Comparative Study of Biogas Production from Locally Sourced Substrate Materials

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ABSTRACT: Comparative study of biogas production from Cow dung (CD), Millet husk (MH), Rice husk (RH), Saw dust (SD) and Paper waste (PW) was conducted. The biogas production potentials for the substrates were of the order: Cow dung ($8772.50 cm^3$) > Millet husk ($6680 cm^3$) > Rice husk ($1386.25 cm^3$) > Saw dust ($973.75 cm^3$) > Paper waste ($476.25 cm^3$). Physico - chemical analysis revealed decreasing pH in the spent slurry indicating acidification of the content. The ash content is higher in the spent slurry ranging from 16 – 24% for the raw substrate and between 18 and 29% for the spent slurry. Kinetic studies show the slurry concentration have a direct relationship to the volume of biogas produced from all the substrates. There was strong correlation between slurry concentration and the volume of biogas generated.

INTRODUCTION

Biogas refers to a combustible gas (primarily composed of methane) produced when organic matter is fermented with the assistance of microorganisms in the absence of air or oxygen. The composition of biogas is by no means fixed but certain approximations can fairly be made on its composition. i.e. 40 – 75 % methane, 25 – 60%, carbon (IV) oxide and 2% of other gases mainly hydrogen, hydrogen sulphide, carbon (II) Oxide and nitrogen (Zuru *et al*., 1998).

The various microbial groups involved in the flow of carbon from complex polymers to methane are diverse in nature. The complex polymers are broken down to soluble products by enzymes produced by fermentative bacteria, which ferment the substrates to short chain fatty acids, hydrogen and carbon (IV) oxide. Fatty acids longer than acetate are metabolized to acetate by obligate hydrogen – producing acetogenic bacteria. The major products after digestion of the substrate by these two groups are hydrogen, carbon (IV) oxide and acetate. Hydrogen and carbon (IV) oxide can be converted to acetate by hydrogen – oxidizing acetogenic bacteria or to methane by carbon (IV) oxide – reducing and hydrogen – oxidizing methanogens. Acetate is also converted to methane by aceticlastic methanogens. For instance nearly seventy per cent (70%) of the methane from biogas digesters fed with cow dung is driven from acetate (Nagamani and Ramasamy, 2005).

Like any biological process, methanogenesis involves consortia of microorganisms that convert organic matter into methane, carbon (IV) oxide and traces of other gases. The overall rates of waste utilization and methane production depends on the extent to which the nutritional requirements of the methanogens and non-methanogens could be met by constituents of the wastes and by primary or secondary metabolites produced by one species and utilized by another (Preeti and Seenayya, 1993). Trace elements necessary for anaerobic digestion include iron, nickel, calcium, barium and cobalt. Iron is an important micronutrient for many microorganisms and is essential for various enzymes.

Biogas production from various organic matter of either plants or animal origin has been going on for decades, but a lot still remain desired in the field because the process like any chemical reaction, can be influenced by conditions such as temperature, concentration, surface area, etc. This paper aim at investigating the effect of slurry concentration on biogas production potentials of selected substrate in order to determine the optimum slurry concentration for each substrate.

MATERIALS AND METHODS
Materials
Cow dung, millet husk, rice husk, saw dust and paper waste were obtained from various locations around Sokoto metropolis. The fresh cow dung and millet husk were collected from Shama village. The Rice husk and saw dust were collected from the Timber market in Sokoto while the paper waste was collected from a refuse dump near the University Clinic, Main Campus, Usmanu Danfodiyo University, Sokoto.

Methods
The samples collected were air dried and further dried to constant weight (obtained within 24 hours) at 110^0C in an oven. The dried samples were ground by means of wooden pestle and mortar. The samples were further ground to smaller particles using a three bladed blender and then stored in black polythene bags.

