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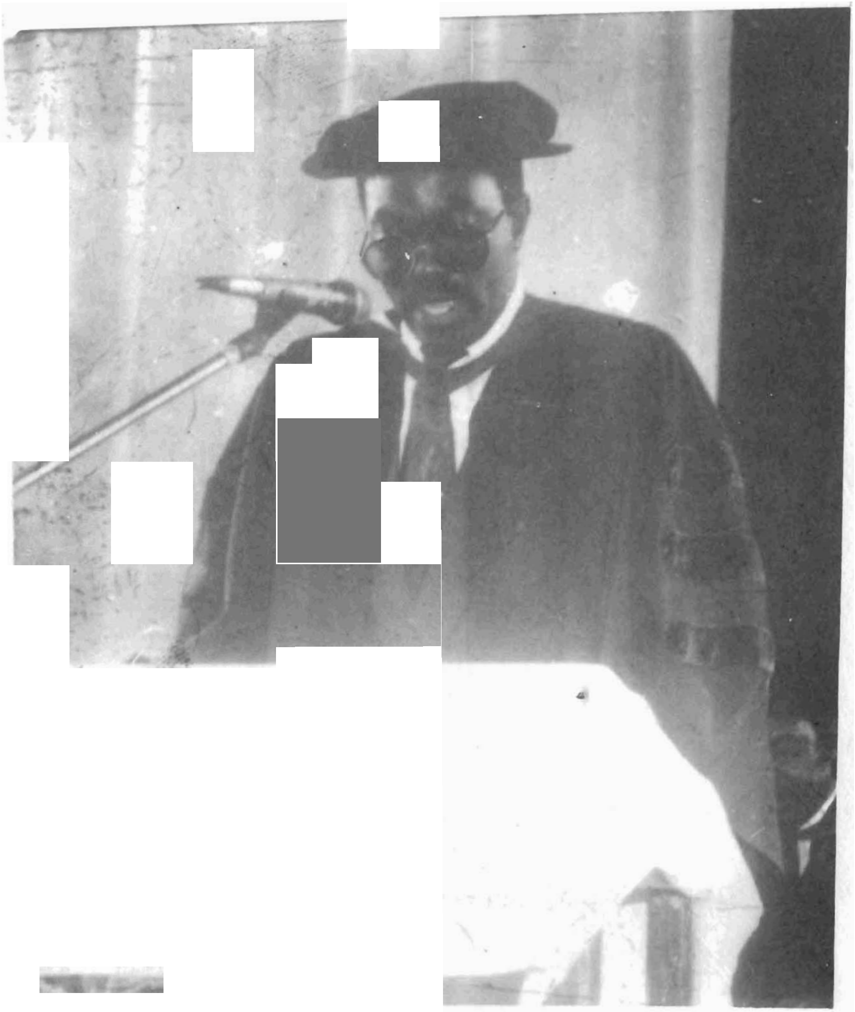

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In the sixties and early seventies, the world was speaking mostly about the Green Revolution which came about through extensive plant breeding efforts (geared towards increased food production, shorter growing season and increased pest and disease resistance) and cultivation of large areas of land. Increasing food production by increasing acreage or yield per acre was then a more readily applied concept while reducing post-harvest losses to increase food supplies was a less obvious strategy. In many instances, the beneficial impact of increased agricultural production was offset by the tremendous losses incurred after the harvest. This was complicated sometimes because the increases in production put additional pressures on already inadequate post-harvest system creating possibilities for increased levels of loss at all stages of the post-harvest system. This trend of events occurred in spite of the availability of a considerable body of information on prevention of post-harvest food losses.

Post-harvest losses can arise from a number of causes which can be grouped into three main categories namely physical loss that can be measured by weight; loss of quality with changes in appearance, taste or texture that may cause food to be rejected by potential buyers; and loss of nutritional value. These losses are in economic, qualitative, quantitative and nutritional terms and have consequences to the farmer, the buyer/consumer and the society or nation as a whole. For example, it was estimated that the food wasted or lost during the post-harvest period could provide basic nutritional requirements for almost 200 million people and that investments in efforts to save food after harvest was less costly than that required to increase production by an equivalent amount (Booth, 1974; NAS, 1978)

By the middle seventies it had already been realised worldwide that food production increases should go hand in hand with plans for post-harvest loss reduction and that more scientific and development efforts were necessary in reducing losses after harvest. At the World Food Conference held in Rome in 1974, the reduction of post-harvest food losses was emphasized as a major means of increasing the world food supplies. Subsequently, the growing international awareness of the need for reducing post-harvest food losses culminated in a resolution of the Seventh Special Session of the United Nations General Assembly in September 1975 which states that "the further reduction of post-harvest food losses in the developing countries should be undertaken as a matter of priority with a view to reaching at least 50 % reduction by 1985."

At this time, the total magnitude of post-harvest food losses, the extent to which it is avoidable and the methodology for collecting

reliable data were not reliably known. However, there were spirited efforts made at loss estimation and prevention in most parts of the world. This led to the preparation of the Harris-Lindblad manual for loss estimation and the establishment of several multinational efforts at post-harvest loss prevention (Spensley, 1981).

Estimates of post-harvest losses in Nigeria in the seventies were very scanty and not so accurate but they ranged from 20 to 50% for most crops. Efforts to reduce these losses should normally begin with quantitative assessments of the problems so as to get a clear picture of the problems, to be able to assess the effectiveness of loss reduction and to evaluate the cost effectiveness of loss reduction activities. These post-harvest losses were not quantitatively assessed making it difficult for policy decisions to be made on allocation of resources to reduce the losses. In spite of these problems some efforts were still made in the country to reduce post-harvest losses. Most of these efforts were biased towards storage of cereal grains. The non-grain staples, which were and are still the main sources of calories, at least in the diets of many Nigerians, did not receive attention commensurate with their importance in the diet and the economy. This was also true for fruits and vegetables.

