm portions of the temperate region (ECHO, 2003).The economic importance of okro cannot be overemphasized. Okro contains carbohydrate, proteins and vitamin C in large quantities (Adeboye and Oputa, 1996). The essential and nonessential amino acids that okro contains are comparable to that of soybean. Hence it plays a vital role in human diet.

In Nigeria, there are two distinct seasons for okro, the peak and the lean seasons. During the lean season okro fruits are produced in low quantities, and so are scarce and expensive to get (Bamire and Oke, 2003). In the peak season, they are produced in large quantities much more than what the local populace can consume. The Isoya group of the Department of Agricultural Extension and Rural Development, Obafemi Awolowo University, Ile-Ife, identified an area in Osun State (Egbedore Local Government) where okro is produced in large quantities and owing to lack of appropriate processing, preservation, marketing and utilisation techniques a lot of wastage was being experienced during the peak season.

In order to map out interventions, an assessment of all the activities carried out by the farmers and processors was undertaken (Farinde *et al.*, 2007). The result of this survey shows that majority of the respondents planted okro on a small scale due to land tenure system and probably due to the problem of non-availability of storage, processing, and preservation facilities. Processing and preservation are carried out using traditional techniques of slicing, sun-drying and grinding (using mortar and pestle). Sliced and dried okro are stored in gourd, baskets and clay-pots. Okro is consumed either fresh or dried mostly to make draw soup.

Development of an okra slicer

The first intervention carried out was the development of an okro slicing device to aid in the production of dried okro. The properties of fresh okro were determined (Owolarafe and Shotonde, 2004). A manually-operated okro slicing device adapted from a plantain slicer designed in the Department some years ago (Mogaji, 1998) and suitable for on-farm use was designed, fabricated and tested based on the engineering properties of this vegetable. The machine which simulates the traditional method of okro-slicing, consists of the feeder, slicer and receiver. It was made simple for ease of operation and maintenance. The machine has a slicing efficiency of 77.4% and throughput of 8.4 kg/h (Owolarafe *et al.* 2007d).

The machine was modified and motorised to improve on its efficiency and throughput. The result of evaluation of the motorised version indicates that the machine has a slicing efficiency of 85.7% and throughput of 21 kg/hr which shows an improvement over the previous version (Owolarafe *et al.*, 2012b). Plate 11 shows the picture of the motorised okro slicer. Plate 12 shows the picture of the whole okro fruit and the slices produced by the machine.

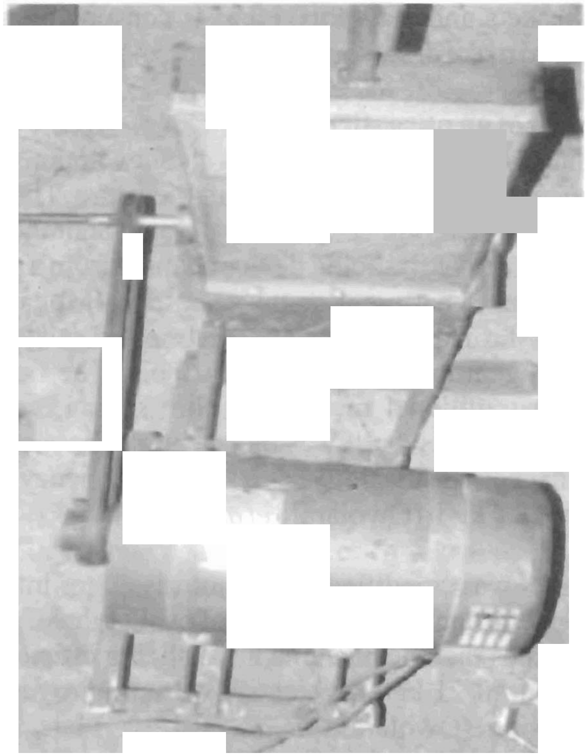
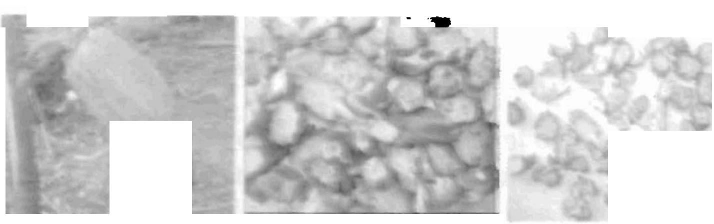


Plate 11: Picture of the okro slicer



(a) wholeokro (b) damaged slices (c) smooth

Plate 12: Whole okro and samples of slices produced by the machine

Development of an okro dryer

The next intervention was the development of an okra drier to dry the slices. An okra dryer was designed, constructed and evalua by my research team in another study (Owolarafe *et al*., 2011b). The dryer consists of a heating chamber, two drying trays, a blower of 1 hp, two heating elements of 2000 W each, 4 roller tyres for ease of mobility, a control box which consists of a thermostat that regulates the temperature in the dryer. The result of evaluation of the dryer in no load indicated that it was able to yield temperature very close to the preset (by the thermostat) after about 3 mins. The dryer was evaluated by drying okro of different thicknesses (5 and 10 mm), in two trays at two heights (25 and 50 cm from the bottom) and at a preset temperatures of 50 and 70°C. Moisture losses from the slices were obtained at intervals of 30, 45, 60 and 90 mins. The result showed that increase in temperature from 50 to 70°C, increases moisture loss from the slices. Slices of 5 mm thickness were observed to dry faster than 10 mm slices with those on the upper tray losing more moisture. The study further showed that slice thickness of 5 mm dried at 70°C in the upper tray level of 60 cm from the base of the dryer are suitable for drying okro slices in the dryer. Plate 13 shows the picture of the prototype dryer. Mr. Vice Chancellor Sir, based on this knowledge, a multipurpose dryer that can accommodate other crops has just been designed by me and other researchers in my department such that it is affordable by farmers.

