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Biogas Potential of Some Selected Kitchen Wastes Within Kaduna Metropolis

Abubakar Aisha Aliyu (NDA/PGS/FS/M/1094/12)
Department of Chemistry Faculty of Science Nigerian Defence Academy, Kaduna

ABSTRACT: *A comparative study of biogas potential of some selected kitchen wastes within Kaduna metropolis was carried out. The Volatile Solid, Total Solid, Moisture Content and Ash Content were examined. The materials used as feedstock were Food waste (yam peels, plantain peels, and potatoes peels) and fruit waste (orange and pineapple peels). Varying volumes of digesters were employed for biogas generation. The digestion process was carried out under ambient temperature for a retention period of 30 days. Anaerobic digestion is very sensitive to change in pH therefore pH was maintained at 6.7 - 6.9 for a healthy system. The result of the study showed that yam peel gave the highest value of 89.37ml/week of biogas and the lowest yield was observed with orange peel having 18.26ml/week of biogas. The mean values were within the range of 32.15ml - 92.43ml weekly for all the food wastes. While all the fruit wastes gave a mean value of 18.26ml – 36.20ml weekly. This showed that the type of waste had significant effect on the quantity of biogas produced thus, anaerobic digestion process a viable option for effective degradation of organic wastes.*

I. INTRODUCTION

One of the problems faced by the world today is management of all types of waste and energy crisis. Rapid growth of population, uncontrolled and unmonitored urbanization has created serious problems of energy requirement and solid waste disposal. Energy is a basic tool for development. Developing countries like Nigeria faces added dilemma regarding environment pollutions due to the heavy dependency on biomass and access to energy resources presents challenges to human health and economic development (Mshandete and Parawira, 2009). Besides the alarming pollution and its contaminating effect on natural resources such as deforestation due to increased wood fuel or charcoal fuel production and consumption is not sustainable in the long term. Therefore any reduction in wood fuel consumption might have favorable effect on the reduction in deforestation and environmental protection as well as curbing the emission of greenhouse gases (Odeyemi, 1979). In response to these problems the need for alternative renewable energy sources from locally available resources cannot be over emphasized. Biomass such as agricultural wastes, municipal waste, and green waste (kitchen waste) present a promising renewable energy opportunity (Sagagi *et al.,* 2009). Kitchen waste comprises high fraction of organic matter which causes environmental and health risks, hence the need for a strong appropriate management system. In most cities in Nigeria, waste is disposed off as landfills or discarded which causes health hazard and diseases like malaria, typhoid, cholera etc. (Adeyosoye *et al*., 2010). Inadequate management of waste like uncontrolled dumping has several consequences, it is not only polluting surface water and ground water through leachates it also promote the breeding of flies and other diseases bearing vectors, and emits unpleasant odor and methane which is a major greenhouse gas contributing to global warming (Abubakar, 1990). Biological conversion of biomass to methane has received an increasing attention in recent years. There are many technologies such as incineration and Refuse Derived Fuel (RDF) for producing energy from solid waste. Among them anaerobic digestion has become a promising technology particularly for recovery of energy from organic fraction of solid wastes (Alkan *et al*., 1996). Anaerobic digestion is a potential environmental friendly technique, producing energy in form of biogas and residue, which can be used as soil conditioner. It is known that organic waste materials such as vegetables contain adequate quantity of nutrients essential for the growth and metabolism of anaerobic bacteria in biogas production (Muhammad *et al.,* 2013).

1.1 Definition of waste

Wastes are substances, objects or any unwanted material which are disposed off. It is also referred to as rubbish, garbage, trash, refuse etc. (Sagagi *et al.,* 2009).wastes is generated in all sorts of ways and its composition and volume largely depend on consumption pattern and the industrial and economic structures in place. (Kumar, 2000).

1.2 Types of Solid Wastes

Solid waste can be classified into different types depending on their sources.

i- Household waste generally classified as municipal waste.
ii- Industrial waste as hazardous waste.
iii- Biomedical or hospital waste as infectious waste.

1.2.1 Municipal Solid Waste

These consist of household waste or everyday items discarded by the public. It is also regarded as garbage. There are several types of municipal wastes which include biodegradable wastes like food and kitchen wastes, green wastes, recyclable wastes such as bottles, jars, tins, plastics etc.

1.2.2 Industrial wastes

These are referred to as hazardous wastes because they pose substantial or potential threats to public. Such wastes are generated from automobile repair shops, oil refineries, chemical manufacturing industries etc.

1.2.3 Biomedical wastes

These include wastes of medical or laboratory origin. They can be solid or liquid such as infusion kits, unused bandages, unwanted microbial cultures and stocks, discarded blood, as well as wastes containing biomolecules (Kumar, 2000).