In the eighties and early nineties improved efforts were made to reduce post-harvest food losses in Nigeria. A substantial proportion of these efforts were still related to the improvement of storage systems of grains but some efforts were also made at the development of improved processing technologies for tubers and oilseeds and preservation of fruit and vegetables. Such government departments as the Rural Agro-industrial Development Scheme (RAIDS), Crop Storage Unit (CSU), National Centre for Agricultural Mechnisation (NCAM), Nigerian Stored Products Research Institute (NISPRI) etc, coordinated these efforts. The level of research and development as well as extension activities in post-harvest processing also increased substantially. These activities focused on crops of high food security and economic value in the country and led to some significant successes. For example, the motorized cassava grater used for processing cassava into *gari* became available in most Nigerian villages where cassava is processed and there was wide adoption of the digester for palm fruit processing. By the early nineties the food loss figures being quoted in Nigeria were between 10 and 25 % (Olayemi, 1995). These are still relatively high figures but there seemed to have been some improvement in the post-harvest situation.

For a substantial impact to be made in the post-harvest sector there is need to understand the situation in some more details and relate

appropriately to the complexities of the situation. Losses vary greatly and are a function of crop variety, pest and pest combinations, climate, the system of harvesting, processing, storage, handling and marketing and the social and cultural setting. The importance of losses in particular localities varies according to the availability of food and the purchasing power of the various sectors of the society. Given such enormous variability, it is not surprising that reliable statistics regarding the type, location, causes and magnitude of post-harvest losses are not readily available. Lack of these data also makes it difficult to priortise in the allocation of limited resources for loss prevention activities. This prioritisation will need to deal with crops of major focus and the type, point and scale of intervention.

Several criteria have been suggested for rating the importance of agricultural crops for post-harvest loss prevention activities but one that seems quite acceptable internationally is one that seems to measure the contribution of the commodity (or group of commodities) makes to the aggregate Gross Domestic Product. Such a measurement will comprise not only of the farm gate value of the crop, but also the extent to which value is subsequently added by post-harvest processing together with the commodity's export contribution and foreign exchange earnings. This criterion, which has been used by some international organizations to assess priorities for research in developing countries, is presented in Figures 1 and 2. Figure 1 shows a pie chart relating to the value of the commodity groups in less developed countries in 1970. The total value of the chart at the time of the estimate was about $100 billion which corresponded to 36% of the Gross Domestic Product of the developing countries. Figure 2 presents the post-harvest aspect of the data. It shows the relative importance of post harvest activities to the value of the commodity groups. The proportion of the ultimate value to the consumer which arises from post-harvest activities, was greatest with tobacco, fibre and sugar, being around 60 to 70%, below 50% for most other crops and was least for cereals at under 20%. At this time the post harvest proportion of total value of food commodities as a whole in the UK was about 50%.

Specific information of this type may not be available for Nigeria but it is known that of the 93 million tones of staples produced in Nigeria in 1998 cassava accounted for over 34 million tones and yam accounted for more than 25 million tones. This is an indication that the non-grain staples, which are known to experience high levels of post-harvest losses, should receive attention commensurate with their importance in the diet and the economy.

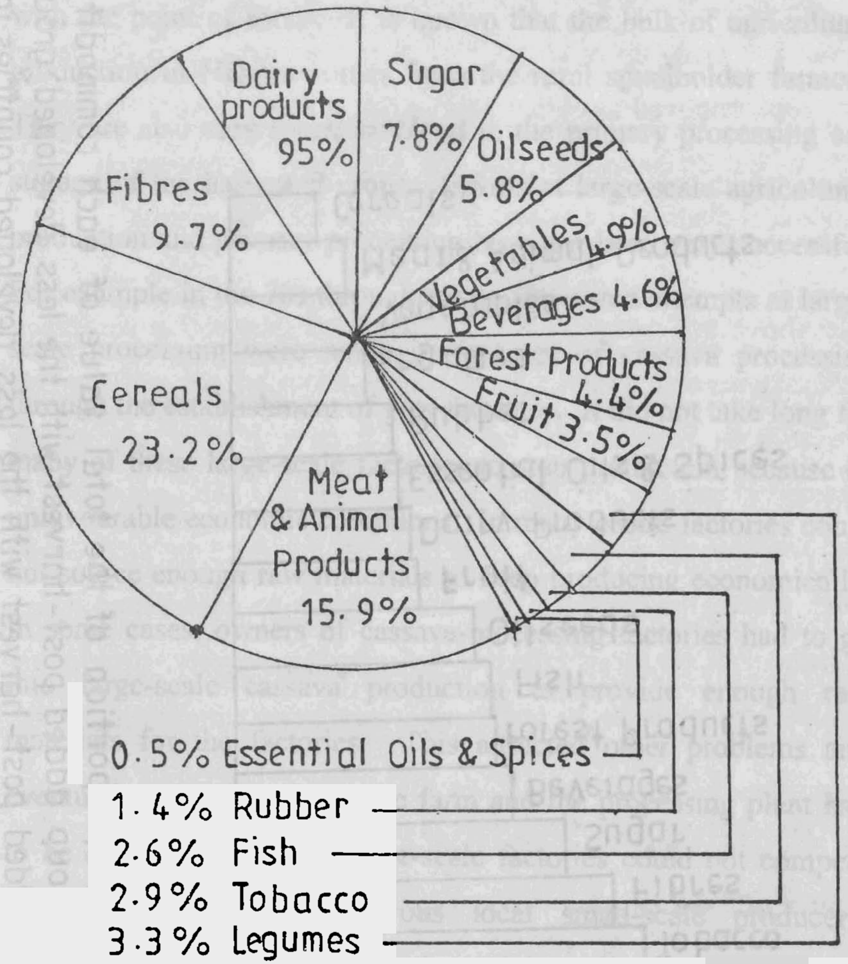

Figure 1 : The contribution of commodity groups to the total value of the agricultural sector in less developed countries in 1970.

