



ORIGINAL RESEARCH ARTICLE

BIOGAS PRODUCTION USING A MIXTURE OF AVOCADO SEEDS AND CASSAVA PEELS BLENDED WITH COW DUNG

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ABSTRACT

Increase in the cost of fossil fuels as a source of energy, coupled with environmental pollution associated with their consumption, calls for the search for alternative energy sources. Therefore, this study focused on the construction and performance evaluation of a biodigester to produce biogas as a renewable energy source for domestic use. A 24-litre biodigester was constructed and used in this study. The biogas was produced using a mixture of cassava peels and avocado seeds with cow dung as inoculum under mesophilic conditions. The cassava peels and avocado seeds were mixed in the ratio 5:1. The experiment was carried out under mesophilic conditions, while the mass and composition of the produced biogas were measured. The findings showed the production of 256 g of biogas corresponding to 0.438 m³. The biogas produced was found to contain 64.4% of methane, 5% of water vapour, 0.9% of O₂ content, 560 ppm of CO, and 478 ppm of H₂S. interestingly, a relatively higher methane content was observed in this study than in previous studies. Thus, implying the influence of the choice of the agricultural wastes (cassava peels and avocado seeds in this case) and inoculum used as substrate which enhanced anaerobic digestion process in connection with the improved biodigester. These results revealed that biogas generation could be achieved using locally sourced agricultural wastes and thus promoting green and renewable energy in agreement with the Sustainable Development Goals. Therefore, Biogas production would not only provide an alternative source of energy but would also aid in farmland and marketplaces' waste management.

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1.0 Introduction

Biofuel is a source of renewable energy found to be cheap and environmentally friendly (Agoundedemba et al., 2023). It is any fuel sourced from biological materials or animal waste. The resources used to produce biofuel are readily available and require only a little effort in production. The usage of biofuels promote waste management and reduce greenhouse gas emissions (Shonhiwa et al., 2023). Biogas is an energy source produced through the breakdown of organic matter such as food and animal waste (Asante et al., 2024). It is an environmentally friendly fuel produced using biochemical process processes in the absence of oxygen to break down the organic matter and stabilize the material, by converting it to biogas and residue (Koley et al., 2023). Biogas production through anaerobic reaction involves four basic reactions, which are hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Daniel et al., 2023; Koley et al., 2023). It provides a dependable source of energy, reducing the country's dependence on imported fuels (Sekoai et al., 2023). It can be used for various applications such as vehicle fuel, heat production, and electricity generation, and can also provide an extra revenue source for farmers and waste management facilities (Shonhiwa et al., 2023). In the developing countries, biogas is produced using small-scale domestic digesters for cooking or even lighting, while in developed countries, biogas is used on a larger scale, farm-based and commercially, for electricity and heat purposes (Scarlat et al., 2018; Shonhiwa et al., 2023). Globally, biogas is increasingly becoming a very important source of energy, with the growing energy derived from biogas on a global scale from 1990 to 2022

presented in Figure 1. This reveals the rising interest in biogas as a renewable and viable source of energy globally.