Plate 13: Picture of the picture of the inner parts of the okro dryer

Development of an okra harvesting device

Harvesting of okro is carried out manually by handpicking of the fruit on each plant. Apart from the fact that manual handpicking is characterised with low throughput, Okro has a skin that itches the hand during harvesting by hand-picking. This reduces the quantity harvested at a time. A lot of the fruit is therefore not harvested fresh particularly during the peak season. I therefore designed and developed a simple and handy okro-harvesting device which is user-friendly (Owolarafe, 2012a) such that more quantity is harvested while ensuring that the hazard of itching is completely eliminated. The device (Plate 14) consists of a spring-loaded cutting mechanism, fruit conveyance unit and a collector. The collector can be easily removed as soon as it is filled up to discharge the fruits. The cutting efficiency of the device is 83% while it has a throughput of about 4.35 kg/hr. Plate 15 shows the operation of the machine on the field. This device has also been exhibited by the University in the past NURESDEFS.

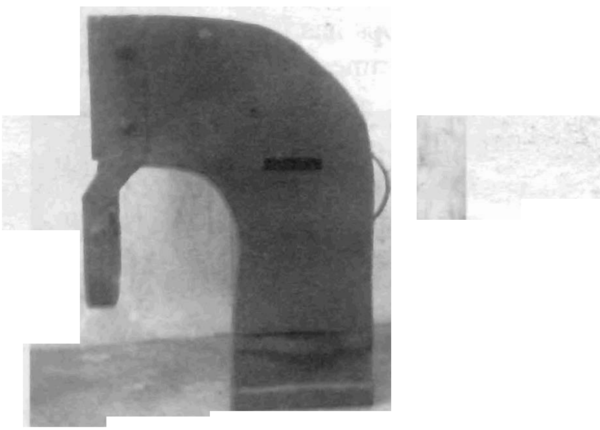


Plate 14: Picture of the Okro harvesting device

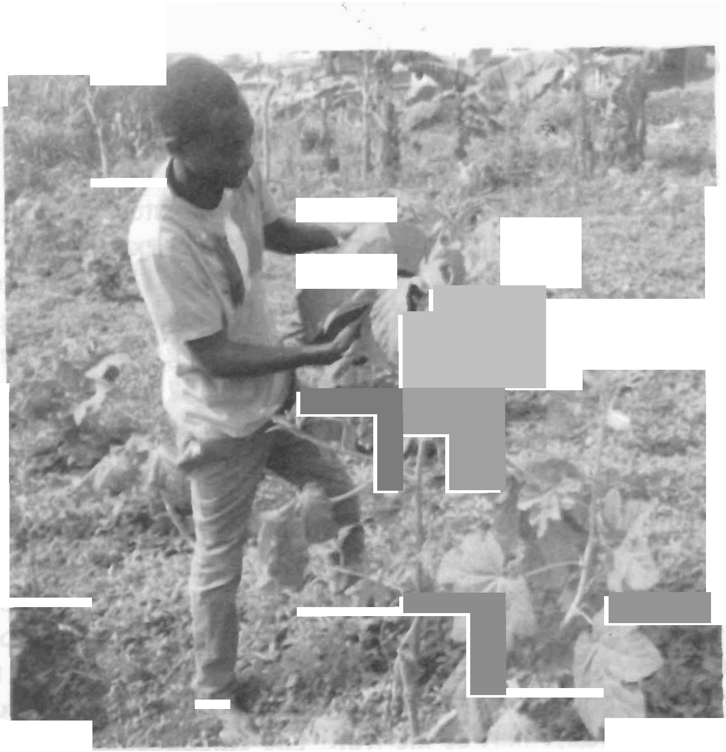
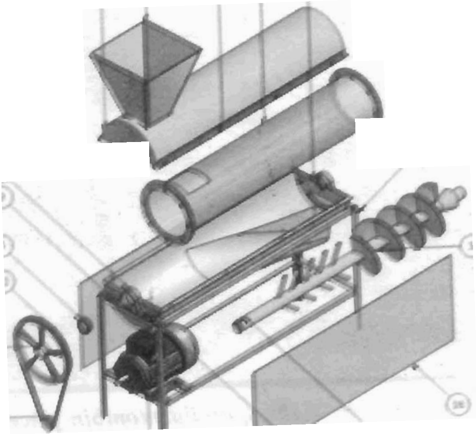


Plate 15: Demonstration of the okro harvester on okro farm

Spondias Mombin Juice Extraction Technology

Mr Vice Chancellor Sir, sometimes ago, I was with Prof. C.O Adebooye formerly of the Department of Crop Production and Protection of this University (and now at Osun State University), at an automobile mechanic workshop where there were many fruits of plum tree *(iyeye)* (*Spondias mombin)* spread all over the workshop. A discussion of what we can make out of the fruits which were almost becoming nuisance ensued and from there a research plan was outlined as a response to salvaging the wastage situation. Some properties of the fruit were determined in a study conducted by Owolarafe *et al.* (2006). The average fruit length, width and thickness were 33.3, 25.1 and 24.5 mm, respectively. The average sphericity and aspect ratio of the fruit were 82.2% and 75.4, respectively. The average fruit mass was 12.5 g. The average true density and bulk density of the bed of the fruits were 788.1 and 616.5 kg/m3, respectively, giving a density ratio of 79.4. The average porosity of the bed of the fruits was 20.7%. The dynamic angles of repose for the fruit on plywood, galvanized sheet and mild steel sheet were 31.1. 28.7 and 28.5°, respectively. The moisture content, ash, crude fibre, crude protein, carbohydrate and ether extract were 85.0, 0.53, 0.30, 0.93, 13.1 and 0.11%, respectively. The total soluble solids (TSS) content was 4.6. The vitamin C content was 38 mg/100 g while the pH was 5.6. The oxalate (1.4 mg/100g) composition was low. The essential amino acids contents, ranged from 0.88 to 14.4 g/16 gN. The high moisture, vitamin C, essential amino acids and TSS contents with very low anti-nutritional oxalate content suggested that the fruit can be a good source for beverage juice. Subsequently the plan to develop a juice extractor for the fruit was mapped out.