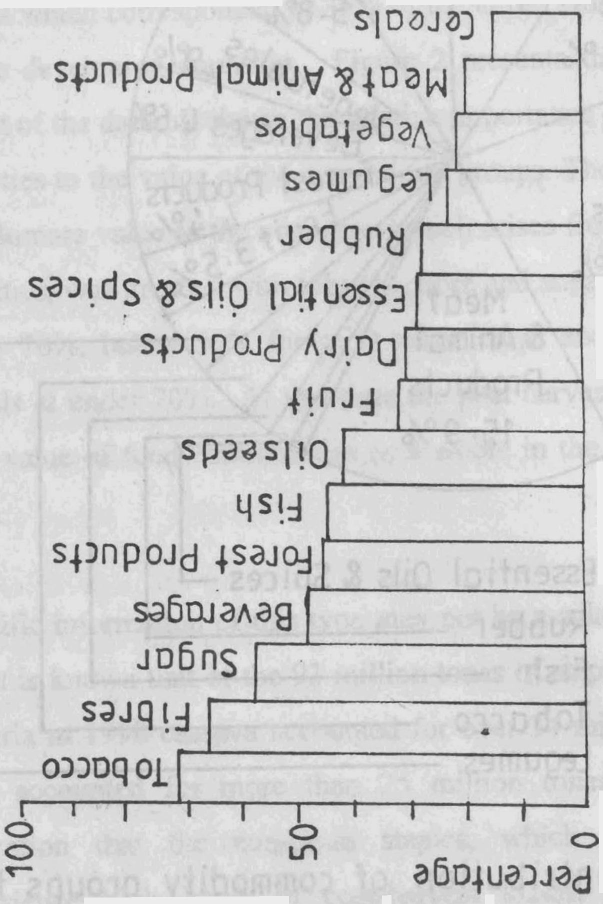

Figure 2 : The proportion of the total value of each commodity group added post-harvest with the less developed group added post-harvest with the loss developed countries in 1970

Apart from the crops to focus on, another important issue deals with the point of focus. It is known that the bulk of agricultural production in Nigeria comes from the rural smallholder farmers. They are also very much involved in the primary processing and storage of the harvested crops. Efforts at large-scale agricultural production and primary processing have not been very successful. For example in the 70s through to the 80s, some attempts at large-scale processing were made in the area of cassava processing through the establishment of *gari* factories. It did not take long for many of these large-scale factories to stop production because of unfavourable economic conditions. In many cases, factories could not source enough raw materials to keep producing economically. In some cases, owners of cassava-processing factories had to go into large-scale cassava production to provide enough raw materials for the factories. This attracted other problems and eventually both the large-scale farm and the processing plant had to be closed down. The large-scale factories could not compete effectively with the numerous local small-scale producers. Although they were able to produce high quality *gari* with higher storage periods being better dried, the prices put on the products could not attract enough buyers. This is because the demands for raw materials by the big time processor, with high capacity plants, could not be satisfied by farmers in their immediate localities so there was need to source tubers from long distances to keep the factories producing at close to full capacity. These tubers had to be transported over long distances before processing. Since cassava is made up of about 70% water and almost all this water has to be removed to obtain good quality *gari*, it meant that about 70% of the transportation cost was spent on waste material. This was a cost element not experienced by the local processor.

The above and many such examples have shown that resources, technologies and technological skills allocated for post-harvest activities in Nigeria will be most effective if they are mostly targeted at smallholder farmers and processors. The emphasis of our post-harvest activities should be at the farm or small-scale level where the products are more prone to losses and value addition can be more effective in reducing poverty, developing smallholder agribusiness and thereby improving national economy

The post-harvest issue is further complicated by other factors that may not seem too obvious. Although post-harvest losses will ultimately be felt by society as a whole, individual groups are likely to experience the economic consequences to different degrees. Further, strategies to prevent or reduce post-harvest losses could have different economic effects on producers, consumers, processors etc. Farmers could, for example, take steps to improve grain storage that involve substantial costs to each

farmer. In the short term, there could be a surplus of grains and a lowering of prices so that farmers individually and collectively would lose while the consumers benefited. Such a situation may not lead to sustained and widespread adoption of the storage technology introduced. It is important therefore, when planning a post-harvest loss prevention programme at the national level, to take into consideration not only the economic effects but also the social responsibility and the national development goals of the government to be able to come up with the 'right' answers to these complex and changing situations.

Post-harvest prevention activities will likely require some investment from the farmer. The farmer being a private entrepreneur is primarily concerned with private profitability. On the other hand, the investment of government in post-harvest loss reduction must be considered in terms beyond the primary objective of loss reduction and increased food supply. There are also secondary objectives which may include promotion of agro-industrial sector, employment generation, income distribution, nutrition, social stability etc. The farmers' harvest must be seen to provide government and other players in the post-harvest sector the opportunity for attainment of numerous national objectives. A post-harvest prevention loss programme should therefore exploit value added agriculture with potential for expanded processing and industrialisation. Such a programme will have to focus on the processing of some portion of agricultural products as raw materials for agro-based industries which can become another major source of income for the farmer.

Historically, most countries first developed industries based on primary processing of agricultural products and providing services to these industries and to agriculture. The potential is still there in Nigeria for more small- and medium- scale agro-based industries in the rural areas for extracting starch from tubers and grains, extracting vegetable oils from oilseeds, producing animal feed from grains, producing juices from fruits etc. These industries would provide employment opportunities, create wealth in the rural areas and lead to industrialization of the country. The focus of such industries should be the agricultural products in which we have comparative advantage in terms of production and processing. Good examples are cassava and oilseeds.

In Nigeria, there were increases in cassava production in the 1980s into the early 90s. However, the level of increases could not be sustained for long. The increased production came about because the level of poverty and economic problems in the country led many 'new farmers' into cassava production (since cassava continues to play a significant role in the national food security

equation of Nigeria). The relative gluts that came in the mid 1990s were caused by the limited nature of cassava tuber utilization in the country and because the increased production was not brought about by increased demand for the product. Increased production of cassava can only be sustained at a high level if it is demand-driven with the crop being considered an economic crop and its utilization diversified and increased through the promotion of new uses for the tubers. Diversified processing and utilization of cassava will lead to increased demand for the crop thus increased production of the crop can be sustained. This will lead to increases in the income of cassava farmers, reduction in rural poverty, reduction in the importation of some agro-industrial products, development of agro-based industries requiring cassava as raw materials, etc. This is the kind of development that is now desired in the agricultural sector.

Cassava tuber has a lot of industrial potentials particularly in the production of flour, starch, chips, pellets, glucose and fructose syrup, textiles, adhesives, alcohol, and other chemicals such as monosodium glutamate, citric acid, mannitol and sorbitol. These potentials are presently under-exploited partly due to ignorance on the part of processors and also due to non-availability of appropriate and efficient technologies at the cottage level as well as small and medium scale levels for producing good quality industrial products from cassava.