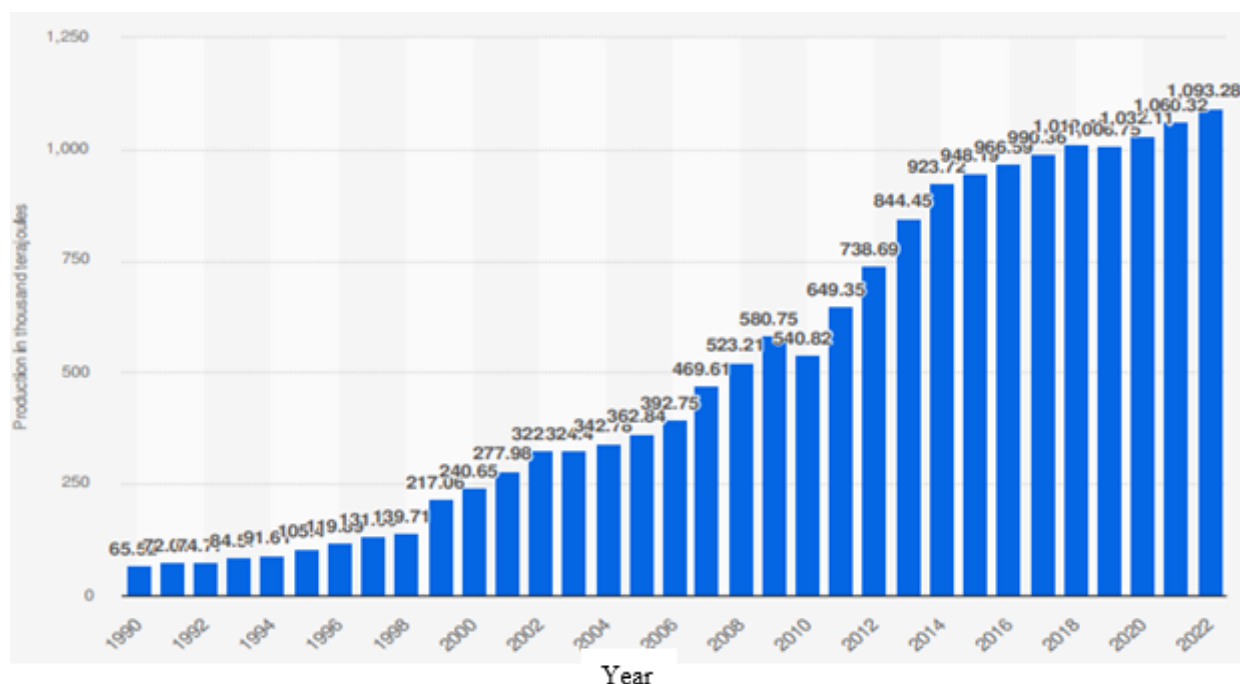


Figure 1: Global energy derived from biogas from 1990 to 2022 (Statista, 2025).

Different biological feedstocks (single and mixture) have been used as substrates in various types of biodigesters to produce biogas. For example, Illori *et al.* (2007) studied the production of biogas from banana peels and plantain peels contained in a 10-liter laboratory-scale digester. Under a mesophilic range of 32 – 35 °C and after 35 days, 8800 cm³ and 2409 cm³ of biogas were generated from the banana peels and plantain peels, respectively. Singh *et al.* (2009) used chicken waste as a substrate in a digester to produce biogas. A total of 3000 litres of biogas was produced during the experiment. Wikandari *et al.* (2015) produced biogas using orange peel wastes pre-treated to remove limonene using hexane. A 28.6% decrease in methane was observed, which was due to hexane residue in the substrate.

Over time, studies (Ezekoye and Okeke, (2006) ;Ezekoye, (2013)) showed the use of substrates consisting of more than one feedstock in the production of biogas. Ezekoye and Okeke (2006) constructed and evaluated the performance of a 300-gallon plastic biogas digester containing a mixture of 50% spent grain and 50% rice husk to produce biogas. The biogas digester was operated at mesophilic temperatures (20 – 45 °C). After 20 days of charging the feedstocks, 150 litres of biogas were produced by the 47th day. The rice husk was noticed to enhance the number of microbes in the spent grains, which augmented biogas production. Ezekoye (2013) conducted a comparative study of using plantain peel/almond leaves and pig dung in the production of biogas. Using a batch method, the biogas digester was operated within a mesophilic range of 20 to 31 °C. The use of plantain peel/almond leaves produced 220.5 litres of total biogas while the pig dung produced 882.5 litres. Biogas from the plantain/almond leaves contained 72.7% methane, while that from the pig dung contained 70.2% methane.

Deressa *et al.* (2015) investigated biogas production from fruit and vegetable wastes (avocado, papaya, mango, tomato, banana peel) co-mixed with cow manure using different digesters maintained at a pH of 6.7 – 7.4. Fantozzi and Buratti (2009) conducted two separate experiments using a mixture of chicken, pig, and bovine manures, and chicken, cow manure, and olive husk with rumen fluid and digested sludge as inoculum to produce biogas. The biogas yield showed that the first set of substrates produced a maximum of 0.35 Nm³/kg of biogas with an energy content of 1.35 kWh/kg while the second set of substrates yielded a higher production of 0.63 Nm³/kg. Tambuwal *et al.* (2019) experimented the use of fresh and dried banana peels and plantain peels and their co-mix with cow dung as substrates for biogas production in a batch-type digester. The work was carried out at a temperature range of 30 – 34 °C. Results showed biogas production order of banana peels + cow dung > plantain peels + cow dung > fresh banana peels > fresh plantain peels > dried banana peels > dried plantain peels. This revealed that co-mixed substrates produced more biogas than single-feedstock substrates.

