Biogas Production from Rumen, Municipal Waste and Co-Digested Substrates: An Opportunity for Small and Medium Scale Entrepreneurs (SME)

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***Abstract* - Comparative study of anaerobic digestion of rumen, municipal waste and co-digested feedstock in Minna, Niger State, Nigeria were investigated. The substrates were designated R (rumen), M (municipal waste) and R+M (mixture of both). 10kg of rumen, municipal waste and co-digested feedstock each was used in a 30 litres anaerobic digester. Each substrate was digested separately before co-digestion. The digester was loaded batch wise for 30 retention day runs up to 80% volume of the digester nominal volume. The cumulative biogas production was recorded as 181900, 217350 and 180250 ml/g VS^{-1} respectively. Methane percentage in the composition of the various biogas were 56.42, 55.81 and 58.820 % for untreated biogas samples. When treated, (scrubbed) the percentages were 84.08, 51.54 and 95.52 % respectively, as methane produced from various feedstock. Co-digested substrate has higher significant effect on production and composition of the gas produce. Additionally, the fermented manure residues from the biogas plant contain significant amounts of nitrogen, phosphorus and potassium and can thus be used as organic fertilizer for a variety of crops.**

Keywords: Anaerobic digestion, rumen, municipal waste, water scrubbing, biogas production, organic fertilizer

I. INTRODUCTION

Despite the availability of many technologically feasible sources of energy generation the Nigerian supply mix is positively skewed in favour of the dominance of thermal and other non-green sources such as fuel wood. For instance, over the period 1989-2000 fuel wood and charcoal accounted for between 32 percent and 40 percent of total energy consumption in the country. Also, current estimate put the proportion of Nigeria's rural population that relies almost entirely on fuel wood to power their cooking and other domestic operations at around 60 percent. It is well documented in literature that this pattern of consumption is not only unsustainable but also environmentally unfriendly. A need therefore, exists for the country to seek for better ways of diversifying and improving the composition of its energy source so that it can engender a more efficient supply mix [1]

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Biogas generally, describes gases released from decomposition of organic matter.

Biogas production is through anaerobic decomposition of organic matter [2]. Its production is generally viewed as a two-stage process; such as acid forming and methane forming stages [3]. In, addition, waste raise a major environmental concern both industrially and domestically, since proper disposal facilities are not available within the abattoir, residential and industrial layout of most towns and even where available, they are costly to run. However, a simple conversion of waste into fuel can be tremendously useful as renewable fuel source especially for domestic and industrial uses. When organic wastes are put in containers isolated from the outside air, conditions arise for anaerobic process. However, as long as there is oxygen inside the container, gas will not be produced. Since slurry also contains aerobic bacteria, the oxygen contained in the slurry is consumed during the aerobic reaction. Once the oxygen is used up, the anaerobic reaction commences, thus, there is a time lag between feeding the waste into the digester and production of gas [4].

Rumen is one of the slaughter house wastes that is frequently disposed into drainage system. This waste disposal system causes environmental nuisance, particularly, health hazard to human; due its content of millions microorganisms and odour. However, rumen may be useful as an activator in producing biogas through anaerobic fermentation. Since some of rumen microorganisms are cellulolitic and methanogenic bacteria. This fermentation process is similar to that in biogas digester [5]. Municipal solid waste (MSW) can be used as substrate for the biogas production too; however, not so many plants are utilizing it, due to the problems of sorting of the impurities or the problem of odour. For municipal solid waste, substrate properties can widely vary depending on its origin [6]. Climate, extent of recycling, collection frequency and cultural practices are also the factors that influence the production and composition of MSW. The municipal solid waste was collected from a refuse site, while the rumen waste was collected from central abattoir. Since waste and its disposal are major environmental concern, these simple steps could be explored to tackle the environmental problem as well as job creation for small and medium scale entrepreneurs (SME). This is an alternative way to convert waste into fuel that can be tremendously useful as renewable fuel source especially for domestic and industrial use.

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II. METHODOLOGY

Before the digestion, the following analysis were carried out on the feedstock; carbon nitrogen (C/N) ratio, dry matter content (DM), volatile fatty acid (VFA), total khjedahl nitrogen (TKN), volatile solid (VS), ammonia and ammonium ion, chemical oxygen demand (COD), total solid (TS) and pH. The following parameters; organic load, operating temperature, capacities, reactor volume, gas quantity, hydraulic retention time, gas composition analysis were tested for at the commencement of digestion.

