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Characterization of Kitchen Waste for Biofuel Production

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Abstract- Feed stock characterization plays a significant role in determining the properties of the raw materials and its effect on the yield of the desired product. The kitchen wastes (cassava, yam, banana, plantain peel and pumpkin stalk and wasted rice) obtained for this study was characterized for its proximate and ultimate properties to study its suitability for the production of biofuels. The properties studied were: ash content, total solids, volatile solids, crude protein, crude fibre, lipid, nitrogen free extract, moisture and carbohydrate. This analysis is essential for evaluating the viability of biomass and optimizing its applications, particularly in renewable energy production. The results of the characterization show that the kitchen waste contains 14.09% Ash content, 91.375% Total solids 78.602% Volatile solids, 7.85% Crude protein, 8.42% Crude fibre, 3.27% Lipid, 59.729%, Nitrogen free extract, 8.525% Moisture and 39.86% Carbohydrate. These properties show closeness with some of the results obtained from literature, also, the result of the biofuel obtained from the sample gives a good yield. Therefore, it can be concluded that the kitchen waste characterized in this study show the properties of a good biofuel feed.

I. INTRODUCTION

Kitchen waste has been identified as a big economic, social and environmental problem nowadays. According to the official statistics published by Eurostat, each year, more than 240,000 tonnes of waste is produced in the European Union (Eurostat, 2018). Bio-waste, the organic fraction of municipal solid waste, i.e., garden, kitchen and domestic waste, accounts for one third of the total waste and is a valuable resource that could be used as raw material to produce high value-added products as shown in Figure 1 (Ashtab and Gong 2020). In many countries domestic waste is currently landfilled or incinerated together with other combustible municipal wastes for possible recovery of energy (Mrosso *et al*., 2023; Zhang *et al*., 2010). However, these two options are facing more and more economic and environmental stresses. Due to its organic and nutrient-rich nature. Theoretically, kitchen waste can be converted to valuable products (e.g. bio-products such as methane, hydrogen, bioethanol, biodiesel, enzymes, organic acids, chemicals and fuels) through various fermentation processes (Esra *et al*., 2022). kitchen waste valorisation has therefore gained interest, with value added bio-products such as methane, hydrogen, ethanol, enzymes, organic acids, chemicals, and fuels. (Esra *et al*., 2022).

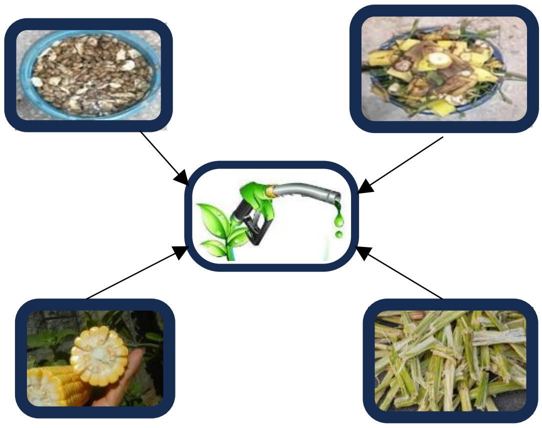

Figure 1: Biofuel production from biomass

A sustainable bioeconomy can turn bio-waste, residues and discards into valuable resources (as shown in Figure 1) and can create innovations and incentives to help retailers and consumers cut domestic waste by 50% by 2030. Besides, the growing population is directly proportional to the increased demand of domestic wastes. According to the United Nations Food and Agricultural Organisation (FAO), one third of the total domestic waste produced was lost in the supply chain and harvesting which contributed to the estimated USD 1 trillion annual loss (FAO, 2015).

However, the use of domestic by-products and the conversion of domestic waste are still limited. This is due to current limitations in its quantification along the domestic supply chain (Caldeira *et al.,* 2019), limited data on its quality and level of homogeneity, and differences in national implementations of the waste legislation (FAO, 2011). The composition of kitchen waste, as already said, is not stable. It presents significant variations depending on the season, the area, and the dietary habits of the population. Despite the inevitable variation in the composition of domestic waste including kitchen waste, it can indisputably be said that it is rich in carbohydrates, proteins, lipids and minerals which makes it an ideal raw material for the production of biofuels through microbial conversion (George *et al*., 2020). The exploitation of domestic waste for the production of biofuels is also in line with the 2030 Agenda for Sustainable Development set by the United Nation in 2015 (George *et al*., 2020). More precisely, it is directly related to the Sustainable Development Goals: Affordable and Clean Energy, Responsible Consumption and Production and Climate Action (George *et al*., 2020).

