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Anaerobic digestion and agricultural application of organic wastes

Leh-Togi Zobeashia S. Suanu[1], Aransiola S. Abiodun[2], Ijah U. J. Josiah[3] and Abioye O. Peter[*3]

[1]National Biotechnology Development Agency, Lugbe, Abuja, Nigeria
[2]Bioresources Development Centre, National Biotechnology Development Agency, KM 5 Ogbomoso/Iresapa Road, Onipaanu, Ogbomoso, Nigeria
[3]Department of Microbiology, Federal University of Technology, PMB 65, Minna, Nigeria

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Abstract. The anaerobically digestion and agricultural application of organic wastes was conducted using food wastes and cow dung. Twenty kilograms each of the feed stocks was added into two 30 liters-capacity batch digesters. The anaerobic digestion was carried out within a temperature range of 25-31°C for a retention time of 51 days. The results showed a cumulative gas yield of 5.0 bars for food waste and no gas production for cow dung within the retention time. Bacteria such as *Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa, Proteus vulgaris* and *Clostridium* sp were isolated. Fungi isolated included *Aspergillus niger*, *Aspergillus nidulan, Trichophyton rubrum* and *Epidermophyton flocossum.* The non-dispersive infrared (NDIR) analysis of the biogas produced confirmed that the gas consisted of CH_4, CO_2 and H_2. Statistical analysis revealed there was no significant correlation between temperature and biogas produced from the organic wastes ($r= 0.177$, $p = 0.483$).The organic wastes from the biogas production process stimulated maize growth when compared to control (soil without organic waste) and indicated maximum height. The study therefore reveals that food waste as potential substrates for biogas production has a moderate bio-fertilizer potential for improving plant growth and yield when added to soil.

Keywords: waste; biogas; digestion; methane (CH_4); carbon dioxide (CO_2)

1. Introduction

The increase in population and economic growth has led to rapid energy consumption globally (Zhang *et al.* 2014). Implementation of renewable energy becomes attractive alternative for reducing fossil fuels through the development of sustainable energy. Biogas production through anaerobic digestion is an environmental friendly process utilizing the increasing amounts of organic waste produced worldwide. A wide range of waste streams, including industrial, municipal waste, agricultural, and food industrial wastes can be treated with this technology. It offers significant advantages over many other waste treatment processes. The main product of this

*Corresponding author, Professor, E-mail: bisyem2603@yahoo.com

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treatment, i.e., the biogas, is a renewable energy resource, while the by-product, i.e., the digestate, can be utilized as fertilizer because of its high nutrient content available to plants (Ward *et al.* 2008). The performance of the anaerobic digestion process is highly dependent on the characteristics of feedstock as well as on the activity of the microorganisms involved in different degradation steps (Batstone *et al.* 2002). The conversion of organic matters into biogas can be divided in three stages: hydrolysis, acid formation, and methane production. In these different stages which are however carried out in parallel, different groups of bacteria collaborate by forming an anaerobic food chain where the products of one group will be the substrates of another group. The process proceeds efficiently if the degradation rates of the different stages are in balance (Yong *et al.* 2015). The majority of people in developing countries like Nigeria do not easily and steadily have access to advanced forms of energy such as electricity; therefore, they entirely depend on solid forms of fuels like firewood to meet their basic energy needs such as cooking. At the same time, over 60% of the total wood in developing countries is used as fuel in form of either charcoal, especially in the urban areas or as firewood mostly in the rural areas. This has resulted in depleting forests at a faster rate than they can be replaced thereby leading to a decrease in the fertility of land by soil erosion. One of the burning problems faced by the world today is management of all types of wastes and energy crisis.

These problems (shortage of energy, accumulation of waste and negative effect of chemical fertilizer) have brought about the need for an alternative eco-friendly source of energy using organic waste which automatically manages the waste and also a substitute as an organic fertilizer for agricultural crops. Anaerobic digestion and agricultural application of organic wastes settles these problems. This process of digestion utilizes organic wastes as a substrate for biogas production whereas the residue was used as bio-fertilizer for crop production.

