LEVERAGING FOOD SECURITY CHALLENGES IN NIGERIA:

THROUGH AGRICULTURAL PRODUCTION, PROCESSING AND STORAGE FOR MITIGATING ECONOMIC RECESSION

33rd INAUGURAL LECTURE

Of the Federal University of Technology Owerri

Delivered on: Wednesday, 24th October, 2018.

BY

ENGR. PROF. SABBAS NWABUEZE ASOEGWU

B.Sc. Hons (UNN), M.Sc. (Ife), Ph.D. (FUTA)

FNIAE, FNSE, MASABE, MISTRO, COREN R.

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PROTOCOL

The Vice-Chancellor

Deputy Vice-Chancellors (Academic, Administration, and Research, Development and Innovation)

Registrar, Librarian and Bursar

Members of the University Senate

Deans and Directors

Distinguished Professors

Heads of Departments and Coordinators of Units

His Royal Highnesses and Majesties,

My Lords Spiritual and Temporal

Distinguished Professionals and Academic Colleagues

Members of all Unions in the University (ASUU, SSANU, NASU, NAATS)

Distinguished Alumni of the University (Great FUTOITES at home and in diaspora)

Invited Guests here present and those unable to attend

Members of the Fourth Realm - the Press

Distinguished Ladies and Gentlemen

PREAMBLE

It is a great honor and privilege that I most humbly present this 33rd Inaugural Lecture. It is by the special grace of God that this is possible today. May He take all the glory, honor and thanksgiving in the Mighty Name of Jesus. I will like to appreciate the Chairman, Prof. F. C. Eze, the Vice Chancellor, and his management team for permitting and sponsoring this lecture. The efforts and sacrifices of the Chairman and members of the University Lecture Series Committee are also appreciated. But above all, let me appreciate all of you who are here present to listen to what I intend to say. You all are making this occasion special and splendid. I thank you all.

Mr. Vice-Chancellor, Sir, after my Division One in WASC in 1966 at St Aidan's Secondary School, Umuezeoka, Abakaliki, I enrolled for Higher School Certificate (HSC) in 1967 to study Pure Mathematics, Applied Mathematics and Physics with a minor in Metaphysics at Mary Knoll College, Okuku, Ogoja. With the war, I joined the Biafran Army and was engaged in the 57th Bridgade. At the end of the war, I continued the Higher School Certificate (HSC) program at College of Immaculate Conception (CIC) Enugu in 1970 graduating in 1971. Taught a while at St Augustine's Seminary Ezzamgbo, now in Ebonyi State, moved to the then Post and Telecommunication Department, Enugu (P&T) as an Assistant Technical Officer (ATO) in training, The work ended when I got admission in 1972 to study Agricultural Engineering at the University of Nigeria Nsukka (UNN) and to University of Ibadan (UI) to read Mathematics/Physics combined honors by direct entry. With a Federal Government scholarship to read Physiotherapy, my efforts to get admitted into UI's College of Medicine failed because I neither did Chemistry nor Biology in HSC. With my application for change of scholarship and the instrumentality of my senior uncle Surveyor Prof. Romanus Nnubia Asoegwu (now late), my scholarship was converted from Physiotherapy to Agricultural Engineering at UNN. That is where this journey began in 1972.

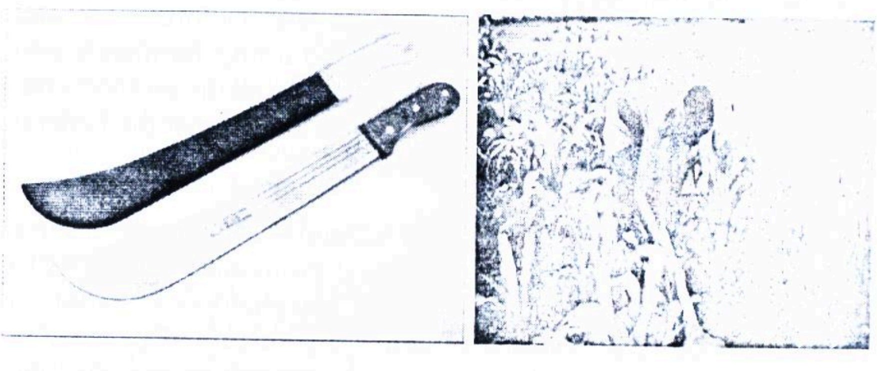
On graduation in 1976/1977, I did my National Youth Service Corp (NYSC) at the Engineering Division of the Nigerian Institute for Oil Palm Research (NIFOR). There, we were involved in the design and fabrication of systems and processes for the production, processing and storage of oil palm and oil palm products. It was then that the first bottled palm wine "Emu" was made and introduced into the market. We also installed a high capacity turn-key automated oil mill, the first of its kind in Nigeria and West Africa. At the end of the NYSC in 1978, I started as a Pupil Research Officer at the National Horticultural Research Institute (NIHORT) and rose to the rank of Senior Research Officer. In NIHORT, I was involved with research activities in irrigation, tillage, estimation of input effects on production of horticultural crops as well as the development and maintenance of systems and processes for their production, processing and storage. I enrolled at the University of Ife (now Obafemi Awolowo University, OAU) in 1979 for my M.Sc. in Agricultural Engineering graduating in 1981. Between 1982 and 1986, I was the officer-in-charge of NIHORT sub-Station at Mbato, Okigwe, Imo State. There at Mbato, we were able to establish orchards and plantations of various horticultural crops (exotic and indigenous), maintained them for optimum productivity using state-of-the art agricultural engineering technologies. In February 1987 I left NIHORT to join Imo State Agricultural Development Corporation (ADC) at Nekede as a Principal Agricultural Engineer in charge of the Engineering Division overseeing the engineering activities of the Corporation in the old Imo State, under the Managing Directorship of Mr. Okechukwu Anyim. We were able to rehabilitate and make functional many oil palm plantations and oil mills, rubber plantations and factories, cashew plantations and established the crumb rubber factory at Nekede that produced and exported the first ever processed rubber from Eastern Region, with Dr. F. Uzu, as consultant. The Livestock section with its battery cages, incubators and feed mill were brought back to live and people from Owerri and environs found a cheap and steady market to buy livestock products and other agricultural products.

It was from Imo ADC that I joined the services of the Federal University of Technology, Owerri (FUTO) in October 1987 as a Lecturer 1 in the then Department of Agricultural Engineering now Department of Agricultural and Bioresources Engineering. That I am standing here today is because of that move from ADC to FUTO where I had risen virtually from the ranks to be what I am today, by the grace of God, and the instrumentality of many of you here present. I thank you all.

1.0 INTRODUCTION

Nigeria today is in recession and there are serious food security challenges. When between 1970 and 1980 the price of crude oil increased tenfold to $30 per barrel, oil producers were swimming in windfall revenues and spending at record rates (The Economist, 2003). In 1975, Juan Perez Pablo Alfonso, Venezuela's oil minister in the early 1960s and the co-founder of OPEC voiced a contrary opinion of the "blessing" of oil and called petroleum the "devil's excrement" for it brings trouble, waste, corruption, consumption, and makes public services to fall apart. Some of us here are very much aware that a Nigerian Head of State was quoted as saying "our problem is not the money but how to spend it". As the 1980s and 1990s progressed, Alfonso's quote turned out to be prescient, and the "oil curse" was born in Nigeria. For Nigeria to shake off "the oil curse" is to increase economic diversification thereby providing alternatives to the vagaries of oil-related economic activities through revitalizing the agricultural sector which held the vibrant Nigerian burgeoning economy before the "oil curse" and could hold the key now, subsequently diluting the impact of the "oil curse" on Nigeria's economy (Spencer, 2012). In order to encourage needed development in the agricultural sector, the Nigerian government should focus on supporting smallholder farms, increasing productivity, and improving rural infrastructure. Achieving this feat calls for more cohesive local agricultural value chains that leverage technology, processing, manufacturing, and industry to transform raw materials into sophisticated semi-finished and finished products, ultimately earning farmers higher and more stable incomes. While Auty (1993) first used the term "resource (oil) curse" to describe how countries blessed with great natural resource wealth seem to have problems translating their blessing into higher performing economies, especially when compared to countries not similarly gifted with this resource wealth, Ross (2012) called it "Dutch Disease" defined as the process by which a surge in a country's natural resource sector causes a rise in the prices of domestically-produced agricultural and manufactured goods. This may, in effect, be the starting point of economic recession in Nigeria.

Recession is the **decline in economic activity:** a period, shorter than a depression, during which there is a decline in economic trade and prosperity. It has a direct link with food security and poverty. Most Nigerian farmers, over 75% of the rural dwellers, are hard-working and industrious, but lack the money to buy the food; produce the food; and, or even the money to procure the small piece of land to grow the food, and cannot purchase some affordable modern agricultural techniques or simple machines and tools. So food availability becomes a problem because of poverty, which hinges on recession. Most Nigerian farmers are still making use of outdated manual farm tools - like cutlass and hoe (Fig. 1) - as their fore-fathers used to.



(a) **(b)**

Fig. 1: Some hand tools: (a) cutlass, (b) hoe

Though arable fertile agricultural lands are available with favourable climatic conditions, the nation has not been able to translate these to increased food production. With over 90% of agricultural production in Nigeria been rain-fed and at subsistence level, the smallholder-farmers account for over 80% of all farm holdings. This makes crop and livestock productions remain below potentials. Even for the products produced, there is lack of adequate food storage, preservation or processing facilities. There are other problems of agriculture in Nigeria which include: illiteracy (rural farmers are uninformed in modern agricultural education and non-use of native languages in pursuit of modern education); ignorance (most Nigerians see agriculture as a poor man's backyard business and not as an agro-business); lack of essential amenities such as roads, water, electricity, medical facilities in the rural areas; lack of food storage and processing facilities (to mitigate waste of agricultural produce); lack of appropriate scientific and technological know-how for indigenous agricultural production; disorganization of farmsteads and non-accountability of farm operations. Nigeria's agriculture lacks appropriate leadership, is strut with mismanagement, corruption and embezzlement and lacks patriotism, trust and honesty. There is lack of agro-industries and agro-businesses by private entrepreneurs because of poorly articulated and implemented government policies. Climate change and greenhouse gas emissions impinge on the environment, which aggressive expansive agricultural activities can thoroughly mitigate. Deforestation and overgrazing by free range cattle rearing is turning farmlands into deserts and also cause erosion. These may not be all the problems but let's keep these in view as we turn our attention to what the Federal Government plans to do about agriculture.

Mr. Vice Chancellor, Sir, the Buhari's Administration hopes to solve the above problems using the Agricultural Promotion Policy (APP) (FMARD, 2016) by working with key stakeholders to build an agribusiness economy, capable of delivering **sustained prosperity** by meeting domestic food security goals, generating exports, and supporting sustainable income and job growth. In this regard, of the five specific objectives for the period 2016 – 2020, I am more concerned with growing the agricultural sector two folds, adding value to the products of agriculture as well as meet the food security, food safety and quality nutrition obligations of government. These will drive job growth, create wealth and enhance the nation's gross domestic product (GDP). However, government must streamline her policy framework, have the political will to implement the policies, advance agricultural technology and infrastructure, provide access to financial services, and put in place institutional reforms to clarify mandates and ensure accountability.

You may recall, Mr. Vice Chancellor, Sir, that during the 28th Inaugural Lecture here in FUTO, Onyeka (2016) posed three pillars of food security – availability of food, food access and food use and opined that food security should not be seen only from the perspective of these three but that food hygiene and safety should be given important consideration. Yes, I agree with her because quantity, quality, hygiene and safety of food are perspectives of agricultural production, processing and storage. Food security, to me, should among other things introduce technologies to increase agricultural productivity at the farm and processing levels, decrease post-harvest losses and introduce low-cost innovations for food production, storage, and preparation so that the food consumed by the populace is mostly produced locally with minimal importation. I may make further to describe food security not only as the availability of the food, but also as the ability to purchase the food. Food security could now mean having a ***reliable*** source of food and ***sufficient*** resources to purchase it. Ndirika (2016) stated that food security is the availability and accessibility of food of adequate quantity and quality to every household in a nation. However, for Adekanye and Ojediran (2013) food security is currently a fundamental issue in Nigeria as the country faces serious challenge in meeting the food needs of her growing population. Because of this challenge, Mr Vice Chancellor, we will be discussing the topic titled:

"LEVERAGING FOOD SECURITY CHALLENGES IN NIGERIA: THROUGH AGRICULTURAL PRODUCTION, PROCESSING AND STORAGE FOR MITIGATING ECONOMIC RECESSION".

1.1 Leveraging:

In Mechanics, leveraging is the action, by a pivot or fulcrum, that influences a system, or an environment in such a way that a small effort is multiplied to greater effects or results. In this Lecture, we are going to use Agricultural Production, Processing and Storage at one end to leverage food security challenges at the other end for mitigating economic recession. (What then is the fulcrum or pivot?) If you ask me, I would say that the Agricultural/Bioresources/Biological engineers and associated agricultural and other professionals are the pivot for the leveraging action. Science, Technology and Engineering must play the key role for leveraging food security challenges in Nigeria.

1.2 Food Security Challenges

According to Metu *et al.* (2016), the World Bank (2012) estimated the population of Nigeria to be above 160 million people, and increasing with increasing demand for food. Since domestic food production has failed to meet up with increasing food demand, World Development Indicator (WDI, 2016) gave Nigeria's food import as increasing from 19.9% in 2000 to 30.6% and 32.7% in 2011 and 2012, respectively (Vaughan *et al.*, 2014). This is a major challenge to food security in Nigeria which has caused tremendous hardship. To me, the worst food security challenge is the fast disappearance of our local indigenous foods like *akidi, anyu, ede, ukwa-oyibo, ugboguru,* etc.

1.3 Causes of Economic Recession in Nigeria

According to Noko (2016), economic recession is typically accompanied by a drop in the stock market, an increase in unemployment, slowing economy, reduction in industrial output, high inflation, negative agricultural growth, voluntary cut in production, lay-offs, reduction in wages, shutting down of companies etc. Our consumerist economy has been forecasted by Vaughan *et al.* (2014) for 2015 and 2020 and shown in Table 1. Also Table 2 shows the **Real Structure of the Nigerian Manufacturing Sector as captured by the RTC Advisory Services Ltd. Lagos, Nigeria in October 6, 2016.**

Table 1. 2015 and 2020 Food imports forecast for Nigeria. '000MT

Commodity	2015	2020
Wheat	4,294.51	5,035.58
Fish	3,917.06	4,648.20
Rice	1,296.25	1,380.55
Sugar	752.17	774.72
Prepared vegetables, etc.	363.79	480.59
Prepared cereals	362.47	466.08
Milk	93.63	120.58

Source: Vaughan *et al.* (2014)

Table 2: Real structure of the Nigerian manufacturing sector

Sector	**Percent**
Oil Refining	1.73%
Cement	9.08%
Food, Beverage and Tobacco	43.32%
Textile, Apparel and Footwear	22.69%
Wood and Wood Products	3.31%
Pulp, Paper and Paper Products	0.82%
Chemical and Pharmaceutical Products	2.38%
Non-Metallic Products	4.06%
Plastic and Rubber products	3.71%
Electrical and Electronics	0.06%
Basic metal, Iron and Steel	2.63%
Motor Vehicles & assembly	0.78%
Other Manufacturing	5.40%

Source: RTC Advisory Services Ltd. Lagos, Nigeria in October 6, 2014

The forecast in Table 1 is frightening and it will only take planning and appropriate action in the agricultural sector to re food importation in Nigeria. In Table 2, food, beverage and tob (43.32%), textile, apparel and footwear (22.69%) and wood wood products (3.31%) amounting to about 70% of the real stru of the manufacturing sector of the Nigerian economy is dependent on agriculture. Strengthening the agricultural sector to develop will have an exponential impact on the manufacturing sector, for not only leveraging food security challenges but also mitigating economic recession.

The causes of economic recession in Nigeria are: poor economic planning; high inflation rate; high interest rate; high taxation and policy conflict. There is reduced consumer confidence in the economy, reduced real wages as worker's paycheck is not keeping pace with inflation, thus reducing his/her purchasing power. For most workers, the take-home pay does not reach home. The high percentage differences in prices of some common food items in the market between 2015 and 2017 (Table 3) speaks volume of the problem at hand.