All over the world, energy supply is predominantly dependent on fossil fuels, which are not only limited in availability but also harmful to the environment (Kumar and Majid, 2020). Fossil fuel-based carbon dioxide generation has been identified as one of the main causes of the global warming phenomenon, which leads to various adverse effects (Riphah, 2015). However, in the case of energy, exhaustible fossil fuels represent 80% of the total world energy supply. At constant production and consumption, the presently known reserves of oil will last around 41 years, natural gas 64years, and coal 155years according to World Energy Review, 2024.

This hinders the current and future generation of oil producing countries like Nigeria and therefore leads to the need to explore an alternative source of clean energy (Edenseting *et al*., 2020). Also, there has been a continuous indiscriminate disposal of domestic waste in Nigeria which are predominantly domestic waste, which can be linked to poverty, poor governance, urbanization, population growth, poor standards of living, and low level of environmental awareness and inadequate management of environmental knowledge (Edenseting *et al*., 2020). Some available conversion technologies such as pyrolysis, gasification, biodigester etc. are energy demanding with consequent effect on the environment with resultant capital implication. Therefore, this study seeks to study the properties and characteristics of domestic waste obtained from Uyo, Akwa Ibom state, and its suitability for the production of bio fuels.

II. MATERIALS AND METHODS

2.1 Collection and Preparation of kitchen waste

The materials used for this study comprise of Kitchen waste (cassava, yam, banana, plantain peel pumpkin stalk and wasted rice) collected from Fast foods, and homes in Ewet housing estate, Ifa and Shelter Afrique all in Uyo, Akwa Ibom State as shown in Figure 2. The sample was washed, and dried for two days with direct sunlight, and subsequently oven dried at 70 ^oC to constant weight. It is then milled into powder. It was subsequently sieved with 500µm sieve to obtain fine particles of the waste for enzymatic reaction, 333g of well blended substrate was weighed for analysis, 1L of deionized water was added to the biomass and stirred thoroughly for two hours to achieve homogeneity. 50g of 10% NaOH was added for pretreatment (Prasertwasu *et al.,* 2014).

Figure 2: Kitchen waste sample used

2.2 Characterization of Kitchen wastes

2.2.1 Determination of Moisture Content

Moisture content is the mass of water held in the material; it is normally indicated as a percentage of weight (Hossain *et al.,* 2021). The Kitchen waste was mixed enough to provide three samples of ten grams each for the moisture meter. The moisture content analysis was determined using an electronic moisture analyser (Model MA100) shown in Figure 3. The meter was turned on and was set for reading, thereafter the tray of the moisture tester with the sample was tested, then the knob was turn on to obtained moisture reading, three samples were tested for average reading.

Figure 3: Moisture content analyzer

2.2.2 Determination of Total Ash

To determine the ash content of the samples, the method of Mrosso *et al.,* (2023) was used, crucibles were placed in muffle furnace, heated at 550°C for 15mins, then cool in a desiccator for 1hr and weighed, 5g of sample was weighed in the crucible (W_1). Subsequently the sample was placed on a hot plate until smoking ceased and sample charred. Thereafter, the crucibles were placed inside the muffle furnace, heated to 550°C for 5hrs. the furnace was then allowed to cool after which the crucibles containing ash, was cleaned. Due to the presence of carbon, the crucibles were cooled by addition 2mm of deionized water and stirred with a glass rod to break up the ash. Then it was dried on steam bath and place in a muffle furnace and heated at 550°C thereafter transferred to a dedicator. Then, the crucible in a desiccator was reweighed (W_2). The ash content was determined using Equation 1.

$$Ash\% = \left\{\frac{(W_2 - W)}{(W_1 - W)}\right\} X\,100 \qquad \text{Equation 1}$$

Where, W = Weight of empty crucible, W_1 = Weight of empty crucible + Sample, W_2 = Weight of empty crucible + Ashed Sample

