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Effective Food Waste Utilization: A Veritable Source of Biofuel for Nigerian Economic Sustenance and Development - A Review

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Abstract

Waste generation is on the increase as the population of Nigeria increases. The current waste management practice is becoming unsustainable in the country. Nigeria generates over 25 million tonnes as municipal solid waste with one third of it generated being kitchen waste. Demand for biofuels is rapidly growing worldwide as petroleum-based fuels are finite and environmentally unfriendly. Kitchen waste is capable of producing biogas, bioethanol and biodiesel which will afford the country affordable cleaner energy for national development. It is therefore imperative to optimize this source of renewable energy for advancement of transportation, industrial growth, power generation and overall national economic growth. Hence, this review highlights the enormous energy potential in kitchen cum domestic waste.

Keywords: *Waste, environment, energy, biofuel, economics.*

1.0 Introduction

One of the biggest problems facing the world today is that of the environment. The demand for food and other essential goods is increasing due to the rapidly growing world population, and this leads to a large production of biomass waste, especially kitchen waste. This leads to serious environmental problems and directly increases the cost of waste disposal. The demand for food increases in direct proportion to population growth, which in turn leads to more food being produced and, as a result, masses of food waste. The Food and Agriculture Organisation of the United Nations (FAO) estimates that a third of the food produced is lost at harvest and in the supply chain, which corresponds to an annual loss of USD 1 trillion [1].

About 26% of all food waste is generated in the beverage industry, followed by the dairy industry (21%), the fruit and vegetable industry (14.8%) and the cereal industry (12.9%) [2]. In addition to its negative economic impact, food waste also contributes to environmental damage by emitting powerful greenhouse gases, especially methane. Recently, food waste has been directly linked to soil degradation, biodiversity loss, air and water pollution and climate change. The loss of nutrients in the diet is likely related to the loss of food that was intended for human consumption and is now thrown away. Fruit and vegetable waste, spoilt food, crops left in the field, leftover food from households, hotels and restaurants, and any other food that is lost at home is considered household waste. Fruit and vegetable waste, spoilt food, crops left in the field, leftover food from households, hotels and restaurants and any other food that is lost at any point in the supply chain is considered household waste. Although it is difficult to completely avoid food waste, especially in our households or canteens, it is possible to minimise its amount. Therefore, developing strategies for food waste reuse is crucial for creating a sustainable bioeconomy and achieving the United Nations (UN) 2030 Sustainable Development Goal (SDG) [3].

Energy crisis is a global concern and Nigeria, as the most populated country in Africa is currently suffering severely from energy access inadequacy. This challenge is the biggest setback in Nigeria's economic growth Presently, Sambo, 2006. Nigeria consumes paltry 4000MW which is grossly adequate for a country with over 200 million people [4].

The world is witnessing increasing demand of energy due to global population rise which doesn't commensurate with its depleting fossil energy supply. Today, 85% of the world's energy needs are met by fossil fuels, which are delicious. By 2025, global energy consumption is expected to increase by almost 50%, with most of this growth coming from rapidly developing countries such as Nigeria. With the world's growing population, increasing energy demand per capital and global warming, the need for a long-term alternative energy supply is obvious. The advantage of biofuels is that they are produced from vast, mostly unutilised biomass resources (food waste and kitchen scraps) which are renewable and sustainable in a closed carbon cycle that reduces environmental impact. Biological materials (biomass) can be converted into solid, liquid or gaseous fuels that can be used to generate electricity, heat or motive power [5], [6].

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The raw material that can be used for the production of biofuels is biomass from food waste. Two major advantages of using biomass from food waste as an energy source are its almost unlimited supply and its ability to be utilised without significant environmental impact. In addition, biomass resources are considered renewable due to their natural occurrence and their favourable energy efficiency, affordability and storability compared to other renewable energy sources such as solar and wind. Domestic food waste includes both edible and non-edible waste generated along the entire food supply chain [7], [8].

According to the 2021 UN Environment Programme Food Waste Index report, around 931 million tonnes of food waste were produced worldwide in 2019 [9]. Around 40% of the food produced worldwide is wasted along the supply chain. This figure varies greatly from region to region and at different stages of the supply chain. In developing countries (low-income countries such as Nigeria), a significant amount of food is usually wasted in the pre-harvest and post-harvest phases, while in industrialised countries it is wasted in the consumption phase [10], [11].

A survey carried out by National Bureau of Statistics (NBS) (2012) shows that 39% of Nigerian households dump their domestic refuse in unauthorized heaps, while another 38% dispose theirs within their compounds by burying or burning the waste. The remaining households either dump their waste in approved dumpsites or have their wastes collected. The organic fraction of the refuse consists of food wastes which end up being burned, buried or discarded in water bodies, thus contributing to environmental degradation which hitherto could be converted to energy.

