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Characterization of Sludge from a Biogas Reactor for the Application Bio-Fertilizer

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***Abstract*—*Biogas reactor or anaerobic digester was an anaerobic treatment technology that produces (a) a digested slurry (digestate) that can be used as a fertilizer. Anaerobic digestion was applauded as one of the best ways to properly handle and manage these wastes. Animal wastes and peal and leaf of fruit and vegetable have been recognized as suitable substrates for anaerobic digestion process, a natural biological process in which complex organic materials were broken down into simpler molecules in the absence of oxygen.*

***Keywords*—** *Biomass, animal wastes, anaerobic digestion, biodigester, public health. biogas, sludge, bio-slurry, fruit and vegetable, biofertilizer.*

I. INTRODUCTION

In anaerobic digester, due to the action of methanogenic microbes the complex organic molecules were broken down in multiple steps and finally biogas and bio fertilizer was generated as the end product. The composition of biogas slurry (Composted organic fertilizer) comprised of moisture content, organic carbon, potassium, nitrogen, phosphorus etc. in the percentage of 40.21, 11.77, 0.33, 0.71 and 0.43 respectively with the C: N ratio of 17:1. The organic waste without composting will have the C: N ratio in the range of 20:1.

Organic and inorganic substances were necessary for anaerobic digestion process. Very low metal concentrations may make the anaerobic degradation process inefficient [20]; but, above a certain threshold level it can be inhibitory. An average COD/N/P ratio of 600/7/1 can be recommended for substrates to be anaerobically digested [4]. Alphernaar et al. (1993) suggested a minimum C: N: P ratio of 100:28:6 [1]. Waste material that was low in C can be combined with materials high in N to attain desired C: N ratio [27]. Presently there was no universal recommendation for nutrient concentrations that can be given because they are strongly dependent on the actual circumstances at which the AD was performed [18].

Co-digestion in the anaerobic digestion process improves nutrient balance of total organic carbon, nitrogen and phosphorus, and buffer capacity of the substrates which results in a stable and maintainable digestion process and good fertilizer quality [16, 17, 30,28] and has economic advantages in the possibilities of utilizing digesters in sewage treatment plants, and other organic waste as co-substrates [29, 2].

During digestion, about 25-30% of the total dry matter (total solids content of fresh dung) of animal/human wastes will be converted into a combustible gas and a residue of 70-75% of the total solids content of the fresh dung comes out as sludge which was known as digested slurry or biogas slurry(4**)**. Biogas and bioslurry offer several benefits by improving fertilizer qualities, reducing odors and pathogens and providing renewable energy and fuel (8). The composition of bioslurry depends upon several factors: the kind of dung (animal, human, or other feedstock), water, breeds and ages of the animals, types of feed and feeding rates (9).

A major limitation of anaerobic digestion of fruit and vegetable wastes were the rapid acidification due to the lower pH of wastes and the larger production of volatile fatty acids (VFA), which reduce the methanogenic activity of the reactor. The rate limiting step in fruit and vegetable wastes were methanogenesis rather than hydrolysis because methanogenic bacteria take long mass doubling time of 3-4 days in anaerobic reactors (6). There were different types of reactors used for the bioenergy recovery from solid wastes like fruit and vegetable

The mixture of fruit and vegetable, dung and water which enters the biogas plant in semi liquid form was called "undigested slurry." The undigested slurry undergoes a series of anaerobic digestion processes or fermentation in a biogas digester and is converted into combustible gas called "biogas." The residue of the fermentation came out as sludge which was known as "digested bio-slurry." A biogas reactor is an airtight chamber that facilitates the anaerobic degradation of blackwater, sludge, and/or biodegradable waste (e.g. animal manure, fruit and vegetable wastes). It also facilitated the collection of the biogas, a mixture of methane (CH_4) and carbon dioxide (CO_2) produced in the fermentation processes in the reactor. The gas forms in the slurry and collected at the top of the chamber, mixing the slurry as it rises. The digestate was rich in organics and nutrients, almost odorless and pathogens are partly inactivated.

II. MATERIAL AND METHODS

2.1. Design Considerations

Anaerobic digestion was a biological process, which was carried out by a special mix of bacteria. When the reactors first are installed, it may take some time until the specific biogas producing bacterial community has installed. It can help to seed the reactor with anaerobic sludge an anaerobic digester.

