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RESEARCH ARTICLE

ENHANCEMENT OF LOW FLAMMABLE BIOGAS FROM MAIZE BRACT WITH BIODEGRADABLE WASTES

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ABSTRACT

The focus of the research paper is to investigate the importance of biogas as an alternate energy source. Biogas production is one of the number of tools that may be used to alieviate the problems of global warming ,energy security and waste management. Biogas fuel production from blends of biological wastes such as pumpkin pod (P), cow(C) and swine(S) dung with maize bract (M) waste was understudied. The wastes were combined in the ratio of M: P (1:1), M:C(1:1), M:S (1:1) and M:P:C(1:1:2) and charged separately into biodigester of the same capacity (20.0L). Maize bract waste alone acted as the control. Its initial experimental study gave rise to the present investigation. The blends were thereafter subjected to anaerobic digestion batch process for 35 days on the prevailing atmospheric ambient temperature and pressure conditions. cumulative biogas yield of blends (MP, MC, MS and MPC) were 7800, 11235,15140,10540 ml/10gm respectively. The lag days (waiting period before flame production from each system) were also different; maize bracts alone – 24 days, while MP, MC, MS and MPC were 15, 6, 27 and 4 days, respectively. Results also indicated increased biogas production from MS, MC and MPC systems. However, MS had lower quality biogas because of longest onset of flammable gas production (27 days). Comparison of volume of gas production from the blends with that of control using least significant differences (LSD) of means showed that gas yield was highly significant for MS,MPC and MC blends ($P<0.05$). Again, analysis of biogas produced from the blends showed that MP contained 75.9% moist methane, 4.5% O_2, 19%CO_2, 0.05% NO_2 and NO_2, MC- 79.21%, 1.75%O_2, 17.0%CO_2, 0.02%NO_2 and NOx, MS- 79.94% moist CH_2, 1% O_2, 19% CO_2, 1.03% NO_2 and NO_2 , MPC – 74.94% moist CH_2, 3% O_2, 22% CO_2, 0.03% NO_2 and NO_2. CO and NO were not found in all the blends during the analysis. Overall results indicated that the low flammable biogas from the maize bract waste could be enhanced significantly by blending with cow and swine dung.

INTRODUCTION

Biogas is a mixture produced by anaerobic bacteria (acidogens and methanogens) in the presence of little or no molecular oxygen, comprises 50-70% methane, 30-40% carbon dioxide and low amount of other gases (hydrogen, ammonia, water vapor, nitrogen, hydrogen sulfide, etc). However, the composition of the mixture depends on the source of biological waste and management of digestion process (Yadav and Hesse, 1981; Wantanee and Sureelak, 2004). Biogas production has been developed as a result of waste management, agricultural production, cooking, electricity generation, correction of impact of negative effects of climate change and transportation amongst others. Abundant and readily available biodegradable wastes have been used as inputs for flammable biogas production in many places of the world (Anonymous, 1989; Energy Commission of Nigeria, 1998, Wantanee and Sureelak, 2004, etc.), in the form of blending, chemical and biological treatments, addition of metals at the required level, etc, and these in most cases resulted to improvement in the level of gas production. Biological materials have different biochemical characteristics. Hence, their gas productions potential vary. Blending under this process may involve addition of two or more biogenic wastes provided that the growth of bacteria during digestion is favoured. It has been seen as a very cheap method of optimizing biogas fuel production since the wastes are readily and abundantly available. Manures from human beings, animals and poultry are easily biodegradable and are rich in nitrogen than those of most plants. Raw plant materials are bound up in plant cells usually strengthened with cellulose and lignin, which are difficult to biodegrade. Therefore hydrolysis of ligno- cellulose materials from plants can be a major rate determining step in anaerobic digestion process (Kozo *et al*., 1996).Most suitable plant wastes for biogas production are those rich in biodegradable carbohydrate (sugars, starch), lipids and proteins and poor in hemi- cellulose and lignin (El-bassam, 1998). Animal wastes that have been utilized in biogas production include those of cow, swine, rabbit, horses, elephant, donkeys etc, because they are better biogas producers than plant wastes such as field grasses, spent grains, straws, peels, etc (Anonymous, 1989, Anonymous, 2009a, Ofoefule *et al*., 2010). Maize bract waste is obtained as a by product resulting from consumption of freshly harvested maize cobs during maturity and harvesting period. The bracts are thrown away as garbage along street dustbins. Reports on the utilization of maize bract in biogas production is not so common but has been used in feeding cows, as a dry forage material (Anonymous, 2009b). This paper therefore, carries report on comparative study of maize bract flammable gas