Composition of Agricultural/Food waste

Food wastes in real sense are generated from agricultural produce. Waste products from agriculture are categorised as lignocellulosic biomass, which consists of complex molecules such as cellulose, hemicellulose, lignin, ash and some extractives, mostly proteins. Before the waste can be converted into different configurations, its structures are first broken down into simple monomers during degradation [12]. Most agricultural waste contains more cellulose than hemicellulose and lignin. Cellulose is an essential structural element of lignocellulosic biomass. It is a chain-shaped polysaccharide that is rigid, fibrous and impenetrable. To keep the structure of a plant stable, it is also organised in packets of microfibrils. The cellulose properties of the biomass determine its mechanical stability, strength and chemical fingerprint [13].

The most important link between cellulose and lignin is hemicellulose, the randomly distributed heterogeneous structure of branched polysaccharides found in cellulose. It consists of arabans, xylans and galactans and is formed from a heterogeneous arrangement of sugars, including d-xylose, d-mannose and d-galactose. Hemicelluloses dissolve well in alkaline, slightly acidic and enzymatic environments, but not in water. They are more susceptible to chemical attack and alteration and have lower mechanical strength than cellulose. The content of hemicellulose in biomass has a great influence on its ability to be converted into biofuels [14].

Lignin is a vital component of plants and is second only to cellulose. The amount of lignin in the water of woody biomass controls the development of cell walls, stiffness, water resistance and physical, chemical and microbiological attack. It provides structural support to the growing plant and contributes to the plant's ability to absorb water from the soil [13], [14]. Food waste is a subset of most agricultural waste, consisting of 35–50% cellulose, 20–35% hemicellulose, 15–20% lignin and 15–20% extractives (ash, protein, etc.) on a dry basis.

2.0 Valorization of Domestic food waste

It is impossible to avoid all food waste, but it is possible to reduce the amount that is wasted. To develop a sustainable bioeconomy and achieve the United Nations (UN) goal for sustainable development by 2030 [3], it is important to find ways to reuse food waste. Because food waste is so similar to other waste, it has great potential for the production of biofuels, platform chemicals and bio-based materials [15].

Consequently, food waste is typically made up of organic matter with a high potential for energy production through anaerobic degradation and other biochemical reactions. Studies have shown that the methane yield from anaerobic digestion is in the range of 350 - 435 mL/g depending upon operational conditions, reactor types, and composition of the input food waste [16]. There is a trend of increasing quantities of total food wastes produced (which are coming from both domestic, manufacture, food catering services and retail/wholesale sectors). Kitchen wastes are biodegradable and are rich sources of valuable products. Kitchen waste in Nigeria comprises several organic wastes ranging from rice, fufu, garri, beans, meat, fish, oil, etc. These wastes are sources of several products including “high yield low volume product” and “high volume-low yield.

The development of effective strategies to prevent and/or minimise food losses requires a thorough assessment of the quantitative value of food waste or losses. The aim of these measures is to control supply and demand in the food chain. This will become increasingly important as the world's population continues to grow and requires more resources to ensure food security. Sustainable development requires a careful balance between an increased food supply and an overall low environmental impact. However, there are already several studies and

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growing bodies of literature with different definitional frameworks and methodological approaches to measuring food loss (FLW) [17].