Juice extractor for *Spondias mombin* operating on co-axial screw press principle was designed, constructed and tested using locally available materials (Olaoye and Owolarafe, 2014). The fresh fruits required digestion in order to loose the mesocarp from the seed and compress the fleshy part of the fruit. The embedded seed together with the mesocarp constitute a matrix. The matrix with the juice already in the inter-kernel void needs to be pressed to extract the juice. Thus the design principle adopted was borrowed from that of the digester screw press. The juice extractor was designed and fabricated based on the data obtained on the properties of the fruit. The performance of the machine was carried out using a 3x3x2 factorial experimental design with shaft speed (120, 130 and 150 rpm), loading (5, 10, and 15 kg) and ripeness (about to ripe and ripe) as factors. The through put capacity of the machine increased with an increase in shaft speed while an increase in loading condition and degree of ripeness also increased the quantity of juice extracted. The extractor has an extraction efficiency of 94% and a throughput of 100 kg/hr. Fig. 9 shows the exploded view of the machine while Plate 16 shows the picture of the machine. Efforts are ongoing for the development of a nutritive beverage juice with our colleagues in the Department of Food Source and Technology of this University.



ITEM	PART NUMBER	QTY	MATERIAL
1	Frame	1	
2	Lower Chamber	1	Stainless Steel
3	Auger	1	Stainless Steel
4	Bearing house	2	Steel
5	Rolling bearing 71810 C GB/T 292-94	2	Steel, Mild
6	Screen	1	Stainless Steel
7	Upper Chamber	1	Stainless Steel
8	Hopper	1	Stainless Steel
9	ISO Washer 7089 - 5 - 140 HV	40	Stainless Steel
10	ISO Bolt 4033 - M5	12	Steel
11	AC Motor	1	
12	V-Belt	1	Rubber
13	Grooved Pulley1	1	Steel
14	Grooved Pulley2	1	Steel
15	ISO Keyway 2491 - A 14 x 6 x 40	1	Steel, Mild
16	Frame Cover	2	Steel, Mild
17	Discharge Plate	1	Stainless Steel
18	Brace Plate	4	Steel, Mild

Fig. 9: Exploded view of the *spondias mombin* juice extractor

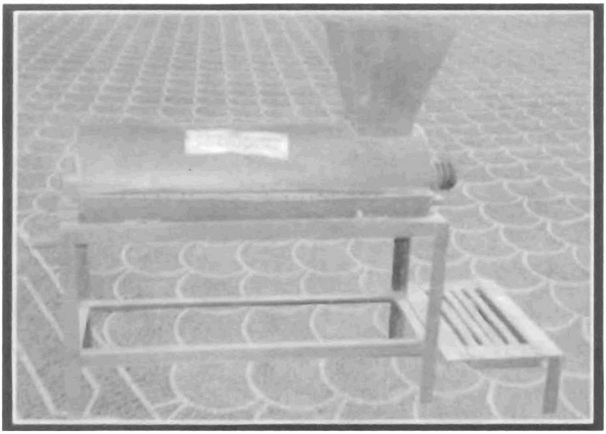


Plate16: Picture of the *spondiasmombin* juice extractor

Coconut Dehusking Technology

Mr. Vice Chancellor Sir, coconut is a popular tree in this part of the world sometimes planted as ornamental plant but has a nut that is useful. The very first step in coconut processing is the practice of dehusking, which is the removal of the coconut husk with either machete or a vertical chisel type dehusking tool to obtain coconut meat, coconut water and shell which are important raw materials in the production of coconut milk, copra, oil, cake, carbon, pyrolysate, and coir fibre. The existing coconut dehusking methods are the use of machete or vertical chisel. In the first method, a sharp machete is used to shear the coconut at the posterior and anterior ends lengthwise, which is followed by hitting the sides of the coconut with the blunt edge of the machete until the husk is removed. Where there is no need for preserving the length of the husk, the machete is used to shear up the coconut along both ends and the blunt edge of the machete is used to hit the husk until it is removed. In this manner the husk is sheared to pieces. The second method involves holding a coconut at a height and bringing it down against a pointed iron stake (chisel) inserted into the ground or on a concrete base. Repeated twisted pushes of the nut against the pointed edge of the rod would get the husk removed. This method requires great skill and a skilled worker can deal with 200 nuts on a normal day's work (Child, 1974). The tedious process of dehusking has remained largely male-dominated due to the enormous manual labour involved. There has been no appropriate dehusking technology, hence the preference for the use of machete and the vertical chisel type-dehusking tool. This operation is skill dependent but there are not many skilled workers available for this task. As such the much priced long fiber, which is about 50% by weight of the coconut, gets damaged during this shearing process.

A tool of second class lever mechanism type for aiding manual dehusking of coconut was developed while I was working with my collaborators in NIFOR, Benin City (Badmus *et al.*, 2008). The design of the dehusker (Plate 17) was based on the physical and mechanical properties of coconut. The machine, on testing, indicated that a manual effort (force) of 107 to 157 N on the handle of the lever is required to dehusk the Nigerian tall coconut variety having sphericity of 75 - 81%. Comparatively, a female worker (1.57 m height, 46 kg weight) was able to dehusk an average of 35 nuts/h with a machete; she was able to dehusk an average of only 12 nuts /h using a vertical tool; while she was able to dehusk an average of 47 nuts/h using the new dehusking lever. With this device the drudgery of processing coconut is reduced and many processors involved in this