1.3.0 Biogas

Biogas is a byproduct of decomposition or bio-degradation of organic material under anaerobic conditions (Suyog, 2011). Naturally, generation of biogas is an important part of bio-geochemical carbon cycle. Biogas is a clean and renewable energy that may be substituted to natural gas to cook, to produce vapor, hot water or to generate electricity. At room temperature and pressure biogas is in gaseous form unlike liquefied petroleum gas LPG which is liquid. The gas is called by several other names, such as dung gas, marsh gas, sewage gas, and swamp gas (Dangoggo and Fernando, 1986)

1.3.1 Types of wastes that produces biogas

Any organic wastes has the ability to produce biogas, these include human excreta, animal slurry, fruit and vegetable wastes, slaughter house wastes, diary factory wastes, brewery and distillery wastes. Fiber rich wastes like wood, leaves, cotton etc. makes poor feedstock for digesters as they are difficult to digest (Ziana and Rajesh 2015).

1.3.2 Composition of biogas

Components	Concentration (by volume)
Methane (CH_4)	55- 60%
Carbon dioxide (CO_2)	35- 40%
Water (H_2O)	2- 7%
Hydrogen Sulphide (H_2S)	20- 20.000 ppm (2%)
Ammonia (NH_3)	0- 0.05%
Nitrogen (N)	0-2%
Oxygen (O_2)	0 -2%
Hydrogen (H)	0-1%

1.3.3. Characteristics of biogas

Biogas is an odorless and colorless gas. It burns with pale blue flame. Biogas is about 20% lighter than air, has an ignition value 750^0C, it burns with blue flame similar to liquefied petroleum gas its caloric value is 20 mega joules per cubic (MJ/m^3) and it usually burns with 60 % efficiency in a conventional biogas stove. This gas is useful as fuel to substitute firewood, cow-dung, petrol, LGP, diesel, and electricity depending on the nature of the task, and local supply condition. Anaerobic digestion effluent has superior nutrient qualities over normal organic fertilizer; it is in the form of ammonia and can be used as manure. Anaerobic biogas digesters also function as waste disposal systems, particularly for human wastes, and can, therefore, prevent potential sources of environmental contamination and the spread of pathogens and disease causing bacteria. Biogas technology is particularly valuable in agricultural residual treatment of animal excreta and kitchen refuse (Ziana and Rajesh 2015).

1.4 Stages of Biogas Production

Organic substances exist in wide variety from living being to dead organisms. Organic matters are composed of Carbon (C) combined with elements such as Hydrogen (H), Oxygen (O), Nitrogen (N), Sulphur (S) to form variety of organic compounds such as carbohydrates, proteins & lipids. Naturally micro organisms break these complex organic compounds into smaller substances through digestion process (Chen *et al*., 2010). There are 2 types of digestion process: Aerobic digestion and anaerobic digestion.

Aerobic Digestion: This digestion process occurs in the presence of oxygen and produces mixtures of gases having carbon dioxide CO_2, one of the main “green houses” responsible for global warming.

Anaerobic Digestion: This digestion process occurs without (absence) oxygen, which generates mixture of gases. The gas produced, which is mainly methane, produces 5200-5800 MJ/m^3 which when burned at normal room temperature presents a viable environmentally friendly energy source to replace fossil fuel (Suyog, 2011).

1.4.1 **Aerobic Digestion**

Aerobic digestion of waste is a natural biological degradation and purification process in which bacteria that thrives in oxygen rich environment break down and digest the waste. During oxidation process, pollutants are broken down into carbon dioxide (CO_2), water (H_2O), nitrates, sulphates and biomass.

1.4.2 **Anaerobic Digestion**

It is also referred to as biomethanization; it is a natural process that takes place in the absence of air (oxygen). It involves biochemical decomposition of complex organic material by various biochemical processes with release of energy rich biogas and production of nutrient-rich effluents. Anaerobic digestion is a three-stage process.

