# FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

# AGRICULTURAL CROP PROCESSING AND STORAGE: A PANACEA TO FOOD SECURITY

*By*

**ENGR. PROF. BOLANLE ADENIKE ADEJUMO**
*B.Eng. (Ilorin), M.Sc., PhD. (Ibadan), MNIAE, MNSE, R. Eng (COREN)*
***Professor of Agricultural Engineering***

INAUGURAL LECTURE SERIES 80

5TH MAY, 2021

ISSN 2550 - 7087

global links communications
+234 805 6074 844, +234 703 6446 818

# FEDERAL UNIVERSITY OF TECHNOLOGY
# MINNA

# AGRICULTURAL CROP PROCESSING AND STORAGE: A PANACEA TO FOOD SECURITY

***By***


**ENGR. PROF. BOLANLE ADENIKE ADEJUMO**
*B.Eng. (Ilorin), M.Sc., PhD. (Ibadan), MNIAE, MNSE, R. Eng (COREN)*
***Professor of Agricultural Engineering***



INAUGURAL LECTURE SERIES 80

**5TH MAY, 2021**

This 80th Inaugural Lecture was delivered under
the Distinguished Chairmanship of:

**Professor Abdullahi Bala,** FSSSN
*Vice-Chancellor*
Federal University of Technology, Minna



ISSN 2550 - 7087

*Published by:*
**University Seminar and Colloquium Committee,**
Federal University of Technology, Minna.

**5th May, 2021**

*Design + Print:*
**Global Links Communications, Nigeria**
*✆: 08056074844, 07036446818*

**Engr. Professor Bolanle Adenike Adejumo**

*B.Eng. (Ilorin), M.Sc., PhD. (Ibadan), MNIAE, MNSE, R. Eng (COREN)*

***Professor of Agricultural Engineering***

# AGRICULTURAL CROP PROCESSING AND STORAGE: A PANACEA TO FOOD SECURITY

## Preamble

All glory and honor be to the Most High God, who can raise the poor out of dust and lift up a beggar from the dunghill to set them among princes, to make them inherit the throne of glory: for the pillars of the earth are the LORD'S and hath set the world upon them (I Samuel 2:7-8). I appreciate the Holy One of Israel who chooses the foolish things of the world to confound the wise; and a weak thing of this world to confound the things that are mighty, and the base things of this world and things which are despised, hath God chosen, yea, and things which are not, to bring to nought things that are: that no flesh should glory in his presence (I Corinthians 1:27-29).

Glory and honor be unto the only wise God! For the rare privilege that He has given me to stand before the high and mighty, erudite scholars, nobles, kings and princes, to deliver this lecture.

This inaugural lecture titled "Agricultural crop processing and storage: A panacea to food security" is the 80$^{th}$ in the Federal University of Technology and 6$^{th}$ from the Department of Agricultural and Bioresources Engineering. This lecture is a summary of my research work which was borne out of my passion to prepare and process food that will make man enjoy the full benefits of nutrients concealed therein by God Almighty.

My research which has spanned over 20 years has been in the area of Agricultural Crop Processing and Storage with a view to address the problem of food security and challenges nationwide. Mr. Vice-Chancellor Sir, in this inaugural lecture, I will discuss my work and research findings including my contributions to research through collaborations and Postgraduate student supervision. I will highlight my contributions to the processing and storage of some agricultural crops, development of processing equipment and storage structures. Permit me Sir, to provide a brief history of the Agricultural Engineering profession and the food security challenges.

## 1.0 Historical Development of Agricultural Engineering Profession

All engineering problems on the farm were initially solved by adapting the knowledge from the field of Architecture, Civil and Mechanical Engineering. The development of Agricultural Engineering started as far back as 1896; O. V. P Stout and C. R. Richard were teachers of Agricultural Engineering at the School of Agriculture, University of Nebraska. In 1906, a three man forum attended by F. R. Crane (University of Illinois), J. B. Davidson (Iowa State College) and C. A. Ocock (University of Wisconsin), was held at the University of Illinois to discuss the teaching techniques and development of instructional materials for the Agricultural Engineering profession. In 1907, at the second meeting held at University of Wisconsin in Madison, the American Society of Agricultural Engineering (ASAE) was formally organized and initiated as a national engineering society. With this development Agricultural Engineering became a distinct profession. Iowa State University was reported to be the first university to award a first degree of Bachelor of Science in Agricultural Engineering in 1910. By 1950, the number institutions awarding degree in Agricultural Engineering had risen to 41 and thereafter it began to spread to other parts of the world (Aboaba, 2000).

## 1.1 Agricultural Engineering Education in Nigeria

The popularity the Agriculturists, Mechanical and Civil Engineers in Nigeria enjoyed in providing engineering services on the farm prompted retraining in Agricultural Engineering. Therefore most of the pioneers Agricultural Engineers in Nigeria were also specialists in other disciplines. Gradually, the relevance of Agricultural Engineering began to be appreciated by government and those engaged in agricultural practice. Local training of Agricultural Engineers in Nigeria began with the teaching of part of the present curriculum in tertiary institutions with degree and certificates awarded in Agricultural Mechanization but not in Agricultural Engineering. In 1963, a Department of Agricultural Engineering was established at the University of Nigeria, Nsukka and in 1967 the Bachelor of Science (B.Sc.) degree in Agricultural Engineering was awarded to two graduates. Other universities took turn to establish the Agricultural Engineering departments. Today, in Nigeria, there are a number of Polytechnics and Colleges of Agriculture offering training in Agricultural Engineering up to the Ordinary National Diploma (OND) and Higher National Diploma (HND). There are also a number of universities in Nigeria offering training leading to the award of B.Eng/B.Sc., M.Sc. and PhD in Agricultural Engineering (Mijinyawa *et al.,* 2000).

## 1.2 Agricultural Engineering Profession

Agricultural Engineering is derived from two words: Agriculture and Engineering. Agriculture is the practice of producing crops and rearing livestock; processing to varied degree of products and marketing of the end products. The Almighty God created man and a catalogue of materials both living and non-living intended to provide comfort for him. This comfort can only be achieved by man only if the relevant materials are identified and harnessed. Engineering has been defined as the practice of employing the materials and forces of nature for the benefits of man. The problems often encountered in agriculture require more than one branch of engineering to solve; hence a combination of more than one of the branches as may be required. Agricultural Engineering has been defined as the application of any or all branches of engineering knowledge to the extent that such knowledge may be used in farming in all its ramifications and in rural living. The Agricultural Engineering profession is sub-divided into five (5) specialisations; each deals with related problems on the farm. These sub-divisions are: Farm Power and Machinery, Soil and Water Conservation, Agricultural Processing and Storage, Farm Structures and Environment and Farm Electrification.

## 2.0 Food Security Challenges

Today, one of the main global challenges is how to ensure food security for a world growing population whilst ensuring long-term sustainable development. According to the FAO, food production will need to grow by 70% to feed world population which will reach 9 billion by 2050 (FAO, 2019). Consequently, there is a need for an integrated and innovative approach to the global effort of ensuring sustainable food production and consumption. Food availability and accessibility can be increased by increasing production, improving distribution, and reducing the losses. Thus, reduction of post-harvest food losses is a critical component of ensuring future global food security. Food and Agriculture Organization of U.N. predicts that about 1.3 billion tons of food are globally wasted or lost per year (UNDP, 2019). Reduction in these losses would increase the amount of food available for human consumption and enhance global food security. A reduction in food loss will also improve food security by increasing the real income for all the consumers.

The number of food insecure population remains unacceptably high worldwide. Massive quantities of food are lost due to spoilage and infestations on the journey to consumers worldwide. In some African countries, where tropical weather and poorly developed infrastructure contribute to the problem, wastage can be as high as 40-50%. Therefore, the ways of strengthening food security is by reducing postharvest and food losses (FAO, 2011).

Postharvest loss can be defined as the degradation in both quantity and quality of food production from harvest to consumption.

Food losses refer to the decrease in edible food mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption. Food losses takes place at production, postharvest and processing stages in the food supply chain. Food losses are mainly due to poor infrastructure and logistics, lack of technology, insufficient skills, knowledge and management capacity of supply chain actors, and lack of access to markets. Food losses can be quantitative or qualitative. Quantitative food loss can be defined as reduction in weight of edible grain or food available for human consumption which can be as a result of spillage, consumption by pest, physical changes in temperature, moisture content and chemical changes. Qualitative loss refers to the reduction in nutritive value and unwanted changes to taste, color, texture, or cosmetic features of food.

Given that many smallholder farmers in developing countries live on the margins of food insecurity, a reduction in food losses could have an immediate and significant impact on their livelihoods. Agricultural processing and storage of crops have been recognised as the major factors in the solution of food problems.

## 3.0 Agricultural Crop Processing and Storage

Agricultural crop processing and storage will be considered in two (2) parts; these are:

1. Agricultural Processing
2. Storage of Agricultural Products

Agricultural processing is defined as an activity which is performed to maintain or improve the quality or change the form or characteristics of agricultural products. Processing operations are undertaken to add value to agricultural materials. The main purpose of agricultural processing is to minimize the qualitative and quantitative deterioration of agricultural materials after harvest. The aim of processing is to handle and manipulate products so that it will yield the highest possible net returns after being processed. Agricultural processing consists of a series of unit operations. The sequence of processing maybe classified as: cleaning, sorting and grading, drying and dehydration, cooling, milling, material handling and packaging. The essence of processing irrespective of the method adopted is to ensure preservation of surplus harvest and to provide insurance against unfavorable changes in nutritive, utility or market value of produce.

Storage is an interim and repeated phase during transit of agricultural products from producers to processor and its products from processors to consumers. The production of agricultural commodities is seasonal and storage is necessary to ensure availability throughout the year and to provide the products in the best possible conditions. Storage must solve certain problems of deterioration and loss such as:

1. Arresting microbiological activities and slowing down respiration of agricultural crops.
2. Controlling chemical processes and moisture depending on the nature of crops.
5. Prevention of insect damage.

However, some crops can be stored as harvested without the need for further processes, but a vast majority requires further processing to make it more stable during storage.

## 4.0 My Contributions to Research in Agricultural Crop Processing and Storage

Mr. Vice-Chancellor Sir, the processing and storage of agricultural crops have been from time immemorial depending on the characteristics of the crops with varying degree of successes. Agricultural produce may be classified into three categories:

1. Cereals and legumes (grain) - rice, wheat, sorghum, maize, soybean, cowpea.
2. Roots and tubers - cassava, yam, potatoes, and
3. Fruits and vegetables - Tomatoes, mangoes, lettuce, green, spinach.

I will take time to talk about our work in the area of crop processing and storage, extraction of oil from underutilised seeds, development of storage structures and processing equipment.

### 4.1 Processing and Storage of Cereal Crops

Cereal grains are the fruit of plants belonging to the grass family (Gramineae). Cereal grains includes rice, wheat, corn, barley, and oats, it provides the world with majority of its food calories and micronutrients. Cereals are staples consumed in large quantities by majority of population in the world either directly or in modified form. Cereals are easy to store due to its low moisture content.

#### 4.1.1 Rice Processing

Rice importation in Nigeria increased in 2010, to over 2 million tonnes from Thailand and over 73,000 tonnes of rice from the United States with a total estimated value of over US$ 1 billion. The annual import bill on rice importation has however tremendously increased to over N356 billion, translating to about N1 billion per day. With the closure of Nigeria's border, rice importation from both legal and illegal means stopped or drastically reduced, hence there is more focus on the processing of rice paddy locally. Locally processed rice is generally significantly inconsistent in all its physical characteristics. It is usually brown in colour with various admixtures (stones, foreign matters) in a single bag. The major limitation to producing clean and export quality milled rice is the lack of adequate post-harvest paddy handling capacities of farmers, processors and millers in Nigeria (Ogunbiyi, 2011). Parboiling, which is one of the major post-harvest handling processes of rice is the hydrothermal treatment of paddy prior to milling which determines the final qualities of rice. Parboiling of rice paddy is an essential activity of rice processing in Nigeria and it is still mostly carried out using traditional methods. The use of the traditional method of rice parboiling comes with a number of challenges which negatively affect the efficiency of the operation, milling quality and yield of the parboiled paddy.

In order to solve the problems associated with the use of traditional paddy parboiling, we developed a 5kg per batch capacity mini rice paddy parboiler to improve the efficiency of the parboiling operation (Ogunbiyi et al., 2017). The fabricated parboiling equipment (Plate I) consists of a soaking/steaming chamber measuring 30cm x 30cm x 26cm and a heat generation chamber or furnace measuring 30cm x 30cm x 40cm. The equipment was designed to use a variety of heat sources (either a movable 5kg capacity gas cylinder with burner, a raised bed charcoal pot, a kerosene stove or an electric hot plate). The soaking/steaming chamber has a false bottom made of perforated mild steel plate and contains a movable perforated paddy basket which holds the paddy for soaking and steaming. The chamber is fitted with 2 drain valves to regulate the quantity of water during the parboiling process. A lid is provided at the top of the steaming chamber to conserve the steam and enhance adequate circulation of the steam generated.


a. The mini parboiler with the gas burner option

b. Paddy holding baskets

**Plate I:** The fabricated improved parboiling equipment

This design prevents the paddy from getting in contact with the boiling water and prevents overcooking of the paddy. Uniform steaming results to uniform gelatinization, uniform drying and efficient milling thus reduced cracking and breakage of the rice kernels. The equipment enables soaking and steaming to be performed in the same chamber providing for convenience and uniformity in product quality in the same parboiling batch. The removable paddy holding basket in the steaming chamber provides for easy and safe discharge of the parboiled paddy. A corresponding effect of this is that less fuel is utilized to achieve the desired parboiled state of the paddy making the equipment very economical to operate. Periodic inspection of the paddy during parboiling is made easy by the provision of a relatively airtight lid which can easily be opened and closed.