Aisien and Aisien (2020) used six batches of 10-liter anaerobic biogas digesters containing cow manure and cassava peels (fresh and stale) as substrates to produce biogas and biofertilizer. The studied feedstocks were pre-

treated using buffer solutions (sodium hydroxide, calcium hydroxide, and ammonium chloride), and the biogas production was examined for forty days under a pH range of 6.5 – 7.5 and a temperature range of 28 – 35 °C. The produced biogas contained 62.3% methane with a total volume of 104960 cm³ using stale cassava peels + cow dung as against 95592 cm³ generated using fresh cassava peels + cow dung. This was achieved using ammonium chloride for pre-treating the substrates. The digestate was examined for total solids, volatile solids, phosphorus, nitrogen, and other values. Kabri *et al.* (2022) engaged mixtures of cow dung, plantain peels, and cassava peels as substrates in a digester to produce biogas. The results showed the production of 0.04 m³ of biogas at 39 °C and 89.9 N/m², composed of 65% methane, 30% CO₂, and 5% water vapour.

Mibulo *et al.* (2023) investigated the production of biogas from Jackfruit waste, banana peels, and pineapple peels co-mixed with cow dung at different amounts (0%, 25%, and 50%) as substrates using a laboratory-scale 250 mL anaerobic digester. Total biogas production of 82.3, 189, and 262 mL was recorded for Jackfruit waste, pineapple peels, and banana peels, respectively, as 50% of cow dung and Jackfruit waste improved biogas by twofold. Ramjani *et al.* (2023) produced biogas from different mixtures of coconut water and cow dung using a batch-type anaerobic digester. At a 1:1 mixture of the substrate, peak biogas of 976.67 mL was produced with 53% methane content.

With over 200 million people in Nigeria and the ever-increasing demand for energy, coupled with the over-dependence on fossil fuels and the attendant effects, the need to deploy sustainable energy resources to address the energy, emissions, climatic, and environmental challenges have become inevitable in line with the AU 2063 and UN 2030 agenda (Chaudhuri, 2021; Dyantyi-Gwanya *et al.*, 2025). Decarbonization of energy consumption in the country, based on the carbon neutrality concept in agreement with the Sustainable Development Goals, has made biogas a significant and viable source of renewable energy for Nigeria. Biogas allows the country to generate green electricity, as 6.52 and 4.98 billion cubic meters of biogas can be produced per year using cow dung and crop residues (Akhator *et al.*, 2016). The abundance of organic wastes (agricultural waste, livestock waste, and food waste) and favourable climate have made Nigeria a suitable candidate for biogas production. Based on the above assertion and the gap in research concerning the use of avocado seeds and cassava peels (feedstocks) + cow dung (inoculum), this study aimed to examine the production of biogas using this as a substrate containing these feedstocks and the inoculum in a locally built batch-type digester. The present work explored the feasibility and significance of producing biogas from otherwise inedible agricultural wastes (avocado seeds and cassava peels). Besides, the performance of the biodigester and the characterization of the biogas produced were also carried out.

2. Materials and Methods

2.1 Construction and Description of Biodigester

An overview of the biodigester set-up is shown in Plate 1. The biodigester set-up consists of three major components; bioreactor, purification chamber, and gas storage chamber. Bioreactor is the structure where the anaerobic reaction occurs. It was constructed using a 24 litres plastic drum. The opening at the top of the reactor was made to serve as inlet through which the substrate was poured into the biodigester. Purification chamber is the place where the produced gas is purified to remove unwanted particles. The a 4 litres plastic bucket was improvised to serve as purification chamber. The plastic tube is used to store the purified biogas. The PVC pipes were used for the connection of these three major components. The elbow, couplings and nipples were also used for the joining of the pipes, change the direction of the pipe and also to help prevent leakages. Valves were used to prevent the gas from returning to the biodigester. This biodigester was constructed similarly to a previous study by Adeleke *et al.* (2020), the only difference lies in the use of a tubular storage unit instead of a gas cylinder used in the earlier study.

