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Biogas Production Potential of *Moringa (oleifera* L.) Residues at Mesophilic Temperature

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Abstract

The rise in standard of living due to the increase in world population is steadily increasing the demand for energy. The universal hazard issues such as global warming poses serious problem on energy production. A shift to renewable energy resources which are eco-friendly are inevitable. Moringa plants are therapeutic in nature but there are scarce published literature using its residues for energy generation. Hence, this study evaluated biogas production potential of moringa residues [Moringa Pods (MP) and Moringa Leaves (ML)] at Mesophilic Temperature (MT). The residues were analyzed for thermal and chemical properties such as pH, conductivity, dry matter, oDM, NH_4-N, TDS and volatile solids. The experiment was carried out using a laboratory scale batch digester. The amount of substrate and sludge weighed into the fermentation bottles were determined. The volume of the gas produced were analyzed in batch anaerobic digestion at a MT of 37°C. Methane (CH_4) and Carbon dioxide (CO_2) gases were also determined in replicates. The results for the selected substrates were 3549 μS/cm, 88.367%, 78.01533%, 11.362 g/kg, 1760mg/dl and 11.6321% for conductivity, dry matter, oDM, NH_4-N, TDS and moisture content respectively. The results showed that 75%MP with 25%ML has the highest biogas yield of 360 ml compare to that of 100%MP with 0%ML of 320-ml. The study has established high biogas production potential of moringa pod which was also enhanced when co-digested with moringa leaves. Thus, moringa residues have taken up a step further in the feasibility of producing biogas from readily available and cheap materials in our locality.

Keywords*: Moringa Residues, mesophilic temperature, chemical properties, biogas yield.*

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I. INTRODUCTION

Battling the difficulty in energy which many countries in African are experiencing necessitates the need for alternative sources of energy. Energy is highly central to the existence of human being and play a vital role in the technological advancement of a nation (Jibril and Omprakash, 2018). Nevertheless, several difficulties are related with the fossil fuel and some of these difficulties are that they are non-renewable in nature, causes health impediment due to the release from fossil fuel into the atmosphere and changing in prices of fuel (Adebayo and Ahmed, 2017). Biogas is a renewable energy which is produced through anaerobic digestion of biomass-residues. It is ecologically friendly and renewable in nature (Song *et al.*, 2004; Adebayo *et al.*, 2015). Agricultural residues are the non-product outputs of production and processing of agricultural produce that may contain materials that can benefit man but whose economic values are less than the cost of collection, transportation, and processing for beneficial use (Obi *et al.*, 2016). There are many benefits to be derived from the use of agricultural residues for biomass energy generation (Oladeji, 2012). Prominent among these merits are stumpy emissions of green-house and acid gases, which are friendly both to human and ecology. Agricultural residues are existing in great quantity in Nigeria and can be used for energy production (Oladeji, 2013; Jekayinfa and Schlolz, 2009). One of these residues is moringa residue. Moringa (*Moringa oleifera* L.) is a highly valued plant that is mostly cultivated in the tropics and subtropics region of the world. It is a native to the Indian. Every part of *moringa oleifara* is useful (Ikubanni *et al*., 2017). For example, its seed contains flocculants, anti-microbial substance and edible oil (Ikubanni *et al.,* 2017). However, residues from *moringa oleifera* which consists of moringa pods and leaves are abundantly available and are categorize as crop residues. These residues, especially moringa pods are mostly treated as waste since they are not compact enough to be used as fuel (Busani *et al.,* 2011; Adebayo *et al.,* 2013). Therefore, the need to examine the potential use of *moringa oleifera* residues for biogas production. The use of these crop residues for biogas generation will profit the environment in the form of reduction in gases that cause leaching from arable land and increase productivity in the use of plant nutrients (Adebayo *et al*., 2015). Researchers in previous similar studies have used some mutual sources of biomass-residue for biogas generation. Researchers such as Adebayo *et al*. (2015) and Adenekan and Bamgboye (2009), Song *et al*. (2004) and Adebayo and Ahmed (2017), Linke and Schelle (2000), Keefe and Chynoweth (2000) and Igoni *et al.* (2008) used agricultural crop residues, livestock residues, organic waste, sewage sludge, and municipal solid waste respectively for biogas production. However, there are scarce published literature on the use of moringa residues for Biogas generation. Thus, this study aimed to evaluate biogas production potential of moringa residues (pods and leaves) at mesophilic temperature so as to establish a set of parameters that will guide biogas production in Nigeria using the chosen substrate.

