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Comparative Effect of Co-Digestion of Some Agricultural wastes on Biogas Yield and Some Physical Parameters

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Abstract: *A comparative study of biogas yield from mixed and mono-substrate agricultural wastes was carried out Thirteen (13) substrates as treatments A-M: 100% cowdung (A), com cob (B) aid poultry manure (C); 50/50 (w/w) of A+B (D), A+C (E), and B+C (F), 75/25 (w/w) of A+B (G), A+C (H), and B+C 0); 25/75 (w/w) of A+B (J); A+C (K), B+C (L) and 1:1:1 w/w mixtures of A+B+C treatment M were used. Slurries made by mixing 1 kg of each of these substrates with 3L of water (1:3 ration w/v) were loaded into a 13.6l locally fabricated digester. Three replicates per treatment of these batch-digestion systems were kept 8 week retention period. Initial weight of each digester and its content were taken. Parameters on mean volume of biogas produced, weight and temperature variations were determined weekly. Mean volume of biogas production and weight loss increased with digestion time and were significantly correlated except at the 7th and 8th weeks when there was a decreased in temperature. Treatments Hand B recorded the highest and lowest mean volume of biogas of 621.0ml/kg and 348.7ml/kg respectively at week 6. While single substrates (100% A, B and C) gave a mean cumulative volume of biogas of 1996.7 ml/kg, 2628.2ml/kg, 2238.8ml/kg, 2090.2ml/kg and 2200.7ml/kg were recorded for mixed substrates of 50/50%, 75/25%, 25/75% and 1:1:1 ratios respectively. At the same time the highest temperature of 44.1 ± 0.3^{0}C was recorded. Analysis of variance (ANOVA) of the parameters were significantly different (P<0.05). This technology therefore provide a means of reducing ago waste biomass which could have constituted health hazard as well as environmental pollution.*
Keywords*: Biomass, Biogas, Digesters,*

I. Introduction

The world today is faced with the challenges of supply of reliable, efficient and sustainable energy. The drivers of the current energy crisis (Energy commission of Nigeria, 2003; Oildrum 2009) have been traced to population explosion, growth in industrial and agricultural activities (Ojolo*et al*, 2007). The supply of efficient energy from non-renewable sources is currently very expensive, coupled with attendant environmental challenges arising from their continuous usage (Sambo 2005, Awogbemi and Asaolu, 2008). Biomass energy (biofuels) provide a relatively cheaper inexhaustible and sustainable alternate option out of the current energy crisis (Ndineche*et al*., 2012).

Global attention is shifted to exploit the huge potential of agricultural waste (biomass) using variable biological processes thereby realizing energy need and simultaneously addressing environmental problems consequent upon these and other players (Adelakan and Bamgboye, 2009). Organic components of municipal and solid waste (MSW) have been exploited to constitute sources of a wide range of environmental problems. These include increasing nitrate concentration and ground water pollution (Haruhisa, 2005), pathogenic microbes threatening human health (Baath and Anderson, 2003; Ilori, *et al*., 2007) as well as sources of greenhouse gases (GHGs) and global warming (Vindis*et al*., 2008; Saev, *et al*., 2009; Adewumi, *et al*., 2011)

Anaerobic digestion is a proven process of decentralized fuel supply and waste management system (Muyiiya and Kasisira, 2009). The technological processes generate a gaseous product called (biomethane) predominantly, with some traces of CO_2, and H_2S and water vapour, while the effluents are useful fertilizers.

Although some studies have been carried in this regard using different organic substrates, efforts in exploitation of cellulose agricultural crop residues and animal dungs for biogas production in Nigeria is still in its infancy (Ojolo, *et al*., 2007; Elijah, 2010; Rafiu, *et al.*, 2012; Gupta, et al., 2012). Present study focuses on the effects of co-digestion of some agricultural waste on biogas production and some physical parameters.

II. Materials And Method

The cowdung, poultry manure and maize cu used for the study were obtained from animal unit and farm of the Federal College of Forestry, Jos (9^{0}51'N and 8^{0}53'E, at an altitude of 1.158M above the sea level and a mean relative humidity of 40% (Udo, 1978; Morgan, 1979). These organic substrates were prepared by sorting (removal) of extraneous materials, and mixed in varying proportion (w/w) as shown in table 1;

Slurries of these mixtures were made by mixing with water (w/v) in a 1:3 ratio (Ojolo, *et al*., 2007) before loading into separate digesters of uniform capacity of 13.6L. The digesters were fabricated from empty cylinders of refrigerator gas compressors. It has openings for fitting thermometers and gas outlet tap. Each digester in triplicate was firmly sealed to ensure air-tightness. These were arranged in a completely randomized design, (CRD). The digesters were shaken twice daily at regular interval to free trapped gases.