2.2 Production of Biogas

2.2.1 Collection of substrates

The avocado seeds were collected at mile 12 market in Lagos state, Nigeria while the cassava peels were obtained from the garri production unit of the Federal University of Agriculture, Abeokuta, Nigeria. Similarly, an inoculum (cow dungs) was obtained at the College of Veterinary Medicine, Federal University of Agriculture, Abeokuta, Nigeria.

2.2.2 Preparation of substrates

The cassava peels were sun dried for 2 weeks to reduce the moisture content, while the avocado seeds were partially sun dried for a week and then ground before being used (Plate 2). Both the ground avocado seeds and cassava peels were stored at room temperature for proper preservation.

2.2.3 Preparation of purifier

Activated charcoal was prepared by grinding and mixing it with lime (in a container). The mixture was left for 24 h and then heated in a crucible placed in an oven to completely dried up. The prepared activated charcoal acts as a purifying substance for the biogas.

2.2.4 Production of biogas

To prepare the feedstock, 2.3kg of cassava peels and 450g of avocado seed were mixed in the ratio 5:1. The mixture of dried cassava peel and avocado seeds were soaked in water for three hours to absorb water in order to create more surface area for the reaction of methanogenic bacteria bringing about biogas production. This mixture was co-prepared with cow dung as inoculum into a slurry using water and fed as substrate into the biodigester. The studied substrate filled slightly over 60% of the biodigester as recommended by Fagbenle *et al.* (2022). Cow dung was included to improve the degradation kinetics, augment the microbial associations, and guarantee the carbon-nitrogen (C/N) balance.



Plate 1: Biodigester set up

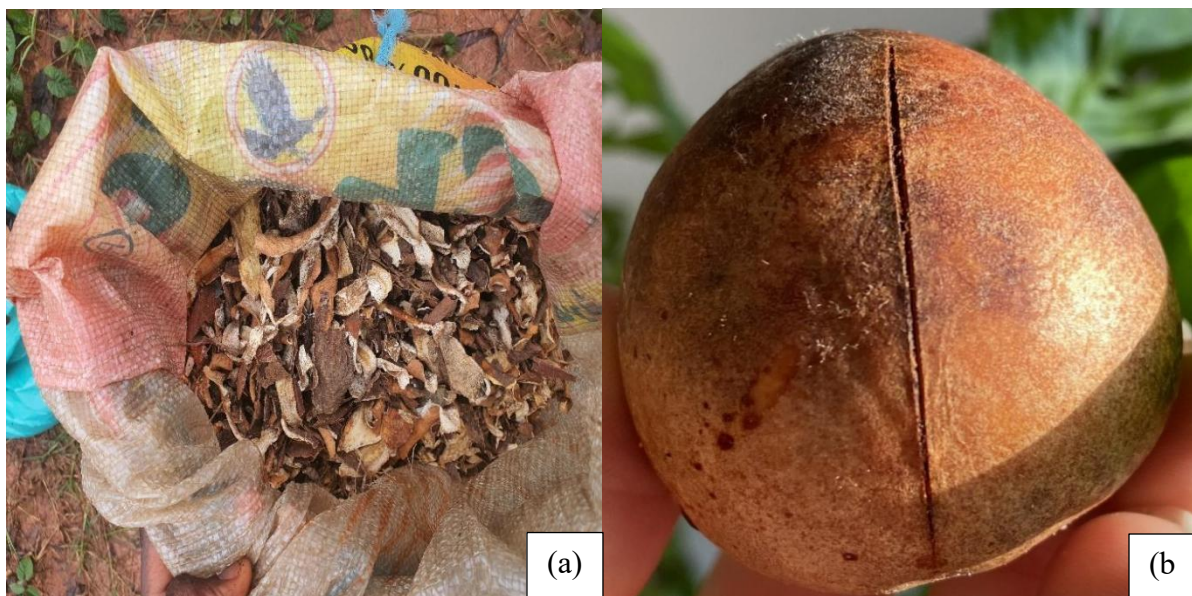


Plate 2: Sun dried (a) cassava peels and (b) avocado seed

The substrates and the inoculum were left in the biodigester to charge for a hydraulic retention time of 12 days following Asante *et al.* (2024) and Daniel *et al.* (2023) works. The cover of both the biodigester and the