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yield from blending it with biogenic wastes such as pumpkin pod (P), cow (C) and swine (S) under definite proportions of MP (1:1) MC (1:1), MS (1:1) and MPC (1:1:2).

MATERIALS AND METHODS

Fresh maize bracts were collected from the street dustbin and left for two months before its digestion. Swine dung was obtained from Veterinary farm, whereas cow dung was collected from a local market Fresh pumpkin pod was procured from a market dustbin.The biogas production is carried out in the methane reactor, a 20-litre capacity plastic bottle shown in figure1.Arrangements for feeding tubes and effluent extraction tube were so made that,they were just 3-4 cm above the bottom of the bottle.The tip of effluent extraction tube is kept lower than feeding tube.The opening of methane reactor bottle is sealed perfectly to maintain anaerobic conditions.The volume of gas produced is measured by water displacement method.The gas collecting unit consists of 1 litre capacity calibrated measuring glass jar,which is interconnected with methane reactor.The gas produced in methane reactor displaces the water in the jar into the water vessel in which the inverted jar is placed (Lalit B.Bhuyar,et al. 2009).

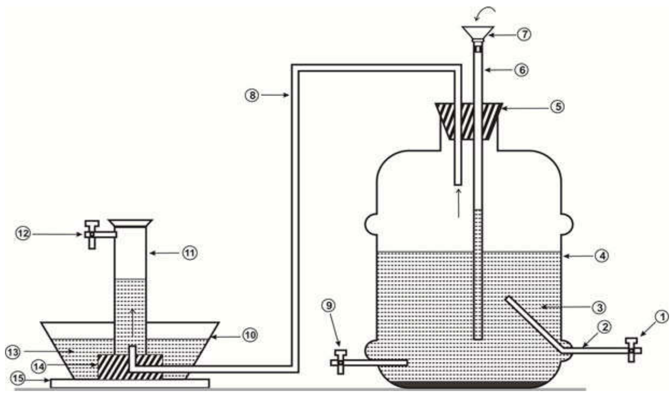
Digestion Studies

Size-reduced (3 inches) dry maize bract wastes soaked for 7 days (Fulford, 1998) was differently batch digested with one of the biodigester for 35 days followed by the degradation of the various blends (MS, MC, MP and MPC). The ratio of waste to water in each charging was 1:3 which was based on the moisture content of the organic wastes at the point of charging the biodigesters while the pH levels of the single wastes formed the basis for the blending. The waste to waste ratio were used as follows: M: C (1:1), M: S (1:1), M: P (1:1) and M: P: C (1:1:2), (Srinivasan *et al*, 1997). The M system that acted as the control was fermented anaerobically within the ambient temperature range of 23.5-38.0 ◦C whereas the variants were later digested for the same retention time (35 days) at the prevailing ambient temperature range (23.5-33.8 ◦C) and pressure conditions of the atmosphere. Flammability test was also carried out on daily basis until the system produced flammable biogas and occasionally till the end of digestion period.

Analyses of the Wastes

Physicochemical analysis: The physical and chemical compositions of the undigested wastes were determined before the digestion. Ash, moisture and fiber contents were carried out using AOAC method of 1990. Crude fat, nitrogen and protein contents were determined using Soxh let extraction and micro-Kjeldahl method described in Pearson (1976), respectively. Total carbohydrate and energy contents were obtained by use of methods in (Onwuka, 2005) while cellulose and lignin analyses were carried out using the methods of Crampton and Maynard (1938), Morrison (1972), respectively. Carbon content was done using Walkey and Black (1934) method while total and volatile solid contents were carried out using Meynell (1976) method.