The experimental study was conducted in a batch digester reactor of 30 litres capacity cylindrical plastic drum at an ambient environmental condition. The reactor was coupled with appropriate channel for feeding feedstock, stirring and mixing, digestate discharge and biogas collection. The reactor was seal such that it is air tight and also purge or evacuated of air. The reactor was fitted with piping, PVC 32 mm and 25 mm, sealing material of M-seal or water prove adhesive valves. The scrubber was made of a 2 litre colourless glass material, a stirrer. mechanical shaking and vibrating frequency of the digester was 2-10 seconds once daily.

Figure 1: A mini cylindrical plastic digester

A polyvinylchloride (PVC) bag was connected to the screw lock valve with gas line turned on. The valve was tightened before the bag becomes over pressurized with gas line turn off, the gas was emptied with repetition of this procedure three times to ensure purging band evacuation of air and impurities contaminant before filling of the sample bag with appropriate biogas product.

III. RESULTS AND DISCUSSIONS

The Biogas composition was analysed using a GC. The gas chromatography was Hewlett Packard 5890 Series II gas chromatography with an FID detector and forte BPX70 column (SGE analytical science) with dimensions 0.32 mm i.d. and 50 m length. The GC analysis revealed that the biogas from rumen (R), municipal waste (M) and mixture of both (R+M) contains methane, CO_2, CO, H_2S, H_2O, O_2 and trace of impurities in different negligible proportions. The chromatograms indicating the presence of methane in the three different samples are shown in Figures 2 to 4.