Table 3: Consumer prices of some commodities

Commodity	May 2015	May 2016	May 2017	%? (2015 -2017)
Tomato (Basket)	N12,000	N45,000	N30,000	150
Pepper (Basket)	N16,000	N20,000	N45,000	181
Yellow Garri (50kg)	N11,000	N18,000	N30,000	173
Rice (50kg)	N9,000	N14,500	N18,000	100
Beans (50kg)	N15,000	N16,000	N35,000	133
Onions (Basket)	N4,000	N10,000	N6,500	62.5

Source: http://educacinfo.com/economic-recession-nigeria/ & **Asoegwu** (2017a)

1.4 Economic Recession Mitigation

In order to mitigate economic recession, Muonye (2016) opined that government needs to itemize specific actions and drive performance which the populace can identify to enhance confidence to re-initiate growth and investment. She should expand her tax base and cut taxes to encourage investment; re-invest extra funds to increase productivity and take proactive measures to reflate the economy.

To really attempt to mitigate economic recession in Nigeria, the first shot should be on agriculture. Agriculture is becoming a hotbed for entrepreneurs with new ideas for higher-quality products and advanced methods, sustainable processes in food production and distribution, integrated supply chains, value-added exports, and a variety of other lucrative business opportunities. Some examples abound in Nigeria: N10billion Africa largest rice mill in Kebbi; N30billion Africa largest feed mill in Kaduna; Dangote 250,000 metric tons rice mill in Kano; Biggest poultry farm in Olam, Kaduna State; Obasanjo Farms Nigeria (integrated farm) in Otta, Ogun State; etc. This is the way Nigerian entrepreneurs should be going to bring Nigeria out of recession. However, focus should also be directed towards empowering smallholder farmers as our younger entrepreneurs are pursuing opportunities along the value chain despite a myriad of constraints including a difficult business terrain, unavailability of inputs (fertilizer and improved seeds), lack of access to finance and insurance, high taxes, poor transport networks, few advanced technology options, absence of affordable field equipment, lack of access to markets, and a dearth of quality extension, advisory, and training services. In order to solve some of these problems, the agricultural/biological/bioresources engineering profession and the agricultural/biological/bioresources engineer have a lot to contribute.

2.0 AGRICULTURAL AND BIOLOGICAL/ BIORESOURCES ENGINEERING

Agricultural and Biological/Bioresources Engineering is the discipline of engineering that applies engineering principles and the fundamental concepts of biology to agricultural and biological systems and tools, for the safe, efficient and environmentally-sensitive production, processing, and management of agricultural, biological, food, and natural resources systems (ASABE, 2008). Agricultural and Biological Engineering combines the principles of mechanical, civil, electrical and chemical **engineering** with knowledge of **agricultural** and biological principles to design machinery and to improve the existing techniques that are being used in agricultural production, processing and storage.

Asoegwu and Asoegwu (2007) asserted that science and technology, through farm power and machinery among other technologies "interrogates and integrates" the essence of agriculture as a way of life, occupation or business; the timing of crop and animal production; and the art of their production through acquired skill and practice. This way humanity is rescued from drudgery and the dignity of the farm worker improved (**Asoegwu**, 2017b)

According to Onyekwena (2006), the role of the agricultural and biological/bioresources engineering discipline is to provide engineering solutions to agricultural production, processing and storage problems. Agricultural and biological/bioresources engineering is vital to agriculture, agriculture itself is central to industrial production through supply of needed raw materials which agricultural and biological/bioresources engineering processes and stores. Agricultural and biological/bioresources engineers develop appropriate machines, systems and processes that would facilitate the emergence of strong agricultural, industrial and technological bases that would mitigate economic recession in Nigeria. These machines, systems and processes that conserve energy, reduce drudgery, increase production and enhance efficient and economic production, processing and storage are in the purview of the agricultural and biological/bioresources engineer.

i. Agricultural and biological/bioresources engineers interested in farm structures, design and build better animal shelters to house animals and barns for farmers to store crops/grains, building dairy effluent schemes, housing environments that improve the health of livestock. Agricultural engineers interested in areas that deal with rural electrification help with the improvement of electric power and renewable energy sources and analyze power distribution systems that concern machinery for preserving, processing and storage of crops. Plan and direct construction of rural electric-power distribution systems.

ii. Agricultural and biological/bioresources engineers in soil and water conservation design better watersheds or analyze soil and expand irrigation and drainage systems, and maintain and manage these systems. They provide solutions to water quality issues, and flood control systems for soil and water conservation. Agricultural engineers design sensing, measuring, and recording devices, and other instrumentation including computer-aided design technology used to study plant or animal life and also collect data on agricultural product processing and environmental impact and use research results to improve the relevant factors.

iii. Agricultural and biological/bioresources engineers design and test agricultural machinery, food processing plants, packaging, transporting, and distributing the food and fiber products, and many other solutions that impact both farming and the food that we eat. Any many more.

Even with the above list of what agricultural and biological/bioresources engineers can do, most organizations including governments in Nigeria do not patronize agricultural and biological/bioresources engineers. The post of agricultural and biological/bioresources engineers is not advertised even for agricultural mechanization projects and services because of their lack of adequate knowledge of what agricultural engineers can do. Even where these engineers respond to such adverts, they are not shortlisted, considered or favored. This is a serious disadvantage to our profession despite several public enlightenment campaigns and the many exploits of agricultural engineers in Nigeria and around the globe. This is seriously militating against our quest for agricultural sustainability and economic emancipation in this country. **Therefore, there should be a wholesome policy instrument to support the agricultural engineering profession and professionals in Nigeria if she would mitigate economic recession and overcome food security challenges.**

3.0 AGRICULTURAL MECHANIZATION IN PERSPECTIVE

According to Odigboh (1985), in the face of soaring labor costs and the unfavorable position of agriculture as a competitor for labor among numerous dynamic and more lucrative sectors of the Nigerian economy and, faced with the ever increasing aversion of Nigerian youths to the drudgery, indigence and indignity of old-fashioned muscle-power subsistence agriculture, mechanization has been recognized as the missing input needed to accelerate agricultural production in Nigeria. Agricultural mechanization may be defined as the application of agricultural engineering principles and technology in crop and animal production, processing and storage. Mechanization uses hand-, animal-, or engine-powered machines, equipment, processes and facilities necessary for producing food, feed, fur, fuel and fiber. Mechanization increases power input into agriculture; improves quality of field operations; reduces production cost and increases labor productivity; reduces losses and improves product quality (**Asoegwu,** 1998).

According to **Asoegwu** (2001), agriculture involves operations that depend primarily on the application of power (power-intensive or control-intensive) (The World Bank, 1987). The power-intensive ones which are usually the first to be mechanized include land preparation, transport, milling, grinding etc. and control-intensive ones are weeding, pest control, etc. Those with intermediate power intensity such as harvesting and secondary tillage are the next to be mechanized followed by the control-intensive operations. There is a viable alternative source of power in Nigeria. Nwakuba, Chukwuezic and **Asoegwu** (2016) posited that Nigeria generates about 542.5 million tons of wastes from crops and animals annually. These have the potential of generating about 25.53 billion m^3 of biogas (about 169,542.66MWh of energy) and 88.19 million tons of bio-fertilizer per annum. This gives the biogas the capacity to completely displace the use of kerosene and coal for domestic cooking and even reduce the use of fuel wood by about 66% in Nigeria, as well as providing cleaner and healthier environment with very little contribution of greenhouse gases (GHG) in the atmosphere. **The adoption of biogas can ease the financial strain of fossil fuel subsidy, stand in for the constant power failure and take over from the limited and over-stretched fossil fuel resource. It has the potential to contribute over N4.54 trillion ($29.29 billion) to the Nigerian economy annually.**

In the light of these, Mr. Vice Chancellor, our agriculture needs the application and control of power in several forms, the use of growing variety of materials and the improvement in the technical processes required to raise agricultural productivity and efficiency and to reduce its requirement of human labor. This is the main thrust of agricultural mechanization which has been saddled with many constraints.

4.0 CONSTRAINTS OF FARM MECHANIZATION IN NIGERIA

The problems of agricultural mechanization in Nigeria are many. Some of these are: i) there are many small fragmented farm holdings which hinder efficient use of equipment and machinery; ii) we have abundance of primitive agronomic/cultural practices (e.g. multiple cropping, crop rotation, mixed cropping) which limit the scope and efficiency of machinery to be adapted for use; iii) there are problems of soil conservation and soil fertility, pests and diseases; iv) the technical know-how on machine-soil fertility relationships and suitability as well as machine-crop adaptability and performance, are lacking; v) inadequate repair and maintenance facilities to put the machines and implements operable; vi) there is little financial muscle (in terms of credit) to enable the illiterate and conservative farmers purchase agro-technological inputs; vii) there are absence of incentives for indigenous design and manufacture of equipment; viii) there are unstable, uncoordinated agricultural and industrial policies of Government; ix) Government pronouncements are insincere with almost an utmost disregard to the many problems of agriculture.

They above problems are too complex and too sophisticated for the armament and arsenals of hand hoes, machete and similar tools which form the only weapons available to the army of traditional, aged and ageing peasant farmers (Odigboh, 1988). The farmers need simple, cheap, modified and user-friendly designs of these traditional implements. The tractors, combine harvesters and the other sophisticated, though efficient equipment, that could otherwise be used, are either not adapted to our environment, too costly to acquire or too technical and sophisticated for farmers to use and maintain (Yiljep *et al.*, 1995). These lower the rates of mechanization in Nigeria and limit farm and labor productivities. **There is the need for suitable, reliable and affordable access to mechanization when it**

comes to accelerating agricultural growth in Nigeria. However despite the push for an increase in mechanization, uptake o machinery by both small- and medium-scale farmers remains low due to paucity of funds.

5.0 NIGERIAN AGRICULTURAL POLICY THRUST

To refocus the agricultural sector, the Government in 2010-201 implemented a strategy tagged the Agricultural Transformation Agenda (ATA) whose core purpose was to help turn Nigeria' attention on agriculture based on a productivity challenge driven by an input system and farming model that is largely inefficient. Fo 2016 -2020, the Federal Ministry of Agriculture and Rura Development (FMARD) initiated a new policy called the Agricultur Promotion Policy (APP) to tackle the two identified gaps facing th Nigerian agriculture: 1) inability to meet domestic food requirement and 2) inability to export at quality levels required for market success The latter challenge is driven by an equally inefficient system fo setting and enforcing food quality standards, as well as poo knowledge of target markets (FMARD, 2016).

Crops identified as priority crops for productivity improvemer include rice, wheat, maize, fish (aquaculture), dairy milk, soya beans poultry, horticulture (fruits and vegetables), and sugar. The ones to b promoted for export markets are: cowpeas, cocoa, cashew, cassav (starch, chips and ethanol), ginger, sesame, oil palm, yams horticulture (fruits and vegetables), beef and cotton. Partnerin closely with private investors across farmer groups and companies processors and other stakeholders, the FMARD will develop end t end value chain solutions, deepen the supporting infrastructure t ensure that quality standards are defined and maintained across th value chain. These measures would improve the distribution syster for fresh foods so as to reduce time to table, reduce post-harves losses, and improve overall nutritional outcomes. FMARD's goal to build a high quality brand for Nigerian foods, protect food safet for both domestic and export market consumers, and move Nigeria agriculture from "a small business" to a large commercial ecosystem This is to create sustainable jobs and wealth and close the demand supply gaps of some products as shown in Table 4. Gap closing wi also include tackling related input, financing, storage, transport and market access issues present in key value chains (FMARD, 2016) for the following four priorities: food security; import substitution; job creation; and economic diversification.

Table 4: Gaps in Nigeria demand and supply across key crops and activities (2016 Estimate)

Crop	Demand (tons)	Supply (tons)	Observations
Rice	6.3 million	2.3 million	Insufficient supply chain integration remains the issue
Wheat	4.7 million	0.06 million	Driven by demand for various types of wheat (white, hard, durum), etc. for bread, biscuits and semovita
Maize/Corn	7.5 million	7.0 million	Limited imports required but can shift due to feed demand
Soya Beans	0.75 million	0.6 million	Animal feed and protein cost are driving demand
Chickens	200 million birds	140 million	Gap filled by illegal imports that enter market at lower price point than domestic producers; gap also a moving target based on fast food demand
Fish	2.7 million	0.8 million	Fall off in ocean catch and weakness in aquaculture yields due to cost of fish feed a constraint on growth
Milk / Dairy	2.0 million	0.6 million	Driven by insufficient milking cows and low yields (~15-25 liters/day versus normal of 35 – 40 liters/day in NZ/US)
Tomato	2.2 million	0.8 million	Actual production is 1.5 million tons but 0.7million ton is lost to post-harvest handling issues
Yams	39 million	37 million	Limited gap today but volumes expected to rise in planning period
Oil Palm	8.0 million	4.5 million	Refers to fresh fruit bunch (FFB) from which oil is extracted at a 10% - 15% efficiency rate
Cocoa	3.6 million	0.25 million	Demand is global demand which will rise to 4.5million by 2020
Cotton	0.7 million	0.2 million	Demand is for seed cotton and could rise to 1.0 – 1.5 million tons subject to textile sector revival
Sorghum	7.0 million	6.2 million	Demand will rise further as use in feed grows in 2016 – 2020. Import of malt extracts and glucose syrup is currently used to manage gap, hence a commercial threat for Nigerian farmers

Source: FMARD, 2016

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Milk / Dairy	2.0 million	0.6 million	Driven by insufficient milking cows and low yields (~15-25 liters/day versus normal of 35 – 40 liters/day in NZ/US)
Tomato	2.2 million	0.8 million	Actual production is 1.5 million tons but 0.7million ton is lost to post-harvest handling issues
Yams	39 million	37 million	Limited gap today but volumes expected to rise in planning period
Oil Palm	8.0 million	4.5 million	Refers to fresh fruit bunch (FFB) from which oil is extracted at a 10% - 15% efficiency rate
Cocoa	3.6 million	0.25 million	Demand is global demand which will rise to 4.5million by 2020
Cotton	0.7 million	0.2 million	Demand is for seed cotton and could rise to 1.0 – 1.5 million tons subject to textile sector revival
Sorghum	7.0 million	6.2 million	Demand will rise further as use in feed grows in 2016 – 2020. Import of malt extracts and glucose syrup is currently used to manage gap, hence a commercial threat for Nigerian farmers

Source: FMARD, 2016

6.0 SEQUENCE OF AGRICULTURAL PRODUCTION OPERATIONS

Agricultural production operations especially for crops follow a definite sequence with their demand for different amounts of energy. The time required for each operation will vary according to the size and type of power source used. Capacities of different power used in agricultural production are: human (manual by men, women, and children developing a maximum of about 0.06kW (men), 0.048kW (women) and 0.03kW (children); animal (draft by bullocks, buffaloes, camels, donkeys, with power outputs ranging from 0.50kW to 0.80kW/pair); mechanical power [oil/diesel engines (6 – 12kW), power tillers and tractors (14 – 300kW), electrical power (0.5 – 10kW for electric motors); and renewable energy (3 – 30kW for solar energy, 2 – 55kW for biogas, biomass and 0.075 – 0.67kW for wind energy).

Fig. 2 shows different power sources. All these sources of farm power have their own advantages and disadvantages and where they are employed in agricultural production, processing and storage.

Human beings are the main sources of power for operating small tools and implements, and doing manual farm operations. Animal (draft) power, found mainly in the northern region, is used for all types of work including land preparation (tillage), threshing, water lifting for irrigation, transportation, etc. The mechanical power includes tractors, power tillers, stationary diesel/oil engines, electrical power, etc. which are the bedrock of mechanized agriculture. **To successfully utilize mechanical power there is, therefore, the need for improved design, manufacture and use of small-scale farm machinery for soil tilling, crop planting and weeding, within the context of the rural illiterate population and their ability to operate them, to reduce drudgery, increase productivity and profits, improve crop quality, reduce expenses, and leverage food security challenges in Nigeria (Asoegwu,** Nwakuba and Ohanyere, 2018). Electrical power is a clean smooth running source of power whose operating cost remains almost constant throughout its life. Its maintenance and operation are cheap as it needs less attention and care. Electrical power (highly efficient, clean, smooth running, cheap in maintenance and operation) is used mostly to power electrical motors on the farm equipment for water pumping, dairy industry, cold storage, farm product processing, fruit industry and many similar things, and not affected by weather conditions.

