International Journal of Advanced Engineering and Technology
ISSN: 2456-7655
Impact Factor: RJIF 5.54
www.newengineeringjournal.com
Volume 2; Issue 2; May 2018; Page No. 22-26

A comparative study of characterized cow dung and poultry droppings as a substrates in biogas digester

Henry VI[1], Ani OI[2], Iloabachie ICC[3], Chime AC[4]
[1, 3] Department of Mechanical Engineering, Institute of Management & Technology, Enugu, Nigeria
[2] Department of Mechanical & Production Engineering, Enugu State Univ. of Sc. &Tech., Enugu, Nigeria
[4] Department of Agricultural & Bio-Environmental Engineering, Institute of Mgt & Tech., Enugu, Nigeria

Abstract
In this study, poultry droppings and cow dung were evaluated and characterized under anaerobic conditions as substrates for the production of biogas. Fermentation slurry was prepared by the addition and vigorous mixing of dried cow dung and dried poultry droppings separately with an equivalent amount of water needed for maximum yield in the ratio 1:1. 2 batch-type anaerobic-digesters of 25L each were equipped with pH probe, stirrer, thermometer and sampling port. Digestion was carried out for 30 days at room temperature. The substrates were characterized using X-ray fluorescence (XRF) according to the method of AOAC and Proximate analysis of the substrates was carried out according to the method of AOAC. The pH value of the cow dung substrate was found to be mainly alkaline which favoured digestion and biogas production. The result of the proximate analysis revealed that the cow dung substrate had a higher calorific energy value and carbon content. The XRF result showed that poultry droppings substrate contained traces of heavy metals (which act as inhibitor to anaerobic digestion) more than that of cow dung. This results of this study established that cow dung substrate is a better effective feedstock for biogas production.

Keywords: cow dung, poultry droppings, substrates, biogas digester

1. Introduction

The development of new methods of production and use of renewable energy sources that suit the economic and the geographical conditions of the developing countries will be required in order to solve the problems of energy crisis and climate change. Climate change presently is everyone's concern and is among the leading problems if not the only one linking the international community and drawing much attention. The anaerobic bio digester process is not a new technique of converting waste material into usable product. However, there is a need for further investigation to improve the process especially in this era of climate change. Conventionally, the anaerobic digestion (AD) process should occur in a strict anaerobic environment with no free available oxygen. Such aerobic (oxygen presence) invasions can or may deteriorate the performance of the digestive system.

The anaerobic fermentation of organic materials has long been used to generate useful resources which have been harnessed for the use of mankind (Uri, 1992; US Environmental Protection Agency, 2001) [4].

As early as the 18th century, anaerobic process of decomposing organic matter was known, and in the middle of the 19th century, it became clear that anaerobic bacteria are involved in the decomposition process.

As the demand for energy is increasing astronomically, and the fossil based fuels become scarce and more expensive, and carbon dioxide emission levels become of greater concern Ofoefule and Uzodima, (2005) [6] are of the opinion that biogas a by-product of anaerobic fermentation and a renewable energy source has currently been recognized globally as a means of solving the problem of rising energy prices, waste treatment /management and creating sustainable development

Biogas is a colorless, flammable gas produced via anaerobic digestion (fermentation) of animal, plant, human, industrial and municipal waste (Abubakar, 1990) [1] to produce methane (50-70%), Carbon dioxide (20-40%) and traces of other gases such as nitrogen, hydrogen, ammonia, hydrogen sulphide, water vapour etc. Cheremisinoff (1980) [2] and is appreciably lighter than air. However, the composition of the mixture depends on the source of biological waste as Milono *et al*. (1981) [8] observed and management of digestion process Yadar and Hesse, (1981) concluded. The natural generation of biogas is an important part of biochemical reaction which takes place under anaerobic condition in the presence of highly pH sensitive microbiological catalyst that are mainly bacterial (Uzodinma and Ofoefule, 2009) [7]. Chinwendu *et al*, (2013) [9] stated that biogas production comprises three biochemical process, which includes; hydrolysis, acidogenesis/acetogenesis, and methanogenesis. Complex molecules (carbohydrate, protein, fats) are broken down into a broad spectrum of end products (.i.e. acetic acid, H_2/CO_2, mono carbon compounds and organic fatty acids larger than acetic) by fermentative bacterial (US Environmental Protection Agency, 2001) [4].

Milono *et al*. (1981) [8], reported that the production of biogas from biomass is dependent on the amount of acid formed which depends on the types of biomass (feedstock) used.

