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Potentials of Banana Peel, Vegetable Waste (*Telfairia occidentalis*) and Pig Dung Substrates for Biogas Production

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Authors' contributions

This work was carried out in collaboration between all authors. Author SOI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript and managed literature searches. Authors BEA, DRT managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The research study was aimed at investigating the potentials of Banana Peel, vegetable waste (*Telfairia occidentialis*) and pig dung substrate for biogas production. Marian market, Watt Market and University of Calabar Pig farm were randomly sampled within Calabar Metropolis for collection samples. The study was completed within a period of six months. Standard microbiological methods using anaerobic digesters were used to screen the waste substrates for biogas production. The amount of biogas produced by the substrates were measured on a daily basis in a gas metric chamber by displacement of paraffin oil, while the methane yield of the substrates was gotten by dividing the amount of flammable gas from the total biogas produced by the substrates. The volume of biogas produced varied significantly ($p<0.05$) between the substrate treatments and digestion intervals (days). Maximum biogas yield of 380.29 cm^3 was obtained over a period of 35 days of digestion from substrate combination (Banana Peel + vegetable + pig dung) as compared to other substrate treatments. However, the percentage methane yield ranged between 25.10%

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from substrate combination of pig dung and vegetable waste (PD +VW) to 49.16% from substrate combination of Banana Peel, vegetable waste and pig dung could serve as suitable substrates for biogas production.

Keywords: Biogas; substrate; treatments; anaerobic digester.

1. INTRODUCTION

The demand of Nigeria and the world economy at large for energy generation and transportation in over 80% is obtained from non-renewable resource mainly petroleum and natural gas derived from fossil fuels [1]. The over dependence on these fossil fuels as primary energy source has led to global climate change and environmental pollution due to the release of by products such as SO_2, P_60, CO, and CO_2, when petroleum products are used in internal combustion engines thus leading to health problem [2]. The cost and scarcity of improved petroleum products used for industrial, agricultural and domestic fuels are drastically increasing, as this makes it difficult for most people to rise beyond subsistence level especially in developing countries like Nigeria. These realities have led to a boost in the search for renewable and sustainable alternative to fossil fuels.

Researches have shown that Biogas, a flammable gas produced when organic materials are fermented under anaerobic condition, is one of such alternative [3,4]. Biogas is a readily available energy source that significantly reduces greenhouse gas emission compared to the emission of land fill gas to the atmosphere [4]. Biogas being an alternative energy source is important for generating electricity, car fuelling, cooking and varies other purpose [5,6].

Agricultural biomass and residues such as fruit and vegetable waste have been reported as a substrate for biogas production and recently as a valuable source of renewable energy [7], while [8] reported that animal wastes can also be used for biogas production. Also study by [9] reported the importance of wheat straws, maize combs and other starchy wastes in biogas production.

Therefore, this study was designed to investigate the potentials of Banana peel, vegetable waste (*Telfairia occidentalis*) and pig dung substrates for biogas production.

2. MATERIALS AND METHODS

2.1 Sample Collection

2.1.1 Banana peel

Banana peels were collected in sterile polythene bags from Marian market in Calabar and then transported to the laboratory for analysis.

2.1.2 Vegetable (*Telfairia occidentalis)* waste

Vegetable wastes were collected in large quantity from Watt Market in Calabar and placed in polythene bags and transported to the laboratory for analysis.

2.1.3 Pig dung

Pig dung were obtained from University of Calabar farm and placed in polythene bag and transported to the laboratory for analysis.

2.1.4 Digester design used

Anaerobic digesters (a batch-types) of about 5 litres each for the digestion of substrates for biogas production was fabricated locally according to the method described by [9]. 8 empty gas cylinder consisting of an opening through which the substrates was introduced into the digester and an outlet tap where samples were collected for analysis was used.

2.1.5 Preparation of slurry and loading of digesters

Preparation of substrates for biogas generation was carried out according to the methods described by [4,9].

2.1.6 Banana peel

1 kg of freshly grinded banana peel was mixed with distilled water in a ratio of 1:3. The mixture was agitated thoroughly and transferred into the digesters and tightly corked with stopper to create anaerobic conditions.

