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Evaluation of the Effect of Total Solids Concentration on Biogas Yields of Agricultural Wastes

Tsunatu D. Yavini*, Azuaga I. Chia, and Agabison John
Chemistry Department, Taraba State University, P.M.B 1167, Jalingo – Taraba State,

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Abstract

Agricultural wastes (groundnut shell, maize cobs and rice straw) which are relatively found in abundance due to increase agricultural activities contain mainly of organic content, which decomposes under anaerobic conditions. Various total solids (TS) concentrations of these wastes influence on the amount of biogas generated was studied in order to determine the conditions for optimum gas generation. Five (5) sets of bio-digesters were utilized, each contains varying amount of the total solids, and biogas production was measured indirectly by the saline water displacement method. It was observed that, the amount of gas generated from these substrates decreases with decreasing and increasing the percentage total solid concentration below and above the optimum value of 9% Total Solids which gave the maximum volume of biogas generated for the three substrates to be 325ml, 468ml and 680ml respectively. The result shows that bio-digester C (Rice Straw) at PTS concentration 9% had the highest yield of biogas with cumulative volume of 680ml. Therefore, the efficiency of gas production could be seen decreased with increasing total solid concentration yielding approximately 43.2% more gas/gTS at 9% TS than 12% TS.

Keywords: Agricultural wastes, % total solids, biogas yield, organic, rice straw, anaerobic digestion.

Introduction

Agricultural wastes, when burn to produce energy directly through combustion results to only small percentage of the fuel been available, due to the use of insufficient burner. Therefore in the quest to improve the efficient utilization of its potential energy content, anaerobic digestion was discovered to produce a combustible, clean, healthy and economic gas as one of the alternative options for proper agricultural wastes utilization[1,2].

Biogas is a mixture of different gases produced as a result of the anaerobic micro-organic action on agricultural waste, 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 [3,4].

Agricultural wastes anaerobic degradation yardstick involves the presence of high lignocelluloses with low nitrogen content[5]. Thus, a high volatile solid contents of substrates may not necessary translate to high biogas yield due to the presence of non available volatile solids in form of lignin. It is important to note that the volatile matter content of any substrate accounts for the proportion of solids that is transformed into biogas[6,7]. Hence, for a successful digestion to take place, the process of co-digestion of agricultural wastes with animal manure will provide a balance between the lignin content and the carbon to nitrogen ratio[8].

The application of anaerobic digestion technology has a tremendous scope for future sustainability for both agricultural practices and environmental trends, because it represents a feasible and effective waste-stabilization method in converting solid bio-waste and agro-wastes into renewable energy with nutrient rich organic fertilizer[9].

This study presents biogas production from the anaerobic digestion of agricultural wastes groundnut shell (GS), maize cobs (MC) and Rice Straw (RS) co – digested with cow dung/poultry droppings were investigated. Percentage Total Solids (PTS), Volatile Matter Materials (VMM) effects on Specific Biogas Productivity (Gas Yield) were also investigated during the research period.

Material and Methods

Materials: Groundnut Shell (GS), Maize Cobs (MC) and Rice Straw (RS) were all obtained within the state with GS from Gassol L.G.A while MC and RS from Jalingo metropolis. Parts of these wastes were sun dried within the premises of the Chemistry Laboratory, Taraba State University and chopped into smaller pieces using mortar and pestle and kept for experimental use, while the other parts were oven dried and pounded for proximate analysis. Fresh poultry droppings was collected overnight from a domestic poultry pen at University Staff Quarters, TSU-B28 and fresh cow dung was obtained from the Animal Science Department farm, TSU-Jalingo.