One major problem with industrial exploitation of cassava is that the tubers consists of 60-70 % water and needs to be processed into a dry, more durable and stable product with less volume if it is to be kept or transported. It is also known that cassava deteriorates irreversibly without processing after 24 hours and drying is the first preservation option. It follows therefore that dried cassava in whatever form (grits and chips) is the recommended raw material input for commercial level of cassava exploitation. Further processing such as the extraction of starch from dried cassava products provides operational flexibility and allows for the establishment of cottage industries which can collect their raw materials from farmers at reduced transportation costs without having to process immediately since the dried products can keep for some time in storage. If the processing technology for the production of the starch of acceptable quality is promoted successfully it will lead to industrial linkages within the different scales of industries. The starch will serve as raw materials from which dextrins are hydrolysed for formulating adhesives and to industries involved in the production of glucose and high fructose syrup as well as other industries using starch as raw materials. Some food and beverage industries now utilize detoxified cassava

starch instead of the more expensive corn starch. This has encouraged the exploitation of cassava flour and starch in other applications, however, improved processing techniques for the production of cassava starch needs to be developed to enable it meet the stringent microbiological specifications of the food industry. This is just an example of the many possibilities with cassava tuber.

As for oilseeds, this class of crops also offers unique opportunities for substantial addition to the value of the farmers' harvest. Nigeria is blessed with many varieties of oilseeds grown in about all the corners of the country that the oils and fats industry could be an important industrial sector if the oilseeds are properly harnessed and utilized. The vegetable oil industry could contribute significantly to further industrialization of Nigeria and satisfy our needs for edible oils and fats, animal feed and industrial raw materials for the manufacture of soap, paints, detergents, candles, lubricants, linoleum, printing ink, vanishes, polymers and some pharmaceutical products. Presently this is not being achieved because most of the locally available oilseeds that can be used for the provision of edible and industrial oils and useful press cakes and meals are un-exploited or greatly under-exploited leading to a lot of waste. Those oilseeds that are exploited are processed using crude technologies that are wasteful and produce low quality oils and cakes. There are also the new but potent problems posed by dumping of vegetable oils from abroad and trade globalisation. The locally available oilseeds include groundnut, soybean, sunflower seed, melon, locust bean, conophor, benni-seed, cocoa bean, palm kernel, coconut, shea butter and cottonseed. These oilseeds, their oil contents, annual production in Nigeria and normal/potential uses are shown in Table 1. There is need to upgrade the technology of obtaining oil from these seeds by identifying appropriate processing conditions and machines that will optimize the oil yield and quality of oil and press-cake. The technology should be without the complexity and high cost that will discourage the small and medium scale farmers and processors from the oil industry and should provide opportunity for global competition.

In spite of the potentials available for utilizing our agricultural products, the post-harvest sector remains relatively under-developed. An evaluation of the situation indicated clearly that most of the results obtained in the universities and research institutes are not reaching farmers and processors. One has to accept that a major problem with the adoption of agricultural processing technologies developed in many of our research and development activities is the inappropriateness of some of the

Table 1: Nigeria's oil seeds production levels and some properties their oils.

Oilseed	National Production Level ('000 Tones)	Oil Content (%)	Iodine Value	Saponification Value	Specific Gravity	Refractive Index	Type of oil	Possible Uses
Soy- bean	327	19	120 –141	189 – 195	.917 – .921	1.470 – 1476	Semi Drying	Food, Paint, Resin, Chemicals
Groundnut	2,227	51	84 – 100	188 – 195	.910 - .915	1.407 - 1.470	Non Drying	Food
Palm kernel	572	49	14 - 22	240 – 255	.860 - .873	1.449 – 1.452	Vegetable fat	Soap
Coconut	167	63	7.5 - 10.5	245 – 264	.869 - .874	1.448 – 1.450	Vegetable fat	Soap
Cocoa bean	345	43	35 - 40	190 – 200	.856 - .864	1.453 – 1.458	Vegetable fat	Food, Pharmaceutics, Perfume
Melon	328	50			.917 - .919	1.467 – 1.470	Semi Drying	Food
Conophor	NA	40-60	190 - 214	200 – 206	.931 - .934	1.476 – 1.479	Drying	Paint, Vanishes etc.
Sesame seed	78	48	103 - 116	188 – 195	.914 - .919	1.470 – 1.474	Semi Drying	Food, Soap
Cotton seed	349	19	99 – 113	189 – 198	.916 - .918	1.468 – 1.472	Semi Drying	Food, Soap
Sunflower	Na	33	125 –136	188 – 194	.915 - .919	1.472 – 1.474	Semi Drying	Food, Resin
Shea nut	396	50	53 – 65	171 – 190			Vegetable fat	Food
Oil bean	NA	36	119 – 122	166 – 176			Drying	Vanishes, Alkyd resin
Rubber seed	NA	43	136 – 149	190 – 195		1.466 – 1.469		
Tobacco seed	NA	38	129 - 142	186 – 197	.923 - .925	1.474 – 1.483		
Oil palm	780	21	49 - 57	197 – 202	.869– .901			Food, Soup

Sources: Ajibola *et al* (1990a & b), CBN (1998), Swern (1964), Williams (1960) developed technologies to the users or the circumstances of the users (Ajibola and Faborode, 1992; Ajibola, 1993). Any serious attempt at promoting mechanization of the processing of agricultural products in Nigeria must take into consideration the players in the agricultural sector and the linkages that exist among them.

It is common knowledge that the bulk of agricultural production and processing in this country is from rural farmers who are low-income, small-scale technology users. A substantial proportion of these processors are women. Many of them have little contact with extension workers who themselves are not up-to-date with knowledge on post-harvest matters. Technological skills and resources will be of little use in reducing post-harvest losses and promoting agro-industrial growth unless they are effectively transferred to these users.

Another problem is that there is a general misconception that agricultural technology is gender neutral. This assumption overlooks the gender-specific nature of agricultural processing and allied activities. There have been cases where the introduction of technologies have led to the displacement of women from some beneficial traditional roles leading to their dis-empowerment. This unfortunate phenomenon, which is not uncommon in donor

assisted projects in Nigeria, has led to the rejection of some technology packages that are otherwise efficient in performing the operations for which they were designed. Machine developers must recognize that the machines to be introduced to farmers and processors must not destroy the balance in the community by allowing men to take over the jobs of women, depriving women of their source of income, turning women into customers of men operators of machines on an operation they had complete control.

