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Effect of Cow Dung on the Production of Biogas from Food Wastes

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ABSTRACT: The study investigated the effect of cow dung on the production of biogas from food wastes. Biogas was generated from the mixture of cow dung (CD) with cooked and uncooked food wastes of yam, cassava and plantain. Specific amount of each substrate was weighed and combine with equal mass of water before being poured into different digesters. The slurries were left to undergo anaerobic digestion for nineteen days with the ambient temperature, digesters (slurry) temperature and pressure daily monitored and recorded. Biogas production started before 24 hours after loading and the biogas yield from uncooked food wastes (UCFW) co-digested with CD was more compared to the yield from cooked food wastes (CFW). The addition of CD to the substrates influence biogas yield and the pressure and temperature of the substrates in the digesters. Statistical analysis using ANOVA revealed that the differences in biogas yield across the digesters were significant ($p < 0.05$) for both cooked and uncooked food co-digested with cow dung. The study therefore converts wastes from cooked and uncooked yam, cassava and plantain to useful energy in form of biogas which can be employed for domestic purposes.

Keywords: Biogas, Cow dung, Cooked and uncooked food wastes, Anaerobic digestion

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INTRODUCTION

The increasing cost of conventional fuel in urban areas necessitates the exploration of other energy sources. Animal and plant wastes are abundant especially in rural areas, biogas one of the renewable energies, can be produced from plant (uncooked food waste) wastes as a substitute for fossil fuels (Olugasa, Odesola, and Oyewola, 2014) and (Abdeshahian, Lim, Ho, Hashim, and Lee, 2016). The use of anaerobic digestion of organic waste to produce biogas has the ability to replace fossil fuel as our primary energy source. With several food waste (cooked and uncooked) and hundreds of millions of cow around, biogas generation or production potential is colossal (Callaghan, Wase, Thayanithy, and Forster, 1999); (Bond and Templeton, 2011) and (Olugasa et al., 2014). Virtually all types of plant, animal wastes and organic materials are potential substrate for biogas production. According to Arthur, Baidoo, and Antwi, (2011) and Garfí, Martí-Herrero, Garwood, and Ferrer (2016) biomass is a cellulose material, which can broadly be classified as woody and non woody biomass; it can be converted into heat energy for heating, cooking, generation of electricity and other useful applications. Biogas, an inflammable gas is obtained from wet biomass by conversion through biological process of fermentation by microbes in a certain range of temperature, moisture and acidities under airtight conditions (Rao, Baral, Dey, and Mutnuri, 2010). It is a colorless mixture of methane (60-70%), carbon dioxide (20-30%) and traces amounts of hydrogen sulphide (Mao, Feng, Wang, & Ren, 2015). The process of converting biomass into

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fuel energy produces by-products like carbon dioxide and carbon monoxide which are factors in greenhouse effect and environmental pollution (Abdeshahian et al., 2016). The process was based on the age long Chinese tradition of composting human, animal and plant wastes to produce high quality organic fertilizer known as compost manure (Rao et al., 2010).

It was reported by (Rupf, Bahri, De Boer, & McHenry, 2015) that no energy source is completely environmentally friendly and therefore energy must be used more wisely. They also stated that humankind annually expends an amount of fossil fuel that took nature an average of about one million years to produce. They added that fossil fuels are depleted by human activities at a rate of 100,000 times faster than they are formed, hence the research in different corners on new sources of energy, like renewable energy resources such as solar, wind, biomass, and hydro sources of energy. Biogas is distinct from other renewable energies because of its characteristic to be generated from almost any type of organic waste, effluent being used as fertilizer, simple production technology and its application for both domestic and industrial purposes (Olugasa et al., 2014) and (Bond & Templeton, 2011). The search for alternative energy sources such as biogas should be intensified so that ecological disasters like deforestation, desertification and erosion can be arrested.