II. MATERIALS AND METHODS

Moringa pods and leaves were harvested from Stadium area in Ogbomoso (8^o08^1N 4^o15^1E), Oyo state, Nigeria. These pod and leaves were grounded into puff for easy feeding into the digester. The amount of substrate and seeding sludge weighed into the fermentation bottles were determined in accordance to German Standard Procedure VDI 4630. The gas volume produced from the Moringa Leaves (ML) and Moringa Pod (MP) were analyzed in batch anaerobic digestion at a constant temperature of 37°C and was maintained through a digester (Plate 1). The characteristic chemical and thermal properties of the moringa leaves and pods used were determined according to German standard methods (VDI, 2004).

. Vessels (0.9 litre capacity) were filled with 250g of the stabilized inoculum. Two bottles were used for each of the combinations and the average yields found at the end of the experiment. At the initial stage of the experiment, anaerobically digested material from a preceding batch experiment was used as inoculums for the study. The moringa leaves and pods fed into the digestion bottles were calculated (Equations 1 and 2) and found to be 78.01g (100% MP with no ML) and 45.14 g (75%MP and 25%ML). The evaluated amount of the substrates was added to 250g inoculums to ensure compliance of the oDM feedstock to oDM inoculum ratio being less or equal 0.5 as it is recommended in VDI 4630.

Moreover, another digestion vessel was also filled with 250g of inoculums only as control. The biogas produced was collected in scaled syringe meters for 20 days. The volume of the gas produced was measured daily. Besides, other gas components, that is methane (CH_4) and carbon dioxide (CO_2) contents were determined at least eight times during the batch fermentation test using a gas analyzer (GA 2000). The tests were conducted in two replicates. Plate 1 shown the set-up of the batch experiment conducted at mesophilic temperature (37°C). Quantitative evaluation of the results obtained in a batch anaerobic digestion tests included the following steps: standardizing the volume of biogas to normal litres (1N); (dry gas, t=273 KPa=101.3bar) and correcting the methane and carbon dioxide contents to 100% (headspace correction, VDI 4630). The amount of substrate fed into the digester was calculated using equation (1).

$$\frac{oTS_{substrate}}{oTS_{seeding\ sludge}} \leq 0.5 \qquad (1)$$

Where: $oTS\,substrate$ = organic total solid of the substrate and;

$oTS\,seeding\,sludge$ = organic total solid of the seeding sludge (the inoculum)

Equation (1) can be modified as

$$p_i = \frac{m_i . c_i}{m_s c_s} \qquad (2)$$

Where P_i= mass ratio =2; m_i= amount of inoculum, g.

c_i=Concentration of inoculum, oDM in % Fresh mass

m_s= amount of substrate, g

c_s= Concentration of substrate, oDM in % fresh mass

The amount of substrate fed into the digester is less than 0.5.

Plate 1: Experimental set up for batch digestion.

The readings of the gas production (ml), air pressure (mbar), gas temperature (37^oC) and retention time were taken on daily basis throughout the period of the experiment. The gas produced was analyzed at least twice per week. The gas factor and the fresh mass biogas were calculated while the methane yields with the volatile solid biogas were determined on daily basis. The amount of gas formed were converted to standard conditions (273.15 K and 1013.25 mbar) and dry gas. The factor were calculated according to equation (3).

$$F = \frac{(p - P_{H_2O}).T_o}{(t + 273.15).p_o} \quad (3)$$

Where:
T_o= 273.15^oC (Normal temperature),
t= Gas temperature
P_o= 1013.25 mbar (standard pressure)
P= Air Pressure

The vapour pressure of water is dependent on the gas temperature and amounts to 23.4 mbar for 20^oC.The respective vapour pressure of water as a function of temperature for describing the range between 15 and 30^oC is given in equation (4) as

$$P_{H_2O} = y_o + a.e^{b.t} \quad (4)$$

Where:
y_o = -4.39605; a = 9.762 and b= 0.0521
The normalized amount of biogas volumes was given as

$$Biogas\ [N\ ml] = Biogas\ [ml] \times F \quad (5)$$

Normalized by the amount of biogas, the amount of gas taken off of the control batch is given as

$$Biogas\ [N\ ml] = (Biogas\ [Nml] - Control\ [Nml]) \quad (6)$$

The mass of biogas yield in standard liters / kg is based on the weight.
The following applies:
1 standard ml / g =1 standard liters / kg FM = 1 m^3 / t

$$Mass\ of\ biogas\ yield = \sum \frac{Biogas\ [N\ ml]}{Mass\ [g]} \quad (7)$$

The oDM biogas yield is based on the percentage of volatile solids (VS) in substrate

$$oDM\ biogas\ yield = \sum \frac{Biogas\ [N\ ml).100]}{Mass\ [g].VS\ [\%\ FM]} \quad (8)$$

$$CH_{4\,corr.} = \frac{CH_4[vol\ \%].100}{(Mass\ [g] + CO_2[vol\ \%])} \quad (9)$$

$$Fresh\ Mass\ Methane\ yield = \frac{Fresh\ mass\ biogas\ yield \times CH_{4\,corr.}}{100} \quad (10)$$

$$oDM\ Methane\ yield = \frac{oDM\ biogas\ yield \times CH_{4\,corr.}}{100} \quad (11)$$

