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Comparative Study of Mesophilic Biogas Production Potentials of Selected Agro-Wastes

Tsunatu D. Yavini[1*], Usman H. Taura[2], Nuhu Mohammed[3] And James M. Namo[3]

[1,]*Chemistry Department, Taraba State University, P.M.B 1167, Jalingo – Taraba State*
[2,]*Chemical Engineering Department, University Of Maiduguri, Maiduguri – Borno State*
[3,]*Chemical Engineering Department, Ahmadu Bello University, Zaria – Kaduna State*

ABSTRACT

Biogas production from agricultural wastes (Groundnut shell, Maize Cobs, Rice Straw and Bagasse) inoculated with cattle dung/poultry droppings was investigated. These substrates were charged into batch digesters and labeled sample A-D with the ratio of amount of total solids to water in each of the bio-digester being the same and were subjected to Anaerobic Mesophilic conditions. The biogas produced was collected by the saline water displacement method and subsequently measured. Results obtained showed that, Sample C (Rice Straw) has the highest cumulative biogas generation of 692.9ml, followed by Sample B, A and D with cumulative biogas generation of 468.7ml, 325.5ml and 185.9ml respectively, with a p^H range of 6.5 – 7.7. It could be concluded that, the inoculation of agricultural wastes with methanogenic bacteria sources have an important role and efficacy in the biogas generation quantity. Wastes recycling and biogas production requires strong governmental support to be successful in terms of environmental pollution control and management that might have resulted from the domestic disposal of these agricultural wastes.

KEYWORDS: Bagasse, Inoculums, Biogas, Rice Straw, Anaerobic, Pollution, Mesophilic

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I. INTRODUCTION:

The crisis faced globally in terms of energy utilization has generated interest in the use of agricultural waste as a substitute for fossil fuels. Agricultural wastes have a large potential as an energy source. The increase in agricultural activities resulting to increased agricultural wastes and the expansion of the renewable energy sector shows that agricultural wastes could play a vital role in future's biofuels sources. Biogas is a mixture of different gases produced as a result of the anaerobia micro-organic action on both domestic and agricultural wastes, with a composition of approximately 50% methane and other gases in relatively low proportions such as CO_2, H_2, N_2 and O_2 (Ezeomu et al, 2005; Kalia et al,2000). Anaerobic Digestion (AD) could be a good approach for agricultural waste utilization because it cannot only produce biofuels but also a residue which has been regarded as an organic fertilizer (Bio-fertilizer) with high NPK concentration (Diaz et al, 2011). The breaking down of inputs (reactants), that are complex organic materials, is achieved through a three (3) stage process as shown below:-

Hydrolysis: The waste materials of plant and animal origins consist mainly of carbohydrates, lipids, proteins and inorganic materials. The bacteria release an extra cellular enzyme which helps in the solubilization of large molecular complex substances to simpler ones. This stage is also known as Polymer breakdown stage. For instance, the cellulose consisting of polymerized glucose is broken down to dimeric, and then to monomer sugar molecules (glucose) by the action of a cellulosic bacteria.

Acidification: At this stage, the acid forming bacteria break down molecules of six atoms of carbon (glucose) into molecules of less atoms of carbon (acid), which are in a more reduced state than glucose. The simple compounds (acids) produced in this process are acetic acid, butyric acid and ethanol.

Methanization: Involves conversion of simple compounds (acids) into methane, CH_4 and carbon dioxide, CO_2 utilizing anaerobic methanogenic bacteria (Itodo and Philips, 2001), as shown by the following equations:

CH_3COOH Acetic acid	$\rightarrow$	CH_4 Methane	+	CO_2 Carbon dioxide				
$2CH_3CH_2OH$ Ethanol	+	CO_2 Carbon dioxide	$\rightarrow$	CH_4 Methane	+	2CH3COOH Acetic acid		
CO_2 Carbon dioxide	+	$4H_2$ Hydrogen	$\rightarrow$	CH4 Methane	+	$2H_2O$ Water		