1.4.2.1 **Hydrolysis**

The first stage consists of microorganisms attacking the organic matter where complex organic compounds such as cellulose and starch are converted to less complex soluble organic compounds. Polymers are transformed into soluble monomers through enzymatic hydrolysis.

$$n\,(C_6H_{10}O_5) + nH_2O \xrightarrow{\text{hydrolysis}} n\,(C_6H_{12}O_6) \qquad (1)$$

1.4.3.2 **Acidification**

These monomers become substrates for the micro organisms in the second stage where they are converted into organic acids by group of bacteria.

$$n\,(C_6H_{10}O_5) \xrightarrow{\text{acid forming bacteria}} 3n\,(CH_3COOH) \qquad (2)$$

These organic acids primarily acetic acid form the substrate for the third stage.

$$CH_3COOH \xrightarrow{\text{methane forming bacteria}} CH_4+CO_2 \qquad (3)$$

1.4.4.3 **Methanogenation**

In the third step, methanogenic bacteria generate methane by two routes, by fermenting acetic acid to methane CH_4 and CO_2 and by reducing CO_2 via hydrogen gas or formate generated by other bacteria species (Sagagi *et al.*, 2009).

$$CO_2 + 4H_2 \xrightarrow{\text{reduction}} CH_4 + 2H_2O \qquad (4)$$

Similarly CO_2 can be hydrolyzed to Carbonic acid and to methane as in the equations below:

$$CO_2+H_2O \xrightarrow{\text{hydrolysis}} H_2CO_3 \qquad (5)$$

$$4H_2+H_2COO_3 \xrightarrow{\text{reduction}} CH_4+3H_2O \qquad (6)$$

The carbon dioxide and hydrogen sulphide in the biogas are undesirable. They are removed for optimum performance of biogas as fuel. Carbon dioxide is removed by passing the gas into limewater, which turns milky due to formation of calcium carbonate.

$$Ca\,(OH)_{2\,(aq)} + CO_{2(g)} \longrightarrow CaCO_3+H_2O \qquad (7)$$

H_2S is removed by passing the gas through a lead acetate solution.

$$(CH_3COO)_2\,Pb_{\,(aq)} + H_2S \longrightarrow 2CH_3COOH_{(aq)} + PbS_{(s)} \qquad (8)$$

Major biochemical conversion steps in anaerobic digestion.

In addition to temperature other parameters are controlled to ensure proper operation. Microorganisms are sensitive to pH changes. Buffering is necessary for pH (Sagagi *et al.*, 2009).

1.5. **Factors Affecting Yield and Production of Biogas**

Factors affecting the fermentation process of organic substances under anaerobic conditions are:

i- The quality and nature of organic matter (substrate)
ii- The temperature
iii- Acidity and alkalinity
iv- pH value of substrate
v- the flow and dilution of material
vi- digester construction and size

Biogas is a renewable form of energy. Methanogens (methane producing bacterial) are last link in a chain of microorganisms, which degrade organic material and returns, product of decomposition to the environment (Garba and Sambo, 1995).

1.6 **Aims**

This project aims at assessing the biogas potential of some selected kitchen wastes.

1.7 **Objectives**

1. The objective of this project is to biodegrade anaerobically each of the sample waste to generate biogas.
2. To evaluate which of the wastes has a higher biogas potential.
3. To determine the total solid, volatile solid content of the waste sample

1.8 **Scope of the Study**

This project intends to cover domestic household's kitchen waste within Kaduna metropolis.

II. LITERATURE REVIEW

A number of studies have examined the production of biogas from organic kitchen waste by anaerobic digestion using cow dung and pig dung (Okareh *et al.,* 2012; lissen *et al.,* 2004). Both substrates generated biogas although the quantity and frequency of the gas produced were minimal which was as a result of the substrates used.

(Deressa *et al.,* 2015) explored the production of biogas from fruit and vegetable wastes mixed with cow manure in anaerobic digester. The total solid, volatile solids, moisture content and ash content of the waste were examined. The material used as feed were avocado, papaya, mango, tomatoes, banana peel and cow manure. Varying volumes of digesters were employed for biogas generation. The combustibility of the gas generated was tested. The anaerobic digestion of fruit and vegetable wastes mixed with different wastes took 55days to produce biogas (for complete digestion). Upon adjustment of the factors affecting anaerobic digestion process, it is felt that co digestion between food wastes and cow manure produces biogas without the need of nutrient or chemical addition to the system.

Biogas production from citrus wastes by membrane bioreactor was conducted by Wikandari *et al.,* 2014. The experiments were carried out in thermophilic conditions at 55^0C and hydraulic retention time of 30days. The results obtained showed the highest organic loading rate was successful to produce methane at 0.33 Nm^3/kg while the traditional free cell reactor reduced its methane production to $0.05 Nm^3/kg$. Approximately 73% of the theoretical methane yield was achieved using the membrane bioreactor. While rapid acidification and inhibition by D-limonene were the major challenges of biogas production from citrus waste.