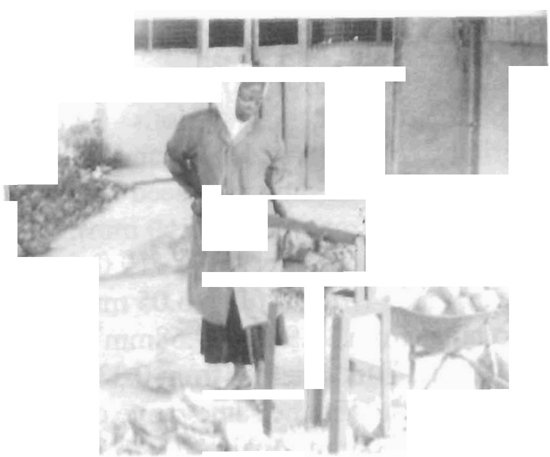


Plate 17: Picture of the operation of the coconut dehusker by a lady

The Snake Gourd Seed Processing Technology

The snake gourd fruit comprises essentially the pulp and the seed. Unlike most oil producing crops, both the pulp and the seed are nutritionally useful. The seed is a good source of edible oil (Oloyede and Adebooye, 2005). Many researchers have observed that the presence of antioxidants, such ascaroteniods, flavorioids, lycopene, phenolics and β-carotene in the oil, helps protect against diseases like cardiovascular, diabetes, and so on (Velioghu*et al.*, 1998; Liu *et al.*, 2000;Konak, 2002; Amin *et al.*, 2004; Zharg and Hamauzu, 2004). Perhaps the most interesting news is that the AIDS drug Compound Q is a refined protein called *trichonanthine* which is derived from the *trichosanthes* (snake gourd) family. It has been shown that the snake gourd seed oil contains 26.2-26.6% crude protein, 44.6-57.7% fat, 7.8-8.15% phosphorus and 0.012-0.026% anti-nutritional oxalate (Adebooye *et al.*, 2005). The oil content compares favourably with that of most seed oil.

Considering the nutritive value of the seed, it becomes imperative to develop a decorticator for the seed such that the kernel can be made available. As a first step, a study of the physical properties of the seed was carried out (Idowu and Owolarafe, 2014). The physical properties of *snake gourd* (*Trancosantiescucumerina L*) seed were evaluated as functions of moisture content (using moisture content range between 6.80 and 17.00% (db)). The properties investigated include one thousand mass, dimensions (length, width and thickness), sphericity, volume, true density and bulk density.

The results of the experiment show that seed length increases from 11.30 to 12.4 mm, width (from 5.60 to 6.60 mm), thickness (from 2.0 to 2.7 mm), one thousand mass (from 110.0 to 240.0g), geometric mean diameter (from 5.02 to 6.05 mm), sphericity (from 0.44 to 0.49), volume (from 38.98 to 69.68mm^3), true density (from 0.91 to 0.97) and bulk density (from 0.3360 to 0.3519). The kernel which was evaluated in the same range of moisture content shows length (5.20 to 6.60 mm), width (2.0 to 3.0 mm), thickness (0.30 to 0.70 mm), one thousand mass (60.3 to 180.4g), geometric mean diameter (0.68 to 1.11mm), sphericity (0.13 to 0.17), volume (8.0 to 38mm^3), true density (0.7563 to 0.8052gmm^{-3}) and bulk density (0.4132 to 0.4462g cm^{-3}). The result of analysis shows that the effect of moisture content is significant ($p<0.05$) on all the properties investigated.

In a related study (Idowu and Owolarafe, 2013), aerodynamic properties of the seed were determined as a function of the moisture content to provide enough data for the development of the decorticator. The result shows that an increase in moisture content from 6.8 to 14 % db increased the terminal velocity from 2.45 to 3.98 m/s for seed, from 2.21 to 3.09 m/s for kernel and from 1.35 to 1.77 m/s for chaff. Also increase in the moisture content in the same range increases the drag coefficient of the seed from 2.24 to 13.95 and 2.35 to 9.00 for kernel. Effect of moisture content was found to be significant over all the parameters investigated at 0.05 % probability. For air separation/cleaning of snake gourd seed, the air speed should be less than 2.4 m/s while for designing the cleaning chamber of a snake gourd decorticating machine to separate chaff from kernel after dehulling process, the air speed should be less than 2.2 m/s but higher than 1.77 m/s. Using these data, the decorticator has been designed by me and my postgraduate student and is now ready for evaluation (Idowu and Owolarafe, 2015). Plate 18 shows the picture of the prototype decorticator.

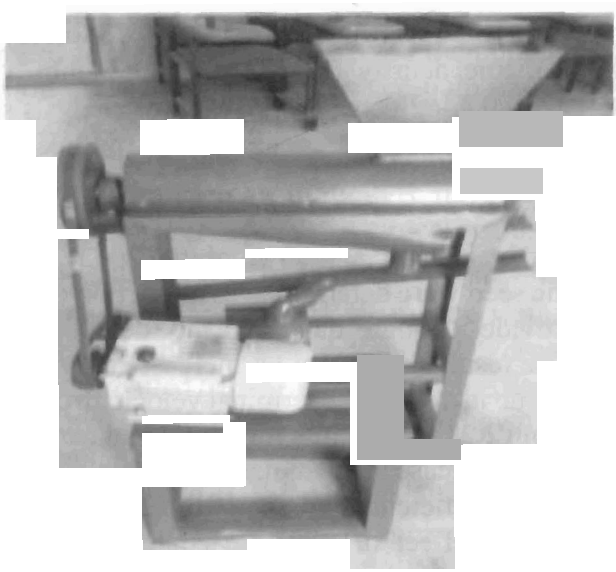


Plate18: Snake gourd seed decorticator

Development of Process line and Machines for Extraction of Oil from Oilseeds

Mr Vice Chancellor Sir, utilisation of appropriate process line in terms of appropriate unit operations at specified levels/ranges is a precursor to optimum extraction of high quality oil. A lot of work has been done in this regard. Processing conditions that guarantee high oil yield of good quality for major oilseeds produced in Nigeria have been determined.