Weekly variations in temperature, weight and volume of biogas produced were determined. Biogas production was measured by water displacement method (Itodo, *et al*., 2001; Anhuradha, *et al*., 2007; Adelekan and Bamgboye, 2009).

All data collected were subjected to analysis of variance to determine their level of significance, while significant means were separated using Duncan Multiple Range Test (DMRT).

III. Results And Discussion

Gas Production

There was a general increase in mean volume of gas production from week 1-6, which gradually decreased between the 7^{th} and 8^{th} week. Treatment E ((50:50)% -Cowdung:poultry) manure recorded the highest mean volume of gas of 621.0 ± 39.7ml of gas production from week 1-4 and 6-8 with a highest mean of 621.0 ± 39.7ml. Treatment B (100% corn cob) had the least mean gas production of 43.3 ± 7.6ml, 78.3 ± 6.5ml, 134.3 ± 12.1ml, 348.7 ± 20.8ml and 303.3 ± 6.1 in weeks 1, 2, 3, 6 and 7 respectively. While treatments J, L and M recorded the least values of 246.7 ± 29.3ml, 310.0 ± 50 and 128.3 ± 18.9 at weeks 4, 5 and 8 respectively (Table 2)

Nature of Substrate

Analysis of variance (ANOVA) indicated significant mean gas production throughout the retention period. Ilori*et al*., (2007) attributed the high mean gas yield to the nature of the substrates. Saev, *et al*., (2009) reported co-digestion (mixed substrate digestion) as an efficient way of converting difficult biomass to biogas as well as enhancing gas production (Adelekan and Bamgboye, (2009), pointed out that co-digestion could also help in stabilizing the C/N ratios to an optimal range of 8-45 (Goldstein, 2000). Thus accounting for the low yield observed in treatment B, J, and M with relatively higher C/N ratio (Table 3)

Weight Loss

Mean weight loss (Table 4 and 5) generally followed the same pattern observed for gas production with ANOVA indicating significant difference throughout the digestion period. The mean weight loss significantly correlated with gas production. This corroborated findings of Adelekan and Bamgboye, (2009).

Temperature

There was a steady rise in temperature (Table 6) for all treatments ranging between (28.7 ± 5 and 30.4 ± 2)^{o}C at wk 1 to between (40.5 ± 0.3 and 44.1 ± 0.3)^{o}C at wk 6. This is in line with Ilori, *et al*., (2007) and Saev, et al., (2009) who reported a thermophilic range of 30-40^{o}C and 50-60^{o}C as ideal for biogas production. They opined that the microbial consortium responsible for biomass degradation were favoured, which consequently could have necessitated the highest weight loss (Vindis, *et al*., 2008). Wu et al., (2006), reported that sudden reduction in temperature on a prolong basis would cause death and decay of methanogenic bacteria, leading to reduction in methanation. Espinosa-Solares, et al., (2010) also reported a strong correlation between temperature and specific methanogenic activity.

The high lignocellulosic fiber content of treatment B, K, and M have been adduced to their low biogas production (Ilori et al., 2007). However the microbial consortium in a mixed substrate has been responsible for lysing the complex lignocellulosic due to production of cellulosome (enzyme complexes) by cellulolytic bacteria (Careeer, *et al*., 2008).

IV. Conclusion

The biogas production is enhanced by co-digestion which provides an additional template of microbial consortium to degradation of otherwise different substrate. This technology is an ecologically and economically effective way of providing alternative energy while solving the problem of environmental degradation.

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TABLES

Table 1: Description of Treatments

Trt	Description	Ratio (w/w)
A	Cow dung	
B	Corn Cob	100%
C	Poultry Manure	
D	A+B	
E	A+C	50:50
F	B+C	
G	A+B	
H	A+C	75:25
I	B+C	
J	A+B	
K	A+C	25:75
L	B+C	
M	A+B+C	1:1:1

Table 2: Mean Gas Production (ml/wk)

