



Agro-Products and Raw Materials Development-A Review of applications in Nigeria

*Ifreke, Okon Akpan, and Utibe Benedict Edem

Received: October 3, 2024 /Accepted: December 5, 2024

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Abstract

Over the years, agro-products have served as foundational resources for the development of various raw materials, with ongoing research continually uncovering novel applications. These materials include methanol, nanomaterials, lignin, cement additives, cellulose, and agro-based enzymes, highlighting their immense industrial and economic potential. Beyond their viability, the utilization of agro-products mitigates environmental issues by converting agricultural waste into valuable raw materials, thereby reducing pollution. Nigeria, endowed with abundant crude oil, natural gas, and other mineral resources, relies heavily on these for foreign exchange despite its vast agricultural potential. This review explores Nigeria's agro-based raw materials, their geographic distribution, and industrial applications, emphasizing their chemical and physical properties. The study underscores the importance of leveraging these resources to spur the establishment of small-scale agro-allied industries, fostering economic diversification and sustainable development.

✉ Ifreke, Okon Akpan: Corresponding author: akpanifreke4live@gmail.com (+23407032211754)
Department of Chemical Engineering, University of Port Harcourt, Choba, Rivers State, Nigeria.

Keywords: Agro-processing, Agro-products, raw-materials development, Nigeria

1.0 Introduction

With the rapid increase in world population, which currently stands at 7.7 billion with an annual growth rate of 1.05% and a projection of reaching 9.7 billion by 2050 (UN World Population Prospects, 2019), much pressure has

been exerted on the existing raw materials for the production of value-added products. The emergence of new technologies, which warrant the exploitation of new frontiers in industrial development for new products and processes, also increases the demand for raw materials.

Thus, it becomes imperative to search for alternative or supplementary raw materials that can effectively and efficiently replace the existing ones.

Raw materials are unprocessed materials that can be processed into many useful products. It is one of the determinants of a product's quality and cost (Makio *et al.*, 2003). Raw materials are supplied in powder and liquid forms. Processing of raw materials, such as grinding and, mixing is very important. A lot of factors could affect the quality of raw materials, such as impurities, moisture contents, particle shapes, particle size and size distribution, etc. (Isreal *et al.*, 2016).

Raw materials can be considered as crude or processed substances that undergo transformation for the production of value-added products. As the name implies, raw material development entails the creation of raw materials from sources that were not initially in use or the manufacturing of raw materials from novel materials. In the quest for these alternative sources of raw materials, it demands that attention be given to the environmental impact of such materials, the economic viability, sustainability, the availability of technology that can convert such raw materials into the needful products, government policy that guides the usage of such materials, etc.; all these boil down to the new concept in the engineering discipline called the 'Green Engineering Practices'. With this current trend in the engineering practices, raw material development focuses now on sources that are renewable.

In order to stall and overcome Nigeria's excessive reliance on its oil and gas sector for national development, as well as expand the economy's growth, it is vital to harness its mineral and agricultural resources (Adindu *et al.*, 2014). Therefore, this paper discusses raw material development and utilization as criteria for Nigeria's economic development. This serves as a first step in strengthening its entrepreneurship and small and medium

enterprises (SMEs) development. The aim of this study is to evaluate agro-based raw materials in Nigeria, their availability, where they can be found in abundance, their applications and value addition for economic growth. The most abundance agro-products are considered in this work.

2.0 Agricultural Potential of Nigeria and Government developmental Policies

Nigeria has approximately 71 million hectares of farm land available for cultivation representing 77% of the total land mass in the country. It is estimated that out the available cultivable land, 84% of the land is owned by the farmers either by purchasing or transfer of ownership from ancestors, 11% is leased to farmers by owners, 4% is leased by third party or the farmer pays royalties and 1% is illegally cultivated. The land Use Act according James (1978) states that, lands in the urban area are owned by the State Government while lands in the rural area are owned by the Local Government. This Act put a check to land usage. In term of manpower, out of over 213 million people in the country, more than 70% are involved in one agricultural practice or the other, there are estimated 18.17 million crop farmers, 12.30 million livestock farmers, 6.39 million poultry farmers and 1.02 million fishery farmers.

To improve agricultural potential of the country, In December 2021, Nigeria Government formulated medium-term National Development plan that covers a period of 5 years (2021 – 2025). This was done to unravel its potential in all sector of the economy for holistic national development and increasing agriculture production for economic growth by the year 2025. This developmental plan gave birth to National Agricultural Technology and Innovation Policy (NATIP) (2022-2027) formulated by Federal Ministry of Agriculture and food Security which aims at promoting agro-based industries by increasing productivity and quality of products in agricultural sub-sector

through infrastructure and financial availability. (Data Collection Survey on Agriculture Sector in Nigeria (2024)). This step was taken by the government to boost agro-products availability for human consumption and for industries purposes.

3.0 Types of raw materials

Raw materials for all production processes are from diverse sources, which are basically from nature. The synthesis, processing, and transformation of materials into secondary raw materials take its bases from the natural sources; thus, nature is the bedrock for all raw materials (Marschallek and Jacobsen 2020).

A basic classification is the nature of how the good is extracted. These classifications include: Mined raw materials extracted from the earth, such as ores, stones, metals, minerals, lime, sand, soil, oil, and coal; Plant-based raw materials come from trees or plants, including fruits, nuts, flowers, vegetables, resins, wood, cotton, and latex, and Animal-based raw materials are extracted from animals such as milk, meat, furs, leather, and wool (<https://www.investopedia.com/terms/r/rawmaterials.asp>).

Manufacturers also have their ways of classifying raw materials. Their classification is based on the extent in which the material has been used in the cause of production of the desired product. On this premise, raw materials are classified into two broad categories; the direct raw materials and the indirect raw materials. The direct raw materials are those materials that form the bases through which finished products are produced. Example includes woods for furniture, leather for bags, wool for cloth, silicon oxide for glass, etc. All these materials form the bedrock and the primary components of the final products. The indirect raw materials are those materials that complement the production of the desired products. Examples are gum, nails, metal hoop,

glue, lining used in cloth making, etc. These materials facilitate the coupling of the direct raw materials.

Among all these sources of raw materials mentioned in the first classification above, natural deposits are the most exploited and used raw materials for production processes for both secondary raw materials and value-added products. The reason is that they are obtained directly from the source, and as such, complex technology is not involved. But with the explosion of the human population and the industrial revolution, the demands for raw materials to cater for the increase also increase, coupled with the fact that natural deposits are non-renewable. This called for the search for alternative sources, which has been focusing on agro-products.