2. Materials and methods

2.1 Collection and processing of samples

The samples (cow dung and food wastes) used in this study were collected from different locations in Abuja, Nigeria. These samples were collected in polythene bags and transported to the study site where they were processed by sorting out non-digestible material and reduction of the size of the sample using pestle and mortar (Sreekrishnan *et al.* 2004)

2.2 Slurry preparation

Ten kilograms (10 kg) each of the different organic substrates were mixed /charged into ten litres (10L) of water in the ratio of 1:1 of waste to water. The slurry was properly stirred to achieve a homogenous mixture. The initial pH and temperature of the mixture were recorded using pH meter and thermometer as described by Eckerts and Sims (1995).

2.3 Digester design

The biodigester was made of steel of 30 litres capacity with internal structure of both metallic and plastic materials. It has cast, internal gas re-injecting agitating mechanism to stimulate mixing within the reactor, temperature sensor to read the average temperature within the reactor, internal

Fig. 1 Anaerobic biodigester used for biogas production

gas agitators with regulating valves and filters, an inlet to feed the reactor and outlet to remove the digested slurry. It has gas outlet to collect the crude methane gas, pressure gauge to measure the pressure within the reactor and a highly resilient adhesive and plastic seals to prevent leakages within the reactor (Fig. 1)

2.4 Experimental procedure

Twenty kilograms (20 kg) each of the prepared feed stocks was fed into each of the two 30 liter capacity batch bio-digesters labeled A and B (A=Cow dung B= Food wastes) through the inlet and sealed properly to prevent air from entering. Anaerobic digestion of the organic wastes by organisms was allowed for a period of 51 days under mesophilic condition (temperature ranged between 25 and 37°C). Within the retention time of biogas production, temperature and the volume of biogas produced from each biodigester were monitored and recorded using thermometer and pressure guage respectively on three days interval for 51 days (modification of methods of Iyagba *et al*. (2009).

2.5 Determination of physicochemical properties of organic wastes

The method of Walkey and Black (1934) was used to determine total organic carbon. Phosphorus was determined following the method described by Bremner and Mulvaney (1982). pH was determined following the protocol described by Eckerts and Sim (1995). Nitrogen and protein were determined by the kjeldahl method (Nelson and Sommers 1996) which involved digestion, distillation and titration. Heavy metals, moisture content and macronutrients were determined using the methods described by Black (1965).

2.6 Determination of aerobic and anaerobic bacteria

Estimation of microbial populations of cow dung and food wastes was carried out by measuring

1 g each of the different substrate into 9ml tryptic soy broth for serial dilution. 0.1 ml of the serially diluted samples was inoculated on tryptic soy agar (TSA) plates using spread plate method (Cheesebrough 2006) for the isolation of bacteria. The plates for aerobic organisms were incubated aerobically in an aerobic incubator at 35°C for 24 hours while the plates for anaerobic organisms were incubated in an anaerobic jar at 28 ± 2°C for 48 hours. Distinct colonies were counted, recorded and expressed as colony forming units per gram of substrate (cfu/g). The colonies were sub-cultured repeatedly on tryptic soy agar to obtain pure isolates of bacteria. The pure cultures were maintained on agar slants for molecular characterization and identification.

2.7 Gas analysis

The methane content of the biogas was measured using non-dispersive infrared (NDIR) gas analyzer (gasboard 3100p),

2.8 Field testing of digested and undigested feed stocks as organic manure

To determine the potency of the digested and undigested feedstock as organic manure, maize seeds gotten from Gwarimpa market, Abuja, Nigeria, were planted in a depth of 3 cm flat in duplicate into seven transparent plastic buckets of 16 cm length. The buckets were filled with loamy soil to a mark of 14 cm and wet with water. Two of the buckets were labeled digested food wastes and cow dung while the other two contained undigested cow dung and food wastes and one of the buckets served as control, which was grown without the substrate. After two weeks of germination of the seeds, ten grams (10 g) each of the digested and undigested feedstock was introduced into the six buckets as fertilizer. Parameters in terms of plant height, number of leaves and length of leaves were measured using measuring tape and recorded for 10 weeks.