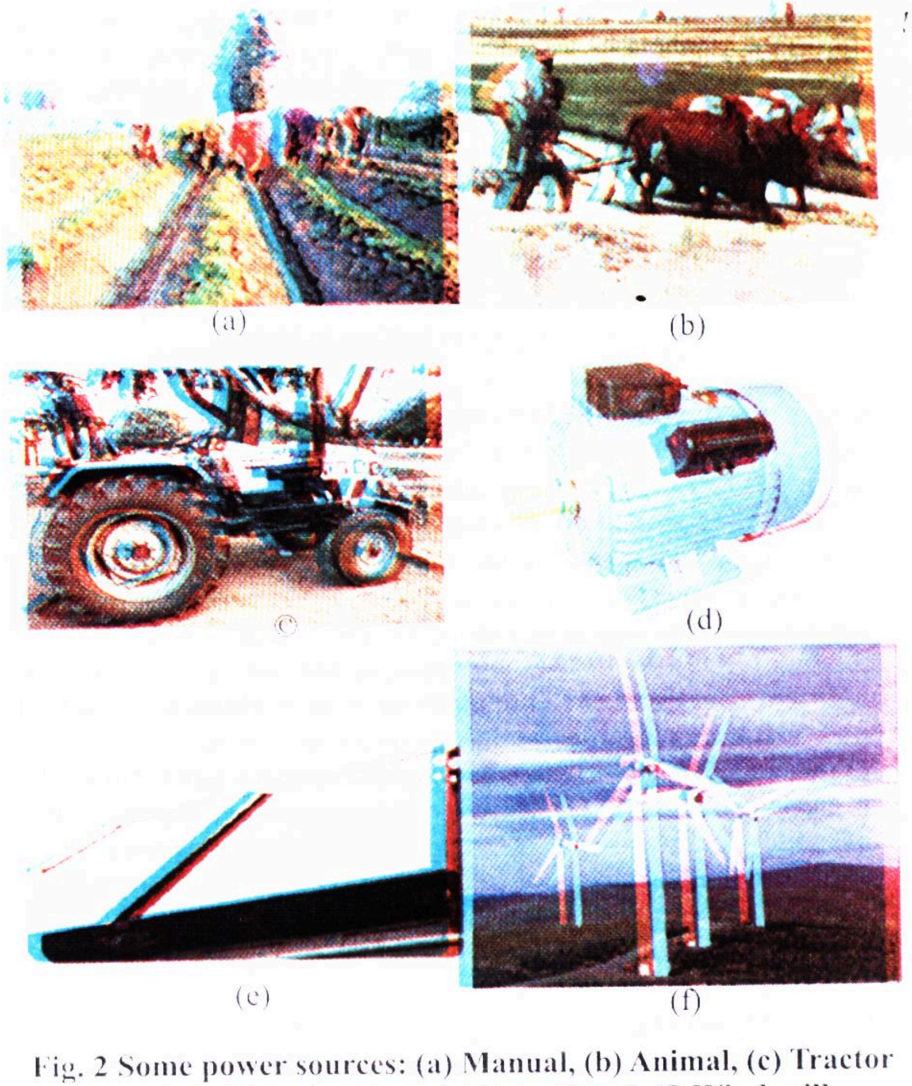

Fig. 2 Some power sources: (a) Manual, (b) Animal, (c) Tractor (FUTO), (d) Electric motor, (e) Solar Panel, (f) Wind mill.

Renewable energy is the energy mainly obtained from inexhaustible renewable sources such as the sun, wind, biomass etc. Biomass energy (from livestock manure, corn cobs, cassava peelings, rice husks, groundnut shells, sawdust, bagasse, human excreta and the resultant biogas), wind energy(from windmills) and solar energy (from solar radiation) are used in agriculture and domestic purposes with suitable devices for lighting, cooking, water heating, space heating, water distillation, food processing, water pumping, and electric generation. There are biofuels derived directly or indirectly from biomass which are used for energetic purposes (Berndes *et al.*, 2003) for cooking and heating. Briquettes are compressed biomass made from sawdust, rice husk, coffee husk, groundnut shells, pulverized mustard stalk, and cotton sticks (Maithel, 2009). They are used mainly for cooking and water heating in boilers.

6.1 Production To Harvesting

Agricultural products have to be produced in large and sufficient quantities, through mechanization, for them to be economically utilized either for direct consumption, sale, storage, or industrial processing. The levels of the mechanization of production and processing contribute significantly to leveraging food security, sustaining livelihood and enhancing the nation's gross domestic product (GDP). **With the potentials of the six (6) agro- or geo-political zones and the enormous favorable climatic conditions and expansive arable land, maximization of agriculture can make Nigeria self-sufficient as a nation, even without crude oil or petroleum.** This will require proper articulation and implementation of good policy instruments, diversification of activities in the agricultural sector championed by private public partnerships (PPP). This way recession will be mitigated and food security challenges overcome.

6.2 Processing

Agricultural processing or value addition produces products with longer shelf-life and better market value (Onwualu, 2006). Value addition is very essential in Nigeria for her to be relevant in the current global economic trends (Saddiqi, 2005) and to mitigate recession.

The agro-processing industries that may be viable in Nigeria may include those for processing:

i. Tuber and root crops: yam, cassava, potatoes, cocoyam etc. into chips, flour, pellets, animal feeds, adhesives, ethanol, starch, etc.

ii. Oil seeds: oil palm, palm kernel, raffia palm, melon, African breadfruit, Avocado pear, African oil bean, castor, coconut, soybean, rubber, etc. into edible and industrial oils, confectionaries, alcoholic drinks, etc.

iii. Grains and cereals: rice, maize, millet, wheat, sorghum, guinea corn, etc. into flour, starch, malt, confectionaries, noodles, ethanol, adhesives, etc. and husks, cobs and stalks for biomass.

iv. Fruits and vegetables: mango. oranges, guava, cashew, banana, plantain, and leafy vegetables like: *Telferia occidentalis* (Fluted pumpkin), *Gnetum africana* (Uziza), *Ocimum gratissium* (Nchanwu), *Cucurbita pepo* (Ugbuguru), *Pterocarpus mildbraedii* (Oha ojii), onions, okra, carrot, pea, cabbage, etc. into fruit juices, powdered spices, puree, ketchup, traditional medicines, etc.

v. Livestock: cow, goat, sheep, pig, chicken, turkey, guinea fowl, duck, pigeon, fish etc. for meat and meat products: for corned beef, sausages, bone crushing, cattle horn craft, biogas production, manures; fish for canned, dried and/or smoked fish; dairy products for milk and milk products, etc.

vi. Wood and forest products: for toothpicks, matches, pencils, furniture, arts and crafts with bamboo and other wood materials and sawdust for briquetting, etc.

6.3 Storage

Storage is the act of storing agricultural goods and the place where they are stored. It is a very important aspect of processing since agricultural products (which are generally perishable) when not used immediately after harvest, are stored. Poor storage is very inimical to industrial processing.

Post-harvest food losses in Nigeria has risen to about $9bn (N2.7tr) annually (Elemo, 2017; Peters, 2017). According to Bolarin and Bosa (2015) post-harvest food losses is one of the greatest threats to food security in Nigeria today with about 52 metric ton of food losses per year. The percentages of these losses for grains, roots and tubers, fruits and vegetables, livestock and fisheries are 15, 35, 50, and 30%, respectively with fruits and vegetables being most vulnerable. Efforts made to reduce post-harvest losses from harvesting to consumption will reduce the need for food importation; increase in food supply; enhance the use of vital resources such as land, labor, water and agricultural input; improve the livelihoods of farmers and agro processors; ensure increased food security. **Food security goes beyond food production to include distribution and marketing, adequate and stable supply, and accessibility to food. For the affordability and availability of the fresh produce to consumers to achieve food security, the stakeholders in post-harvest food chain must synergize to safe-keeping or storage after post-harvest processing**.

However, Mr. Vice Chancellor, the critical question here now becomes "**storage for what**?" The designer of a storage system must see the new dimension in his storage problem. He must need to understand what he is storing the products for. Is the storage for: family use; institutional or public catering; on-farm of food, feed, seed stock; off-farm commercial warehousing; products on transit (trucks, wagons, trains, ships, airplane, etc.); different types of products (fresh vs. dried, living vs. nonliving, solid vs. liquid; human food vs. animal feed, processed vs. unprocessed, direct human consumption vs. factory/manufacturing) and finally storage for different requirements (short-term vs. long-term, mixed-crop vs. mono-crop)? For the agricultural engineer, **Asoegwu** (2006) posited that food storage problems may include: design of storage structures, containers and pellet boxes; selection and installation of storage equipment, materials handling equipment, loading/unloading devices, environmental control equipment, packaging equipment, maintenance of storage hygiene and sanitation and monitoring of product quality in storage. With these, the agricultural engineer will be making tremendous contributions to ensuring food security and mitigating recession as there will be surplus products for human consumption and industrial uses.

Packaging (wrapping) is the science, art and technology of enclosing or protecting a product for distribution, storage and safe use. Traditional wrapping with leaves of banana, plantain, cocoyam, maize, *okpopia (Alchornea laxifora Benth*), coconut, bamboo, miraculous fruit (*Thamatococcus danielli "uma"), Sacophyrynium sp., Marantochloa flexuosa, Tectona grandis, Megaphirinium macrostachymum, Onchocalamas sp., Halea ciliate*, etc. can keep foods such as *moi moi, agidi, okpa, ele le, agbala-ati, ogiri, kolanuts, ugba,* etc. with regards to their packaging properties such as aroma, texture, flavor and taste after fermentation for long periods without going stale and losing taste by reducing contact with air thus prolonging shelf life (Vartan, 2010; Viswanathan, 2017).

7.0 MY CONTRIBUTIONS TO AGRICULTURAL PRODUCTION, PROCESSING AND STORAGE

Agriculture is a complex system comprising soils, crops, livestock, climate, people, watersheds, irrigation, machineries, equipment and other elements which must interact together. To understand the system, simulation modeling is an important tool. It helps to understand how the system works and the implications of the decisions made on the system. In short, it formalizes our conceptualization of the system based on the fact that our personal judgment may lead to inaccurate assessment. The above assertion has made this Inaugural Lecturer to literally focus his research efforts on developing model equations in most of his works. These model equations explain the systems being modeled and simplify their conceptualization to make us understand the system better.

7.1 Agricultural Crop Production

Anyim, **Asoegwu** and Anibaloye (1986) designed, fabricated and tested a hand-operated 4-row; chain-driven-seeder-unit Amaranthus seed drill which can seed one hectare per hour. The seed drill was designed to eliminate transplanting shock, save energy and promote timeliness of operation. At a linear speed of 60m/min, seeding rate was 85%, seed distribution and seed depth were more uniform than when the seeds were broadcasted.

7.1.1 Tillage systems and residue incorporation

Asoegwu (1987a) determined the effects of dry grass mulch (4t/ha) and three seedbeds – raised, flat and no-till – on soil moisture, soil temperature, growth and yield of leaf amaranth *(Amaranthus spp.)*. While soil temperature was highest in un-mulched no-till plots, it decreased with mulching, soil pulverization and soil depth due to soil aeration. Soil bulk density and capillary porosity also decreased with loosening of the soil by tillage operations. Soil moisture content decreased with tillage and increased with mulching. **The modification of soil environmental factors of soil temperature and soil moisture by mulch and tillage provided suitable soil conditions for crop establishment, growth and yield of leaf amaranth. Plant establishment at mulched no-till plots was 70% while soil moisture, soil temperature, and yield were 33.8%, 26.7°C and 7.7t/ha, respectively. This makes the mulched no-till system economically feasible under tropical conditions.**

Asoegwu (1987b) compared different tillage systems for the production of egusi-melon (*Colocynthus citrullus*) and okra (*Abelmoschus esculentus* L. Moench) in Eastern Nigeria. Different tillage systems: no-till, minimum, conventional and strip significantly influenced soil parameters (dry bulk density, penetration resistance, porosity, permeability, etc.) as well as fruit and seed yields of the two crops. **Strip tillage was found to produce highest yields due probably to greater aeration to the root systems during the rains, better anchorage of the plants and lower erosion (Table 5) which translated to greater revenue, showing that only essential tillage operations should be carried out to maximize profit from enhanced yield.**

Asoegwu (1992) found that soil properties variations occasioned by tillage operations also affected both root growth and dry seed weight of egusi-melon linearly in the 0 – 100mm soil depth as shown in Equations 1 to 6.

$$Y_1 = 6644.86 - 4156.46X_1 \quad (r = -0.65) \qquad 1.$$
$$Y_1 = 3887.69 - 20.36X_2 \quad (r = -0.80) \qquad 2.$$
$$Y_1 = -571.56 + 33.23X_3 \quad (r = 0.68) \qquad 3.$$
$$Y_2 = 2172.09 - 1267.65X_1 \quad (r = -0.56) \qquad 4.$$
$$Y_2 = 1505.18 - 7.52X_2 \quad (r = -0.84) \qquad 5.$$
$$Y_2 = 50.38 - 8.64X_3 \quad (r = -0.50) \qquad 6.$$

Where Y_1=root length/unit area (mm/mm^2), Y_2=dry seed weight (kg/ha), X_1=soil bulk density (Mg/m^3), X_2=penetration resistance (kPa), and X_3=total porosity (%, v/v).

Table 5: Effect of tillage and financial returns on the yield of egusi-melon and okra (fruit + seed)

Tillage system	Fruit no (10^3 ha)	Fruit wt (t ha)	Dry seed wt (kg ha)	Production cost (N ha)	Total revenue (N ha)	Net return (N ha)
			Egusi-melon			
No-tillage	5.25	-	284	780	2847	+2057
Minimum	6.50	-	308	870	3082	+2212
Conventional	7.25	-	366	1020	3675	+2655
Strip	7.25	-	[illegible]	990	3720	+2730
LSD (p=0.05)	2.15	-	36.2	-	-	-
			Okra			
No-tillage	19.3	6.0	346	890	3495	+2605
Minimum	23.4	6.6	357	970	3675	+2705
Conventional	27.4	7.8	481	1150	4770	+3620
Strip	27.9	8.4	504	1020	5040	+4020
LSD (p=0.05)	1.6	2.2	28.0	-	-	-

Yield/ha is for egusi-melon seeds only and okra fruit and seeds to give the total revenue. Selling prices were N10/kg (egusi-melon seeds); N300/t (okra fruits); N15/kg (okra seeds); $1 = N3.5 (16/7/87).

While increase in bulk density and penetration resistance decreased root growth and dry seed weight of egusi-melon, increase in porosity and permeability enhanced root growth (Asoegwu, 2005). **Asoegwu** (1999) studied the effects of different tillage combinations: ploughing alone (P), harrowing alone (H), ploughing + once harrowing (P+H) and ploughing + twice harrowing (P+2H) at different depths 5, 10, 15 and 20cm on tractor fuel consumption and profitability of late season okra production and found that $(P+H)_{15}$, $(P+H)_{20}$ and $(P+2H)_{10}$ treatments consumed 98.9, 116.1 and 124.7MJ/ha of tillage energy and produced 8.16, 8.4 and 8.15t/ha of okra fruits, respectively. **The significant difference in tillage energy producing non-significant yields of okra in (P+H) and (P+2H), show that tillage energy input did not affect crop yield directly. What affected yield may have been the improved soil conditions produced by the tillage treatments.**

Asoegwu, Nwandikom and Okoro (1990) incorporated 0, 1, 3, and 5t/ha macerated fresh grass, thoroughly mixed to the depth of 30cm and after 12 weeks, the soil showed that dry bulk densities, porosity, permeability, organic matter, moisture content and liquid limit were all influenced by the amount of residue incorporated. The soil structural stability and drainage were improved. **Asoegwu** and Obiefuna (1991) produced okra under tillage and maize stubble management techniques. **It was found that trash-incorporated treatments reduced the rate of water infiltration, produced the highest dry bulk density, slightly increased organic carbon and produced the tallest plants with the largest leaf area and higher yield.**

Asoegwu (1995a) established the following relationships between soil bulk density (BD), penetration resistance (CI) and moisture content (MC). These are given in Equations 7 to 9.

$$BD = -0.216 + 1.371CI^{0.15} \quad (r = 0.88) \qquad 7.$$

$$BD = 1.026 + 0.043MC \quad (r = 0.97) \qquad 8.$$

$$CI = 9.876 - 5.722 logMC \quad (r = 0.96) \qquad 9.$$

The increase in moisture content lowered the penetration resistance and increased bulk density. Soil compaction, measured by soil bulk density was successfully predicted using soil moisture content. Also, penetration resistance increased bulk density, thereby increasing compaction, which is inimical to plant growth.