Kitchen wastes are organic materials containing several microbes and with high calorific and nutritive values which can produce methane (Callaghan et al., 1999) and (Bis et al., 2006). In most cities and villages in Nigeria and some West African countries, kitchen wastes are disposed in landfills or discarded in open areas which may cause public and environmental health hazards and diseases like cholera, malaria and typhoid fever (Olugasa et al., 2014) and (Arthur et al., 2011). Improper disposal of kitchen wastes, like uncontrolled led dumping, bears several adverse consequences, it does not only lead to polluting surface and groundwater through leaching but further promotes the breeding of flies, mosquitoes, rats and other diseases bearing vectors (Mao et al., 2015).

Due to several microbes that act on kitchen waste, biogas is produced. Biogas is generated from the process of biodegradation of organic material under anaerobic (without oxygen) conditions. The natural generation of biogas is an important part of the biogeochemical carbon cycle. Methanogenes (methane producing bacteria) are the last link in a chain of micro-organisms which degrade organic material and return the decomposition products to the environment (Dhamodharan, Kumar, & Kalamdhad, 2015). In this process biogas as a renewable energy source is generated. The anaerobic decomposition (or anaerobic digestion) process occurs naturally in wet lands, lakes, lake bottoms and deep in soils.

Anaerobic digesters also function as waste disposal systems, particularly for human waste and can therefore, prevent potential sources of environmental contamination and the spread of pathogens. The biogas technology is particularly valuable in agricultural residue treatment of animal excreta and kitchen residue (Haider, Zeshan, Yousaf, Malik, & Visvanathan, 2015).

Premised on the amount of food waste being collected daily at the Jibowu Student Hostel of the Federal University of Technology, Akure, Nigeria, this study was conducted by adding cow dung (CD) to uncooked food wastes (UCFW) of yam, plantain and cassava peels and cooked food wastes (CFW) from yam, plantain and cassava flours. Previous studies have shown that co-digestion of several substrates, for example, banana and plantain peels, sewage and brewery sludge among others have resulted in improved methane yield by as much as 60% compared to that obtained from single substrates (Havukainen, Uusitalo, Niskanen, Kapustina, & Horttanainen, 2014) and (Bis et al., 2006). One of the benefits of using waste in digestion processes is that the produced methane can be used as a fuel. The rest of the product, the digested slurry can be used as fertilizer to support plant growth. Some of the most common applications of biogas include lighting, cooking and utilization as an alternative vehicle fuel (Arthur et al., 2011); (Bond and Templeton, 2011) and (Abdeshahian et al., 2016). This study is focused on the effect of cow dung on production of biogas from some selected food wastes (cooked and uncooked).

MATERIALS AND METHODS

Experimental Procedure

A batch study as shown in Plate 1 was conducted by adding cow dung (CD) to uncooked food wastes (UCFW) of yam, plantain and cassava peels and cooked food wastes (CFW) from yam, plantain and cassava flours collected from the student dormitory. These particular food items were chosen based on a pre-study on food waste collected from the same hostel; the study presented cooked rice as the least in the amount of cooked food waste collected. Cooked yam, plantain and cassava ranked highest within the 15days of pre-study. The digester selected is of a plastic material providing an airtight anaerobic condition. The samples, 6 kg of CFW and UCFW with 2kg of CD and 2L of water were separately made into slurry by milling with a blender and each introduced into a digester.

The slurry was fully stirred manually with a long stick until there were no lumps; this is to avoid formation of scum which could retard the metabolic activities of the bacteria thus hindering the fermentation process. The pH for the slurry is between 6.5 and 8. Parameters such as pressure, ambient and slurry temperatures were observed daily during sunshine between 9.00am to 6.00pm. Data readings were taken at 9.00am, 12.00 noon, 3.00pm and 6.00pm.