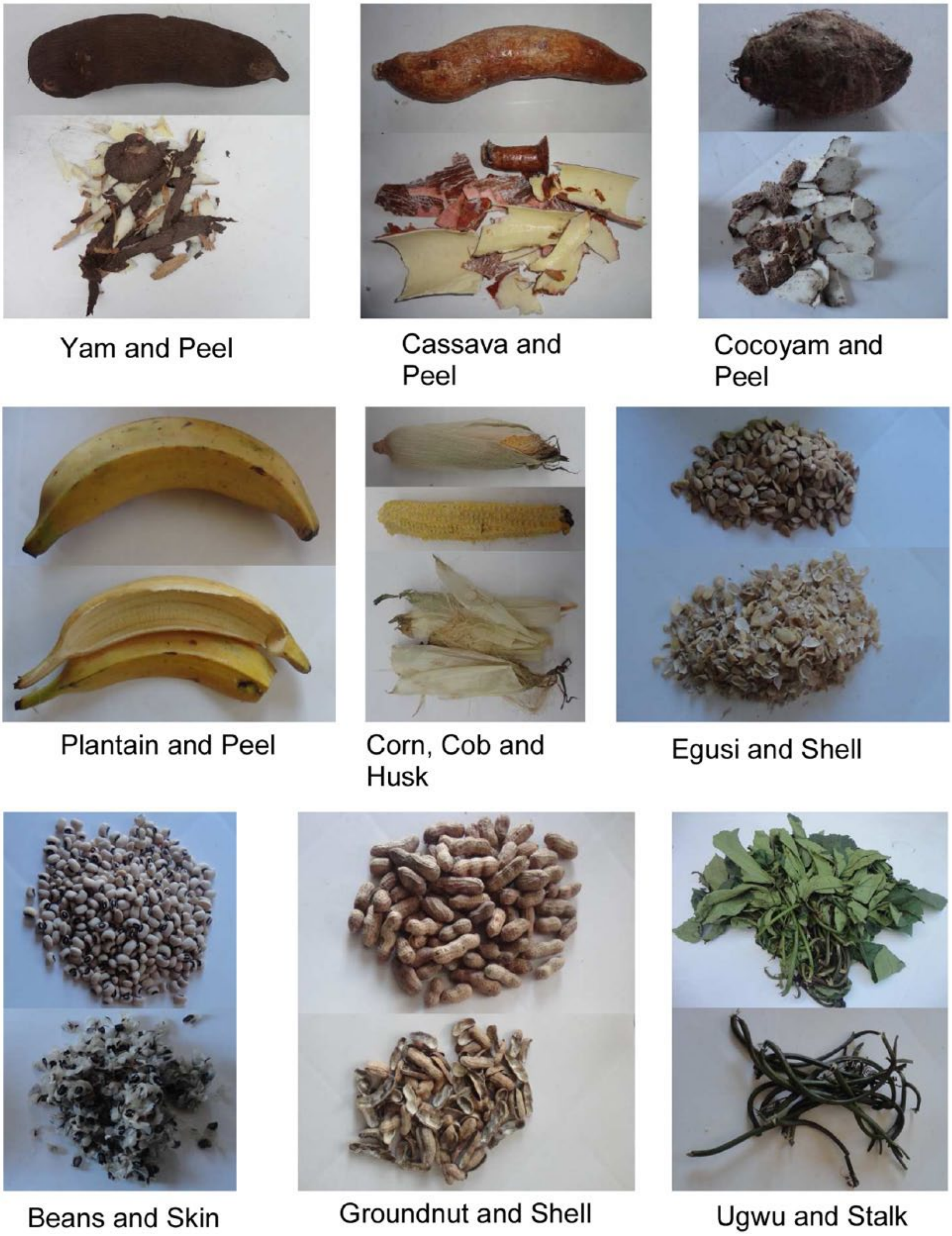

Figure 1: Some common food waste in Nigeria

Nowadays, a large proportion of biofuels such as biodiesel and bioethanol are produced from edible foodstuffs. Biodiesel is made from a variety of edible vegetable oils, including rapeseed, canola and soya oil. On the other hand, a wide range of feedstocks, including sugar cane, bagasse, sugar beet, cereals, switchgrass, barley, potatoes, molasses, corn, beet straw, wheat and numerous other carbohydrate-rich sources can be used to produce

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bioethanol [18]. Transesterification is the technique used to produce chemical biodiesel. Biodiesel is produced during the transesterification process when methanol and tri-, di- and monoglycerides react with a catalyst. However, the process for producing bioethanol involves pre-treatment, fermentation, distillation and enzymatic hydrolysis. Food shortages are cited as a reason for producing biofuels from edible food ingredients, and the food versus fuel debate is already underway. Alternatively, non-edible feedstock can be used for the production of biofuels. Jatropha, Pongamia and other non-edible plant oils are already used for the preparation of biodiesel [18]. Moreso, non-edible, lignocellulosic biomass is also employed for the production of bioethanol. Figure 1 shows some common food waste available in Nigeria.

These common food wastes are especially the peels are waste with huge energy potential particularly biofuel. Nigeria is the world largest producer of cassava with about 60 million tons produced as at 2019. Despite being the largest producer more than 90% of cassava produced in Nigeria are consumed locally. The implication of this is that almost all the peels and associate byproducts usually go into waste instead of bioethanol. Research shows that cassava contains 11.62% cellulose, and hemicelluloses, 21.43% as fermentable sugar in the form of lignocelluloses [19]. The fermentable component of the lignocelluloses makes it a candidate for bioethanol production.

Groundnut shells was investigated and confirmed to generate 27.5% bioethanol with energy value of 14 MJ/kg with the purity of 90.62% makes it suitable and acceptable for commercial grade bioethanol. Similarly, egusi shell has been confirmed to be suitable biodiesel as it contains 59-63% w/w linoleic acid and 16% w/w oleic acid [20].