7.1.2 Irrigation and fertilization

In terms of irrigation studies in crop production, **Asoegwu** and Obiefuna (1987) studied the effect of irrigation on late season plantains (*Musa paradisiaca*) established in September by continuously irrigating during the dry season (L_c), irrigating only between January and February (peak irrigation) (L_p) and no irrigation (as control) (L_o). Results in Table 6 show that plant establishment was 96.8, 84.6 and 71.4% respectively in L_c, L_p and L_o plots. Yields were 12.1, 10.3 and 8.8t/ha for the plant crop and 13.0, 12.9 and 7.3t/ha for the first ratoon crop, respectively.

From the results in Table 6, it may be **suggested that plantains established in the late season (September) in Nigeria could be irrigated only between January and February to reduce production cost, increase water use efficiency and profit.** Similar results were obtained with fluted pumpkin (*Telfaria occidentalis* Hooke. L.) (**Asoegwu** 1988a), plantain (*Musa paradisiaca*) (**Asoegwu,** 1991a) and paw paw (*Carica papaya*) (**Asoegwu** and Okereke, 1995).

Table 6: Effect of different irrigation periods on growth and yield of plantains

Irrigation levels/period	Survival (%)	Days to 50% harvest	Fingers/bunch plant crop	Yield plant crop, t/ha	Fingers/bunch 1st ratoon crop	Yield 1st ratoon crop, t/ha
L_c	96.8	421	23.3	12.1	31.4	13.0
L_p	84.6	472	32.9	10.3	33.6	12.9
L_o	71.4	521	[illegible]	8.8	22.1	7.3
LSD(p=0.05)	10.02	33.3	7.3	1.32	6.8	1.66

Combining irrigation with fertilization, **Asoegwu** (1987c) studied the effects of irrigation and nitrogen (N) on the growth and yield of pineapples (*Ananas comosus*) and posited that increasing N rates was most effective in increasing both potential and harvested yield at the most frequent irrigation ($1.0I_1$ i.e. 100% consumptive use less effective rainfall every 3 days). In no irrigation situation, 200 kg/ha/year N rates produced similar harvested yield as 100kg/ha/year N rates at $1.0I_1$. **This result is interesting because it demonstrates that with irrigation, fertilizer requirement may be reduced to** give **similar yields. However, the 150kg/ha/year N rate and the 0.5I, (i.e. 50% consumptive use every 7 days) irrigation level seems more attractive on the basis of costs and benefits.** When potassium fertilizer was added to nitrogen in irrigated pineapple, **Asoegwu** (1988b) established that increasing irrigation frequency increased growth parameters and that fruit weight was highest at N = 150kg/ha, K = 200kg/ha and irrigation once a week. For K = 200kg/ha, the potential and harvested yields were reduced in all irrigation treatments when N > 150kg/ha. **Thus when 200kg/ha K is added to one week irrigation for pineapple production, N should not exceed 150kg/ha.**

7.1.3 Mulching and erosion control

Asoegwu and Obiefuna (1990) did a preliminary evaluation of pineapple mixed cropping systems for protecting reclaimed gullies in the Tropics using cowpea and egusi-melon intercropped with pineapple. **It was found that high-density (75,000 plants/ha) pineapple planting intercropped with egusi-melon promoted rapid vegetative cover, checked soil erosion, improved soil structural stability and produced high crop yield with least soil loss. Increasing pineapple density enhanced the field establishment of cowpea and egusi-melon.**

Asoegwu (1990,1991b) using wood shavings (WS), rice husk (RH) and sawdust (SD) as mulching materials on pineapple plots established during early rain (April), mid rain (June) and late rain (August) found that cumulative weed weight and soil loss were highest in June planting, while **WS controlled weeds much better and reduced soil loss considerably than RH and SD. Mulching increased soil moisture retention, soil pH and other soil properties, while WS consistently lowered soil bulk density more than the other treatments including the control (no mulch).** Also, some regression relationships were established between yield (Y t/ha) and soil loss (X t/ha) given as Equation 10 and between soil loss (X t/ha) and vegetative cover (V, %) of different materials given as Equations 11 to 14.

$$Y = 98.92 - 13.09X \quad (r = 0.57) \quad 10$$
$$X_{RH} = 2.103e^{-0.0227V} \quad (r = 0.91) \quad 11$$
$$X_{SD} = 1.859e^{-0.0228V} \quad (r = 0.85) \quad 12$$
$$X_{WS} = 1.828e^{-0.0228V} \quad (r = 0.86) \quad 13$$
$$X_{C} = 3.226e^{-0.0268V} \quad (r = 0.87) \quad 14$$

For all mulch treatments, soil loss decreased exponentially with increase in vegetative cover as seen in the above Equations 11 – 14. **Also, soil loss has a decreasing linear relationship with fruit yield of pineapple** (Equation 10). Similar results were obtained with pineapple as ground cover for managing soil loss and erosion control in South East Nigeria (**Asoegwu** and Obiefuna, 1997).

7.2 Agricultural Processing

Agricultural product processing is defined by Knight (2016) as the alteration or modification of agricultural products using agricultural tool, equipment, system or machine for the purpose of storage, transport or sale. To design machines for processing a crop, the crop physical, mechanical, frictional, etc. properties should be known and their reactions with the machine components and their environmental conditions must be understood. The data obtained on any of these properties of the crop will be useful in the structural design of hoppers, bins and silos for storage and the equipment for processing, sorting, sizing and other postharvest operations.

7.2.1 Engineering properties and cracking energy

Asoegwu (1995b) determined some physical properties and cracking energy of conophor nuts (*Tetracarpidum conophorum*), otherwise known as African walnuts, at different moisture contents and found that the African walnut has an average sphericity of 0.91, radial diameter of 2.90cm, axial diameter of 3.19cm, bulk density (when fresh at 68.8% moisture content) of $0.877 g/m^3$ and with shell thickness of 0.057cm. Cracking was achieved using a developed instrument (Figure 3). **With the sphericity of 0.91; the nuts have the capacity to roll. This information is necessary for designing the machine to crack the nuts with an impinging velocity of about 4m/s when the nuts have moisture content of less than 30% to give 85% full cracking without wounds.**

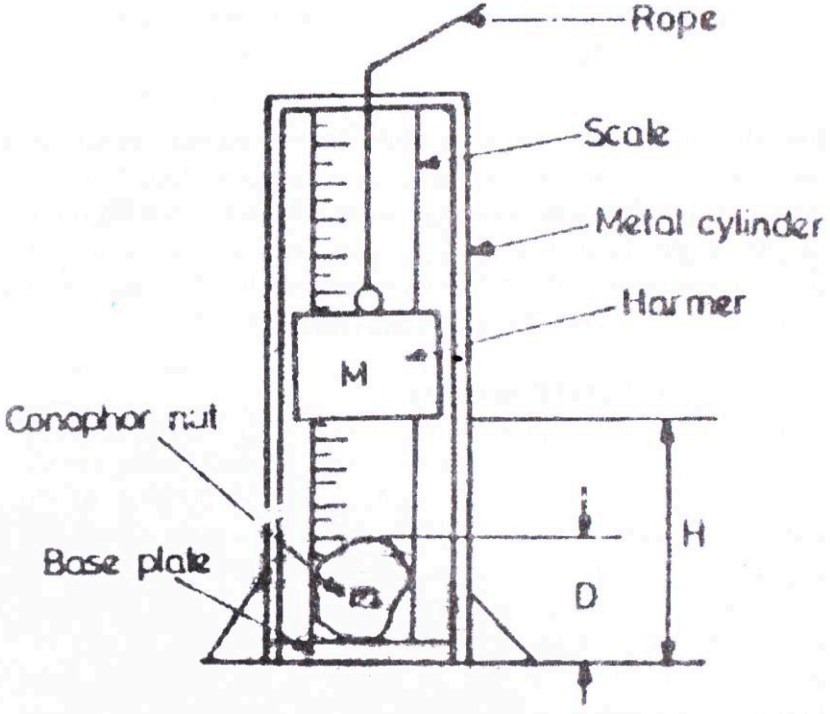

Fig. 3: Cracking energy measurement tool for conophor nuts

For full cracking of the conophor nuts, the cracking percentage (CP was found to be influenced by crop drop height (H) and moistur content (MC) in a multiple regression equation given in Equation 15.

$$CP = 3.38 + 14.31H - 1.44MC \qquad (R^2 = 0.9708) \qquad 15$$

The cracking energy (CE) of conophor nuts was found to b influenced by nut mass (M), radial diameter (D) and shell moistu content (MC) in a multiple regression equation given by Equation 16

$$CE = 4.53 + 0.076M - 1.67D - 8.96\text{-}03MC \qquad (R^2 = 0.9074) \quad 16$$

The positive correlation of nut mass with CE shows it is an importar factor when considering the cracking of the nut. Also, for nuts various moisture contents, the CE correlated linearly with impinging velocity (V) which correlated linearly with MC as given in Equations 17 and 18.

$$CE = 0.039 + 0.017V \qquad (R^2 = 0.7806) \qquad 17$$

$$V = 2.055 + 0.063MC \qquad (R^2 = 0.9653) \qquad 18$$

Equations 17 and 18 show that **CE increased with increased impacting velocity which increased with shell moisture content of the conophor nuts.**

According to **Asoegwu** and Maduike (1999), ogbono (*Irvingea gabonensis*) nuts have an average sphericity of 53.3%, roundness of 73.5% and density of 1.35g/cm^3 at 44.8% moisture content (db). With the above roundness of 73.5%, the nut can be considered as round for design purposes and with sphericity of 53.3%, the nut is not spherical as it lies somewhat flat under natural conditions unlike conophor nuts with 91.2 ±3.5% sphericity (**Asoegwu,** 1995b). **An impinging velocity of 69.54m/s was adequate to successfully and sufficiently crack the nuts at 44.8% moisture content using a 9.75kg hammer dropping onto the nut lying on its natural position.** Using the tool shown in Fig. 3 and within the moisture content range of 31.9 to 44.8% and drop height of 20 to 30cm the impinging velocity ranged from 59.60 to 69.54m/s, cracking energy from 17.31 to 27.52J and cracking efficiency from 38 to 60%.

Full cracking (FC) of the *Irvingea gabonensis* nuts increased as moisture content (MC) decreased as shown in Equations 19, while it increased with drop height (DH) shown in Equation 20.

$$FC = 150.27 - 3.10MC \qquad (R^2 = 0.9821) \qquad 19$$

$$FC = -62.62 + 4.07DH \qquad (R^2 = 0.9920) \qquad 20$$

For African oil bean seeds (*Pentaclethra macrophylla*) at 8.73±0.09% moisture content (db.), **Asoegwu,** Ohanyere, Kanu and Iwueke (2006) determined their major, intermediate and minor diameters as 56.18±8.46mm, 37.89±3.82mm and 12.01±1.66mm respectively. Seed weight, seed volume, aspect ratio, and seed particle density were 13.19±3.28g, 11.61±3.02cm^3, 0.68±0.04 and 1.15±0.18g/cm^2, respectively. The equivalent diameter and sphericity were 32.51±2.82mm and 0.523±0.065, while the seed surface area was 37.16±2.96cm^2. The bulk density was 0.588±0.019 g/cm^3 and porosity was 51.56±3.43%. **The low sphericity of African oil bean seed makes it difficult for it to roll, it can only slide.** Some of these parameters were evaluated as functions of seed weight and found to have linear relationships given in Table 7.

Table 7: Linear relationships (Y = a + bX) of some African oil bean seed parameters with seed weight

Parameter	a	b	R^2	CV
Seed volume, cm^3	3.971	0.519	0.9752	3.460
Bulk density, g/cm^3	0.840	0.033	0.9423	0.218
Major diameter, mm	37.372	1.359	0.7493	9.057
Intermediate diameter, mm	27.782	0.795	0.9596	5.297
Aspect ratio, decimal	0.545	0.122	0.9445	0.440
Equivalent diameter, mm	23.338	0.710	0.9817	4.734
Surface area, cm^2	48.240	-0.839	0.8276	-6.925
Porosity, %	36.337	1.297	0.9397	3.185

The product of equivalent diameter with surface area (Y) had a quadratic relationship with seed weight (W) given by Equation 21.

$$Y = 8.0119 - 0.3613W + 0.0153W^2 \quad (R^2 = 0.9979) \qquad 21$$

For Jackbean seed (*Canavalia ensiformis*) at 6.0±0.73% moisture content (wb), Eke, **Asoegwu** and Nwandikom (2007) found that the major, intermediate and minor diameters of the seeds were 18.66±1.11mm, 13.14±0.85mm and 10.22±1.02mm respectively. The seed weight and volume were 1.59±0.15g and 1.34±0.13mm^3, respectively. The equivalent diameter, sphericity, aspect ratio, particle density, bulk density and porosity of the Jackbean seed were 13.78±0.70mm, 72.88±0.03%, 0.71±0.05, 1.19±0.08g/cm^3, 0.788±0.024g/cm^3 and 0.326±0.001, respectively. **With sphericity and aspect ratio of over 70%, Jackbean seed has the propensity to roll instead of sliding. Asoegwu** and Eke (2009) gave the linear relationships between some physical parameters of Jackbean seed and seed weight as shown in Table 8. **Among the whole weight groups, both sphericity and porosity were not significantly different and so had no linear relationship with seed weight**.

Table 8: Linear relationships (Y = a + bX) between some physical parameters of Jackbean seed and seed weight

Parameter	a	b	R^2
Major diameter, mm	14.37	2.735	0.891
Intermediate diameter, mm	9.676	2.032	0.953
Minor diameter, mm	6.262	2.153	0.939
Volume, cm^3	0.219	1.026	0.976
Particle density, g/cm^3	0.767	0.232	0.961
Bulk density, g/cm^3	0.543	0.138	0.924

Asoegwu, Iroakazi, Agbetoye and Ogunlowo (2011) investigated the effects of moisture content (8.25 – 18.98%) on the frictional properties of African breadfruit (*Treculia africana*) seeds and found that the equivalent seed diameter and the sphericity increased with increase in moisture content from 6.23±0.95 to 7.83±0.51mm and 0.664±0.082 to 0.859±0.069 respectively. The angle of repose, angle of internal friction, and coefficient of static friction, internal and external frictions also increased with increase in moisture content as follows: 25.70±2.07 to 33.01±2.11°; 26.33±0.54 to 33.78±0.25°; 0.448±0.028 to 0.521±0.037; 0.492±0.018 to 0.669±0.052 and 0.684±0.044 to 0.749±0.071, respectively. However, the bulk density decreased from 570±97 to 495±53kg/m^3 as moisture content increased. The true or kernel or particle density and porosity increased with increase in moisture content from 609±24 to 661±37kg/m^3 and 6.40±0.18 to 25.11±0.37%, respectively. These **properties are useful in designing materials handling equipment for African breadfruit and other products.**

The orthogonal dimensions of African breadfruit seeds: major diameter(L_1), intermediate diameter (L_2), minor diameter (L_3) and equivalent diameter (D_e) have linear relationships with moisture content given in Equations 22 to 25.

$$L_1 = 0.2487M + 8.5116 \quad (R^2 = 0.970) \qquad 22$$
$$L_2 = 0.1034M + 4.5108 \quad (R^2 = 0.969) \qquad 23$$
$$L_3 = 0.0507M + 3.8927 \quad (R^2 = 0.939) \qquad 24$$
$$D_e = 0.1374M + 5.2153 \quad (R^2 = 0.980) \qquad 25$$

The frictional properties have quadratic or 2nd order polynomial regression relationships with moisture content as given in Table 9. Once the moisture content of African breadfruit is known, these handling and flow properties/parameters can be obtained for designing machines and storage facilities to handle the seeds.

Table 9: Quadratic relationships ($Y = a + bX + cX^2$) between African breadfruit seeds frictional properties with moisture content

Parameter	Symbol	a	b	c	R^2
Bulk density, kg m^{-3}	ρ_b	[illegible]	10.87	0.714	0.984
Particle density, kg m^{-3}	ρ_p	[illegible]	0.506	0.151	0.93
Porosity, %	ε	[illegible]	-1.601	0.120	0.990
Sphericity, dec	ψ	[illegible]	0.0235	0.0002	0.986
Angle of repose, deg	θ	[illegible]	1.267	0.023	0.988
Angle of Inter. friction, deg	ϕ	[illegible]	-0.0655	0.025	0.965
Coeff. of static friction, dec	μ_s	[illegible]	0.0108	0.0002	0.962
Coeff. of inter. Friction, dec	μ_i	[illegible]	-0.0028	0.0006	0.963
Coeff. of ext. friction, dec	μ_e	[illegible]	-0.0046	0.0004	0.923

It is observed that bulk density, particle density, porosity, sphericity and angle of repose, when related to moisture content, are most affected by it and have higher $R^2 > 0.98$ than other frictional properties.