Not only can the introduction of technological innovations have negative effects on the position of women when the gender division of labour is not taken into account, it can also result in the technology not being accepted and adopted. Many agricultural projects failed and innovations rejected because women farmers and processors were neglected. We will be able to achieve increased adoption of agricultural machines in the post-harvest sector if there is increased interaction between agricultural engineers and the users of agricultural technologies to the levels that our products incorporate the users' capabilities, preferences and relevant socio-economic and cultural factors.

Our research work has indicated clearly that increased interaction between machine developers/fabricators and their customers is useful. It will increase the chances of success in technology adoption and help establish a highly desired linkage. There is also the need to develop appropriate interactions between the farmers and the end users of their products to ensure that their post-harvest activities are market driven. If the opportunities created by these interactions are properly exploited, our post-harvest activities will not only achieve the desired prevention of post-harvest losses but there will also be substantial addition to the value of agricultural production through the provision of raw materials for agro-based industries. My research work in this university has adopted this kind of philosophy in attempting to provide solutions to some of the problems in the post-harvest sector.

Post-Harvest Processing Work in Ife

The department of agricultural engineering of this University was established in 1971. At that time, and in most of the seventies, research efforts were directed at assisting the government and the farmers in their endeavour to meet the declared objectives of increased agricultural production. The department concentrated its research activities on the development of machinery for production such as the portable grain planter, cassava stem-cutting planter, cassava root digger and kenaf decorticator (Makanjuola, 1977). The motivator of these activities was Professor Ayodele Makanjuola (Nigerian National Merit Awardee). Although the focus of research efforts was on farm machinery development, the

department also undertook activities in the development of processing machines. The yam-pounding machine, cowpea sheller, melon sheller and wood fired dryer were developed. Since completion of my postgraduate work and as part of my contribution to the research work in my department I have spent considerable research time on the drying of agricultural crops, processing of cassava tubers, expression of oil from oil-seeds, and management of agricultural mechanization with emphasis on post-harvest processing and storage.

Drying characteristics of some tropical crops

Drying is one of the most important post-harvest processes undertaken to retain the quality and improve the value of agricultural products. For proper modeling, planning, prediction and optimization of the drying process there is need to determine drying characteristics of agricultural products. These characteristics were unknown for most tropical agricultural products hence it was difficult to develop efficient post-harvest processes and machines. The research activities in the department of agricultural engineering of this University involved and still involve the determination of these characteristics, the effects of relevant conditions such as temperature and relative humidity on the characteristics and the development of appropriate models that describe the characteristics. The agricultural products studied include cassava, *gari*, pre-gelled yam slices, cowpea, melon seeds, palm kernel, sesame seed, rubber seed, winged beans, cocoa beans, cashew nut, soybean and sorghum (Ajibola, 1985; Ajibola, 1986a; Ajibola, 1986b; Ajibola, 1986c; Ajibola and Adams, 1986; Ajibola, 1987, Ajibola, et al 1988; Ajibola, 1989a; Dairo & Ajibola, 1994; Ajibola & Dairo, 1997). The drying characteristics determined included equilibrium moisture content at different temperatures and relative humidities, the resistance to airflow at different flow rates and the thin layer drying behaviour.

The equilibrium moisture content of agricultural material at specified air conditions is the moisture content at which the air is at equilibrium with the crop. It indicates the lowest moisture content to which air at certain conditions can dry the material. It is usually presented in form of models which relate the moisture content to relative humidity and temperature. Our research work indicate that the modified Hasley model (Igleseas & Chirife, 1971) and the modified Henderson model (Thomson, 1972) are the best Equilibrium Moisture Content- Equilibrium Relative Humidity models for predicting sorption behaviour of locally available agricultural materials.

The thin layer drying characteristics provide information about the drying behaviour of each layer of the bed of agricultural materials.

This information is needed for the design and modeling of deep bed dryers. The thin layer drying behaviour is usually presented in form of mathematical models with constants related to the drying condition. The exponential model in which the drying constant is an exponential function of temperature and relative humidity was found adequate for predicting thin layer drying of melon seed, cowpea, palm kernel (Ajibola, 1989b).

The resistance of agricultural materials to airflow is the pressure drop experienced when air is passed through the material. This information is required for the sizing of fans to be used in drying and storage systems. The resistance of agricultural crops to airflow has been found to depend on the airflow rate, bed depth, density, presence of foreign materials, moisture content of the material, and surface and shape characteristics of the material (Shedd 1953; Gunasekaran and Jackson, 1988; Dairo and Ajibola, 1994). Models have been developed in our studies that adequately describe the airflow resistance as a function of airflow rate, moisture content, bulk density and percent fine material for sesame seed, palm kernel, melon, cowpea, rice and rubber seed. The information obtained from these studies provided the data for predicting the drying behaviour of many locally available agricultural materials under varying drying conditions and for the optimization of the drying of these crops.

Further work was also undertaken on the drying of such crops as the cocoa beans. The interest in drying cocoa beans was developed because it had been observed that beans dried artificially were not as good in quality as those dried locally in the sun. The local drying of cocoa beans involves sun drying during the day and packing and heaping of the beans whenever the sun was down only to be spread the following day until the beans were dried to appropriately low levels of moisture. Beans artificially dried continuously (i.e. without rest periods) did not exhibit the colour and flavour desired in the market. It is believed that moisture redistribution occurs during the rest period contributing to the completion of the oxidative changes and acid diffusion needed for the production of high quality cocoa beans. The high drying rates obtained in artificial continuous drying, while allowing for quick drying, do not allow for these vital processes to take place appropriately and cause cracking and breaking of the seeds. Broken and cracked beans are susceptible to fatty acid development and lowering of quality.

The local method of drying cocoa beans, on the other hand, has some disadvantages in that it allows for contamination of the beans, is too dependent on uncontrollable factors such as weather and is labour intensive etc. In spite of these, the local method

produced better quality beans because it allows for "resting during drying". Intermittent drying of cocoa beans was therefore explored. This involves drying at specified temperatures for certain periods of time and resting at room temperature for specified periods of time. Our research activities in the optimization of intermittent drying of cocoa beans has shown that using a drying schedule that allows for drying at about 40-43 °C for between 8 to 10 hours and rest period of about 15 hours produces beans of comparable quality as those desired for the high first class in the world market.