2.1 Food Waste for Energy

Many studies have been conducted on utilization of biomass for energy production in Nigeria, biomass residues and their bioenergy potential, agro- bioenergy potential to reduce emissions and mitigate climate change, different crops potential for energy valorization, oil palm [21], maize cob and different residues from corn. Cocoa and kola nut residues [22], *carica papaya*, blending of oil palm and MSW, bioethanol production from lignocelluloses biomass feedstock [23].

To reduce the direct conflict between fuel and food, scientists are working hard to convert inedible and cheap food waste into fuel and energy. This food waste contains a significant amount of fats and carbohydrates, which makes it a valuable resource. Therefore, low-value food waste can be utilised as a resource for the production of low-cost biofuels. The synthesis and characterisation of biofuels from various food wastes has so far been demonstrated as a "proof of concept". Technologies are currently available for the large-scale production of biogas, biodiesel and bioethanol. In this context, Saccharomyces cerevisiae H058 has already been used on an experimental scale for the production of ethanol from food waste [24]. However, the production of fuels from food waste requires cost-effective, environmentally friendly and advanced technologies [25]. The availability of food waste, the effectiveness of the hydrolysis process, the amount of lipids and carbohydrates extracted from the food waste and the effectiveness of the fermentation and etherification processes are the most important factors influencing the industrial production of biofuels from food waste.

Renewable energy is critical if Nigeria will achieve its stated National Determined Contributions (NDC) [21]. It will also offer socioeconomic benefits. Greater number of Nigerians depends on firewood for their energy needs [26]. This represents about 70% of primary energy consumption. Only 40% Nigerians have access to electricity. Put differently, Nigeria, with a population of 200 million have an installed electricity generating capacity of 12,552 MW with available 4000MWfrom the grid for end users whereas South Africa with a population of 60 million have capacity of 58,000 MW. Renewable and sustainable energy is important to realizing the United Nation Sustainable Development Goal 7 (affordable and clean energy) by 2030 [3].

For instance, with 100 tons of food waste per day, anaerobic digestion can generate enough energy to power 800 to 1,400 homes each year. Waste-to-energy plants reduce 2,000 pounds of garbage to ash that weighs between 300 pounds and 600 pounds, and they reduce the volume of waste by about 87% [27].

Figure 2 shows various processes of anaerobic digester to convert food waste, livestock and others into digestate which produces bio fertilizer and biogas which subsequently produces gas and fuel for transportation.

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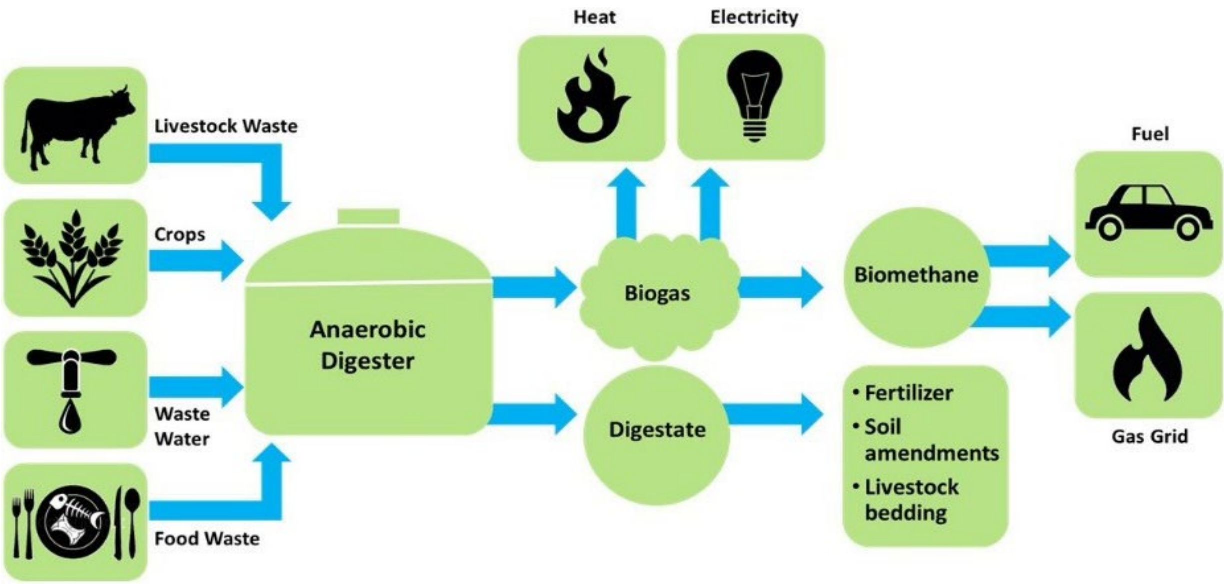

Figure 2: Anaerobic digestion process [27]