For Achi (*Brachystegia eurycoma*) seeds, Irouwa, Asoegwu and Okereke (2016) established the following linear relationships (Equations 26 to 37).

Major diam. $L_1 = 0.0293M + 29.533 \quad (R^2 = 0.992)$ 26

Intermediate. $L_2 = 0.0314M + 15.508 \quad (R^2 = 0.957)$ 27

Major diam	$L_3 = 0.0207M + 2.7371$	$(R^2 = 0.996)$	28
Arith. diam,	$D_a = 0.0297M + 10.043$	$(R^2 = 0.9965)$	29
Square diam.	$D_s = 0.0278M + 11.817$	$(R^2 = 0.9563)$	30
Equiv. diam.	$D_e = 0.0283M + 11.956$	$(R^2 = 0.9803)$	31
Volume	$V = 6.9376M + 890.23$	$(R^2 = 0.9868)$	32
Surface area	$S_a = 2.1725M + 286.07$	$(R^2 = 0.9946)$	33
Sphericity	$S_p = 0.0009M + 0.4662$	$(R^2 = 0.9908)$	34
Geom. Diam.	$D_g = 0.0345M + 9.5511$	$(R^2 = 0.9925)$	35
Bulk density	$\rho_b = -3.446M + 555.07$	$(R^2 = 0.9829)$	36
Aspect ratio	$A_r = 0.0004M + 0.7557$	$(R^2 = 0.8611)$	37

While bulk density decreased with increase in moisture content, all the other measured parameters of Achi seeds increased linearly with increase in moisture content of the seed. The low sphericity of the seeds of Achi makes them unable to roll but can slide. Similar results were got for African locust bean (*Parkia biglobosa*) by Asonye, **Asoegwu** and Ohaeri (2014).

Working with plantain (*Musa paradisiaca*), **Asoegwu** (1996) and **Asoegwu**, Nwandikom and Nwammuo (1998) determined the firmness and stability of plantain fruits under ambient temperatures and their physical and mechanical properties (Table 10). **Firmness was used to classify the plantain fruits into "soft" (< 40N), "Hard" (> 55N) and "firm" (40 – 55N). If 50% of the fingers in the bunch of finger diameters above 40mm have firmness of 45 – 55N, the plantain fruits may be said to have matured for harvest.** In 15-day storage at ambient temperatures (21 – 24°), fruit firmness and moisture content decreased from 56.1 to 30.6N and from 66.8 to 45.3%, respectively.

The fruit can store for 6 days under ambient temperature and still remain "firm"; after which it begins to ripen and gradually become "soft". Interesting linear regression equations were developed, as shown in Table 10, for the following parameters: fruit firmness (FF), fruit weight (FW), fruit diameter (FD), fruit pulp/peel ratio (PP), fruit water content (FWC), days in storage (DS) and fruit weight loss (FWL). Pulp/peel ratio is an important parameter in fruit transportation and storage that affects fruit firmness. It has negative correlation with fruit weight but a positive one with fruit diameter and days in storage.

Table 10: Linear regression coefficients (Y = a + bX) for the firmness parameters of plantain fruit.

Parameter	Symbol	a	b	R
Fruit firmness, N	FF	98.504	-1.102FD	0.8464
Fruit firmness, N	FF	93.602	-23.513PP	0.9120
Fruit firmness, N	FF	146.962	-1.440FWC	0.9428
Fruit firmness, N	FF	-144.761	0.863FW	0.8968
Fruit water content, %	FWC	205.468	-0.612FW	0.9920
Fruit water content, %	FWC	32.496	0.792FD	0.9683
Fruit water content, %	FWC	36.596	16.570PP	0.9761
Fruit pulp/peel ratio, dec.	PP	10.204	-0.037FW	0.9980
Fruit pulp/peel ratio, dec.	PP	-41.256	0.048FD	0.9742
Fruit weight, kg	FW	282.944	-1.302FD	0.9821
Fruit firmness, N	FF	58.371	-1.890DS	0.9545
Fruit water content, %	FWC	66.848	-1.429DS	0.9980
Fruit pulp/peel ratio, dec.	PP	1.553	0.058DS	0.9409
Fruit weight loss, %	FWL	1.354	0.491DS	0.8874

To establish the rule of the thumb for estimating the physical parameters of plantain fruit bunch (*Musa* AAB v. Agbagba), Nwandikom and **Asoegwu** (1990) found that the relationship between the convex (l_1) and the concave (l_2) finger lengths is given as Equation 38.

$$l_2 = 0.44 l_1 + 0.83 \qquad (R^2 = 0.9920) \qquad 38$$

The ratio l_2/l_1 ranging from 0.68 to 0.94 averages approximately 0.8 meaning that a unit increase in l_1 increases l_2 by 0.8 of same unit. The straight finger length (SFL) and other hand and finger characteristics are given in Table 11. These physical characteristics of plantain are important in the production, processing, storage, marketing and utilization of the crop.

Table 11: Plantain finger physical characteristics

Characteristics	Mean hand values					
Finger position	1	2	3	4	5	6
Population, %	31.33	24.0	16.0	15.5	9.5	3.67
Grade	46.8a*	45a	44.9a	45.4a	42.9a	42.3a
Finger length, cm	27.7a	28.4a	26.1b	26.13b	25.09bc	24.6c
Straight finger length, cm	20.75a	19.19b	19.73ab	20.58a	18.01c	16.9c
Fruit curvature, deg	144a	130.8a	147.27a	150.02a	143.33a	131.1a
Uniformity index, dec	0.015a	0.013b	0.017a	• 0.018a	0.017a	0.017a
Fullness index	8.47a	7.95a	8.45a	8.00a	7.83a	6.59a
Weight, g	235.11a	225.79a	225.71a	206.28b	184.3c	173.4c
Volume, cm	227a	219a	223a	208b	190c	182c
Density, g/cm^3	1.04a	1.03ab	1.01b	0.98c	0.97c	0.96c

*Mean values followed by the same letters are not significantly different according to Duncan's Multiple Range Test.

With a vertical shaft centrifugal palm nut cracker (Figure 4), Ndukwu and **Asoegwu** (2010) investigated the functional performance of the cracker after determining the axial and physical characteristics of the palm nuts. The mean axial dimensions and physical characteristics of the palm nuts at 10.94% moisture content (db.) are: major diameter = 3.05±0.02cm; intermediate diameter = 1.73±0.11cm; minor diameter = 1.49±0.15cm; shell thickness = 0.28±0.00cm; nut weight = 3.84±0.28g; nut volume = 3.40±0.26cm^3 and nut density = 1.129±0.126g/cm^3. **These properties influenced the performance of the cracker at various moisture contents (10.54 – 15.18%), feed rates (550 – 880kg/h) and speeds (1650 – 2230rpm). The cracking efficiency increased with speed (63.78 – 84.56%), decreased with moisture content (69.73 – 54.77%), and decreased with feed rate (79.40 – 64.12%). Throughput capacity decreased with moisture content (599 – 534kg/h) and increased with feed rate (411 – 833kg/h) and speed (534 – 696kg/h).**

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Straight finger length, cm	20.75a	19.19b	19.73ab	20.58a	18.01c	16.9c
Fruit curvature, deg.	144a	130.8a	147.27a	150.02a	143.33a	131.1a
Uniformity index, dec	0.015a	0.013b	0.017a	• 0.018a	0.017a	0.017a
Fullness index	8.47a	7.95a	8.45a	8.00a	7.83a	6.59a
Weight, g	235.11a	225.79a	225.71a	206.28b	184.3c	173.4c
Volume, cm	227a	219a	223a	208b	190c	182c
Density, g/cm	1.04a	1.03ab	1.01b	0.98c	0.97c	0.96c

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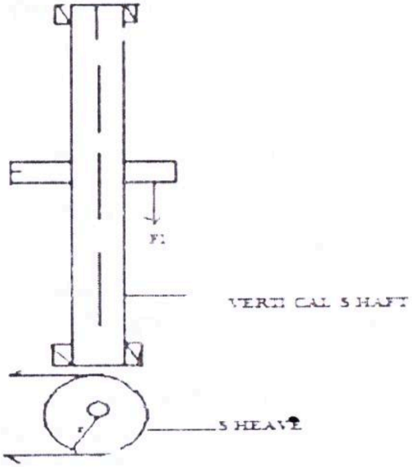


Fig. 4: Schematic arrangement of load on the shaft

Asoegwu (2002) investigated the influence of cooking time on the crackability of conophor nuts *(Tetracarpidum conophorum)* and found that for cooking time of between 60 – 120min, cracking energy decreased from 0.14J to 0.08J, full cracking (FC) of over 80% was obtained for T = 105 to 120min for average impinging velocity of between 3.47 and 3.80m/s. The following Equations 39 to 45 relate full cracking (FC), cracking energy (CE) and impinging velocity (V) to cooking time (T) and drop height (DH) and, nut mass (m) and nut diameter (d).

$FC = 4.0 + 0.7733T$	$(R^2 = 0.9233)$	39
$FC = 104.94 - 3.993DH$	$(R^2\ 0.8160)$	40
$CE = -4.72x10^{-4} - 12.65m + 8.59d$	$(R^2\ 0.874)$	41
$CE = -0.067 + 0.041V$	$(R^2 = 0.9016)$	42
$CE = 0.1997 - 1.066x10^{-3}T$	$(R^2 = 0.9569)$	43
$V = -2.93x10^{3} - 565.92m + 372.37d$	$(R^2 = 0.992)$	44
$V = 6.2736 - 0.0236T$	$(R^2 = 0.9677)$	45

Both cracking energy and impinging velocity decreased with increase in cooking time and are affected by both nut mass and nut radial diameter. Also, impinging nut velocity of 2.71 to 4.72m/s is adequate for full cracking of conophor nuts cooked for 90min.

Asoegwu and Obi-Mgbam (2003) parboiled African breadfruit seeds (*Treculia africana*) at moisture range of 8.1 to 13.5%, for parboiling time of 5 to 15 min, with temperature of 70 – 100°C at pressure of about 55kPa. While the un-parboiled seeds were difficult to shell with shell ability of less than 51%, parboiling for 8 – 10min with moisture content range of 10.1 to 13.5% recorded shell ability of 63.8 – 72.0% because parboiling softened the shells and loosened them from the cotyledons. **Compared with traditional method of shelling, the mechanical method gave lower seed shell ability of between 56.5 to 63.8%, while the traditional method gave 61 – 72% shell ability. This important physical property plays an invaluable role in the postharvest processing of the seed of African breadfruit. Parboiling time and moisture content before parboiling affect shell ability.**

7.2.2 Modeling

Modeling is an important tool to establish predictive equations of some processes and systems in agricultural engineering. Ndukwu and **Asoegwu** (2011) established a mathematical model to predict the cracking efficiency of a vertical-shaft centrifugal palm nut cracker (Fig. 5) using dimensional analysis. Using the seven (7) variables affecting cracking efficiency, the following Equation 46 gives the prediction equation for the cracking efficiency of palm nut.

$$CE = 17.227\left(\frac{T_c}{\sqrt{\delta_2 D^2}}\right) + \left(\frac{1.732 v \delta_2 \varphi D^2}{\gamma_T}\right) + 40.43 \qquad 46$$

Where CE = cracking efficiency (%), T_c = throughput capacity, v= cracking speed (m/s) δ_1 = bulk density of the nut (kg/m³), δ_2 =nut particle density (kg/m³), φ = nut moisture content (%), D = diameter of creacking chamber (m), γ = feed rate (kg/h).

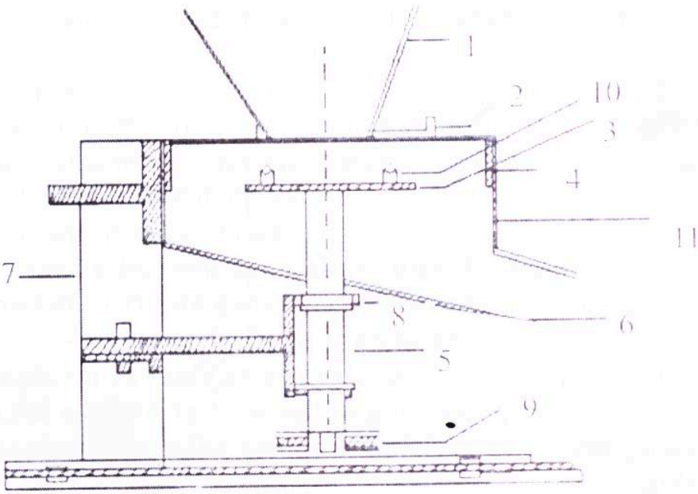


Fig. 5: Sectional view of vertical-shaft centrifugal palm nut cracker

1 – hopper, 2 – feed rate control, 3 – rotor, 4 – cracking ring, 5 – vertical placed shaft, 6 – collector chute, 7 – frame, 8 – bearing, 9 – shaft sheave, 10 – channel, 11 – housing/cracking chamber

With feed rate of 714kg/h, cracking speed of 3.92m/s, diameter of cracking ring of 0.29m and varying moisture content, bulk density and particle density, the linear relationship between predicted CE and measured CE is given by Equation 47.

$$CE_{pred} = 0.637CE_{meas} + 26.18 \quad (R^2 = 0.943) \qquad 47$$

The high correlation (R^2 = 0.943) and standard error of 0.04 between the predicted and measured (experimental) cracking efficiencies is a good testimony that the prediction model is acceptable and in good agreement with the measured. There was no significant difference between the experimental and predicted efficiencies at 5% level of significance.

Ngwangwa, Madubuike and Asoegwu (2014) predicted hydraulic conductivity of Nigerian agricultural soils using dimensional analysis of thirteen (13) variables and developed the following Equation 48.

$$K = \left[-0.003\left(\frac{D_p x pH x ESP}{D_b x OMC x CEC}\right) \mp 0.007\left(\frac{P x S_i}{Cl x S}\right) + 0.01\right]\left[\sqrt{gH}\right] \qquad 48$$

Where K = hydraulic conductivity (cm/s), pH = soil pH (%), ESP = exchangeable sodium (%), D_p =particle density (g/cm³), D_b = bulk density (g/cm³), OMC = organic matter content (%), CEC = cation exchange capacity (%), P = porosity (%), S_i = silt (%), Cl = clay (%), S = sand (%), g = acceleration due to gravity (m/s²) and H = soil depth (cm).

Eleven (11) locations in Imo and Abia States of Nigeria with three (3) soil groups: ferralitic (61%), hydromorphic (31%) and alluvial (8%) (Madubuike, 2006), were used for this modeling of the hydraulic conductivity. Data on the above parameters from eight (8) locations were used to develop the model and data from the three (3) remaining locations were used to validate the model. **The relationship between the predicted and measured hydraulic conductivities is given as Equation 49 with very high coefficient of determination and standard error of 0.048.**

$$K_{pred} = 1.163K_{meas} - 0.154 \qquad (R^2 = 0.9950) \qquad 49$$

Using all the data from the eleven (11) locations, the relationship between the predicted and the measured hydraulic conductivity is given as Equation 50 with R^2 = 0.9400. All in all, the difference between the predicted and the measured hydraulic conductivities was less than 20%.

$$K_{pred} = 1.163K_{meas} - 0.136 \qquad (R^2 = 0.9400) \qquad 50$$

Asoegwu, Agbetoye and Ogunlowo (2010a) modeled the flow rate of egusi-melon (*Colocynthis citrullus*) through horizontal hopper orifice using dimensional analysis with eight (8) variables namely effective diameter of the orifice (D_e, m), hydraulic diameter of the orifice (D_h, m), head of packing above the orifice (H, m), effective orifice area (A_e, m²), acceleration due to gravity (g, m/s²), equivalent diameter of grain (d, m), coefficient of mobility (α, dec.) and volume flow rate (Q, m^3/h). Based on three (3) hopper parameters (D_e, D_h & A_e), the following three (3) flow rate (Q, m^3/h) power regression models were established as Equations 51 to 53.

$$Q = 0.0015D_e^{2.4717} \quad (R^2 = 0.9860) \qquad 51$$
$$Q = 0.0008D_h^{2.658} \quad (R^2 = 0.9880) \qquad 52$$
$$Q = 0.0020A_e^{1.235} \quad (R^2 = 0.9864) \qquad 53$$

These three (3) hopper parameters D_e, D_h & A_e positively influenced the flowrate of egusi-melon (*Colocynthis citrullus*) with high $R^2 > 0.98$. The exponents of D_e & D_h are close to $n = 2.5$ found in Literature for other seeds.