Nigeria as a developing country rely on biomass, dung, straws, agricultural, animal and human power to meet their very basic needs. Hence, the need to imbibe a new technique (Biogas Technology) using some of these agricultural waste to generate gas which could be used for these basic needs, since, approximately 70% of the population of the country resides in the rural areas and will not have access to petroleum fractions such as gas, kerosene, diesel, petrol e.t.c.With the inability of our farmers to use these agricultural wastes in the appropriate ways as agricultural production increase, they are found deposited in domestic areas where it becomes sources of environmental pollution causing environmental degradation, diseases, e.t.c. Hence, these agricultural wastes can be recycled for the production of biogas which could be used as a fuel to power car, heating purposes or electricity generation (Madu and Sodeinde, 2001).Study reveals that, must agricultural wastes undergo anaerobic digestion problem, due to the presence of lignocellulose in most of them resulting to low nitrogen content (Talwage et al, 1973, Haug, 1993). Hence, to improve the digestibility and C:N ratio of most agricultural wastes, size reduction (increased surface area), pre-treatment and co-digestion with animal dung as inoculum is highly recommended to obtain an optimum gas yield.The research is objectively geared towards utilization of the abundantly available agricultural wastes (substrates) from agricultural produce found all around the country with the aim of exploring their biogas production potentials from co-digestion of the selected agro-waste with cow dung/poultry droppings as inoculums. The final aim of this study was to choose the agricultural wastes with the best biogas production potentials and compare the results for all the substrates.

II. MATERIALS AND METHODS

Substrate Collection:

The raw materials for the research were obtained as follow:

Sample A: Groundnut Shell
Sample B: Maize Cobs
Sample C: Rice Straw
Sample D: Bagasse

Sample A was collected from a Groundnut Sheller Plant at Sabon-gida Tukura, Gassol L.G.A, Sample B was obtained from a household maize thresher in Jalingo Metropolis, Sample C was collected from a rice farm along Jalingo-Wukari road (Jauro-Yinu). Sample D was collected from the local sugarcane sellers around the A.T.C Junction, Jalingo.

Proximate Analysis:

These substrates were oven dried at 75^0C for 5 hours. Then crushed mechanically to smaller sizes using mortar and pestle (≈ 1 – 4mm particles). Chemical analyses of these substrates were carried out to estimate their Total Solids (TS), Volatile Matter (VM), Carbon to Nitrogen (C:N) ratio, Ash Contents and Cellulose before the digestion process by the methods described by (APHA, 1998; Page et al, 1982 and Clescerl et al, 1985).

Apparatus /Equipment:

The apparatus used for this research were Eight (1500ml) Buckner flasks with four as the bio-digester while four for the saturated brine solution and four conical flask as collector, each contained the brine solution and was connected to a particular bio-digester by means of a connecting tube and on the other side, connected to a conical flask by another connecting tube. Other apparatus include weighing balance, thermometer (0 – 100^0C), Digital P^H meter, Oven and others for the proximate analysis. The experimental set-up is shown in Figure 1.

Experimental Design:

The set of bio-digesters (Batch Reactors) were labeled (A - D) each containing an agricultural waste inoculated with cow dung/poultry droppings as starters. A total of 27 grams of the substrates was charged into each bio-digester. Recommended water content was determined for each sample as reported by (Ituen et al, 2007). That is, Total Solid (TS) of 8% in the fermentation slurry, this was the basis for the determination of amount of water to be added for any given mass of total solid.The ratio of amount of Total Solid to water in each of the bio-digester was the same. These bio-digesters were maintained at a temperature range of 33 – 35^{0}C. The inoculums volume was kept at approximately 10% (v/v) of the reactant volume as described by (Eltawil and Belal, 2009). A 25g of cow dung/ poultry droppings was prepared by suspending it in a conical flask containing water for about 20 – 30 days at 38^{0}C to produce the enriched methanogenic bacteria to be used as a starter for the fermentation under anaerobic conditions.

Figure 1: Experimental Set-up at the Chemistry Laboratory, Taraba State University.

Burnt lime was added to each bio-digester to buffer the digesting slurry at P^H close to 7, with the P^H of each sample taken every 5 days.

The bio-digesters were set-up as described by (Itodo et al, 1992 and Membere et al, 2012) and biogas measurement was carried out by using the water displacement method in which the amount of saline water (20% NaCl (w/v), P^H = 4) displaced was proportional to the volume of biogas produced, (Figure 1).

The daily biogas generation was measured by means of the acidified water displacement method or technique to prevent the dissolution of CO_2 contained in the biogas at atmospheric pressure, since the basic end products are methane (CH_4) and carbon dioxide (CO_2).