Cassava processing

Cassava is one of the most important food crops in Nigeria and its production has increased substantially in the country over the past 15 years. Nigeria is currently the highest producer of the crop in the world with over 34 million tons of fresh tubers produced annually from over 1,300,000 hectares of land under cultivation. Cassava is one of the food crops in which organized post-harvest research work was started in Nigeria. Several successes have been recorded particularly in the production of *gari* which is the most important food produced from cassava. The production of *gari* involves a number of processes. First, peeled roots are grated and fermented for about 3-4 days. The fermented mash is then dewatered, partially gelatinized by frying, dried to a moisture content of about 10% (wet basis) and milled. Grating of cassava tuber is now undertaken using mechanical and rotary graters. Fermentation and dewatering are undertaken with the mash put in sacks placed under pressure with the use of mechanical or hydraulic presses while gelatinisation and drying are carried out in a single operation of frying in different kinds of pans.

The problems observed in the mechanisation of cassava processing in the early 80s stimulated research activities towards the promotion of on-farm small- and medium- scale processing of cassava to some stable forms since the tuber has to be processed within 24 hours after harvest to prevent deterioration. Another problem was the fact that most of the machines used in cassava processing cannot be used to process other crops. For example, the grater can only be used for grating cassava and the fryer can only be used for frying cassava mash. It was felt that attempts should be made to develop processes and machines that can be used for processing cassava as well as other crops. This way cassava processing plants can also be used to undertake some other processing activities on other commonly available crops to spread and improve the utility of the machines.

The most important factor in the evaluation of cassava processing techniques is the ability of the process in reducing the total cyanide content (bound and free) in the product to acceptable levels

Cassava tubers contain the cyanogenic glucosides (bound cyanide), linamarin and lotaustralin, which upon hydrolysis produce free hydrocyanic acid (HCN) which is considered to be one of the most powerful poisons. Hydrolysis occurs when the glucosides come in contact with the enzyme linamarase. This enzyme, linamarase, is released endogenously when the tuber is crushed or the cellular structure is damaged. Lactic acid bacteria involved in the fermentation of cassava mash also release the enzyme. There has been some debate as to the necessity of fermentation for adequate detoxification of cassava mash. This issue is important for process optimization and food safety more so when it is realized that there are communities in Nigeria in which cassava is being processed into *gari* within 24 hours and without fermentation without cases of food poisoning. My research work shows that detoxification of cassava tuber started substantially during grating or size reduction process when the cells were destroyed. The results indicate that each step (grating, fermentation, pressing and frying) contributes to the reduction in the total cyanide content of the products (Table 2). The reduction in total cyanide during grating and fermentation is due to the hydrolysis of bound cyanide to the more volatile free cyanide. Most of the free cyanide is expressed in the liquor during pressing and volatized during frying (Ajibola, *et al* 1987a). This observation has been confirmed by other workers (Westby and Twiddy, 1991; Vasconcelos, *et al* 1990). It is clear now that the mechanism of the elimination of cyanogens from cassava during processing can be through hydrolysis caused by endogenous linamarase; hydrolysis caused by linamarase produced by bacteria involved in lactic acid fermentation; as well as through leaching during soaking of cassava chips or tubers. The predominant mechanism or mechanisms is determined by the processing conditions (Ajibola 1991, Sokari *et al* 1991, Bokanga, 1991; Oyewole and Odunfa, 1991)

Table 2: Effects of the process steps in the conventional method of gari production on the total cyanide content.

Process step	Total cyanide (mg/100g)
Peeled tuber	18.2
Grated mash	11.7
Fermented mash	5.4
Pressed mash (without fermentation)	4.1
Pressed mash (with fermentation)	3.2
Gari (after frying, without fermentation)	1.5
Gari (after frying, with fermentation)	1.8

Fermentation is important for the development of the characteristic cassava flavour but unnecessary for detoxification **if damage to**

cellular structure of cassava tuber is substantial. Our research activities showed that when cassava is properly grated and dewatered the *gari* produced would be relatively free of cyanide with or without fermentation. However, for cassava tubers and chips in which substantial cell destruction was not undertaken, fermentation (during which leaching and hydrolysis of cyanogens take place) was found to be absolutely necessary and effective for detoxification (Ajibola, *et al* 1987b).

My interest in on-farm processing of cassava made us consider a process line involving the production of *gari* using techniques that involve cutting cassava tuber into slices/chips, fermenting, partially gelatinizing through steaming, drying and milling. The *gari* produced compared favourably with *gari* produced using conventional method. The machines required for this technique can be used for processing other locally available crops. These machines include the chipping machine and machines available in a rice parboiling plant for steam gelatinisation and drying. Milling can be undertaken with conventional plate mill. Thus with the addition of a cassava chipping machine and a plate mill, a rice processing plant can also be used to produce good quality *gari*. An appropriate cassava chipping was developed for the process (Ajibola *et al* 1987a; Ajibola, et al 1987b; Ajibola *et al* 1991).

The production of starch and from there glucose and fructose syrup is the movement of the current research activities on cassava processing in the Department of Agricultural Engineering in collaboration with the Departments of Chemical Engineering and Food Science & Technology. Our work in this area has shown that extraction of starch from stable forms of chips and flour is feasible in terms of quality and quantity.

Vegetable oil extraction/production

Vegetable oil can be removed from an oilseed by solvent extraction, mechanical expression or a combination of expression and extraction. In the case of solvent extraction process, oil is first dissolved in a solvent and then separated by evaporating the solvent (commonly hexane). Although the solvent extraction process is more efficient than mechanical expression, solvent extraction equipment is expensive; there are fire and explosion hazards; there is the risk of dissolved chemicals being in the products; the technology is complicated for small-scale operators and operating cost could be high if there is low solvent recovery. In general, the operations involved in the mechanical expression of oil from oilseeds include cleaning, dehulling or decorticating, size reduction, cooking/heating, pressing (using screw or hydraulic) to expel oil from the cells of seeds followed by filtering and settling. The oil yield, quality and processing costs are significantly

affected by the pre-pressing operations thus optimization of the process requires detailed study of such complex factors as particle size, heating temperature, heating time, moisture content, applied pressure, pressing time etc. My research work on oilseeds therefore involved the identification of the effects of these processing factors on the yield and quality of the oil expressed from some locally available oilseeds with a view to identifying optimum processing conditions. The conditions for production of high grade oil from conophor, sesame seed, melon, groud nut, palm kernel, soybean, rubber seed were identified. I also worked on some aspects of the identification of some characteristics of these oils to determine their possible uses.