purification chamber was sealed properly with the use of silicon to make it airtight. During this time, the anaerobic reaction began to take place. When the gas was fully charged, the valve was opened to allow it to flow into the purification chamber and then to the tubular storage. This process was carried out at an ambient temperature. The experiment was set up and conducted at the College of Engineering, Federal University of Agriculture, Abeokuta. It is imperative to note that the experiment was conducted under mesophilic conditions (26 – 29 °C), which promoted stable biogas production and a relatively constant anaerobic digestion process.

2.2.5 Quantification of biogas produced

The mass of the tubular storage was measured using a digital weighing balance before it was connected to the biodigester. After it was connected, the mass of the tube was then measured throughout the rest of the days of biogas production to obtain the mass of the gas produced. The total mass of gas produced was calculated as expressed in Equation (1):

$$M_T = M_{tube+gas} - M_{tube} \quad 1$$

where, M_T = total mass of the gas produced, $M_{tube+gas}$ = mass of the tube and gas, and M_{tube} = mass of the tube.

2.3 Characterization of the Gas Produced

The characterization of the gas produced was carried out using a gas analyser to determine the methane content (%), oxygen content (%), hydrogen sulphide content (ppm), and CO content (ppm) of the produced gas.

3. Results and Discussion

3.1 Mass of Gas Produced

Figure 2 shows the mass of biogas produced daily from cassava peels and avocado seeds with cow dung. The figure shows that the studied substrates started producing biogas after 10 days. From Figure 3, a sharp increase in biogas production was observed from the 11th day to the 12th day (Fagbenle *et al.*, 2022 and Ramjani *et al.*, 2023), corresponding to a mass of 37 g. This value of biogas resulted in the peak quantity produced. This can be due to the commencement of the biogas production and the initial release of produced gas after over 10 days of anaerobic fermentation of the substrate. Also, the presence of cow dung was expected to augment the degradation kinetics by increasing the microbial numbers and activities. However, a decrease in biogas production was observed from the 12th day to the 16th day of the anaerobic digestion, leading to a 45.9% reduction compared to the value reported for the 12th day. The high rate of production of hydrocyanic acid at the earlier stage of the anaerobic digestion could be the possible reason for the reduced mass of biogas production.

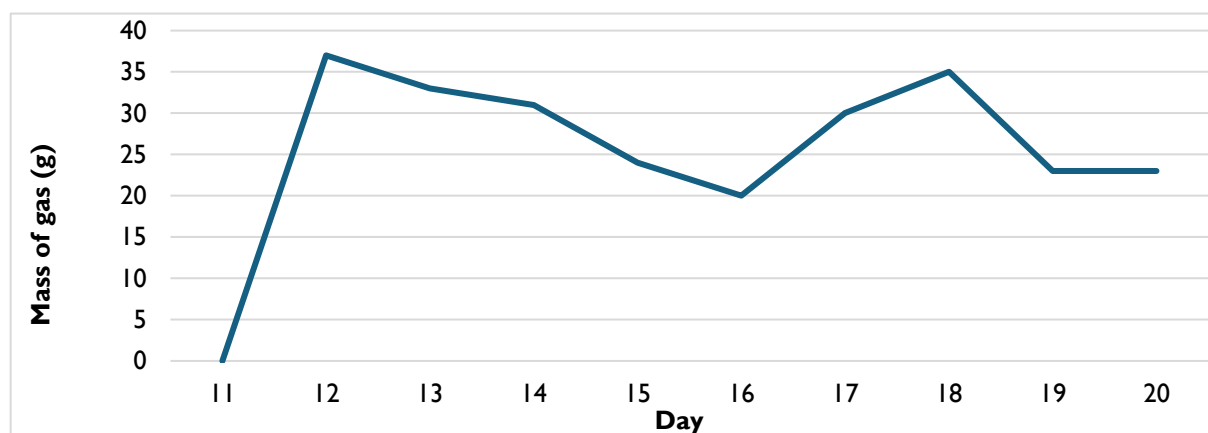


Figure 2: Mass of biogas produced per day

A progressive increase (75%) in biogas production was noticed from the 16th day (20 g) to the 18th day (35 g), which thereafter reduced rapidly by 19th day, and the gas production remained constant by the 20th day. Okudoh *et al.* (2014) documented that the presence of cyanogenic glucosides in cassava peels could induce excess acid production and the release of cyanide, which is highly toxic to methanogenic arches, hence reducing biogas production. The maximum biogas production was recorded on the 12th day. For the duration