(Mohan and Jagadeesan, 2013) attempted to optimize various parameters in order to determine the most favorable recipe for maximum biogas production from digested food waste. The biogas yields have been determined using batch anaerobic thermopilic digestion test for a period of 90 days. Characteristic oscillation was observed in the rate of methane production which may be due to the presence of methylotroph population in the activated sludge, which uses methane as a carbon source for their growth. The total biogas generated in the system over the experimental period was the sum of methane and carbon dioxide. Biogas produced from the decomposition of food wastes was a mixture of 76% methane and 24% carbondioxide.

Vegetable wastes (banana stem, cabbage and ladies finger) were anaerobically digested in a fed batch laboratory scale reactor at mesophilic conditions (35^0C) which was carried out by (Velmurugan and Alwar 2011). The organic loading rate (OLR) was maintained at 2.25g/l with a hydraulic Retention time (HRT) of 30days. The average methane content in the biogas was 65% and the methane yield was 0.387ml.

The estimation of proximate composition and biogas production from invitro gas fermentation of sweet potato and wild cocoyam peels was carried out by (Adeyosoye *et al.,* 2010). The proximate composition in terms of percentage dry matter (DM), crude protein (CP), crude fiber (CF), ether-extract (EF), ash, nitrogen free extract (NFE) and carbohydrate of sweet potato peel (SPP) and wild cocoyam peel (WCP) were determined. Buffered and sieved goat's rumen liquor was added to 200 mg of dried and milled SPP and WCP in 100 ml syringes supplied with CO_2 under anaerobic condition and incubated for 24 hours. Total biogas produced was measured at 3 hours intervals for 24 hours when the fermentation was terminated. The inoculum was also incubated separately. All treatments were replicated three times and readings were taken in duplicates. The differences in biogas production across the treatments were significant ($p < 0.05$). There were no significant differences ($p > 0.05$) in the volumes of methane produced from SPP (42.5 ml) and WCP (39.5 ml), which were significantly ($p < 0.05$) higher than 20.0ml produced by the inoculums. Therefore, fermentation is a cheap method to produced methane gas as fuel for domestic and industrial use, which may sanitize the environment from pollution. The remaining residue can be used as livestock feed.

Other studies have looked at generation of biogas from food and fruits waste rather than using cow dung a substrate (Pune, 2003). The results showed that just 2 kg of each substrate produced about 500 g of methane and reaction was completed within 24 hours while conventional biogas system using cattle dung required about 40 kg of feedstock to produce the same quantity of methane and required about 40 kg for a complete reaction, thus the process is 20 times more efficient.

Sagagi *et al.,* 2009 compared four other potential substrates namely; pineapple, orange, pumpkin and spinach for biogas production, pineapple gave the highest yield while spinach have the lowest yield of biogas.

The viability of co-digestion of kitchen waste with human excreta was conducted by Suyog, 2011; Dahunsi and Oranusi, 2013 using local technology to construct anaerobic digester. Food waste and human excreta generated within a university campus were used. The experiment lasted for 60 days using a 40-liters laboratory scale anaerobic digester. The volume of gas generated from the mixture was 84750 cm^3 and comprised of 58% CH_4, 24% CO_2, and 19% H_2S and other impurities. The physco-chemisty of the feedstock in the digester revealed an initial drop in pH to more acidic range and a steady increase 4.52 – 6.10. The temperature remained relatively constant at mesophilic range 22.0^0C – 30.5^0C throughout the study. The Carbon/Nitrogen (C/N) ratio of the feedstock before digestion was within 139:1 population distributions of the micro flora showed aerobic and anaerobic bacteria to include *Klebsiella* spp. *Bacillus Spp, Escherichia coli, Clostridium spp* and a methanogen of the genera Methanococcus. In most developing nations of Sub-Saharan African where biomass is abundant, and where biogas technology is in its infant stage, the anaerobic digestion system could be the much-awaited solution.

Chen *et al.,* 2010 investigated the potential of five types of food waste for biogas generation. The wastes were from a soup processing plant, a cafeteria, a commercial kitchen, a fish farm and grease trap collection services. Anaerobic potentials of such food wastes individually and in mixtures were conducted at mesophilic 35^0C and thermophillic temperatures 50^0C. The results indicated that it was necessary to use chemical such as NaOH to control the pH of the anaerobic digester. Hence this project intends to use a number of chemicals for more yield and efficiency. Biogas production from anaerobic digestion kitchen waste using cow dung as innocula was conducted by (Eleri *et al*., 2014). This was done by inoculating the processed kitchen waste with both the pre-digested sample, and the kitchen waste alone served as the control. The digestion was carried out at room temperature 35 ± 2^0C for 14 days. From the results, the quantity of biogas in cm^3 produced by the substrate were as follows; pre-digested cow dung 138.6 cm^3, undigested cow dung 13.7 cm^3, kitchen waste alone 3.2 cm^3, a significant difference ($p \geq 0.05$) was also observed in biogas production from kitchen waste using the pre-digested and undigested innocula.