2.1.7 Vegetable (*Telfairia occidentalis*) waste

1 kg of grinded vegetable (*Telfairia occidentalis*) waste was mixed with distilled water to give a ratio of 1:3. The mixture was agitated thoroughly and transferred into the digesters and tightly corked with stopper to create anaerobic condition.

2.1.8 Pig dung

1 kg of pulverized pig dung was mixed with distilled water to give a ratio of 1:3. The mixture was agitated thoroughly and transferred into the digesters and tightly corked with stopper to create anaerobic condition.

2.1.9 Combination of substrates

Substrates were prepared in combinations in the order; Banana Peel and vegetable waste, banana peel and pig dung, vegetable waste and pig dung, Banana peel. Vegetable waste and pig dung, all in the ratio of 1:1 each mixture was loaded into the digesters by mixing with distilled water in the ratio of 1:3.

2.2 Measurement of Biogas Production

The method described by [10] was used. Biogas production was measured daily on volume basis in a gas metric chamber by displacement of paraffin oil. The gas metric chamber consists of a graduated burette with the upper-end connected to the anaerobic digesters and the lower-end to a glass funnel with paraffin oil. The evidence of biogas production was determined by the displacement of the paraffin oil in the graduated burette downward, when the outlet tap of the anaerobic digester and the inlet tap of the graduated burette are opened.

2.3 Measurement of Methane Yield

Methane yield during digestion was determined according to method described by [9]. The amount of flammable gas was divided from the total biogas produced according to the equation below. Moreover flammable gas was detected by lighting a match close to the gas outlet tap to burn off the gas evolved.

$$\text{Percentage methane (\%)} = \frac{Flammable\ gas\ evolved}{Total\ biogas\ volume} \times \frac{100}{1}$$

2.4 Statistical Analysis

Statistical analysis of data obtained from the different treatments were carried out using a 2-way analysis of variance (ANOVA) and the means separated using the fishers least significant difference (LSD) at 5% significant level. All data were expressed as means±standard deviation of triplicate trials.

3. RESULTS

3.1 Biogas Yield from Substrates

Fig. 1 shows the volume of biogas yield from the different substrates treatments. The yield varied significantly ($p<0.05$) between the substrate treatments and the digestion intervals (days). Maximum biogas yield was obtained within 25 days of digestion, with the volume of biogas ranging between 45.58 cm^2 (PD) to 59.90 cm^3 (BP +PD +VW).

The overall volume of biogas produced from each substrate treatment over the digestion period of 35 days ranged between 194.58 cm^3 (PD) to 380.29 cm^3 (BP + PD + VW) (Fig. 2).

3.2 Percentage Methane Yield from Substrates

Fig. 3 shows the percentage of methane yield from the different substrate treatments. The percentage yield ranged between 25.10% (PD + VW) and 49.16% (BP+ VW + PD). The methane yield evolved between the fourth and fifth weeks (30-35 years) of digestion (Fig. 3).

4. DISCUSSION

The study to analyze the potentials of Banana Peel, vegetable (*Telfairia occidentalis*) waste and pig dung substrates for biogas production was investigated. The volume of biogas produced by the different substrate treatments varied significantly ($p<0.05$). The marginal increase in the volume of biogas in the second week (5-10 days) and its peak in the third week (20-25 days) could be as a result of the acclimatization of hydrolyzing microorganisms after hydrolysis of the substrates. The observation confirms with that of Sagagi et al. [11]. The volume of biogas produced in the fourth (25-30 days) and fifth week (30-35 days) of the digestion process declined, this could be as a result of the gradual exhaustion of available nutrient from the

substrates deposition of metabolites by the substrate hydrolyzing organisms, as well as the gradual replacement of his substrate hydrolyzing organisms by organisms that tend to utilize some of the products of their actions. These observations corroborates with that of