2.9 Effects of operational parameters

Operational parameter (temperature) was monitored using thermometer and recorded on a three days interval for 51 days to determine its effect on rate of biogas production.

3. Results and discussion

3.1 Physicochemical properties of organic wastes

Table 1 shows the physicochemical properties of the undigested and digested organic wastes. The variation in pH value is within the range of 6.8-8.0 for the development of microorganism during digestion (Sreekrishnan *et al.* 2004).

pH is an indicator of the system process of digestion (Benito *et al.* 2003). Several studies on anaerobic digestion of wastes have shown that pH of substrates had strong influence on the rate of production and yield of biogas by the substrates. The methanogenic bacteria are known to be very sensitive to pH (Khanal 2011). In this study, the undigested organic wastes had higher pH values 8.2, 8.6 for food wastes, and cow dung than the digested organic wastes which had pH of 7.4 and 7.9 for food waste and cow dung respectively. The pH ranged from 6.9 to 8.9 agrees with Hansen (2001) who reported that pH within that range is required for optimum biogas production while the

Table 1 Physicochemical properties of the undigested and digested organic waste

Parameter	Foodwaste		Cowdung	
	UDG*	DG*	UDG*	DG*
pH	8.2	7.4	8.6	7.9
Moisture (%)	71.3	95.2	65	93.8
Total solid (%)	28.7	4.79	35	6.17
Protein (%)	1.71	0.80	1.32	2.0
Nitrogen (%)	0.30	0.14	0.23	0.35
Phosphorus(ppm)	32.8	23.0	25.3	19.7
Organic carbon (%)	3.87	0.94	3.80	1.03
Organic matter (%)	6.67	1.62	6.55	1.78
Calcium (μg)	16.8	15.8	6.5	17.2
Potassium (μg)	10.4	4.97	8.99	21.5
Zinc (μg)	0.50	0.31	0.27	0.59
Iron (μg)	2.59	0.01	0.65	2.02
Sodium (μg)	16.5	14.9	16.3	13.8
Copper(μg)	0.23	0.00	0.12	0.23
Lead(μg)	-0.63	0.00	-0.79	0.00
Magnesium(μg)	26.3	1.94	18.7	1.36
Chromium(μg)	-0.15	0.00	-0.15	0.00
Manganese(μg)	0.79	7.09	0.06	4.06

UDG: Undigested, DG: Digested, %: Percentage, μg: microgram (-): Below detection level, $P < 0.05$,* Not Significant, ** Significant

decrease is attributed to the loss of ammonium through volatilization, nitrification as well as accumulation of organic acids and CO_2 resulting from intense fermentation of the substrates by the microorganisms (Banegas *et al.* 2007, Wang *et al.* 2012).

The moisture contents measured before and after digestion showed variations within a retention period of 51 days. In the cow dung the moisture increased from 65% to 93.8% and 71.3% to 95.2% in food wastes respectively. The high moisture content of food wastes is in variance with the moisture value (65-80%) recorded by Hafid *et al.* (2010). Moisture is crucial for anaerobic digestion of solid wastes, it enables movement and growth of bacteria facilitating the dissolution and transport of nutrients and reduces the limitation of mass transfer of non-homogenous or particulate substrates (Nijaguna 2002). The increase in the moisture contents of the digested organic wastes in this study might be due to reduction in total solids which connotes substrates digestion by anaerobic microorganisms and depicts system stability (Liang *et al.* 2003). The moisture content to be maintained for the degradation of organic wastes and production of biogas depends upon the type, chemical characteristics and biodegradation rate of the wastes (Nijaguna 2002).