2.1 Substrates and Analytical Procedures

Sample of moringa pod (MP) was investigated, Dry Matter (105^{o}C), Organic Dry Matter in %, pH, NH_4-N, Moisture (%), crude fibre (%), crude lipids (%),Conductivity (µS/cm), TDS (mg/dl), Ash (%). All analyses were performed according to German standard methods.

III. RESULTS AND DISCUSSION

The results for the chemical and thermal properties of the selected substrates before digestion which include dry matter (DM), organic dry matter (oDM), NH_4-N, Crude lipids, Crude Fibre, Ash, Moisture, TDS, pH, and the conductivity of the selected substrates are shown in Table 1.

3.1 Organic dry matter

Batch anaerobic digester in this study were conducted from an inoculum present in excess of the organic dry matter from the substrate 78.01% and 42.05% respectively (Table 1). This implies the high buffering capacity of both the substrate and inoculums by degradation by the micro-organisms.

3.2 Dry matter:

The average dry matter content for both the substrate and inoculums were 88.37% and 47.32% respectively (Table 1). The result of the dry matter of the inoculums is less in percentage (%) compare to some other researchers. The dry matter content is one of the main parameters that influenced anaerobic digestion.

3.3 Crude Fibre

The crude fibre fraction within the crop biomass is another important characteristic of feed for biogas production since it includes the non-digestible organic compounds of the plant cell. The average crude fibres were 9.59% and 9.74% respectively as shown in Table 1. These identified lignin is the main influencing chemical components of methane yields. Lignin is not degradable and thus, decrease methane production and controls the organic dry matter degradation during the anaerobic process.

3.4 Crude Lipid

The crude lipids content was identified as another parameter with positive impact on the methane yields. The average crude lipids for the substrate and inoculums were 2.20% and 3.90% respectively. This implies that crude lipids also contribute to higher methane yields as compared with carbohydrates.

3.5 Moisture Content

The average moisture content for substrate and inoculums were 11.53% and 52.67% respectively. Higher amount of moisture in the substrate stimulates the growth of bacteria to higher levels of lactic, acetic and butyric acid in the substrate. The substrate and the inoculums moisture content were raised by adding little amount of water in order to reach the VDI 4630, 2004 standard.

3.6 Fresh Mass Biogas Yield

Figure 1 shows that the digester gives a relative increase in the Fresh Mass Biogas Yield (ml) on the y-axis against the retention time (days). At the end of around 25 days retention period, the 75%MP with 25%ML has the highest mass of biogas yield of 360ml in volume compare to that of 100%MP with 0%ML of 320ml in volume. The experiment shown that the co-digestion of Moringa pod with Moringa leaves has positive effect on biogas yield with increases in its volume. This study has similar results has compared with the previous similar studies of Song *et al.*, (2004), Adabayo *et al.*, (2013), Adebayo *et al.*, (2015) and Adebayo *et al.*, (2017).

Table 1: Chemical and Thermal properties of Substrate

Parameters	Substrate	Inoculums
Dry matter (105^{o}C) %	88.367	47.323
Organic dry matter (oDM%)	78.01533	42.05258
NH_4-N (g/kg)	11.362	10.051
Crude Fibre (%)	9.748627	9.59776

Crude Lipids (%)	2.195061	3.906557
TDS (mg/dl)	1760	-
Conductivity(µS/cm)	3549	-
Moisture (%)	11.6321	52.67547
Ash(%)	10.35657	5.267947
pH	6.9	-