Preparation of slurry
From the oven dried sample of each substrate the slurries were prepared by taking a known weight (40g, 60g, 75g, 100g and 120g) of the ground sample and diluting with 600 cm^3 of water. The mixtures were thoroughly mixed for more homogeneity before transferring into the digester. Four Digesters were fed with each slurry concentration mentioned.

Generation and collection of biogas
For the generation and collection of total biogas produced, the digesters were fed with the slurry and then sealed before the end of the PVC tube from the digester was connected to the inlet of a Buckner flask containing some quantity of silica gel, which served as drying agent. The digesters were then jacketed in poly urethane foam to minimize the temperature changes in the digesters. Another PVC tube was connected to the outlet of the Buckner flask and the other end of the tube was connected to separate inverted (1000 cm^3) capacity measuring cylinders which were filled with water.

Proximate analysis of substrates and spent slurry
The moisture and ash contents of the substrates and spent slurry were determined using the methods adopted by Garba (1999). The nitrogen content was analysed as described by Dangoggo (2000). The volatile solid (VS) was determined by subtracting the percentages of moisture and ash content from 100% (Garba, 1999), while the carbon content of the substrates was estimated using the equation: %C = 0.58 X % VS (Allen *et al*, 1974). The carbon to nitrogen ratio was evaluated by calculating the ratio of organic carbon content to that of nitrogen content, according to the equation:

$$C/N = \frac{\% \text{ Organic carbon in the sample}}{\% \text{ Nitrogen in the sample}}$$

Determination of pH before and after digestion
The determination of pH, a calibrated pH meter (9015 Model) was used to measure the pH of each of the slurries before digestion. The pH of the digested slurry was similarly measured on the last day of the retention period.

Investigation of the effects of slurry concentration
The five (5) digesters were set up for each substrate type having concentrations of 1:5, 1:6, 1:8, 1:10 and 1:15. The digesters were connected to the Buckner flask containing silica gel to dry the gas generated in the digesters before collecting in the inverted measuring cylinder filled with water. The water displacement in the measuring cylinder was considered as the volume of biogas generated. The daily readings were taken for nine weeks.

RESULTS AND DISCUSSIONS
Results
The results of the proximate analysis, pH determination and biogas production by the different substrates are presented in Tables 1 – 3.

Table 1: Proximate composition and pH of the Raw Substrates.

Parameter	Cow dung	Millet husk	Rice husk	Saw dust	Paper waste
Moisture (%)	12.00	15.00	17.00	14.00	17.00
Ash (%)	24.00	20.00	16.00	18.00	20.00
Organic matter (%)	64.00	65.00	67.00	68.00	63.00
Carbon (%)	37.12	37.70	38.86	39.44	36.54
Nitrogen (%)	1.03	0.65	0.09	0.07	0.06
pH value	6.43	6.79	6.81	6.80	6.76
C: N ratio	36.03	58.00	431.78	563.43	609.00

C: N = carbon: Nitrogen

Table 2: Proximate composition and pH of Spent Slurry.

Parameter.	Cow dung	Millet husk	Rice husk	Saw dust	Paper waste
Moisture (%)	19.00	20.00	22.00	21.00	20.00
Ash (%)	29.00	28.00	22.00	23.00	18.00
Organic matter (%)	52.00	52.00	56.00	56.00	62.00
Carbon (%)	30.16	30.16	32.48	32.48	35.96
Nitrogen (%)	1.36	0.84	0.10	0.08	0.10
pH value	6.20	6.75	6.73	6.30	6.72
C: N ratio	22.18	35.91	324.80	406.00	377.00

Table 3: Biogas production (cm^3) by substrate

Substrate	Volume of Biogas
Cow dung	8772.50 ± 155.35[a]
Millet husk	6680 ± 122.89[b]
Rice husk	1386.25 ± 11.09[c]
Saw dust	973.75 ± 22.87[d]
Paper waste	476.25 ± 20.56[e]