(Knol *et al.,* 1987) studied different fruit wastes and vegetable wastes in a continuously stirred tank reactor. The wastes used include spinach waste, asparagus peels, French bean waste, strawberry slurry, apple pulp, apple slurry, carrot waste and green pea slurry. All the wastes were operated with a capacity of 1l and temperature of 33^0C. spinach was operated with 0.83-1.18 g organic loading rate gave a methane yield of 0.316l/g. asparagus peels, French bean waste, strawberry slurry, apple pulp, apple slurry, carrot waste and green pea slurry with organic loading rate of 0.74-1.06, 0.96-1.15, 1.02-1.15, 1.02-1.60, 0.83-1.15, 0.8-0.9 and 8.87-1.25g/l respectively resulted in a methane yield of 0.219, 0.343, 0.261, 0.308, 0.281, 0.417 and 0.310l/g.

(Ravi and Tiwari, 2013) attempted to test the performance of different ratios of kitchen wastes in a metal floating type biogas plant of volume capacity 0.018 m^3 for outdoor climatic condition of new Delhi, India. Each of the biogas plant contains 30 kg slurry capacity in batch system for all measurement. The temperature, pH, solar radiation and relative humidity were observed on daily basis. Constituents of biogas, volume and rate of biogas production were measured. Comparison between the rate of biogas from kitchen wastes with other energy sources used as fuel for cooking purposes like liquefied petroleum gas LPG, Kerosene and coal was performed.

In general biogas can be produced from nearly all kind of biological wastes ranging from agricultural wastes, household/kitchen wastes, animal wastes and slurries with a promising renewable energy production and a source of nutrients for agriculture. In general, kitchen waste, agricultural waste, animal waste and human excrete have been into test as laboratory to check their performance for biogas production.

III. METHODOLOGY

3.1 Materials and Methods

The materials, equipment and experimental procedures are presented below.

Materials: ¾ pvc pipe, T- tube, valve, tyre tube, 20 litre c-way bottle, 500ml incubation bottles.

Feed stocks: Yam peels, plantain peels, Irish potato peels, pineapple peels, orange peels and inoculum.

Glass wares: Petridishes, crucibles, volumetric flask measuring cylinder, stirring rod, and beaker.

Chemical: Distilled water, sodium hydroxide (NaOH), potassium dihydrogen phosphate (KH_2PO_4), Dipotassium hydrogen phosphate (K_2HPO_4) Magnesium Sulphate heptahydrate ($MgSO_4 .7H_2O$), Potassium Chloride (KCl), Cobalt (II) Chloride ($CoCl_2$), Nickel (II)Chloride ($NiCl_2$), Potasssium hydroxide (KOH), Calcium chloride $CaCl_2$ and Iron (II) chloride ($FeCl_2$).

Equipment: pH meter (Hanna Educational HI 208), weighing balance, thermometer, digester, desiccator, Oven (Drying oven DHG 9030A), and Furnace (Fritsch DD 3305A)

3.2.0 Sampling

3.2.1 Collection of Organic Waste (Feedstock)

The organic wastes used were yam peels, plantain peels, and irish potatoes peels which were collected from NDA cadet mess, faculty of science for a period of one week and were homogenized to get a composite sample of each substrate. The fruit wastes (orange and pineapple peels) were collected from railway station along central market in Kaduna Metropolis. All samples collected were washed, sun dried and pulverized using mortar and pestle and blended to a fine power and then stored separately in polythene bag until use. The inoculum (abattoir efficient) was collected from slaughter house at Anguwan Shanu Market.

3.2.2 Definition of inoculum

Inoculum is a small amount of substance containing bacteria from a pure culture which is used to start a new culture.

3.2.3 Method of Analysis

The physical characteristics pH, total solids (Ts), volatile solids (Vs), moisture content and Ash content were analysed according to standard method (APHA – AWWA 1992) as appropriate.

3.2.4 pH Determination

5g of each substrate (yam peel, plantain peel, irish potatoe peel, pineapple peel and orange peel) was weighed and dissolved with distilled water in a 250ml clean beaker and the pH taken and recorded.