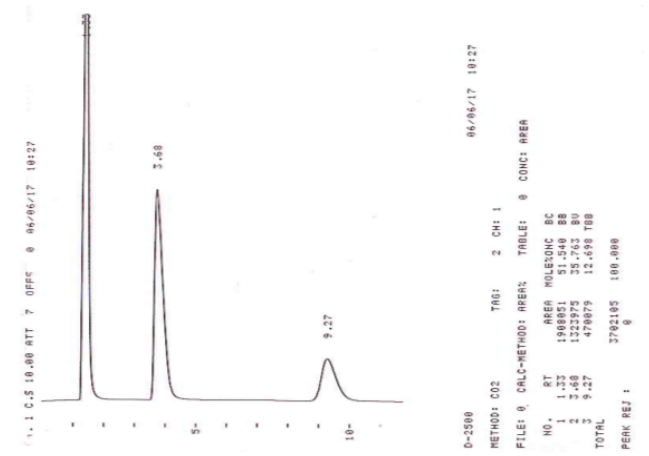

Figure 2: Chromatogram of Purified Biogas from Rumen Waste

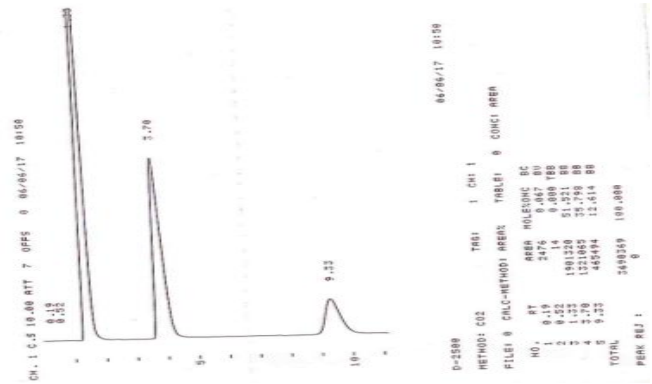

Figure 3: Chromatogram of Purified Biogas from Municipal Waste

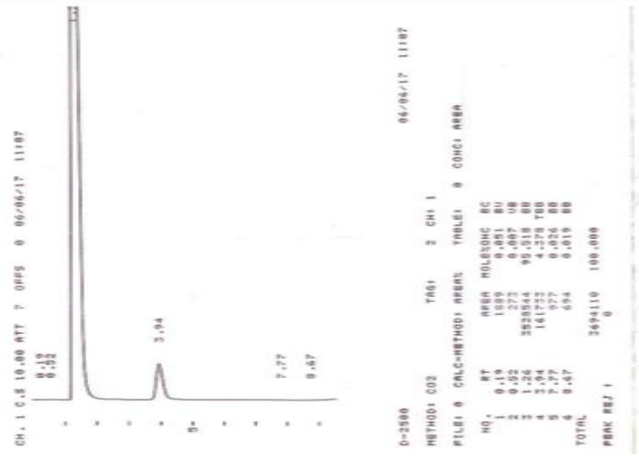

Figure 4: Chromatogram of Purified Biogas from Co-digested

Methane content present in the gas products from the three samples are summarized in the Table 2 showing the content of both scrubbed and unscrubbed samples. The samples contained 56.42 %, 55.81 % and 58.82 % methane in the rumen, municipal waste and the mixture of both respectively. Contrasting with results obtained by [7] but is in range with result reported by [8], [6] and [9]. It was

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discovered that [7] used fresh maize bract classified as higher methane content. When the produced biogas was treated, (scrubbed with water) the percentages were 84.08, 51.54 and 95.52 % respectively, as methane composition produced from various feedstock.

Table 1: Biogas Composition as Obtained from Gas Chromatography

Biogas samples	CH_4 %		CO_2 %		CO %		H_2Sppm	
	U	S	U	S	U	S	U	S
R	56.42	84.08	37.78	0.70	0.21	-	0.00	
M	55.81	51.54	33.78	1.61	0.22	-	0.00	
R+M	58.82	95.52	35.66	0.02	-	-	0.00	

U is unscrubbed; S is scrubbed

The CO_2 in the scrubbed biogas from the different samples was found to be 0.698, 1.614 and 0.019% respectively for substrate R, M and R+M. Analyzing the scrubbed sample indicated a negligible amount of H_2S in the samples within the minimum acceptable level. The use of water as scrubber was found to be an effective and economical technique in terms of cleaning and upgrading of the biogas compare to the use of chemicals.

Cumulative of 181900 ml/g.VS^{-1}, 217350 ml/g.VS^{-1} and 180250 ml/g.VS^{-1} was obtained as show in Figure 5**.** The slurry containing food waste produced higher biogas yield while the rumen and co-digested substrate had close range yield as shown in the cumulative chart. According to [10], [11] and [8], they recorded no biogas production at the initial retention time probably due to inactiveness of methanogen during their metamorphic stage undergoing growth.

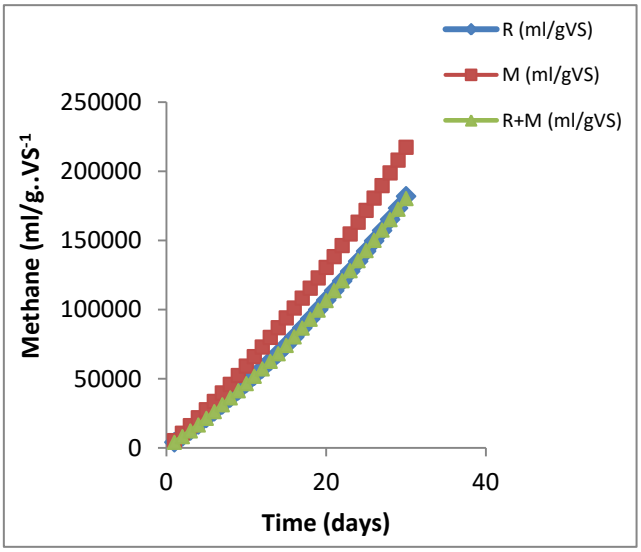

Figure 5: Cumulative biogas yield with retention time

From the initial digestion and retention time, it is generally agreed that first batch biogas production was relatively small due to acid forming and liberating volatile fatty acid resulting in declining pH and diminishing methanogen growth. Subsequently low pH deactivate methanogen responding for digestion [12].

IV. CONCLUSION

The results showed that municipal waste produced less biogas production from co-digestion with rumen waste due to preheating effect on the food wastes collected which resulted in loss of volatile solid content. But the reverse is the case with rumen having a higher methane content and burning potential of 2 days retention time. Water as the purifying solvent had the potential of treating biogas up to 95% purity methane composition with adequate, reliable and durable storage facility.

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