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PHYSICOCHEMICAL ANALYSIS AND BIOGAS PRODUCTION POTENTIAL OF SELECTED ANIMAL WASTE SUBSTRATES

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ABSTRACT

Biogas primarily consists of methane and carbon dioxide, obtained through the anaerobic digestion of biodegradable waste such as animal waste, sewage sludge, and municipal waste. Biogas production plays a crucial role in addressing waste disposal and environmental pollution challenges. The study focuses on the thermochemical characterization of biodegradable wastes, which significantly affect biogas production and biogas production from these wastes. Six samples were collected from 5 locations within Landmark University Omu-Aran in Kwara state. The samples were combined in equal proportion by weight, and proximate analysis was conducted to determine their chemical compositions. The physicochemical analysis results of the substrate indicate that the highest pH value, 8.21, was observed in piggery waste, while the lowest pH value, 7.68, was found in poultry waste. In the analysis of digestate, the maximum pH values for goat, sheep, and poultry waste were 7.91, while the minimum pH values for pig, rabbit, and cow waste were 7.98. The gas production per day varied between 0 and 3mm3, with the maximum quantity of gas produced recorded for goat-sheep-poultry waste. Gas chromatography-mass spectrometry results revealed that methane constituted 63.41% of the biogas produced from pig-rabbit-cow waste, with the lowest concentration observed in helium (0.01%). This research would add to the valuable database for comparative analysis of different animal wastes in biogas production.

KEYWORDS: Physicochemical analysis; animal waste; biogas production; anaerobic digestion; substrate composition

INTRODUCTION

Anaerobic digestion is a controlled process of decomposing biodegradable materials under controlled conditions without the presence of oxygen. It involves the activity of anaerobic, facultative bacteria and archaea species that convert the inputs into biogas and digestate (Ejiko et. al., 2020). The process entails the biochemical degradation of complex organic matter, resulting in the production of biogas consisting primarily of methane CH_4 and carbon dioxide CO_2, as well as trace amounts of hydrogen H_2, nitrogen N_2, and hydrogen sulfide H_2S. The high content of biodegradable components, such as carbohydrates, lipids, and proteins, present in microalgae biomass makes it a favorable substrate for the anaerobic microbial flora, which can convert it into biogas rich in CH_4 (Sumardiono et al., 2013). The anaerobic digestion process is facilitated by different consortia of bacteria. Firstly, organic materials in the substrate, such as cellulose, hemicellulose, and lignin, need to be liquefied by extracellular enzymes and then undergo treatment by acidogenic bacteria. The rate of hydrolysis depends on various factors, including pH, temperature, composition, and concentration of intermediate compounds. Soluble organic components, including hydrolysis byproducts, are converted into organic acids, alcohols, hydrogen, and carbon dioxide by acidogens. The products of acidogenesis are further converted into acetic acid, hydrogen, and carbon dioxide. Methanogenic bacteria produce methane from acetic acid, hydrogen, carbon dioxide, and other substrates, with formic acid and methanol being particularly important. This process is catalyzed by a consortium of microorganisms (inoculum) that convert complex macromolecules into low molecular weight compounds, including methane, carbon dioxide, water, and ammonia (Fantozzi & Buratti, 2009).

Anaerobic digestion is commonly employed in organic waste management systems. The process yields biogas, consisting of 50 to 70 percent methane, which can be utilized as an energy source. Anaerobic digestion is applied in Concentrated Animal Feeding Operations (CAFOs) for livestock manure treatment and wastewater treatment plants (WWTPs) for sewage treatment, and it naturally occurs in all Municipal Solid Waste (MSW) landfills during organic waste decomposition. The level of biogas production is expected to rise with the mechanization of the agricultural process bringing about an increment in crop production coupled with corresponding waste (Filani & Ejiko, 2018).

Biogas can be treated and utilized for electricity generation, transportation fuel, space or water heating, or upgraded to meet natural gas pipeline standards and be delivered through the pipeline. Feedstock for biogas production includes various organic wastes like livestock manure, food processing byproducts, food waste, sewage, green waste (e.g., grass clippings or hedge trimmings), fats, oils, and grease. Many CAFOs, WWTPs, and MSW landfills in the United States, including some in Indiana, are currently producing biogas. While some facilities opt to flare the biogas, others utilize it for on-site electricity generation and/or meeting heating needs. Apart from being a renewable energy source, biogas production and utilization offer other benefits such as environmental balance promotion, cleaner energy, and low cost.

Methane CH4, the primary component of biogas, is a potent greenhouse gas with a global warming potential 21 times higher than CO2. Unless captured and burned, methane produced at these facilities is released into the atmosphere. Additionally, electricity generated using biogas displaces generation at larger power plants that may use fuels like coal, emitting significant quantities of greenhouse gases and various pollutants, including mercury and sulfur dioxide. Therefore, utilizing biogas for electricity generation can contribute to reducing greenhouse gas emissions and air pollutants.

This paper aims to enhance waste recycling and serve as a template for a comparative analysis of different animal wastes in biogas production. However, this study is limited to the comparative analysis of different animal waste in biogas production.

Literature review

Due to the increasing demand for electricity in Nigeria, there is a need to explore alternative means of electricity generation, particularly renewable energy sources. Methane gas, a byproduct of anaerobic digestion of human waste, can be utilized for electricity generation. A case study of the male hostel at the Federal University of Technology, Owerri, reveals that the available biomass waste from the area amounts to 3.66 tonnes per day, with a biogas production of 154.76 kg bi-monthly. This amount of biogas can power a 5 kW biogas generator for six days (Onoja et al., 2012).

Nigeria, being a major producer of crops such as yam, cassava, cocoyam, beans, and melon, generates significant amounts of unavoidable waste during food crop production. Improper waste disposal methods contribute to environmental degradation and pollution. However, this waste can be utilized as feedstock for anaerobic digestion to produce renewable energy. Experimental analysis was conducted to determine the suitability of food waste as a biofuel feedstock. The waste content was analyzed, characterized, and assessed for its bio-methane potential using the Baserga model. The results showed a waste index range of 0.2-1.5, with corn having the highest waste proportion. The bio-methane potentials varied between 35-460 m3/tonne, and the energy potential of the food waste was found to be 31 TWh/yr, which could significantly contribute to the country's bioenergy production and meet the energy demand of Nigerian households (Gurumwal & Zahir, 2018).

In India, the challenge of ensuring energy security in both rural and urban areas has become prominent due to population growth and ongoing urbanization. The energy demand has increased across various sectors such as cooking, cultivation, production, and transportation. Although the adoption of Liquefied Petroleum Gas (LPG) for cooking has increased through government initiatives, biofuels are expected to continue being used by poorer households due to the vast population. While the generation of biogas from cattle waste in India has been promoted through policies, the utilization of human waste for biogas production is still in the early stages. A study explores the potential of recovering energy from human waste and investigates the reasons behind the past failures of initiatives like the Ganga Action Plan (Mukherjee & Chakraborty, 2016).

Solid waste can be seen as either an urban burden or a valuable resource, depending on how it is managed. To meet the growing energy demand and address environmental concerns, a shift from conventional energy systems to renewable resources is crucial. (Sharmina et al., 2012).