Table 1: Physicochemical Properties of the Substrates before Anaerobic Digestion.

Substrate / **Parameters**	**Sample A**	**Sample B**	**Sample C**	**Sample D**
Total Solids (%)	92	84.38	94.43	87.10
Volatile Matter (%)	82.96	77.78	81.48	85.19
Ash Content (%)	17.03	22.22	18.52	14.82
C:N Ratio	39:1	53:1	67:1	87:1
Cellulose (%)	34.72	38.45	39.60	35.80

Table 2: Total Biogas Generation, P^H Values and Temperature Ranges for the Substrates.

Substrate	Total Biogas Generated (ml)	Mean Volume of Gas Produced (ml)	P^H Value		Temperature (^{0}C)	
			Before	**After**	**Before**	**After**
Sample A	325.5	5.92	7-6	6.8	33	32
Sample B	468.7	8.52	7.7	7.1	35	33
Sample C	692.9	12.60	7.5	7.2	33.5	33.2
Sample D	185.9	3.38	6.9	6.5	33	32

III. RESULTS AND DISCUSSIONS

The values of Total Solids (TS), Volatile Matter (VM), Ash Content, Carbon to Nitrogen ratio (C:N) and cellulose content of Sample A – D before the anaerobic digestion are presented in (Table 1). From table 1, it can be seen that, the results of these parameters showed little variation between different agricultural wastes found around the country.The C:N ratios of these agricultural wastes were beyond the optimum range of C/N ratio for biogas production under mesophilic condition, which is 25-35:1 (Maishanu et al, 1991). It has been found that, the bacteria in the digestion process use up the carbon present 30-35 times faster than the rate at which nitrogen is converted. Since nitrogen is the limiting element in the processing of the feed, additive such as manure, clean sewage-sludge (biosolids), septage and urea can be used as a supplemental nitrogen source as used in this research.Table 2 presented the results of total biogas generated with Sample C (Rice Straw) producing the highest value of biogas (692.9ml) with peak production of 23.2ml (day 24) with P^H range of 7.5 to 7.2 before and after the digestion respectively (Figure 2). This high production value was attributed to the fact that a P^H value between 7.0 and 7.2 is optimum for increased biogas yield. It was then followed by Sample B (Maize Cobs), Sample A (Groundnut Shell) and Sample D (Bagasse) with peak production of 16.8ml, 18.4ml and 17.2ml at (day 21, 16 and 17) respectively. The low total biogas production from Sample D may be attributed to the general dominance of carbohydrates material in agricultural wastes especially Bagasse at the expense of protein and lipids which have been reported by (Hobson, 1983) to be the essential precursors for methane production, major constituent of biogas.