Sesame seed is an oilseed that is grown widely in the middle belt of Nigeria where large quantity of the oilseed is eaten as snacks and in soup. It contains about 47% oil which is golden yellow in colour and needs little or no refining. Laboratory studies using hydraulic press (Ajibola *et al*., 1992) indicates that the conditions to express high yield of oil from the seed are pre-treatment at moisture content of 6%, temperature of about 85°C and heating time of 20 mins and subsequently pressing at a pressure of about 20MPa.

Castor seed is another underutilized oilseed in Nigeria. Ajibola *et al.* (1998) observes that moisture content of 6.5%, heating temperature of 90°C, heating time of 30 mins and pressing at pressure of 20 MPa yielded oil of about 40.4% oil (corresponding to extraction efficiency of about 78%). Thus these conditions are suitable for extraction of oil from the seed.

New dimension in oil expression brought into light the concept of oil point pressure. Researchers (Sukumaran and Singh, 1989; Faborode and Favier, 1986; Fornal *et al.*, 1994) have identified oil point pressure as a major parameter influencing optimization of oil expression process. Oil point pressure is defined as the minimum pressure that must be applied to mobilise oil out of interparticle voids. The effective pressure thus corresponds to a value of pressure above this value. Realising the importance of the concept to assist in optimizing the processing operations and equipment design, subsequent oil expression studies were focused on the new idea. Studies on oil point pressure were carried out for sesame, soybean, locust bean, cashew, neem and almond seeds which are all underexploited in Nigeria and I was involved in all of them.

Oil point pressure of sesame seed varies between 1.26 MPa for seed at moisture content (mc) of 4.0% heated at 115^{0}C for 30 mins and 3.03 MPa for sample of 10.0% mc. heated at 70 ^{0}C for 15 mins (Ajibola *et al.*, 2000). Oil point pressure of soybean was observed to range between 10.4 MPa for a sample at mc of 6.0% heated at 115^{0}C for 30 mins and 17.2 MPa for at mc of 12.0 % heated at 70 ^{0}C for 15 mins (Ajibola *et al.*, 2002). Owolarafe *et al.* (2003) however found that the highest value of oil point pressure (4.34 MPa) for locust bean occurred with a sample of 4.5% mc at heating temperature of 120^{0}C and heating time of 30 mins while the lowest (2.90 MPa) was from a sample of 6.0% mc heated at 100^{0}C for 30 mins. Oil point pressure was generally observed to be significantly affected by processing conditions considered in all the studies.

In another study, Ogunsina *et al.* (2008) observe oil point pressure of cashew kernel to be influenced by particle size in addition to the other processing conditions (i.e moisture content, temperature and heating time).

The lowest oil point pressure of 0.157 MPa was observed for fine aggregates at moisture content of 4%, heating temperature of 115°C and heating time of 45 mins. The highest (0.166) was from coarse aggregates at a moisture content of 6% heated at a temperature of 100°C for 45 mins.
An investigation on oil point pressure of neem seed by me and one of my postgraduate students (Dr. Olatunde) revealed a different scenario from other seeds. The study (Olatunde and Owolarafe, 2011) indicates that for coarse aggregates, oil point pressure ranged between 1.21 - 0.39 MPa. It was also noted that as heat treatments got to 60 °C at 13 % moisture content the oil point pressure drastically fell to a point beyond the available pressure that can be detected by the press cage. For fine samples, oil point pressure ranged between 0.48 and 0.21 MPa at 7.4 % moisture content wet basis. At moisture content beyond this point, the dead weight of the hydraulic press was sufficient to bring oil out of the oil bearing cells. Summarily, oil point pressure of coarse sample was observed to be greater than fine samples. Further studies (Aregbesola *et al.*, 2012) with Indian almond kernel indicates highest oil point pressure of 2.33 MPa for coarse particles of 8% mc heated at 70°C for 15 mins while the lowest pressure (1.00 MPa) also occurs for coarse particles at 5% mc heated at 115°C for 30 mins. In another study (Faborode *et al.*, 2003) the available technology for seed-oil extraction were assessed to provide an in sight to the need of the processor.

The essence of these studies is to provide spectrum and data bank which can be accessed for use in the vegetable oil extraction researches and industries. The data available in these studies have been utilised by many international researchers and cited accordingly in their different publications. To us in the Department, the group involved in these studies had it in mind to develop appropriate technologies for seed-oil expression. One of the key machines in the seed-oil expression is an expeller. The design and maintenance of expeller at the level of small scale processors is still not yet perfected. Versions of expeller available are seed-type.

Multipurpose expellers that could handle different seeds are not available. Using the data available and with a lot of trials over the years, a multipurpose oil expeller for small and medium scale processors has been designed and tested by one of my PhD students (Mr. I.O. Olaoye). The expeller has been tested with five seeds and found to be effective. Plate 19 shows the picture of the prototype expeller (Olaoye, 2015).

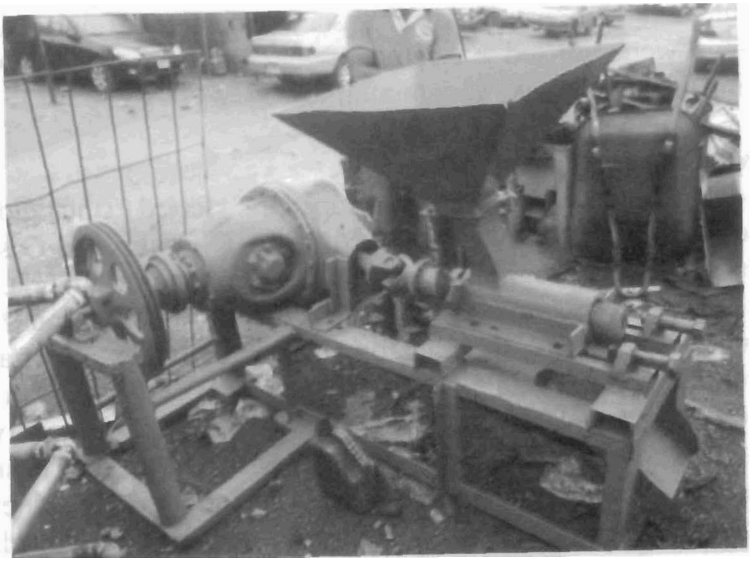


Plate 19: Picture of the multi-purpose oil expeller

Adaptation and Utilisation of Some of the Developed Technologies by the Target Users

Mr. Vice Chancellor Sir, one of the greatest problems of researchers particularly in Nigeria is low uptake of research findings by end-users. The PHTRG of Obafemi Awolowo University founded by Prof. Obafemi Ajibola had developed techniques to overcome this in the sense that most of the researches being undertaken emanated from field reports. At a time some women processors were the target of most of the interventions that were developed for palm fruit and cassava processing.