Anaerobic digestion only removed organics, and the main mineral material and almost all nutrients remain in the bottom sludge. Almost 100 % of the phosphorus and about 50 to 70 %

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of the nitrogen as ammonium was still found in the digested sludge (11). Therefore, the secondary product compost from biogas reactors was a valuable resource for food production. Generally, in a well-functioning and designed biogas digester, the pathogen removal in the slurry is sufficient so the treated sludge can be reused for soil fertilization. To increase the safety, it may be aerobically composted (or processed in a sludge drying or humification bed) before reuse.

A biogas digester consisted of one or more airtight reservoirs (chambers) into which animal manure or a mixture of manure and co-substrate was placed, either in batches or by continuous feed. These biogas generating systems could be categorized on the basis of the number of reactors used into single (one) stage or multi (two) stage and on the mode of feeding into continuous and batch feeding systems.

2.2. Composition of Bio-Slurry

The composition of bio-slurry depended on the feeding and the amount of water added to the dung and fruit and vegetable. When the dung and fruit and vegetable were mixed with equal amounts of water, after digestion the composition of slurry was recorded as: water 93% and dry matter 7%. The Nitrogen (N), Phosphorus (P) and Potassium (K) were the most required nutrients to the plants. NPK content in liquid slurry was 0.25%, 0.13% and 0.12% respectively.

2.3. Characteristics of Digested Bio-Slurry

Being fully fermented, bio-slurry was odorless and does not attract flies. Bio-slurry repelled termites and pests that were attracted to raw dung and raw fruit and vegetable. Bio-slurry reduced weed growth. Application of bio-slurry has proved to reduce weed growth by up to 50%. Bio-slurry was an excellent soil conditioner, adds humus, and enhances the soil's capacity to retain water. Bio-slurry was pathogen-free. The fermentation of dung and fruit and vegetable in the reactor kills organisms causing plant disease.

2.4. Proper utilization of Bio-Slurry

All major plant nutrients (such as NPK) were preserved during fermentation process so that plants can immediately absorb these nutrients. It can also be applied as ready-to-use manure. After being stored for a few days or mixed in a 1:1 composition with water; bio-slurry can be applied directly to vegetables or fruit crops around the household. Bio-slurry application along with installation of regular irrigation channels was beneficial for the growth of vegetables especially root vegetables, paddy, sugarcane, fruit trees, and nursery saplings. Mushroom cultivations also benefits greatly from bio-slurry application. Dried digested slurry has great potential to be used as feed supplement for cattle, pigs, poultry, and fish.

2.5. Carbon to Nitrogen Ratio (C/N)

After determining the total solid and volatile solid the carbon and nitrogen ratio was measured.

2.6. Organic carbon (OC) Determination

The OC was determined using the volatile solid data and employing the formula:- %OC= MDS-M(ASH)/1.72MDS*100%, Where 1.72 = the factor parameter

2.7. Nitrogen Determination

The Kjeldahl procedure was employed to determine the total nitrogen content of the feedstocks. 2 g of dried samples of each of FVW and cow dung were placed in a digestion tube with 15 ml of concentrated sulfuric acid. 7 g of potassium sulphate and copper were then added. The digestion tube was placed into a digestion block where it was heated at 37^0C. Sodium hydroxide was added to change ammonium ion to ammonia in the digestate, and the nitrogen was separated by distilling the ammonia and collecting the distillate in 0.1 N sulfuric acid solutions. Determination of the amount of nitrogen on the condensate flask was done by titration of the ammonia with a standard solution of 0.1 N sodium hydroxide in the presence of methyl red indicator and 0.1 N sulfuric acid solutions. Finally, the amount of nitrogen present was calculated:-%N=(14.01*(ml titrant-ml blank)-(N of titrant)/Sample wt*1000)*100%, Where N=Normal concentration, finally, the ratio of carbon to nitrogen was calculated :-%C/%N

2.8. Set up of the Experiment

The experimental set up for the study using batch digestion consists of amber glass bottle with a plastic cover. All the fifteen anaerobic digesters were constructed at bench-scale experiments at where the degradation of the fruit, vegetable and cow dung was accomplished in sealed serum bottles with a capacity of 2.5 liters. Each bottle was sealed with its cover having two outlets. The first outlet was attached to an 8 mm internal diameter hose gas pipe and immersed up to a little above the bottom of the solution level in order to take samples without introducing air into the digester and indicate the quantity of gas produced inside the digester. Thus, a plastic tube was extended from the bottom of the substrate up to the plastic tube cover to prevent out flow of the substrate from the inside of the digester. The second outlet was above the top of the solution for gas collection. The whole cover and the hose gas pipe were sealed with gasket to protect air leakage from the environment.