Macronutrients have been shown to be important for good biomass growth and system performance and should therefore be added daily in bioreactor. The subject of nutrients needed by microorganisms involved with biological treatment of biomass usually focuses on nitrogen (N) and phosphorus (P). These are the micronutrients required to satisfy the needs of active biota (living organisms) in either aerobic or anaerobic systems (US Environment Protection Agency, 2001) [4].

Potassium (K) is also considered a macronutrient and its requirement is based on the nitrogen requirement (Marcato *et al*., 2007). Nutrient considerations are not limited to nitrogen and phosphorus. Ramasamy and Nagamani (1999) [10] have shown that several inorganic nutrients are required for an anaerobic process to function at optimal efficiency.

The characteristics of solid wastes determine the successful anaerobic digestion process (e.*g.* high biogas production potential and degradability). In municipal solid waste, substrate characteristics may vary due to the method of collection, weather, season and cultural habits of the community (Hartmann and Ahring, 2006) [3]. The composition of waste also determines the relative amounts of organic carbon and nitrogen present in the waste substrate (C/N ratio). A solid waste substrate with high C/N ratio is not suitable for bacterial growth due to deficiency of nitrogen. As a result the gas production rate and solid degradability will be low. On the other hand, if the C/N ratio is very low, the degradation process leads to ammonia accumulation which is toxic to the bacteria (Hartmann and Ahring, 2006) [3]. Kayhanian and Hardy (1994) found that a C/N ratio (based on biodegradable organic carbon and nitrogen) within the range of 25–30 is considered to be optimum for an anaerobic digester. As was observed by Zaher *et al.*,(2009) [11] to maintain the C/N level of the digester material at optimum levels, substrates with high C/N ratio can be co-digested with nutrient-rich organic wastes (low C/N ratio) like animal manure or food waste.

The quality of the substrate is also affected by animal diet, manure handling, and storage method (Uzodimnma and Ofoefule, 2009) [7]. Substrate from animal fed with higher energy feed (e.g. Grain-based diets) has the potential to yield more methane gas compared to substrate from animals fed with roughage diet (Ramasamy *et al*., 1990) [5].

One of the burning problems faced by the world today is management of all types of wastes and energy crisis. Rapid growth of population and uncontrolled and unmonitored urbanization has created serious problems of energy requirement and solid waste disposal. Agricultural wastes such as cow dung and poultry droppings contribute to a great amount of pollution in our environment. The continuous exploration of crude oil and the dependence of most industries and domestic machines on fuel is a constant source of worry. This is because the crude oil reserves are constantly depleted and researches into alternative sources of energy such as biogas are promising solutions.

Agricultural wastes such as cow dung and poultry droppings contribute to a great amount of pollution in our environment. Cow dung (fresh) is obtained in abattoirs where cows are slaughtered for human consumption. The dung is obtained after the evacuation of the dung from the intestine of the cow (Slaugthered). Cow dung is of two types; the intestinal dung and the excrement (excreted) dung from cows: The intestinal dung is the type removed from the intestine of cows slaughtered in the abattoirs for human consumption. The intestinal cow dung consists of the undigested residues of consumed matters. They are very fresh and contains the normal microbial floral as found in the rumen of cow. Excreted dung is the dung excreted by cow species, which are herbivores. It consists of digested residues of consumed matter which has passed through the cow's gastrointestinal system (Teo and Tech, 2011). The increasing demand of chickens as a source of white meat has seen poultry droppings produced in large amounts on a daily basis.

This study therefore, focused on the characterization of cow dung and poultry droppings substrates agricultural wastes, to generate biogas via anaerobic digestion, which will meet the current energy demand and reduce environmental pollution caused by these wastes.

2. Materials and Methods

2.1 Materials

The raw materials, cow dung and poultry doppings used in this research were obtained from Mami Market in (82 Division Enugu) and phenomar poultry farm Ngwo both in Enugu state. About 20kg of cow dung and poultry droppings were collected for the purpose of this study. The cow dung served also as inoculums as it contained the required microorganisms for anaerobic digestion. Other equipment used includes test-tubes, beakers, conical flasks; syringes; measuring cylinder (Pyrex); crucible; Buchner funnel; oven; muffle furnace; hose pipe; water trough; graduated (transparent) bucket.

2.2 Methods

2.2.1 Substrate preparation

The substrates collected were sun dried and thereafter crushed mechanically using a mortar and a pestle to ensure homogeneity. The substrates were weighted using a digital scale 5354M. The prepared substrates were stored at 6^{o}C prior to use.