This study was carried using three digesters categorized into different conditions as follows;

i) Condition A
   CFW + H_2O
   6 kg : 2 kg

ii) Condition B
   UCFW + CD + H_2O
   6 kg : 2 kg : 2 kg

iii) Condition C
   CFW + CD + H_2O
   6 kg : 2 kg : 2 kg

Calculation

The maximum expected pressure in the digester was based on the following assumptions that:

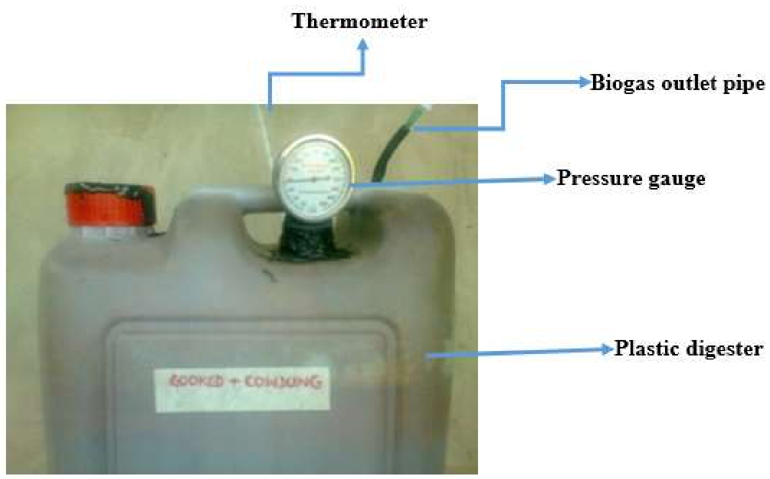

Plate 1: The batch experimental set-up

- the composition of the biogas to be produced would be in ratio 3:2 of methane to carbon dioxide.
- the substrate would occupy half the total volume of the digester
- a maximum temperature of 40°C (313K) is attainable in the digester
- 1 kg of food waste can produce 0.037m^3 of biogas [3]

Therefore, the maximum expected pressure (P_T) is:

$$P_T = P_{CH_4} + P_{CO_2} = 0.233 \text{ MP} \quad (1)$$

where

P_T = Maximum expected pressure
P_{CH_4} = Partial pressure of methane
P_{CO_2} = Partial pressure of carbon dioxide

$$P_{CH_4} = \frac{M_{CH_4} R_o T}{V_T} \quad (2)$$

$$R_o = \frac{R}{M} \quad (3)$$

$$m = nM \quad (4)$$

where

R is the Universal gas constant (8314 J/kg/K)
R_0 is the specific gas constant (J/kg/K)
T is the maximum absolute temperature attainable (313K)
M is the molecular mass of the component gas
m is the mass of the gas
n is the number of moles of the gas

Analysis of estimated specific volume per day (m³/kg)

$$V = \frac{R_O T_{(digester)}}{P_{(estimated)}} \quad (5)$$

where,
is the estimated specific volume per day (m^3/kg)
is the temperature of the slurry in the digester
is the pressure difference (N/m^2)

Statistical Analysis of Data

This is a tests the equality of variance across the experiment categorized by the values of the three variables (pressure, digester and ambient temperature) in the morning and evening respectively. The joint hypothesis tested here is that the Variance (variation or distribution of the values and the mean) in all the sub-groups are equal to the alternative test that at least one sub-group has a different variance. At 5% (0.05) level of significance, the null hypothesis is rejected for all the cases of experiment except for CFW + CD experiment. This result implies that, except for the "Accepted" case, Variance in the values of pressure, digester and ambient temperature, are confirmed to be significantly different between morning and evening in all the cases of the experiment (Kondusamy and Kalamdhad, 2014) and (Deepanraj *et al.*, 2015).

RESULTS AND DISCUSSION

Condition A: CFW + H_2O

The digester temperature ranges from 24 °C to 33 °C in the mornings while 28° C – 36 °C was recorded in the evening, the ambient temperature was between 24 °C to 33 °C. Throughout the study, there was a slight difference between the ambient and digester temperature (Figure 1), probably because at the initial stages of the process, acid forming bacteria produce volatile fatty acids (VFA) which resulted in declining pH value and diminishing growth of methanogenic bacteria (Kondusamy and Kalamdhad, 2014). The inactivity may be traced to the methanogens undergoing metamorphic growth process (Kumar and Bai, 2005) and (Kondusamy and Kalamdhad, 2014). Also, the inability of the digester in condition A to produce biogas might be due to formation of scum on the charge.