The volume and mass of solid waste produced depend on economic prosperity and the percentage of the urban population. Reducing the amount of solid waste is crucial, especially considering the limited availability of disposal sites worldwide. To meet the increasing energy demand and address environmental concerns, a transition from conventional energy systems to renewable resources is essential. Three main pathways required for waste-to-energy conversions are thermochemical, biochemical, and physicochemical processes (Muhammed et al., 2013).

Co-digestion of organic waste is highlighted as an effective biological process for treating a wide range of solid organic waste products and sludge, while also producing biogas. Biogas is produced using a variety of raw materials such as plant material, food waste, and animal dung in a reactor (Ejiko et. al., 2019). The advantages of this technology include the degradation of organic wastes with low nutrient content by co-digesting them with different substrates in anaerobic bioreactors, and the low-cost production of biogas, which is crucial for meeting future energy needs (Alemayehu, 2014).

Waste

According to UNEP (2005), waste refers to materials that are not primary products and are no longer useful to the initial user for their intended purposes of production, transformation, or consumption. Waste is any discarded substance that after being used is referred to as worthless or defective. By-products are different from waste, in that it is the relatively more economic value (Ejiko et. al., 2023). The waste materials are intended for disposal and can be generated during various activities such as raw material extraction, processing, product consumption, and other human actions. It's important to note that residuals that are recycled, reused, or managed on-site are not considered waste. Wastes are considered unwanted materials or substances that are produced during the process of producing and consuming goods. Developed countries generate a substantial amount of refuse, ranging from 500 to 800 tonnes per day. Conversely, in less developed countries, waste generation is relatively easier to compost or utilize for biogas generation, but more challenging to compress or incinerate.

Agricultural residues

Globally, there is a significant annual production of crop residues, which remains largely underutilized. Among these residues, rice husk is the most common agricultural byproduct, constituting 25% of the mass of rice. Additionally, other residues such as bagasse (sugar cane fiber), coconut husks and shells, groundnut shells, and cereal straw are generated. Typically, current farming practices involve plowing these residues back into the soil, burning them, allowing them to decompose, or using them as fodder for cattle. However, various agricultural and biomass studies suggest that it might be advantageous to extract and utilize a portion of these crop residues for energy production, as they provide abundant and cost-effective raw materials. These residues can be processed into liquid fuels or used for combustion/gasification to generate electricity and heat (Sirviö & Rintala, 2002).

Animal waste

A variety of animal wastes offer significant potential as biomass energy sources, with the primary sources being animal and poultry manure. Previously, this waste was commonly utilized as fertilizer or directly applied to agricultural fields. However, stricter regulations addressing odor and water pollution necessitate the implementation of waste management practices, thereby creating additional incentives for waste-to-energy conversion. Food processing and abattoir waste also present promising options as feedstock for anaerobic digestion (Dhussa & Varshney, 2000).

Industrial waste

The food industry generates a significant quantity of residues and by-products that can serve as valuable biomass energy sources. These waste materials originate from various sectors within the food industry, encompassing activities ranging from meat production to confectionery. Solid waste examples include peelings and scraps from fruits and vegetables, substandard food products, sugar and starch extraction by-products like pulp and fiber, as well as filter sludges and coffee grounds. Typically, these waste materials are disposed of in landfills (Gunasegarane, 2002). Liquid waste, on the other hand, is produced during processes such as meat, fruit, and vegetable washing, blanching, pre-cooking of meats, poultry, and fish, cleaning and processing operations, as well as wine-making. These wastewater streams contain dissolved and solid organic matter, including sugars and starches. These industrial wastewaters possess the potential for anaerobic digestion to produce biogas or fermentation to produce ethanol (Rao, 1999).

Municipal waste

Waste presents a highly promising opportunity to produce biofuel, serving as an alternative source of energy and addressing the issue of waste management within communities. Singhal et al. (2012) have reported on the formation of biogas from various waste sources, including municipal solid waste, food manufacturing waste, and waste-activated sludge. Anaerobic digestion emerges as an appealing option for energy generation from the putrescible portion of Municipal Solid Waste (MSW), contributing to waste reduction and mitigating environmental impacts such as greenhouse gas emissions and global warming (Yusuf and Debora, 2011). Municipal solid waste (MSW) encompasses the waste generated within a community, excluding industrial and agricultural waste, and typically contains a significant proportion (30-50%) of organic materials. This includes waste from residential, commercial, and institutional sources, such as households, stores, markets, hotels, schools, and hospitals. Organic or biodegradable waste, such as paper, paperboard, garden waste, and food waste, falls within this category (Tchobanoglous et al., 1993). Current municipal solid waste landfills produce biogas and leachate. Biogas production from waste holds immense potential in resolving waste treatment challenges, and the solid remnants from fermentation can be reused as fertilizers. Landfill gas, a mixture saturated with water, primarily consists of approximately 40-60% methane, accompanied by carbon dioxide CO2, nitrogen, oxygen, water vapor, sulfur, and numerous other contaminants (Asgariet al., 2011).

MATERIALS AND METHOD

The biodegradable waste was collected from various production sites and underwent meticulous sorting manually to separate the samples from impurities. The sorted samples were then prepared for the experimental process, ensuring the appropriate proportions were utilized to achieve the desired thermochemical properties. The anaerobic digester consists of two chambers: the inner tank, known as the digester tank, and the outer tank, referred to as the reactant tank. The digester has a capacity of 5 liters, while the reactant tank also holds 5 liters. Before loading the waste sample into the anaerobic digester, several tests will be conducted, including chemical and biological tests. The chemical tests required for this research work include pH, total nitrogen (T. N), total carbon (T. C), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), total alkalinity, potassium, phosphate PO4, sulphateSO4, magnesium Mg, manganese Mn, iron Fe, zinc Zn, aluminium Al, copper Cu, sample weight, volume of the sample, percentage of moisture content, percentage of total solid, percentage of fixed solid, and percentage of volatile solid.

Determining the pH level and carbon-nitrogen ratio provides insights into the sample's nature and the expected gas production during the anaerobic process. This will help to assess the rate of gas generation (whether high or low). Prior to loading into the anaerobic digester, a computer-controlled anaerobic digester will raise the temperature to approximately 35 degrees Celsius. A hole beneath the digester connects to a chamber containing steam water. The biogas generated in the anaerobic digester compresses the steam water to a certain degree, and the biogas collects at the top of the chamber. This temperature provides an optimal environment for the anaerobic microorganisms responsible for breaking down the waste sample. The microorganisms involved in the decomposition process are anaerobic organisms, which are not visible to the naked eye and can survive in an oxygen-free environment. After 30 days, biogas is collected using a syringe and needle to prevent gas escape. The energy produced after the anaerobic digestion process is in the form of biogas, primarily consisting of methane CH_4 and carbon dioxide CO2. The overall process can be described as a chemical reaction in which organic material, such as glucose, is biochemically digested by anaerobic microorganisms, resulting in the production of carbon dioxide (CO2) and methane (CH4).

