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ORIGINAL RESEARCH ARTICLE

KINETICS OF ANAEROBIC CO-DIGESTION OF PAUNCH MANURE AND SUGARCANE PEELS USING COW DUNG AS INOCULUM

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ABSTRACT

Anaerobic co-digestion offers a prospective medium for transforming organic solid wastes into fuel, thereby providing an extra source of energy. This study investigates the kinetics of anaerobic co-digestion of paunch manure and sugarcane peels using cow dung as inoculum for biogas production. Anaerobic assay setup was in 3 digesters of 4 replicates with a total of 12 replicate batch digesters under mesophilic temperature range (30-35°C) for a retention time of 30 days. Cumulative biogas production for all digesters were measured and fitted to some selected models. The modified Gompertz equation was tested for its fitness. The kinetic parameters viz., biogas yield potential (P), maximum biogas production rate (Rm) and the duration of lag phase (λ) were recorded for each case as the digester with 0g sugarcane peels (control) produced maximum biogas of (83.14 (mL/g VS)) and the kinetic parameters P, Rm and λ were 89.0018 ml (g VS^{-1}), 4.7089 ml (g VS d)$^{-1}$, 0.8734 days respectively. It was observed that biogas production potential was inversely proportional to the substrate concentration of sugarcane peels in the digesters, the highest concentration of sugarcane peels (1.8g SP) recorded the lowest quantity of biogas with 37.9075 mL/g VS, 1.4547 g VS^{-1}, 1.0891 days. Therefore, sugarcane peels should be co-digested with other substrates. The experimental kinetic data in-line with the Gompertz Model, Modified Gompertz Model Equation.

1.0 Introduction

As the world population increases, so also the demand for fossil-based fuels. This demand is further aggravated by urbanization and its attendant effects on energy demand as well as uncertainty in fuel supply and prices in the global market (Bentley, 2002; Cavallo, 2003).

Nigeria loses an estimated five billion (USD) annually to poor environmental management practices from environmental pollution, waste mismanagement and improper agricultural waste handling (Melford, 2003). The resulting output of poor environment management practices leads to pollution of air, water and environment. Exposure to these pollutants pose great threat to human health, economic development and environmental safety. Due to these challenges, researchers have tried to find alternative use of these Slaughterhouse wastes that includes horns, bones, paunch manure, spent-water to transform them into a sustainable and renewable energy source (Ezeoha and Idike, 2007; Monch-Tegeder et al., 2013; Ojolo et al., 2007).

Some researchers argued that, the biogas production potential of paunch manure without co-digestion results in lower biogas yields due to its composition and opined that, paunch manure be co-digested with other substrates during the production process (Ezeoha and Idike, 2007; Melford, 2003; Monch-Tegeder et al., 2013).

Anaerobic co-digestion is a systematic means of having more than one substrate in a formation to form a unit for producing biogas with the aim of improving the biogas yield potential (Jagadish et al., 2012), also as an alternative way of converting these wastes to energy, which is cost-effective where the end products could be used as organic manure for agricultural purposes (Bentley, 2002; Cavallo, 2003). Sugarcane peels (SP) are waste products of sugarcane (suaccherum species) as a result of human consumption of raw sugarcane or as waste product in jaggery production. Sugarcane is one of the major crops cultivated in Northern region of Nigeria popularly known as "Rake" and the peels as "Bawon rake" in the local dialect.

It is noteworthy that because SP waste products are not properly utilized, it would be a good idea to assessed its potentials as alternative source of energy. Therefore, this study intends to investigate the kinetics of producing biomethane from slaughterhouse paunch manure (PM) co-digested with sugarcane peels at different mixture ratios for anaerobic digestion using cow dung as inoculum.

2.0 Materials and methods

2.1 Substrate sources and Characteristics

Fresh samples of paunch manure, sugarcane peels and inoculum were obtained sealed to avoid moisture depletion from kasuwan shanu, Mairi ward and University of Maiduguri Animal farm in Borno state. The samples were sun dried for 48 hours to remove excess moisture before analysis on ash content, moisture content, total solids, volatile solids and pH.

Anaerobic Assay Set Up

Three sets of 473 ml capacity bottles were used as digesters and labelled as A, B and C with each letter having 4 replicates of 3g of paunch manure (PM), 0, 0.6, 1.2 and 1.8g of sugarcane peels (SP) to obtain digesters with 0%, 20%, 40% and 60% co-digestion with total of 12 digester replicates.