Condition B: UCFW + CD

In condition B there are relatively pressure increases from the 1st day till the 8th day with the pressure value of 13.5 kN/m^2. In Figure 2, the

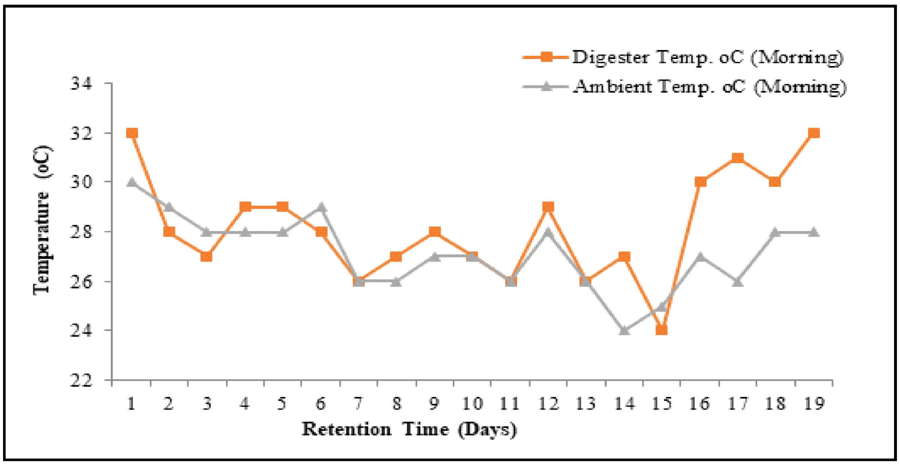

Figure 1: Change in daily ambient and digester temperature for CFW without CD

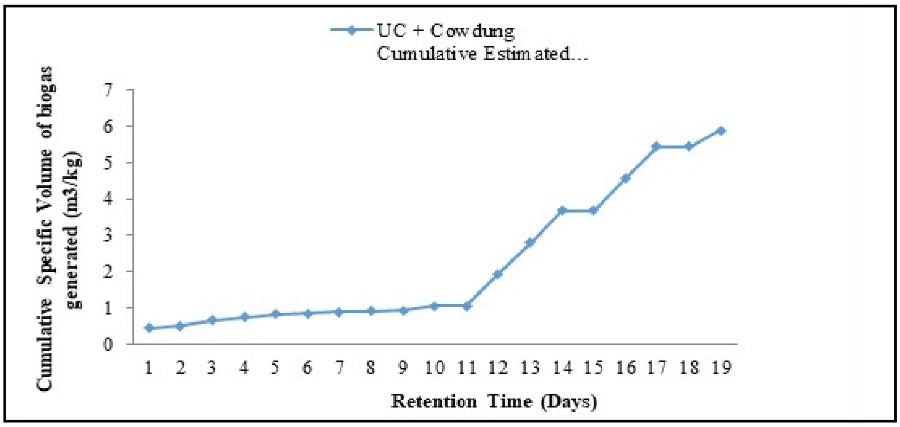

Figure 2: Volume of biogas generated per day from UCFW

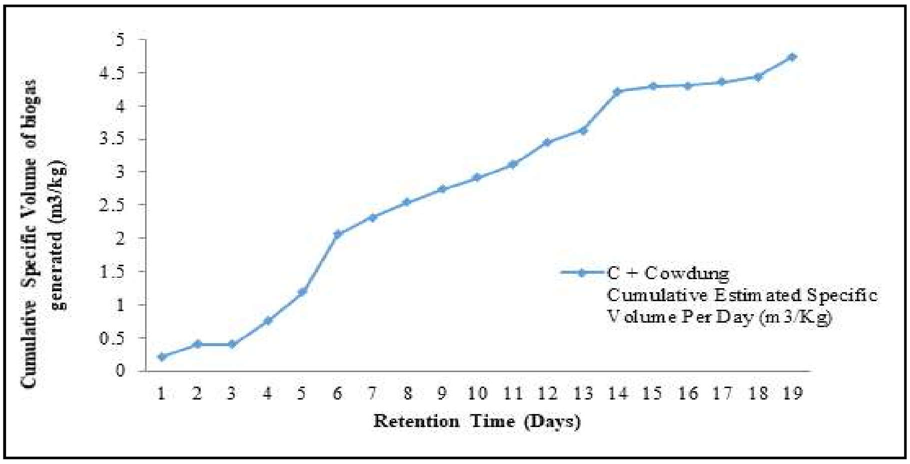

Figure 3: Volume of biogas generated per day from CFW

pressure was seen to have dropped as from the 8th day and attained a value of 9.9 kN/m^2 on the 10th day and remained almost constant throughout the study. On the 19th day the biogas yield for in-door arrangement was 5.88 m^3/kg. The temperature ranges from 18°C - 48°C. This range of temperature favors the mesophilic bacteria. The mesophilic range may be preferred since it is easy to maintain the digester at that temperature; mesophilic bacteria are more stable than thermophilic bacteria. This development could be ascribed to the generation of carbon dioxide with the consequent increase in pressure as reported by Dhamodharan et al., (2015) and Deepanraj, Sivasubramanian, & Jayaraj, (2015). As the oxygen was exhausted and methane production started, carbon dioxide was consumed hence the drop in pressure. The volume of biogas generated on the 19th day of the study was 3.57 m^3/kg. The gas started production less than 24 hours after it has been charged into the digester. The highest pressure recorded was 13.4 kN/m^2, the highest biogas yield of 5.88m^3/kg was recorded on the 19th day. Temperatures were daily measured with the maximum of 32°C in digester temperature and minimum of 23°C ambient temperature. The average value of 2.5°C was a daily temperature difference between the digester and the ambient temperature. This agrees with the study conducted by Kondusamy & Kalamdhad, (2014) and Deepanraj et al., (2015) that temperature variation around 2.5°C can inhibit bacteria growth rate of methane.

Condition C: CFW + CD