Table 1: Crop residues and energy potential in Nigeria

Crop	Production (x10³ t)	Residue Type	RPR	Moisture content (%)	Total residue (million tons)	% available	Weight Available	LHV (MJ/kg)	Residue energy potential (PJ)
Rice	3368.24	straw	1.757	12.71	7.26	100	7.86	16.02	125.92
		husk	0.2	2.37	1.19	100	1.19	19.33	23
Maize	7676.85	Stalk	2	15	15.35	70	10.75	19.66	211.35
		cob	0.273	7.53	2.1	1000	2.1	16.28	34.19
		Husk	0.2	11.11	1.54	60	0.92	15.56	14.32
cassava	42533.10	stalks	2	15	85.07	20	17.01	17.5	297.68
		peelings	3	50	127.6	60	76.56	10.61	212.3
groundnut	3799.25	shells	0.477	8.2	1.81	100	1.81	15.66	28.35
		straw	2.3	15	8.74	50	4.37	17.54	76.83
soyabeans	365.06	straw	2.5	15	0.91	100	0.91	12.38	11.27
		pods	1	15	0.37	100	0.37	12.38	4.58
Sugar cane	481.51	Baggase	0.29	50	0.14	80	0.11	18.1	1.99
		Tops leaves	0.3	10	0.14	100	0.14	15.81	2.21
cotton	602.44	stalk	3.743	12	2.25	100	2.25	18.61	41.87
millet	51070.45	straw	1.75	15	9.05	80	7.24	12.38	81.63
sorghum	7140.96	straw	1.25	15	8.93	80	7.14	12.38	88.39
Cow pea	336.24	shell	2.9		9.77	50	4.89	19.44	95.06
Total							**145.62**		**1,958.94**

Table 1 shows energy rich crops, and the residue which is hitherto waste but is now utilized for its energy potential. Cassava peels, maize husk and rice straw are top in energy potential. Table 2 clearly present states, cap/person/ day, monthly waste generated and more importantly annual organic deposit in tones, Indicating huge waste feedstock available for green energy.

Table 2: Waste feedstock available for green energy in Nigeria

Regional State Capital	Cap/person/day (kg)	Monthly waste (t)	Annual waste (t)	Organic waste (%)	Annual organic (t)
North East					
Bauchi	0.31	25,395	304,740	64	195,033.60
Gombe	0.275	14,006	168,072	70	177,650.40
Yola	0.28	25,365	304,380	68	206,978.40
Damaturu	0.242	14,001	168,012	70	177,608
Maiduguri	0.28	32,956	395,472	66	261,011.52
Jalingo	0.25	14,253	171,036	70	119,725.20
North west					
Kano	0.56	156,676	1,880,112	51	958,857.12

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Kaduna	0.23	44,433	533,196	63	335,931.48
Katsina	0.32	18,452	221,424	70	154,196.60
Sokoto	0.281	15,255	183,060	66	12,819.60
Birnin kebbi	0.28	15,456	185,472	70	129,830.40
Gusau	0.26	14,967	179,604	71	127,518.84
Dutse	0.3	16,340	196,080	70	137,256.00
North central					
Lafia	0.21	13,965	167,422	70	177,230.40
Lokoja	0.26	15,478	185,736	70	130,015.20
Makurdi	0.28	32,956	395,472	66	261,011.52
Ilorin	0.25	34,560	414,720	70	290,304.00
Mina	0.246	14,989	179,868	68	122,310.24
Jos	0.23	27,667	332,004	57	189,242.28
South east					
Abakiliki	0.23	14,346	172,152	70	120,506.40
Umuahia	0.23	15,895	190,740	65	123,941.00
Enugu	0.31	16,009	192,108	58	111,422.64
Akwa	0.31	25,395	304,740	60	111,422.64
Owerri	0.297	15,846	190,152	70	133,100.40
South west					
Lagos	0.73	255,556	3,066,672	36	1,104,001.2
Osogbo	0.24	14,957	179,484	60	107,690.40
Ado ekiti	0.28	14,784	177,480	65	115,315.20
Ibadan	0.31	135,391	1,624,092	61	991,062.12
Akure	0.32	15,089	1,81,976	60	108,640.80
Abeokuta	0.36	36,160	1,413,900	60	260,035.20
South South					
Benin City	0.63	27,459	329,508	54	177,934.32
Yenagoa	0.23	14,246	170,952	65	111,118.80
Calabar	0.26	15,248	182,476	68	124,423.68
Port Harcout	0.7	117,825	1,413,900	60	848,340.00
Asaba	0.28	15,950	191,400	60	114,840.00
Uyo	0.253	16,112	193,344	58	122,139.52
Other cities					
Aba	0.31	64,347	772,164	70	540,514.80
Onitsha	0.7	84,137	1,009,644	62	625,979.28
Abuja	0.81	14,684	176,208	65	144,535.20