With the exit of Prof. Ajibola from the University, it became difficult to have the link with women processors who actually have benefited a lot from the research efforts. The fact that he (Prof. Ajibola) had a dream of transforming the PHTRG into a formidable organisation targeted at solving technological problems in the area of agro-processing made it is so easy to have me as a Consultant on some of the projects that his foundation (New Nigeria Foundation – NNF) executed. I will endeavour to present how some of our research findings were utilised on some of the projects geared towards making life better for some communities.

Akwa Ibom State experience

The dream of having the ideas developed transferred to the field first came in 2006 when I was involved in the Oil Palm and Cassava Competitiveness Programme in Akwa Ibom State of Nigeria. The processors, fabricators and farmers were assessed and the technological needs to transform their activities ascertained (Owolarafe and Jeje, 2006a, 2006b). The design of the oil palm fruit processing machines were made available and fabricators were trained on how to produce the machines based on the new designs. Plates 20 - 21 show how the fabricators were monitored in achieving the objectives of the project. All the machines were developed; the fabricators, the farmers and processors were all happy to have the new technological interventions. Since the fabricators trained were available locally, the sustainability of the technology was guaranteed. Many youths in the State developed interest in palm fruit production and processing and thus many people including youths were occupied. Mr. Vice Chancellor Sir, the impact of this intervention did not come to light until in 2009 when I was involved in a study in Abia State and it was reported (Beveridge *et al.*, 2009) that fruits were being purchased by Akwa Ibom people from Abia State via Ikot-Ekpenne to be processed in Akwa Ibom because they have better small scale processing technologies there!

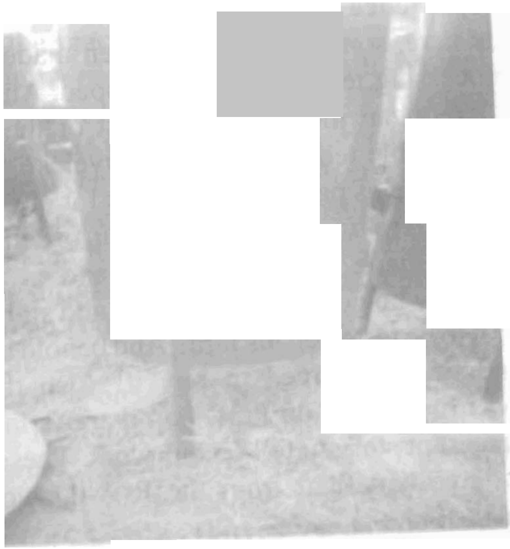


Plate 20: A sterilizer at one of the workshops of the fabricators showing the part to be corrected

Plate 21: One of the palm fruit strippers under construction at another fabricator's workshop.

Osun State experience

In Osun State here, some efforts have been made to introduce the palm fruit processing technologies developed. An experience with Sedot Farm, Gbongan indicates that most of the farmers are not aware of the available technologies. Dr. Oyeleke, the owner of the farm used to provide us palm fruit bunches for our research at some reasonable prices. At a time he became fed up of selling the fruit to us and I had to persuade him to continue and invited him to our workshop. The day he got to the workshop and sighted the press, he requested for it to be tested on his farm. And behold he never returned the press and he just agreed to buy it! Also the new clarifier developed was first tested on Prof. Lamikanra's farm in Ilesa who also have a pleasant story to tell on our work. These are few people among who have benefited from the R & D work on palm oil production in the State.

Abia State experience

I was involved in the Abia State Palm Oil Value Chain Development Project that spanned 2008-2011 as a mill Engineering Consultant. The team has Mr. Andrew Beveridge (a Briton) as the leader. The project was executed by the duo of e-Gen, a Bangladesh Consulting Firm and the New Nigeria Foundation (NNF). The main goal of the project was to revitalize the palm oil industry in the State. A quick assessment of the palm fruit production and processing technologies was carried out. It was revealed (Owolarafe and Oni, 2011) that about 95% of the mills were in the small scale category with capacities in the range of 0.2–3.0 t/hr. Majority (80–90%) of the mills still utilized local drums for sterilisation of fruit and clarification of oil. Palm fruit digestion and oil extraction operations have been mechanised to some extent with about 90% of the mills having one device or the other to handle the operations. Hand-operated screw press was predominant (80%) in most of the mills as a device for palm oil extraction. Fruit- stripping was manually carried out. Nut/fibre separation by mechanical method is adopted by some (40%) of the mills while 90% of these mills utilize nut-cracker to crack their nuts. Most of the machines being utilized are sourced locally.

Maintenance of the machines was being carried out mainly when they develop faults. More than 50% of the mills have abandoned one machine or the other with breakdown of machines being the predominant reason. Most of the mills sourced fruit by purchase or served as processing centre. The extraction rate of the mills was very low and was in the range of 7–13%. Cost of production was very high when compared with other West African palm oil producing countries. It was surprising to observe a pit technology built around a plantation of about 100 ha (Plate 22)!