Available phosphorus, potassium, total organic carbon and total nitrogen obtained in this study showed decrease in the digested organic wastes as compared to the undigested organic wastes. The contents of nitrogen for UFW and UCD were 0.30 and 0.23% while DFW and DCD had 0.14 and 0.35% respectively (Table 1). Phosphorus contents were 32.8 and 25.3ppm for UFW, UCD and 23.0 and 19.7 ppm for DFW and DCD respectively. The decrease in phosphorus could be due to precipitate formation as a result of its reaction with positively-charged ions such as Fe^+, Mg^+ and Ca^+ in the substrates (Sudharsan *et al.* 2013). Phosphorus is present in every living cell and very important to enhance process stability and maintain a stable operation for anaerobic digestion of solid wastes (Kayhanian and Rich 1995). The decrease in carbon and nitrogen contents of the digested wastes could be attributed to their utilization by microorganisms for proper functioning. Carbon is used as energy source and nitrogen is an essential element for amino acids, nucleic acids and protein synthesis by bacteria, which might have led to their rapid proliferation during biogas production (Sudharsan *et al.* 2013). The result therefore implies that the decrease in these macronutrients contributes to biogas yield and system stability.

The analysis of the digested and undigested wastes also indicated the presence of heavy metals (Cr, Zn,Cu, Pb), which according to Nicholas (2005), Sommers (2000) have a negative impact on plant growth, biogas yield and affect digestion by slowing down the rate of metabolism at low concentrations and poisoning or killing the organisms at high concentrations. The undigested organic wastes had higher levels of Cr, Zn, Cu, Pb than the digested. The decrease in the heavy metal concentration probably resulted from total solid reduction, organic matter decomposition and increase in moisture content or a change in other oxidizing and anionic conditions in the biodigester, which therefore increased the solubility of the heavy metals (Hsu *et al.* 2001).

3.2 Molecular characterization of bacterial isolates obtained from food waste and Cowdung

Table 2 Sequence alignment of food waste isolate with known isolates of NCBI data

Description (16SrRNA gene partial sequenced)	Max Score	Total Score	QC (%)	E V	Ident (%)	Accession
Uncultured bacteria SIBG393 N120216S B	1509	1509	96	0.0	99	LN565710.1
Pseudomonas sp CM1	1509	1509	96	0.0	99	AB757830.1
Pseudomonas sp XC1	1509	1509	96	0.0	99	JO246806.2
Pseudomonas sp A84(2010)	1509	1509	96	0.0	99	HQ433472.2
Pseudomonas formosensis strainCC-CY503	1509	1509	96	0.0	99	NR118141.1
Uncultured bacterium clone PB5	1509	1509	96	0.0	99	GU166162.1
Uncultured bacterium SIBG1506 N120216S B	1504	1504	96	0.0	99	LN565712.1
Uncultured bacteria clone Comp2-31	1504	1504	96	0.0	99	KF911195.1

EV: error value. Max: maximum, Ident: identification, QC: Query cover

Table 3 Sequence alignment of cowdung isolate with known isolates of NCBI data

Description (16SrRNA gene partially sequenced)	Max Score	Total Score	QC (%)	E value	Ident (%)	Accession
Alcaligenes faecalis strainRAJ4	1454	1454	98	0.0	98	AB795261.1
Alcaligenes faecalis VIT-RAS	1448	1448	98	0.0	98	KJ437487.1
Alcaligenes faecalis strain Fa1.3	1448	1448	98	0.0	98	KF383272.1
Alcaligenes sp MB207	1447	1447	96	0.0	99	KJ833795.1
Alcaligenes faecalis strain MB090	1447	1447	96	0.0	99	KJ833793.1
Alcaligenes faecalis strain Cu4.1	1447	1447	96	0.0	99	AB967979.1
Alcaligenes faecalis strain SS1.8	1447	1447	96	0.0	99	DC534505.1
Alcaligenes faecalis SOL-8	1447	1447	96	0.0	99	DC534504.1
Alcaligenes faecalis WM2072	1447	1447	97	0.0	98	AY548384.1

The results (Table 2) show that the sequenced nucleotides of food waste isolates had 99% alignment with *Pseudomonas* sp CMl gene for 16S rRNA gene partially sequenced, *Pseudomonas* sp A84(2010) 16S rRNA gene partially sequenced and *Pseudomonas formosensis* strain CC-CY503 gene for 16S rRNA gene partially sequenced. The biodiversity study further substantiates the absolute linear relationship of the isolate as a class of gammaproteobacteria, genus of *Pseudomona* and family of *Pseudomonodaceae* (Olapade 2013).