We carried out a comparative study of the effects of traditional parboiling method and developed mini parboiler on the physical and chemical properties of three commonly grown rice varieties in Nigeria (Ogunbiyi *et al*., 2019). The physical and chemical qualities of the parboiled milled rice were determined using standard methods. The results showed that the traditional method of rice parboiling produced milled rice with lower head rice yield and higher percentage of broken rice. The milled parboiled rice using the developed mini parboiler had higher head rice yield (69.1%) pasting temperature (94.7$^{o}$C) , amylose content (32.4%), alkaline spreading value (6), oil extract (1.05%) as well as lower broken rice (1.1%) and moisture content (11.8%). The use of traditional method of rice parboiling was therefore discouraged for the processing of rice.

We also carried out optimisation of parboiling parameters with the view to establish appropriate set of parameters for good quality rice production by small scale processor (Ogunbiyi *et al*., 2019a, Ogunbiyi *et al*., 2019b). The parboiling parameters are initial water soaking temperature (ITS), soaking time (ST) and final moisture content (FMC), the three (3) improved rice varieties are FARO 44, FARO 52 and FARO 60. Results showed that the optimised parboiling parameters increased the head rice yield, grain hardness and decreased the broken rice ratio for all the varieties. The optimum initial soaking temperature (IST) of 70.3°C, 10 hours, 24 minutes soaking time (ST) and 15% final moisture content (FMC) was for desirable physical qualities of FARO 44, 67.7°C IST; 13 hours, 18 minutes ST and 12.7% MC for FARO 52 while 76°C IST, 6 hours, 54 minutes ST and 15.2% MC was for FARO 60. The minimum cooking time for the three rice varieties is 15 minutes. The optimised conditions obtained from this study are recommended for improved physical and cooking qualities to increase productivity and profitability of paddy processing.

### 4.1.2 Wheat

Wheat flour is an excellent source of complex carbohydrate which is also used for the production of all sorts of pastries and confectionaries. Locally produced wheat flour in Nigeria has been in recent times reconstituted into dough and eaten with soup to replace the popular Amala (yam flour dough) due to its numerous nutritional and health benefits. The effect of selected packaging materials and storage duration on some proximate and physical properties of locally produced and packaged wheat flour in storage was investigated (Adejumo, 2013a). Milled wheat was packaged in hessian bag, polyethylene bag, and covered plastic container; with unpackaged samples as control. All the samples were stored on a shelf at the normal room temperature (27 – 35°C) with the proximate and physical properties determined monthly for 3 months. The results showed that the wheat flour had an initial 9.2% moisture content, 11.5% crude protein, 1.8% fat, 1.4% ash, 2.2% crude fiber, 73.6% carbohydrate, 0.36 glcc loose bulk density, 0.58 glcc packed bulk density, 5.8 pH, 1.3% swelling capacity, 145% water absorption capacity and 6.0% least gelatin concentration. Statistical analysis showed that packaging types and storage duration has significant effects ($p < 0.05$) on the moisture content, swelling capacity, water absorption capacity and pH. The packaging types and the storage duration however does not have significant effects on the crude protein, fat, ash, crude fiber, carbohydrate and least gelatin concentration of locally produced wheat flour stored for three months. It was recommended that wheat flour be packaged in airtight and moisture proof bag especially in areas of high humidity to prevent mold growth and maintain it qualities when stored at room temperature.

## 4.2 Processing of Underutilised Seeds

Underutilised crops have the potentials to play a number of roles in the improvement of food security, these include reduction in the risk of over-reliance on major crops as well as contribution to food quality and dietary diversity. There are a number of indigenous legumes and cereals that are very nutritious which have remained underutilised due to the high anti-nutritional constituents. The processes of removal or reduction of these anti-nutritional constituents are usually time consuming, tedious and often times not economical. These indigenous grains include African breadfruits seeds, finger millets, African Yam beans seeds, among others. The utilisation of these indigenous crops will further enhance the nutritional status of the low income earners. We processed some of these underutilized crops with a view to reduce the anti-nutritional qualities and improve its nutritional qualities.

#### 4.2.1 African Breadfruit (*Treculia africana*) Seed

African breadfruit (*Treculia africana*) locally referred to as *Ukwa* in *Igbo* language; it is one of the many treasured economical plants that are still underutilised. The extracted seeds of *T. africana* are identified to be nutritious when it is adequately processed to remove the anti-nutrients. The seeds are roasted and used as thickeners in soups; it is also eaten as snacks. The seed is a rich protein source (25-35%) which is comparable to most pulses and a good source of vegetable oil 15 – 20%. The oil yield of the seed compares well with that of cotton seeds, palm kernel and sunflower seeds. The fat and oil content of the seed makes it probable industrial raw materials in producing pharmaceutical drugs, vegetable-oils, soaps, paints and perfumes. The knowledge of the appropriate set of processing parameter will enhance the use of African breadfruit seed as a cheap source of protein. The effects of thermal processing methods and duration on some nutritional and anti-nutritional composition of African breadfruit seed (*Treculia africana*) flour was investigated (Nwaigwe and Adejumo, 2015). Matured African breadfruit seeds were sorted, washed, drained and dried. With the initial nutritional and anti-nutritional compositions determined, the samples were divided into three portions and were boiled, roasted and autoclaved respectively. The samples were dehulled, dried and milled to obtain a full fat dehulled breadfruit seed flour. The flours were analyzed for nutritional and anti-nutritional composition using standard methods. The results showed that the raw sample contained 3.33% moisture, 4.33% ash, 15.67% crude fat, 4.64% crude fibre, 25.62% crude protein and 43.49% carbohydrate (CHO). It also contains 1.49mg/100g Hydrogen cyanide (HCN), 1.30TUI/mg, Trypsin inhibitors 32.03mg/100g Tannin, 2.07mg/100g Phytate 4.00% Alkaloids and 3.24mg/100g Oxalate. Boiling and autoclaving yield a better fat and CHO content, with boiling for 90mins having the highest fat content of 18.50%. Increase in thermal processing duration also resulted in a significant decrease in anti-nutritional composition of the flour irrespective of the thermal processing methods.

### 4.2.2 Finger Millet (*Eleusine coracana* L. Gaertn)

Finger millet (*Eluesine Corocana*) also known as *tamba* is classified under the category of minor millet with superior nutritional quality and antioxidant activity even though it is not popularly known (Renu and Sarita, 2015). Its superior nutritional quality can be attributed to the high amount of calcium which is an essential micro- nutrient for infants, growing children, pregnant mothers and the elderly. Finger millet flour proteins do not form gluten making it useful to dilute wheat flour to form dough in baked products such as cookies. Incorporation of finger millet flour in conventionally used refined flour can improve the nutritional quality of baked products. Functional properties determine the baking properties of flour.

We therefore investigated the effects of different thermal processing methods on the functional properties of finger millet flour (Okolo and Adejumo, 2018). Finger millet sample was manually cleaned to remove foreign material. Samples were thermally processed by roasting, steaming, and boiling respectively at three different time intervals. The roasted sample at 140°C was at duration range of 5 to 15minutes and cooled before milling. The sample steamed at 100°C for 20 to 40minutes was dried in an air oven and milled to flour. The boiled sample at 100°C for 20 to 40minutes was dried in an air oven and milled into flour. The functional properties of the sample were evaluated using standard methods. Flour processed by roasting finger millet at 140°C had bulk density (BD) ranging from 0.65 - 0.78, water absorption capacity (WAC) ranging from 1.23 - 1.29 and oil absorption capacity (OAC) ranging from 1.09 - 1.13. Flour processed by steaming finger millet at 100°C had BD ranging from 0.62 - 0.80, WAC ranging from 1.26 - 1.38 and OAC ranging 1.13 - 1.35. Flour processed from boiled finger millet at 100°C had bulk density ranging from 0.59 - 0.76, WAC ranging from 1.25 - 1.35 and OAC ranging from 1.09 - 1.15. It was concluded that thermal processing of finger millet prior to processing into flour will enhance its utilisation for food formulation and suitability for dough making.

### 4.3 Root and Tuber Crops Processing and Storage

Roots and tuber crops are highly perishable; the commonly grown types in Nigeria include yam, cassava and sweet potato. Due to the perishable nature and the difficulty of its storability especially at the village level processing to a more stable form is therefore necessary.

#### 4.3.1 Cassava

Cassava is a tropical root crop primarily grown for its starch containing tuberous roots which serves as a major source of dietary energy for more than 500 million people in the tropics. In Africa, cassava is important not just as a subsistence or food security crop but also serves as a major source of income for producing household. Cassava does not store well and deteriorates after one or two days especially where the tubers are bruised, therefore, little storage is done. Cassava tubers are processed into *gari*, *fufu*, starch, but in West Africa and especially in Nigeria, cassava is consumed mainly in form of *gari*.

## Cassava Processing to *Gari*

Processing cassava into *gari* is an arduous, time-consuming, labor-intensive and monotonous job traditionally undertaken by women. Associated losses may reach up to 42 % of root output. Peeling is done manually because cassava is bulky and irregular in shape with various peel thickness; washing also is done manually for convenience and to reduce cost. Depending on the varieties of cultivars, time of harvesting, age of plant and other environmental factors, the theoretical *gari's* yield per kg of fresh Cassava varies from 18 % to 36 % for 17 tested cultivars (FAO, 2004).

We investigated the losses at the various stages of *gari* production process with a view to suggest ways of reducing these losses (Ola and Adejumo, 2009). The results showed that cassava roots used consist of 15 % peels and 85 % pulp (peel: pulp; 3:17) and losses were observed at the different stages of *gari* production. Losses at the peeling stage ranged between 13.06 % and 21.16 % while at the dewatering stage it ranged between 6.03 % and 13.4 %. The theoretical *gari* yield from the fresh cassava tubers was calculated to be 36.0 % while the actual *gari* yield ranged between 21.5 % and 24.3 %. This is dependent on the expertise of the processor and sharpness of the knives in peeling; uniform stirring during roasting to prevent spilling, burnt crumbs and oversize *gari* grains since all these lead to increase in losses. It was concluded that in order to reduce losses at the various stages of *gari* production, each step of the process should be mechanized, such as the development of cassava peelers, modified graters and fryers.

The fermentation of the grated cassava pulp in *gari* production affects the taste by the production of lactic acid, as well as reducing the content of free hydrogen cyanide, thus imparting an acidic taste in the final product. The extent of the acidic taste imparted on the final product depends on the method and fermentation period used. Anaerobic fermentation takes place in grated cassava mesh in the processing of fresh cassava tubers into *gari*. The optimum temperature for fermentation in *gari* processing is between 35 to 45°C. Fermentation enhances the nutrient content of foods through the biosynthesis of vitamins, essential amino acids, protein quality and anti-nutritional factors.

We evaluated the effect of fermentation period on the physicochemical and microbial qualities of *gari* with a view to produce high quality *gari* (Adejumo and Ola, 2011). Fresh cassava roots, *Okoyawo* variety (MS6) were processed at three (3) days interval for 21 days and allowed to ferment for different periods ranging from 0 – 21days, before *garification*. The *gari* samples produced were analyzed for physicochemical and microbial compositions. The protein content of *gari* increased from 1.68 to 1.95% on the $6^{th}$ day of fermentation and thereafter it decreases. This indicates that the optimum fermentation period for the enhancement of protein content in *gari* is about 6 days. The crude fiber and the carbohydrate contents decreased with increase in fermentation period. Statistical analysis showed that the duration of the fermentation significantly affects ($p \leq 0.05$) the bulk density, swelling capacity, water absorption capacity and color except for density. The total viable count (TVC), total *coliform* count (TCC), total fungi count (TFC) was significantly influenced ($p \leq 0.05$) by fermentation period. A fermentation period of 6 days is therefore suggested since the quality obtained is not significantly different from the recommended standard for *gari* qualities.

## *Gari* Packaging and Storage

*Gari* produced in Nigeria are usually packaged and stored in hessian bags. The products are sold from open containers, polyethylene sheets or mats using small measures. It has been recognised that certain bottlenecks exist particularly in the packaging of products emanating from cassava roots. In line with this, the solution to the problem of packaging had been suggested to be polyethylene bag, however little success has been recorded in the use of polyethylene bags in the storage of *gari* due to the high water activity of the product during storage. Polyethylene is widely used as a packaging material because of its good mechanical properties and low cost. However, these qualities have been overshadowed by its high non-biodegradable nature, leading to waste disposal problems, particularly in short-term packaging applications (Sailaja and Chanda, 2001).