3.2.5 Total Solid Determination

Total solid denotes organic as well as inorganic matter in the feedstock. This involves evaporating the liquid present in a sample and measuring the mass of the residue. 10g of each sample (yam peel, plantain peel, irish potatoe peel, pineapple peel and orange peel) was weighed and poured in a pre-dried crucible at 105^{0}C in drying oven for about 4 hours, it was then cooled in desiccator at room temperature and the weight calculated thus:-

Calculation for Total Solids

$$\%\text{Total solid} = \frac{\text{Weight}_{\text{dry crucible + dry sample}} - \text{Weight}_{\text{dry crucible}} \quad *100}{\text{Weight}_{\text{dry sample}}}$$

3.2.6 Volatile Solids (V.S) Determination

These are solids in water or other liquid that are lost on ignition of the dry solids at 550^{o}C. From the dried residue of total solid determination, 5g was weighed in crucible and reheated for 2hours at 550^{0}C in furnace. After cooling, crucible was weighed and recorded.

Calculation for % volatile solid

$$= \frac{\text{Weight}_{\text{dry crucible dry sample}} - \text{Weight}_{\text{dry crucible}} \quad * 100}{\text{Weight}_{\text{dry sample}}}$$

3.2.7 Moisture content determination

The moisture content of the samples was determined using the oven-drying method. Pre-weighed sample (5g) was dried in the oven 150^{0}C for 24 hours. The residue was then weighed, and percentage moisture was calculated thus.

$$\%\text{ moisture content} = 100 - \left(\frac{w1}{w2} X \frac{100}{1} \right)$$

Where W_1 = Weight of crucible + sample after drying

W_2 = Weight of crucible + sample before drying

3.2.8 Ash Content Determination

A known quantity (5g) of the dried sample from moisture was ignited at 540^{0}C for 3 hours in an oven as described by (Dangoggo and Fernando, 1986).

$$\%\text{ Ash content} = \frac{Wb - Wf}{Wb - We} X \frac{100}{1}$$

Where Wb = weight of sample and crucible before ignition

Wf = weight of sample and crucible after ignition at 540^{0}C

We = weight of empty crucible

3.3 Digester Set-Up

A digester is physical structure commonly known as anaerobic digester or biogas plant which provides internal conditions for various chemical and microbiological reactions to take place. Digestion was carried out in a 500 ml plastic container. 12 g of each dried food and fruits waste were mixed with 110 cm^3 of non- growth medium and 290 cm^3 inoculums respectively to give a slurry of about 450 ml. The mixture was stirred with stirring rod to get homogenous slurry, then labeled appropriately and subjected to anaerobic digestion for 30 days retention period. The full set up of this study was the connection of the biogas to the water displacement set up for gas collection.

3.3.1 Preparation of Non-growth Medium

Non-growth medium was prepared for the anaerobic digestion process using the following compounds; Potassium dihydrogen phosphate KH_2PO_4, Dipotassium hydrogen phosphate K_2HPO_4, Magnesium sulphate heptahydrate $MgSO_4.7H_20$, Calcium chloride $CaCl_2$, Iron (II) Chloride $FeCl_2$, Potassium chloride KCl, Cobalt II Chloride $CoCl_2$ and Nickel II Chloride $NiCl_2$ (Table 1). The required amount of each of the reagents was carefully measured using top digital high precision balance. The medium provided the essential nutrients required by the microorganisms (Horn, 2000).

3.3.2 A pilot system

One of the purpose of this study is to make available and easily accessible biogas production to as low as household level, hence a case study was conducted on a 20 liter digester to determine the efficacy and quantity of biogas yield as feedstock quantity increases. The important aspect of this concept is to add value to the overall system where instead of dumping the post anaerobic residue of the laboratory setup , it could be used as innocula to generate more biogas.

3.3.3. Startup Procedure for the pilot system

Yam peel was selected for the case study owing to the fact that is the most abundant and most frequently used and earlier experimental work had shown that it gave almost the highest yield of gas. 10 kg of the yam peel was mixed with 10 litre of water thoroughly by hand in equal proportion 1kg: The mixture was poured into the 20 litre digester. Content of the previous laboratory set up of yam peel in the 500ml bottle was used as inoculum as it contains the required microorganism for anaerobic digestion. The pH was taken to be 5.02. It was found out that biogas has evolved within the first 12 days making the tyre tube increased in size, showing that digestion has taken place.

3.3.5 Measurement of Biogas

The biogas produced from each of the sample in the 500ml bottle was measured by water displacement method. The water diplacement method of gas collection is a method in which gas is allowed to replace water at equal volume of water displaced and this was used to determine the volume of gas produced daily. The control on the digester was released for the evolved biogas to get into the measuring cylinder and the volume of water displaced equals the volume of gas produced. While a tyre guage metre was used to measure the volume of inflated tyre by taking the reading on the guage and subtracting the initial weight of the deflated tyre which equals the volume of gas produced.

Fig 1: Digester set up

Fig 2: Measurement of the biogas using water displacement method.