Source: [28]

2.2 Biofuels from waste

2.2.1 Biomethane

Biomethane is a renewable gaseous biofuel produced by upgrading a methane-rich gas, called biogas, by removing CO_2 and other impurities from the gasification of woody biomass, municipal solid waste and agricultural waste through a process called methanation. Anaerobic digestion of organic material produces crude biogas containing 50–70% CH_4, 30–40% CO_2 and some traces of H_2O, H_2S, NH_3, N_2, siloxane and solid matter, while the upgraded biogas, known as biomethane, contains 95–97% CH_4 and about 1-3 per cent CO_2 by volume. The operation of power plants, heating and electricity generation all consume biomethane. To reduce CO_2 emissions, biomethane has been used in recent years as a sustainable fuel to power cars and other internal combustion engines instead of biogas and natural gas [29]. Reduced or eliminated carbon emissions, lower production costs, a sustainable environment and energy independence are all benefits of using biomethane.

It has been estimated that 3.2 TWh of biomethane is produced worldwide every year [30]. In 2023, this figure is expected to rise to almost 9.5 TWh. With an annual production of around 1.8 million tonnes (MTPA), Europe is currently the world leader in biomethane production. The USA and Canada follow with 0.6 MTPA. However, Asia and Oceania (165 MTPA) have the greatest potential for the future production of biomethane, followed by Latin America (105 MTPA) and the United States and Canada (125 MTPA) [31]. The global biomethane market is also expected to grow from USD 1.9 billion to USD 4 billion by 2031. The causes of this trend are the increasing concern for the environment, the use of biomethane in the transport and shipping industry and the impact of

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legislation that supports the production and use of biomethane. In addition, biomethane will be increasingly used in the renewable energy mix to mitigate environmental degradation as it is a net-zero fuel. The chemical, steel, food and beverage industries are expected to replace natural gas with biomethane, which will require significant investment to meet the expected demand.

2.2.2 Bioethanol

Bioethanol, a sustainable liquid biofuel, is produced by fermenting sugar and starch components from natural sources, usually agricultural waste or plant derivatives. The most widely used liquid biofuel in the world is bioethanol or simply ethanol. The demand for bioethanol has led to a continuous increase in production. Global demand for bioethanol is forecast to rise to 134.5 billion litres by 2024, up from an estimated 100.2 billion litres in 2016 [32]. Not all of the bioethanol produced is used as fuel, which is an important point. The chemical and pharmaceutical industries also use bioethanol as a raw material for the production of beverages, personal care products and disinfectants.

However, more than 40% of global bioethanol production is used for fuel or fuel additives. In 2016, more than 29 million gallons of bioethanol were produced, up from more than 26 million gallons in 2016, but due to the COVID-19 outbreak, global production dropped to 26 million gallons. Since then, production has increased and will reach more than 27 billion gallons in 2021 [31]. The size of the global bioethanol market has been estimated at around USD 89.1 billion. By 2030, this amount is expected to exceed USD 155.6 billion. The increasing use of ethanol as a biofuel, the renewed interest in bioethanol as a sustainable alternative to fossil fuels and government policies to curb environmental degradation are some of the factors expected to drive growth. Customers benefit from this strategy both economically and in terms of performance. 90 % CO2, 60 % to 80 % SO2 and around 40 % fewer particulate emissions are produced when bioethanol-petrol blends are used in vehicle engines [33], [34]. The significant reduction in these harmful emissions helps to protect the environment, reduces air pollution and lowers emissions of greenhouse gases and other carcinogenic substances such as benzene, xylene, toluene and ethylbenzene. In addition, bioethanol is generally inexpensive and contributes to waste disposal and cleanliness, as it is usually produced from waste biomass as a raw material.

Currently, various agricultural waste and crop residues such as wood, sugar beet, maize straw, rice, barley, wheat, sorghum, sugar cane and sweet sorghum bagasse are used to produce bioethanol. These materials are inexpensive, easily accessible and non-edible at a fair price. There are no ethical issues or food security implications when they are used as feedstock for fuel production. Nigeria should focus on the use of this feedstock for bioethanol production as there have been numerous advances in this process over the past decades.