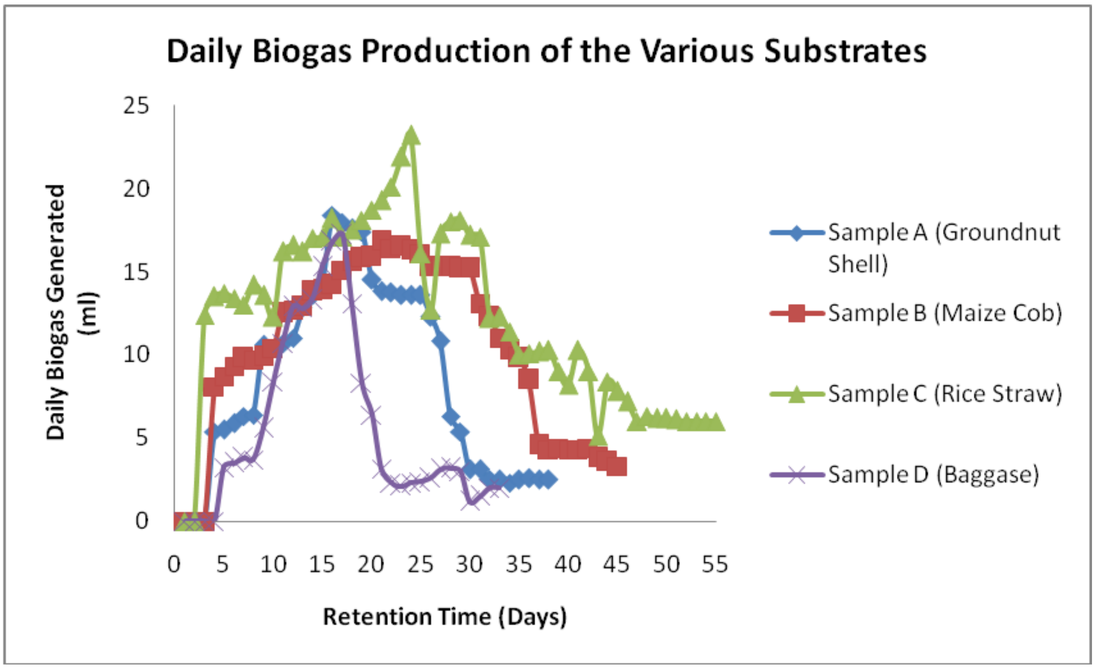

Figure 2: Daily Biogas Production of the various Substrates with their Retention time.

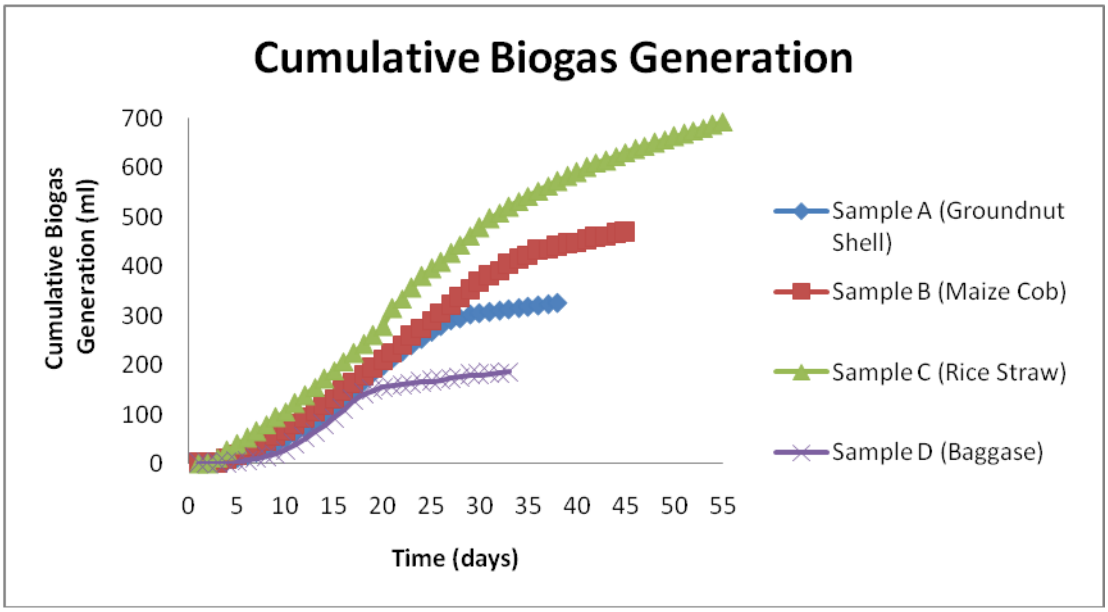

Figure 3: Cumulative Volume of Biogas Generated for the Research Period

Finally, this result indicated that the processes of biogas generation from agricultural wastes inoculated with animal manure to supplement nitrogen deficiency proceeds better than when agricultural wastes were digested alone. This forms the basis that biogas production is rarely constant, because it is susceptible to fluctuation, due to variations of loading rates, inner and outer operating conditions, possible inhibitors e.t.c (Gregor and Viktor, 2012).

IV. CONCLUSION

The overall results indicated that the low biogas generation of Sample A and D could be significantly enhanced in the presence of inoculation at the appropriate ratios with the cow dung and poultry droppings. Sample C (Rice Straw) gave the best optimum result in terms of being the first sample to start biogas production in day 3 after the set-up and a cumulative yield of biogas generated. It was observed that, stabilization of agricultural waste was obtained from co-digestion of these wastes which gives a reasonable biogas production. Therefore, from the results shown, it can be concluded that Groundnut Shell, Rice Straw, Maize Cobs and Sugarcane Bagasse which naturally would have been dumped carelessly as domestic wastes can provide an alternative feedstock for efficient biogas production. Further investigation on the kinetic study, effects of Total Solids concentration on the optimum Gas Yield will be presented on separate reports.

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