We carried out an appraisal of *gari* packaging and sale in *Ogbomoso*, Nigeria with a view to suggest safe, appropriate and affordable packaging materials for *gari* packaging and storage (Adejumo and Raji 2010). The study was carried out by administering structured questionnaire combined with personal interviews with producers and marketers. A total of 50 respondents consisting of 35 marketers and 15 producers were interviewed. The results showed that the packaging materials used for *gari* packaging are all improvised material not specifically made for *gari* packaging. Ninety-six percent (96%) of the respondents uses hessian bags, 1% polyethylene bags while 2% combine hessian and polyethylene bags for the packaging of *gari*. Ninety percent (90%) of the respondent stored *gari* for between 1-6 months, 8% for 6-12 months while 2% stored for above 12 months in hessian bags. The percentage loss of *gari* during storage ranges between 3-10% for the packaging methods assessed which is a function of the type of storage materials used, storage conditions, storage duration and the quality of the *gari* before storage. The losses were in terms of change in colour, odour and taste. Ninety-five percent (95%) of the respondent retail *gari* from open containers, 4% from mats and 1% in 50kg bags usually wholesalers. It was observed that the problem of poor keeping quality of many dehydrated foods such as *gari* in the tropics is related to moisture uptake during merchandising. The use of plastic packaging bags cannot be overemphasised.

The effect of initial moisture content on some selected proximate quality attributes of *gari* packaged in polyethylene and hessian bags was investigated (Adejumo, 2012a). The initial proximate properties of the *gari* samples fried to initial moisture content (%) of 17.1, 13.1 and 8.6 were determined within 24hrs of production. Fifty grams (50g) each of *gari* samples were packaged in the polyethylene and hessian bags. The samples were stored on a shelf at tropical ambient temperature which represents the common storage environment for sale of *gari*. The results showed that the initial moisture content and packaging materials had significant effects ($p < 0.05$) on the moisture and carbohydrate contents but had no significant effect on the protein and fat contents of *gari* in storage. The fluctuations in the moisture and carbohydrate content of *gari* at the various initial moisture contents and package materials types will influence some other factors of deterioration which could result in contamination. It was therefore recommend that *gari* should be packaged in moisture proof materials such as polyethylene at a moisture content range of between 8.6 to 13.1 %.

**Shelf Stability of *Gari* in Selected Packaging Materials**

The hygroscopic nature of *gari* stored in humid tropical countries makes it susceptible to deterioration. Shelf-life of stored packaged *gari* largely depends on temperature, relative humidity and moisture content. The quality of packaged *gari* as affected by permeability of selected packaging materials on its shelf-life was investigated (Adejumo, 2010a). Initial physicochemical and microbial properties of freshly produced *gari* were determined and then packaged in polyester, polypropylene and hessian bags with unpackaged samples as control. Samples were stored for six months spanning dry and wet seasons under temperature and relative humidity of 16.0 - 34.5$^{o}$C and 48.6 - 80.5% representing the commonly used storage conditions. The experiment was conducted using a randomized block design of three packaging materials, three storage conditions at three replications. The physicochemical properties, microbial load and sensory qualities of packaged *gari* as well as the mechanical properties of the packaging materials were determined on monthly basis using standard methods.

The results showed that the moisture content of *gari* packaged in polyester, polypropylene and hessian bags increased from 4.5 to 5.8, 5.5 and 13.7% respectively (Figure 1). The highest changes in crude fibre (1.9 - 1.18%), bulk density (2.8 - 2.4g/cm$^{3}$), water absorption capacity (3.9 - 5.1%) were observed in sample in polypropylene bags while fat (0.9 - 1.0%), pH (5.5 - 6.4), carbohydrate (90.9 - 81.5%) and swelling capacity (29.7 - 38.8%) were in hessian bags (Adejumo, 2010b, Adejumo and Raji, 2011). Total viable fungi and bacteria counts increased from zero count to 56, 49, 95 and 10, 15, 30 x 10$^{4}$cfg-$^{1}$ in polyester, polypropylene and hessian bags respectively (Figure 2) (Adejumo and Raji, 2012). Sensory score of *gari* in polyester films ranked highest but lowest in hessian bag for taste, aroma and crispness. *Gari* qualities were within acceptable values in polyester and polypropylene after six months but one month in hessian. Comparative tensile strength (N/mm) and percentage elongation (%) for polyester decreased from 0.98 to 0.36 and 57.0 to 9.0 (Figure 3); polypropylene 3.19 to 0.37 and 17.0 to 8.0 and hessian 3.68 to 0.35N/mm and 14.0 to 11.0% respectively. Comparative tensile strength of polypropylene and hessian bags was lower than their threshold values of 1.49 and 1.2N/mm, hence not suitable for long term storage (Adejumo, 2013b). Predictive models for moisture stability, physicochemical properties, microbial load and estimated shelf-life gave $R^2$ value greater than 0.94 for all samples. Polyester bags retained the quality of packaged *gari* and as well its own mechanical strength hence a suitable packaging material for storage. Hessian bag is discouraged for storage in this study area.

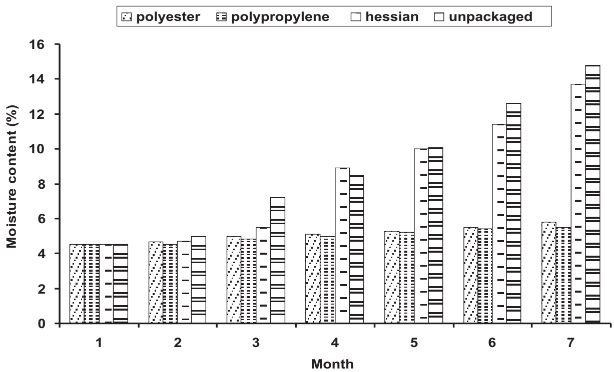



**Figure 1:** The effect of packaging materials on the moisture content of packaged *gari*

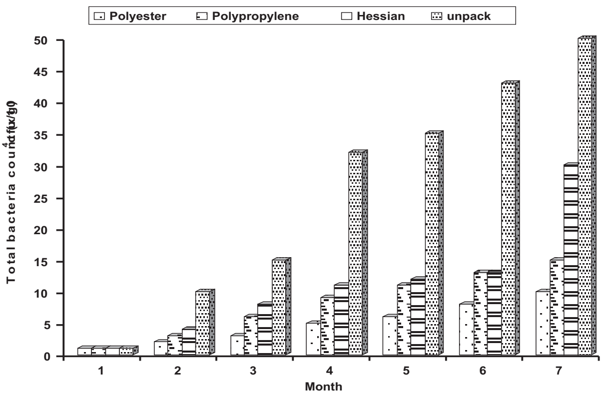



**Figure 2:** The effect of packaging materials on the total viable bacterial count of packaged *gari*

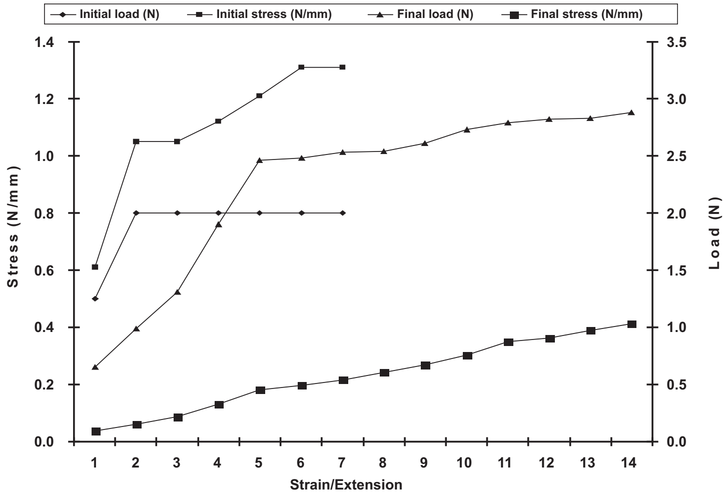



**Figure 3:** The mechanical properties of polyester bag

## *Gari* Storage in Specialised Warehouse

The Federal government of Nigeria introduced *gari* storage into its strategic grain reserve (SGR) stock in 2003. This is with a view to absorb the glut of *gari* in the market and ensure competitive price for cassava farmer as well as *gari* processor thereby guaranteeing return on investment. *Gari* are procured from accredited government processors under the Licensed Buying Agents (LBA) and stored in strategic grain reserve specialised warehouse across Nigeria. We therefore evaluated the nutritional qualities of *gari* properly packaged in double layer polypropylene bags stacked in layers on pallets in the specialized warehouse of the strategic grain reserve (SGR) silo complex Minna (Haruna *et al.*, 2015). This is with the view to ensure safety and general acceptability of *gari* released from the specialised warehouse. The nutritional qualities were determined on monthly basis at three replicates for twelve months. A randomized block design of 7 (Quality attributes) x 12 (Storage duration) x 3 (replicates) making a total of 252 samples used for the experiment. The results showed that the sample had initial 11.04 % moisture content, 0.84% crude protein, 1.93% crude fat, 1.00% crude fibre, 1.99% crude ash, 75.12% carbohydrate content, 1.32mg/g hydrogen cyanide content, 4.80 pH and 88.96% total solid content. The storage of *gari* in the specialised warehouse did not significantly affect ($p > 0.05$) moisture, crude fat, carbohydrate, and total solid contents after 12 months of storage. The quality attributes of the *gari* samples after 12 months of storage were still within the FAO/WHO and SON recommended standard for *gari*, hence fit for human consumption. It is therefore concluded that packaging of *gari* in double layer polypropylene bags stacked on pallets in specialised warehouse of SGR silo complex Minna is effective for *gari* storage and protection against deterioration.

### 4.3.2 Sweet Potato Processing

Sweet potato (*Ipomea batatas* L. Lam) is a major food and industrial root crop in Nigeria with an estimated annual production of 2.52 million tons. Sweet potato has a high nutritional value – about 50% higher than the Irish potato (Marczak *et al.,* 2014) and it plays an important role in the diet of the world's population. The tubers contain carbohydrates (starches and simple sugars), protein, fat, dietary fibre, calcium, iron, sodium, potassium, Vitamin A, Vitamin C and the cultivars with yellow flesh also contain significant amounts of carotenes. Sweet potato is a highly perishable crop and difficult to store for extended period of time. This is mainly due to its high moisture content, metabolic activity following harvesting and thin, permeable skin. In the tropics fresh sweet potato roots are commonly boiled, fried or roasted and eaten as a carbohydrate constituent of diet. The most common method of cooking sweet potato before consumption includes boiling (either with the peel or without peel), roasting, frying and baking. Cooking has been reported to be beneficial or detrimental to the nutritional content of food. Cooking helps to improve the microbiological and organoleptic qualities of food, increase digestibility and nutrient bioavailability, destroy toxins and anti-nutritional factor of food.

A study was therefore undertaken to determine the effects of cooking methods on some proximate properties of sweet potato (*Ipomoea batatas* L) (Adepoju and Adejumo, 2015). The cooking methods are boiled peeled, boiled unpeeled and roasted unpeeled respectively. The properties determined for the samples are moisture content, ash, fibre, protein, fat, carbohydrate, vitamins A and C. Data collected were analysed statistically to determine the effect of cooking methods on the properties of sweet potatoes. The results showed that cooking methods used has no significant effects ($p > 0.05$) on the moisture, ash and crude fibre contents of cooked sweet potato. Cooking generally increased the protein content but decreased the vitamin C and β-carotene content. Cooking of sweet potatoes unpeeled has the highest protein and carbohydrate content, hence recommended for cooking sweet potatoes.

Orange flesh sweet potato (OFSP) (*Ipomoea batatas (L*) is a variety of sweet potato characterised by its orange or yellow coloured tubers. It is rich in vitamin A and beta carotene (a carotenoid plant pigment responsible for the yellow colouration). It is an important staple for the poor and less privileged considering its relative ease of cultivation, and poor utilisation and numerous health benefits, for children and pregnant women. The orange flesh sweet potato (OFSP) may contain up to 4,000 μ/mg fresh weight basis of beta carotene. Orange flesh sweet potato tubers can be processed into flour which is less bulky and more stable than the highly perishable fresh root thereby reducing losses. The Orange flesh sweet potato flour can be used as thickener in soup, bakery products and as substitute for cereal flours.

We evaluated some nutritional properties of flour from orange flesh sweet potato produced at different drying temperatures (Haruna *et al*., 2018). The fresh unpeeled orange flesh sweet potato tubers were washed thoroughly, drained, peeled and sliced into 0.5 mm slice thickness. The samples were dried in hot air oven set at temperature range of 40°C to 60°C respectively. The cooled dried slices were crushed, milled and sieved using a 75μm (micron meter). The nutritional properties of the flour were determined using standard methods. The results showed that drying decreased the moisture, fat, crude fiber, protein, vitamin C and beta carotene contents of fresh orange flesh sweet potato tubers while drying increased the ash and carbohydrate contents irrespective of the drying temperature. The drying temperature of 45°C was recommended for drying fresh orange flesh sweet potato tuber to obtain high quality flour in terms of lower moisture content of 4.9% and higher protein of 3.51%, vitamin C of 10.1 mg/100g and beta carotene of 289.8 mg/100g.