Nigeria's short-to-medium-term potential lies in her natural comparative advantage, namely resource-based industries, which will provide a competitive platform for finished products in the longer term, as well as an immediate market for resource input industries.

4.0 Agro-products

Agro-products are those products obtained from agricultural inputs. By extension, agro-based raw materials are simply materials derived naturally from plants and animals (Israel et. al., 2016).

It includes both plant and animal products. Examples include fruits, seeds, nuts, silks, bulbs, grains, latexes, gum, fat and oils, meat, hides and skin, residues of all kinds etc. According to records as reported by Searle (2013), about 1.3 billion tons of food produced, globally representing one-third of annual food production is wasted. 25–50% of vegetables and fruits are usually lost from farm to fork, together called post-harvest losses (Ray, 2022). European Union food waste alone stands at about 59 million tons every year (Eurostat, 2024). 39% of these losses are incurred during processing

handling and storage levels (Mmereki *et al.*, 2024). However, in most African countries (such as Nigeria) food is primarily wasted at the consumer level mainly at caterers, restaurants, and cafeterias. eateries and above all, by households (Orhororo *et al.*, 2017; Oelofse *et al.*, 2021).

Aside from the losses incurred from the edible agricultural materials, which posed major environmental challenges through means of disposal. The plant and animal residues, such as cobs from maize, husks from rice, bagasse from sugarcane, bones, blood, etc., also posed a serious environmental challenge because all

these materials contained essential nutrients that are major food for microbes, rodents, and other dangerous organisms; thus, they act as breeding grounds for these organisms. If these wastes are not controlled, it can lead to disease outbreaks, pollution at various levels, and other environmental degradation, thus the need to control their disposal. It is in the search for proper waste management of these agricultural products that researchers found out that these materials can be converted to useful materials as alternative sources of raw materials for chemical and biological processes. Table 1 highlights some agro-products and their residues.

Table 1: Agro – products Residues

S/N	Agro - products	Residues generated
1	Corn, wheat, rice	Straw, stalks, husks, cobs
2	Cattles, goat, poultry	Animals' wastes, bones, blood, dung
3	Sugarcane	Bagasse, pines
4	Fruits and vegetables	Seeds, peels, husks
5	Potatoes	Starch waste water
6	Oils and oil seed	Shells, husk, fibres, sludges, press cake
7	Coconut	Coir, dust, fibres, shells
8	Trees	Wood, gum, bulb

5.0 Agro-products Availability and Location in Nigeria

Nigeria is blessed with varieties of agro-products distributed across the six geopolitical zones of the country. The distribution of these products is based on climatic conditions of the various zones which support production of these products. For this study some important agro-products are consider, their availability and where it can be found in the country. They are classified into five categories (cereal and Tuber crops, vegetable crops, crops for processing, livestock and diary and Aquaculture) as described by Japan International Agency Cooperation in Data Survey of Agriculture sector in Nigeria (April, 2024). Additionally, timber is also considered as it plays a vital role in raw materials development in the country. The map in Figure 1 shows the different

geopolitical zone in the Nigeria as stated in the legend.

5.1 Cereal and Tuber crops

Table 2 shows the availability of most abundance cereal and tuber crops and zones they are cultivated with yam and cassava taken the lead in tube crops while maize and rice take the lead in cereal crops. They are other crops in this group that are not in abundance but they are also distributed in the different zones of the country according to Federal Republic of Nigeria Data Collection Survey on Agriculture Sector in Nigeria Quarterly Crop Baseline Survey (QCBS) final report of 2004.

5.2 Vegetable crops availability

National Report of Wet Season Agricultural Performance in Nigeria, 2021 is a bar chart showing the amount of common and most

abundant vegetable crops in thousands of tons available in the country and the different zone in which they are cultivated. From the Chart in

Figure 2, it can be deduced that the most abundant vegetable crop in the country is cowpea.

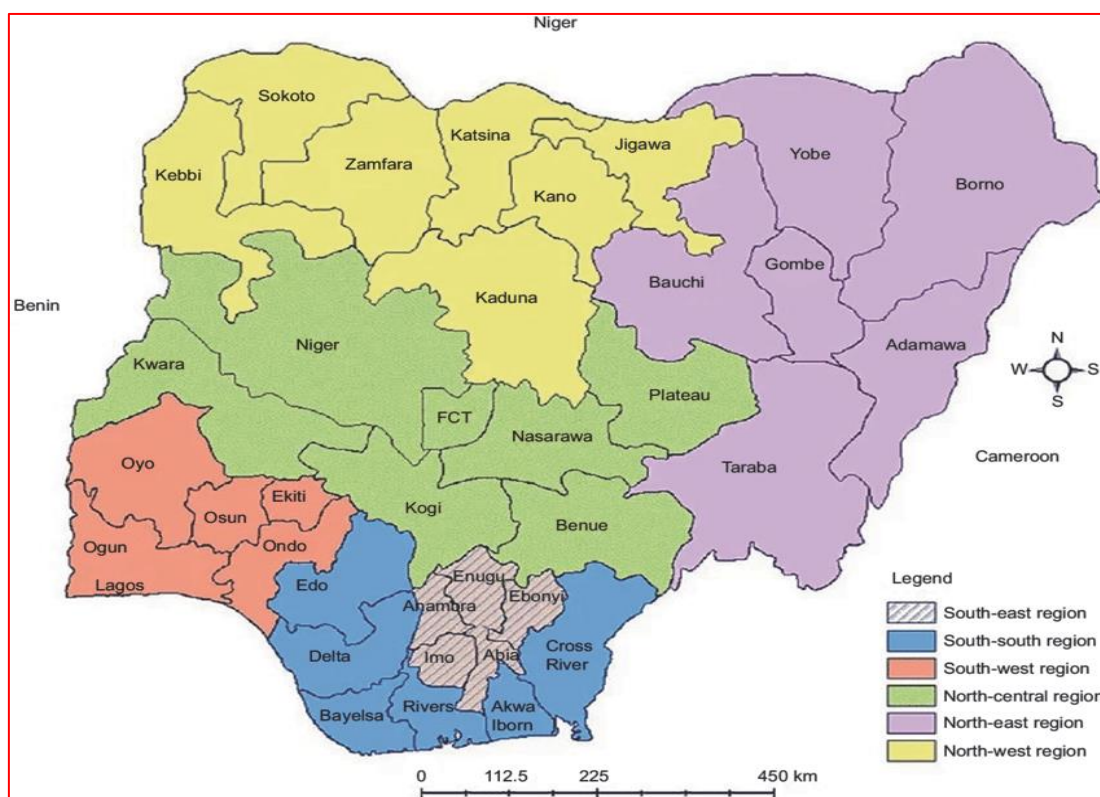


Figure 1: Map of Nigeria showing different Geopolitical Zone (Chukwuonye *et al.*, 2018)