Experimental Set-Up: A total of 5 sets of bio-digesters for the three substrates were set-up with varying Percentage Total Solids (PTS) of 2%, 5%, 7%, 9% and 12%. Recommended water content was determined for each sample as reported by Ituen et al[10]. The P^H of the slurry was measured every 5 days using a digital P^H meter with an accuracy of ±0.01 P^H unit. The bio-digester were set up as described by Stewart D.J. et al[11] and biogas measurement was carried out by using the water displacement method in which the amount of saline water (20% NaCl (w/v), pH = 4) displaced was proportional to the volume of biogas produced. The inoculums volume was kept at approximately 10% (v/v) of the reactant volume as described by Eltawil and Belal[12]. These bio-digesters were maintained at a temperature range of 33 – 35^{0}C.

Results and Discussion

The use of biogas also ensures that methane (gas causing the greenhouse effect) generated in agricultural wastes is retained but not emitted into the atmosphere. The ratio of the main components of biogas, CH_4 and CO_2, depends on the primary composition of the substrate and the properties of the fermentation process (temperature, duration of preservation and work load of the bio-digester). Biogas also contains small quantities of H_2, N_2, and H_2S (table 1).

Biogas production volume (ml) is expressed in table 2. This represents the measure of the biodegradation efficiency of the system. Figure 1-3 shows clearly the relationship between Gas Production/Unit Volume and Percentage Total Solids (PTS), for the agricultural wastes (GS, MC and RS) under study.

It could be deduced from the graphs that generally at low concentrations of total solids, the gas production increases steadily than at higher concentrations of total solids. But, it could be noticed also that, as the solid concentration increases above the recommended Percentage Total Solids (PTS) of 7–10% as described by Eltawil and Belal, 2009, the gas production begins to drop or falls drastically with increased amount of total solids.

Figure 4 shows the cumulative volumes of biogas generated from each of the bio-digesters; they are 14.53ml/g VM, 22.32ml/g VM and 31.5ml/g VM respectively.

Table-1
The main properties of biogas and its components (Savickas and Vrubliauskas, 1997)[13]

Property and Measurement Unit	Components				Biogas (60% CH_4 + 40% CO_2)
	CH_4	CO_2	H_2	H_2S	
Theoretical Content	55 – 70	30 – 45	<1	<3	100
Calorific Value MJ/M^3]	37.7	-	10.8	22.8	22.6
Flash Point [^{0}C]	650-750	-	530-590	290-487	650 – 750
Lower Explosive Limits [%]	5 – 15	-	4 – 74	4 – 42	6 – 12
Density [kg/m^3]	0.72	1.98	0.09	1.54	1.2
Critical Temperature [^{0}C]	- 82.5	31.0	-	100	- 82.5
Critical Pressure [MPa]	4.6	7.3	1.3	8.9	7.3 – 8.9

Table-2
Biogas production at different % total solids concentrations

TS (%)	Gas Production (ml)		
	Digester A	Digester B	Digester C
2	10.9	16.8	39.6
5	112.9	131.7	189.2
7	267	290.4	396.2
9	317.9	423.2	542.6
12	253	236	219