Table 3 shows alignment with known isolates with the sequenced nucleotides of isolate of digested cow dung. The sequenced nucleotide had 98% identity of *Alcaligene faecalis* for 16S rRNA gene partially sequenced, *Alcaligene faecalis* VIT-RAS of 16S rRNA gene partially sequenced, *Alcaligene faecalis* strain Fa1.3 for 16S rRNA gene partially sequenced, *Alcaligenes* species MB207 for 16S rRNA gene partially sequenced and other *Alcaligenes* sp. The biodiversity study in Appendix E further substantiates the relationship of the isolate as a family of Alcaligenaceae, order of *Burkolderiales* (Olapade 2013).

3.3 Biogas production

The cumulative biogas produced from the digestion of the organic wastes (food wastes and cow dung) for a retention time of 51 days is shown in Fig. 1. It was observed that the biogas production from the organic wastes increased gradually till the 51 day of the experiment except for cow dung. This probably resulted from methanogens undergoing a metamorphic growth process by consuming methane precursor (acetic acid, hydrogen and carbon dioxide) produced from the initial activities of hydrolytic and acid-forming organisms as recorded by Lalitha *et al.* (1994) and Bal *et al.* (2001). The gradual increase is also attributed to the type of fermentation system used (batch system). Biogas production rate in batch condition is directly equal to specific growth rate of methanogenic bacteria (Nopharatana and Pullammanappallil 2007) or due to the lag phase of the microbial growth (Gupta *et al.* 2007).

Biogas production increased within 4-6 days with food waste having 1.4 bars of the gas (Figure 2). Cow dung supported less biogas production in this study. This probably might have resulted from limited anaerobes/ methanogens or a decrease in pH to below 5, which could lead to significant inhibition of methanogenic bacteria (Sreekrishnan *et al.* 2004). The consequence of this is that it may result to acidic environment which is proven to be toxic for methanogenic bacteria thereby leading to eventual stoppage of biogas production at low pH (Sreekrishnan *et al.* 2004). It could also be due to improper pretreatment of the cow dung wastes, which involved sorting for undigestible material and mixing might have resulted to limited contacts between the substrates and the microorganisms. According to Nielson and Angelidaki (2008), non-removal of lignin content can lead to unavailability of cellulosic material for digestion. The non-biogas production by cow dung in this study might be attributed to the substrate used. Cows are fed with roughages, which are high in lignin (Giger-Reverdin 2002) or due to the presence of *Alcaligenes faecalis* (methanogenesis inhibitor) capable of using acetic acid as a substrate under anaerobic conditions (Joo 2006, Lu *et al.* 2011)

In this research, contrary to Ojolo *et al.* (2007), who reported high biogas potential in poultry droppings when compared to food wastes and cow dung, food wastes produced 5.0 bars (500 kPa) of biogas at a temperature of 31°C. The differences in the quantities of the biogas produced may have resulted from the difference in the bio-digestibility of the organic wastes and the concentration of total solid as suggested by Baggi *et al.* (2007). The biogas increased as total solid decreased from 28.7%, 35% for UFW, UCD to 4.79%, 6.17% for DFW, DCD respectively. The

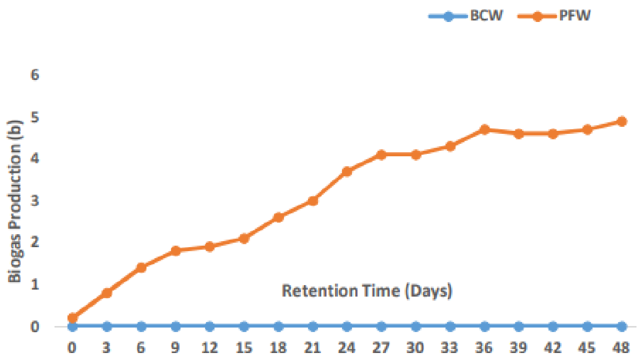

Fig. 2 Biogas productions from the organic wastes, BFW: Biogas from food wastes, BCW: Biogas from cow dung