2.2.3 Biodiesel

Biodiesel is an environmentally friendly, sustainable and biodegradable type of liquid biofuel. It is usually produced from vegetable oils, animal fats, recovered cooking fat and used cooking oil and consists of long-chain fatty acid esters [35]. Biodiesel is a sustainable alternative to fossil fuels and has been proven to increase engine longevity and reduce greenhouse gas emissions and other harmful pollutants. Compared to diesel fuel derived from fossil fuels, it is non-toxic, has a high flash point and higher combustion efficiency. The use of non-edible feedstocks for biodiesel production has solved the problems of high production costs and conflicts with the food chain. However, as biodiesel tends to gel, clog the engine and block fuel philtres and hoses, it is not suitable for use in cold climates. The quality of biodiesel varies greatly from country to country, as different raw materials and production techniques are used. In addition, the combustion of biodiesel in compression ignition engines leads to higher NOx emissions compared to diesel fuel from fossil fuels [35]. Fortunately, Nigeria is located in an area with high temperatures, so it is not affected by the above-mentioned restrictions.

Biodiesel is used today in many heavy construction and agricultural machines. In recent years, interest in biodiesel and its use has grown due to concerns about increasing pollution and greenhouse gas emissions, particularly from transport vehicles. This has led to an increase in the production of biodiesel. For example, the amount of biodiesel produced globally increased from 42 billion litres in 2021 to 43 billion litres in 2021, with an average production of 46 billion litres expected between 2023 and 2025 [30]. The value of the global biodiesel market by revenue, which stood at USD 46.79 billion in 2021, is expected to rise to USD 51.48 billion by 2026.

2.2.4 Other forms of biofuel

There are other forms of biofuels some of which are listed below;

i. **Biobutanol:** A biofuel derived from fermenting organic material like crops, algae, or agricultural and forest waste, it has a higher energy density than ethanol and is easier to transport.
ii. **Bio-CNG:** A purified form of biogas, processed to produce 95% pure methane gas, similar to commercially available natural gas.
iii. **Bio-jet fuel:** A biofuel used to power aircraft, also known as sustainable aviation fuel.

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iv. **Biohydrogen:** refers to hydrogen gas (H_2) produced through biological processes, such as fermentation or photolysis by microorganisms.
v. **Solid biofuels:** Biochar, which can be used directly as a solid fuel or as a catalyst for other biofuel production.
vi. **Hydrotreated pyrolysis oil (HPO):** A biofuel produced through the pyrolysis of biomass, followed by hydro treatment
vii. **Biobutanol**: is a four-carbon alcohol, a potential biofuel produced from renewable biomass sources through fermentation, offering benefits like higher energy density and lower volatility compared to ethanol.
viii. **Algae biofuel or algal oil:** is a renewable energy source that is an alternative to fossil fuels and traditional biofuels like corn and sugarcane.

2.3 Mechanisms for biofuel production

2.3.1 Anaerobic Digestion (Biogas)

Microorganisms break down organic matter in the absence of oxygen, producing a mixture of gases, primarily methane and carbon dioxide, known as biogas. Anaerobic digestion is a biochemical process of producing energy from high moisture biomass which may be agricultural or another biodegradable residue. The high moisture biomass of about 90% is acted upon by microorganisms in an oxygen-deficient condition. This results in CO_2, CH_4 rich gas (biogas) and traces of other gases like H_2S, are main sources of waste for biogas generation are food scraps, agricultural residues (e.g., crop stalks, husks), and animal waste.

The waste collected is processed by shredding it, and then fed into a digester tank. The digester is kept at a specific temperature and pH to optimize microbial activity. Available researches recommend acidic medium as suitable environment for microbial activity. Temperature between 30-40^{o}C and pH of 4-5.5 is most appropriate [36].

2.3.2 Transesterification (Biodiesel)

A chemical reaction that converts vegetable oils or animal fats (triglycerides) into biodiesel (esters) using an alcohol and a catalyst. Additionally, transesterification is a process in which biodiesel is produced through the reaction of glycerides and alcohol specifically methanol or ethanol in the presence of a catalyst such as sodium hydroxide, to produce fatty acids, alkyl esters and alcohol. Several researches have carried out in Nigeria on the production of biodiesel using different feed stocks such as palm kernel oil, mango seed oil, coconut oil, tobacco seed oil, jatropha oil, pinari oil, sheabutter oil and milk bush oil especially those considered as waste [37].

Primary sources are waste cooking oil, animal fats, vegetable oils (like soybean, canola, and palm oil), animal fats, and recycled restaurant grease, with algae also being a promising, though less developed, waste oils and fats are collected, cleaned (filtered and dried), and then mixed with an alcohol (like methanol) and a catalyst (like sodium hydroxide) in a reactor. Biodiesel, a renewable fuel that can be used in diesel engines [38].

2.3.3 Fermentation (for Bioethanol)

Carbohydrates in domestic wastes are acted upon by microorganisms with the support of yeast to convert sugars into bioethanol through fermentation. Carbohydrate-rich wastes like food scraps, agricultural residues, and certain types of industrial waste are sources of waste for the biochemical reaction. There are many more conversion mechanisms and or technologies for converting kitchen wastes to biofuel such as gasification, pyrolysis and so on [39].