It is clear from our research work that moisture content, heating temperature, heating time, and applied pressure play important interactive roles in determining oil yield from oilseeds and the responses of oilseeds to these factors vary substantially depending on the characteristics of the oilseed bed. For example, the moisture content after heating, the amount of heat treatment given to sample, and applied pressure were the most significant factors affecting the yield of oil expressed from conophor, while oil yield from melon was determined mostly by initial seed moisture content, heating temperature and heating time (Fasina and Ajibola, 1989; Fasina and Ajibola, 1990; Ajibola *et al*, 1990; Ajibola *et al* 1993; Ajibola *et al* 1997).

Our results have also indicated that the dependence of oil yield to pressure varies for different oilseeds and is related to the characteristics of the oilseed bed. It was shown that the amount of oil expressed from some soft oilseeds such as groundnut, conophor and melon leveled off at an expression pressure of 15 - 20 MPa and above while increases were observed in yield with increase in applied pressure up to 25 MPa for harder seeds like palm kernel. The leveling off of oil yield beyond the identified pressure was related to the narrowing and sealing of some inter-kernel voids (consolidation) with pressure application (Adeeko and Ajibola, 1990; Ajibola *et al,* 1990b; Ajibola 1989a).

It was necessary to properly relate the oil expression behaviour to the measurable characteristics of the oilseeds for optimization of oil expression processes. The conventional theory of mechanical expression of oil from oilseeds suggests that oilseed cells must be ruptured by physical (crushing) and thermal (cooking or heating) pretreatment before substantial oil expression can be carried out and that pre-pressing operations designed to break the highest number of cells will lead to high yields (Ward, 1976). More recently, it has been suggested that the pores of the cell walls

might be the channels through which oil flows out of the seed during expression, and that the real function of pre-pressing operations is not to rupture the oil-cells but to make the cell walls become more porous and give a better outlet for the oil (Diekert and Diekert, 1976; Mrema, 1979; Khan and Hanna, 1983).

A theoretical model based on flow through a porous medium was developed and it was concluded that in the oil expression process, oil is initially expressed into the inter-kernel voids which when full result in a build up of pore pressure, leading to the development of pressure gradient which causes oil to flow through the porous medium and is finally expressed through the porous retaining envelope. Furthering this approach to oil expression analysis, the oil point was defined as the point at which a bed of oilseed has been sufficiently compressed such that the oil from the individual cells has moved from the interior to the surface and fill the inter-particle voids (Sukumaran and Singh, 1989). It occurs prior to flow of oil. Application of pressure beyond the oil point leads to expression of oil from the oilseed, the effective pressure for oil expression being the applied pressure less the oil point pressure (Mrema and McNulty, 1985; Sukumaran and Singh 1989; Ajibola *et al* 1999). The oil point pressure which has been shown to be a function of moisture content and rate of deformation, can be used as a measure for evaluating the relative effectiveness of alternative pre-pressing operation since any treatment that lowers oil point pressure will enhance oil expression. A relationship can therefore be developed relating oil point pressure to some physical characteristics of seed and processing conditions.

Analysis of oil expression from oilseeds can therefore be conceptualized by considering three components of the process:

a. Oil flow through the cell wall pore
b. Oil flow in the kernel void
c. Compression of the oil seed cake (Mrema and McNulty, 1985).

Our studies on oilseed processing have adopted this approach. The flow of oil through the cell wall pore is being studied through the analysis of the oil point pressure and its relation to such factors as moisture content, particle size, bed depth, bed deformation, void ratio, heating temperature and duration of heating. The excess pressure above the oil point (effective pressure) has two components. One responsible for compression and the other for oil flow in the outer kernel void. The oil flow in the inter-kernel void is being studied using Darcy's law of fluid through porous media with the oil flow being related to oil viscosity, effective pressure, particle size etc. The compression of the cake is being studied using the compression ratio model (Faborode and O'Callaghan, 1986). The effective pressure is being related to the initial density,

compression ratio, porosity index, and bulk modulus of the oilseed and cake. The three components are being unified into a generalized model to give a complete picture of the oil expression process.

Probably, the most important oil bearing crop in this country is the oil palm fruit and a lot of research efforts have been devoted to the extraction of oil from it. The palm fruit is a drupe with a fleshy outer layer called the mesocarp and a hard core called the nut. The nut comprises the endocarp (shell) which encloses the endosperm (kernel). Two types of oil are obtainable from the palm oil fruit, mesocarp oil (palm oil) and endocarp oil (palm kernel oil). The national productions for 1998 were 792,000 and 191,000 tonnes respectively for palm oil and palm kernel oil (CBN, 1998). Palm oil is used for soup and table fat such as margarine in many countries. It is also used in the manufacture of soap and cosmetics. Palm kernel oil is similar to coconut oil and is used in the manufacture of soaps, toiletries, surface active ingredients (the active constituents of detergent and cleaners), baking coatings, whipped creams and sugar confectionery. The meal obtained after oil extraction from the kernel is also valuable as animal feed. Oil extraction from the palm kernel follows the same process line as other oilseeds, but the extraction of palm oil from freshly harvested palm fruit bunch is different involving basically five operations namely: fruit loosening, sterilization, digestion, oil expression and clarification. These operations are carried out in both small-scale mills and large industrial mills, the difference being in the sequence and equipment used. Figure 3 shows the operational flow diagram for both types of mills.