Values are mean ± standard deviation of four replicates.
Values with different superscripts are significantly deferent ($p < 0.05$)

The effects of slurry concentration on the levels of biogas production are presented in Figure 1.
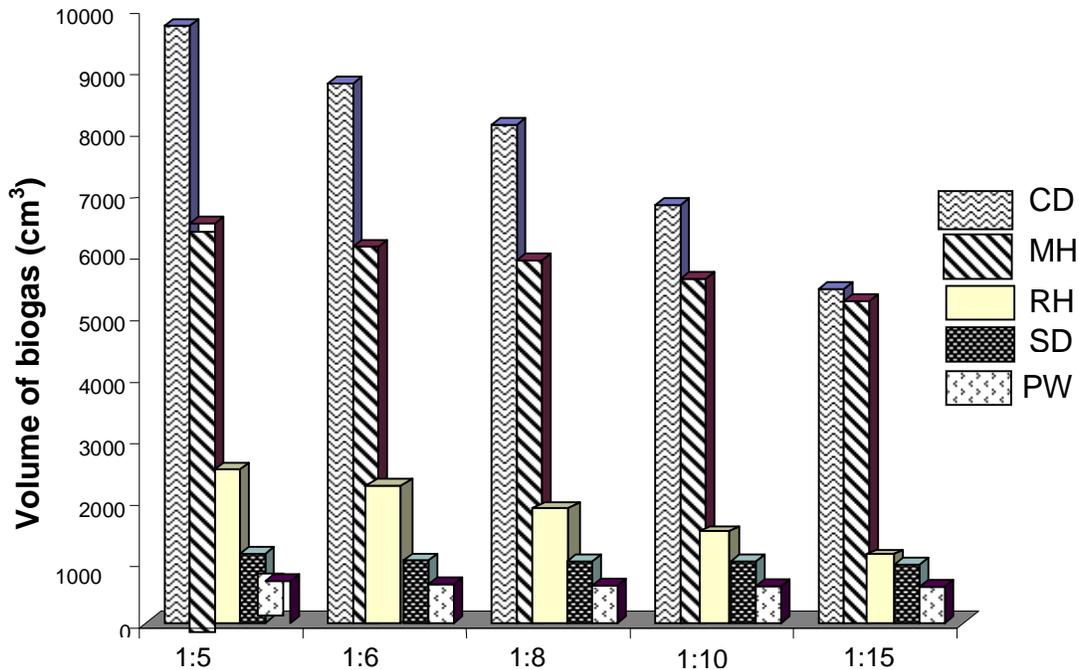

Figure1: Effects of slurry concentration on the volume of biogas production.

DISCUSSION

Moisture, Ash and Organic matter contents

The Tables 1 and 2 gave the moisture, ash and volatile solid or Organic matter content, %Carbon, %Nitrogen, pH values and C/N ratios of the fresh and spent slurries. The general trend of the two tables showed that there was an increase of all the parameters except C/N ratio, pH, C and Organic matter, which showed a general decrease from the fresh to the spent slurry. The production of biogas is a complex multistep process involving degradation of the substrates by various microorganisms under the influence of physico-chemical conditions within an anaerobic environment. The process occurs by three stages; hydrolysis of the substrate, acedogenesis and methanogenesis (Garba, 1999, Dangoggo *et al,* 2004). Hashimoto *et al.* (1988) suggested that the process consisted of four stages namely hydrolysis, acedogenesis, methanogenesis and homoacedogenesis. In either case, hydrolysis of the substrate was considered as the fist step, suggesting that all the other stages depend on the rate and extent of hydrolysis, of

the substrate (Anderson, 1979). This step undoubtedly requires the presence of water. However the higher the moisture content, the less the total solids content and hence, lower biogas production potential since biogas production is related to the amount of total solid and hence volatile solids content of the substrate.