Materials

The materials utilized for both thermochemical characterization and anaerobic digestion are listed in plates 1 to 7. These materials include cow dung, goat dung, pig dung, rabbit dung, sheep dung, and poultry waste. All the specified waste materials were obtained from the local environment. The waste consists of cow waste, pig waste, rabbit waste, goat waste, sheep waste, and poultry waste. To prepare the waste, it was dried and mixed with a chemical substance, sodium hydroxide (NaOH). The purpose of adding this chemical is to neutralize the acidic substances (pH) in the waste, creating a favorable environment for microorganisms. The anaerobic digester used in the experiment was manufactured by Edibon Engineering company and has a capacity of 5 liters. The experiment was conducted at the Environmental Laboratory of Landmark University in Omu-Aran, Kwara State.

Plate 1: Poultry Waste

Plate 2: Rabbit Waste

Plate 3: Cow Waste

Plate 4: Pig Waste

Plate 5: Sheep and Goat Waste

Plate 6: Anaerobic Digester

Plate 7: Computer Controlled System

Gas chromatography-mass spectrometry (GC-MS) analysis

Gas chromatography is a method that effectively separates the components of a mixture, while mass spectroscopy allows for the characterization of each component. By combining these two techniques, samples can be analyzed both qualitatively and quantitatively. When the sample is injected into the chromatograph, the mixture is separated into its components based on their distinct flow rates when vaporized without decomposition. Gas chromatography and mass spectroscopy analysis are particularly useful for identifying organic components in complex mixtures, performing quantitative analyses, and determining traces of organic contamination.

Calibration of gas chromatography-mass spectrometry (GC-MS)

The calibration standards used in this study cover a concentration range of 0.1–100 mg L-1. The internal standard (ISTD), known as HEDS, has a concentration of 10 mg L-1. Here is the information about the ISTD stock solutions:

i. ISTD stock solution I1: It has a concentration of 10 g L-1 in heptane, prepared by dissolving 0.1 g in 10 mL

ii. ISTD stock solution I2: It has a concentration of 0.2 g L-1 in heptane, prepared by diluting 1 mL of I1 in 50 mL

iii. To obtain a concentration of 10 mg L-1 of HEDS, 100 µL of I2 is dissolved in 2 mL of heptane.

A nine-point calibration curve is created using solutions with different concentrations of the individual compounds: 0.1–0.25–0.5–1–2.5–5–10–50 and 100 mg L-1. Each calibration solution is spiked with 500 µL of ISTD solution I2 (HEDS). The response ratios obtained after normalizing with the internal standard show a linear relationship from 0.1 to 100 mg L-1, with a correlation coefficient (R2) of ≥ 0.998.

For samples with concentrations lower than 10 mg L-1, quantification is performed using a calibration curve ranging from 0.1–10 mg L-1, with a detection limit of 0.1 mg L-1 as the lowest point on the calibration curve.

Analysis of gas chromatography-mass spectrometry

The substances in the samples are identified using a substance database, such as the "NIST library," while quantification is carried out using a calibration line prepared beforehand. The amounts of substances are determined by analyzing the peak areas of the chromatogram obtained. A representative spectral output of all detectable compounds present in the empirical sample is displayed using a GC-MS machine, as shown in Plate 8, and monitored with a Plate 9 device. The GC-MS machine used in the analysis is a Varian 3800/4000 gas chromatograph mass spectrometer equipped with an Agilent and a capillary column DB5ms (30.0 m x 0.25 mm, 0.25 µm film thickness) was utilized. The temperature of the GC column oven was programmed to increase from 70°C to 300°C. The initial temperature was set at 70°C (held for 2 minutes) and gradually rose to 300°C (held for 7 minutes) at a rate of 10°C per minute. The total run time was 32.0 minutes. Nitrogen with a purity of 99.9995% served as the carrier gas at a constant flow rate of 1.51 ml/min. The injector and detector temperatures were maintained at 200°C. The mass spectrometer scanned a range of 30-800 Da. The identification of compounds was achieved by comparing the retention times with those of authentic compounds and by referring to spectral data obtained from the data library of corresponding compounds. The quantities of compounds were expressed as relative area percentages derived from the integrator. The GC-MS data were acquired in selected ion mode. Retention times, molecular ions, and major fragment ions used for compound identification are summarized. The target molecules were identified by comparing their retention time, molecular ion peak, and major fragment ions with those of corresponding standards. For quantization purposes, the analytical responses were normalized to the response of the internal standard (HEDS). To account for technical and biological variations, all the samples and replicates were continuously injected as one batch in random order. Additionally, prepared pooled samples were used as quality controls (QCs) and injected at regular intervals throughout the analytical run to assess repeatability.

Plate 8: GCMS Machine.

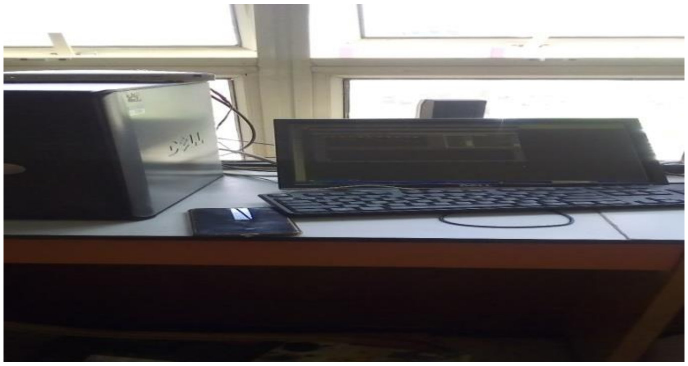

Plate 9: GCMS Monitor

RESULTS AND DISCUSSION

The physiochemical analysis presented in Figure 1, with parameters identified in Table 1, indicates various characteristics of the waste samples. The pH of piggery waste is the highest at 8.21, while the lowest is observed in poultry waste. The mean total alkalinity for all samples is 450 mg/l, and the total nitrogen content in the waste samples averages 24.75 ± 5.75 mg/l. Among the waste samples, pig waste exhibits the highest total carbon content of 288.3 mg/l, while cow waste has the lowest at 178.7 mg/l. The potassium content in all samples is 1.5±4.75 mg/l. The phosphate concentration is lowest in piggery waste at 1.5 mg/l, whereas the highest value for sulphate is found in sheep waste at 138 mg/l. The calcium content in all waste samples is 39±26, and the average magnesium content is 53 mg/l. Sheep and goat waste show the same value for manganese at 0.012 mg/l. Cow waste has the highest iron content among all waste samples at 7.0 mg/l, and the lowest zinc content is observed in piggery waste at 14.0 mg/l. Goat waste exhibits the highest biological oxygen demand (BOD) among all waste samples at 148 mg/l, while the mean chemical oxygen demand (COD) is 878.67 mg/l. The overall mean value of all waste samples is 1648.7 G.

Regarding moisture content, poultry waste has the highest value at 80%, while the lowest value for total solids percentage is found in rabbit waste at 8%. The maximum percentage of fixed solids is observed in poultry waste at 17.52%, and the minimum percentage of volatile solids is found in sheep waste at 78.81%. These results provide insights into the expected gas constituents that would be generated after the waste samples are fed into the anaerobic digester.