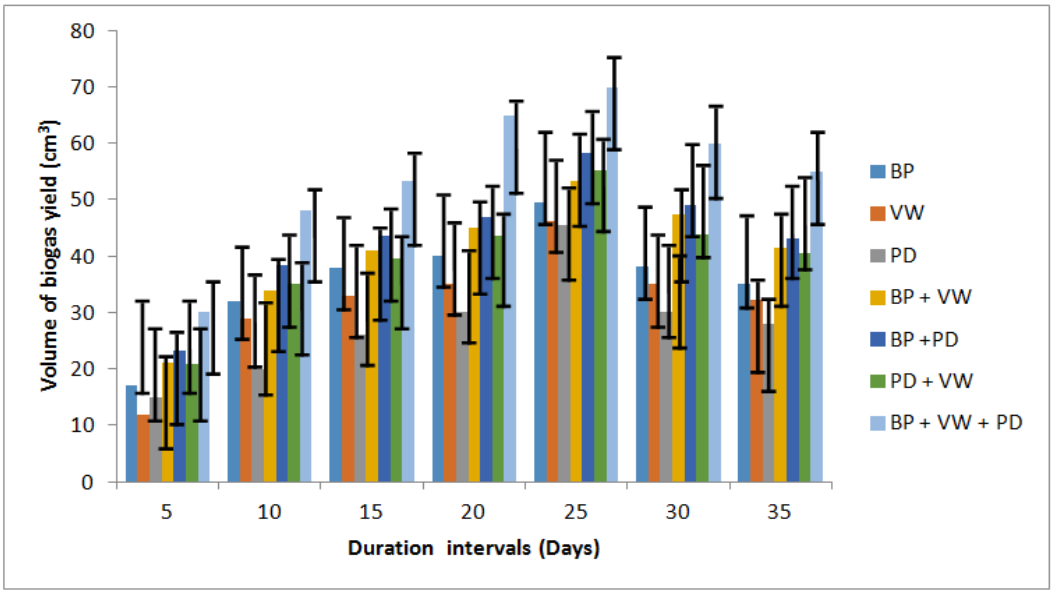

Fig. 1. Mean biogas yield during anaerobic digestion of substrates at varying retention time (5-35 days)

Key: BP = Banana peel, VW = Vegetable waste, PD = Pig dung, BP+VW= Banana peel and Vegetable waste, BP+PD = Banana peel + Pig dung, PD+VW = Pig dung and Vegetable waste, BP+VW+PD = Banana peel and Vegetable waste and Pig dung

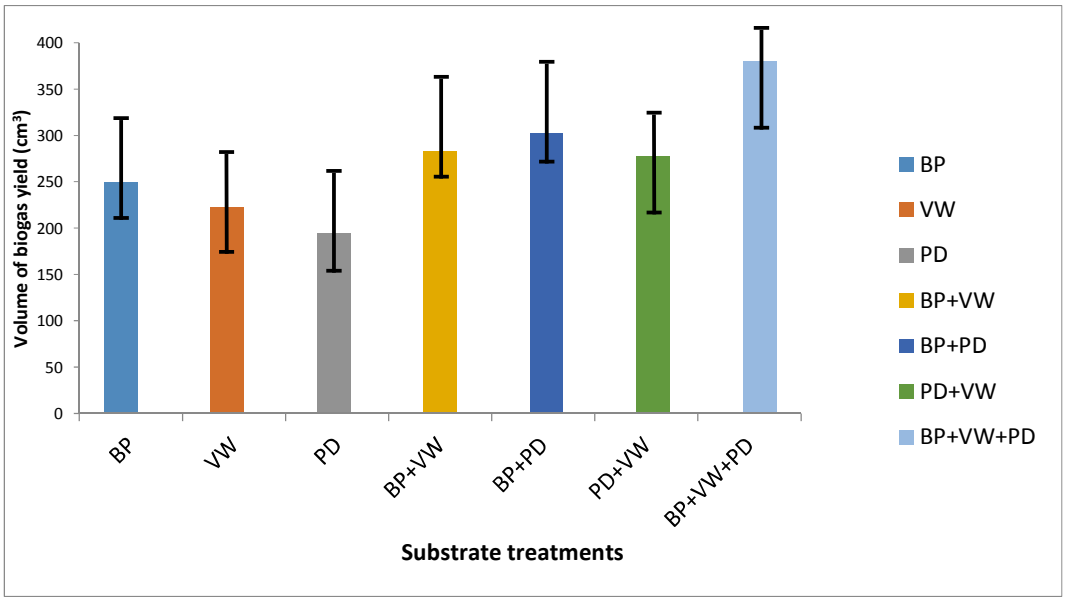

Fig. 2. Total biogas yield during anaerobic digestion of substrates over the retention time of 35 days