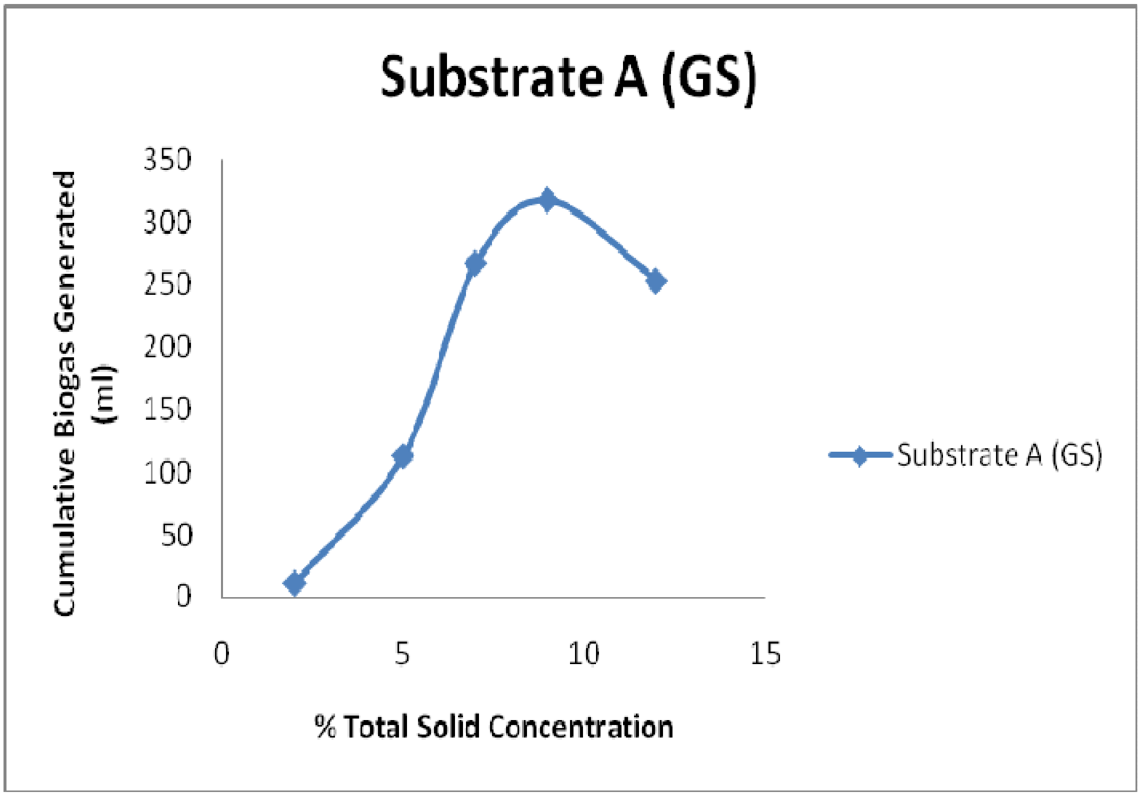

Figure-1
Variation of Volume of Biogas Generated in Bio-digester A with Percentage Total Solid Concentration