2.2.3 Determination of Crude Protein

The Kjeldahl method of Nitrogen analysis is the standard for calculating the protein content in wide variety of materials ranging from domestic waste, and fertilizer (AOAC 2006; Ho and Chu 2019.) The nitrogen, from the amine groups found in the peptide bonds of the polypeptide chains was converted to ammonium ion, which dissolves in the oxidizing solution, and later be converted to ammonia gas. The sample was first digested in strong H_2SO_4 in the presence of a catalyst, which helps in the conversion of the amine nitrogen to ammonium ions, The ammonium ions are then converted into ammonia gas, heated and distilled. The ammonia gas was led into a trapping solution where it dissolves and becomes an ammonium ion once again. Finally, the amount of the ammonia that has been trapped was determined by titration with 0.1 N HCl. Crude protein (CP) content was calculated by total nitrogen multiplied by 6.25, as most proteins contain 16% nitrogen (Nollet 2004).

2.2.4 Determination of Total Carbohydrates

The basic units of carbohydrates are the monosaccharides which cannot be split by hydrolysis into simpler sugars. Thereafter, one hundred grams of the sample was weighed into a boiling tube. It was then hydrolyzed by keeping it in a boiling water bath for 3hrs with 5ml of 2.5N -HCl, thereafter cooled to room temperature. It was then neutralized with solid sodium hydroxide until the effervescence ceases. The volume is made up to 100ml and centrifuged. The supernatant was cooled, and 1ml aliquots obtained for analysis.

Standard was prepared by taking 0.2, 0.4,0.6,0.8 and 1ml of the working standard."0" served as blank. The volume was made up to 10ml in all the tubes including the sample tubes by adding distilled water. Thereafter, 4ml of anthrone reagent were added. After which it was heated for eight minutes in a boiling water bath. Sample allowed to cool at 630nm. Standard graph was then plotted of concentration against absorbance. From the graph the amount of carbohydrates present in the sample was determined. Amount of carbohydrate present in 100mg of the sample is

$$\frac{\text{Mg of glucose}}{\text{Volume of test sample}} X\, \frac{100}{1} \qquad \text{Equation 2}$$

2.2.5 Determination of Lipid

2 gm of the sample was placed in a porous thimble of a Soxhlet extractor with cotton plug at its mouthed and thimble was placed in an extraction chamber which was suspended to previously weighed flask containing ethanol. The whole assembly was adjusted and flask was heated using heating mental for 8-10 hrs to extract crude lipid. After the extraction, thimble was removed from the Soxhlet apparatus and the solvent was removed under reduced pressure to

afford crude lipid. Furthermore, the flask containing lipid was placed in oven at 100ºC for 30 minutes to remove residual solvent, cooled in a desiccator and weighed. The amount of crude lipid was calculated and expressed as percentage crude lipid content (Vaishali and Sharma 2016)

2.2.6 Determination of total solid (TS)

The total solid is the quantity of solid available in the feedstock following the disappearance of water or the amount of organic matter remaining in the crucible following the vaporescence process. The drying process was done in an oven at 105ºC was then applied to determine the percentage of total solids (Orhorhoro *et al.,* 2017);

$$TS = \frac{W_3 - W_1}{W_2 - W_1} \times 100\% \qquad \text{Equation 3}$$

2.2.7 Determination of total volatile solids (TVS)

The remains obtained during the calculation of TS were burnt in a muffle furnace at 550ºC for 1hrs until grayish-white ash was obtained. The ignited sample and the crucible were allowed to cool in the kiln for 6hrs. The sample was weighed and recorded (W_4), and the TVS was calculated as per equation (4).

$$TVS = \frac{W_3 - W_1}{W_2 - W_1} \times 100\% \qquad \text{Equation 4}$$

Where, W_4=Weight of residue after ignition + weight of crucible while %TVS = percentage Volatile total solid.

2.2.8 Nitrogen Free Extract (NFE)

NFE represents soluble carbohydrates and other digestible and easily utilizable non-nitrogenous substances in feed. NFE is determined by mathematical calculation. It is obtained by subtracting the sum of percentages of all the nutrients already determined from 100 following Equation 5.