Preparation of Fermentation slurries

The PM and SP used in this experiment were pulverized into about 2mm size then sun dried for 48 hours. A moisture free PM and SP were used to prepare the fermentation slurries into 0%, 20%, 40% and 60% co-digestion, 100 ml of water was added to each digester with 1 ml of stock solution and 50 ml of inoculum. A blank assay for inoculum (Control) was used to measure the inoculum activity in 3 replicates as in Srinidhi et al. (2012).

The digesters were set up in control temperature range of 30-35o C then allowed to undergo anaerobic digestion for a retention time of 30 days' mesophilic temperature range. The gas collection was done using liquid displacement method over a 24-hour interval to measure Cumulative biogas production (Jagadish et al., 2012).

Analytical methods

Solid analysis: Total solids (TS) and volatile solids (VS) analysis were performed for PM and SP according to standard methods (Sluiter et al., 2008; Lay et al., 1998).

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Modified Gompertz Model

The kinetic data obtained from the study were checked using modified Gompertz model for fitness. The equation gives the cumulative biogas production from the digesters with assumption that the gas produced is a function of bacterial growth (Jagadish et al., 2012; Luengo and Alvarez, 1988; Atlas, 2008).

$$M = P * \exp\{-\exp\left[\frac{Rm*e}{P}(\lambda - t) + 1\right]\} \quad (1)$$

$$y = A\exp[-\exp(b - ct)] \quad (2)$$

where:

M = cumulative biogas production, l/g(Vs) at any time t

P = Biogas yield potential, l/g (Vs)

Rm = Maximum biogas production rate, l/ (g VS d)

λ = Duration of lag phase, d (days)

t = time at which cumulative biogas production M is calculated, d

y = biogas production accumulation (L kg-1) at time t

t = time (day) over the digestion period.

A = biogas production potential (L kg-1)

c = constant (d-1), b= constant (no unit)

the parameters P, Rm and λ were estimated for each of the digesters using Microsoft Excel software. These parameters were determined for best fit.

3.0 Results and discussions

3.1 Physic-chemical properties of Paunch manure and Sugarcane peels

Table 1 showed the physic-chemical properties of PM and SP. The results showed that, PM appeared to have the same TS as SP with 80 %. The VS of SP was 88.14 % because of its organic matter contents which was higher than that of PM with 67.78 %. The ash content for PM was 14.95 % higher than SP with 12.42 %, this is because PM contains more nonorganic nutrients as compared to sugarcane peels which is in line with Ojolo et al., (2007). The pH values were lower than 6.5 which inhibit the formation of acetic, lactic and propionic acids which becomes toxic for methane forming bacteria and are essential for acetogenesis and methanogenesis. The optimum pH for biogas production was between 7 and 8 similar to the findings of Budiyono et al., (2013), who investigated the effect of pH on food wastes and on Buffalo manure. Moisture content shows the percentage of liquids to solids constituents of the materials, higher liquid contents aids in increased biogas production through increased contact between microorganisms and organic matter as observed by Alnakeeb et al., (2017), PM and SP had 6.39% and 4.17% solids and 93.61%, 95.83% liquids.

Table 1: The Physic-chemical properties of paunch manure and sugarcane peels

Materials	Total solids (%)	Volatile solids (%)	Moisture content (%)	pH	Ash content (%)
PM	80	67.78	6.39	7.4	14.95
SP	80	88.14	4.17	7.4	12.42

3.2 Simulation of Biogas Production Accumulation

Figure 1 shows the biogas accumulation of PM co-digested with SP, Control over a thirty-days retention time. It was observed that the digesters (Control, SP 0.6g, SP 1.2g SP 1.8g) had 83.14 mL/g, 49.83 mL/g, 46.45 mL/g, and 30.89 mL/g respectively. This shows that as the concentration of SP is increased in the co-digestion process with PM the production accumulation decreases.