The process used in the small-scale mills is time consuming, labour intensive and tedious in nature and although short delays and fermentation improve fruit recovery (loosening) from the bunch, they however lead to production of poor quality oil. The extraction process used in the large industrial mills requires equipment that are complicated and too expensive for small-scale operations. There is still also the traditional method of producing palm oil and a substantial proportion of the palm oil obtained in the local market in many communities is produced using the traditional method. The traditional method involves fermentation of the fruit for about five days, manual separation of the fruit from the spikelets by hand picking, cooking of the fruits, pounding/foot mashing of the cooked fruits, aqueous separation of the crude oil in cemented pit or canoe followed by clarification of the oil by cooking. The traditional method is time-consuming, low yielding, labour intensive and results in low quality oil (Ajibola, *et al* 1998). A recent survey of South Western Nigeria undertaken by the author and some others shows that only the digestion and

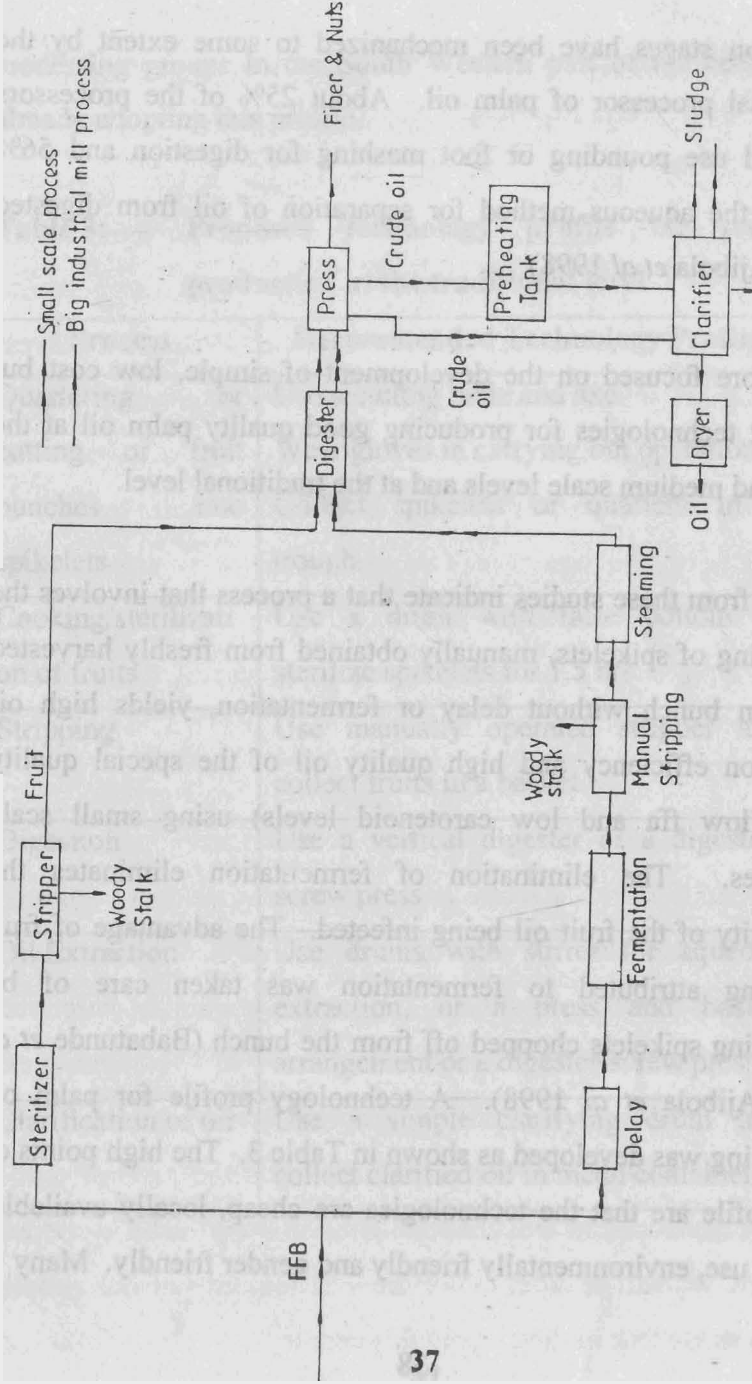

Figure 3 : Flow sheet for palm oil extraction

separation stages have been mechanized to some extent by the traditional processor of palm oil. About 25% of the processors surveyed use pounding or foot mashing for digestion and 56% employ the aqueous method for separation of oil from digested mash (Ajibola *et al* 1998).

I therefore focused on the development of simple, low cost but efficient technologies for producing good quality palm oil at the small and medium scale levels and at the traditional level.

Results from these studies indicate that a process that involves the processing of spikelets, manually obtained from freshly harvested oil palm bunch without delay or fermentation, yields high oil extraction efficiency and high quality oil of the special quality grade (low ffa and low carotenoid levels) using small scale machines. The elimination of fermentation eliminates the possibility of the fruit oil being infected. The advantage of fruit loosening attributed to fermentation was taken care of by processing spikelets chopped off from the bunch (Babatunde *et al* 1988; Ajibola *et al* 1998). A technology profile for palm oil processing was developed as shown in Table 3. The high points of this profile are that the technologies are cheap, locally available, easy to use, environmentally friendly and gender friendly. Many

processing groups in the South Western part of the country are already adopting this profile.

Table 3: Proposed technology profile for palm oil production at the traditional level

Process	Recommended Technology Profile
Quartering or cutting of fruit bunches into spikelets	Use a cutting table and axe. Wear gloves in carrying out operations. Collect spikelets or quarters in a trough.
Cooking/sterilization of fruits	Use a drum with false bottom to sterilize spikelets for 1.5 hrs.
Stripping	Use manually operated stripper and collect fruits in a basket.
Digestion	Use a vertical digester or a digester-screw press
Oil Extraction	Use drums with stirrer for aqueous extraction, or a press and basket arrangement or a digester-screw press.
Clarification of oil	Use a simple clarifying drum and collect clarified oil in metal containers.

Concluding Remarks

Mr. Vice Chancellor sir, I have tried in this lecture to present some of the issues that have engaged my research time in this university. We have come a long way but there is a whole lot more to do. There is need for Nigeria to make more efforts in the development of the agro-industrial sector through the promotion of post-harvest processing of our agricultural products into appropriate agro-industrial raw materials. Most of such processing activities will have to be undertaken at the small- and medium- scale levels. In this way, jobs and wealth will be created, poverty substantially reduced and there will be promotion of industrialization and substantial value will be added to the products of the farmer's labour.

This will require concerted and collaborative efforts of government, the private sector and NGOs using the large army of educated/uneducated as well as skilled/unskilled unemployed labour in this country. It will also require the creation of improved linkages among researchers/developers of technologies, farmers/processors of agricultural materials and operators of the agro-industrial sector. Without these linkages the pace of agro-industrial development will continue to be slow and there is serious doubt that we will be able to get the vast majority of our people involved in the task of developing this country.

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