Trts	Weeks One	Two	Three	Four	Five	Six	Seven	Eight	Cumm	Mean Cumm
A	66.7^{bc}	110.0^{b}	177.3^{bc}	320.7^{cde}	358.0^{b}	393.0^{b}	381.3^{cd}	272.0^{d}		
B	43.3^{a}	78.3^{a}	134.3^{a}	287.3^{bc}	321.3^{a}	348.7^{a}	303.3^{a}	196.7^{b}	5990.1	1996.7
C	93.3^{ef}	150.7^{c}	262.7^{gh}	316.3^{cde}	382.3^{bc}	423.3^{bc}	385.0^{cd}	184.3^{b}		
D	76.7^{bcde}	108.0^{b}	188.0^{cd}	328.3^{de}	421.7^{de}	519.3^{e}	437.3^{fg}	363.0^{g}		
E	98.3^{f}	176.7^{d}	280.3^{h}	345.7^{e}	447.3^{ef}	621.0^{f}	562.0^{h}	429.7^{h}	7884.6	2628.2
F	63.0^{b}	113.0^{b}	240.0^{fg}	309.7^{cd}	462.3^{fg}	512.0^{e}	418.0^{ef}	363.3^{g}		
G	77.7^{bcde}	120.7^{b}	256.3^{gh}	329.3^{de}	482.0^{g}	538.0^{e}	451.7^{g}	266.7^{d}		
H	62.0^{b}	105.0^{b}	214.0^{def}	304.7^{cd}	376.7^{bc}	415.7^{bc}	314.0^{a}	239.0^{c}	6716.5	2238.8
I	62.0^{b}	102.3^{b}	190.0^{cd}	295.0^{cd}	398.0^{cd}	442.7^{cd}	366.7^{c}	306.3^{e}		
J	73.3^{bcd}	105.3^{b}	157.0^{ab}	246.7^{a}	311.3^{a}	427.3^{c}	336.7^{b}	255.0^{cd}		
K	86.7^{def}	150.0^{c}	221.7^{ef}	315.7^{cde}	396.7^{cd}	462.3^{d}	345.3^{b}	263.3^{cd}	6270.6	2090.2
L	60.0^{ab}	108.0^{b}	193.3^{cde}	262.3^{ab}	310.0^{a}	464.0^{d}	382.7^{cd}	336.0^{f}		
M	83.0^{cdef}	114.7^{b}	196.0^{cde}	328.3^{de}	426.0^{de}	525.7^{e}	398.7^{de}	128.3^{a}	2200.7	2200.7

Means along each column bearing different superscripts are significantly different ($P < 0.05$)

Table 3: Carbon / Nitrogen Ratio

Trt	%C	%N	C/N ratio
A	35.75	1.94	18.43
B	52.99	0.49	108.14
C	37.03	2.59	14.30
D	38.94	1.35	28.84
E	31.92	2.49	12.82
F	40.22	1.71	23.52
G	43.41	1.82	23.85
H	45.33	2.12	21.38
I	39.58	0.91	43.49
J	38.94	0.85	45.81
K	51.71	2.51	20.60
L	43.41	2.20	19.73
M	60.00	0.98	61.22

Table 4: Mean Weight Loss (g/wk)

	Weeks							
Trt	**One**	**Two**	**Three**	**Four**	**Five**	**Six**	**Seven**	**Eight**
A	26.4^{ab}	37.7^{c}	83.6^{de}	109.1^{d}	61.6^{bcd}	63.8^{de}	34.3^{ab}	28.0^{a}
B	23.1^{a}	32.1^{a}	67.3^{a}	86.8^{a}	50.2^{a}	48.3^{a}	30.4^{a}	23.7^{a}
C	39.3^{d}	57.4^{f}	85.0^{e}	117.6^{e}	65.9^{d}	50.7^{ab}	43.1^{c}	34.3^{b}
D	25.7^{ab}	37.5^{c}	82.9^{de}	97.9^{bc}	50.0^{a}	52.1^{abc}	37.1^{b}	26.7^{a}
E	39.7^{d}	58.6^{f}	85.8^{e}	118.5^{e}	64.6^{cd}	66.0^{e}	37.5^{b}	27.5^{a}
F	27.8^{b}	38.1^{cd}	77.5^{bcde}	106.2^{cd}	54.4^{ab}	58.5^{cd}	36.5^{b}	27.5^{a}
G	31.5^{c}	43.5^{e}	80.7^{cde}	$107.2\pm^{d}$	55.9^{ab}	58.2^{bcd}	33.9^{ab}	26.9^{a}
H	29.4^{bc}	35.9^{ab}	67.1^{a}	106.4^{cd}	58.5^{abcd}	59.2^{cde}	34.3^{ab}	26.4^{a}
I	25.3^{ab}	35.5^{ab}	66.2^{a}	105.8^{cd}	56.2^{abc}	56.7^{bcd}	34.6^{ab}	25.4^{a}
J	26.6^{ab}	37.2^{c}	66.9^{a}	94.8^{b}	55.4^{ab}	57.7^{bcd}	34.5^{ab}	25.4^{a}
K	31.4^{c}	42.4^{de}	74.3^{abcd}	107.0^{d}	57.9^{abcd}	60.2^{de}	33.9^{ab}	24.8^{a}
L	28.6^{bc}	39.7^{cde}	71.0^{abc}	101.2^{bcd}	56.9^{abc}	58.5^{cd}	34.1^{ab}	24.7^{a}
M	28.5^{bc}	40.0^{cde}	68.9^{ab}	104.6^{cd}	55.7^{ab}	57.9^{bcd}	32.4^{ab}	24.4^{a}