Table 2: Cereal and Tuber crops and their availability as at 2021 (Thousands of tons) source: APS 2021

Zone	Rice	Maize	Sorghum	Yam	Cassava	Millet	Cocoyam	Plantain	Wheat	Potatoes	soybean
North east	1479	3207	2030	3431	3197	779	223	0	11	0	238
North central	3197	3279	1646	22690	15682	434	1076	398	2	2	533
North west	1967	2878	2971	3780	5269	714	0	0	24	0	352
South East	483	691	14	10189	9265	0	2488	2656	0	0	0
South south	551	751	0	10569	11926	0	2376	4335	0	0	0
South west	665	1941	665	9224	12899	0	2039	0	0	0	42
Total	8342	12747	6726	59884	58238	1927	8203	7389	37	2	1166

APS* National Report of Wet Season Agricultural Performance in Nigeria

These crops are not the only vegetable crops, others are distributed in various zones in the

country and are still very useful for different applications.

5.3. Crops for processing

Crops for processing are those that are converted into secondary products before being used. There are several crops in this category, but the most abundant ones are considered in this study.

Figure 3 shows their distribution across various zones of the country, with groundnut leading and being most commonly cultivated in the North Central and North East zones, followed by oil palm in the South-South and South East zones

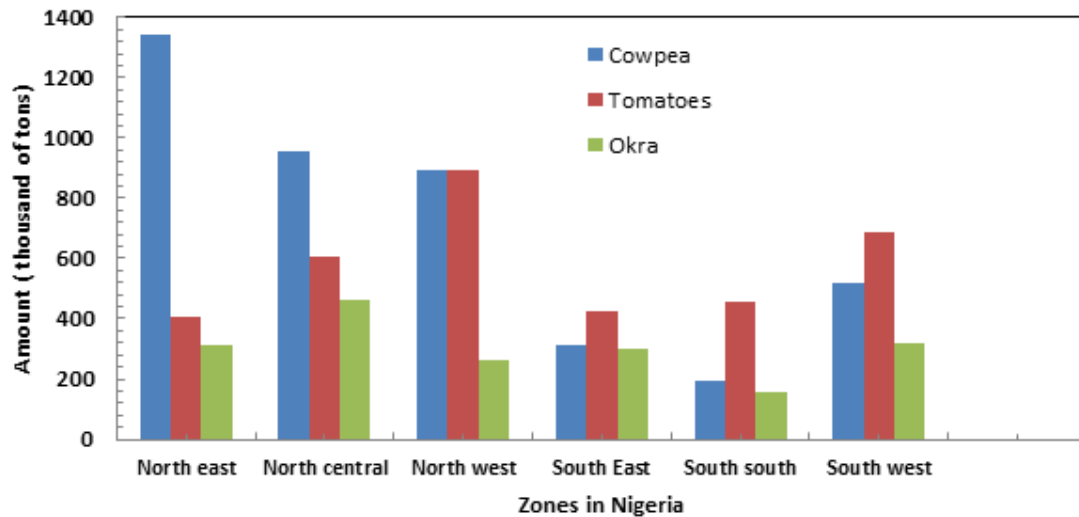


Figure 2: Common vegetable crops and their availability as at 2021 (Thousands of tons) source: APS 2021. APS* National Report of Wet Season Agricultural Performance in Nigeria

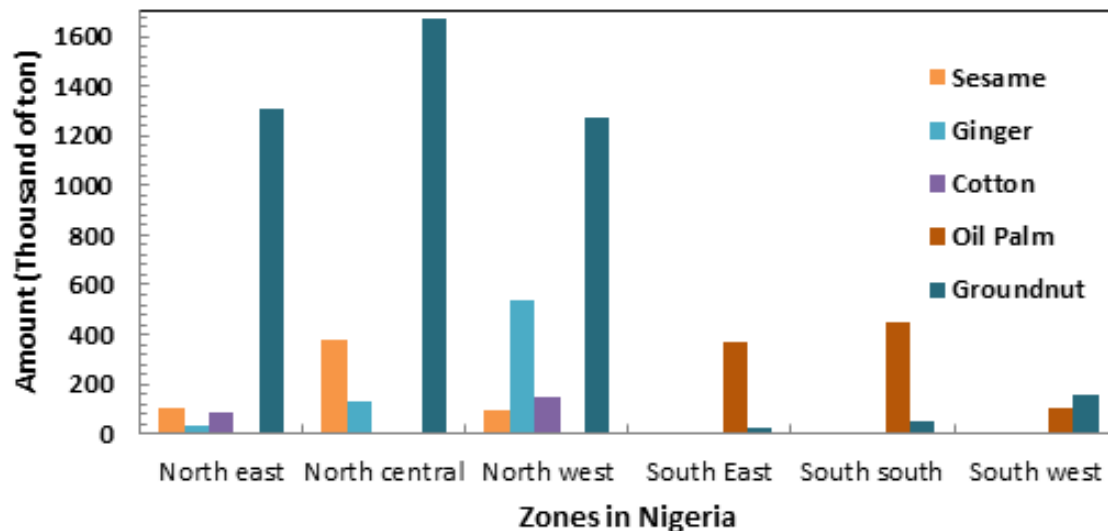


Figure 3: Crops for processing and their Availability as at 2021 source: APS 2021 APS* National Report of Wet Season Agricultural Performance in Nigeria

5.4. Livestock and Dairies

Aside from their consumption, these agro-products are also useful for various industrial applications, such as the manufacturing or processing of secondary products like leather, clothing, and food additives. The most common and abundant livestock and dairy animals in the country are highlighted in Figure 4, where a bar chart shows that chicken is the leading and most

abundant in the North West and North Central zones. In addition to the livestock and dairy animals mentioned, others, such as donkeys, horses, and dogs, are distributed across various zones in the country.

5.5 Aquaculture availability

To supplement the available aquatic products, farmers also undertake fish production in

artificial environment (pond). Two major products in this category that performed optimal in artificial habitat are the cat-fish and tilapia.

Figure 5 highlights amount being produced in different zones of the country.