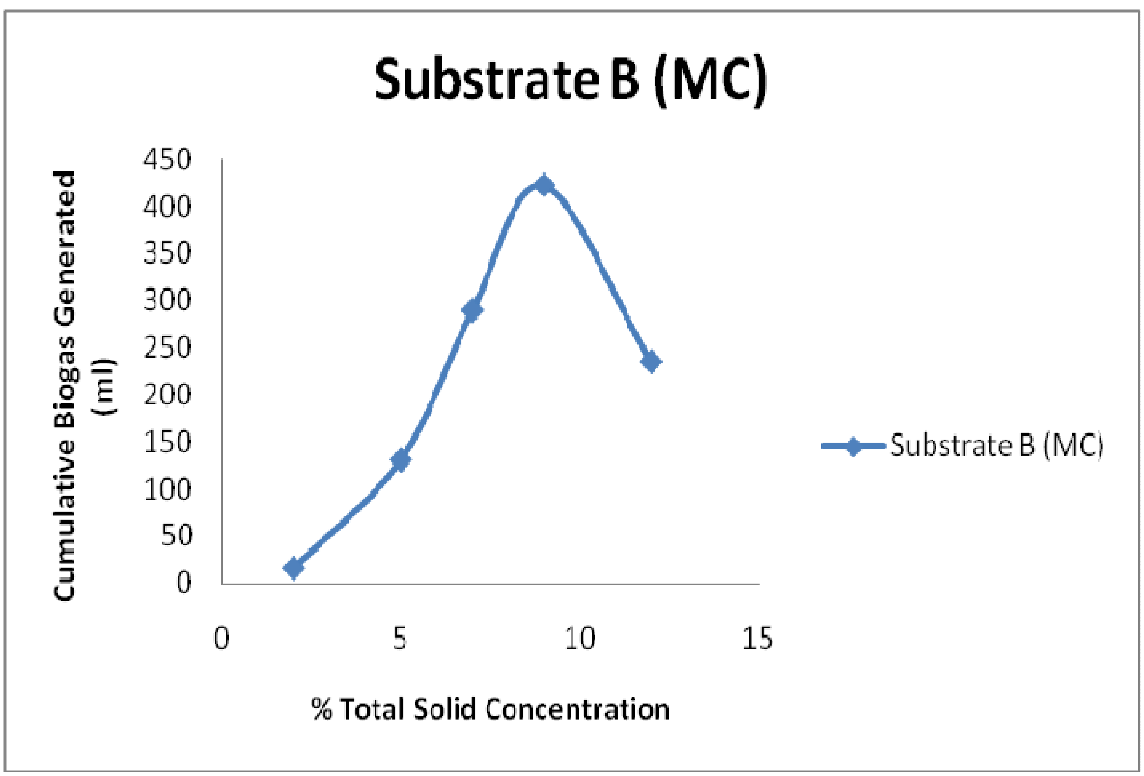

Figure-2
Variation of Volume of Biogas Generated in Bio-digester B with Percentage Total Solid Concentration

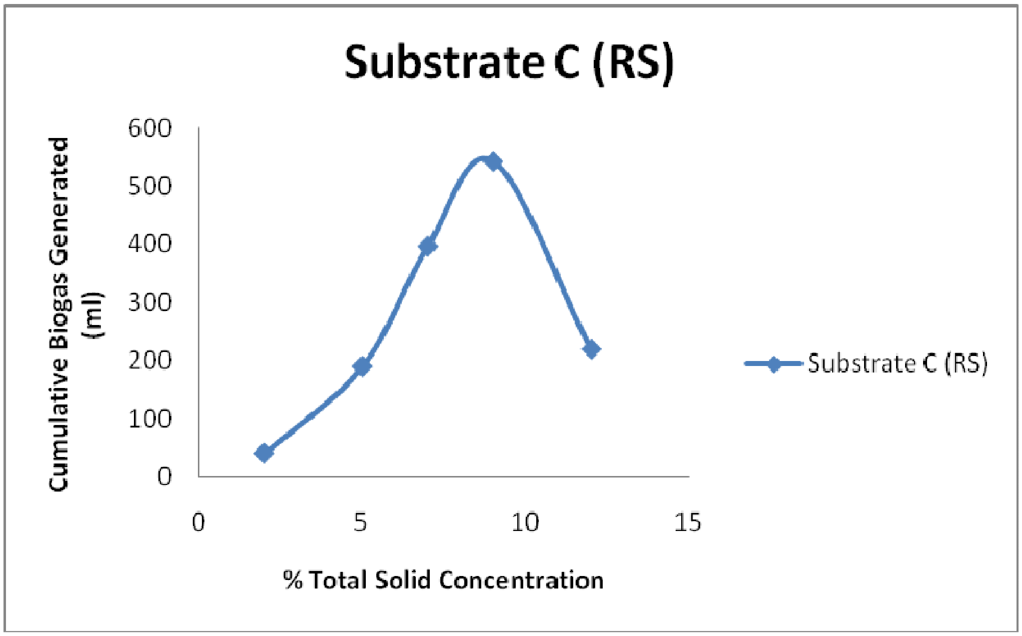

Figure-3
Variation of Volume of Biogas Generated in Bio-digester C with Percentage Total Solid Concentration