Means along each column bearing different superscripts are significantly different ($P < 0.05$)

Table 5: Correlation Analysis of Gas Production (ml/wk) and Weight Loss (g/wk)

	Weeks							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Trt	**Coefficients (r)**							
A	-0.144	0.075	0.393	0.721	1.000*	0.986	-0.129	-0.13
B	0.875	0.969	0.909	0.788	0.990	0.927	0.973	0.976
C	0.882	0.485	0.326	0.477	0.404	0.840	0.830	-0.983
D	-0.500	0.159	0.686	0.641	0.452	0.287	-0.466	-0.74
E	0.991	0.466	-0.888	-0.614	-0.694	-0.604	-0.225	-0.533
F	0.928	0.996	0.998*	0.892	0.963	0.842	0.938	1.000*
G	0.980	0.795	0.996	0.924	0.992	0.997*	0.958	0.999*
H	0.985	-0.349	0.981	0.996	0.868	0.985	0.997*	0.971
I	0.983	0.986	0.864	0.988	0.881	0.915	1.000**	-0.984
J	1.000*	1.000*	0.936	0.913	0.982	0.994	0.988	0.993
K	0.972	0.998*	0.931	0.478	0.591	0.792	0.309	0.413
L	0.998*	0.997	0.967	0.998*	0.973	0.978	0.899	0.986
M	0.986	0.997	0.951	0.798	0.937	0.989	0.999*	-0.845

**. Correlation is significant at the 0.05 level (2-tailed)*
***. Correlation is significant at the 0.01 level (2-tailed)*

Table 6: Temperature Variations (^oC/wk)

Trt	**Week One**	**Two**	**Three**	**Four**	**Five**	**Six**	**Seven**	**Eight**
A	29.8±0.3	36.6±1.5	40.3±1.9	42.7±0.1	43.2±0.4	43.5±0.3	35.7±0.6	28.5±0.3
B	30.0±0.2	33.2±0.9	36.3±0.7	38.2±0.7	43.2±0.9	43.6±0.9	35.6±0.2	28.4±0.2
C	30.3±0.1	38.9±0.8	41.5±1.1	42.8±0.4	43.5±0.3	44.1±0.3	36.4±0.2	27.6±0.2
D	29.7±0.5	35.5±2.8	36.8±0.4	37.9±0.3	38.7±0.1	41.4±0.2	35.4±0.2	28.4±0.2
E	30.4±0.7	35.7±0.4	38.2±0.4	39.0±0.5	42.5±0.3	43.2±0.3	36.6±0.2	29.8±0.3
F	29.4±0.2	35.3±0.6	36.5±0.3	38.5±0.3	41.2±0.7	42.1±0.3	35.2±0.6	28.1±0.4
G	29.1±0.6	35.2±3.0	36.3±0.1	38.5±0.1	40.2±0.4	42.2±0.4	36.4±0.2	28.6±0.1
H	28.7±0.5	32.3±1.4	34.6±0.9	36.3±0.8	38.4±0.2	40.5±0.3	33.8±0.1	27.9±0.2
I	28.7±0.8	32.4±2.0	34.7±0.2	36.6±0.2	38.4±0.1	40.6±0.2	33.4±0.1	27.6±0.1
J	28.8±0.4	32.0±1.7	35.0±0.7	37.3±0.5	39.2±0.4	41.0±0.7	34.6±0.9	28.1±0.3
K	30.4±0.2	36.8±0.9	37.3±0.5	38.9±0.4	40.4±0.3	42.0±0.7	34.9±0.6	28.6±0.5
L	28.6±0.2	34.7±2.2	34.9±0.5	36.8±0.7	39.1±0.6	41.5±0.8	34.0±0.5	28.0±0.3
M	29.8±1.4	32.9±0.5	35.7±0.6	37.7±0.7	39.8±0.4	41.0±0.5	35.7±0.6	28.5±0.3

Values represent means of three replicates