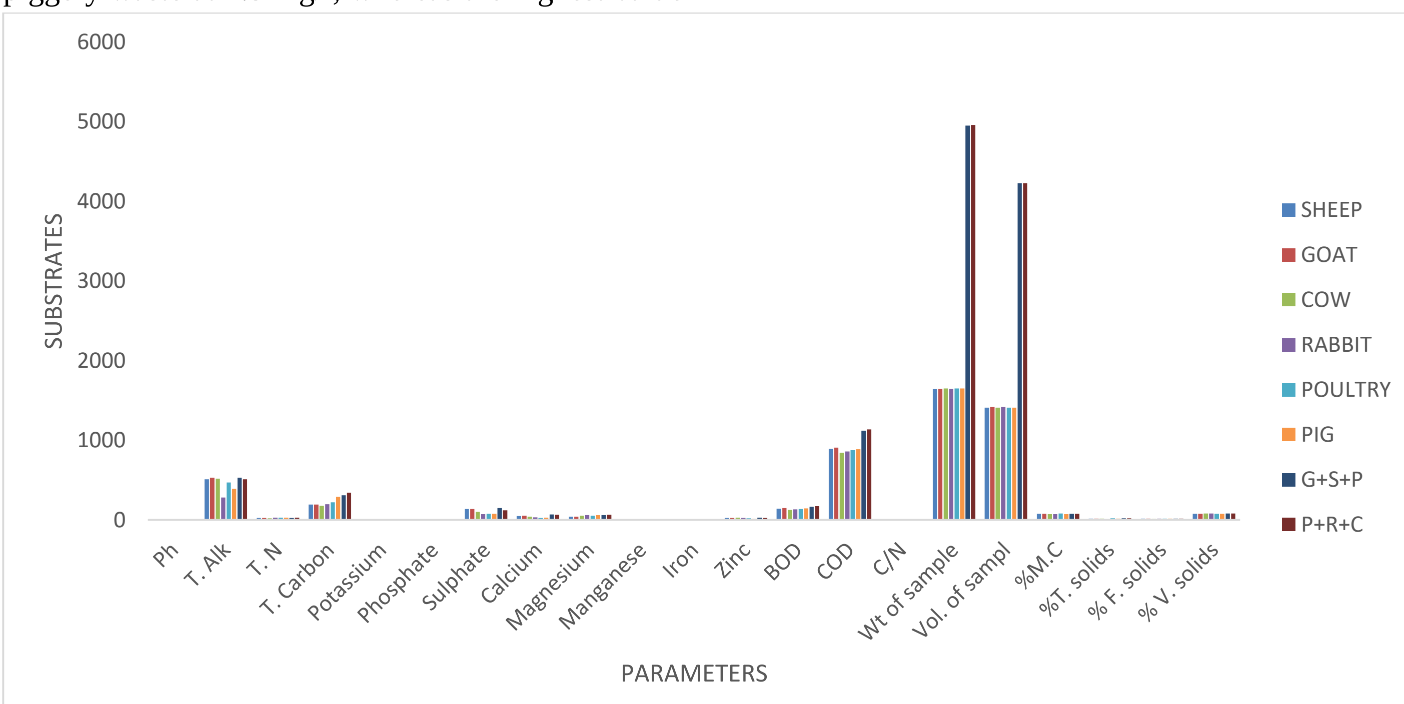

Figure 1. Physiochemical analysis of Substrate

Table 1: Keys for the Anaerobic Codes

pH.	Acidity/neutrality
T. ALKS	Total alkaline
T.N	Total nitrogen
T. CARBON	Total carbon
K	Potassium
PO_4	Phosphate
SO_4	Sulphate
Ca	Calcium
Mg	Magnesium
Mn	Manganese
Fe	Iron
Zn	Zinc
BOD	Biochemical oxygen demand
COD	Carbon oxygen demand
C/N	Carbon/nitrogen ratio
SAMPLE WT	Sample weight
V.S	Volume of sample
%M.C	Moisture content
%T.S	Total solid
%F.S	Fixed solid
%V.S	Volatile solid

Figure 1 shows the physiochemical analysis and Table 1 shows the meanings of the abbreviation used for results.

Physiochemical analysis of digestates

Goat, Sheep, and Poultry (G+S+P1) and Pig, Rabbit, and Cow (P2+R+C) wastes were utilized in capturing the mixture as presented. According to the standard pH level in anaerobic digestion which ranges between 6.8 to 8.0. The pH level of (G+S+P1) waste is 7.91Mg/L while that of (P2+R+C) is 7.78Mg/L which indicates that (G+S+P1) waste has the highest pH value compared to the (P2+R+C). The total alkaline and total nitrogen for G+S+P1waste is 42Mg/L and 23.8Mg/L, while that (P2+R+C) waste is 40Mg/Land 28.3Mg/L. The total alkaline of (G+S+P1) waste is higher compared to that of (P2+R+C) waste. The total nitrogen of (G+S+P1) waste is 23.8Mg/L while that of (P2+R+C) waste is 28.3 Mg/L, the mixture of (P2+R+C) waste will produce the highest volume of total nitrogen. The total carbon generated for G+S+P1 waste is 292Mg/L while that of (P2+R+C) waste is 321.9Mg/L according to the result (P2+R+C) waste produced the minimum amount of total carbon. The potassium waste for (G+S+P1) waste is 4.4Mg/L while that of (P2+R+C) waste is 4.7Mg/L. It was observed that (P2+R+C) waste would generate the highest amount of potassium. Phosphorous generated for (G+S+P1) waste is 2.4Mg/L while that of (P2+R+C) is 2.28Mg/Therefore, phosphorous generated of (G+S+P1) waste is higher than that of (P2+R+C) waste. The sulphate production for (G+S+P1) waste is 131Mg/L and that of (P2+R+C) waste is 104Mg/L, it was observed that the sulphate generated by (G+S+P1) waste is 27Mg/L higher than of (P2+R+C) waste. The calcium production of (G+S+P1) waste is 65 and 62Mg/L for (P2+R+C) waste which means the (G+S+P1) waste is 3 higher than that of (P2+R+C) waste, the magnesium production of (G+S+P1) waste is 45 and 49Mg/L for (P2+R+C) waste. The maximum manganese production was experienced in (P2+R+C) waste 0.017Mg/L while the minimum was produced in (G+S+P1) waste 0.014Mg/L. (G+S+P1) waste produced 4.2Mg/L of iron while (P2+R+C) waste produced 4.4Mg/L of iron, the minimum level of zinc was experienced in (P2+R+C) waste 20.3Mg/L while the maximum is found in (G+S+P1) waste 28.7Mg/L. the BOD of G+S+P and (P2+R+C) waste are 146 and 166Mg/L respectively also the COD of (G+S+P1) waste is 1115 and 1128Mg/L for (P2+R+C) waste. The C/N FOR P2+R+C waste IS 10:1 and 11:1 for (G+S+P1) waste. The mean weight for both samples is 4925.39Mg/L. Also, the mean volume S for (G+S+P1) and (P2+R+C) waste was 4176Mg/L, the moisture content for (G+S+P1) waste is 68.4 and 69.5Mg/L for P2+R+C waste. The mean total solid for both samples is 23.55Mg/L, the fixed solid for (G+S+P1) waste is 19.81 and 19.73Mg/L for (P2+R+C) waste also the volatile solid for (P2+R+C) waste is 77.86 and 78.48Mg/L for (G+S+P1) waste.