%NFE = 100- (%moisture + %CF + %CP + %EE + %Ash) Equation 5

2.2.9 Crude Fibre

The fat in the samples were extracted by adding petroleum ether, stir, and allow to settle and decant. The fat-free material was then transferred into a flask/beaker and 200mls of pre-heated 1.25% H_2SO_4 was added and the solution was gently boiled for about 30mins, maintaining constant volume of acid by the addition of hot water. The Buckner flask funnel fitted with Whatman filter was pre-heated by pouring hot water into the funnel. The boiled acid sample mixture was then filtered hot through the funnel under sufficient suction. The residue as then washed several times with boiling water (until the residue is neutral to litmus paper) and transferred back into the beaker. Then 200mls of pre-heated 1.25% Na_2SO_4 was added and boiled for another 30mins. Filter under suction and wash thoroughly with hot water and twice with ethanol. The residue was then dried at 65ºC for about 24hrs and weighed. The residue is transferred into a crucible and placed in muffle furnace (400-600ºC) and ash for 4hrs, then cool in desiccator and weigh. Equation 6 was used to calculate the crude fibre of the samples.

$$\%\ Crude\ fibre = \frac{w_{tb} - w_{ta}}{w_t\ of\ sample} \times 100 \qquad \text{Equation 6}$$

W_{tb} = dry weight of residue before ashing W_{ta} = drying weight of residue after ashing

III. RESULTS

The kitchen waste samples were analysed and the results obtained are compared to those obtained from literature as presented in Table 1. The nutritional characteristics of interest, including total solid (TS), volatile solids (VS), crude fibre (CrF), crude protein (CrP), oils, nitrogen-free extracts (NFE), ash and moisture content were determined from the kitchen waste using proximate analysis.

Table 1: Result of Proximate analysis of kitchen waste

S/n	Constituent	Obtained value	Obtained value from literature
1.	Ash (g)	14.09	11.16 - 12.83 % Gupta et al., 2023
2	Total solids (g)	91.375/100	14.4
3	Volatile solids (g)	78.602/100	89.5 Ramzan et al., (2010)
4	Crude protein (%)	7.85	11.4-28.2 Hossain et al., (2016)
5	Crude fibre (%)	8.42	9.9-32.3 Hossain et al., (2016)
6	Lipid (%)	3.27	16.5% Barik et al (2018)

7	Nitrogen free extract (CHO) (%)	59.729	
8	Moisture (%)	8.525	6.56-86.6 Gupta et al., (2023); Ramzan et al., (2010)
9	Carbohydrate	39.86	

High-carbohydrate biomass is a promising source for producing biofuel, according to studies (Kawai and Murata 2016). High carbohydrate content in biomass often boosts biofuel yield because Carbohydrates are readily transformed into fermentable sugar (Rizwan *et al.,* 2017). According to several research, kitchen waste typically contains more than 50% carbohydrates, with a range of 16.6% to 74.6%. High levels of carbohydrates were found in waste food and some simulated wastes (Luo and Wong 2019, Ariunbaatar 2021). The kitchen waste used in this study had a carbohydrate percentage of 39.86%, indicating a high carbohydrate content that can be used to produce biofuel.

One limiting factor affecting the solid biofuel's quality is the moisture content of the concentrated biomass. The yield of biofuel is greatly impacted by moisture content; excessive amounts lower energy density, encourage deterioration, and obstruct chemical reactions necessary for generation, including biomass pyrolysis. On the other hand, by restricting heat and mass transmission during processing, excessive dryness can also lower yields (Atadashi *et al.,* 2012). The manufacture of biofuel is hampered by inappropriate moisture content ass stated by Ma *et al.*, (1998). Although moisture has a significant detrimental impact on the transesterification of free fatty acids, even refined oils and fats retain trace levels of water and FFAs, according to Ma *et al.,* (1999). Water raises the amount of FFAs in vegetable oils and accelerates the hydrolysis of triglycerides. Therefore, in order to maximize biofuel yield and quality across various production processes, an ideal, moderate moisture content is essential. Depending on the source and kind of waste, the moisture content of food waste can vary from 48% to 95%, with an average of 77%, according to Selvam *et al.,* (2021). The analyzed sample gives moisture content of 8.5% dry matter, this is due to the drying of the sample prior to analysis. This gave a better yield of ethanol as shown in the study of Edesetting (2025), also, Manimaran *et al.,* 2020 reported a high percentage of yield of bio-oil at 6% of moisture content from waste Trichosanthes cucumerina seeds which is close to that obtained in this study.