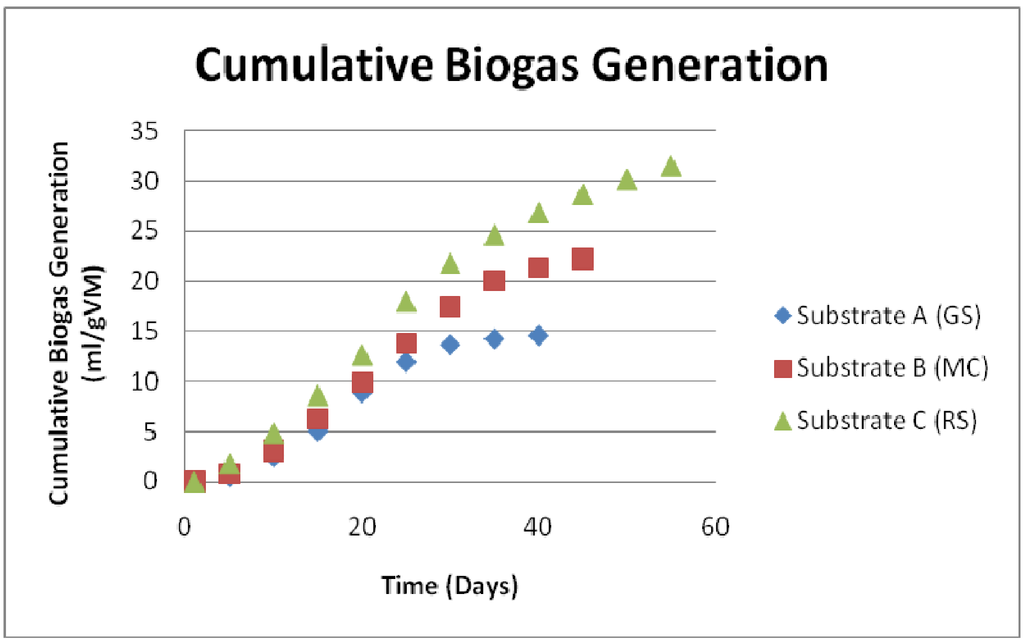

Figure-4
Comparison of Experimental Data for Cumulative Biogas Generation for Substrate A – C

The best performances in these bio-digesters are: Digester C (at TS = 9%) gave the highest volume of gas produced as can be seen at figure 3 while digester B (at TS = 9%) follows suits as shown in figure 2.

Figure 5 – 7 shows the variation of volume (ml) of gas produced with respect to the Gas Yield (ml/gVM). Being a batch system, this relationship shows that a marginal increase in the PTS results in an increase in the volume of biogas produced, suggesting that with a continues increase in PTS will result to a decrease in the volume of biogas produced, which becomes immaterial. This findings shows that, when PTS increases, the amount of water decreases, thus reducing the level of microbial activity, which then affects the amount of biogas, particularly at higher values of the PTS[14].

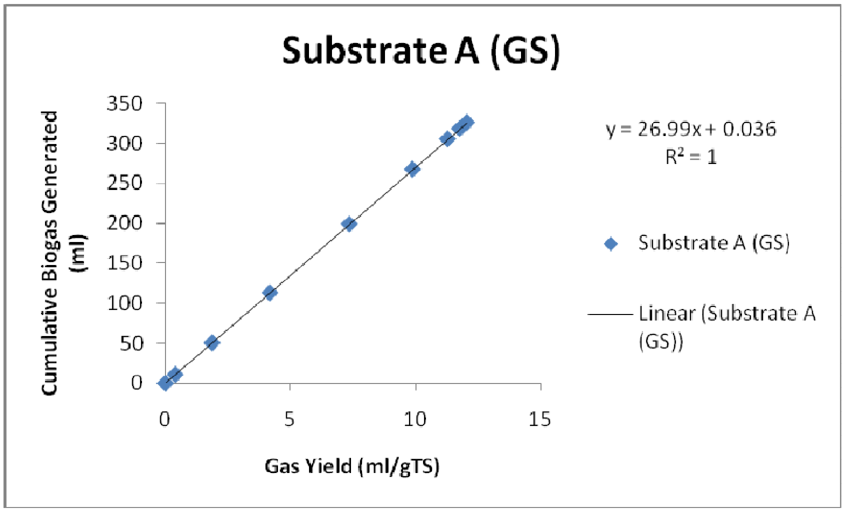

Figure-5
Variation of Volume of Biogas Generated in Bio-digester A with Gas Yield