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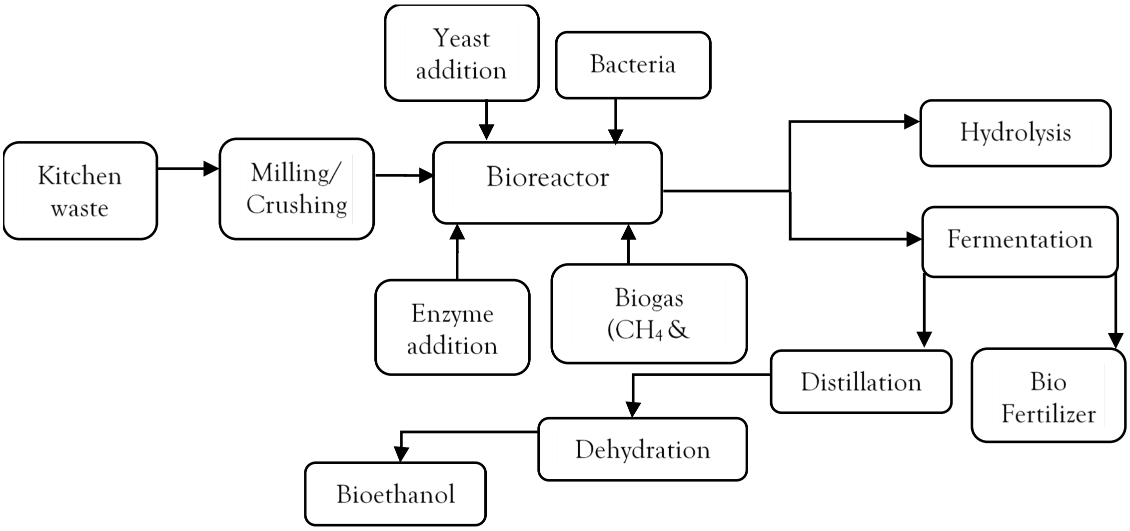

Figure 3: Flow diagram for the conversion of kitchen waste to biofuel
Source: [40]

The way forward

Starch based kitchen Wastes ranges from Rice, to Cassava based meals, to lignocellulosic wastes from soups are available feedstock for biofuels production. Starch is a first-generation feedstock and is the most abundant renewable carbon source. Starch (α-D-glucose monomer) degradation is complex than the sugar fermentation process. It initially breaks down into glucose, through amylase or diastase and maltase hydrolysis. Then, bioethanol and carbon dioxide are fermented from sugars through enzyme activity [41].

Currently, the fuel subsidy removal on premium motor spirit (PMS) by federal government of Nigeria has created untold hardship to its citizenries making it difficult to move goods and services around the country. Besides, the adverse effect on ozone layer gives Nigerian government reason to evaluate alternative available options for greener ecosystem. With the population of over two hundred million and waste generation being on the rise, critical interest in conversion of waste to energy is therefore imperative. Hence, it is important to examine the waste content of food waste in Nigeria and subsequently evaluate nutritional composition of the waste products for energy.

3.0 Concluding Remarks and Future Prospects

Food waste mainly obtained from agricultural feedstock in Nigeria is steadily on the increase as the populations continue to increase. This waste so far generated constitutes serious environmental issues with attendant health implication, Hence the need to harness it for energy. Some commonly consumed crops in Nigeria under consideration had residue energy of 1958pJ as shown in table 1. Again, thirty-six states of Nigeria including FCT generates over 9,945,933 tons of organic waste annually which is capable of generating 2.5*10^14 KJ of energy. Projection by International Energy Agency (IEA) puts biomethane production at 9.5TW/hr, and 155.6 billion litres as at 2030 whereas biodiesel projected production is 46 billion liters between 2023 – 2025.

Research shows enormous potential of the waste in Nigeria that has to be valorized into biofuels through different processes such as pyrolysis, gasification, Mechanical/thermal process but biochemical processes such as fermentation, digestion, and hydrolysis are the most acceptable due to its environmental friendliness.

The valorization of food waste via enzymatic process generates biomethane and bioethanol whereas tranesterification process generates biodiesel.

The conversion of Nigeria's waste into biofuels is a sure path to a viable bioeconomy thereby solving energy deficit created by over dependency on fossil fuel. The effectiveness in the application of biochemical process in valorization of domestic waste into renewable energy will provide a sustainable energy source for the country. Therefore, investment by government, private firms, energy players and researchers will be a big win for Nigeria as other countries had embraced renewable energy as a veritable option for safer environment and good energy-mix. Besides, more technological designs is on the increase towards growing Nigerian economy and in boosting our renewable energy source.

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