For the plantations, it was observed (Owolarafe, 2012b) that majority of the plantations (88%) were in the small scale group with 67.5% acquiring land through inheritance. Most of the plantations (about 76%) were generally old. Cost of establishment and maintenance depends on plantation size. Plantation maintenance was carried out haphazardly. Harvesting and haulage of fruit were not standardized. However majority of the plantations were closer to the mills. Despite the inadequate management practices, oil palm was adjudged to be more profitable than other crops grown in the State.

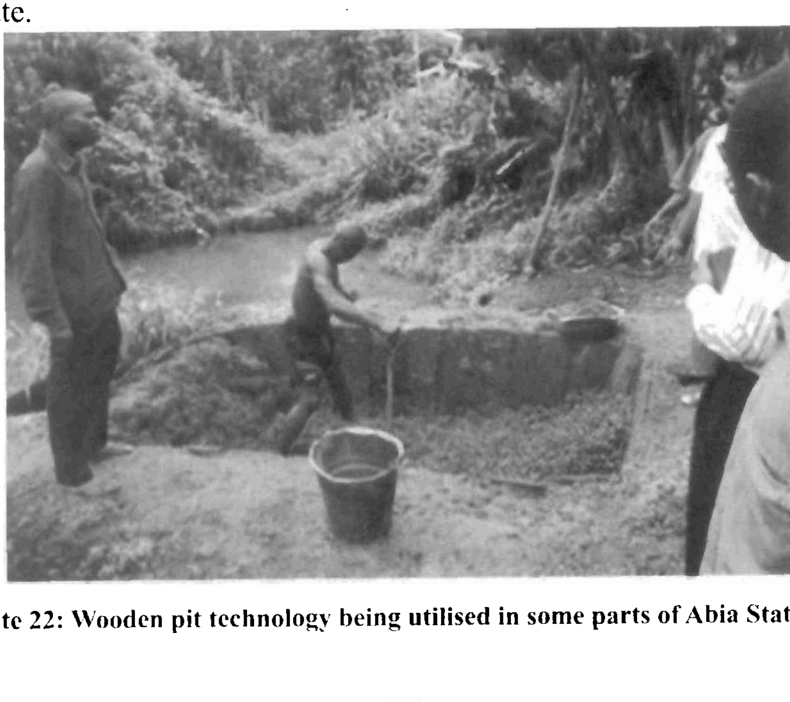


Plate 22: Wooden pit technology being utilised in some parts of Abia State

Subsequently, an intervention plan was proposed. The intervention plan consisted of acquisition and planting of improved seeds/seedlings, best plantation management practices (in terms of maintenance, harvesting and haulage of fruit) as well as introduction of organized plantations. Also for the palm fruit processing, an introduction of a small scale mill utilising modern technology (and centralised processing system) in form of Public Private Partnership was proposed. Such system will have to be backed up by a palm oil act as well as adequate mobilization of the farmers in order to facilitate the adoption of the system by farmers. A modern mill of 5 t/hr capacity was planned to serve a group of farmers in a catchment area as a model. This system will make available prompt returns to the farmers to strengthen their palm fruit production capacity and guarantee high quality oil that can be exported. This is the type of successful scheme adopted in India which I evaluated as part of my research activities during my postgraduate fellowship programme in the country (Owolarafe and Arumughan, 2007a; 2007b). This was just a future plan. In the mean time, the stakeholders (nursery operators, plantation farmers, processors and fabricators) were all trained on the improved techniques and technologies for carrying out their activities and these were all adopted before the project was completed.

Imo and Rivers States experience

Early in 2012, I got a phone call from one young man named James Elekwachi that my expertise was needed in a palm oil scoping study to reorganize the palm oil industry in the Niger Delta by the Partnership Initiatives in the Niger Delta (a consulting firm). I first ignored the call but with the persistence of this man I had to give him an audience. He then revealed that he had gathered a lot about me having read the report of the Abia State project submitted to the National Investment Promotion Council (NIPC) and that his organization will be willing to have me in their team with the proviso that the project will run through. I agreed to serve on the project. As usual, the scoping study involved assessment of the needs of the people and provision of interventions. The study took place in Imo and Rivers States as pilot areas. The initial focus of the work was to determine the feasibility of production of special palm oil (SPO) in the study area. As a result the whole value chain for this commodity was captured. Data on the demand for SPO was first gathered and the result indicated that a total of 142,200 Mt is required for just four food processing industries sampled. The distribution of this demand is shown in Table 3.

Table3: SPO Need for Secondary Processors /End Users

Company	Demand/year	Local Supply	Gap/Import
Honeywell	4,200Mt	2,520Mt	1,680Mt (import)
Indomie	48,000Mt	14,400Mt	33,600Mt (import)
Golden Oil	37,200Mt	9,300Mt	27,900 (No import)
Envoy Oil	52,800Mt	15,840Mt	36,960 (No import)

A demand gap of about 94,860 Mt was observed in the supply of SPO for the use of these industries. The business analysis to meet this gap shows that about 387.5 small scale millers are required and this will create about N91billion in the sector (Elekwachi *et al.*, 2012). It is opined that if this quantum of millers is engaged in the area, one can imagine the number of oil palm farmers that will be involved to supply the fruits and of course the marketers of the products. The overall effect of this will be having many actors in the entire value chain, keeping them busy and having sustainable good living.