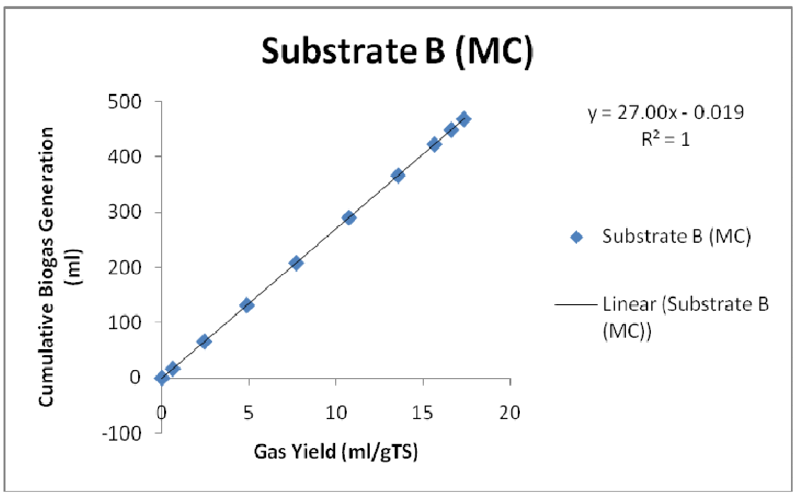

Figure-6
Variation of Volume of Biogas Generated in Bio-digester B with Gas Yield

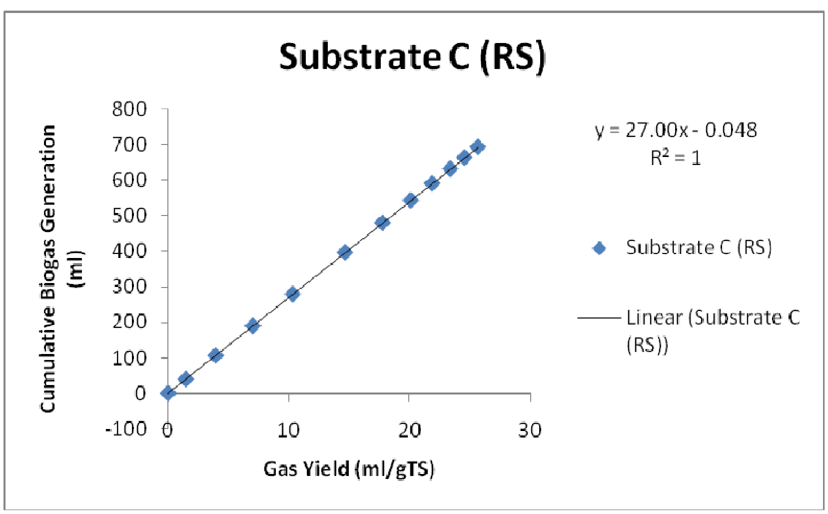

Figure-7
Variation of Volume of Biogas Generated in Bio-digester C with Gas Yield

Conclusion

The results obtained revealed that bio-digesters should be run at 9% total solids, since maximum biogas generation was obtained at this Percentage Total Solids Concentration. The graphs and charts plotted shows that on decreasing the PTS, gas production was reduced due to lack of enough substrates and when the PTS is increased beyond 9% total solids, biogas production reduces due to an increase of substrate loading. Aside, the effect of PTS concentration on the volume of biogas generated, it was found that the largest production of the biogas was obtained using rice straw when inoculated with cow dung/ poultry droppings at approximately 9% total solids. In conclusion, cow dung mixed with poultry droppings can be used as inoculums for anaerobic digestion of agricultural wastes for biogas production.

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