Since crude protein requires more energy and is more difficult to convert than Carbohydrates and fats, it is typically not a direct source for fuel production (Solati *et al.,* 2018). For the production of biofuel, the lower it is in the sample, the better. Crude protein levels in the samples were 7.85%, which is regarded as low. This value is lower than the result obtained by Hossain *et al.,* (2016) as shown in table 1. This will also contribute to the high yield of bioethanol.

High lipid content favours biodiesel production. For biofuel of interest (biogas and bioethanol), low lipid is desired to avoid product inhibition. Crude fibre Crude fibre is the complex carbohydrate of a sample (Longjan and Dehouche 2018). The crude fibre obtained in this study is closed to that obtained by Hossain et al., (2016) which is also an indication of a good property of the kitchen waste sample.

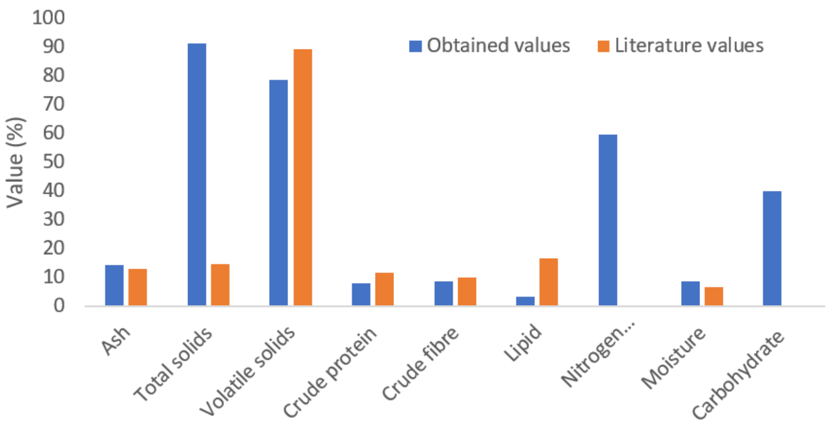

Figure 4: Result of characterization and literature values for kitchen waste

Total solids are the dry matter of a sample after all moisture has been eliminated, whereas volatile solids are the fraction of solid matter in a liquid or waste sample that is lost when the sample is heated to a high temperature. Volatile Solids or organic content ranges from 73% to 98% with an average value of about 91.6% in similar wastes analyzed as reported by Ammayappan *et al*., 2021. When comparing a sample of biofuels to other waste kinds, a significant fraction of volatile solids is anticipated (Ammayappan *et al*., 2021). The result confirmed volatile solids is within desired range for value for valorisation and bioenergy production. Total Solids of 91.33g/100g and Volatile solids of 78g/100g in the sample was acceptable for biofuel production (Ismail, 2017).

Report has shown that a high ash content in biomass can reduce sugar yield in a fermentation process (Wu et al., 2019). According to the study of Kumar *et al.,* (2024) Ash can interfere by neutralizing acids used in pretreatment, limiting enzyme access to cellulose during hydrolysis, and altering the pH of the fermentation medium. These impacts can result in a reduced ultimate sugar yield by impeding the effective conversion of biomass into fermentable sugars. The result of the ash content obtained in this study was 14.09g/100g. Literature shows ash content is slightly higher than o 6-8.9g/100g obtained by Ismail, (2017) which is appropriate for organic waste velarization. The deviation is minimal. Ash content is the remaining incombustible residue. Usually, it should be within 5-10 percent by volume as reported by David (1999).

Table 2: Biofuel yield

Bioproduct	Yield
Bioethanol	966ml
Biogas	9.194m^3

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The characterized kitchen waste from the said location was used for the production of bioethanol and the result shows a high bioethanol as shown in Table 2. This shows that the properties of bioethanol obtained from this study resulted in a high yield of the biofuel being considered.

IV. CONCLUSION

The kitchen wastes obtained for this study was characterized its proximate and ultimate properties to study its suitability for the production of biofuels. The results showed that the kitchen wastes obtained from several fast food in uyo Akwa Ibom state show a good property as depicted in the yield obtained from the bioethanol production and literature data. This show that the valorization of kitchen waste for the production of biofuel is feasible.

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