The total solids content of the slurry means the part of the substrates remaining after the expulsion of moisture. This is made up of both the volatile solids and ash contents of the substrates. Since biogas is produced from the conversion of only the volatile solids (Organic matter) content of the substrates, it would be expected that the total solid content of the substrate to be higher than that of the spent slurry. The difference in the total solid between the substrate and its' spent slurry should therefore be directly proportional to volume of biogas generated from the substrate.

From the results it can be deduced that the values for moisture, ash, organic matter and carbon were all increased during the bioconversion process. The increase could be due to the conversion of the volatile organic matter, which was present in the fresh slurries as diluents materials.

pH of the slurries before and after digestion
Generally the pH of all the slurries before and after the digestion are found to be slightly acidic but it is apparent from the results in Tables 1 and 2 that the pH values of the spent slurries are slightly lower than those of the fresh ones. Since the acidity levels in the slurries were not too high the bioconversion of the substrates took place. The general decrease in the pH in the spent slurries as compared to the fresh ones may be attributed to formation of sulphide (S^{-2}) in the slurries due to breakdown of biodegradable sulphur containing organic and inorganic compounds and also due to the formation of fatty acids by acetogenic methanogens during the process of digestion. The acidity may also be attributable to the pH of the water used in the formation of the slurry as suggested by Ahmad (2000)

Biogas production potentials of the substrates
The biogas production process has been investigated for each of the substrates and it was observed that the highest individual production was recorded for the cow dung slurry with the average production of 8.55 dm^3. This was followed by millet husk, which gave 6.53 dm^3 of biogas. This was followed by rice husk, which ranked 3rd. Sawdust ranked 4th and paper waste 5th. The ranking order is thus as follows; cow dung > millet husk > rice husk> saw dust> paper waste. The difference in the production of biogas to a large extent depends on the nature of the substrate, since they are significantly different in their C: N ratio which may be responsible for the differences in biogas production levels, while cow dung which has a lowest C: N ratio of 36.03 had the highest biogas production (8545 cm^3). It was followed by Millet husk and Rice husk with C: N ratio of 58 and 388.60 respectively. While Paper waste and saw dust, on the other hand have high C: N ratios of 563.43 and 628.33 respectively and correspondingly had lower biogas production. From this it can be said that

biogas production potentials of any substrates is inversely proportional to the C: N ratio. In other words the higher the C: N ratio the lower biogas production potentials. The reason being, the shortage of nitrogen needed, for the cell growth of microorganisms, and also because of the fact that deficiency of nitrogen in the substrates limits bacterial activity (Garba, 1998)

Effects of slurry concentration on the volume of biogas production.
The total volume of biogas obtained from the various digesters holding different concentrations of slurries were recorded. From the results presented in Figure 1, it was found that, there is a linear increase in the volume of biogas as the concentration of the slurries increasesd, this is in line with the findings of Bankole, and Ogunkoya, (1977) and Arianne, (1985). Increasing the slurry concentration therefore enhances the production process of biogas. Figures 1, indicated also that concentration of the slurry is directly proportional to the volume of biogas produced from all the substrates, in other words there is a positive correlation between slurry concentration and volume of biogas produced. It worth mentioning here that slurries too dilute 1:25 and 1:30 did not give any appreciable yield of biogas (data not provided); these may be due to the shortage of substrates that can support microbial growth. The Digesters fed with slurries too concentrated i.e 1:2 and 1:3 did not produce biogas to any appreciable extent (data not provided), may be due the shortage of water for microbial activity or due to the formation of scum. The two extremes were both discarded since the desired trend was clearly given by the slurry concentrations of between 1: 5 and 1:15.

CONCLUSION
The following conclusions could be drawn from the results of the investigations carried out;
That all the substrates under investigation could be biodegraded under anaerobic condition to produce biogas,

That cow dung is more suitable as a substrate for biogas production compared to the rest on account of the volume of biogas produced, that slurry concentration affects the bioconversion rate of the substrate.

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