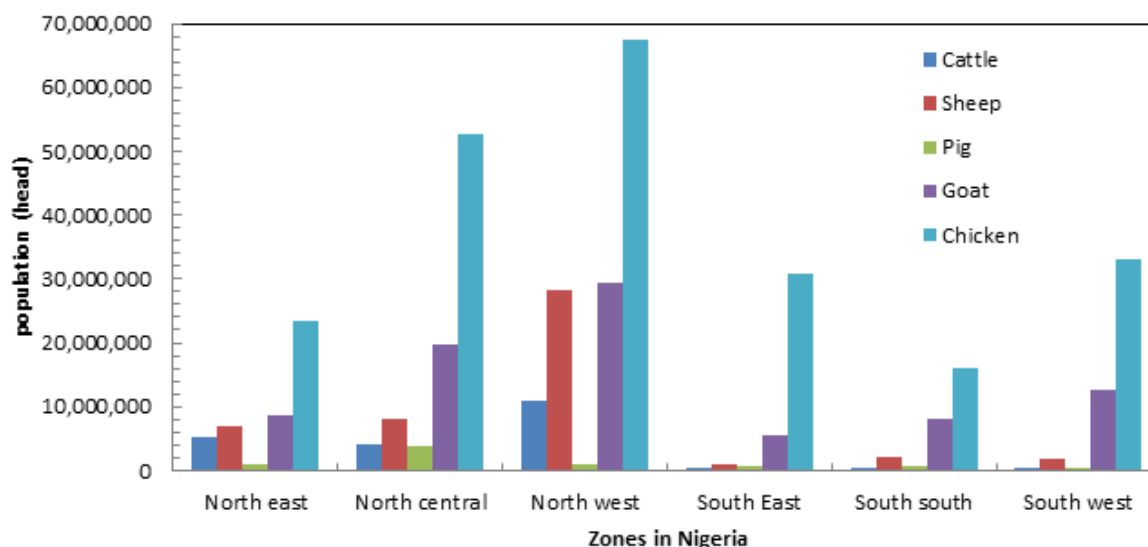


Figure 4: Livestock and Dairy availability in Zone as at 2021(head) source: APS 2021 APS* National Report of Wet Season Agricultural Performance in Nigeria

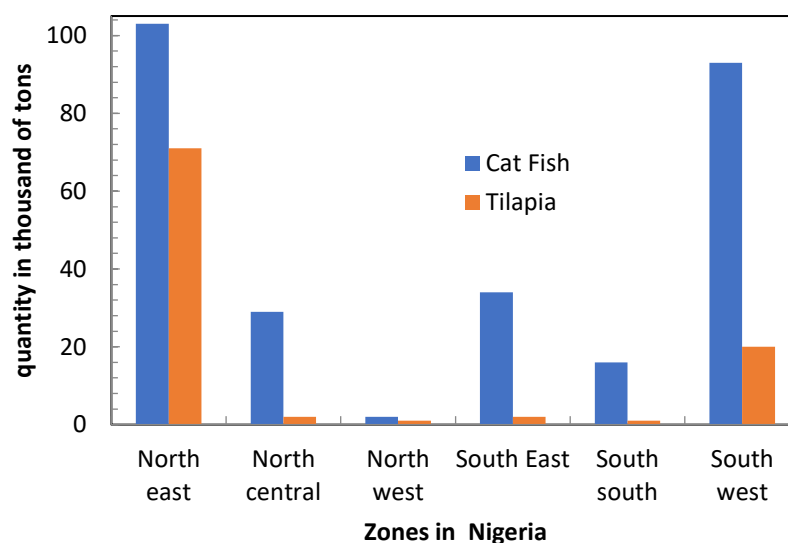


Figure 5: Aquaculture availability by Zone (Thousands of tons) as at (2019) source: APS 2019 APS* National Report of Wet Season Agricultural Performance in Nigeria

5.6. Timber

There are approximately 2,300 tree species in Nigeria that are commercially important. These trees are found in all the geopolitical zones of the country ranging from the short shrub in the savanna region to gigantic trees in the mangrove forest. Some example of these trees includes Iroko, Opepe, Afara, Obeche, Abura, Mahogany, Teak, etc. They are very essential agro-product that have wide applications in

structural and non-structural uses. (Maiguru *et al.*, 2022).

6.0 Agro-processing

Agro-processing can be defined as the transformation of products originating from agriculture to final products (Swai *et al.*, 2019). Such products include maize, fruits and vegetables, wood, sugarcane, cotton, oilseeds, sunflower seeds, wheat, rice, tea, coffee, skin, milk etc. Agro-processing occurs through

primary as well as secondary processing (Wanniarachchi et al., 2016). Primary processing involves the preservation of raw materials that are to be used in the final processing. This type of processing can be done either through drying, shelling and grading and does not alter the shape and contents of materials significantly. On the other hand, however, secondary processing involves transforming these materials completely to new products. Examples of secondary processing involve extracting juices from fruits and vegetables, processing cotton to get oil, crushing sunflower seeds to extract oil etc. (Ampadu et al., 2015).

7.0 Materials and Methods

The materials and methods used in the review were obtained from previous literature seen in related journal articles.

7.1. The potential of agro-products residues as raw materials

Many studies have been performed recently to investigate the potential of agro-products as sources of raw materials for the manufacturing of useful products and as means for effective management of wastes associated with the agro-products. The first phase of this noble venture is the characterization of these materials to ascertain their composition so as to know where these materials can be effectively utilized. Some of the agro-product characterizations are highlighted below.

7.1.1 Oil palm bunch ash

Palm oil bunch ash is obtained from the burning of waste palm oil bunch and has been found to contain several useful elements. That shows close likeness to conventional cement. The composition and physical properties of palm fruit ash are as given in Table 3.

Table 3: Chemical composition and physical properties of oil palm bunch ash (Awang et al., 2014)

Compound	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	Salt content
% composition	19.98	5.17	3.27	63.17	0.79	2.38	Max. 5
Physical properties/ characteristics							
Appearance							Brown to light brown
PH in solution							7.5 to 8.0
Chloride as NaCl							Nil
Size of particles							Fine coarse

7.1.1.2 Application of Oil palm fruit bunch Ash

Oil palm fruit ash is used in acidic soil treatment and as fertilizer for crops. Ogbuehi, (2016) reported increase in soil P^H from 5.22 to 6.87 when oil palm bunch ash was used in treating acidic soil. It can also be used as substitute for commercial basic catalyst in biodiesel production and other chemical reactions. The high calcium oxide content also suggests that it can be used as additive to increase the compressive strength of concrete. Thus, the used of palm bunch ash in agro-sector for soil quality improvement and construction companies as

additive to cement, help in increasing crop yield and reduce construction cost respectively.

7.1.2 Sugarcane bagasse ash

When sugarcane bagasse was burned, it was found to contain useful compounds in good percentage. The percentage composition of different components and basic physical properties are as shown in Table 4.

7.1.2.1 Application of sugarcane bagasse ash

It is an essential raw material in paper and pulp industries and also as cement replacement and blending due to its high pozzolanic characteristics. The high silicon oxide content

also suggests its usage in ceramic manufacturing.