Figure 3.1 Set up of the experiment of biogas production and the residue of the feedstock used as bio-fertilizer.

3.2. Data Analysis

Between November 2011 and June 2012; The study was carried out in order to assemble data using methods of fruit and vegetable organic waste laboratory analysis, physical and operational properties measurement, observation and other important physical activities in 9 month study period was done performance of fruit and vegetable organic waste production of biogas if variation of seasons was not considered.

The mean, standard error of the mean for average biogas yield and methane percentage of the replications of five treatments, F-test. In addition, the NPK values of the slurry of cow dung were compared with other treatments using a bar chart.

III. Results

3.1. Characterization of Feed Stocks

The TS and VS content of both FVW and cow dung were determined with three replications and their average values

Table 1:- Fresh FVW characteristics of feedstock.

Parameters	Cow Dung (%)	FVW (%)
Moisture Content	81.76	21.15
TS	18.24	78.85
VS as Percentage of TS	92.02	90.602
Ash as Percentage of TS	43.72	11.11
OC	26.37	52.21
TN	.08	1.56
C/N	330:1	33:1
pH	5.18	4.98

As it was seen from Table 1, the total solid content of FVW for TS, VS and ash (fixed solid) of the substrate were, 78.85%, 90.602% and 11.11% respectively. The TS value of FVW was higher than Chat waste (29.35%) as reported by Tesfaye (26), and the VS content value 90.602% is more than the range of 75-80% stated by Steffen et al. (25). This shown that large fraction of FVW is biodegradable and thus it can serve as an important feedstock for biofertilizer production. For cow dung the TS was 18.24% within the range of 18-20% as reported by Rai (22), the VS as percentage of TS is 92.02% and fixed solid as percentage of TS is 43.72%. The carbon to nitrogen ratio (C/N) of the feed stocks is another factor that affects the anaerobic digestion process. Bio-fertilizer yield and its production rates are highly influenced by the balance of carbon and nitrogen in the feeding material. The nitrogen content of FVW was 1.56 which was by far higher than the expected value as most fruit and vegetable matter contains lower nitrogen (higher C/N ratio). The C/N ratio of FVW and cow dung was 33:1 and 330:1, respectively which agree with Pyle (21) which recommended for an anaerobic digester a value of 10 to 30 and C/N ratio of night soil, cow manure, chicken manure, bagasse, wheat straw, oat straw and saw dust were 6 to 10, 18, 8, 150, 150, 48 and 200 to 500. This shows that FVW could serve as a substrate for biogas production even without mixing it with cow dung or other animal and human waste provided that it is available in the area. For the mixture treatments of these substrates, the possible ratio is still around 33:1. Thus, in both substrates the balance of carbon and nitrogen is good for the bacteria so that both could be used (their combination or each alone) for anaerobic digestion to produce biofertilizer for the sludge of biogas.

3.3. Solids Removal and Biogas yield in the Reactor

The Total solids in the feedstock and in the residue were 3.504g and 1.374g respectively. The removal efficiency of Total solids was 60.77%. The Volatile solids in the feedstock and in the residue were 2.701g and 0.848g respectively. The removal efficiency of Volatile solids was 68.6%.

3.4. pH and Nutrient Values of the Slurry

One advantage of anaerobic digestion was the use of the slurry as organic fertilizer. As a result, the pH and the macro-nutrients for the slurry of treatments, T_1 (cow dung alone), T_4 (3:1) and T_5 (FVW alone) were determined and it was found that 6.37, 5.95 and 5.94 respectively. The pH of the slurry of cow dung alone (T_1), 6.37, was similar to 6.3 as reported by Fokhrul (7). The pH of the slurry of T_5 (FVW alone) and T_4 (3:1) were lower than T_1 (cow dung alone), and the values in the three treatments were between the minimum and maximum accepted values of 6.0 and 8.5, respectively (7).

Table 2:- Nutrient from fresh and slurry sample.