Microbial analysis: The population of the microbes in each of the digester systems was determined at different times (At: charging, flammable, peak of production and end of digestion), during the period of study to monitor the growth of the microbes at the various stages. Modified Miles and Misra method described in Okore (2004) was used.



1.Supernatant removal cock 2. Supernatant removal pipe 3.Influent and feed material mixture 4. Methane reactor 5.Air tight cock 6. Feeding tube 7. Effluent feeding funnel 8.Gag pipe 9.Sludge removal cock and pipe 10.Water vessel 11.Gas collecting flask 12.Gas exit pipe 13.Water 14.Hallow gas pipe holder 15.Stand

Fig.1.Experimental setup of the biomass digester

Data analysis: The data obtained from the volume of gas production for each of the systems was subjected to analysis using Microsoft Excel XP and Gen stat software package 7.22 DE, 2008.

Gas analysis: The flammable gas from the blended systems was analyzed using Unigas 3000^+ (E Instruments Group LLC).

RESULTS AND DISCUSSION

The results of the experimental study indicated that blending of maize bract waste with the other biogenic wastes (cow and swine dung, pumpkin pod) affected the total biogas fuel yield including the onset of flammable gas production with respect to synergy that existed between each blend. Daily biogas production, an index of digester performance, from the bracts and the various blends are displayed graphically in figure 2. Biogas production from M-C and MP-C commenced within 24 h of the experimental set-up while gas production commenced on the 2nd day for M-S and M-P systems. Again, the production of flammable biogas took place at different waiting periods (lag days), (Table 2). The M system produced flammable gas on the 25th day of the digestion period with low mean gas biogas yield of 101ml/10gm/day. This may be as a result of high fiber and cellulose contents, low crude fat and protein contents and very low pH of undigested M (Table 1).Delay in pH changes pattern of M system at the initial stage of biodegradation may also have affected the onset of flammable gas production. The high fiber content indicates that M contains a lot of cellulose as shown on the table l, hemi-cellulose, pectin, lignin, plant wax etc. These structural polysaccharides are very difficult to biodegrade and can be a major rate determining step in anaerobic digestion process (Kozo *et al*., 1996). Moreover, the most suitable plant wastes for biogas production are those rich in biodegradable carbohydrates (sugars, starches), lipids and proteins but poor in hemi-cellulose, cellulose, lignin, pectin and plant wax (El-bassam, 1998). Besides, the effect of low pH on methanogenic bacteria has been confirmed by various research reports. The

Table 1: Physicochemical Properties of Undigested Pure Waste and the Blends

Parameters	M	P	C	S	MC	MS	MP	MPC
Moisture (%)	5.5	10.4	22.6	38.04	37.9	6.3	9.1	38.7
Ash (%)	18.6	8.38	42.0	40.0	5.52	12.0	7.45	5.50
Crude fiber (%)	46.0	60.2	21.3	51.1	28.0	25.2	53.3	31.9
Crude fat (%)	0.42	1.55	0.48	0.12	1.02	1.08	0.65	1.55
KjeldhaI Nitrogen (%)	0.7	0.56	1.40	1.48	0.4	0.9	1.25	0.75
Crude protein (%)	4.32	3.45	8.7	9.2	2.64	5.7	7.9	4.75
Total solid (%)	94.50	90.00	77.4	62.0	62.05	94.0	91.0	61.6
Volatile solid (%)	94.0	81.5	35.35	7.2	56.6	81.9	87.9	33.6
Carbon (%)	27.0	35.5	27.0	15.3	27.0	21.0	41.7	35.3
C/N ratio (%)	38.0	78.8	20.22	16.4	24.0	27.25	26.8	46.5
Total carbohydrate (%)	71.0	76.2	26.2	12.6	25.0	65.5	75.0	50.0
Lignin (%)	0.32	0.78	-	-	-	-	-	-
Cellulose (%)	2.0	1.32	-	-	-	-	-	-
Energy (KJ/g)	13.6	18.0	8.64	8.75	12.3	11.9	12.4	8.9
pH at charging	4.9	5.75	8.12	7.7	7.8	8.10	6.0	7.6