IV. RESULTS AND DISCUSSION

In this experimental work, the following result were obtained

Table1: Proximate Analysis of Food and Fruit Wastes.

S/N	SAMPLE	PARAMETERS				
		Moisture content (%)	Total solid (%)	Ash content (%)	Volatile solid (%)	pH
1.	Yam peel (A)	12.80	7.75	49.25	54.59	7.25
2	Plantain peel (B)	15.35	28.08	40.25	53.16	6.7
3	Irish potato peel (C)	3.34	9.90	43.50	50.02	6.85
4	Orange peel (D)	10.77	15.80	39.50	52.23	6.65
5	Pineapple peel (E)	18.07	22.40	40.00	56.50	6.02

From the table above it is evident that pineapple peel had maximum moisture content of 18.07% and Irish potatoes peel the least with a moisture content of 3.34%. The maximum total solids were recorded in plantain peel as 28.08% while yam peel gave a lowest value of 7.75%. The volatile solids in all the samples used for the study varied between 50.02% (Irish potatoes peel) to 56.50% (pineapple peel). These results were comparable with values reported by (Deressa *et al.*, 2015). The pH of wastes in each digester ranged from 6- 6.9 which are in conformity with the optimum pH range for biogas production (chua *et al.*, 2008). The results showed that microorganism in the anaerobic digesters were not affected by the pH of the slurry in the digester, therefore no inhibition of biogas production due to effect of pH. The temperature in all the digesters ranged from 26- 32^{0}C which happens to be in the range of mesophilic 25- 45^{0}C which is allowed for production of biogas.

Table 2: Quantity in ml/day of Biogas Production by Each Batch Digester.

Biogas production in ml/day for the 1st week

DIGESTER	NO. OF DAYS								
	1st Day	2nd Day	3rd Day	4th Day	5th Day	6th Day	7th Day	8th Day	Mean
Yam peel A	150	80	120	50	-	60	90	115	83.13
Plantain peel B	64	75	88	130	90	45	67	72	78.88
Irish potatoe peel C	85	75	-	58	35	20	70	100	55.38
Orange peel D	-	35	20	10	-	40	25	80	26.25
Pineapple peel E	-	-	28.5	65	-	40	38	27	24.81

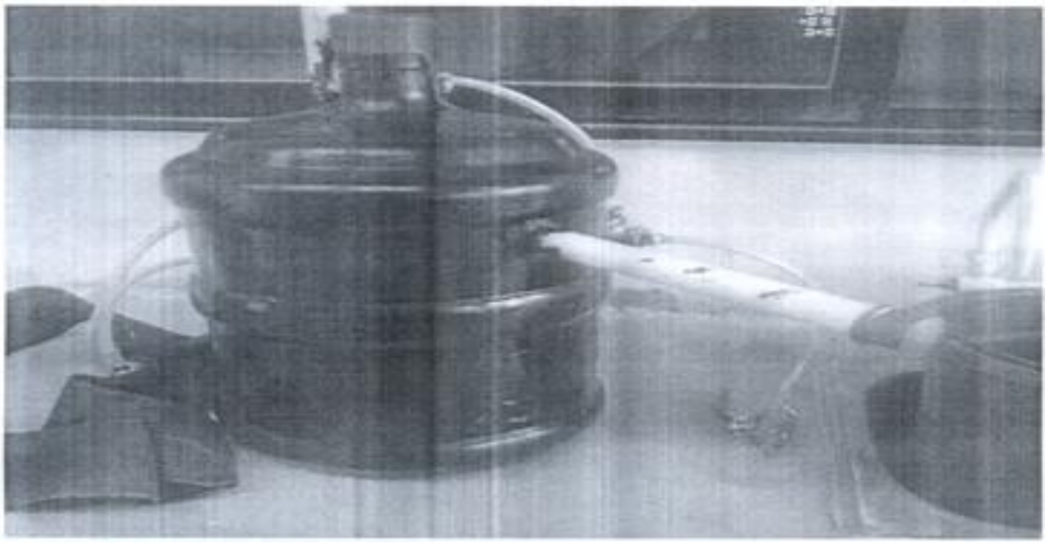
From the table above, it can be seen that digester A which contains yam peels as feedstock produced the highest biogas in ml for the first day of 150 ml, with no production on the 5th day. Followed by B (plantain peel) with highest volume of biogas (130ml) on day 4 and then production began to fluctuate which is in conformity with (Otun *et al.*, 2015).The production of biogas began right from the first day for C (irish potatoe peel) with 85ml, and the highest volume was observed on the 8th day (100ml). Digester D (orange peel) and E (pineapple peel) have not begun production until the 2nd and 3rd day respectively with the least of 10ml for digester D and 27ml for digester E which is similar to the work of (Sagagi *et al.*,2009).