In Figure 3, biogas yield of 4.74 m^3/kg was recorded by CFW with cow dung as against 5.88 m^3/kg of UCFW. The temperature recorded for the cooked food waste digester limited the metabolic activities of methane producing bacteria thus reducing the production of biogas. The average digester temperature at various yields was 300°K (27.5°C). Low pressure was observed as a result of low temperature since pressure is directly proportional to temperature. The inactivity of methane producing bacteria and the nature of the substrate was responsible for the low yield of biogas (Biswas, Chowdhury, & Bhattacharya, 2007).

The introduction of CD necessitated the biogas yield contrary to no yield experienced in when the substrate is without CD. This confirmed the fact that animal wastes are easily and quickly digestible as compared to plants wastes which are complex biological substances, which needed time before they could be broken down into simpler chemical substances (Alfa, Dahunsi, Iorhemen, Okafor, and Ajayi, 2014); (Mel, Ihsan, and Setyobudi, 2015) and (Haider et al., 2015). This equally affected the yield of biogas as the bacteria were inactive. The addition of cow dung (catalyst) tends to improve both the gas yield and methane content in biogas hence, it is possible to increase gas yield and reduce retention period by addition of a catalyst (Dhamodharan et al., 2015); (Haider et al., 2015) and (Kondusamy and Kalamdhad, 2014).

CONCLUSION

The performance of the plastic digester made from locally available material for production of biogas for cooking activities outlined in this paper was very satisfactory in the provision of clean fuel and good quality fertilizer. The problem of rusting or corrosion which typically affects the production of biogas was solved through the use of non-corroding materials. It was also observed from category B and category C that with addition of cow dung (catalyst) to the substrates, the uncooked food waste comprises of cassava peel and plantain peel produced much more of biogas than cooked food waste (rice + pounded yam). Hence uncooked food wastes are found to be better substrate for biogas production than cooked food wastes. The quick and easy digestibility prowess of animal wastes added to the substrate has also been discovered to be an enhancer of biogas yield. The statistical study of the experiments conducted using ANOVA has shown that temperature and pressure are significant factors in the production of biogas.

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