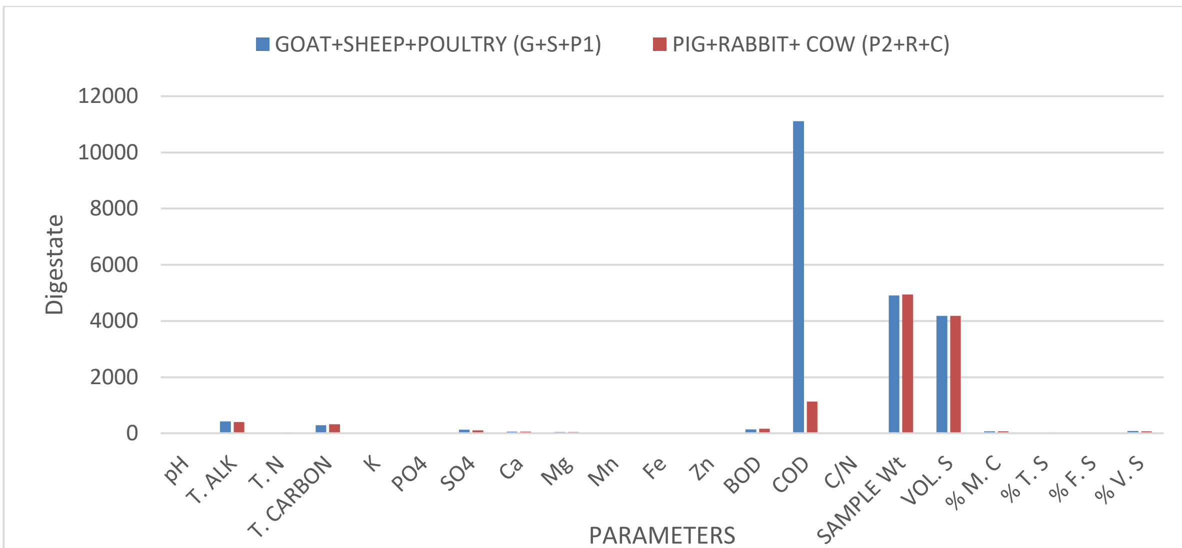

Figure 2. Physiochemical analysis of Digestate

Goat, sheep, and poultry waste analysis in biogas production

On the first day there was no biogas production in the anaerobic digester with a pH level of 7.84 at a temperature of 35℃, in the second to 4th day there was biogas production of 1mm^3 each per day with a constant temperature of 35.10℃ from the initial 35℃. It was observed that the pH level from the third to fourth day increased by 0.08%. The fifth day produced a gas of 0.03256l with a reduction in temperature and pH level. 6th and 7th days produced the same volume of gas per day with the same pH level and temperature, biogas of 0.01628 l with a pH of 7.8and a temperature of 35℃, from day 8th to 19th uniform volume of biogas was produced 0.03256 l and a pH level of 7.86 with a temperature of 35℃. There was an increased production of biogas from 0.03256l to 0.52096 with a temperature of 35℃. It was observed that there was constant production of biogas from the 21st day to the 29th day 0.03256l then from the 30th to the 32nd day the biogas production was the same as pH and temperature. Figure 3 shows the data for the production energy for three waste samples (goat, sheep, and poultry) that were fed to the anaerobic digester. The complete breakdown of all the substrates takes a total of 32 days inside the anaerobic digester with a temperature of 35.0 - 35.1℃.

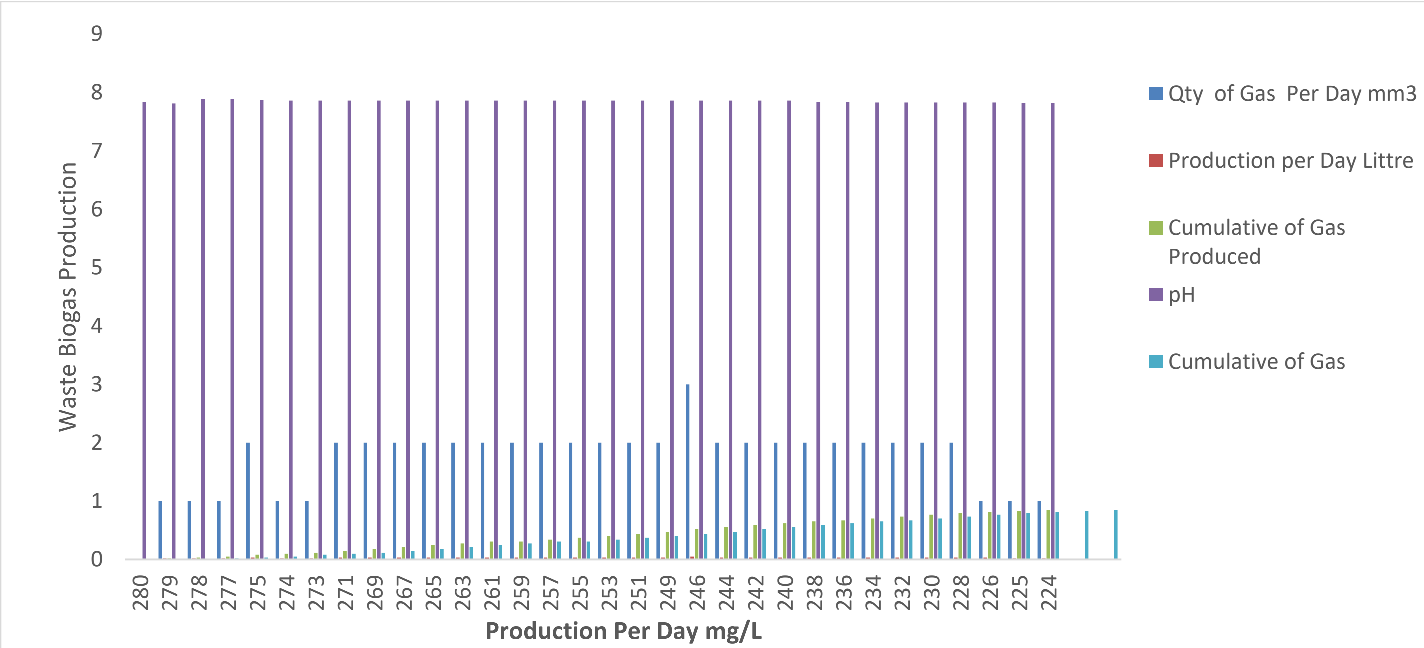

Figure 3. Goat, sheep, and poultry waste biogas production

Pig, rabbit, and cow (P_2+R+C) waste analysis in biogas production

There was no production of gas for the first day inside the anaerobic digester with a pH of 7.81 and a temperature of 35.0℃. There was a uniform production of gas from the 2nd to the 4th day, a biogas production of 0.01628l, the second and third days had a pH of 7.80 and a temperature of 35.0℃ but for the third day there was a change in temperature and pH level7.81 and 35.1℃, there was a steady production of gas from the 5th to the 10th day a pH of 7.80 and a temperature of 35.10 ℃, there was also a steady production of gas from the 11th to the 13th day with the same temperature. From the 14th to the 23rd day there was a constant production of biogas with the same temperature and pressure except for the 18th and 19th day with the pH level of 7.82. There was an increase in the production of biogas for the 24th day 0.03256 with a temperature of 35.1℃, from the 25th to the 29th day the production of gas was the same also with the pH and temperature. From the 30th to the 32nd day the production of biogas was the same but with different pH levels and temperature. Figure 4 is a data presentation of biogas production for three waste samples (pig, rabbit and cow) that were fed to the anaerobic digester. Figure 5 shows the biogas production from Goat, Sheep, and Poultry Waste, while Figure 6 captures the biogas Production from Pig, Rabbit, and Cow Waste. The complete breakdown of all the substrates took a total of 31 days inside the anaerobic digester with a temperature of 35.0 - 35.1℃.