### 4.3.3 Yam Processing

Yam belongs to the family *Dioscorea spp* that is grown widely in many parts of the world. Yam is high in moisture, dry matter, starch, dietary fiber, vitamins C and $B_6$, but low in saturated fat, sodium and vitamin A contents. Yam as a source of carbohydrate has a lower glycaemic index which makes it a sustainable source of energy and gives better protection against obesity and diabetes. Fresh yams are difficult to store and are subject to post harvest losses during storage. In the absence of good storage facilities, yam tubers are prone to gradual physiological deterioration after harvesting, hence the need to process to a more stable form.

We investigated the effect of blanching water temperature and soaking time on some quality attributes of yam flour (Adejumo *et al*., 2013a). Fresh yam tubers (*Dioscorea rotundata*) without rot and decay was selected, peeled, cut into cubes of 25mm $\pm$ 2mm thickness, blanched, soaked, dewatered and oven dried. The dried samples were milled, sieved and packaged for analysis. The experiment was carried out at three blanching temperatures (40, 50 and 60°C) and three soaking time (12, 24, 48 hours). The unblanched and unsoaked samples were used as control. The physical and proximate qualities of yam flour samples were determined using standard methods. The result showed that the blanching water temperature and soaking time had significant effects ($p \leq 0.05$) on the moisture content, protein, carbohydrate, loose bulk density, packed bulk density, swelling capacity, foaming capacity and water absorption capacity of yam flour. However these processing parameters had no significant effects ($p \geq 0.05$) on the fat and ash contents of yam flour. It is therefore recommended that yam should be blanched at 40°C water temperature and soaked for 12h prior to drying for high quality yam flour production.

### 4.4 Processing and Storages of Fruit and Vegetable Crops

Fruits and vegetables are important sources of carbohydrates, proteins, organic acid, vitamins and minerals for human nutrition (Irtwange, 2005). Fruits and vegetables include tomatoes, pepper, lettuce, spinach, okra etc. Postharvest losses in fresh fruits and vegetables may occur anywhere from the point of harvest to the point of consumption. It has been observed that postharvest losses of fruits and vegetables can be as high as 30% (Tunde-Akintunde, 2008). Handling and preservation of vegetables is a unique problem, which causes excess losses during the postharvest life span on account of its fragile texture and high moisture content, which are responsible for rapid deterioration. The methods of preservation of fruits and vegetables include drying, pickling, blanching, freezing, freeze drying and refrigeration.

#### 4.4.1 Tomato

Tomato (*Lycopersion esculentum*) is one of the most popular and widely consumed vegetables grown worldwide with an annual production of more than 120 million tons in the world. Tomatoes are very high in nutrients, but highly perishable once harvested with about 60% lost annually in Nigeria. Sun drying is one of the most common methods of tomato preservation in Nigeria resulting in an unattractive dried tomato chips. The effects of pre-treatment and drying methods on the nutritional qualities of fresh tomatoes were evaluated with a view to preventing the high loss in quantitative and qualitative values (Adejumo, 2012b, c). The sun and oven drying methods were used while 1% metasulphite was used as pre-treatment. Results showed that drying and pretreatment had no significant effects ($p > 0.05$) on the total sugar, riboflavin content of tomatoes. The method of drying used and pretreatment resulted in significant increases in the ash, crude fiber mineral, ascorbic acid, thiamin, niacin, β.Carotene contents. The sundried tomato had the highest increase in mineral and vitamin contents. It was therefore concluded that sun drying method without the use of pretreatment should be used for tomato drying in terms of retained nutritional qualities. The use of solar dryers was suggested for the drying of tomatoes to enhance prompt drying and prevent contamination from dirt, dust and development of microorganisms.

### 4.4.2 Processing and Storage of *Moringa Oleifera* Leaves

*Moringa oleifera* has been reported to be highly utilised in the tropics and sub-tropics for numerous purposes. As a source of nutrient, *moringa oleifera* leaves probably rank as the best of all tropical vegetables. The leaves possess remarkable nutrients such as vitamin C, vitamin A, calcium, potassium, proteins, and medicinal qualities. Spoilage of fresh vegetables usually occurs during processing, transportation and storage. The need for preservation of fresh *moringa oleifera* leaves is very essential due to its medicinal and therapeutic properties. The *moringa oleifera* leaves contains a very high level of nutrients, some of which may be lost during drying. The effect of drying on some nutrients of *moringa oliefera* leaves was therefore evaluated to determine the most suitable drying method for the production of *moringa oleifera* leaves powder (Adejumo, 2014). Fresh *moringa oleifera* leaves were harvested, defoliated, washed and drained. With the initial mineral and vitamin contents of the leaves determined, 120 g each was then sundried and dried at ambient conditions. The dried samples were milled and the mineral and vitamin contents determined using standard methods. The results showed that the samples dried at the ambient conditions had higher contents of phosphorus, potassium, magnesium and vitamin A. Drying however has no significant effects ($p > 0.05$) on the zinc and copper contents of *moringa oleifera* leaves. It was therefore recommended that *moringa oleifera* leaves should be dried at ambient conditions due to the higher retention of some essential minerals and vitamins content of the dried samples.

We investigated the effect of packaging materials and storage duration on the nutritional and microbiological composition of *moringa olierfera* leaves powder with a view to ensure its quality retention (Adejumo and Dan, 2018, Adejumo *et al*., 2018). Fresh *moringa oleifera* leaves were defoliated, washed in saline water, rinse in sterile water, drained, dried at ambient room conditions, milled and sieved. With the initial nutritional and microbiological properties of the *moringa oleifera* powder determined, the samples were packaged in a sterile glass jar, plastic jar and polyethylene bag and stored at ambient room conditions. The packaged samples were analysed monthly for nutritional and microbiological properties for five months at three replicates respectively using a randomized block design. The samples were also evaluated for antibacterial activities against six pathogenic bacteria using Agar diffusion method and measuring the diameter of zones of inhibition formed.

The results showed that there are no significant differences ($P \geq$

0.05) in moisture content, crude protein and sodium of all the package samples. Sample packaged in glass jar had the highest carbohydrate (43.53%), vitamin E (11.08 mg/g) and zinc (9.41) while the sample packaged in polyethylene bags had the lowest carbohydrate content (42.05%), ash content (10.30%) and zinc content (8.16mg/g). The moisture, crude fibre and carbohydrate content of the samples in each of the packaging materials were observed to decrease with increase in storage duration. *Moringa oleifera* leaves powder stored in glass and plastic jar had significantly higher crude fat (3.35 - 4.81%), crude protein (25.34 - 28.81 %) and ash (10.93 - 11.28 %) as storage duration increased.

The results also showed that there was no growth of bacteria and fungi on the packaged samples as well as the control sample throughout the storage period of five (5) months. The *moringa oleifera* leaves powder extract inhibited the growth of *Pseudomonas aeruginosa* (16mm), *Shigella dysentria* (24mm), *Klebsiella pneumoniae* (26mm), *Salmonella typhi* (41mm), *Staphylococcus aureus* (nil) and *Bacillus subtilis* (nil). It was concluded that *moringa oleifera* leaves powder extract has some antibacterial properties and will be nutritionally and microbiologically safe for consumption after Five (5) months of storage.

### 4.4.3 Processing and Storage of Fluted Pumpkin Leaves

Fluted pumpkin (*Telfairia occidentalis*) which belongs to the family *Cucurbitaceae*, is a tropical vine grown mainly for its leaves. These leaves constitute an important component of the diet of many people in the West Africa countries. The green leaves of fluted pumpkin are generally called *ugwu.* The leaves are low in crude fibre, rich source of protein, oil, vitamins and minerals which good for human health. Fluted pumpkin leaves (*Telfairia occidentalis)* are perishable and deteriorates within few days after harvest. Keeping these leaves in its fresh form and the ability to retain the actual nutrient, flavour, taste and colour has remained a problem yet unsolved.

We evaluated the effect of drying methods and storage durations on the nutritional qualities of dried packaged fluted pumpkin leaves (Raji *et al*., 2016). Freshly harvested fluted pumpkin leaves were sorted, washed, drained and sliced. Samples were freeze-dried, oven dried and sun dried respectively. The initial properties of each dried sample were determined, packaged in sterile polyethylene bags and stored at ambient room conditions. Proximate composition of each samples were determined on monthly basis for three months. Results showed that freshly harvested fluted pumpkin leaves contains 84.00% moisture, 2.16% ash, 5.21% crude protein, 5.32% crude fibre, 2.00% fat and 1.28% carbohydrate. The moisture, crude fibre, crude protein, fat, carbohydrate and ash content of dried fluted pumpkin leaves decreased significantly ($P < 0.05$) irrespective of the drying method used. The moisture, ash, crude fibre, and fat content of the dried packaged fluted pumpkin leaves decreased generally as storage period increased. Freezing drying method is recommended for drying of fluted pumpkin leaves in terms of retained proximate composition. The portability and availability of packaged fluted pumpkin leaves will increase its utilisation, thereby enhancing the income of the farmers and producers.

## 5.0 Extraction of Oil from Underutilised Seeds

Oils extracted from plant sources have a rich history of use by local people as a source of food, energy, medicine and for cosmetic applications. The continued increase in human population has resulted in the rise in the demand as well as the price of edible oils, leading to the search for alternative unconventional sources of oils, particularly in the developing countries. About 36% of the world's energy comes from petroleum oil and 22% from gas. This dependency on fossil fuel has also led to increasing pollution and cost, yet it is non-renewable. Consumer nations have become dependent on foreign suppliers and their economies have become hostage to international events such as wars, coup d'états, and terrorism. The desire to move away from dependency on fossil fuels created an interest in alternatives as reliance on imported petroleum and fluctuating prices is creating apprehension among users. Biodiesel is a promising alternative which is already in use in some countries. Due to the need to achieve this, crops or other similar agricultural sources would have to be considered as potential source of biodiesel. Consequently, there is an increasing need to search for oils from vegetative sources to augment the available ones and also to meet specific applications. Hence, neglected and underutilized plant species readily comes to mind, as exploitation of this will greatly reduce poverty in developing countries. In Nigeria, there are some native oil seed plants which grow well in fallow lands and could be used as source of alternative to fossil fuel. There are strong political and social pressures to avoid the use of edible oils as a biodiesel source.

There are hundreds of underexplored plant seeds rich in oil suitable for edible or industrial purposes such as *moringa oleifera*, watermelon, tigernut, *delonix regia* among others. It has been reported that the seeds pre-treatment (moisture content, heating temperature, heating time) prior to extraction and method of extraction influences the oil yield and characteristics of oil from oil bearing seeds (Olaniyan, 2010; Sirisomboon and Kitchaiya, 2008). We carried out researches on the effects of processing parameters on the yield and characterisation of oil extracted from some of these underutilized seeds.

## 5.1 *Moringa Oleifera* Seeds Oil

*Moringa* seed can be extracted and eaten as “peas” (boiled or fried) when still green. The dry seeds are apparently not used for human consumption, due to the bitter coating when it becomes hardened or dry. The matured seed contains 38-40% oil which has an excellent quality (73% oleic acid) similar to olive oil. The effect of heat treatment and moisture content on the oil yield and characteristics *moringa oleifera* seeds was investigated respectively (Adejumo *et al*., 2013b, c). The *moringa oleifera* seeds samples were heated at temperature range of 100°C to 150°C for 30 minutes; the oil was extracted using solvent extraction method and the oil characterised. Moisture content of *moringa oleifera* seeds samples was varied between 7.28% and 20% prior to oil extraction and characterisation. The results showed that percentage oil yield, saponification value, free fatty acid, acid value, peroxide value and iodine value decreases with increase in heating temperature, while heating temperature has no significant effect on the specific gravity of the oil. The results of the variation in moisture content showed that increase in moisture content decreases the oil yield with the highest yield of 38.5% obtained at 10% moisture content. It was concluded from the results obtained that *moringa oleifera* seed oil is edible with high resistance to rancidity and can also be used as lubricant and for biodiesel production.

## 5.2 Tiger Nut Oil

Tiger nut (*Cyperus esculentus*) is commonly known as earth almond, *chufa*, yellow nut sedge and *zulu* nuts. In Nigeria, the three common varieties cultivated are the black, brown and yellow. It is known as "*Ayaya*" in Hausa, "*ofio*" in Yoruba and "*Akiausa*" in Igbo. Among these three varieties, only the yellow and brown varieties are readily available in the market. Tiger nut can be eaten raw, roasted, dried, baked or made into a refreshing beverage called "*Horchata de chufa*" or tiger nut milk. Tiger nut produces high quality oil about 25.5% of its content and is non acidic. Tiger nut oil has golden colour and a nutty taste which makes it ideal for different users.