7.1.3 Rice husk ash

Rice husk ash has been found to contain over 90% of amorphous silica (SiO_2) and some other elements. Table 5 shows the chemical compositions and some physical properties of rice husk ash.

7.1.3.1 Application of rich husk ash

Rice husk ash is used as insulating powder in steel production. It is also used in food

processing industry as bio-adsorbent in vegetable oil refining and removal of heavy metal from food materials. In brick manufacturing, it is used as additive to reduce cost of production due to its high pozzolanic index. Other usages include, base material for silica and silicon compounds, as organic fertilizer for quality improvement etc. (Patil *et al.*, 2018; Zou, 2019).

Table 4: Chemical composition and physical properties of sugarcane bagasse ash (Suvash *et al.*, 2019)

Compound	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O
%	65.3	6.9	3.7	4.0	1.1	2.0
Physical properties						
Fineness of particles (μm)						5.1
Specific gravity						1.8
Blaine fineness (m^2/kg)						900

7.1.4 Bamboo leaf ash

The composition and physical properties of bamboo leaf ash are as stated in Table 6. From Table 6 it can be deduced that silicon oxide has the highest percentage in the ash.

7.1.4.1 Application of bamboo leaf ash

Bamboo leaves ash is use in Construction Company as partial replacement of cement and as stabilizer for soft soil treatment. The high

silicon oxide content also suggests that it can be used for production of silicon and silica-based compounds (Olutoge *et al.*, 2017).

Other agro-residues have been examined by several researchers to ascertain their composition and where they can be effectively used. Table 7 gives some common residues and their chemical composition.

Table 5: Chemical composition and physical properties of rice husk ash (Suvash *et al.*, 2019)

Compound	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O
%	93.4	0.05	0.06	0.31	0.35	1.4
Physical properties						
Fineness of particles (μm)						8.6
Specific gravity						2.05
Pozzolanic activity index (%)						99
Water absorption (%)						104

Table 6: Bamboo leaf ash composition and physical properties (Suvash *et al.*, 2019)

Compound	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O
%	75.9	4.13	1.22	7.47	1.85	5.62
Physical properties						
Specific gravity						2.25
Moisture content (%)						0.40

Table 7: Chemical composition (%) of important agro-residues (Rajeev *et al.*, 2018)

Residues	Carbohydrates	Crude fibre	Ash	Pectin	Fat	Protein	Lignin
Sugarcane bagasse	66.48±2.68	-	8.8±0.02	-	-	2.3	17.79±0.62
Rice bran	14.1 ±1.1	26.9	3.4 – 8.1	-	30.4±0.9	38.2±2.3	25.63
Wheat bran	56.8	33.4 – 63.3	3.9 – 8.1	-	3.5 – 3.9	13.2 – 18.4	5.6
Spent coffee waste	55.53±0.85	60.46±2.2	1.3±0.1	-	2.29±0.3	17.44±0.1	23.90±0.3
Brewer's spent grain	79.9±0.5	3.3±0.1	7.9±0.1	-	-	2.4±0.2	30.48±0.8
Cassava peel	75.5±1.2	11.2±0.6	2.4±0.2	-	3.1±0.1	1.7±0.1	1.92±0.07
Apple pomace	48.0 – 62.0	-	4.7 – 51	-	-	3.9 – 5.7	23.5
Crude Olive pomace	34.8±0.9	-	6.6±0.5	-	16.65±0.09	0.4	43.2±0.5
Banana peel	79.0±0.5	9.3±0.1	2.7±0.0	-	3.0±0.2	0.6±0.1	6.4 – 9.6
Citrus peel	30	-	1.7	14.4	-	7.9	1.0

7.2 Cellulose as Agro-product

Cellulose production is one the recent focus on raw materials development because of its wide range of usages. It is an organic polymer making up approximately 40% of plant cells. It has high molecular weight unbranched chain homo – biopolymer with repeating glucose unit attached together by 1 – 4 glycosidic bonds. One end is hemiacetal functionality (Moon *et al.*, 2011). The three major types are Alpha cellulose, Beta cellulose and Gamma cellulose. Generally, the structure of cellulose is complicated due to the different arrangement of the cellulose chain, which varies from one source to another. It comprises of three hydroxyl groups in each glucose monomer with a degree of polymerization ranging from 1000 to 1500 depending on the source of the cellulose. Tables

8 and 9 give some common sources through which it can be extracted.

7.2.1 Application of Cellulose

It has wide range of applications. Its usage cut across industries like construction industry, pharmaceutical industry, food industry, textile industry, pulp industry, cosmetic industry, biotechnology industry. Table 10 highlights some types of cellulose and where they can be used according to Hadi *et al.* (2021).

Many other types of cellulose are in used for various industrial applications and for synthesis of other raw materials for different categories of industries. There are other potential substances yet to be derived from cellulose backbone.

Table 8: Sources of Cellulose (Hadi *et al.*, 2022)

S/N	Source
1	wood Hardwood and softwood
2	Plant and Residues Plants (Cotton, jute, hemp, flax) residues (bagasse, Potato peel waste, Oil palm biomass, Cereal straw) etc.
3	Algae Grey, Green, Red, Brown
4	Animal Tunicate
5	Bacteria Gram negative (Rhezobium, Pseudomonas, Azotobacter etc.). Gram positive (Sarcina)

Table 9: Sources and Composition of Cellulose in Fibers (Devabaktuni *et al.*, 2011)

Type of fiber	Description	Examples	% of cellulose
Leaf fibers	Fiber collected from leaves	Sisal, pique, guava	33
Seed fibers	Fibers from seeds or their cases	Cotton, kapok, palm kernel, etc.	90
Bast fibers/ Skin fibers	Fibers gotten from skin or the bast of plant	Hemp, jute. Ramie, vine fibers, flax, rattan, etc.	33
Fruit fibers	Fibers gotten from fruit	Coconut, palm fruit, etc.	30-50
Stalk fiber	Gotten from plant stalks	Maize, rice, bamboo, wheat barley	40 - 50

Table 10: Uses of Cellulose

Cellulose	Succine, Fumaric, Malic acids, 2,5 Furandicarboxylic acid, 3-Hydroxypropionic acid, Aspartic acid, Glucaric acid, Glutamic acid, Itaconic acid, Levuline acid, Glycerol, Sorbitol, Xylitol, Arabinitol etc.
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Other Applications of Cellulose

