OPTIMIZATION OF BIOGAS YIELD FROM CO-DIGESTION OF SAWDUST AND COW DUNG UNDER ANAEROBIC CONDITION USING CHINESE FIXED DOME BIOREACTOR (CFDB).

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ABSTRACT

The co-digestion of sawdust with cow dung was understudied to investigate the optimum biogas yield and the best ratio for optimum production by varying the organic loading rate (OLR) of the biomass with constant water ratio. Five (5), fifty kilogram capacity prototype of Chinese fixed dome bioreactors (CFDB), labeled bioreactor 1-5 was charged with the organic loading rate ratio of (1:0:4), (0:1:4), (3:2:4), (2:3:4) and (1:1:4) of cow dung: sawdust: water respectively into the bioreactors. The pH, temperature and daily biogas production of the bioreactor operating conditions were monitored over the hydraulic retention time (HRT) for 33 days. The result showed that at the end of the 33 days, bioreactor 5 (1:1:4) had the highest cumulative biogas yield of 36.3 L/TS, followed by bioreactor 3(3:2:4) with a good cumulative biogas yield of 35.5L/TS, compared with bioreactos1 and 2 which serve as control. The time lag (the onset of flammability) of bioreactor 3 (3:2:4) and bioreactor 1(1:0:4) was 13 day shorter than that of bioreactor 5 (1:1:4) which was 15 day and bioreactors 2 and 4. The result obtained implies that bioreactor 5(1:1:4) (3.8kg CD and 3.8kg of SD) is a better ration for optimum biogas yield. This also showed that the blending of sawdust with cow dung optimized the biogas yield and the time lag when compared with the control bioreactor 2 (0:1:4) which is only sawdust with the biogas yield of 8.5L/TS and a time lag of 23 day and bioreactor 1 (1:0:4) having only cow dung and a biogas yield of 19.5 L/TS.

Keywords: Biogas, bioreactor, co-digestion, organic loading rate, and sawdust.

INTRODUCION

The increase in human population and its activities in this 21st century have been of growing concern especially its increasing demand and dependence on fossil based fuels and the large production of waste without proper or commensurable utilization of the waste products. The increase activities have enormously contributed to the increase in the green house gases, depletion of the ozone layer, global warming and its consequences including flooding and others, with its attendant environmental consequences (Uri, 1992).

Saw dust, a by-product of saw cutting of timber in sawmill, is one of the numerous activities of human that has generated a growing concern thus, presenting an environmental challenge. The constituent of saw dust includes cellulose and lignin and other groups such as tannins or other phenolic compounds (Vinodhiini and Das, 2009). Digestion of saw dust with cow dung under anaerobic condition will be one of the ways to control and utilize saw dust as a renewable energy. Furthermore, daily production of cow dung in abattoirs has contributed enormously to environmental pollution and contamination of water bodies. Cow dung also serves as a good breeding medium for microorganism and this informed our choice of blending it with sawdust.

Biogas technology has been recognized as having the potentials to provide alternative energy (biogas), handling human, animal, agricultural and industrial waste safely, controlling environmental pollution and contributing to the expansion of food production and supplies (Uri, 1992, Ofeofule and Uzodinma, 2006).

Cow dung has been reported to be of superior quality in biogas production over other wastes (Odeyemi, 1987). This has been attributed to its potentials of supplying the microbial population for the degradation of organic matter and its onset of biogas production and flammability. Uzodinma and Ofoefule (2009) have demonstrated that biogas yield of field grass can be optimized by co-digestion with rabbit, cow dung, swine dung and poultry waste. The onset of biogas flammability and production (time lag) has also been shown to improve significantly by blending cow dung with poultry waste (Ofoefule and Uzodinma, 2006).

However, blending of saw dust with cow dung prior to digestion may improve the quantity and quality of biogas yield. This informed the undertaken of this research to investigate the optimal biogas yield by varying the organic loading rate of the biomass under anaerobic condition using Chinese fixed dome bioreactor.

This study is aimed at optimizing the biogas yield of co-digestion of sawdust and cow dung by varying the organic loading rate of the biomass under anaerobic condition using Chinese fixed dome bioreactor.

MATERIALS AND METHODS

Experimental Design

Five batch bioreactors (labeled 1-5) of 50-liters capacity were set up and were charged up to ¾ of the bioreactor volume, varying the amount of cow dung and sawdust while the volume of water remained constantas shown below

Table1: The ratio and actual quantity of the biomass charged into the bioreactor labeled bioreactor 1-5.