The effect of heating temperature and moisture content variation on the oil yield and characteristics of tiger nut was investigated respectively (Adejumo *et al*., 2015a; Adejumo and Salihu, 2018). The tiger nut samples was heated for 30 minutes at 100°C and 140°C temperature range, oil extracted using the solvent extraction method and characterized using standard methods. The results showed that the percentage oil yield, acid value, peroxide value and free fatty acid decreased with increase in heating temperature. The heating temperature however had no significant effect on the specific gravity, density, refractive index, saponification value and iodine value of the extracted oil. It was concluded that tiger nut should not be heat treated above 100°C prior to oil extraction for optimum oil yield and reduction in peroxide value.

The moisture content of tiger nut was varied between 9.5% and 40%, with the oil extracted using the solvent extraction method and the oil characterised. The result showed a percentage oil yield of 25.89% at 9.05% moisture content which then decreased with increase in moisture. Moisture content has no effect on the refractive index of tiger nut oil; the high free fatty acid value indicates its edibility. Therefore, an initial seed moisture content of 9.5% is recommended for the extraction of oil to obtain maximum oil yield. The oil can be use as lubricant, cooking as substitute for other vegetable oil and good for soap making.

### 5.3 Watermelon Seed Oil

Qualities of watermelon seed oil at four moisture content was also evaluated (Adejumo *et al*., 2015b). Oil was extracted using solvent extraction method with the moisture content of seed varied between 4.31% and 30% moisture content (wb). Result showed that the acid values (mg/KOH/g) ranged between 5.61 - 10.10, iodine values (g/100) 122.60 - 135.66, peroxide values (m/mol/kg) 2 - 16, saponification values (mg/KOH/g) 196.35 - 325.38 and free fatty acid values (mg/KOH/g) 11.22 - 20.20. The increase in moisture content had no significant effects ($p \geq 0.05$)

on the refractive index, viscosity and specific gravity of watermelon seed oil while saponification value, acid value, free fatty acid and peroxide value increased significantly. The oil yield and iodine content decreased with increase in moisture content. It was concluded that water melon seed oil will be suitable for lubrication and soap making.

## 5.4 Fluted Pumpkin Oil

The effect of heat treatment on the characteristics and oil yield of fluted pumpkin seeds was investigated (Adejumo and Oyedeji, 2015). The fluted pumpkin seed samples was heated for 30 minutes at temperature range of 100°C and 150°C and the oil extracted using the solvent extraction method. The results showed a highest percentage oil yield of 46.37% at 150°C heating temperature. The density (kg/m$^3$) of the extracted oil ranged from 19.95 - 27.47; Saponification (mg/KOH/kg) value 173.56 - 375.87 and iodine (g/100) 105.48 - 109.93. The free fatty acid (mg/KOH/kg) values ranged between 1.10 and 3.00 for oil samples extracted. It was concluded that the oil yield, saponification value, free fatty acid, acid value increased with increase in heating temperature while iodine and peroxide values decreased with increase in temperature. The properties of fluted pumpkin seed oil indicate its edibility.

## 5.5 *Delonix Regia* Seeds Oil

The characteristic of *delonix regia* seed oil was investigated with a view to establish its suitability for use as feedstock for the production of biodiesel (Adejumo *et al.*, 2019a). The seeds were removed from the *delonix regia* pods and boiled for 30minutes to enhance the easy removal of the seed coat and extraction of oil from the seeds. The boiled seeds were dehulled, sundried and milled using a Burr mill. The *delonix regia* seed oil was extracted and characterised using the solvent extraction and standard methods respectively. The results showed that the *delonix regia* seed contains 29.0% oil with 0.942 density (kg/m$^3$), 201.30 flash point (°C) and 43.75 kinematic viscosity. The saponification value of the extracted oil was 213.48 mg KOH/g, 127.92 g/100 iodine value, 1.97 mg KOH/g acid value and 0.985 mg KOH/g free fatty acid. The higher acid value, viscosity and flash point makes the oil unsuitable for direct use in combustion engines without further processing. It was concluded that the low saponification value and higher molecular weight will make *delonix regia* seed oil suitable for use as biodiesel feedstock.

## 5.6 *Delonix Regia* Methyl Ester

The optimisation of the production parameters of *Delonix regia* ester was carried out with the view to establish the parameters for the production of optimum methyl ester yield from *Delonix regia* seed oil (Adejumo *et al*., 2019b). The effects of reaction temperature, reaction time, alcohol:oil molar ratio, catalyst concentration and its interaction effects on the yield of methyl ester was investigated. The response surface methodology Box behnken design was used for the experiment. Data obtained were analysed statistically using Design expect 9.0 statistical package to determine the response model, surface respond analysis of variance (ANOVA). The data collected from optimisation of the reaction process was fitted to model. The results showed that the percentage yield in terms of reaction temperature, time, molar ratio, concentration and interaction terms of reaction temperature and reaction time were significant ($p \leq 0.05$). The lack of fit F-value for the *Delonix regia* methyl ester yield response showed that it was not significant ($p \leq 0.05$) relative to the pure error. This indicates that all the models predicted for methyl ester yield response were adequate. Regression models for data on response methyl ester yield were significant ($p \leq 0.05$) with satisfactory $R^2$ value of 0.829. The boundaries of the design intergalactic of methyl ester yield had the lowest value at 72% within the process range of 40°C to 56°C for temperature, 30 to 53 minutes for reaction time, for all production processes while the highest of 90.21% with the process boundary range of 55 to 60°C for temperature and 40 to

60 minutes reaction time. The optimisation solution gave the process conditions for each process factors at the highest desirability prediction of 0.642 as best reaction temperature of 53.20°C and the reaction time of 60 minutes, alcohol: oil molar ratio of 2:1 and catalyst concentration of 0.69% when the set goal is based on the physic-thermal properties of produced methyl ester.

## 6.0 My Contributions to Research in the Development of Agricultural Crop Storage Structures

The Sudan Savannah climatic zone of Nigeria support the production of large quantities of cereal and pulses annually, of which the major ones include millet, Sorghum, cowpea, maize and groundnuts. We conducted a technical survey of the village level grain storage structures existing in this zone with a view to determine the efficiencies of the construction materials and develop better grain storage structures (Adejumo and Raji, 2007). The survey revealed that the prominent structures are the mud rhombus (Plate II), thatched rhombus (Plate III and Plate IV) and underground pit (V).

### a. Mud Rhombus

A mud rhombus is a specially built structure made from a mixture of dry grass and clay. It consists of a bin resting on large stones and covered with a thatched roof (Plate II). A mud rhombus consists basically of the foundation – floor assembly, Shell or wall and roof. The shape and sizes of the mud rhombus depend on the tradition of the area and the availability of materials. The shape could be cylindrical, spherical, circular or domed shaped. The height ranges from 7 – 10 meters while the diameter ranges between 3 – 7 meters. The capacity of mud rhombus ranges from 1000kg – 8,000kg of unthreshed cereals and legumes. The mud rhombus is generally not moisture proof, rodent proof or airtight. The grains are manually loaded into the storage structure through the roof. Mud rhombus generally does not have any external support or reinforcement. The physical defects of mud rhombus are usually on the roof and wall of the structure. The physical defect includes leakages of roof, cracks on the wall. The defects are usually as a result of poor strength of materials, change in climate condition and structural failure. The maintenance methods include the repair and replacement of structural parts. The damage on the stored grains often results from pest/insect infestation, structural failure, variation in climatic conditions, micro – organisms among others. The losses in grain and economic values are between 10 – 20% during a storage period of 6 months to 3 years the end use of the stored

and sales.

**Plate II:** Mud Rhombus

**Plate III:** Thatched Rhombus

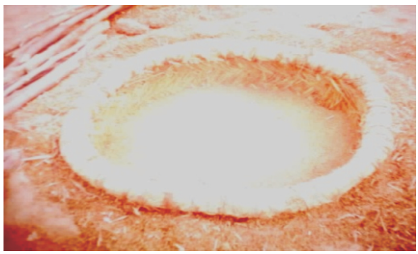


**Plate IV:** Failed Thatched Rhombus

**Plate V:** Underground Pit

### b. Thatched Rhombus

The thatched rhombus is made of woven grass stems resting on irregular stores and or tree stems (Plate III). It is usually cylindrical or circular in shape with various capacities ranging from 500kg to 8,000kgs depending on the size. The grains are usually stored in unthreshed forms. Thatched rhombuses are generally not airtight, moisture and rodent proof; it usually has external support ranging from 6 – 16 units depending on the size of the rhombus. The foundation – floor assembly is usually made of irregular stones and tree stems or tree poles stems penetrating the ground, and crossed with other tree stems. The wall of the thatched rhombus made of woven grass stems has two layers, being reinforced with two or three tension rings. The materials usually used for the roofs are straw/thatched, tree stem, polyethylene sheets, and robes; it is usually of 2 – 3 layers to prevent water seepage. The physical defects are usually on the wall, foundation and roof (Plate IV). The defects include inadequate support, low elevation, termite infestation which is as a result of poor strength of material structural failure, inadequate design, of the foundation and age of the structures. Maintenance is usually done by the repair and or replacement of structural parts. Fumigants are usually applied to reduce pest infestation, but are usually not effective because the structure is not airtight. The type of grain loss includes change taste, colour, and odour, pest infestation. The extent of loss depends on the duration of storage. The main causes of losses include pest infestation, poor strength of material, and structural failure among others. The percentage loss in quantity and economic value ranges between 10 % and 20% and above respectively depending on the duration of storage and other factors of deterioration.

**c. Underground Pit**

This is commonly found in Borno and Yobe states where the water table is low. The pit, which may be round or square in cross section, is 1 – 3m deep and 1 – 3 m in diameter or square, underground pit is usually lined with straw (Plate V). The pit and the straw mat are padded with 40 – 60cm of corn husk. Also a layer of husk padding or insulation is provided at the bottom of the pit. The common types of grain stored are millet, sorghum and cowpea stored in threshed form. The capacity ranges from 1000kg – 6000kg and above. After loading the grains into the pit, tree stems are placed across the pit then covered with Polyethylene or metal sheet. Then a layer of husk before finally layers of sand or laterite is used to cover it. The duration of storage could be between 1 – 5 years without opening and usually, once opened; all the content must be emptied. The same site can be used for up to 12 years with annual re-digging. The location of the defect is usually in the wall lining, which may be eaten up by termite, and the structure is not rodent proof. Maintenance is usually done by cleaning and replacement of the wall lining. The damages or loses in stored grains includes change in colour, odour and taste. It is believed that these grains have low viability. Grains stored in this structure are protected against insect attack because of reduced oxygen level. Causes of grain damage/loss include microbial organisms, structural failure and changes in the chemical composition of grains. Approximate percentage loss of quantity and economic values are 10 – 20% and 5 – 10% respectively. The underground pit is easy and cheap to construct and requires minimum materials, but however great difficulty is experienced in emptying and cleaning the structure (Adejumo and Raji, 2011).

It was concluded from the survey that there is the need for technical improvement on the construction materials, nature of columns, elevation and the loading/unloading facilities. The farmers' shows willingness in adopting new storage techniques provided such structures has concept or technology that builds up on or improves the existing ones in use rather than one which imposes a totally new idea.

Therefore, we made efforts to develop storage structures using locally available materials with better integrity. The developed structures include double walled metallic structure, sandcrete block rhombus for grain storage and evaporative coolers for fruits and vegetable storage.

## 6.1 Development of a 350 Kg Double-walled Insulated Metallic Silo

In the warm and humid climate prevalent in Nigeria, metal silos which are predominantly used for grain storage in strategic grain reserves experience moisture condensation and high temperature fluctuations, resulting in grain deterioration. A 350 kg double-walled insulated metallic silo was designed and the prototype was constructed with galvanized iron sheet, using wood shavings as an insulating material between the walls. The potential of sawdust as an insulator in a double walled metallic silo was also investigated, with a view to solve the problems of environmental pollution from the sawmilling industry as well as reduce losses of grain stored in metallic silo (Adejumo, *et al*, 2010; Adejumo, 2013). A pre-storage evaluation was carried out on the silo to ascertain the potential of sawdust as an insulator prior to grain storage.

The silo is a cylindrical, double-walled structure made of galvanized iron sheets (Plate VI). With a total height of 2.70m above the ground level, the silo consists of four major sections viz – the roof, cylindrical section, conical hopper and the foundation. Grains are loaded into the silo from the top and unloaded via the unloading channel on the conical hopper. The body of the silo comprises of two cylinders (outer and inner) with diameters 0.90m and 0.80m and length 1.22m and 1.18m respectively. Wood shavings was placed in the space (5cm) between the two walls to serve as an insulating material. The choice of wood shavings was due to its low thermal conductivity (0.06W/(mK)) and the fact that it is readily available at little or no cost to the farmers who are the primary users of the structure. The performance evaluation result showed a temperature range of 19 - 40.7°C and 22.5 - 42.5°C inside the silo and ambient respectively. Statistical analysis revealed significant difference ($p < 0.05$) in the temperature range in the silo and ambient during the test period.