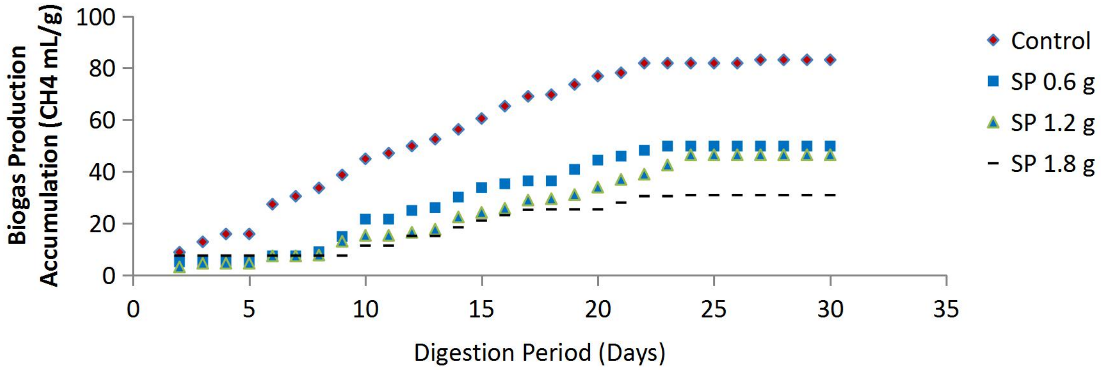

Figure 1: The biogas production accumulation of PM CD 0.6 g SP, 1.2 g SP and 1.8 g SP

Figure 2 shows the plot of Gompertz Model equation for the digesters; Control, PM co-digested with 0.6g, 1.2g, and 1.8g SP. From the graph it is clear that the experimental data fits well with the Gompertz model equation and the values for R2 were 0.98, 0.95, 0.99 and 0.99 for the control, 0.6g SP, 1.2g SP and 1.8g SP respectively.

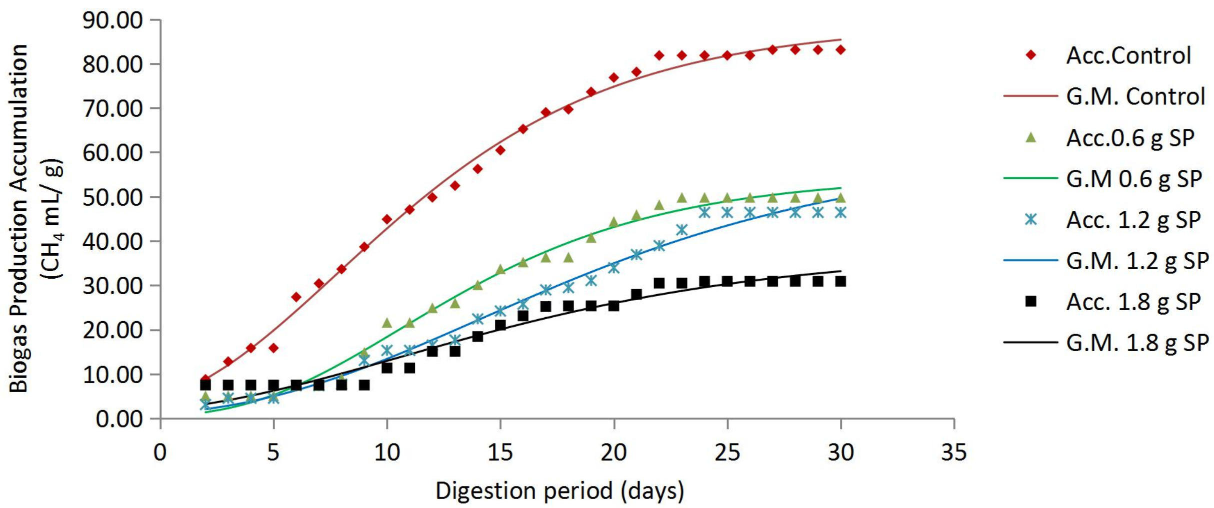

Figure 2: shows the plot of Gompetz Model Equation for control, PM CD with 0.6g, 1.2g and 1.8g SP