ACTUAL AMOUNT OF SAMPLES IN BIORECTORS				
Bioreactors	Ratio (ws:wt)	Cowdung (kg)	Sawdust (kg)	Water (litre)
1	1:0:4	7.5	-	30
2	0:1:4	-	7.5	30
3	3:2:4	4.3	3	30
4	2:3:4	3	4.3	30
5	1:1:4	3.75	3.75	30

Charging of Bioreactor(s)

The different variants were weighed and mixed thoroughly in a water trough. The mixtures were charged into the 50-litres metal prototype batch bioreactor(s). The waste was charged up to ¾ of the bioreactor volume, leaving ¼ head space for gas collection.
The bioreactors were properly tightened with the valve locked to exclude air. The bioreactor contents were stirred adequately (50 periods per minute) on a daily basis throughout the retention period to ensure homogenous dispersion of the substrate and microbes in the mixture**.**

Determination of Quantity of Biogas Produced as Described by Uzodinma&Ofeofule (2009).

The quantity of biogas produced in litre/total solid was obtained by downward displacement of water by the biogas on daily.

Determination of pH of the Slurry in the Bioreactor

The pH of the slurry were determine daily using pH meter (Search Tech, model PHS 3C, UK). Sample of the slurry were collected before and after stirring, and the pH were determined using pH meter at 12 hours interval.

Determination of the Ambient and Slurry Temperatures of the Bioreactor

The ambient and slurry temperatures of the bioreactor(s) were also monitored at 12 hours interval throughout the retention period after charging of the bioreactors a thermometer. The slurry temperature was determined by immersing the mercury bulb into the slurry and it was held at the tip of the thermometer. The temperature was taken when the mercury reading in the glass had been steady for one minute.

Determination of Biogas Flammability

The flammability of the biogas produced was determined using a fabricated gas burner. The fabricated gas burner was connected to the bioreactor's valve (tap); with a pipe hose, the valve was then open to allow the flow of gas through the hose to the gas burner, and was ignited (Uzodinma&Ofeofule, 2009).

Determination of the Composition of Biogas Produced

The composition of the flammable biogas produced in each of the reactors was determined using Speriam Gas Analyzer (Model 66429 made in USA) in a method described by Uzodinma&Ofeofule (2009), which showed composition of methane, carbon monoxide, hydrogen sulphide and oxygen. The inlet pot of the Speriam Gas Analyser was taken close to the biogas outlet pipe and the gas was allowed to flow into the analyzer which analyzes the quantity of methane and carbon dioxide produced in percentage, while the quantities of hydrogen sulphide and oxygen are given in ppm.

Determination of the Total Microbial Count of the Slurry

Total viable counts (TVC) of the microbes for the digested slurry mixture were carried out to determine the microbial load of the variant mixture using the modified method of Miles and Misra (1938) as described by Okore (2004). This was carried out at four different periods during the digestion; at the point of charging, flammability, peak of production and at the end of the retention time.

The method consists of placing drops (0.02ml) of serial dilution on the surface of poured agar plate and counting the colonies that develop on incubation of the plates. The method is useful when the bacteria are best grown in surface culture or when an opaque medium is employed.

Ash, moisture and fibre contents of both the substrates were determined by the methods of AOAC (1990).

$$\% \text{ Ash} = \frac{(\text{weight of crucible} + \text{weight of ash- weight of crucible})}{\text{Weight of sample}} \times 100$$

$$\% \text{ moisture content} = \frac{100 \times \text{weight of sample - weight of crucible} + \text{sample after drying}}{\text{Weight of sample taken}}$$

$$\% \text{ Fibre} = \frac{\text{Change in weight (loss in wt in ignition in grammes)}}{0.03}$$

$$\% \text{ oil (w/w)} = \frac{\text{initial weight of sample} - \text{final weight of sample after extraction}}{\text{(Initial) weight of sample taken.}} \times 100$$

$$\% \text{ N} = \frac{0.00014 \text{ X Titre value X } 50 \text{ X } 100}{\text{Weight of sample taken}} \quad \text{OR} \quad \text{T x N x } 14.01/1000 \text{ x } 100/\text{ws} = \% \text{ N}$$

% c.p = N X 6.25

Where: T = Sample Titre, N = Normality
Ws = weight of sample

Determination of Carbon Content of the Substrate, Using the Method of Walkley and Black

Using the Walkley-Black method, the calculation of organic matter assumes that 77% of the organic carbon is oxidized by the method and that soil organic matter contains 58% carbon. Since both of these factors are averages from a range of values, it would be preferable to omit them and simply report the results as "easily oxidizable organic carbon.