methanogenic bacteria which strictly survive in the absence of molecular oxygen are highly pH sensitive and survive optimally in the pH range of 6.5 to 7.5 and sometimes up to 8.5 (Anonymous, 1989; FAO/CMS, 1996). Again, the amount of carbon and nitrogen in the waste also effects the growth of the anaerobes. The carbon to nitrogen (C/N ratio) of undigested M (Table 1) was above optimum range which has been given to fall within the range of 20 to 30: 1 (Kanu, 1988, Viswanath *et al*., 1992). The mean biogas yield for the blends (MC, MS, MP and MPC) is shown in Table 2. The onset of flammable gas production for the blends also varied. The M-C., 7, M-P; 16th and M-S; 28th day, respectively. The mean biogas yield from M-S blend was highest but has longest waiting period for the flame production (27 days). This yield would have resulted from the adequate physicochemical properties of undigested blend such as total carbohydrates, crude protein, fat, volatile solid, C/N ratio, etc., which are necessary for efficient biogas production (Table 1). However, its longest waiting period for flammable gas production could be as a result of pH pattern of changes (Table 3) during the experimental period. The slightly acidic range that operated for a longer time may have delayed the growth of methanogens. The mean gas yield was followed by that of MPC system (Table 2). Result showed shortest waiting period of 4 days amongst the blends. This may be due to fairly constant pH changes between neutrality and slightly alkaline condition within the period of gas production in addition to other favourable conditions discussed above. Again, feaces from cow, a rumen animal, would have created a favourable environment that aided faster growth of methane-producing bacteria and shortest onset of flammable gas production from the system. However, higher cumulative volume of gas may come from this system if the C/N ratio of the undigested blend is within the optimum range (Table 1). The MC system also followed after MPC in high cumulative volume of flammable gas yield and shorter waiting period of 6 days (Table 2). This may be due to adequate physico-chemical properties of the undigested blend (ash, fat, C/N ratio, volatile solids, pH etc). The undigested blend also had very low crude protein and dung by other researchers as being superior in quality biogas production over other biodegradable wastes (Odeyemi, 1987). The MP system had mean gas yield of 222.8ml/gm/day and a waiting period of 15 days (Table 2) which could have resulted from very high crude fiber content of the undigested blend and dealy in low Ph changes shown in figure 5 at the initial stages of fermentation..Mean and total gas yield from pure and blended wastes are shown in figure 3 and 4 respectively.

The results of analysis of flammable gas composition from the blends are shown in (Table 3).