Type of Cellulose	Application
Oxycellulose	Used in production of cosmetic, pharmaceutical, anti-acne cream, anti-fungal cream etc.
Microcrystalline cellulose	Used as emulsifier, stabilizer, anticaking, dispersing agent etc.
Ethyl cellulose	Used as thickening agent and binder in tablets, for coating of solid dosage etc.
Methyl cellulose	Used as thickener and emulsifier, treatment of constipation, production of capsule, mild glue, used as substitute for tears or saliva
Hydroxyl ethyl cellulose	As gelling and thickening agent, as film forming, as pesticide, as cosmetic, in textile and paper production
Hydroxyl propyl cellulose	Used as lubricant for artificial eye, as food additives, as binder in tablet, as sieving matrix in DNA separation
Carboxy methyl cellulose	Food science as viscosity modifier or thickener, as lubricant in non-volatile eye drop, in toothpaste, in oil drilling, for protein purification etc.
Sodium Carboxyl methyl cellulose	In oral pharmaceutical formulation, protecting colloid to reduce water losses, oil drilling, creams, lotion jellies etc.
Cellulose nitrate	Painting and coating production, explosive material etc.
Bacterial cellulose	Tissue engineering.

7.3 Enzyme from Agro-products

Several studies also showed the production of enzymes from agro-products. The production of these enzymes is facilitated by the use of appropriate microorganisms. The list of enzymes produces by agro – products are inexhaustible, some common ones are as stated in Table 11.

7.3.1 Applications of Enzymes

Enzymes play vital roles in many industrial processes either as a catalyst, modifier, additives or raw material for production of value-added products. Some of its sources and applications are given in Table 12.

7.4 Agro- Products as Source of Nanoparticles

Agro-products especially plants, have been used recently to develop nanoparticles for various purposes. The use of plants for the synthesis of nanoparticles has been assessed to be economical, ecofriendly, less technologically required, etc. Nanoparticles derived from agro-source have advantage in medical applications as they are biocompatible and non – toxic. Several plants have been investigated to assess their potential as sources of nanoparticles. Some

of the verified sources are highlighted in Table 13.

7.4.1 Applications of Nanoparticles

Nanoparticles are novel materials synthesized from agro-products; they have wide application in various industrial processes, both as raw materials and as additives. Some sources and applications are as stated in Table 14.

Table 11: Production of Enzyme from Agro-products via Solid State Fermentation (Paulina *et al.*, 2021)

Enzyme	Microorganism	Substrate
Cellulose	Myceliophthora thermophile	Sugarcane bagasse and wheat bran
	Aspergillusibericus	Olive mill waste
	Trichoderma	Jatropha cake, Olive pomace, Olive oil
Xylanase	Aspergillusniger	Wheat bran, Sugarcane bagasse
	Myceliophthora thermophile	
B-glucosidase	Aspergillusibericus	Winery and Olive mill waste
	Aspergillusniger	Coffee industry waste
B-mannanase pectinase	Aspergillusniger	Wheat bran, sugarcane bagasse, Orange pomace, Citrus pectin
	Aspergillusniger	Cashew apple, corn stalk
Polygalacturonaslaccases	Trametesversicolor	Sweet sorghum bagasse
	Coriolusversicolor	
Lignin peroxidase	Coriolusversicolor	Sweet sorghum bagasse

Table 12: Application of Agro-based enzyme (Rajeev *et al.*, 2018)

Agro- product as substrate	Enzyme	Application
Banana waste, Brewer spent grain	Alpha - amylase	Detergent, Pulp, Beer, bread Pharmaceutical
Wheat bran, yam peels, cassava peels etc.	Amyloglucosidase	Bakery industry, brewing etc.
Mango peels, Banana peel, Brewer spent grain	Cellulase	Bioethanol production, textile, detergent.
Grape pomace, wheat straw, Apple pomace,	Xylanase	Animals feed, biomedical etc.
Coconut oil cake, orange peel, rice bran	Inulinase	Citric acid, lactic acid, bioethanol etc.
Soybean, wheat bran, Rice husk, sunflower meal	Bacitracin	It promotes the production of enzyme in laying chicken and infection control in poultry
Peels, wastes cakes etc.	Mannanase	Paper, food, oil industry, feed production and textile etc.
Apple and Grape pomace, orange bagasse and wheat bran	Pectinase	In wine industry for clarification of turbidity in finished products.
Oat meal, Orange peels etc.	B-gluconase	Facilitate viscosity reduction in juice
Wheat bran	Lactase	For lactose production use in food and diary.

Table 13: Plant sources of Nanoparticle (Yu-Jin *et al.*, 2016)

Plant	Part of plant for extraction	Type of Nanoparticle
Banana	Peel	Cadmium sulfide
Red gingeng	Root	silver
Panaxgingeng	Root	Silver and gold
Citrus medica	Fruit	copper
Orange and pineapple	Fruit	silver
Cocosnucifera	Leaves	Lead
Sargassum algae	Alga	palladium
Cymbopogoncitratrus	Leaves	Gold
Lawsoniainermis	Leaves	Iron

Table 14: Source and Application of Biological Nanoparticles (Yu-Jin *et al.*, 2016)

Plants	Plant Tissues for Extraction	Type of Nanoparticle	Shapes	Size (nm)	Applications
Euphorbia prostrata	Leaves	Silver and Titanium dioxide (TiO ₂)	Spherical	Silver 10–15; TiO ₂ , 81.7–84.7	Leishmanicidal
Sargassum algae	alga	Palladium	Octahedral	5 - 10	Electrocatalytic activities towards hydrogen peroxide
Ginkgo biloba	Leaves	copper	Spherical	15 - 20	Catalytic
Panax ginseng	Root	Silver and Gold	Spherical	Silver, 10–30; gold, 10–40	Antibacterial
Red ginseng	Root	Silver	Spherical	10 - 30	Antibacterial
Banana	Peel	Cadmium sulfide	-	1.48	Antibacterial
Cocosnucifera	Leaves	lead	Spherical	47	Antibacterial and photocatalytic
Azadirachta indica	Leaves	Silver	Spherical	41 - 60	Biolarvicidal
Citrus medica	Fruit	Copper	-	20	Antimicrobial

8.0 Other Agro- products and their applications

The applications of agro-products for industrial purposes are inexhaustible. Its usage cuts across all industrial sectors, including the oil industry, biomedical, pharmaceutical, and many other industries. Substances like methanol, cellulose, hemicellulose, lignin, bio-nanoparticles, etc. have been found to be very useful in the production of secondary raw materials; they act

as the bases in which other secondary raw materials are developed. Presently, research is

ongoing for the development of novel raw materials for the advancement of industrial processes and the optimization of the existing ones. Other raw materials from agro-products and their usages are highlighted in Table 19- 21.