Calculation
% organic carbon:
%C = (B-S) x M of Fe^{2+} x 12 x 100
g of soil x 4000
Where:
B = mL of Fe^{2+} solution used to titrate blank
S = mL of Fe^{2+} solution used to titrate sample
12/4000 = milliequivalent weight of C in g.

Statistical Analysis

The data obtained in the experiment were analyzed statistically for mean and standard deviation and regression using Statistical Package for Social Sciences (SPSS) version 19.

RESULTS

Proximate Analysis of Cow Dung and Sawdust

Table 2shows the results of proximate analysis of cow dung and saw dust. The saw dust contained less moisture, ash, fibre, C:N and fat while there was a slight increase in protein, total solids, carbon and volatile solids when compared with the untreated saw dust. The cow dung contained higher moisture content due to the nature of the waste.

Table 2: Proximate Analysis of the cow dung and sawdust.

PARAMETERS (%)	COW DUNG	SAWDUST
Moisture	83.55	27.23
Ash	2.7	1.95
Fibre	0.04	4.84
Crude nitrogen	0.25	0.38
Crude protein	1.62	2.34
Fat content	0.15	5.23
Total solids	15.32	72.65
Carbon content	97.3	31.91
Volatile solid	12.68	70.70
Carbohydrate	15.32	58.30
C:N	29.20	155.46

Time Lag, Cumulative Gas Yield, biogas Yield, pH and Temperature in Bioreactors.

The result of table 3 below shows that bioreactors 1 and 3 had very short time lag of 13 day each, followed by bioreactor 5 with time Lag at the 15th day and with highest cumulative biogas yield of 36.3 l/TS, while bioreactor 2 (saw dust only) had the longest time lag of 23 with least biogas yield. The ambient temperature showed a positive correlation with the daily biogas yield and with the slurry temperature.

Table 3: Time lag, cumulative gas yield, mean volume of biogas yield, pH, and Temperature in bioreactors.

Parameter	Bior1 (1:0)CD	Bior2 (0:1)SD	Bior3 (3:2)CD:SD	Bior4 (2:3)CD:SD	Bior5 (1:1)CD:SD
Time Lag	13	23	13	21	15

Cumulative gas yield(l/TS)	19.5	8.5	35.5	12.3	36.3
Mean±SEM of biogas produced	0.6±0.8*	0.3±0.3*	1.1±0.9*	0.4±0.6*	1.1±1.7*
Mean±SEM of Ph	8.42±0.35	6.22±0.44	7.16±0.56	6.41±0.29	7.00±0.6
Mean±SEM of Temperature	31.8±3.4*	32.0±3.7*	32.5±3.7*	33.3±3.8*	32.6±3.6*

Ambient Temperature = 27.3±2.6^{o}C; Retention Time = 1-33 Day.

Bior= Bioreactor; CD = Cow dung; SD = Sawdus

Total Viable Count for the Mixture in the Reactor (cfu/ml).

Table 4 below shows the microbial population of the mixtures of cow dung and saw dust in each of the bioreactors; measured in colony forming unit per ml (cfu/ml).The microbial population of the reactors were determined at the point of charging, flammability, peak of production and the end of the retention time. Between the point of charging and the point of flammability, there was a high population of bacteria.

Table 4:Total Viable count for the mixtures in the reactors (cfu/ml).

PERIOD	Bior 1 CD	Bior 2 SD	Bior3CD:SD (3:2)	Bior4CD:SD (2:3)	Bior5CD:SD (1:1)
At the point of charging.	$2.71x10^2$	$2.12x10^2$	$6.1x10^2$	$1.17x10^2$	$1.02x10^2$
At the point of flammability.	$5.4x10^3$	$2x10^3$	$2.73x10^3$	$5.2x10^3$	$2.20x10^3$
At the peak of production.	$2.76x10^3$	$1.3x10^3$	0	$5x10^3$	$2.1x10^3$
At the end of retention period.	$3.0x10^2$	0	$1.76x10^2$	$1.5x10^2$	$1.7x10^2$

Bior = Bioreactor; CD = Cow dung; SD = Saw dust.

Composition of Biogas Produced in the Bioreactors.

The result in table 5 shows the composition of biogas produced from the mixtures in the bioreactors, respectively. The mixture of cow dung (CD only) 1:0 ratio had a highest percentage of methane (72%) with the least quantity of carbon dioxide followed by bioreactor 3 3:2 (CD:SD) with 70% methane and bioreactor 5 with 70% methane. Bioreactor 4 2:3 (CD: SD), while bioreactor 2 (saw dust only) had the lowest methane composition of 18% and highest carbon dioxide composition of 90%.