Bearing this in mind, the technology profile for the production of SPO at the small scale level was revised but the challenge was identifying fabricators in the study area who could be trained to produce machines involved. Let me say here that Nigeria is blessed with a lot of hardworking people with high initiatives and who are ready to face challenges of perfecting things on their own. On the field, we were able to see some starring technologies already adopted and being maintained by the fabricators. However they felt short of the requirement for higher extraction efficiency of palm oil. The technologies are also not suitable for production of SPO. It was concluded that with little rearrangement and addition of some

accessories the profile could be upgraded for the production of special palm oil. After many efforts, we were able to get nine of the fabricators who could be trained for the possibility of producing machines for SPO production. Efforts are on-going to achieve this in the shortest possible time.
In the course of the palm oil scoping study in Imo State, the farmers raised the problem of harvesting. A lot of losses is incurred at the harvesting stage. Harvesting using the traditional method is time-consuming and tedious. As a result, many FFB get deteriorated before harvesting while substantial quantity is not harvested in some cases. To address this problem, a motorised harvester was imported from Malaysia with a view to adapting it to the harvesting of the Nigerian oil palm trees. On testing the machine, it was observed that it was effective on short palms. There was a little challenge in the sense that the harvester could not reach even what I referred to as medium palms in the typical Nigerian plantation let alone tall palms (Aramide *et al.*, 2015). A support mechanism (Plates 23 - 24) for the harvester was designed by one of my M.Sc postgraduate students (Aramide and Owolarafe, 2015) to ensure that the harvester could be adapted to the palms. It was observed that with the support mechanism, the time of harvest is drastically reduced. The time of harvest per hectare for the motorised harvester and the support mechanism is 9 hr/ha as against that for the traditional rope and axe/knife of 20 hr/ha.

Plate 23: The support mechanism for usage of motorised palm bunch harvester

Plate 24: Use of the support mechanism with the motorised harvester.

Similarly the production of the commercial versions of the technologies developed for okro harvesting and processing, locust bean processing , *spondia smombin* as well as for snake gourd seed are almost completed and the entire package will be adapted to appropriate areas very soon. Orders are already being received for some of the machines.

The Way Forward

Each State of this Federation is endowed with many agricultural crops, the processing of which will create a lot of wealth in addition to generating employment. To achieve these laudable objectives the following steps should be taken in each of the States.

i. Each state should concentrate on crops which it has comparative advantage in its production for industrial development

ii. In each state, local government areas should also adopt developing crops which they have comparative advantage in its production.

iii. Production, processing, storage and utilisation of the crops should be properly coordinated

iv. Research and Development (R & D) Institutions that can develop technologies for the production, processing, storage and utilisation of the crops should be identified and commissioned to handle the projects.

v. The R&D institutions should adopt participatory approach in developing the technologies.

vi. The products from the farmers and processors should be taken up by the government and appropriate prices offered to the farmers and processors.

vii. Youths should be trained through the establishment of farm settlements as being carried out at present in Osun State.

Concluding Remarks

Mr. Vice Chancellor Sir, Distinguished Audience, Nigeria is blessed with many agricultural resources. It is high time the country invested in the development of agricultural sector to improve output from the sector, reduce high rate of unemployment which has induced high crime rate. Food production will also be boosted. The coordination of the development and adoption of appropriate technologies through R&D for processing agricultural crops at small and medium scale levels is pivotal to the revitalisation of the agro-industrial development. When this is achieved everybody will live in tranquil environment and hence the country will be transformed into a paradise on earth.

Acknowledgements

I wish to thank my late parents Mr. Abdul-Salaam and Mrs Salamaat Owolarafe for struggling to give me education despite their old age and meagre income. Unfortunately they could not live long enough to reap the fruits of their labour. May Almighty Allah grant them paradise. I sincerely thank my late father for imparting rigorous training in me as this has enabled me to face the challenges of this world.

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I must not hesitate to acknowledge the efforts of Prof. Obafemi Ajibola, a former DVC, (Administrator), my main mentor, who saw something good in me and encouraged me in my aspiration to join academics. His vision to establish the Post-harvest Technology Research Group in 1996 and the way he managed the affairs of the group widened my horizon of research even while at the lower rungs of the academic ladder. I really enjoyed his tutelage. The contribution of my former supervisor (at both M.Sc and PhD levels), and a former Vice Chancellor of the University, Prof. M.O. Faborode, to my academic career is greatly acknowledged.

I also appreciate the contributions of Prof. O.A. Ajayi, the current DVC (Administration) Prof. J.A. Osunade, Prof. K.O. Adekalu, Dr. L.A.O. Ogunjimi and all the members of staff of the Department for their support even before I became Head of Department. The efforts of Late the Prof. M.O. Ogedengbe my professional mentor and a father at all times while alive are also hereby acknowledged. I also thank Prof. L.O. Adekoya for his support both academically and professionally.

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I wish to thank members of the Nigerian Society of Engineers, Ile-Ife Branch for the key role they played in the course of my academic and professional endeavours. I have been in the Executive committee of the Branch since 2004 and served as the Chairman between 2011 and 2014. It was on this platform that I have been appointed as the Chief Inspector for COREN on regulation and monitoring (ERM).

I wish to register the support of the members of my research team, Drs O.A. Odejobi, S.O. Ajadi, S.O. Obayopo, O.J Odejobi, B. S. Ogunsina and A.S. Osunleke. I thank the following families: Prof. and Prof. Mrs. Taiwo; Prof. and Mrs. Ajibola; Engr. and Mrs. Jeje; and Dr. and Mrs. Odejobi for caring for me since I joined the University system.

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Mr. Vice-Chancellor Sir, I wish to inform you that the encouragement to deliver this Inaugural Lecture came from my class mates (1989 Set) under the leadership of Mr. R.O. Sarumi (The managing Director of Saro Agro-Chemicals), old alumni of the Faculty of Technology who are my friends, some of my old students (particularly the 1997 and 2002 graduating sets), UNIFEMGANS as well as my post-graduate students. I wish to thank them all.

I also specially thank Prof. Saburi. Adesanya, the current Vice Chancellor of the Olabisi Onabanjo University (OOU), Ago-Iwoye and his family for the support given to me since we came together and up-to-date. I appreciate the kind gesture accorded me (as a Visiting Professor) by the Provost (Prof. Kayode Oyesiku), Acting Dean of the Faculty of Engineering (Dr. Taiwo Samuel) and the entire staff of the College of Engineering of Environmental Studies, Ibogun Campus of OOU for providing the opportunity to continue sharing my ideas and expertise in the development of appropriate technologies for processing of agricultural crops even outside OAU.

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