A. Methanol

Methanol is a primary alcohol which can be obtained from anaerobic digestion of agricultural waste or gasification of forestry

waste. It is very essential agro-product for production of secondary raw materials. It uses cut across industries like pharmaceutical industry for antiseptics and drugs production, agro-industry as solvent for pesticide and

herbicide, paints and coating industry, production of acetic acid, etc. Table 15 give a breakdown of some of the primary and secondary raw materials obtained from methanol used in different industries.

Table 15: Uses of Methanol

Raw material	Primary Products	Secondary Materials/Applications
Methanol	Acetic acid	Vinyl acetate, Acetic anhydride, Chloroacetic acid, Ethyl acetate, Butyl acetate, Isopropyl acetate, Acetyl chloride, Acetanilide
	Dimethyl aniline	Solvent, Flavouring, Dyes, Fragrance
	Methyl acetate	Paint remover
	Dimethyl amine	Dimethyl acetamide, Dimethyl formamide, Dimethyl hydrazine, 2,4-Dichlorophenoxy acetic salt
	Mono methanol	Naphthyl-n-methyl carbamate, Monoethyl hydrazine, Monomethylamine nitrate
	MTBE	Oxygenate
	Methyl methacrylate	Cast sheet, Surface coating, Moulding resins, Oil additives
	DMT/polyethylene terephthalate	Polyester Fibre and film, Adhesives, Wire coating, Textile sizing, Herbicides
	Methyl halides	Quaternary amines, Methyl cellulose, Butyl rubber, Trimethanol propene
Formaldehyde	Phenolic resins, Tetraoxane, Pentaerythritol, Sulphoxylate, Formaldehyde, 1, 4-butanediol	

B. lignin

Lignin is a very important agro-chemical obtained from wood; it is used as both primary and secondary raw materials in the production of various industrial chemicals for cosmetic industry, paper and plywood production, in agro-industry for soil amendment, fertility etc. in construction industry as insulation materials and composite etc. Some of the various chemical obtained from lignin are given in Table 16.

C. Biochar

Biochar is charcoal- like material produced from the pyrolysis of biomass. Their various sources and some applications are as stated in Table 17.

9.0 The challenges of agro-raw materials development and the way forward

Agro-raw materials development faces enormous challenges which required multi-facets approach to tackle in order to boost agro-

products availability which in turn would increase availability of agro-raw materials for industrial purposes. Some of the challenges affecting agriculture in Nigeria include climate change, soil degradation, water scarcity, price volatility, financial accessibility, limited technical expertise, inadequate infrastructure, limited technology access, poor quality control, the country dependence on external agro-input such as improve seed, fertilizer, drugs for livestock and agro-chemicals. In the area of policies, government have made good policies toward creating enabling environment for farmers in the country, but the problem lies in the implementation of these policies. There are not enough instruments on ground for the actualization of these polices making it obsolete after formulation. These challenges militate agro-raw materials availability in the country.

Table 16: Uses of Lignin

Raw material	Primary Products	Secondary Materials/Applications
Lignin	Toluene	Dinitrotoluene, diaminotoluene, benzoic acid, toluene diisocyanate
	Xylene	Isophthalic acid, terephthalic acid
	Phenol	Cyclohexanol, cyclohexanone, nitrophenols, aminophenols, pigments, dyes, resins, alkylphosphites etc.
	Syringol	Syringyl cresol, syringyl alcohol, syringic acid, sinapic acid, methyl syringate etc.
	Dimeric structures	Bivanillyl alcohol, Bivanillin, bicresol methane, Diguaiacylstibene and their monomer and aromatic derivative
	Vanillin	Vanillic acid, vanillic acid methyl ester, homovanillic acid, vanillyl alcohol etc.
	Guaiacol	Cresol, propyl guaiacol, Eugenol, isoeugenol, Apocynol, methoxyhydroxyphenyl glycol etc.
Benzene	Phenol, cyclohexane, cyclohexanol, cyclohexanone, caprolactam, Adipic acid, Styrene, Cumene, 1,6-Diaminohexane	

Table 17: Application of Biochar-based materials for energy

Biomass	Treatment process	Application
wood	Pyrolysis with H ₃ PO ₄ , KOH activation	Hydrogen storage
corn cob	Pyrolysis at 450 ^o C for 4hrs, KOH activation	Hydrogen storage
Water hyacinth	Pyrolysis with ZnCl ₂	Electrocatalysis
bamboo	Pyrolysis at 700 ^o C	Fuel cell
Neem leaves	Pyrolysis at 600 ^o C	Super conductors
Corn stalks	Pyrolysis with CaCl ₂ at 300 ^o C for 3hrs	Lithium-ion Batteries
Apricot shell	Pyrolysis at 900-1500 ^o C, Ar/H ₂	Sodium ion Batteries

Thus, to cater for these challenges, it is imperative for government to put appropriate machineries in place for effective implementation of its policies at each phase so as to achieve the aim in which the policies were made for. Regular retraining of farmers in new farming technology is also very essential in boosting agricultural out-put. Over the years farmers are still practicing old methods of crops cultivation using poor farmer input and this affect their output greatly. In the area of technology, government and private sector should be kind enough to set-up companies for manufacturing of farm machines and equipment to lower the cost of importation; this would make it affordable to farmers. Sponsoring of agricultural base research is also necessary as it would enable in development of improve varieties of crops and livestock. Another area in which government can improve agro-product

availability is by partnering with countries that are using improve technology via exchange programmes, this would afford farmers the opportunity of learning new methods of farming. If these challenges are duly tackled, it would go long way in boasting agro-raw materials availability for industries without contention with food security.

10.0 Conclusion

Agro-products are important sources of alternative raw materials for industries. Many studies in the past two decades have shown the conversion of agro-products to raw materials for virtually all types of industries. The development of agro-products into essential raw materials is in progress, although with some challenges of yield maximization, this called for the need to develop a new route or optimize the existing one so as to produce enough raw

materials to cater for the ever-increasing demand in the industries. Also, there is a need to increase cultivation of food crops so as to checkmate food shortages as a result of utilization of food crops as raw materials.

Data Availability. The authors confirm that the data supporting the findings of this study are available from related journal article online, which have been duly acknowledged.