Substance	pH	Average (cmol+)/kg sample	Average (cmol+)/kg sample.	%TN	%TS
Fresh cow dung	5.18	-	-	0.08	18.24
Fresh FVW	4.98	-	-	1.56	78.85
T_1(100) CD	6.07	2.17	367.5	0.11	1.38
T_2(25FVW:75CD)	4.85	3.07	198	0.08	0.67
T_3(50FVW:50CD	4.58	3.39	152	0.08	0.68
T_4(75FVW:25 CD)	4.49	6.20	112	0.1	0.19
T_5(100 FVW)	3.67	4.35	95.40	0.08	1.56

3.5. Determination of Macro-Nutrients of the Slurry

Following the completion of gas production the NPK value of the slurry of treatments that shown relatively maximum biogas production. The comparison from previous studied the amount of plant nutrients excreted with urine per person per year has been reported as 2.5-4.3 kg nitrogen, 0.4-1.0 kg phosphorus and 0.9-1.0 kg potassium [10]. About 50% of the N and majority of the K in fresh faeces were water soluble, while P is primarily found as calcium phosphate particles that are slowly soluble in water [15].market waste [19], fruit and vegetable [4], household waste [23], food waste [24], kitchen waste [25], biowaste [12] and organic fraction of municipal solid waste (OFMSW) [3]. From Now my study was T1 (for the purpose of comparison) was determined. The procedure for the determination of TN was mentioned above. For the determination of available potassium and phosphorus the following procedures were followed. 35 ml of each sample material was mixed with 200 ml of 0.05 M of calcium acetate, 0.05 M of calcium lactate and 0.3 M of acetic acid solution and was buffered to pH of 6.58. After it had been shaken for two hours, the solution was filtered and then, phosphorus and potassium were determined by spectrophotometer and flame photometer, respectively. Finally, their values were calculated in mg/L, Available nutrient (mg/l)=IR (mg/l)*EV(l)*DF/sample of volume(l),Where: IR= Instrument

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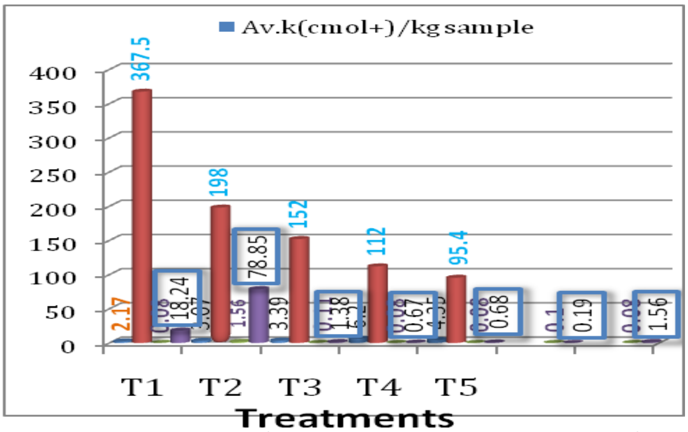
Reading, EV= Extract Volume, DF= Dilution Factor, The pH value of each of the samples was determined by using a potentiometer.

As it can be seen from graph 3 the macro-nutrients of treatments of FVW (T_5) next better in potassium than T_4 were higher than cow dung alone except that of the available phosphorus which was lowest for FVW alone. T_1 was highest in pH (near neutral), medium in TN and low available K, and highest in available phosphorus. Thus can be considered as an alternative to chemical fertilizer. Thus, use of the 1:3 ratios of cow dung and FVW could provide better potassium than T_1. Thus, use of the 1:3 ratios of cow dung and FVW (T_4) could provide better fertility fertilizer for potassium and T_1 for phosphorus production.



Graph 3:- Nutrient Status of some selected treatments and the values of the macro-nutrients.

IV. Conclusions and Recommendations

4.1. Conclusions

From the laboratory result, the VS content of the FVW was 92.602% of the TS. This shown that a large fraction of the fruit and vegetables was biodegradable. This implied that fruit and vegetables can serve as an important feedstock for biogas production. Biogas and methane production from T_1(100%CD),T_3(50%CD:50%FVW) and T_5(100%FVW) were not statistically significant at 0.5 level .Co-digestion of cow dung and fruit and vegetables biomass was therefore, one way of addressing the problem of lack of enough feedstock for biogas production. If suitable materials for co-digestion, such as manure, were not available; fruit and vegetables can be digested alone and create a good opportunity for poor people who have not livestock. Environmental, slurry and foreign currency benefits can also be obtained from biofertilezer production of these feed stocks.

4.2. Recommendations

Awareness and skill development training on the sustainable use of fruit and vegetable as a substrate for biogas production and the slurry as a fertilizer for each household biogas users (potential users too) and companies is essential. The fertilizing value (micro-nutrient content and other properties) of treatments of fruit and vegetable should be studied. The conversion of fruit and vegetable wastes to biogas using anaerobic digestion process represents a viable and commercial one. But the rapid acidification of fruit and vegetable wastes tends to operate the reactor at a lower organic loading rate

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