Observations made from Table 2 shows that the cumulative biogas production from each digester was tested for fitness with the Modified Gompertz Model equation, the equation described the cumulative biogas production with the time of digestion through biogas yield potential (P), maximum biogas production rate(Rm) and duration of lag phase (λ). The parameters obtained shows that the digesters Control and PM CD with 1.8 g SP had the shorter lag period of 0.873588 days and 1.089084 days respectively while PM CD with 1.2 g SP has the highest lag period of 4.168447 days followed by PM co-digested with 0.6g SP with 4.021884 days. Control has the maximum biogas production rate of 4.708995383 mL/ g VS then 0.6g SP with 3.070026891 mL/ g VS, 1.2g SP was 2.251043986 mL/ g VS and 1.8g SP with 1.4546893 mL/

g VS. The maximum biogas produced at the end of the digestion period was highest for Control which as 89.00184625 mL/ g VS. This could be because Paunch manure is rich in nutrients and contains adequate amount of carbon, oxygen, hydrogen, nitrogen, phosphorus, potassium, calcium, magnesium and a number of trace elements which are very essential elements for the growth of anaerobic bacterium as in Kanwass and Kalia, (1992). It also could have optimized syntrophic (cross feeding) interaction between acetogenes and methanogens which is the most critical step in the biomethanation process as reported by Schink and Stams, (2005). Furthermore, the digesters; control, PM co-digested with 0.6g, 1.2g and 1.8g SP produced 83.14 mL/ g VS, 49.83 mL/g VS, 46.45 mL/g VS, 30.89 ml/ g VS respectively. Figure 3 shows The experimental kinetic data fits well with the Modified Gompertz Equation.

Table 2: shows the summary of the results obtained from the Modified Gompertz model Equation to check the performance of the digesters.

Digesters	Biogas yield (mL/ g VS)	Modified Gompertz parameters (model)			R2
		P, (mL/g VS)	Rm (mL/g VS d)	λ, d	
Control	83.138	89.0018	4.7089	0.8734	0.91
0.6 g SP	49.834	54.6859	3.0700	4.02198	0.98
1.2 g SP	46.446	60.5884	2.2510	4.1684	0.72
1.8 g SP	30.889	37.9075	1.4547	1.0891	0.68

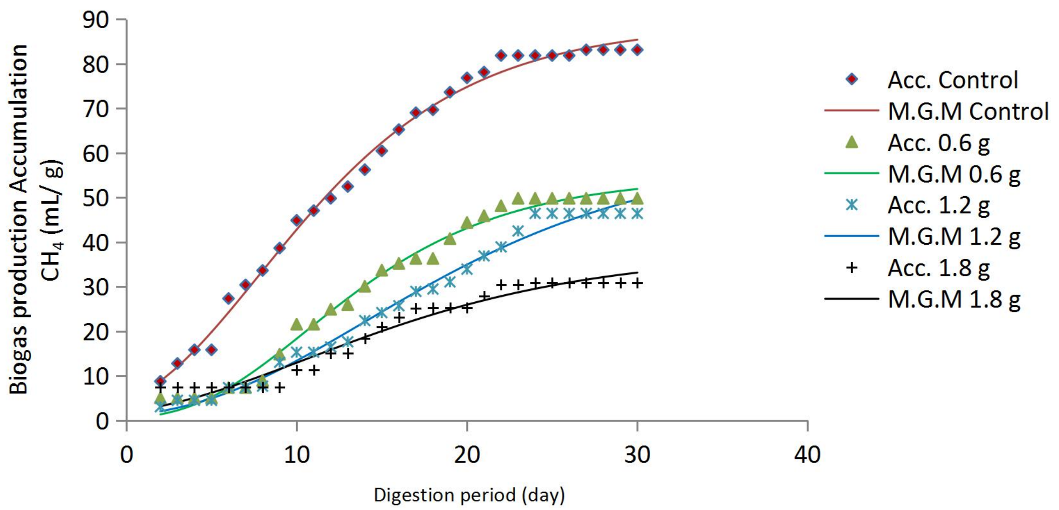

Figure 3: shows the plot of Modified Gopertz.Model Equation for the digesters control,PM CD with 0.6g , 1.2g and 1.8g SP.

4.0 Conclusions

The conclusions drawn from this study were:

Sugarcane peels had higher volatile solids when compared to paunch manure indicating a higher biogas potential.

It was observed that, the digester(control) produced the highest biogas with better production rate as compared to when co-digested with varying substrate concentrations of SP.

Higher substrate concentration of SP was found to be very poor when co-digested with PM as the digester with 1.8g SP recorded the lowest biogas production over 30 days' retention period.

SP should be co-digested with other organic wastes to investigate further alternatives to its biogas potentials.

The simulation results indicated that the First Order Exponential Rise, Gompertz and Modified Gompertz Model Equations best predicted the Cumulative Biogas Produced as a function of retention time.

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