Key: BP = Banana peel, VW = Vegetable waste, PD = Pig dung, BP+VW= Banana peel and Vegetable waste, BP+PD = Banana peel + Pig dung, PD+VW = Pig dung and Vegetable waste, BP+VW+PD = Banana peel and Vegetable waste and Pig dung

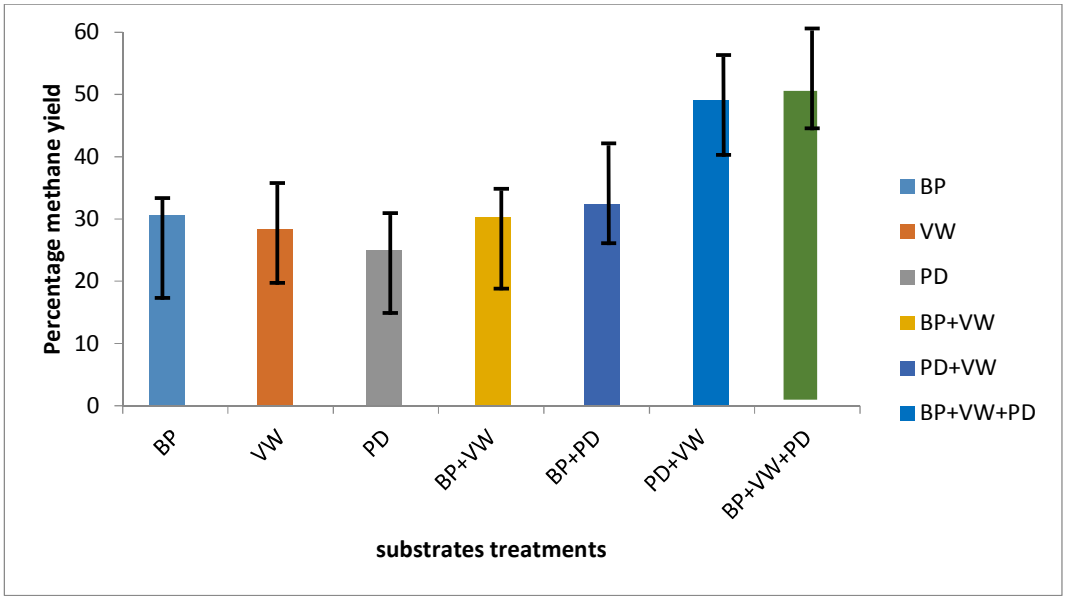

Fig. 3. Percentage methane yield during anaerobic digestion of substrates at varying retention time

Key: BP = Banana peel, VW = Vegetable waste, PD = Pig dung, BP+VW= Banana peel and Vegetable waste, BP+PD = Banana peel + Pig dung, PD+VW = Pig dung and Vegetable waste, BP+VW+PD = Banana peel and Vegetable waste and Pig dung

Tsunatu et al. [12]. Evidence of methane production was observed between the fourth and fifth weeks (30-35 days) of digestion. The percentage (%) yield of methane also varied significantly ($p<0.05$) between the substrates. The highest percentage (%) yield was observed with the co-digestion of Banana peel, vegetable waste and pig dung (BP+VW+PD) while the lowest percentage was observed with the digestion of pig dung (PD). These observations corroborates with that of Welb et al. [13] who reported a higher reasonable biogas productions from the co-digestion of groundnut shell, straw, maize cobs and sugar came bagasse as compared to other of the substrate treatments. The highest percentages of methane yield observed in the co-digestion of banana peel, vegetable waste and pig dung may be due to the varying proximate composition of the different substrate.

5. CONCLUSION

The results of this research was indicated that organic waste materials such as Banana peels, vegetable substrates for biogas production. The utilization of these substrates for this purpose could be due to their accessibility to hydrolyzing microorganisms. Hence, using these substrates for biogas production could eliminate their disposal problems and create another abundant source of sustainable energy.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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