The volumetric flow rates of African breadfruit (*Treculia africana*) were measured by **Asoegwu**, Agbetoye and Ogunlowo (2010b) through horizontal circular and square hopper orifices of 70° side slope angle, equivalent orifice diameter of 3.44 – 7.05cm and hydraulic diameter of 4.47 – 8.05cm.The coefficients of the power regression $\alpha\beta^n$ equation developed using different grain and hopper parameters for both circular and square hopper orifices are given in Table 12.

Table 12: Coefficients of the power regression equations ($a\beta^n$) for volumetric flow rate of African breadfruit seeds through horizontal circular and square orifices

	Circular			Square		
β	α	n	R^2	α	n	R^2
d	13.16	-0.330	0.998	10.24	-0.380	0.998
D_h/D_e	3.058	0.332	0.998	2.018	0.381	0.998
D_h	0.012	3.069	0.999	0.011	3.149	0.999
D_e	0.055	2.529	0.999	0.053	2.568	0.999
A_h	0.016	1.571	0.998	0.011	1.574	0.999
A_e	0.075	1.264	0.999	0.053	1.284	0.998

Using D_e, the exponents were 2.529 and 2.568 for the circular and the square orifices respectively which are round the 2.5 found in literature (Chang and Converse, 1988; Kusiňka and Olejarczyk, 2005). **The flow rate of African breadfruit seeds is 30% higher through circular orifice than through square orifice. The ratio**

$D = D_h/d$ has been found to influence the jamming of granular matter (Garcimartin, 2007) and flow rate through orifices follow Beverloo law only when D exceeds a critical value, D_c (Mankoc *et al.*, 2007). Jamming is likely to occur for African breadfruit seeds when D > 16 for both circular and square orifices.

The seed velocity (V) through the hopper orifice increased linearly as orifice size increased for African breadfruit seeds as shown in Equations 54 to 57 with high R^2 of 0.977 to 0.992 for circular (V_c) and square (V_s) orifices. Lower R^2 is for square orifices. The higher R^2 for the circular orifice is indicative of the faster and higher flow through it than through the square orifice.

$$V_c = 0.017D_h + 0.059 \qquad (R^2 = 0.992) \qquad 54$$

$$V_s = 0.016D_h + 0.034 \qquad (R^2 = 0.985) \qquad 55$$

$$V_c = 0.017D_e + 0.077 \qquad (R^2 = 0.992) \qquad 56$$

$$V_s = 0.016D_e + 0.050 \qquad (R^2 = 0.977) \qquad 57$$

This information is a necessary design tool for hoppers and other materials handling systems for the seed.

Also, through circular and square horizontal orifices, moisture content affected the flow rate of egusi-melon (*Colocynthis citrullus*) seeds as given in Table 13 for power regression $Q = \alpha D_h^{\beta}$ equations (**Asoegwu**, Ogunlowo and Agbetoye, 2015). Table 13 gave the following quadratic model equations for the flow rate of egusi-melon seeds as a function of moisture content (M) for both circular (Equation 58) and square (Equation 59) horizontal orifices.

$$Q_c = -0.0011M^2 + 0.0100M + 1.3185 \qquad (R^2 = 0.9397) \qquad 58$$

$$Q_s = -0.0031M^2 + 0.0486M + 1.0724 \qquad (R^2 = 0.9716) \qquad 59$$

Table 13: Coefficients of power regression equations for flow rate of egusi-melon as affected by moisture content using hopper hydraulic diameter (D_h = 4.472cm). $Q = \alpha D_h^{\beta}$

Moisture content % (db)	Circular			Square		
	α	β	Q	α	β	Q
6.76	0.0194	2.8311	1.5472	0.0159	2.9143	1.2507
12.50	0.0180	2.8628	1.3108	0.0124	3.0292	1.1586
13.90	0.0173	2.8705	1.2830	0.0102	3.1137	1.0816
15.70	0.0261	2.5405	1.1728	0.0088	3.1680	1.0122
16.20	0.0259	2.5267	1.1400	0.0065	3.3104	0.9254
18.90	0.0234	2.5626	1.0869	0.0045	3.4943	0.8438

It is quite clear from the above Equations 59 and 60 that increase of moisture content decreases the flow rate of egusi-melon because of the interspatial friction caused by the presence of moisture. However, even with the decreasing influence of moisture content on flowrate of egusi-melon, flow through the circular orifice was still higher than through the square orifice.

7.2.3 Drying and cooking

Nwakuba, **Asoegwu**, Nwaigwe and Chukwuezie (2017a, 2017b) designed and evaluated the no-load performance of an arduino-primed hybrid solar-electric dryer (Figures 6 & 7). The arduino platform was able to monitor moisture loss per given time, energy requirement for drying and other drying parameters automatically. During the test, five (5) different air velocities (0.1, 0.5, 1.0, 1.5 and 2.0m/s) were used to determine the dryer's thermal profile and the time to reach pre-set optimum temperatures of 50, 55, 60, 65 and 70°C, respectively. **On the average, it was observed that the drying chamber heat-up times for 70°C at air velocity 2.0m/s were 6.2 minutes for the hybrid and 9.8 minutes for the electric heat sources; while they developed maximum chamber temperature of 92.2 and 82.1°C, respectively after 210 minutes.**

In terms of energy, the peak energy at no-load was as follows: 2269kWh for the hybrid (E_h), 1485kWh for the electric (E_e) and 784kWh for solar heat (E_s) sources. These energy values developed by the hybrid dryer are adequate for moist-laden crops such as tomato, banana, apple, garlic, etc. as suggested by Abdulla *et al.* (2011) and Afolabi *et al.* (2014).

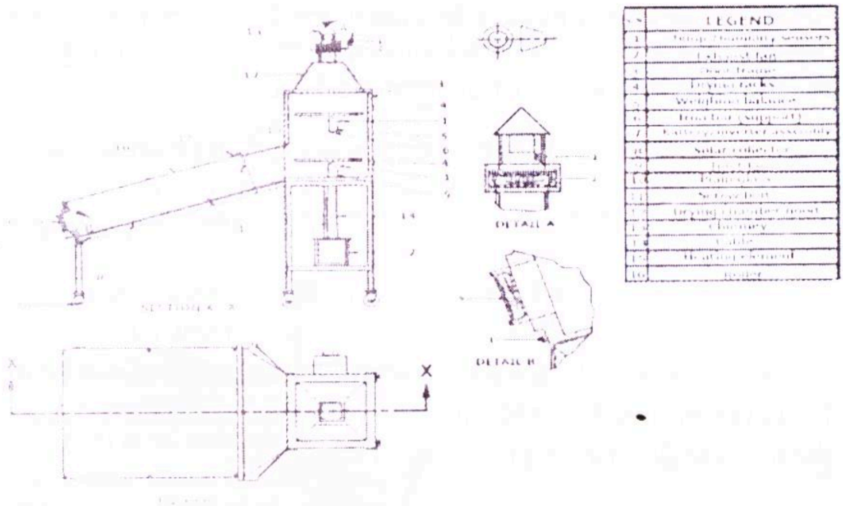


Fig. 6: Sectional view of the ardiuno- primed hybrid solar-electric dryer\\

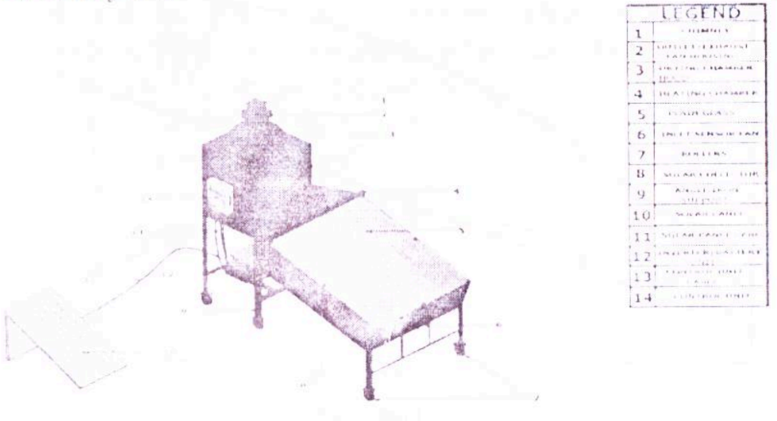


Fig. 7: Isometric view of the arduino-primed hybrid solar-electric crop dryer.

However, the energy models developed for the different heat sourc (hybrid, electric and solar) are shown in Fig. 8 with the regressi equations/models given in Equations 60, 61 and 62.

$$E_h = -30.894T^2 + 989.55T - 6037.5 \qquad (R^2 = 0.993) \qquad 60$$

$$E_e = 165.05 - 1320 \qquad (R^2 = 1.000) \qquad 61$$

$$E_s = -30.865T^2 + 823.73T - 4712.7 \qquad (R^2 = 0.952) \qquad 62$$

The $R^2 = 1.000$ for E_e is understandable because it is direct heatin However, the low $R^2 = 0.952$ for E_s may be because of the variation the solar radiation during the hours of the day.

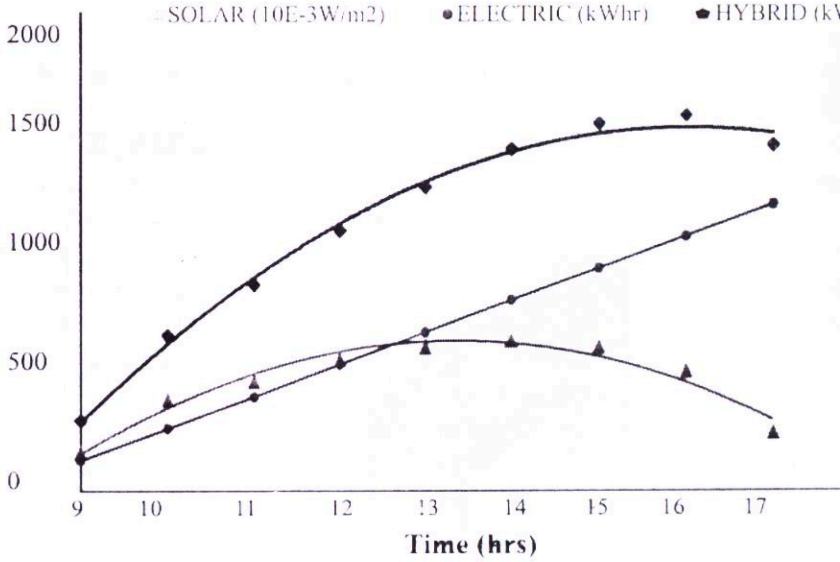


Fig. 8: Energy development of the hybrid dryer heat

Nwakuba, **Asoegwu** and Nwaigwe (2016a, 2016b) reported that cr functional characteristics, initial and desired moisture contents, sl thicknesses, air temperatures, relative humidities and specific h capacities of the crops are necessary parameters that determine t energy required for drying crops. **They posited that for drying moisture-laden crops as mentioned above, the minimum energy required for their drying varied between 4.22 and 24.99MJkg^{-1} of water removed. This is in agreement with the minimum theoretical energy amount required for drying sliced moisture-laden crops in convective hybrid solar dryers which Raghavan *et al.* (2005)** stated ranged from 5.21 to 90.4MJkg^{-1} of water removed.

The drying kinetics and determination of the thermodynamic properties of 10mm thickness sliced tomato samples were done by Nwakuba, Chukwuezie, **Asoegwu**, Nwandikom and Okereke (2018) using hot air drying in a hybrid solar-electric dryer. **They found that the Midilli *et al.* model adequately described the drying process of the tomato slices at all temperatures tested, with highest R^2 (0.9999), lowest sum of squares error (SSE) and lowest root mean square error (RMSE) as 0.1136 and 0.0212, respectively at 70°C (temperature) and 2.0ms^{-1} drying air velocity.** The moisture ratio (MR) of the tomato slices is given as Equation 63. Other results of the investigation are: **the drying constant (K_d) as a function of temperature was represented with the Arrhenius model (Equation 64);** moisture diffusivity increased with increase in temperature and drying air velocity; activation energy to dry 1kg batch of 10mm thickness sliced tomato samples was 39.34kJmol^{-1}; enthalpy, Gibbs free energy and entropy decreased with increasing drying temperature.

$$MR_{tomato} = 4.926e^{(-0.804t^{1.822})} + 0.007t \quad (R^2 = 0.9999) \qquad 63$$

$$K_d = 724328.28exp\left(\frac{38382.22}{8.3143T_a}\right) \quad (R^2 = 0.9967) \qquad 64$$

Investigating the appropriate cooking temperature for freshly harvested corn cobs, Iheonye, **Asoegwu** and Nwaigwe (2015) observed that uniformity of corn browning affects people's decision on which roasted corn cob to accept or reject. To achieve uniform browning, the process of combination cooking method was utilized to achieve the appropriate temperature and duration of cooking. **They** found that 195°C and 30 minutes were the appropriate cooki temperature and duration. However, they did not see the init moisture content of the freshly harvested corn cob of betwe 69.7 – 85.3%w.b. affecting the above cooking temperature a duration for corn cob of 90 days maturity period. The regress equation between the cooking temperature (T) and appropri cooking duration (CD) is given as Equation 65.

$$CD = 1.191x10^{6} - 3.996x10^{4}T + 5.565x10^{2}T^{2} - 4.115T^{3} + 1.704x10$$
$$- 3.749x10^{-5}T^{5}$$
$$+ 3.422x10^{-8}T^{6} \quad (R^2 = 0.9491) \qquad 65$$

7.2.4 Renewable energy

Energy in agriculture has been fueled by depleting fossil fuels wh have negative impact on the environment and public health. There thus, the need to focus on renewable energy sources such as bioma biofuel, biodiesel, ethanol, biogas, solar, wind, etc. (Asonye, Abl and **Asoegwu**, 2014).

Egbufor, Okereke and **Asoegwu** (2016) produced biogas from tw blends of cow dung, pig dung, poultry droppings and water hyaci in an 84 liter capacity cylindrical digester on batch basis for 24 d each batch (Figure 9). Ten kilograms (10kg) of each material v blended with 10kg of the other and mixed with water in the ratio 1:2. However, before the twin blending of the materials was do they were characterized in terms of moisture content, bulk dens and volatile matter content as shown in Table 14.

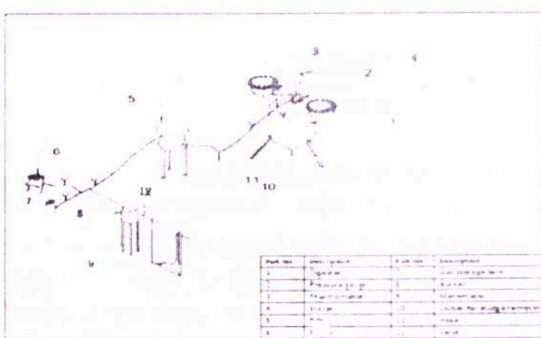


Fig. 9: Isometric view of biogas digester assembly

Table 14: Characteristics of the waste materials

Waste material	Ave. moisture content (%)	Bulk density (g/m^3)	Ave. volatile matter (%)
Cow dung	44.5	1.02	24.0
Pig dung	24.3	1.12	12.3
Poultry droppings	34.0	1.12	20.0
Water hyacinth	45.4	1.03	15.2

The Table 14 showed that cow dung and water hyacinth have similar moisture contents and bulk densities but cow dung has the highest volatile matter of 24.0%. The biogas production from the blends is given in Table 15.

Table 15: Biogas production from the blended waste materials

Waste material blend	Cumulative gas yield after 24 days (l)	Mean rate of gas production (l/day)	Lag time (hr.)
Pig + cow	47.94	2.00	48
Pig + poultry	51.08	2.13	48
Pig + water hyacinth	46.00	1.92	48
Cow + poultry	49.68	2.07	72
Cow + water hyacinth	48.42	2.02	72
Poultry + water hyacinth	43.61	1.82	72

The blends with pig waste had shorter lag time of 48hrs than the other blends with 72hrs lag time. The pig + poultry blend produced the highest cumulative gas yield after 24 days with an average rate of gas production at 2.13l/day at a lower lag time of 48hrs. The biogas can be used in a burner for thermal energy provision or as fuel in an engine to provide mechanical power or electricity (Maithel, 2009).

Chinyere, **Asoegwu** and Nwandikom (2014) produced briquettes from sawdust with corn starch as the binder. The binder was at three treatment levels of 30, 40 and 50ml mixed with sawdust at 100, 150 and 200g levels and water at 75, 100 and 125ml. Each treatment combination was thoroughly mixed in a blender for 60secs. The briquettes produced are shown in Figure 10. The briquettes were evaluated in terms of calorific value (C_v), boiling time (B_t), fuel consumption rate (F_c), fuel efficiency (F_e) and cooking efficiency (C_e). All the evaluated parameters were significantly ($p>0.5$) influenced by both sawdust and binder.