Table 3: Weekly gas production for the different digesters for the 30 days retention period
Total weekly biogas production

DIGESTER	MEAN WEEKLY BIOGAS PRODUCTION IN ML				
	A	B	C	D	E
Week 1	83.13	78.88	55.38	26.25	24.81
Week 2	92.43	75.52	75.25	30.15	36.2
Week 3	70.56	60.0	54.62	22.02	28.88
Week 4	40.12	34.52	32.15	20.22	18.26

The graph on the appendix showed the variations in the biogas produced for all 5 samples in different week. The maximum gas production was observed for A (yam peel) in the 2nd week with mean value of 92.43ml and then the quantity of biogas started reducing for the remaining weeks. Digester B (plantain peel) had its highest production in the 1st week with 78.88ml as mean value thereafter decreases gradually for the weeks left for the completion of the experiment. The 2nd week also recorded the maximum quantity of biogas of 75.25ml for digester C (Irish potatoe peel). Digesters D and E (pineapple and orange peels) have recorded the least yield of biogas although a significant amount has been recorded in the 2nd week with 30.15ml and 36.2ml respectively which are not comparable with digester A (yam peel) that gave more than double the quantity from the first week which can be due to its higher percentage of carbohydrate contents (sugar) which is the basis for fermentation or anaerobic digestion process. It was observed that degradation process started during the first 1-15 days of set-up.

Biogas production process is affected by temperature, pH, volatile and total solids, all these have to be monitored for effective quality and quantity of biogas. Production of biogas from kitchen wastes is a major step towards harnessing one of the world’s most prevalent, yet least utilized renewable energy resource.



V. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

From the results obtained, it can be concluded that kitchen waste containing high carbohydrate are amenable to anaerobic process and the maximum gas production was observed during 5-10 days of digestion. This shows that carbohydrates have been broken down much faster than protein, fats and vitamins/ minerals present in the waste which produced the gas. The maximum value obtained for biogas within the 30 days retention period was observed with digester A (yam peel) having 286.216ml and digester D (pineapple peel) gave the least value of 98.64ml which were compared with values obtained from Muhammad *et al*., 2009 and Otun *et al.*, 2015. The potential of four substrate namely pineapple, orange, pumpkin and spinach to produce biogas by Sagagi *et al*., 2009 gave an almost similar results obtained here owing to the fact that carbohydrate content of fruits is low compared to that of yam or tuber. Thus successful implementation of this technique (anaerobic digestion) as a method of waste treatment has the potential to change the concept of waste into that of a valuable resource which will lead to total utilization of renewable energy resources reducing energy requirement, creating more jobs and income, reducing costs, making it readily available and minimize environmental pollution.

i.2 Recommendations

i- It is recommended that the possibility of developing this green technology for biogas production be looked into so as to enable Nigeria effectively reduce the high amount of wastes currently generated.

ii- It is further recommended that the use of fruit peels especially citrus, there may be the need to pretreat to remove D-limonene oil which is well known as anti-microbial agent that may cause failure of anaerobic digester.

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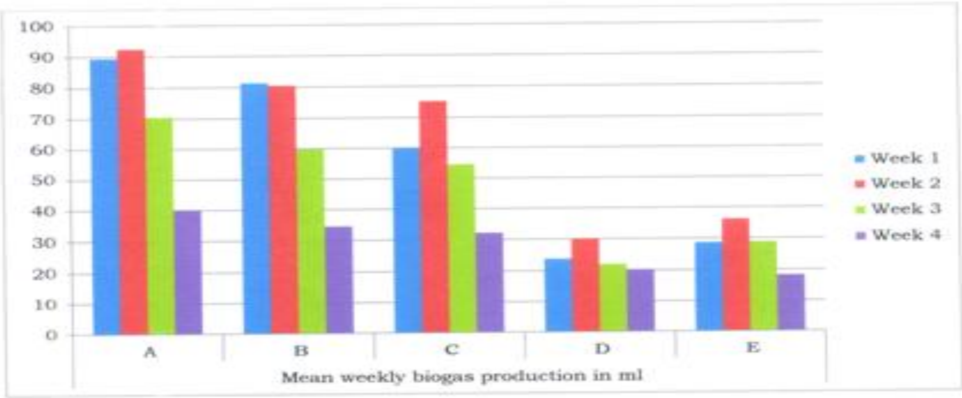
Appendix



The above data is shown in form of bar chart in the figure below.

Key: A= Yam peel
B= Plantain peel
C= Irish potatoe peel
D= Orange peel.
E= Pineapple peel.