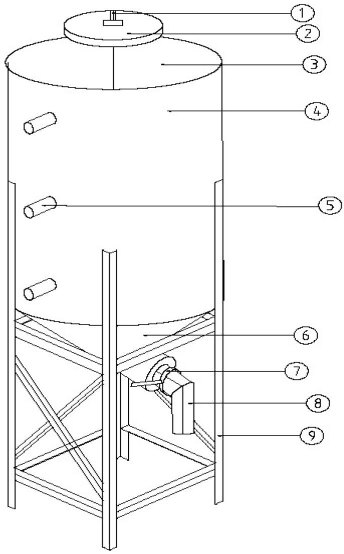
**Advantages of the Double-Walled Silo**

The advantages of the grain storage structure includes:

1. Little or no expertise is required in its operation as there are no complex parts in the design.
2. The high cost of maintenance in most traditional grain storage structures is eliminated in the design because there is minimum maintenance in the operation of the silo.
3. The silo unloading channel provides for an easy and convenient discharge of grains from the structure.
4. The silo makes efficient use of space as against what is obtained in traditional storage structures.
5. Small capacity silos such as the one developed in this study will suite the requirement of the individual.

It was concluded that the double-walled metallic silo demonstrated some prospects for use in grain storage and reduction in temperature within the silo due to the low thermal conductivity of the sawdust.

**Plate VI:** The Double-Walled Metallic Silo




Isometric view of the double - walled silo

## 6.2 Development of Sandcrete Block Rhombus

The availability and cost of construction materials of traditional storage structures makes it adoption advantageous to the subsistence farmers despite series of defects. The mud rhombus which is commonly used for grain storage in the northern parts of Nigeria has various defects occurring mainly in the roof, wall and foundation of the structure. These defects include cracks, leakages, and structural failure of parts among others. A sandcrete block rhombus was developed to solve the problems of cracks, insect pest infestation, structural failure of the foundation and roof as well as the unloading of stored grains that exist in the traditional mud rhombus (Adejumo, 2012). A 1.46 tones capacity experimental sandcrete block rhombus with a total volume of 2.46 $m^3$ was designed to store shelled maize. The main structure was constructed using sandcrete blocks, cement, gravel and roofed using wood and roof asbestos (Plate VII).

**Plate VII:** Sandcrete block rhombus

The sandcrete block rhombus is a four corners structure with an internal dimension of 1219 mm × 1219 mm and a total external height of 2744 mm. The inner part of the structure was incorporated with a 2 mm iron sheet which was casted in a trapezoidal form and was made to slant at an angle of 30° to ease the discharge of stored grains by gravity. The metal section was made to project out of the wall by 203.2 mm × 203.2 mm × 127.0 mm which serves as discharge outlet for the stored grains. A galvanized iron sheet was installed at the right side of the wall to serve as the loading inlet. The inner and the outer parts of the wall were plastered and the structure roofed with asbestos roofing sheet. Eight probe channels were inserted using

20 mm PVC pipes placed at regular intervals on the four sides of the structure. These channels were covered with PVC cover to prevent insect pest infestation. This is to allow for testing and monitoring purposes of the stored grains. The cost of construction was estimated to be N60,000.

The advantages of the sandcrete block rhombus over the traditional rhombus include the following:

1. Structural stability and durability: The use of more durable materials such as cement, sand, sandcrete blocks etc in place of irregular stones, mud/clay, sticks, straws etc and the use of a concrete foundation has enhance the stability of the structure with minimal repair and maintenance cost.

2. Ease of loading and unloading: Loading is done through a loading inlet instead of loading through the roof as practiced for storage in the traditional rhombus. The incorporation of an inclined trapezoidal metal sheet in the unloading unit enhanced the discharge of the loaded grains through gravity. The inlet and outlet were provided with security lock to avoid pilfering.

3. Reduce risk of insect pest infestations and other agents of deterioration: The use of planks and roof asbestos instead of tree stems, straw, palm leaves used in the traditional rhombus will reduce insect infestation and water leakages into the structure. The problem of structural failure of the roof is also taken care of.

The developed sandcrete block rhombus was more structurally stable than the traditional rhombus. The ease of loading and unloading coupled with the locking devices gives it more advantage than the traditional rhombus.

## 6.3 Performance Evaluation of a Metal-in-Block and Jute-cane Evaporative Coolers

Deterioration of fruits and vegetables commence immediately after harvest from the parent material hence preservation is very essential to reduce losses. Deterioration of fruits and vegetables during storage depends largely on temperature, relative humidity, handling, and physiological properties of crops among others. A Metal-in-Block (MIB) and Jute cane evaporative cooler was constructed with the aim of reducing on-farm post harvest losses of fruits and vegetables (Adejumo, 2011).

The metal-in-block evaporative cooler was constructed using sandcrete block; mild steel iron sheet and river-bed sand (Plate VIII). The design was based on the evaporative cooling effect of a porous body using water. A well ventilated area overhead shade was selected to harness the advantage of the effect of evaporative cooling. The structure consist of a metal box constructed using mild steel iron sheet with a dimension of 0.90m × 0.93m × 0.48m inserted in a sandcrete block work of 1.2m × 1.2m × 1m. The space between the metal box and the sandcrete block work was filled with riverbed sand. River bed sand covered with jute materials was placed on top the metal box with wooden planks to keep the jute materials in place so as to prevent heat penetration from the sun. The inner part of the metal box was partitioned into three sections to enhance its capacity. The cooling chamber was watered daily to keep the riverbed sand constantly wet.

Jute cane cupboard that was made from bamboo, jute bag and plastic bowl with a length of 0.6 m, 0.9 m width and 1.2 m high (IX). The bamboo frame was wrapped with jute bag and the cooling chamber was partitioned into three compartments in order to store the fruits and vegetables separately and to enhance its capacity. In order to prevent the stored products from insect attack, a clearance of 0.3 m from the ground level was added to the structure. A plastic bowl drilled in eight places with 0.5 mm pin was filled up with water and placed on top of the structure to continually moisten the jute material; which will in

turn reduce the temperature and increase the relative humidity in )
pr

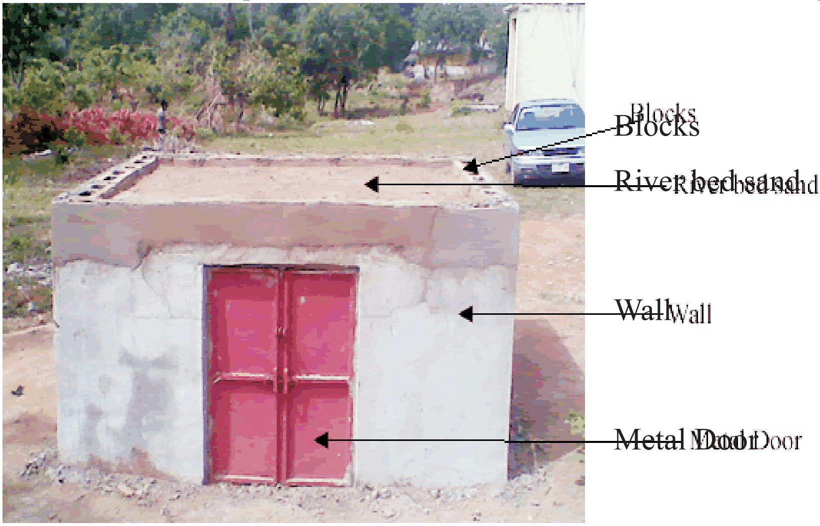



**Plate VIII:** Jute cane evaporative cooler

Freshly harvested oranges, pawpaw, amaranths, pepper and garden egg were procured from a daily market and the samples were weighed separately and divided into three equal parts (Adejumo, 2012). One part each was kept inside the metal -in-block evaporative cooler, jute cane cupboard and plastic basket at ambient storage conditions to serve as control. A digital thermo hygro-meter was used to monitor the daily temperature and relative humidity

**Plate IX:** Metal in Block evaporative cooler range inside the metal-in-block evaporative cooler, jute cane cupboard and ambient. All the stored samples were evaluated daily for weight loss, visual freshness and changes in physical qualities. The results showed a temperature range of 25 - 32°C, 23 - 30°C and 26 - 37°C for the metal-in-block evaporative cooler, jute cane cupboard and ambient conditions respectively. The relative humidity inside the metal-in-block evaporative cooler varied from 74 to 90 %, 76 to 93 % in jute cane cupboard and 72 to 88 % at ambient condition. The fruits and vegetables stored inside jute cane cupboard retained its freshness more than those stored in the metal-in-block evaporative cooler while the least freshness was observed in those stored at ambient condition. The jute cane cupboard preserved orange, amaranth and pepper better in terms of weight loss while the metal-in-block evaporative cooler stored garden eggs and pawpaw better at the end of the storage period.

## 7.0 Contributions to Research in the Development of Agricultural Processing Equipment

We developed some agricultural processing equipment to solve the problems of drudgery, low capacity and low efficiency during some processing operation. The developed equipment was constructed from locally available materials and easy to operate.

## 7.1 Performance Evaluation of an Okra Thresher

The seeds of okra have been used as coffee substitutes and edible oil also has been extracted from dried okra seeds. Vegetable curds prepared from dried okra seeds have been used as substitutes for cheese in recipes. The amino acid profile of the seed indicates that it could be used to complement other partially complete protein sources such as soybean. The economic value of the fresh okra pods, fresh stems, dry okra stem, pods and seed cannot be over emphasized; hence there is the need to produce large quantities of dried okra seeds for seedlings and for use in other processed forms. The traditional methods of threshing dry

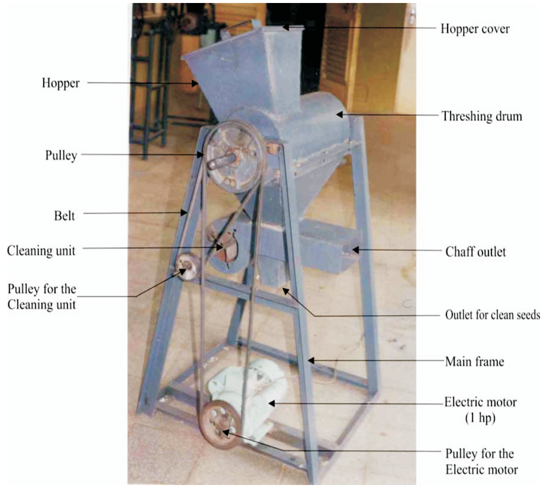



**Plate X:** Okra Thresher

okra pods involve manual rupturing of the pods and the separation of the seed from the chaff. The process is tedious and time consuming; it also results in losses as well as low quality product. An okra thresher had 88.1% threshing efficiency, 46% cleaning efficiency and 15.3% percentage total loss had been constructed (Bolaji 2000), design modifications was carried out on this initial design to further improve its performance (Ajav and Adejumo, 2005). The modified thresher (Plate X) was evaluated at three different levels each of cylinder concave clearance (10, 20, 30mm), seed moisture content (12.5, 14.0, 17.0%), two levels of cylinder speed (peripheral speed 4.2m/s and 4.4m/s), and feed rate 10kg/hr of dried okra pods. Performance parameters for the study were threshing efficiency, cleaning efficiency, total loss of seed and germination. The test results indicated a maximum of 97% threshing efficiency and 97.7% cleaning efficiency, a minimum of 3.3% total seed loss and a maximum germination of 85%. The average output capacity of machine was 6.3kg/hr of seed. The performance was found to be influenced by all the study variables. The machine is dismantleble for easy transportation.

## 7.2 Development of a Combine *Gari* Post Grinder- Sifting Machine

The processing of *gari* from cassava has been reported by many authors as a labour demanding operation with women and children being the major producers. It is estimated that at least 45% of labour requirement are accounted for by peeling and sifting. Sifting of *gari* is also important before frying to ensure uniformity in particle size. The final product *gari* is also sifted after frying to separate it into chaffy, medium and coarse size particle. The finer grain *gari* sells at a higher price while the bigger grains are sold at a lower price. This makes the sifting of the *gari* inevitable by the producers, to make the products attractive and improve the market value. The development of a combine *gari* post grinder-sifting machine was to solve this problem by both sifting and grinding the bigger grain *gari* (Adejumo and Ola, 2010).

The machine consists of the hopper, sieving unit, grinding unit, electric motor mounted on a frame (Plate XI). All the necessary joints are carefully done using the right jointing method and materials. The machine is powered by an electric motor which, is bolted to a slotted table which aids the tensioning of the belt. Apart from the pulley of the driver (electric motor) the machine has two additional pulleys of which one is double groove and the other is of single groove. The electric motor pulley functions as the driver of the double groove pulley while this in turn drives the single groove pulley of the grinding machine. The double groove pulley is keyed to camshaft which runs parallel under the sieve trough. The cam is always in direct contact with the sieve trough base. Hook attachment are incorporated at mid-point of sieve trough and the frame top, this allow the fixing of extension to keep the trough in constant contact with cam during operation. From the cam, the sieving unit receive the power and results in the reciprocating motion that make the *gari* to fall into the chamber and pass out through the outlet. The test results showed that the machine had a highest sifting capacity of 28.2 kg/hr with sifting and grinding efficiencies of 85.5 and 84.0% respectively. A minimum and maximum loss of 12.8 and 27.3% of *gari* grains respectively were observed during the performance test. The sifting efficiency decreased with increase in loading of the machine while the grinding efficiency increases with loading. The machine could be adapted to handle other low bulk density materials such as yam flour, ground spices and other powdery products. The machine can easily be dismantled and the operational and maintenance procedure is simple.