of the study, a total of 256 g (0.256 kg) of biogas was produced. This gave an average of 28.4 g/day. About 0.438 m³ (from a mass of 0.256 kg at a density of 0.584 kg/m³) of biogas was produced for 20 days of anaerobic digestion.

3.2 Biogas Characterization

The biogas produced was characterized and found to consist of 64.4% methane, 560 ppm of CO, 478 ppm of H₂S, and 0.9% O₂ content. This revealed that methane had the highest content than other gases and can be said to be the main constituent of the biogas produced from the studied substrate (Fagbenle *et al.*, 2022). This work recorded a slightly higher content of methane in comparison with the work of Aisien and Aisien (2020), which produced 62.3% of biogas (under mesophilic conditions) with the use of cassava peels inoculated with cow dung (after treatment with NH₄Cl) in a 10-l batch-type anaerobic digester. The work involved pre-treating the substrate, purification (NaCl solution) of the produced biogas, using 3.6 kg of cassava peels and 4 g of cow dung, and 40 40-day retention time. It can be deduced that the co-mixed feedstock engaged in this study could be responsible for the high methane content. A moderately lower methane content (33.6%) was reportedly produced from cassava peels (25 kg), cow dung (25 kg), and 100 kg of water used as substrate in a 200 litres batch biodigester before and after purification of the produced biogas in comparison to the present work (Fagbenle *et al.*, 2022). The substrate (under mesophilic conditions) had a retention time of 30 days in the biodigester with the use of Ca(OH)₂, silica, and activated carbon to purify the produced biogas.

Similarly, the methane content obtained in this study was higher than that reported by Szilágyi *et al.* (2021) in a biogas comparative analysis, where biogas contents ranging from 46 – 48% were produced from the engagement of tomato biological wastes in a biodigester. The work of Ramjani *et al.* (2023) that used coconut water, water, and cow dung mixed at 2:1:1 ratio in a laboratory-scale 2-l biodigester (under mesophilic conditions) produced biogas with 53% methane content, which remained lower than what was recorded in this present study. A retention time of 35 days was reported with biogas purification using NaOH solution. However, the work of Ezekoye (2013), which produced biogas from plantain/almond leaves + pig dung and pig dung using a 1.47 galvanized metal biodigester (under mesophilic conditions) reported methane contents of 70.2% and 72.7% respectively, which are found to be slightly higher than the methane content obtained in this study. From these previous studies used for comparison, it can be deduced that this present work recorded a relatively higher methane content compared to previous studies. This can be connected to the use of cassava peels and co-digestion with avocado seeds employed as substrate in this study (Okudoh *et al.*, 2014), which strengthens the use of agricultural produce wastes to alleviate the problem of waste management and promote a cleaner and odourless environment, especially in marketplaces. In addition, the digestion of a co-mix of organic feedstocks such as avocado seeds and cassava peels was observed to influence the biogas yield.

4. Conclusion

Clean biogas has been successfully produced via the anaerobic digestion process in a locally built biodigester using cassava peels and ground avocado seeds with cow dung as substrate under atmospheric temperature and pressure. A total biogas of 256 g corresponding to 0.438 m³ was produced under 20 days of anaerobic digestion of the studied substrate. The biogas produced consists of 64.4% methane, 560 ppm of CO, 478 ppm of H₂S, and 0.9% O₂ content. A relatively high yield of methane was obtained from this study in comparison with other previous studies. This is because of the effective digestion of the inoculum, avocado seeds, and cassava peels, and the simplicity of the biodigester. The findings demonstrated biogas production via the anaerobic digestion of mixed feedstocks (especially agricultural wastes) as substrate. Further improvement in the operation of the biodigester, novel materials for biogas purification, better selection, and combination of organic wastes as substrates, and choice of other kinds of inoculum have been recommended for consideration for future studies.

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