Fig. 10: Dried briquette after production

Generally, it was observed that C_v, C_e and F_e increased while B_t and F_c decreased with increase in binder level. For the 50ml starch binder, the following regression Equations 66, 67, 68, 69and 70 were developed for the evaluated parameters in terms of sawdust (S).

$$C_{v50} = 1.4904\ln(S) + 34.014 \qquad (R^2 = 0.999) \qquad 66$$

$$B_{t50} = 27.42S^{-0.1} \qquad (R^2 = 0.885) \qquad 67$$

$$F_{c50} = 103.4S^{-0.25} \qquad (R^2 = 0.919) \qquad 68$$

$$F_{e50} = 0.019S - 0.57 \qquad (R^2 = 0.992) \qquad 69$$

$$C_{e50} = 13.29e^{0.007S} \qquad (R^2 = 0.986) \qquad 70$$

The different evaluated parameters gave different regression models when influenced by sawdust. Its logarithmic influence on calorific value gave the highest $R^2 = 0.999$. The linear regression relationship of fuel efficiency with sawdust ($R^2 = 0.922$) is interesting for it makes for easy calculation.

In a review on diesel engine performance of Jatropha biodiesel, Chukwuezie, Nwaigwe, **Asoegwu** and Anyanwu (2014) revealed that Jatropha biodiesel functions smoothly in diesel engines without modifications. However, blending the biodiesel with pure diesel (specifically between B5 – B30) gave more preferred and appreciable performance in terms of brake specific fuel consumption (BSFC), brake thermal efficiency (BTH) and exhaust gas temperature (EGT).

In an attempt to enhance the production of biodiesel from non-edible oils, Chilakpu, Nwandikom, **Asoegwu** and Egwuonwu (2014a, 2014b) modified an existing biodiesel batch reactor by **incorporating two rotating different stirring-arm stages with a horizontal detachable baffle. This was to increase turbulence at mixing, thereby creating inter-surface interactions for greater molecular separation and interface reaction. This arrangement produced 85% of biodiesel at 200rpm and 98% of biodiesel at 300rpm in 60minutes.**

When two and four stirring arms without baffle on one hand and two and four stirring arms with baffle on the other hand were installed in the batch reactor (Figures 11 & 12), it was ran at 200, 300, 400 and 500rpm to produce biodiesel from Jatropha seed oil.

Fig. 11: Transesterification Batch Reactor

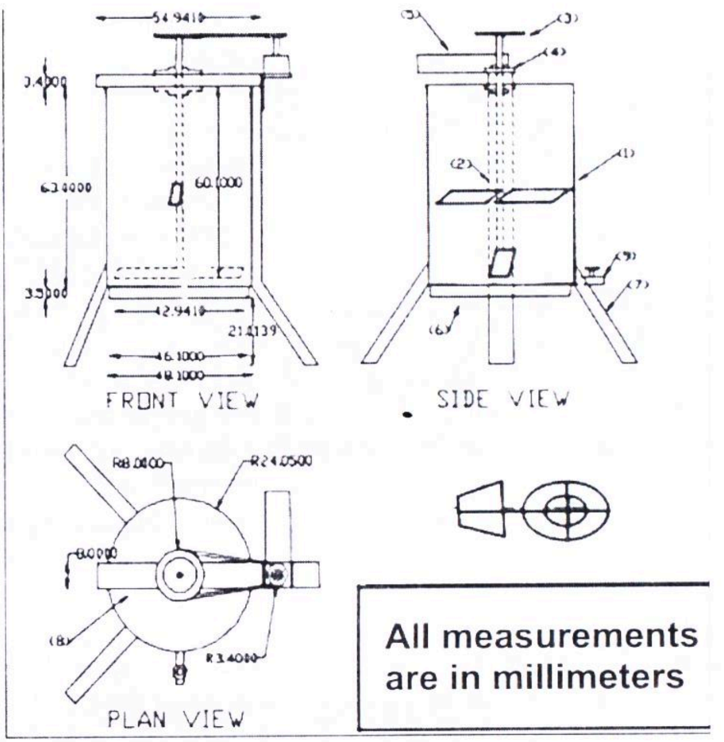


Fig. 12: Orthographic Projection of Biodiesel Reactor

Results show that only 67.5% volume of biodiesel was produced when using two stirring arms without baffle at 200rpm. However, with increased number of stirring arms and baffle, the biodiesel yield was increased to 85% at 200rpm. Also, the peak biodiesel yield of 98% was achieved with four stirring arms with baffle at 300rpm. This shows that using more stirring arms to interface the mobility of the alkoxide solution would yield optimum diesel at 300rpm.

Abbah, **Asoegwu** and Nwandikom (2016) investigated the optimum moisture content of the neem seed for the production of biodiesel because of moisture's negative effects on biodiesel. The investigation considered neem seeds of moisture content ranging from 6.8% to 14.1%wb which were used to produce neem oil and neem biodiesel by transesterification process with potassium hydroxide (KOH) as catalyst and methanol as alcohol. Then, the free fatty acid (FFA) was further reduced from 4.2% to less than 1.0% by two step acid esterification processes. **It was found that the treatment at 8.2% moisture content (M, wb) gave the highest yield of neem oil of 4.5% and the highest yield of neem biodiesel of 86.2%.** These yield processes were modeled and their regression equations for neem oil (N_o) and neem biodiesel (N_b) are given as Equations 71 and 72.

$$N_o = 0.558M^3 - 18.36M^2 + 193.3M - 573.0 \qquad (R^2 = 0.951) \qquad 71$$

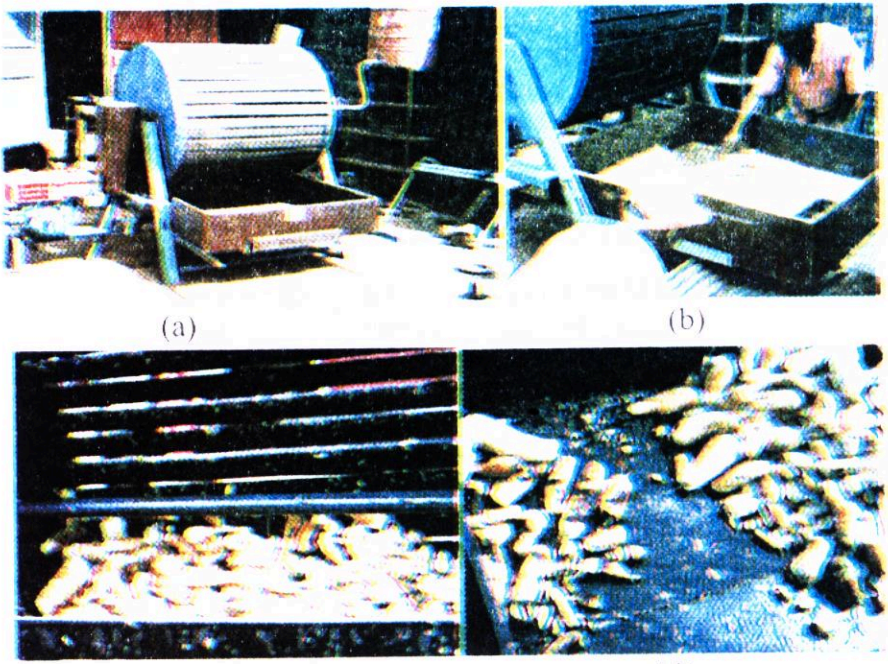
$$N_b = 0.111M^3 - 3.784M^2 - 41.31M - 51.63 \qquad (R^2 = 0.956) \qquad 72$$

The 3rd order polynomial relationship between N_o and N_b and moisture content (M) with similar R^2 = 0.95 is an interesting result showing how intricate M interacts with the neem oil and its biodiesel.

7.2.5 Cassava peeling

Cassava peeling, one of the operations in its processing, has been problematic. This was confirmed by Egbeocha, **Asoegwu** and Okereke (2016) who found that the various cassava peeling machines in Nigeria have operating speeds ranging from 40 – 700rpm with output capacities, peeling efficiencies and tuber losses at 10.4 – 725kg/h, 48.8 – 92.0% and 2.5 – 42%, respectively. None of these designs have been able to completely peel cassava tuber because of its irregular shape, resulting in additional manual removal of the peels with knives. However, the challenges in cassava peeling are gradually been overcome with new designs (Ndukwu, **Asoegwu** and Ahaneku, 2018).

Asoegwu and Chilakpu (2006) developed a cassava peeling and washing machine (Fig. 13) which operated at 450rpm to give 1650kg/h with peeling efficiency of 78.0% and tuber loss of 6.3%. Different variants of the machine have been developed but none has been commercialized because of poor government policies on research and development (R&D).



(a) (b)

© (d)

Fig. 13: Cassava peeling and washing machine processes (a) the machine, (b) cassava peels after processing, (c) peeled cassava in peeling chamber, (d) peeled cassava sorted out.

7.3 AGRICULTURAL STORAGE

With increased agricultural productivity in Nigeria through breeding new varieties, developing new production strategies and new production operations, **Asoegwu** (2006) posited that these efforts may come to naught if storage, processing and marketing which are highly engineering-based are not adequately addressed. **Thus, there is the need for proper and efficient storage of agricultural products.** Leaves play an important role in food preservation by physical and barrier protection (packaging) from storage problem-causing environmental factors like oxygen and water vapor. **Traditional wrapping with leaves provides sustainability by being functional in terms of product protection, cost effective by being locally sourced and available as well as being healthy for they contain antioxidants like polyphenols that fight cancer and**

Parkinson's disease and ecologically renewable. Some foods when wrapped with leaves, are allowed to ferment for specific reasons.

Fermentation, as it were, enhances and enriches the dietary properties and characteristics of foods. It preserves food through the production of acids; enriches food with vitamins and proteins; detoxifies food; decreases cooking time and fuel requirement. The use of leaves in wrapping foods is, to say the least, nutritional. It also enhances the aromatic, taste and aesthetic properties of food. However, even though well known, the documentation is spotty (Ng, 2015) and this informs the next two works.

Kabuo, **Asoegwu**, Nwosu, Onuegbu, Akajiaku, and Nwaimo (2015) assessed leaf-type and number of leaves used in wrapping on the quality of "*ugba*" (fermented *Pentaclethra macrophylla* Benth seed). After the "*ugba*" had been prepared traditionally from the raw African oil bean seeds, it was wrapped with three different leaves: plantain leaves (*Musa paradisiaca*), cocoyam leaves (*Colocasia esculenta*) and *okpopia* leaves (*Alchornea laxifora* Benth) with different number of leaves (ranging from 1 – 5) and fermented for 72h. The organoleptic and proximate analyses of the "*ugba*" were affected by both the wrapping materials and the number of leaves used for the wrapping. The 5-leaf wrap of *okpopia* leaves gave for aroma, taste, texture color and overall acceptability the values (in %) 6.1±1.2, 4.7±1.4, 5.8±1.9, 8.0±0.8 and 6.3±1.4 respectively. However, the 3-leaf wrap of cocoyam leaves and plantain leaves had the best results within their group of 1-5 leaf wrap. For cocoyam leaves, the values (in %) were 5.9±1.4, 5.3±1.9, 5.3±1.8, 6.7±2.0 and 6.3±1.2 respectively. For plantain leaves, the values (in %) were 6.4±1.4, 5.9±1.4, 5.7±2.0, 6.8±1.4 and 6.1±2.2 respectively. The effect of wrapping on the proximate composition of "*ugba*" is given in Table 16.

Table 16: Effects of wrapping materials on proximate composition of "*ugba*" (fermented *Pentaclethra macrophylla* Benth seeds) (in %).

Samples	Moisture content	Protein	Fiber	Ash	Fat	Carbohydrate
5-leaf *okpopia*	44.33^{c*}	8.59^{a}	17.00^{c}	18.50^{b}	6.50^{b}	44.57^{a}
3-leaf cocoyam	52.83^{a}	7.45^{b}	39.00^{a}	13.00^{c}	12.00^{a}	41.49^{b}
3-leaf plantain	47.04^{b}	6.77^{c}	33.50^{b}	33.00^{a}	12.00^{a}	35.23^{c}
LSD p=0.05	0.02	0.02	1.17	2.00	1.64	0.02

*=means in the same column with the same superscript are not significantly different (p = 0.05)

The low moisture content of 44.33% of 5-leaf *okpopia* compared to the other leaves show the certainty of prolonging shelf life. Even though the protein content of the wrapped samples ranged from 6.77% to 8.59%, it could still be considered high because fermented African oil bean seeds are good sources of protein. **The 5-leaf *okpopia* maintained highest protein content of 8.59%, showing that there was less leaching. The 3-leaf cocoyam samples maintained the highest fiber at 39.00%. This is good because fiber consists of coarse fibrous substances, largely of indigestible plant matter which play a role in the prevention of many diseases of the digestive tract, and aid digestion.** Fiber reduces plasma cholesterol in the body (Mbajunwa, 1995).

"*Ogiri-egusi*" was traditionally prepared as specified by Kabuo, **Asoegwu,** Omeire, Bede, Peter-Ikechukwu, Akajiaku and Nwanes (2015) and wrapped with treated miraculous fruit leaves (*Thaumatococcus daniellii* called "*uma*" in Igbo), banana leaves (*Musa sapientum*) and cocoyam leaves (*Colocasia esculentum*) and allowed to ferment for 5 days at 28±2°C temperature. This is to enable them develop their characteristic aroma, improve taste, enhance digestibility, increase nutritional value and preserve them from degradation by noxious organisms. After the 5-days fermentation, the "*ogiri-egusi*" in the different leave wraps underwent proximate analysis and organoleptic tests. The result of the proximate analysis is given in Table 17.

Table 17: The mean values of the proximate composition of "*ogiri-egusi*' samples (%)

Samples	Moisture	Protein	Fat	Crude fiber	Ash	Carbohydrate
Uma	7.64^{b*}	12.93^{b}	7.83^{b}	4.00^{b}	3.50^{b}	66.27^{a}
Banana	9.17^{a}	15.75^{a}	9.83^{a}	14.00^{a}	3.67^{b}	64.08^{b}
Cocoyam	3.67^{c}	11.09^{c}	6.50^{b}	3.00^{b}	7.00^{a}	30.40^{c}
LSD (0.05)	0.30	0.29	1.89	3.83	1.77	1.01

*=means in the same column with the same superscript are not significantly different (p = 0.05)

From Table 17, **the banana leaves wrapped samples of the "*ogiri-egusi*" had the highest moisture content (9.17%), protein (15.75%), fat (9.83%) and crude fiber (14.00%). This result confirms the very wide use of wrapping with banana leaves worldwide** (Viswanathan, 2017) especially in Africa, Asian countries and South America. The ash content was highest in the cocoyam leaves wrapped samples (7.00%) while the carbohydrate content was lowest in the cocoyam leave samples (30.40%). **Since the samples were from the same mixture, the differences in the proximate compositions observed must be due to the wrapping materials.**

From the organoleptic characteristics of the "*ogiri-egusi*", the panelists observed that there were only slight differences in taste from the different leaves used in the wrapping of the products. **The taste was best from the *uma* leave-wraps.** Their observations were captured in Table 18.

Table 18: Mean score of organoleptic characteristics of "*ogiri-egusi*" samples wrapped in different materials

Sample	Color	Aroma	Taste	Texture	Overall acceptability
Uma	5.60a	4.50a	7.90a	4.90a	4.60a
Banana	5.7a	5.40a	6.10b	5.10a	5.00a
Cocoyam	5.40a	4.90a	7.30ab	4.80a	5.50a
LSD (0.05)	1.97	1.87	1.72	1.33	1.45

*=means in the same column with the same superscript are not significantly different (p = 0.05)

Judging from the organoleptic characteristics of the "*ogiri-egusi*" wrapped with different leaves, it was found that most of the characteristics were similar for the leaves. However, the reason for this similarity could not be fathomed since it had been thought that the different leaves would have impacted on the "*ogiri-egusi*" some characteristic color, aroma, taste or texture. While the banana leaf wrapped samples had slightly higher values for color, aroma and texture, they scored lowest for taste. **Again, just like the "ugba" delicacy above, the banana leave showed more promise when used for wrapping processed foods for storage.**

8.0 HUMAN CAPACITY BUILDING

Mr. Vice Chancellor, my efforts at human capacity building started in 1972 immediately after my Higher School Certificate (1971), when my former Principal (Late Rev. Fr. V. Cullen) employed me to teach in St. Augustine's Seminary, Ezzamgbo, Eboyi State. Because I did Pure Mathematics, Applied Mathematics and Physics in the HSC, I was asked to teach Physics, Mathematics, Chemistry, Biology, Geography to almost all the classes (trust the missionaries). My approach in rendering these subjects endeared the students to me and enkindled their interests in them. Among the many of them is Prof. Boniface Iwuchukwu of the Imo State University, Owerri.