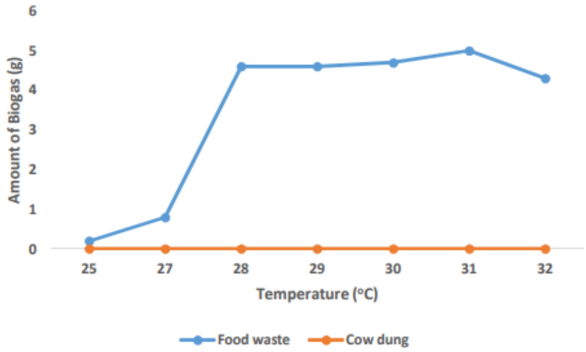

Fig. 3 Effect of temperature on biogas production

substantial drop of the total solids indicated the effectiveness of anaerobic digestion and therefore justified the report of Baggi *et al.* (2007).

From this observation, it is clear that food wastes is effective feed stocks for anaerobic digestion and could significantly enhance biogas production. It therefore shows that considerable amount of strict anaerobic and facultative anaerobes function effectively to degrade the organic fractions of these organic wastes. Although pH was not regulated/monitored during biogas production, but the pH value (6.9, 7.4 and 7.9) at the end of digestion of the organic wastes (51day), implies that all the processes involved in the production of the biogas are most likely in balanced and stable operation.

3.4 Effect of temperature on biogas production

According to Ilori *et al.* (2007), temperature is critical for anaerobic digestion, since methane-producing bacteria operate most efficiently at temperatures 30-40℃ (mesophilic) or 50-60℃ (thermophilic). In this study, the rate of biogas increased as temperature increased. The temperature of relatively below 31℃ in which this experiment was conducted could have contributed to the slow development of methanogens and consequently low biogas production. This is in line with the findings of Ilori *et al.* (2007) that the recovery time for biogas production as well as the quality and quantity of biogas produced are a function of the nature and composition of the digester feedstock (Fig. 3)

Table 4 Composition of biogas from food waste

Time(min.)	CO_2 (%)	CH_4 (%)	H_2 (%)	O_2 (%)	Caloric value (Kcal/m^3)
0.00	-	32.37	3.15	4.44	461
5.00	2.16	29.68	3.06	4.35	451
10.00	3.79	27.96	4.16	6.28	645
15.00	5.16	26.80	4.23	6.56	670
20.00	6.75	25.45	4.86	6.99	724
25.00	8.38	23.47	6.17	9.13	941
30.00	11.10	20.92	6.88	10.71	109.5
35.00	13.88	18.59	7.35	11.58	118.2
40.00	16.81	16.43	7.49	12.47	126.1
45.00	19.08	15.33	6.47	11.94	119.0
50.00	19.42	16.13	4.71	9.38	925
55.00	15.14	20.62	1.89	5.55	524
60.00	9.14	26.31	0.04	2.37	204
65.00	4.79	29.98	6.74	3.03	278

(-) below detection

Table 5 Mean value of maize plant height (cm)

Days	UFW*	UCD*	DFW**	DCD*	CTL**
12	13.2	20	20.1	26.9	5.1
24	22.1	27.4	27.7	32	9.4
36	48.3	49.5	66.8	54.6	32.5
48	76.5	65.8	83.8	65.5	51.6
60	89.7	73.9	101	74.2	57.2
68	99.3	78.7	110	76.7	59.2

UFW: undigested food wastes, UCD: undigested cow dung, DFW: digested food wastes, DCD: digested cow dung, CTL: control, $P < 0.05$, * Not Significant, ** Significant