**Plate XI:** *Gari* post grinder sifter

## 7.3 Development of an Automated Fuzzy Logic Controlled Reactor for Production of Oleo-chemical

An automated fuzzy logic controlled rector was developed to solve the problem of drudgery, nonuniform temperature and poor quality products associated with the common available reactors in the production of oleo-chemical (Obasa and Adejumo, 2017). The developed reactor consist of reactor tank, heating element (coil), stirrer (agitator), fuzzy programmed and control system. The control system of the developed reactor was evaluated using crude castor oil at pre-set temperature and time. The pre-set temperatures are $100^{o}C$ and $300^{o}C$, reading were taken at regular interval for 120 minutes at a speed of 500rpm. The results showed that the controlled temperature reading for 100$^{0}$C ranges between 98$^{0}$C to 102$^{0}$C; uncontrolled temperature ranges between 97$^{0}$C to 110$^{0}$C while for temperature pre-set at 300$^{0}$C ranges between 294$^{0}$C to 304$^{0}$C and for uncontrolled temperature ranges between 296$^{0}$C to 316$^{0}$C respectively. It was concluded that the developed reactor has an excellent temperature monitoring and regulation performance compared to that of the manually controlled that has been the practices in most exiting reactors.

**Conclusion**

Mr. Vice-Chancellor Sir, this lecture has highlighted that with the appropriate processing methods, packaging and storage conditions as well as using adequate structures, post harvest food losses can be minimised. Some of the oil extracted from underutilised seeds, are edible and suitable for industrial application in cosmetic and biofuel/biolubricant industries. The developments of improved storage structures using locally available materials with operation methods requiring minimal expertise suggest its acceptability to the peasant farmers. Crop processing and storage will adequately solve the problem of food loss and wastage which is crucial in achieving food security in Nigeria.

**Recommendations**

Nigeria is blessed with fertile soil capable of producing food supply for all its populace all year round if adequately processed and stored. Therefore, the following recommendations are made:

1. Teaching and training of Agricultural Engineers in all Polytechnics and Universities should be restructured to provide solutions to the needs of the farmers and processors.

2. The synergy between research institutes, universities and

industries should be strengthened to enhance technological and industrial growth in terms of agricultural crop processing and storage to attain self sufficiency in food supply.

3. Adequate technological transfer to the farmers, medium scale enterprise and the appropriate end users to reduce post harvest and storage losses.

4. Government should provide incentives to students and medium scale entrepreneur to invest in the processing of crops into more suitable forms as well as in production of indigenous equipment for crop processing.

5. The government should implement all documented food security programs to the letter.

**Future Research Endeavour**

My future research endeavour includes:

1. Development of indigenous processing and storage equipments that will be readily available, easy to operate and relatively cheaper than the imported types.

2. Studies on the shelf life of indigenous crops and its utilisation in development of new products that will be nutritious, palatable, relative cheap and acceptable to the consumers to further enhance food security.

3. Extraction and characterisation of oil from indigenous oil bearing seeds for use as edible oil, biofuel, biodiesel and biolubricants.

# ACKNOWLEDGEMENTS

I start by acknowledging the Most High God, whose grace and mercy has brought me this far, as evidenced in my life today; the One who makes glorious things out of nothing to confound the high and mighty. I will never be ungrateful to you Lord.

I owe a debt of gratitude to numerous people who have touched my life in so many ways and at different times. Kindly forgive me if I do not mention your name in this acknowledgements, your worth and contributions in my pursuits are highly appreciated.

My sincere appreciation goes to my parents Deacon Isaac Adepoju Adeyemo and late Mama Rachael Adunola Adeyemo, for their unflinching love, care, support and prayers which are unquantifiable. I am indeed very grateful and forever remain proud of you. My sincere appreciation goes to my able brothers: Dr. Adebowale, Mr. Adeyinka, and Arc. Dr. Adekunle, my wonderful sisters: Prof. Oluwatoyin Odeku, Barrister Olajumoke Ayano and Mrs. Shade Obayemi and their families for being consistently there for me. My uncles Dr. John Adeyemo, Mr. Luke Adeyemo, Dr. Odedele and their families are highly appreciated. My sincere gratitude goes to my in-laws Pa Francis Adejumo Ayeni (late), Deaconess Florence Adejumo (late), Mrs. Nike, Mrs. Toyin Fadugba, Mr. Temitope, Mr. Seun and their families for continuous support.

My teachers at all levels: primary, secondary and university levels - Rev. Amos Alabi, Engr. Olu, Prof O. O. Babatunde (late), Prof. J. C. Igbeka, Prof. K. Oje, Prof. A. O. Raji, Prof. E. A. Ajav, Prof. I. A. Bamgboye and Prof. Y. Mijinyawa, You all made meaningful impact in my career. My senior colleagues: Dr. A. B. Fasina, Prof. Jeremiah Ojediran, Prof. S. O. Jekayinfa, Prof. Taiwo, my colleagues in the Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso, the wealth of experience gained from our relationship is really worthwhile.

I appreciate the past Vice-Chancellor, Prof M. A. Akanji for his support and exemplary leadership, may you continue to enjoy more of God's goodness. I appreciate all the Deans of SEET/SIPET (past and present), for their unflinching support. May sincere appreciation goes to the Head of Department Agricultural and Bioresources Engineering, Prof

N. A. Egharevba and the entire members of staff; I say a big thank you.
I warmly acknowledge all students I have had the privilege of teaching and mentoring especially my Postgraduate students' past- Dr.(s) Haruna Sule and Ogunbiyi Marcus, Judith Okolo, Musa Ebayaya, Tosin Paul, Obasa Peter, Rosemary Uju, Jeremiah Nwaigwe and the present Postgraduate students.

I sincerely appreciate my friends: Dr. and Mrs. Seye Adeleke, Dr. and Mrs. Ola, Engr. (Mrs.) Kehinde Olorunfemi. All my classmate and colleagues at the University of Ilorin (Undergraduate), University of Ibadan (Masters and PhD); I really cherish the moments shared together.

I deeply appreciate my parents in the Lord: Pastor and Pastor (Mrs.) Mathew Olutunmbi, Pastor and Pastor (Mrs.) Adesanya Kolajo, Pastor and Pastor (Mrs.) Jimi Ajibade, Pastor and Pastor (Mrs.) Emmanuel Ibitayo, Pastor and Pastor (Mrs.) C. T. Oni. The entire members of the Redeemed Christian Church of God, Niger Province I, particularly Kings Zone, I say a big thank you for all your prayers.

I appreciate the Vice-Chancellor, Prof Abdullahi Bala (FSSN) for the support and opportunity given to me to present this lecture.

I wish to thank members of the Seminar and Colloquium Committee under the leadership of Professor Bisi Ayanwale for all the efforts put in to make necessary arrangements for this presentation.

To the men in my life: My husband, friend, brother and pastor, a precious and rare gem: Pastor Engr. Oluwarotimi Adejumo, who had stood solidly by and with me for over 24 years; your love, care, understanding, patience, support, prayers and companionship are unquantifiable and sincerely appreciated. I thank God for His grace upon your life. My son: Oluwatimilehin Toluwanimi, I thank God for making you a bundle of joy and a part of me, I will always be proud of you!

Now unto the king eternal, immortal, invisible, the only wise God be honour and glory forever and ever (I Timothy 1:17) Amen.

Mr. Vice-Chancellor, distinguished ladies and gentlemen, thank you for your kind attention. God bless you all.

# REFERENCES


Aboaba, F. O. (2000). An address presented at the Inauguration of the South-West Chapter of the Nigerian Institution of Agricultural Engineers (NIAE) on 8th June, 2000 at Lafia Hotel, Ibadan.

**Adejumo, B. A.** & Raji, A. O. (2007). Technical Appraisal of Grain Storage Systems in the Nigerian Sudan Savannah. *Agricultural Engineering International: The CIGR Ejournal Manuscript. Vol. IX September, 2007*. 1-12

**Adejumo, B. A.** & Raji, A. O. (2010). An Appraisal of *Gari* Packaging in Ogbomoso, Southwestern Nigeria. *Journal of Agricultural and Veterinary Sciences* 2, 120-127.

**Adejumo B. A**. & Ola, F. A. (2010). Development of a Combine *Gari* Post Grinder- Sifting Machine. *Journal of Agricultural Engineering and Technology*, 18(2), 77-86.

**Adejumo, B. A**., Ola, F. A., Odubiyi, A. A., Oyefeso, A. O. & Aje, J. O. (2010). The Potentials of Sawdust as an Insulator in a Double Walled Metallic Silo. *Journal of Agricultural Engineering and Technology*, 18(2), 1-6.

**Adejumo B. A.** (2010a). Shelf Stability of *Gari* in Selected Packaging Materials. *First International Conference on Engineering and Technology Research, held at Ladoke Akintola University of Technology, Ogbomoso*. 28-30th September, 2010.

**Adejumo, B. A.** (2010b). Studies on the Moisture and Microbiological (*staphylococcus aurens*) Contents of *Gari* in Selected Packaging Materials. *Journal of Biological Sciences and Bio-conservation* 2, 76-83.

**Adejumo, B. A.** (2011). Performance Evaluation of a Metal-in-Block Evaporative Cooler. *Proceedings of the 11th International Conference and 32nd Annual General Meeting of the Nigerian Institution of Agricultural Engineers, (NIAE 2011)*, October 17-20, 2011, Ilorin, Nigeria. Vol. 32, 633 – 638.

**Adejumo, B. A.** & Raji, A. O. (2011a). Shelf Stability of *Gari* Packaged in

Hessian Bag in Southwestern Nigeria. *LAUTECH Journal of Engineering and Technology*, 6(2), 19-24.

**Adejumo, B. A.** & Raji, A. O. (2011b). Storage Losses in Traditional Grain Storage Systems in Sudan Savannah Nigeria. *Proceedings of the 11th International Conference and 32nd Annual General Meeting of the Nigerian Institution of Agricultural Engineers (NIAE Ilorin 2011), October 17 – 20, 2011, Ilorin, Nigeria*. NIAE/2011/PHEP/104/1- 6.

**Adejumo B. A**. & Ola, F.A. (2011). The Effects of Fermentation on the Quality Attributes of *Gari. LAUTECH Journal of Engineering and Technology*, 6(2), 7-11.

**Adejumo, B. A.** (2012a). Influence of Initial Moisture Content on Some Proximate Quality Attributes of Packaged *Gari* in Storage. *An International Journal of Applied Biological Research*, IJABR 4(1 & 2), 32-38.

**Adejumo, B. A.** (2012b). Effect of Drying Methods and Pretreatment on some Physicochemical Quality Attributes of Tomato Powder. *International Journal of Innovative Research and Development*, 1(11), 50 – 58. www.ijird.com

**Adejumo, B. A.** (2012c). The Effect of Pretreatment and Drying on some Vitamin Contents of Tomato Powder. *Annals Food Science and Technology*. 13 (2), 156- 160. Available online at www.afst.valahia.ro

**Adejumo, B. A.** (2012d). Development of a Sandcrete Block Rhombus. *Journal of Agriculture and Veterinary Science*, 4, 16 – 22.

**Adejumo, B. A.** (2012e). A Comparative Analysis of the Performance Evaluation of Two On-Farm Fruits and Vegetable Storage Structures. *Proceedings of the 33rd Annual Conference and Annual General Meeting of the Nigerian Institution of Agricultural Engineers, WIKKI SPRINGS, 2012, Bauchi, Nigeria*. 33, 339 – 348.