When I was in NIHORT, I was involved in the reach-out extension program where we go to schools to establish pineapple and plantain farms/plantations and teach the students on how to operate the farms from planting to harvest. During the National Accelerated Food Production Project (NAFPP) I participated extensively in the education of farmers on mechanized agriculture.

In FUTO, I have been privileged to have supervised over 1[illegible] undergraduate and postgraduate students' projects and theses. I wish to appreciate my postgraduate students who have endured the hot-[illegible] of my academic crucible and were baked by and passed through my Ph.D. – Engr. Dr. K. O. Chilakpu (Senior Lecturer and presently [illegible]

HOD in ABE Dept. FUTO), Engr. Dr. N. R. Nwakuba (Lecturer I at MOUA, Umudike), Pst. Dr. C. O. Chukwuezie (Lecturer 111 at Imo Poly. Umuagwu); - the last two were produced the same day, and I was nicknamed "*papa ejima*". M.Eng. – C. N. U. Eke (Principal Lecturer at Federal Polytechnic, Nekede), N. V. Ngwangwa, A. C. Iheonye (Asst. Lecturer ABE Dept. FUTO & Ph.D student at McGill University, Canada), Oji Irouwa (Farmer/Consultant at Abuja), E. C. Abbah (Snr Technologist, ABE Dept. FUTO), U, C, Egbufor (Lecturer 111 at Imo Poly, Umuagwu), V. C. Onyewuchi (Farmer/Consultant on Soil Erosion/Land Degradation Matters), F. N. Orji (Lecturer 11 at MOUA, Umudike), C. C. Asuzu (Lecturer 111 at Imo Poly, Umuagwo), D. C. Chinyere (Agro Logistics Officer at Agricultural Marketing Project -- World Bank Assisted, Umuahia) , A. L. Okojie (Site Engr. for Ripe-Tech Engineering Consultancy Services, Benin City). Many others are at different levels of the baking process and undergoing academic tutelage under me and would soon be delivered to the glory of God and the benefit of humanity.

9.0 CONCLUSION AND RECOMMENDATIONS

9.1 CONCLUSION

i. Improved technologies are necessary to reduce drudgery, save energy and promote the timeliness of farming operations, conserve the soil, improve fertility, process, preserve and store agricultural crops to provide more food locally and more crops for export, both in quantity and quality, to ensure food security.

ii. Best tillage practices and systems have been developed and established for soil management, soil protection and conservation for such crops like amaranths, egusi-melon, pineapple, etc. Models for several relationships between soil parameters and growth and development of these crops have been developed. Use of these models and tillage systems and practices will help in increasing crop yield and revenue. Soil compaction, measured by bulk density, was successfully predicted using soil moisture content. With increased productivity, food security will be assured and economic recession squarely addressed.

iii. Soil conservation and protection using mixed cropping systems with biomass (wood shavings, rice husk and sawdust) has been proposed. Mulching increases soil moisture retention, soil pH, and lowers soil bulk density. Regression models have been developed for crop yield, soil loss and vegetative cover. Wood shaving has been found to lower soil bulk density, control weeds and reduce soil loss better than rice husk and sawdust. Soil loss decreases exponentially with increase in vegetative cover. Mitigating these ravages and improving the soil structural stability will go a long way in increasing agricultural productivity for leveraging food security challenges.

iv. Late season planting (in September) and peak irrigation (between January and February) were established as the system for profitable and economic production in terms of plant establishment and yield and to increase water use efficiency for the growth of plantain, fluted pumpkin, pawpaw, and pineapple. Combining irrigation with fertilization is beneficial in the sense that with irrigation less amount of fertilizer will be required to get high yield. Also, with irrigation the amount of nitrogen fertilizer applied should not exceed 150kg/ha, when the frequency of irrigation is once a week and potassium at 200kg/ha. This will increase yield and productivity and help mitigate economic recession.

v. The physical, mechanical and frictional properties of crops like African oil bean seeds, Jackbean seeds, African breadfruit seeds, Achi seeds, plantain fruit, ogbono (*Irvingea gabonensis*) nuts, palm nuts, conophor nuts, etc. which are important in designing equipment for their handling, separation, conveying, drying, storing, aerating and processing have been determined. Several regression models for various parameters were developed. Also, the energies required to crack some of these nuts were established to help conserve energy of the system. It has been established that parboiling time and moisture content affect shell ability of African breadfruit seeds. Also, measures to determine the firmness and stability of plantain fruit for storage were developed.

vi. Mathematical models were developed to predict the cracking efficiency of a vertical palm nut cracker, the hydraulic conductivity of Nigerian agricultural soils, the flow rates of egusi-melon and African breadfruit seeds through horizontal hopper orifices. These models predicted the systems to more than 95% accuracy.

vii. An arduino-primed hybrid solar-electric dryer was designed and developed to be largely automatic. It proved effective and efficient as it generated enough temperature and drying energy to successfully dry slices of okra, pepper and tomato. The dried products from this dryer stored for about three months under ambient environment. The developed dryer has the capacity to dry other moisture-laden crops for increased food security.

viii. To achieve uniform browning, the process of combination cooking method was utilized to achieve the appropriate temperature and duration of cooking for corn cob. Also, to be able to predict the appropriate cooking time for mature corn cob to be done for eating, a regression model was developed relating cooking duration to temperature.

ix. With a modified biodiesel batch reactor, some biodiesels were produced from Jatropha, neem and waste vegetable oils. Characterization of the biodiesels showed that the B5 –B30 blends with conventional diesel gave best engine performance. To enhance environmental cleanliness, briquettes of good quality were made from sawdust and corn starch as binder. This technique could introduce other forms of energy for household use.

x. To package "*ogiri-egusi*" and "*ugba*" for longer shelf life and quality, a number of leaf-types and numbers of their leaves per wrap were assessed and specific leaf type and number were chosen for each of the delicacies. Because of the economic, nutritional and social importance of the crops, standardization of their packaging will help ensure food security.

9.2 RECOMMENDATIONS

i. The "oil curse" or "Dutch disease" or "Devil's excrement" can be abrogated or cured by encouraging the needed development in the agricultural sector by the Nigerian government focusing on supporting smallholder farmers, increasing productivity and improving rural infrastructure. Nigeria must reposition her economy to be productive through agricultural development and solid minerals exploration and exploitation.

ii. Nigeria is an agrarian country/nation blessed richly and generously with climate, water, animals, crops, fish, mountain and forest resources. Agriculture would not only provide food materials for the nation but with adequate mechanization can generate raw materials for many industries and contribute immensely to the industrial and economic growth of the nation to mitigate recession.

iii. The Agricultural Promotion Policy (APP) of the Federal Government of Nigeria should be pursued with strong political commitment and institutional reforms and realignment to increase productivity and growth in industrial raw materials and export crops to boost the national gross domestic product (GDP) and mitigate recession. The proper articulation and implementation of good policy instruments, diversification of activities in the agricultural sector championed by public private partnerships (PPP) will ensure demand-driven outfits that will ensure employment opportunities and mitigate economic recession and food security challenges.

iv. Agricultural mechanization could be responsible for the technical and infrastructural development of rural areas with respect to: - Rural housing and farm settlements; Animal housing and storage structures; Rural road and transport development; Rural water supply; Rural communication infrastructural development; Rural electricity; Agricultural land clearing; Farm irrigation schemes; Flood control; Reclamation of oil spilled lands and soils; Erosion control and drainage systems' maintenance; etc.

v. The various industries that agricultural mechanization can support or generate for diversified economy include: - a) Power and energy: biomass, bio-energy, bio-fuel, biogas, biodiesel, earth dam for rural electricity supply and irrigation, wooden electric poles, etc. b) Furniture and construction industries; forestry and wood products. c) Pharmaceutical industries from fruits, vegetables, stems, leaves, roots, barks of plants, etc. d) Specialized health foods industries: added value chain and food products development, etc. e) Tourism industry from wildlife parks and forestry, etc. f) Agro-manufacturing/processing industries from crop and animal materials, etc. g) Leather industry from animal skin. h) Textile industry from cotton. For these to be achieved, it is necessary to establish large-scale farms to produce the required raw materials in sufficient quantities to sustain their proposed agro-processing industries.

vi. Recent government actions on its populace has dwindled people's confidence in government policies and programs. Government should boost people's confidence by itemizing specific actions and drive performance which can re-initiate growth and investment and mitigate recession.

vii. There should be a wholesome policy instrument from government to support the agricultural engineering profession and professionals in Nigeria if she would mitigate recession, for agriculture holds the key, and agricultural engineering is the pivot.

iv. Agricultural mechanization could be responsible for the technical and infrastructural development of rural areas with respect to: - Rural housing and farm settlements; Animal housing and storage structures; Rural road and transport development; Rural water supply; Rural communication infrastructural development; Rural electricity; Agricultural land clearing; Farm irrigation schemes; Flood control; Reclamation of oil spilled lands and soils; Erosion control and drainage systems' maintenance; etc.

v. The various industries that agricultural mechanization can support or generate for diversified economy include: - a) Power and energy: biomass, bio-energy, bio-fuel, biogas, biodiesel, earth dam for rural electricity supply and irrigation, wooden electric poles, etc. b) Furniture and construction industries; forestry and wood products. c) Pharmaceutical industries from fruits, vegetables, stems, leaves, roots, barks of plants, etc. d) Specialized health foods industries: added value chain and food products development, etc. e) Tourism industry from wildlife parks and forestry, etc. f) Agro-manufacturing/processing industries from crop and animal materials, etc. g) Leather industry from animal skin. h) Textile industry from cotton. For these to be achieved, it is necessary to establish large-scale farms to produce the required raw materials in sufficient quantities to sustain their proposed agro-processing industries.

vi. Recent government actions on its populace has dwindled people's confidence in government policies and programs. Government should boost people's confidence by itemizing specific actions and drive performance which can re-initiate growth and investment and mitigate recession.

vii. There should be a wholesome policy instrument from government to support the agricultural engineering profession and professionals in Nigeria if she would mitigate recession, for agriculture holds the key, and agricultural engineering is the pivot.

viii. The above recommendations, if implemented, wou leverage food security challenges in Nigeria throu agricultural production, processing and storage for mitigati recession.

I rest my case.

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CLOSING/MAGNIFICAT

Mr. Vice Chancellor. Ladies and Gentlemen and all who are here present, follow me to pray Psalm 103:1 – 3 which says "Bless the Lord, my soul; all my being, bless His holy Name! Bless the Lord, my soul, and do not forget all His gifts. Who pardons all my sins, and heals all my ills, Who redeems my life from the pit of destruction, and crowns me with mercy and compassion".

My soul now glorify/ The Lord Who is my Savior
Rejoice for who am I/ That God has shown me favor

The world shall call me blessed/ And ponder on my story
In me is manifest/ God's greatness and His glory

For those who are His friends/ And keep His Love as Holy
His mercy never ends/ And He exalts the lowly

But by His powers the great/ the proud, the self-conceited
The kings who sit in state/ Are humbled and defeated

He fills the starving poor/ The Lord guides His Holy Nation
Fulfilling what He swore/ Long since in revelation

Then glorify with me/ The Lord who is my savior
One Holy Trinity/ Forever and forever

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List of FUTO Inaugural Lectures

S/No	LECTURER	TOPIC	DATE
1	Prof. C. O. G. Obah	"Communication in the service of a nation"	Dec. 12, 1986
2	Prof. E. O. I. Banigo	"Food Processing and Preservation. Paths to Self Sufficiency"	Jan. 18, 1989
3	Prof. V. O. Nwoko	"Where Rust Doth Corrupt"	Nov. 14, 1990
4	Prof. S. C. O. Ugbolue	"In the Throes of Polymer and Textile"	Dec. 11, 1996
5	Prof. O. O. Onyemobi	"Mineral Resources Exploitation, Processing and Utilization: A Sine Qua Non for Nigeria's Industrial Development"	Jul. 17, 2002
6	Prof. A. B. I. Udedibie	"In Search of Food FUTO and the Nutritional Challenges of Carnavalia Seeds"	Sep. 18, 2003
7	Prof. E. O. N. Okorafor	"Expendable Polystyrene Patter Casting Process: A Revolution in Metal Casting"	Mar. 17, 2004
8	Prof. P. B. U. Achi	"Acquisition of Indigenous Machinery Design Manufacturing: The Engineering Education and Training Perspective"	Jun. 28, 2004
9	Prof. M. I. Nwufo	"Securing the Harvest to Ensure Food for All: A Plant Pathologist's Perspective"	Jul. 28, 2004
10	Prof. M. U. Iloeje	"The Chicken or the Egg: Nature and Nurture: New Genetic Spread Sheet and Gene Pool in the Breeding and Evolution of a New Nigerian Man"	Nov. 17, 2004
11	Prof. J. O. Uzuegbu	"Salvaging our Food from Fungi Rot to Ensure Food Security"	Oct. 29, 2008
12	Prof. C. S. Nwadiaro	"Inland Water Data Base AS. A Sine Qua Non for Fisheries Development in Nigeria"	May 7, 2009
13	Prof. M. C. Ofoh	"Food Security and Mitigation of Climate Change through Ecosystem-based Agriculture"	May 27, 2009
14	Prof. B. O. Esonu	"Unconventional Feed Resources for Livestock Development and Food Security: Paradigms for Nigeria Livestock Industry"	Jun. 24, 2009
15	Prof. E. O. P. Akpan	"Project Management: A Catalyst for Rapid Industrial Development for Emerging Economies"	Oct. 10, 2009
16	Prof. C. C. Asiabaka	"Scaling-up Agricultural Technologies for Food Security and Poverty Reduction: Whose Knowledge Counts: The Farmer of The Scientist?"	Feb. 15, 2010
17	Prof. C. O. Owuama	"Foundation Engineering in a Difficult Environment"	Jun. 10, 2010
18	Prof. N. N. Onu	"Training in Geophysics: The Challenges of Oil Exploration, Gully Erosion and Water Resources"	Mar. 16, 2011
19	Prof. Mrs. H. C. Nwigwe	"Aquatic Resources Management: A Tool for Food Security in Nigeria"	Mar. 30, 2011
20	Prof. C. N. Ubbaonu	"Enhancing Acceptability and Economic Value of Local Foods through Product Development and Promotion"	Apr. 27, 2011
21	Prof. G. C. Ehedaru	"Towards a Unified World View: The 'god particle' and the Traditional Christian Belief"	Oct. 4, 2012
22	Prof. E. E. Anyanwu	"New Energy Technology Revolution: A Catalyst for Sustainable National Development"	Oct. 29, 2012
23	Prof. G. N. Onuoha	"The Chemical Pathway: Small Changes That Made a Difference"	Mar. 27, 2013

24	Prof. C. C. Eze	"Agricultural Finance: A Panacea for Agricultural and Rural Development"	Mar. 26, 2014
25	Prof. A. N. Amadi	"Environmental Health: The Dynamics, Application, Implications and Way Forward in Nigeria's Healthcare Delivery System"	Jul. 23, 2014
26	Prof. G. F. Okorafor	"Depopulating the Unemployed Mass in Nigeria through Effective Project Delivery"	Sep. 10, 2014
27	Prof. A. A. Ayuk	"The Question of the Electron : It's Origin and Impact on Chemical Processes"	Mar. 10, 2016
28	Prof. Mrs. E. U. Onyeka	"Food Security: Concerns and Comforts in Food Processing"	Apr. 27, 2016
29	Prof. J. S. Orebiyi	"Agricultural Credit: A Policy Catalyst Needed for Poverty Reduction and Rural Agricultural Transformation in Nigeria"	Sep. 22, 2016
30	Prof. B. C. Anusionwu	"Liquid Metals: Searching for Properties at Elevated Temperatures"	Oct. 19, 2016
31	Prof. U. U. Egereonu	"Analytical Assessment of Atmospheric Residual Aerosol in the Environment"	Mar. 29, 2017
32	Prof. N. J. Okeudo	"Human Food and Healthy Lives: Confronting Insufficient Production and Preservation of Good Quality Meat and Egg"	Apr. 26, 2017