Table 5: Composition of biogas produced in the bioreactors.

Parameters	Bior1CD	Bior2SD	Bior3CD:SD(3:2)	Bior4CD:SD(2:3)	Bior5CD:SD(1:1)

(%)					
Methane	72	18	70	65	70
Carbon	27	80	28	30	28

Bior = Bioreactor; CD = Cow dung; SD = Sawdust

DISCUSSION

The hydraulic retention time of the digestion was monitored for 33 days, at temperature of 21-33^{o}C and slurry temperature of 23-40^{o}C. The quantity of water used was kept constant while the quantities of the saw dust and cow dung used were varied as shown in Table 1.

The production of flammable biogas commenced in the bioreactors at different time lag (Table 3), the result shows that bioreactor 3 (3:2:4) had cumulative biogas yield of 35.5 l/TS and bioreactor 1(1:0:4) 19.5 l/TS with the shortest retention time lag of 13 day. Bioreactor 5 (1:1:4) with time lag of 15 days had the highest cumulative biogas yield of 36.3 l/TS. Bioreactor 4 (2:3:4) blend had the time lag of 21 and cumulative biogas yield of 12.3 l/TS while Bioreactor 2 (0:1:4) saw dust only, had the least time lag of 23 and the least cumulative biogas yield of 8.5 l/TS (table 3). The least time lag and cumulative biogas yield observed in Bioreactor 2 (saw dust only) could be attributed to less microbial population (table 4), high fat and fibre content (table 2). This indicates that saw dust only contained a lot of cellulose, hemi-cellulose, pectin, lignin, plant wax etc, which are very difficult to degrade and could be a major rate-determining step in anaerobic digestion as stated by Kozoet al. (1996). The less microbial population and high fat and fibre content of saw dust in bioreactor 2 led to the reduction in the pH of the slurry to less than 6.5-8.0 which agreed with the work done by Ntegwe et al (2010) as the pH range needed for maximum activity of methanogenic organisms to covert the free fatty acid into acetate and acetate into methane.

The onset of flammable biogas as observed in bioreactor 1(cow dung only) could also be as a result of the less fat content of the waste (cow dung) as shown in table 2 and microbial population of the waste (table 4). Bioreactor 4 (2:3:4) CD:SD with time lag of 21 and biogas yield of 12.3 l/TS, has the influence of high fat and fibre content of the waste on the pH of the slurry as also observed in Bioreactor 2. However, it showed an improvement both on the time lag and the biogas yield when compared with Bioreactor 2 (sawdust only). This was due to the addition of cow dung which supplied the microbial population that degraded the fibre and converted the fatty acid into acetate, thereby improving the pH of the slurry for methogenic activities. The higher quantity of cow dung over the saw dust in Bioreactor 3 (3:2:4) contributed to the shorter time lag and increase in the biogas yield when compared with Bioreactors 1, 2 and 3 (Table 3) which agreed with the work done by Uzodima&Ofeofule, 2009; Nagamani&Ramassa, 1999). Contrary to this, Bioreactor 5 (1:1:4) CD:SD had the highest cumulative biogas yield when compared with Bioreactors 1, 2, 3 and 4. These could be attributed to the equal quantity of the cow dung and saw dust in the bioreactor, which encouraged the mass transfer and direct contact of the microorganisms with wastes to enable easy digestion.

The average ambient temperature of 27.3±2.6^{o}C shows a positive correlation with the slurry temperature and the quantity of biogas produced in Bioreactors 1, 2, 3, 4, 5 which is significant at $p \leq 0.05$.

Bioreactor 1(CD only), had the best quality of biogas which is 72% methane, followed by bioreactor 3 and bioreactor 5 with 70% respectively. These values show improved quality when compared with bioreactor 2 (SD only) and bioreactor 4 (2:3:4) that have 18% and 65% respectively.

The result of this investigation implies that Bioreactor 5 (1:1:4) CD:SD with 3.8kg cow dung and 3.8kg of saw dust is a better waste combination or blend for flammable biogas yield, if there is no urgent need for biogas utilization, whereas, the mixture (3:2:4) (Bioreactor 3) would be preferred if the biogas is required urgently.

CONCLUSION

As obtained in this study, bioreactor 5 (1:1:4) is the best ratio of cow dung: sawdust: water for optimum yield of biogas. The quality of the biogas produced from sawdust can be improved by blending it with either equal or greater quantity of cow dung as observed in Table 5.

There is need for further studies such as mathematical modeling of the studied system, determination of other agents (such as additive, maintaining the mesophilic temperature and pH range) for anaerobic digestion.

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