**Adejumo, B. A.** & Raji, A. O. (2012). Microbiological Safety and Sensory Attributes of *Gari* in Selected Packaging Materials. *Academic Research International*, 3(3), 153 – 161. www.journals.savap.org.pk

**Adejumo, B. A.** (2013a). Some Quality Attributes of Locally Produced Wheat Flour in Storage. *IOSR Journal of Environmental Science, Toxicology and Food Technology* (IOSR-JESTFT) 5 (2), Pp 01-05. www.iosrjournals.org

**Adejumo, B. A.** (2013b). Preliminary Investigations on Some Mechanical Properties of Selected Plastic Packaging Materials for *Gari* Packaging In Nigeria. *International Journal of Scientific and Technological Research*. 2 (10), 164-167. www.ijstr.org

**Adejumo, B. A.** (2013c). Development of a 350 Kg double-walled insulated metallic silo for tropical climate. *Greener Journal of Science Engineering and Technology Research* 3(6), 195 – 204. www.gjournals.org

**Adejumo, B. A.**, Okundare, R. O., Afolayan, O. I., & Balogun, S. A. (2013a). Quality Attributes of Yam Flour (*Elubo*) as affected by Blanching Water Temperature and Soaking Time. *The International Journal of Engineering and Science* 2(1), 216 – 221. www.theijes.com

**Adejumo, B. A.**, Alakowe, A. T. & Obi, D. E. (2013b). Effect of Heat Treatment on the Characteristics and Oil Yield of *Moringa Oleifera* Seeds. *The International Journal of Engineering and Science* 2(1), 232 – 239. www.theijes.com

**Adejumo, B. A.**, Inaede, S. G. & Adamu, T. S. (2013c). Effect of Moisture Content on the Yield and Characteristics of Oil from *Moringa oleifera* Seeds. *Academic Research International*, 4(4), 160 – 170. www.journals.savap.org.pk

**Adejumo, B. A.** (2014). The Effects of Drying on some Nutrients of *Moringa Oliefera* Leaves. *Annals Food Science and Technology*. 15 (2), 1 - 5. www.afst.valahia.ro

**Adejumo, B. A.**, Olorunsogo, S. T. & Omodaiye, S. I. (2015a). Qualities of Tigernut Oil as Influenced by Heating Temperature. *International Journal of Emerging Technologies and Engineering* (IJETE). 2 (3), 49 – 52. www.ijete.org

**Adejumo, B. A.**, Olorunsogo, S. T. & Njoku, C. B. (2015b). Qualities of Watermelon Seed Oil Extracted at Different Moisture Content. *International Journal of Advanced Engineering Research Technology* (IJAERT). 3 (3), 97 -100. www.ijaert.org

**Adejumo, B. A.** & Oyedeji, O. O. (2015). Some Characteristic of Fluted Pumpkin Oil Extracted at Three Heating Temperatures. *International Journal of Innovation and Scientific Research* (IJISR). 17 (2), 336 – 340. http://www.ijisr.issr-journals.org

**Adejumo, B. A.** & Dan, E. J. (2018). Nutritional Composition of Packaged *Moringa Oleifera* Leaves Powder in Storage. *Annals Food Science and Technology*. 19 (2), 226 - 231. www.afst.valahia.ro

**Adejumo, B. A.**, Sadiq, I. A. & Obasa, P. A. (2018). Microbiological Quality of Packaged *Moringa Oleifera* Leaves Powder in Storage. *Journal of Science, Technology, Mathematics and Education* (JOSTMED), 14(2), 81- 89.

**Adejumo, B. A.** & Salihu, M. E. (2018). Effects of Moisture Content on the Yield and Quality of Oil from Tigernut (*cyperus esculentus*). *Annals Food Science and Technology*. 19 (2), 236 - 243. www.afst.valahia.ro

**Adejumo, B. A.**, Agboola, J. B., Orhevba, B. A., Obasa, P. A. & Simeon, M. I. (2019a). Extraction and Characterisation of Oil from *Delonix Regia* Seeds. IOSR *Journal of Engineering* (IOSRJEN). 9 (7), 40-43. www.iosrjen.org.

**Adejumo, B. A.**, Agboola, J. B., Orhevba, B. A., Obasa, P. A. & Simeon, M. I. (2019b). Optimisation of the Production Parameters of *Delonix Regia* Methyl Ester Using Box- Behnken Design. *International Journal of Scientific & Technology Research*. 8 (9), 2036-4043. www.ijstr.org

Adepoju, A. L. & **Adejumo, B. A**. (2015). Some Proximate Properties of Sweet Potatoes (*Ipomoea Batatas* L) As Influenced by Cooking Methods. *International Journal of Scientific and Technological Research*. 4 (3), 146-148. www.ijstr.org

Adewuyi, M. A. A. (2004). Postharvest Technologies in Rice Production iIn Nigeria. In: Abo, M.E., Abdullahi, A.S., Ike, E., (Eds.). *The Nigeria Rice Memorabilia*. Project Synergy Limited, Abuja, Nigeria, pp. 474–481.

Ajav, E. A. & **Adejumo, B. A.** (2005). Performance Evaluation of an Okra Thresher. Agricultural Engineering International: *The CIGR Ejournal Manuscript*. PM 04 006 Vol.VII October 2005.

Bolaji, O. E. (2000). The Development of a Low Cost Okra Threshing Machine. *Unpublished B.Sc. thesis, Department of Agricultural Engineering, University of Ibadan.*

FAO (2004). A Cassava Industrial Revolution in Nigeria. http//www.fao.org/documents/show/ Accessed 22nd May 2006

FAO (2011). Gobal Food Losses and Food Waste. Study conducted for the International Congress: SAVE FOOD at Interpack 2011, Dusseldorf Germany.

FAO (2019). Food Loss and Food Waste. http/www.fao.org/food-loss-and-food-wase/en. Accessed 27th October 2019.

Haruna, S. A., **Adejumo, B. A**., Ismail, A. D. & Okolo, C. A. (2015). Nutritional Qualities of Gari Stored in Specialised Warehouse of the Strategic Grain Reserve Silo Complex Minna, Nigeria. *International Journal of Engineering Research & Technology* (IJERT) 4 (5), 216-221

Haruna, S. A., **Adejumo**, **B. A.,** Chinma, C. E., Akanya, H. O. & Okolo, C. A. (2018). The Influence of Drying Temperature on Selected Properties of Flour Produced from Orange Fleshed Sweet Potato Tubers. *International Journal of Engineering Research & Technology* (IJERT) 7 (7), 338-341.

Irtwange, S. V. (2005). Application of Modified Atmosphere Packaging and Related Technology in Postharvest Handling of Fresh Fruits and Vegetables. *Proceeding of the 6th International Conference and 27th Annual General Meeting of the Nigeria Institution of Agricultural Engineers.* 27: 226-235.

Marczak, K. B., Barbara, S., Jacek, S., Tomasz, C. & Katarzyna, P. (2014). Nutrition Value of the Sweet Potato ( *Ipomoea Batatas* (L.) Lam) Cultivated In South–Eastern Polish Conditions. *International Journal of Agronomy and Agricultural Research* (IJAAR), 4 (4), 169-178.

Mijinyawa, Y., Ogedengbe, K., Ajav, E. A. & Aremu, A. K. (2000). Introduction to Agricultural Engineering. Stirling–Horden Publishers (Nigeria) limited, Ibadan, Nigeria. 57 pages

Nwaigwe, J. O. & **Adejumo, B. A.** (2015). Qualities of African Breadfruit (*Treculia Africana*) Seed Flour as Influenced by Thermal Processing Methods and Duration. *International Journal of Technology Enhancements and Emerging Engineering Research* (IJTEEE). 3 (4), 102 – 108. www.ijteee.org

Obasa, P. A. & **Adejumo, B. A.** (2017). Development of an Automated Fuzzy Logic Controlled Reactor for Production of Oleo-Chemical. *Proceedings of the 18th International Conference and 38th Annual General Meeting of the Nigerian Institution of Agricultural Engineers*, (UMUDIKE, 2017), October 3-6, 2017, Umudike, Nigeria. 38, 10-14.

Ogunbiyi, M. O. (2011) Assessment of Postharvest Handling and Quality Control Practices of Rice in North Central Nigeria: A Case Study of

Lafia, Nasarawa State. *Journal of Developments in Sustainable Agriculture* 6(2), 143-163

Ogunbiyi, M. O., **Adejumo**, **B. A**., Gbabo, A. and Chinma, C. E. (2017). Development of an Improved Mini Rice Paddy Parboiler. *Journal of Science, Technology, Mathematics and Education* (JOSTMED), 13(4), 37- 44.

Ogunbiyi, M. O., **Adejumo**, **B. A**., Gbabo, A. & Chinma, C. E. (2018). Optimisation of Parboiling Process using Response Surface Methodology (RSM) to Improve the Physical Properties of Parboiled Milled Rice. *International Journal of Engineering Research & Technology* (IJERT) 7 (7), 312 - 318. www.ijert.org

Ogunbiyi, M. O., **B. A**. **Adejumo**, A. Gbabo & Chinma, C. E. (2019a). Comparative Analysis of the Physicochemical Qualities of Milled Rice Processed with Traditional and Improved Parboiling Methods in Nigeria. *International Journal of Engineering Research and Technology* (IJERT). 8 (7), 97 -102. www.ijert.org

Ogunbiyi, M. O., **Adejumo**, **B. A**., Gbabo, A. & Chinma, C. E. (2019b). Physical and Cooking Qualities of Milled Rice Parboiled at Optimal Conditions for Three Selected Rice Varieties In Nigeria. *International Journal of Food Science and Nutrition*, 4 (4), 99-105. www.foodsciencejournal.com.

Okolo, J. C. & **Adejumo, B. A.** (2018). Functional Qualities of Thermally Processed Finger Millet (*Eleusine Coracana* L. Gaertn) Flour. *International Journal of Research in Engineering and Science (IJRES)* 6 (5), 22-26. *www.ijres.org*

Ola, F. A. & **Adejumo, B. A.** (2009). The Assessment of Losses at various Stages of *Gari* Production. *Science Focus: An International Journal of Biological and Physical Sciences* 14 (4), 496-501.

Olaniyan, M. A. (2010). Effect of Extraction Conditions on the Yield and Quality of Oil from Castor Bean. *Journal of Cereals and Oilseeds*, 1(2), 24-33.

Raji, A. O., **Adejumo, B. A.** &. Obasa, P. A. (2016). Effect of Drying Methods and Storage Duration on the Proximate Composition of Fluted Pumpkin Leaves. *Proceedings of the 37th National Conference and Annual General Meeting of the Nigerian Institution of Agricultural*

*Engineers,* (MINNA, NIAE 2016), October 4-7, 2016, Minna, Nigeria. 37, 39-43.

Renu, S., & Sarita, S. (2015). Functional Properties of Finger Millet and Barnyard Millet Flours and Flour Blends. *International Journal of Science and Research (IJSR)* 6 (6), 775-780. www.ijsr.net

Sailaja, R. R. N. & Chanda, M. (2001). Use of Melaic Anhydride Grafted Polyethylene as Compatibilizer for HDPE: - Tapioca Starch Blends: Effects on Mechanical Properties. *Journal of Applied Polymer Science*, 80, 863-872.

Sirisomboon, P. and Kitchaiya, P. (2008). Physical Properties of *Jatropha Curcus* L. Kernels after Heat Treatments. *Journal of Biosystem Engineering*, 102 (2009), 244-25

Tunde-Akintunde, T. Y. (2008). Effect of Soaking Water Temperature and Time on Some Rehydration Characteristics and Nutrient Loss in Dried Bell Pepper. Agricultural Engineering International: the CIGR Ejournal. Manuscript FP 08 013. Vol. X. October, 2008. 1-7

UNDP (2019). Goal 12: Ensure Sustainable Consumption and Production Patterns. http/www.un.org/sustainable development-consumption-production. Accessed 20th October 2019

## PROFILE OF PROF. BOLANLE ADENIKE ADEJUMO

Bolanle Adenike Adejumo (Nee Adeyemo) was born in Kaduna on the 23rd March 1970 to the family of Deacon Isaac Adepoju Adeyemo and late Mama Rachael Adunola Adeyemo. She had her primary school education at Ja'afaru Estate Primary School, Kabala, Costain, Kaduna and her secondary school education at the Queen Elizabeth Secondary School Ilorin, Kwara State. She proceeded to University of Ilorin in 1989, where she graduated with the Bachelor in Engineering (B. Eng) Agricultural Engineering in 1995. After her, NYSC in Awe LGA of Plateau State now in Nasarawa State, she worked briefly as an Agricultural Science teacher at Bishop James Yisa Secondary School, Suleja.

In 2000, she proceeded to University of Ibadan for her Masters in Agricultural Engineering (Farm Power and Machinery) which she obtained in 2001. She then worked as a teacher with the Kano State Government before proceeding back to the University of Ibadan for her PhD, which she obtained in Agricultural Crop Processing in 2010. Bolanle was first appointed as an Assistant lecturer in the Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso on the 5th May 2005, she was upgraded to Lecture II in 2007 and Lecturer I in 2009. She joined the services of the Federal University of Technology, Minna on the 1st October 2011 as a Lecturer I in the Department of Agricultural and Bioresources Engineering. She was promoted to the rank of Senior Lecturer on the 1st October 2012, Associate Professor on the 1st October 2015 and Professor on the 1st October 2018. She has successfully supervised 2 PhD and co-supervised 3 PhD students as well as 15 masters' students. She has 64 journal articles and 32 conference proceedings to her credit. She is a reviewer for several National and International journals. Bolanle Adejumo attended a short course on Product Quality and Food Safety at the PTC+ in the Netherlands in 2013

Professor Adejumo has held several administrative positions as level Advisor (2005 – 2011), Postgraduate Coordinator (2012 – 2013), Head of Department (2013 –2017) and member of senate. She has served in several committees with the School of Engineering and the University. She is an external examiner to Department of Food Science and Engineering and Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso. She is a registered Engineer with Council for the Regulation of Engineering in Nigeria (COREN), member American Society of Agricultural and Biological Engineers (ASABE), Nigerian Society of Engineers (NSE) and Nigerian Institution of Agricultural Engineers (NIAE).

She is happily married to Pastor Engr. Oluwarotimi Enitan Adejumo.