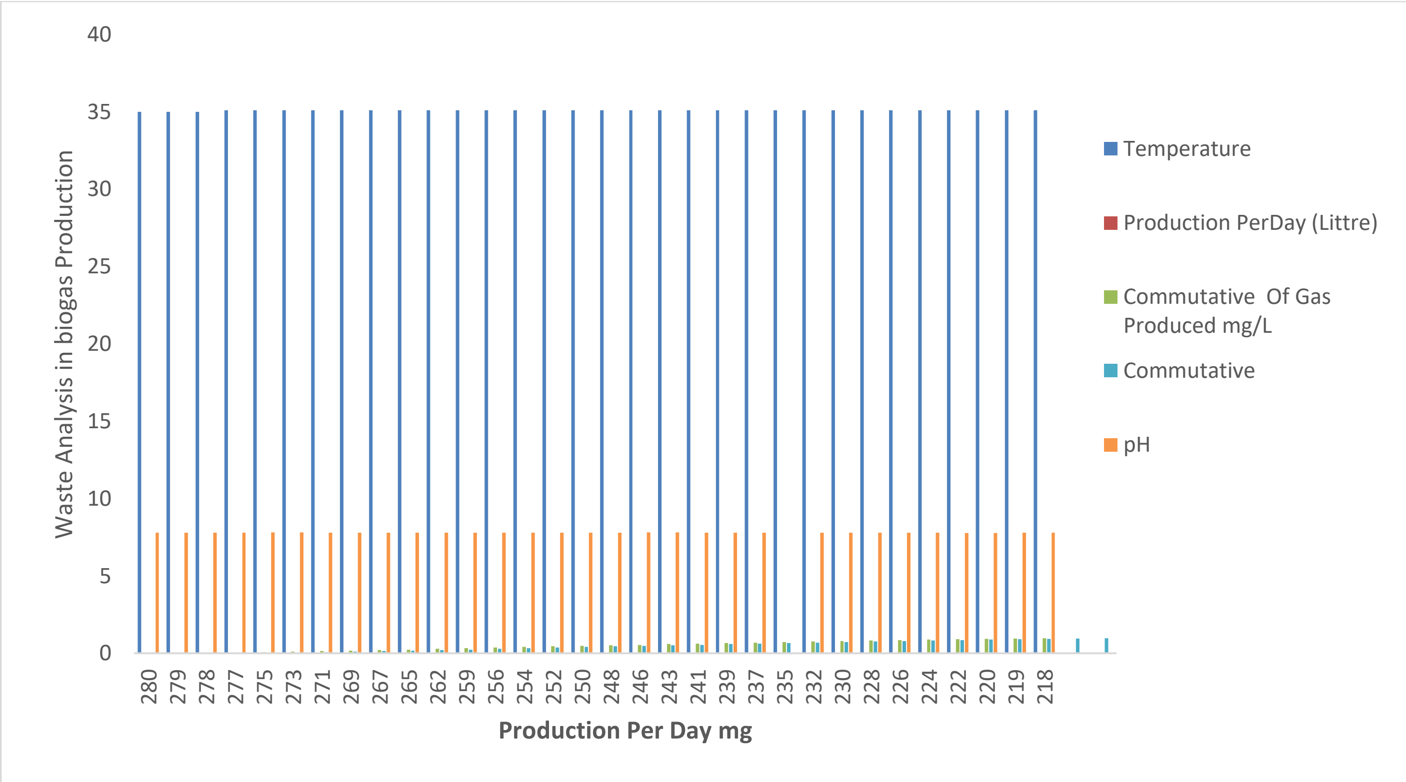

Figure 4. Pig, rabbit, and cow waste analysis in biogas production

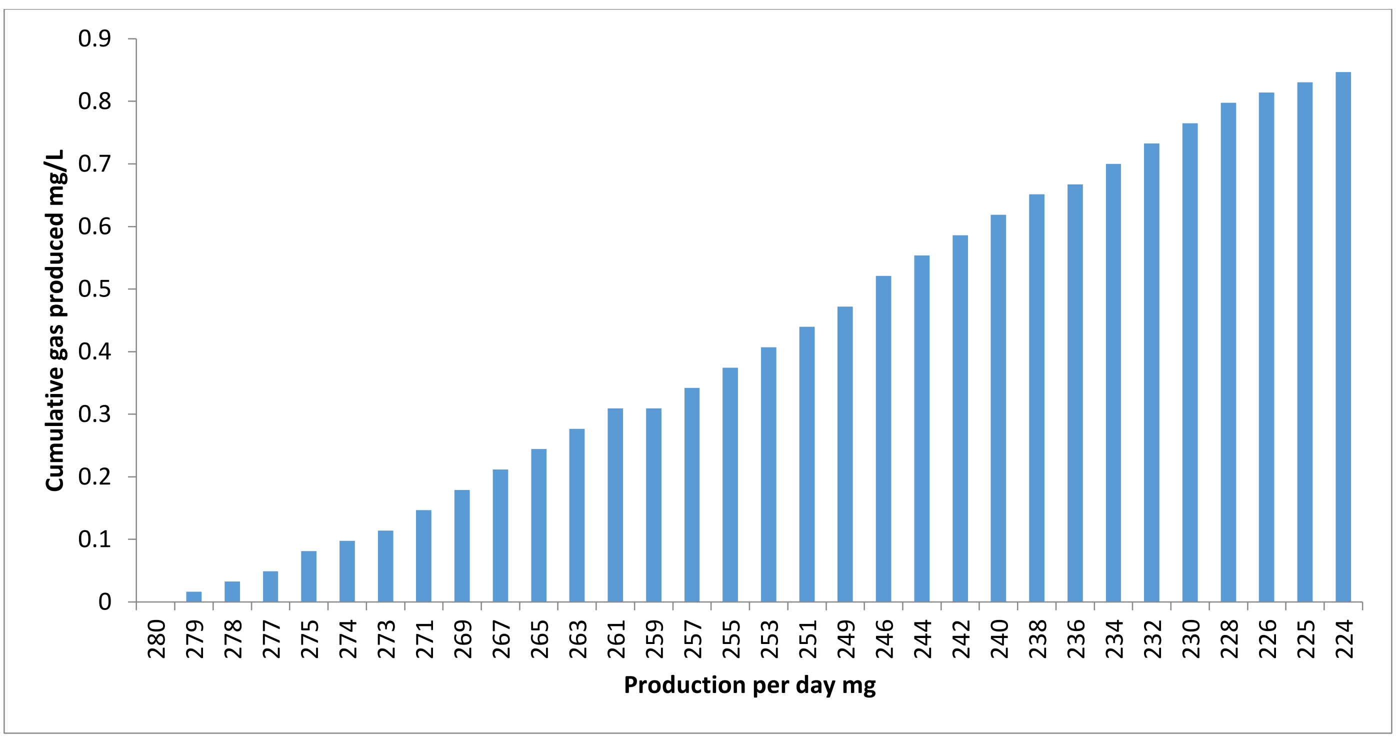

Figure 5. Biogas production from goat, sheep, and poultry waste (G+S+P_1)