3.5 Composition of gas generated

Characterization of the biogas generated detected CH_4, CO_2, H_2 and O_2 gases in the food wastes (Table 4). At 0.0 minute, the methane and carbon dioxide contents for food wastes was 32.37% and 0% respectively. At 65 minutes, food wastes had methane content 29.98% and 4.79% for CO_2.The highest caloric value of 941 kcal/m^3 was observed for food wastes biogas when the gas was analyzed at 25 minutes. The presence of hydrogen gas is probably attributed to the methanogenic stage of biogas production. The hydrogen gas combined with CO_2 to produce methane by hydrogenotrophic methanogens as well as the presence of high percentage of H_2-utilising methanogens (Gray 2004) while oxygen possibly ensued from atmospheric interference at the point of gas collection or the container used for collection, during transportation to the point of analysis or scrubbing before analysis. The average methane content of 38% (FW CH_4 at 0 minutes

Table 6 Mean value of leaf length (cm)

Day	UFW**	UCD**	DFW**	DCD**	CTL**
12	12.7	18.8	19.3	27.2	4.8
24	16.3	25.9	26.2	29.7	8.4
36	33	33	35.6	36.3	20.6
48	50.8	40.6	45	43.2	31.2
60	55.6	45.7	53.3	45.7	35.1
68	53.6	45.7	57.6	45.7	35.1

UFW: undigested food waste, UCD: undigested cow dung, DFW: digested food waste, DCD: digested cow dung, CTL: control, ** Significant, * not significant, $P<0.05$

Table 7 Mean value of leaf number

Day	UFW*	UCD*	DFW*	DCD*	CTL*
12	3	4	4	5	3
24	5	6	5	6	4
36	9	9	9	8	7
48	11	10	12	10	9
60	13	11	14	10	10
68	13	11	15	10	10

UFW: undigested food waste, UCD: undigested cow dung, DFW: digested food waste, DCD: digested cow dung, CTL: control, ** Significant, * not significant, $P<0.05$

divided by two) is below the range of 50-70% methane content of biogas reported by Nabuuna and Okure (2005). This probably might have resulted from the substrate used, the composition and concentration of the substrate that was fed into the biodigester, the production process or the design and operational condition of the digester (Castillo *et al.* 2006). Table 4 show the gas composition/mixture of biogas produced by food waste.

3.6 Field testing of digested and undigested feed stocks as organic manure

This is to show potency of the organic wastes as an organic manure to grow maize crop. Organic manure is a key component of soil fertility, plant growth and crop yield (Hammad 2011). In this research, food wastes and cow dung were used as organic manure to promote maize growth.

The results (Table 5) indicated that at day 68, UFW, UCD, DFW and DCD had plant height of 99.3 cm, 78.7 cm, 110 cm, 76.7 cm respectively, when compared to control that had 59.2 cm. DFW and UFW had the tallest plant (Table 5), leaf length (Table 6) and number of leaves (Table 7) compared to UCD, DCD and CTL, which may be attributed to plant population density.

Low plant population density results in increased number of leaves while plant height decreased with number of plants population (Ali *et al.* 1996, Morrisson *et al.* 1990). According to Tollenaar *et al.* (1990), high plant population increase stem lodging and such cases represent intense interplant competition for soil nutrient and soil water. DFW and UFW had moisture content of 95.2 and 71.3% (Table 1) respectively, which probably justifies the plant height, leaf length and number since moisture transports nutrient from the soil up to stems and leaves

(Tollenaar *et al.* 1997).

In this study, UCD propagated late while UFW and DFW tasseled late, which probably justifies the plant height since maize plants stop growing taller when they start developing tassel (Nielsen 2007).

4. Conclusions

The results of this research on anaerobic digestion and agricultural application of organic wastes have shown that biogas can be produced through anaerobic digestion. It clearly revealed that food wastes could serve as a suitable substrate for biogas production. The utilization of this substrate for biogas production could eliminate its disposal problems and create another abundant source of sustainable energy. Apart from biogas, the result of the study also showed that the remaining slurry in the bio-digester after digestion was rich in nutrients that can be used to improve agricultural soil for crop production. The use of these organic wastes as manure completely waive off external costs incurred due to investment in chemical fertilizers, pesticides, nutrient runoff and a number of health issues that result from agro-chemical residues.

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