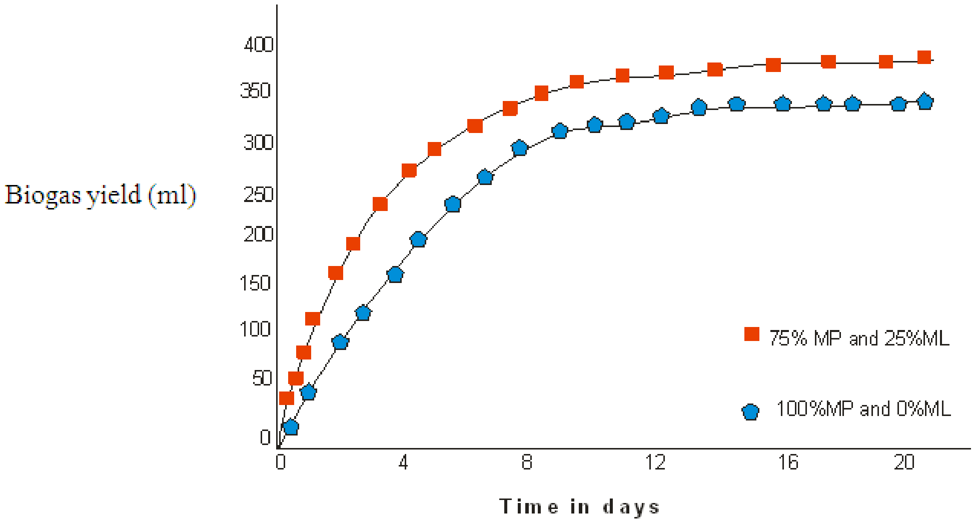

Figure 1: Fresh-Mass Biogas Yields of Digestion of MP with ML

3.7 Fresh Mass Methane Yield

Figure 2 shown volume (ml) of Fresh Mass Methane Yield from the experiments at the end of the retention period (20 days). The methane yield obtained from the substrate of moringa pod and leaves (75% MP and 25% ML) reduced from 360ml to 300ml after the removal of H_2S, CO_2 from the biogas to give pure methane gas compared to the biogas produced in Table 1. The volume of methane yield of 100% MP was lower to 230ml due the removal of H_2S, CO_2 than the results obtained from that of 75%MP and 25% ML. It implies that the mixture of MP and ML is higher in the C/N ratio than 100% MP and thus enhancing methane production. The cumulative biogas and methane productions obtained from batch digesters are shown in Figures 1 and 2.

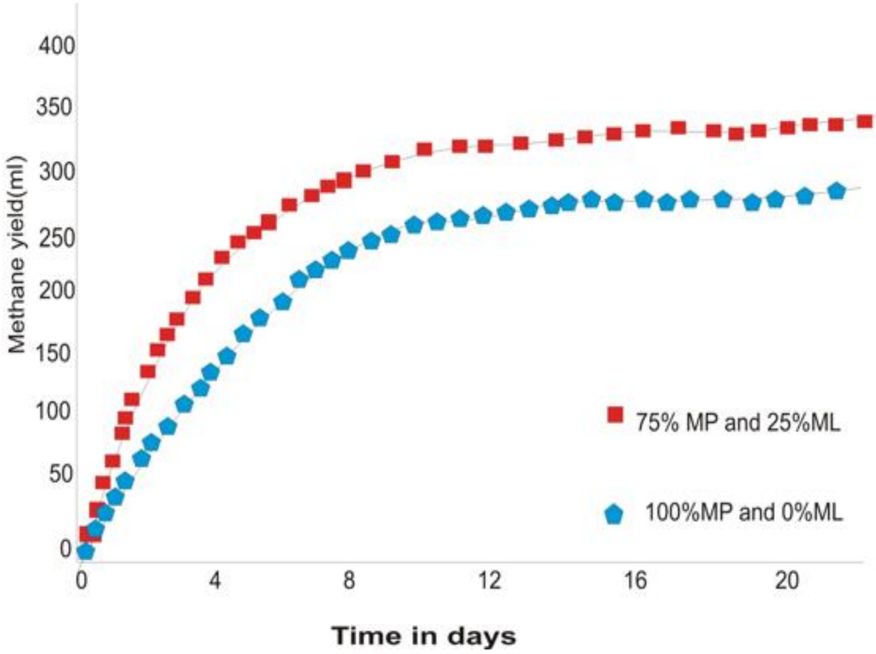

Figure 2: Fresh-Mass Methane Yields of Digestion of MP with ML

IV. CONCLUSION

A laboratory batch anaerobic digester has been used to evaluate biogas yields of moringa pod and moringa leaves at two different ratios (100%MP and 0%ML, 75%MP and 25%ML) using mesophilic temperature. The different ratios of MP and ML have different effect on yields of the selected substrates. It was concluded that both the moringa leaves and pods have good proximate composition that support biogas production. Also, the results showed that co-digestion of Moringa pod and moringa leaves have higher yields than when 100%MP was used. The study was in agreement with the previous similar studies of various researchers on the effect of co-digestion on biogas yields (Adebayo and Ahmed, 2017, Adebayo *et al.*, 2015). .

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