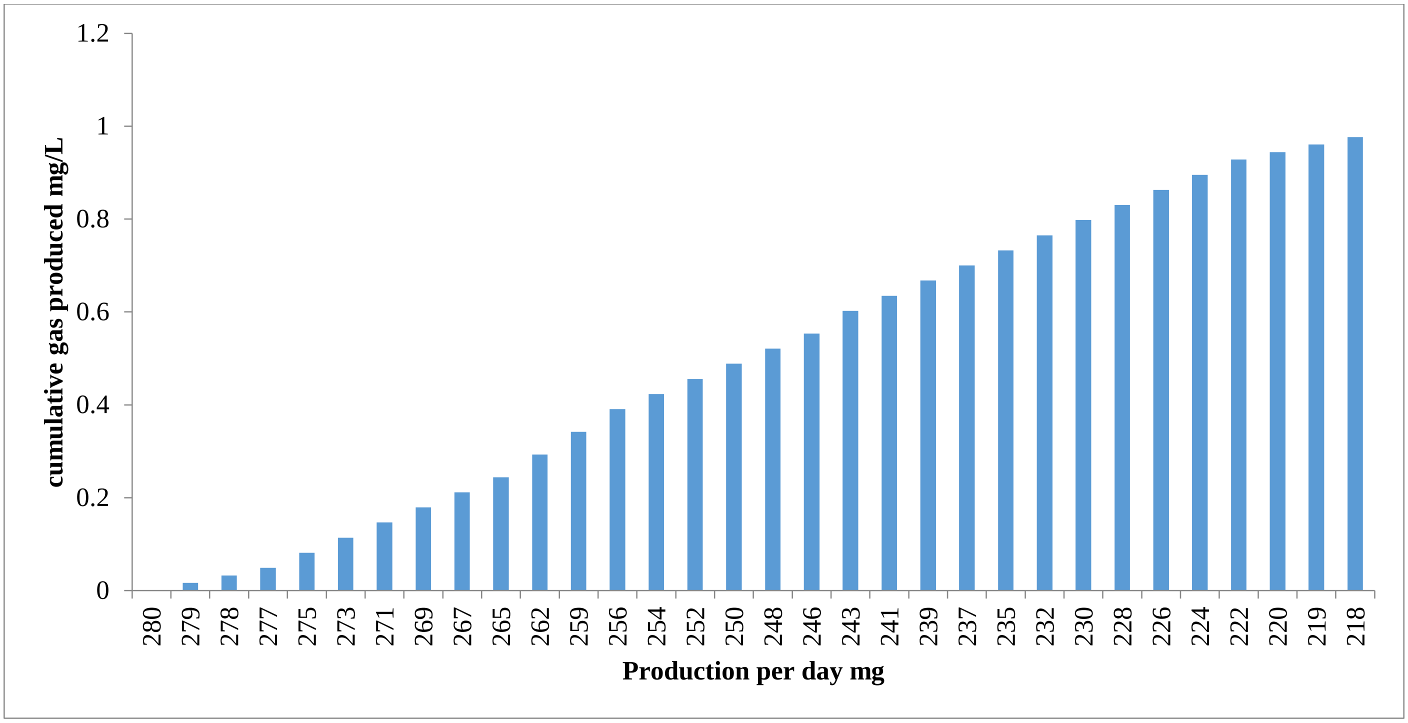

Figure 6: Biogas production from pig, rabbit, and cow waste (P_2+R+C).

Gas chromatography-mass spectrometry sample 1 analysis for pig, rabbit, and cow

The gas chromatography-mass spectrometry analysis for pig, rabbit, and cow is presented in Figure 7. Helium was the first substance that was separated from the biogas at a retention time of 9min 50sec with a composition of 0.01%, followed by oxygen at a retention time of 11min 28sec with a composition percentage of 0.10.%. Ethane was separated at a retention time of 13min and a composition of 2.31%. Hydrogen sulphide was also separated from the biogas at a retention time of 15min, 98sec with a composition of 0.09%, carbon monoxide was also gotten at a retention time of 16min 50sec with a composition of 0.08%, carbon dioxide was separated at a retention time of 18min 97sec with a composition of 20.14%, methane was separated from the remaining biogas at a retention time of 25min 21 sec with composition of 63.41%.Argon/oxygen composite was also separated at a retention time of 33min 26sec with a composition of 0.12. hydrogen was separated from the biogas at a retention time of 34min 50sec with a composition of 0.01% while nitrogen was separated at a retention time of 41min, 20sec with a composition of 1.98%. This research work reviews that the mixture of pig, rabbit, and cow waste will produce 8 different substances with the highest substances found in methane with a composition of 63.41% which means the three waste is a good means for methane generation.