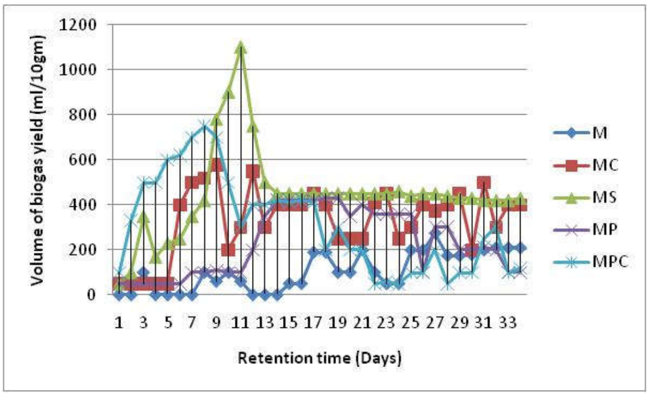


Figure 2 : Daily biogas yield for maize bracts and blends

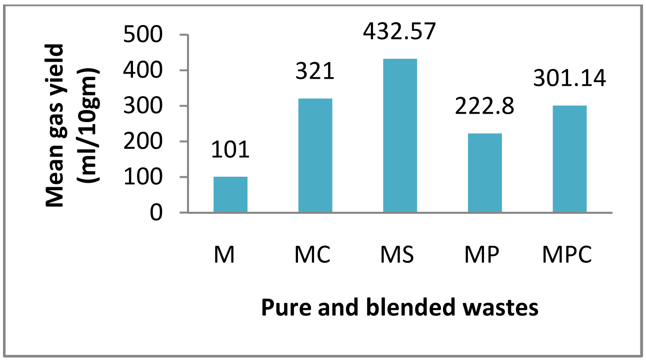


Fig. 3 : Mean gas yield from pure and blended wastes

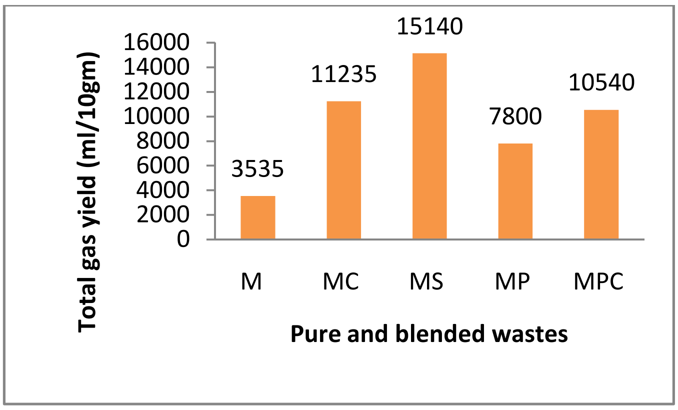


Figure 4: Total gas yield from Pure and blended wastes

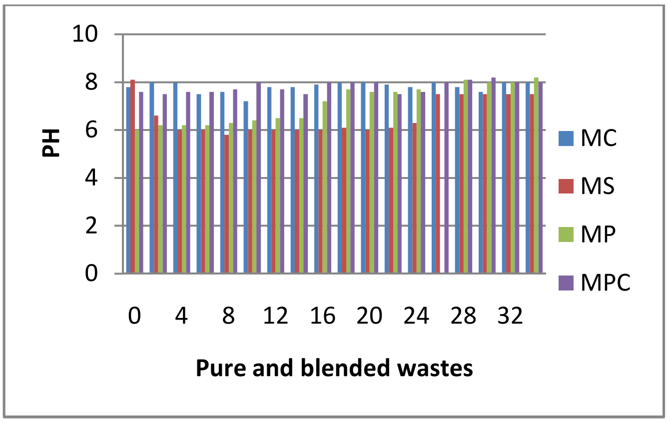


Figure 5 : PH changes at two- day interval of pure and blended wastes

Table 2: Summary of Bio digester Performances during the Experimental Period

Parameters	M	MC	MS	MP	MPC
Lag days	24	6	27	15	4
Total gas yield (ml/10gm)	3535	11235	15140	7800	10540
Mean gas yield (ml/10gm/ day)	101	321	432.5 7	222.8	301.1 4
Percentage gas yield with reference to the highest yield (%)	23.34	74.20	100	51.51	69.61

Table 3: Analysis of Component of Flammable Biogas from the Maize bract blends

Waste blends	O_2 (%)	CO (%)	CO_2 (%)	NO (%)	NO_2 (%)	NO_x (%)	Moist CH_4 (%)
MC	1.75	0.0	17.0	0.0	0.02	0.02	79.21
MS	1.0	0.0	19.0	0.0	0.03	0.03	79.94
MP	4.5	0.0	19.5	0.0	0.05	0.05	75.9
MPC	3.0	0.0	22.0	0.0	0.03	0.03	74.94

CONCLUSION

The result of this study has shown that biogas fuel yield from maize bract could be enhanced significantly by mixing it with cow, swine and pumpkin pod wastes. The maize bract-pumpkin-pod-cow blend gave the best result in onset of flammable gas production followed by maize bract-cow blend and then maize bract-pumpkin pod waste. However, maize-bract – swine blend produced highest cumulative volume of biogas fuel but had longest waiting period before flammable gas production. Overall results indicate that the low flammable biogas from maize bract waste could be enhanced significantly in the presence of cow, swine and pumpkin pod wastes. Never the less, addition of required chemicals to blends prior to digestion may lead to qualitative and quantitative biogas fuel yield from the blended wastes. Hence, maize bracts that are carelessly thrown away could be a cheap source of renewable energy for urban/rural dwellers by blending it with the dung of domestic animals that are commonly reared in the environment.

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