Competing Interests Statements. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Reference

- Adindu, C. I., Moses, J., Thaddeus, C. A. and Tse D. T. (2014). Exploring Ceramic Raw Materials in Nigeria and their contributions to Nation's Development. *American Journal of Engineering Research (AJER)*. 3(9): 127-134.
- Ampadu-Ameyaw, R and Omari, R. (2015). Small-scale rural Agro-processing enterprises in Ghana: Status, challenges and livelihood opportunities of women, *Journal of scientific Research and Report*, 6 (1), 61-67, doi:10.9734/JSRR/-2015/15523
- Awang, H., Al-Mulali, M.Z., Khali, H.A., Aljournaily, Z. (2024). Utilization of oil Palm as in Foamed concrete, *Web Conf*, 15, 01033.
- Chukwuonye, I. I., Ogah, O. S., Anyabolu, E. N., Ohagwu, K. A., Nwabuko, O. C., Onwuchekwa, U., and Oviasu, E. (2018). Prevalence of chronic kidney disease in Nigeria: systematic review of population-based studies. *International journal of nephrology and renovascular disease*, 165-172.
- Data Survey of Agriculture sector in Nigeria, Final Report (April, 2024). Japan International Agency Cooperation. Eurostat, (2024). https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Food_waste_and_food_waste_prevention_-_estimates
- Federal Republic of Nigeria (2024). Data collection Survey on Agriculture Sector in Nigeria Quarterly Crop Baseline Survey (QCBS)
- Hadi, S., E.O., Erfan O., H. J, J., Hengameh H., Jianfeng J., Lester, C.G., Rommel, G. B., Jenneke, K. (2021). Cellulose and its derivatives; Toward Biomedical Application. *Cellulose* (2021) 28:1893 – 1931. <https://doi.org/10.1007/310570-020-03674-w>
- Israel, A. U., Sunday, E. A., Mansong, S. and Ubong, U. V. (2016). Agro-based Raw Materials and the Chemical Industries in Nigeria. *Journal of Industrial Technology*, 1(2): 1-15.
- James, R.W. (1978). *Nigerian Land Use Act policy and Principles* (pp. 177-179) University of Ife Press Ltd.
- Makio, N., Nobuhiro, S. and Keizo, U. (2003). Raw Materials. In: *Handbook of Advance Ceramics*. Elsevier Inc.
- Marschallek, B. E. and Jacobsen, T. (2020). Classification of material substances: Introducing a standards-based approach. *Materials & Design*, 193, 108784.
- Maiguru A. A and Zaku S.S (2022). Assessment of Timber Tree Species Availability in Baissa Forest Reserve Taraba State,

- Nigeria. *International Journal of Agriculture, Environment and BioResearch*. Vol 7, No. 02.
- Mmerek D., David, V.E., Alfred, H.W. B. (2024). The management and prevention of food losses and waste in low- and middle-income countries: A mini-review in the Africa region. *Waste Management & Research*. 2024; 42(4):287-307. doi:10.1177/0734242X231184444
- Moon RJ, Martine A., Nourn J, Simonsen J. Youngblood, J. (2011). 'Cellulose Nanomaterials review: structure, Properties and Nanocomposites. *ChemSoc Rev* 40:3941-3994. <https://doi.org/10.1039/c0cs001086>.
- National Report of Wet Season Agricultural Performance in Nigeria, 2021.
- National Report of Wet Season Agricultural Performance in Nigeria, 2019.
- Oelofse, S., Polasi, T., Haywood L. and Musvoto C. (2021). Increasing reliable, scientific data and information on food losses and waste in South Africa. Department of Science & Innovation, and the Council for Scientific and Industrial Research (CSIR). CSIR, Pretoria, South Africa. Available at: https://wasteroadmap.co.za/wp-content/uploads/2021/06/17-CSIR-Final_Technical-report_Food-waste.pdf (accessed 10 May 2022).
- Ogbuehi, H. C. (2016). Potential of Palm Bunch Ash Application on the Growth and Yield of Okra (*Abelmoschus esculentus* L.). *Glob. J. of Biol., Agric. and Health Sciences*, 5(1), 12-19.
- Olutoge, F. A. and Oladunmoye, O. M. (2017). Bamboo leaf ash as supplementary cementitious material. *Am. J. Eng. Res*, 14(6), 1-8.
- Orhorhoro, E.K, Ebunilo, P. O, Sadjere G.E (2017) Determination and Quantification of household solid waste generation for planning suitable sustainable waste management in Nigeria. *International Journal of Emerging Engineering Research and Technology* 5: 10.
- Patil, V. N., Pawar, R. B., Patil, A. A., and Pharande, A. L. (2018). Influence of rice husk ash and bagasse ash as a source of silicon on growth, yield and nutrient uptake of rice. *International Journal of Chemical Studies*, 6(1), 317-320.
- Paulina L., Daniel S., Helena F., Marta F., Ana R. C., Diogo F., Margarida G., Helena P., Isabel B., and Jose M.S., (2021). 'Recent Advances in Production of Linocellulolytic Enzymes by Solid State Fermentation of Agro-industrial wastes.
- Rajeev R., Shady S. H., Gwilym A. W., and Amit K. J. (2018) A Review on Bioconversion of Agro- industries wastes to industrial important Enzymes: *Bioengineering* (2018), 5, 93; doi: 10.3390/bioengineering5040093.
- Searle, S. M.C. (2013) Availability of Cellulose Residues and Waste in the EU; ICCT Washington, DC, USA.
- Suvash C. P., Peter B. K., Mbewe, S.Y. K. and B. S., (2019). Agriculture Solid Waste as source of Supplementary Cementitious Materials in Developing Countries. doi:10.3390/ma12071112.
- Swai, J .K., Mmbando, A.S., Ngowo, H.S., Oduuwa, O.G., Finda M.F., Mkponzi, W., Nyoni, A.P., Kazimbaya, D.,

- Limwagu, A.J., Njalambaya, R.M., Abbasi, S., Moore, S.J., Schellenberg, J., Lorenz L.M., Okumu, F.O. (2019) Protecting migratory farmers in rural Tanzania using eave ribbons treated with the spatial mosquito repellent transfruthrin, *Malaria Journal*, 18 (414), <http://doi.or/10.1186/s12936-019-3048-8>
- World Population Prospects (2019); Retrieved from <https://population.un.org/wpp/publications/files/wpp2019.Highlights.pdf>.
- Wanniarachchi W.N.C. G., Gopura R.C., Punchihewa, H. K. G. (2016). Development of a layout model suitable for the food processing industry, *Journal of industrial Engineering*, Vol. 2016, ID 2796806. <http://doi.org/10.1155/2016/2-796806>
- Yu-Jin K., Dabing Z., Priyanka S., and Deok-Chun Y. (2016). 'Biological Synthesis of Nanoparticles from Plants and Microorganisms; Trends in Biotechnology. <http://dx.doi.org/10.1016/j.tibtech.20016.02.006>.
- Zou, Y. and Yang, T. (2019). Rice husk, rice husk ash and their applications. In *Rice bran and rice bran oil* (pp. 207-246). AOCS Press.