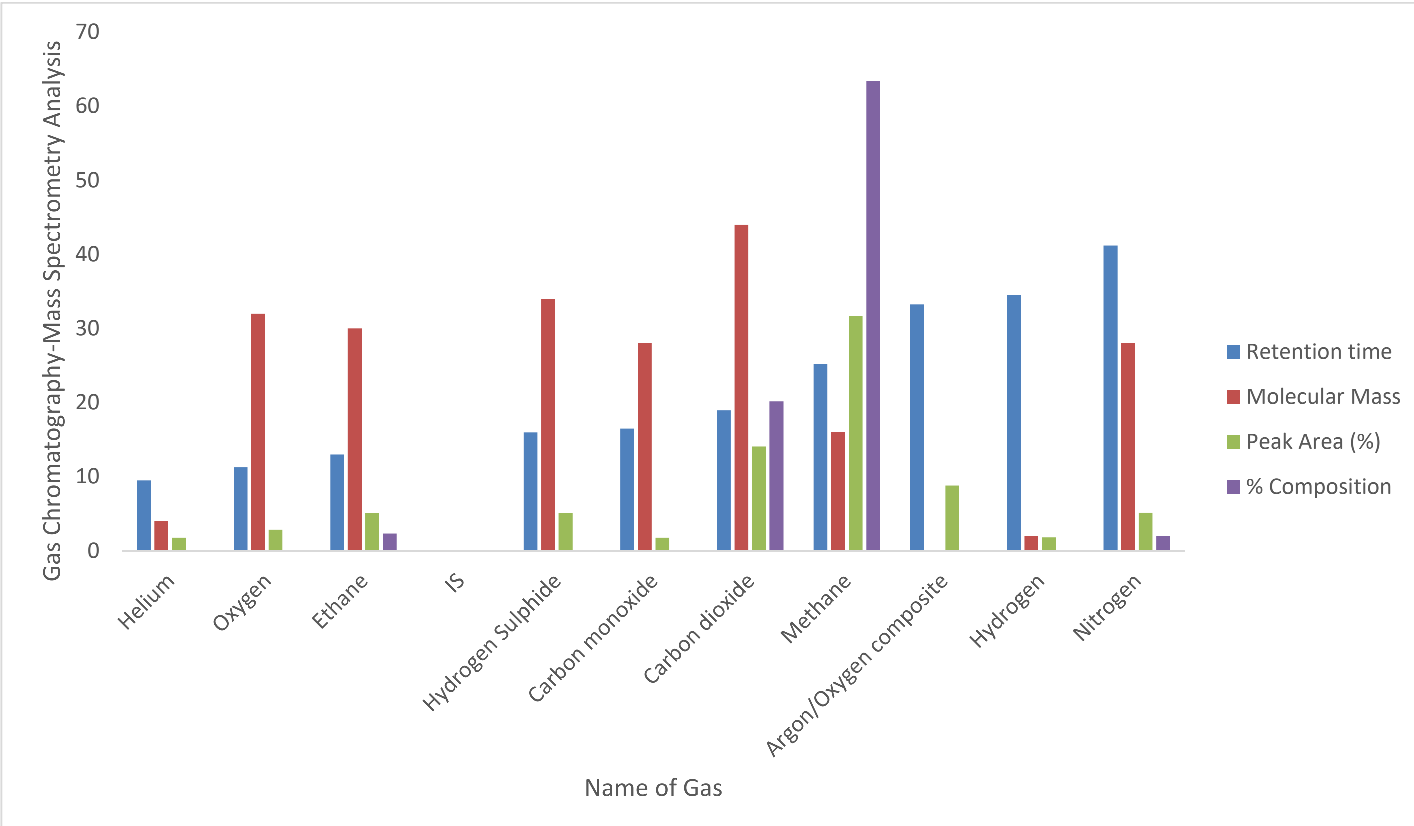

Figure 7. Gas chromatography-mass spectrometry analysis sample 1 pig, rabbit, and cow

Gas chromatography-mass spectrometry sample 2 analysis of goat, sheep, and poultry

The gas chromatography-mass spectrometry analysis for Goat, Sheep, and Poultry in Figure 8 shows that helium was the first substance that was separated from the biogas at the retention time of 9min 50sec with a composition of 0.01%, followed by oxygen at a retention time of 11min 28sec with as composition percentage of 0.08.%. Ethane was separated at a retention time of 13min and composition of 2.26 % hydrogen sulphide was also separated from the biogas at a retention time of 15min, 98sec with a composition of 0.05%, carbon monoxide was also gotten at a retention time of 16min 50sec with a composition of 0.06%, carbon dioxide was separated at a retention time of 18 min 97sec with a composition of 23.62 %, methane was separated from the remaining biogas at a retention time of 25 min 21 seconds with a composition of 68.30 %, Argon/oxygen composite was also separated at a retention time of 33 min 26 sec with a composition of 0.15. hydrogen was separated from the biogas at a retention time of 34 min 50 sec with a composition of 0.01% while nitrogen was separated at a retention time of 41 min, 20 sec with a composition of 1.78%. Therefore, this research work reviews that the mixture of Goat, Sheep, and Poultry waste, will produce 8 different substances with the highest substances found in methane with a composition of 68.30% which means the three wastes are good substrates for methane generation.

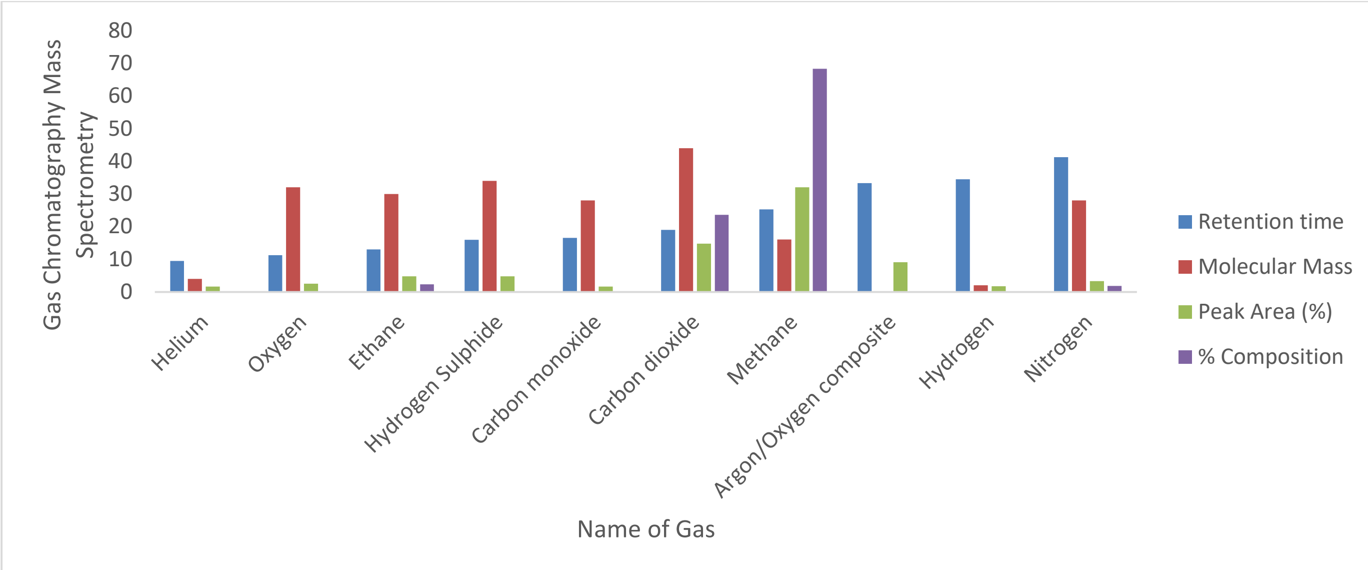

Figure 8. Gas chromatography-mass spectrometry sample 2 analysis of goat, sheep & poultry

CONCLUSIONS AND RECOMMENDATIONS

The biodegradable wastes were obtained from different waste generations at Landmark University, and the waste samples are goat, sheep, poultry, rabbit, cow, and pig. The wastes were characterized, and different analysis was carried out on the waste, and they were physicochemical analyses on both the substrate and the digestate. The result obtained from the substrate indicates the pH of piggery waste was the highest with 8.21 while the minimum was detected in the poultry waste. The mean alkaline for the entire sample is 480Mg/l. The total nitrogen for all the waste samples is 24.75 ± 5.75Mg/l. The waste samples were fed to the anaerobic digester and the microorganism fed on the waste for 32 days producing biogases for all the 32 days. The corresponding energy was determined using the gas chromatography-mass spectrometry machine. Eleven substances were obtained from the biogas and it took 9 minutes and 50 seconds for helium to be separated with a composition of 0.01, and 16 minutes and 50 seconds for carbon monoxide to be separated with a composition of 0.06. It took 25 minutes 21 seconds for methane to be separated with the composition of 68.30 which happens to be the highest for goat, sheep, and poultry waste. For the pig, rabbit, and cow waste it took 13minutes for ethane to be separated with a composition of 2.31, 18 minutes, and 57seconds for carbon dioxide to be separated with a composition of 20.14 while it took 25minutes 21second for methane to be separated with a composition of 63.41. Conclusively animal waste is a good source of biogas with the prominent gas found in methane and carbon dioxide.

It is recommended that governments and institutions take advantage of the high energy potential of biodegradable waste as a source of renewable energy and as a means for biogas production. Further studies and research should be made in the area of waste disposal to reduce environmental pollution and take advantage of the energy potential of waste.

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