Fermentation slurry was prepared by the addition and vigorous mixing of dried cow dung and dried poultry droppings separately with an equivalent amount of water needed for maximum yield in the ratio 1:1 according to Ituen *et al.* (2007) [12]. Fresh rumen content of a freshly killed cow was retrieved anaerobically and 0.23 kg of the rumen content was measured and used to inoculate the medium in each of the bio-digesters as a source of methanogens. The waste samples were weighed and poured into the digester based on the experimental design.

2.2.2 Experimental Procedure

The digestion of wastes was undertaken by a 2 batch-type anaerobic-digesters. Cow dung and poultry droppings were used as substrates in the experiments. Two 25L digesters equipped with pH probe, stirrer, and sampling port were used in this study. A thermometer model 00384RM was inserted in each digester to measure temperature. A U-tube was used to measure the gas pressures, while the pH of the mixtures was measured with a digital pH meter model 2221.

The working volume of the bioreactor was maintained at 18.75L and ran under uncontrolled pH, which is without acid or base solution. The experiment was carried out at ambient temperature and the mixing was aided by a mechanical stirrer. The two reactors were seeded with sample of cow dung and poultry droppings and stirred for 5minutes at interval of 3hrs thrice daily to enable digestion take place in the entire medium. After 3 days retention time biogas evolved from the reactor was measured and collected in a gas holder by water displacement and analyzed with gas analyzer PAC2 model. Also small quantities of the samples were withdrawn from the reactor and sent for analysis. The experiment was carried out at the Energy Center, University of Nigeria, Nsukka.

The bio-digesters were covered with black polythene sheets to prevent light penetration which can stimulate algae growth and also to trap the heat that has been absorbed in the day. Leakages in the bio-digester systems were checked by immersing bio-digesters into water-bath to check for air bubbles at intervals to prevent loss of medium and the gases generated.

2.2.3 Chemical characterization of cow dung and poultry droppings substrates

Chemical characterization of the cow dung and poultry droppings was done using proximate analysis and X-ray fluorescence (XRF) according to the method of AOAC (AOAC, 1984) [13].

Proximate analysis of the substrates was carried out according to the method of AOAC (1990) [15] as described in Ukpabi *et al* (2012) [18]. For the XRF, an ARL 9400XP + Wavelength-dispersed XRF spectrometer with Rh source was used for the x-ray fluorescence analyses of the samples. The NBSGSC fundamental parameter programme was used for matrix correction of the major elements as well as Cl, Co, Cr, V, Sc and S while the Rh Compton peak ratio method was used for the other trace elements. The tests were conducted at Ahmadu Bello University Zaria.

2.2.4 Analytical methods

The substrates were also analyzed for total solids (TS), volatile solids (VS), and moisture content using the Standard Method (APHA, 1998) [14]. The moisture content of the substrates was determined in line with the AOAC (1990) [15] Procedure.

2.2.5 Total solids content

The total solid content of feed materials will be determined as per the standard method. The initial weight of the sample of 50g biomass with pre-weighed porcelain boxes will be taken by using an electronic balance with least count of 0.1g. The samples will be first heated at 60 ºC for 24hrs and then at 103 ºC for 3hrs using a hot oven. The final weight or dried samples weight with pre-weighed porcelain boxes were recorded. The percentage total solids content of the samples will then be calculated using the formula:

$$TS = \left(\frac{W_d}{W_w}\right) x\ 100 \qquad (3.6)$$

Where, TS is the total solids in percentage (%); W_d is the weight of oven dried sample and W_w is the weight of wet sample in gram (g).

2.2.6 Volatile solids and non-volatile solid content

The volatile solids and non-solids content of feed materials will be determined as per the standard method. The oven dried samples used for the determination of total solids content were further dried at 550$\pm$ 50ºC temperature for 1h in a muffle furnace and allowed to ignite completely. The dishes will then be transferred to desiccators for final cooling. The weight of the cooled porcelain dishes with ash will be taken by electronic balance. The volatile solids content and non-volatile solids content of the sample will be calculated using the formulas:

$$VS = \left(\frac{W_d - W_a}{W_d}\right) x\ 100 \qquad (3.7)$$

$$NVS = \left(\frac{W_a}{W_d}\right) x\ 100 \qquad (3.8)$$

Where, VS is the volatile solids in dry sample, %; NVS is the non-volatile solids in dry sample, %; W_d is the weight (g) of oven dried sample; W_a is the weight (g) of dry ash left after igniting the sample in a muffle furnace.

2.2.7 Determination of Moisture Content of the substrates

This was done in observance of AOAC (1990) [15] procedure**.** A clean crucible was ignited and cooled in a desiccator and the weight taken. Exactly 2g of the sample was placed in the crucible and the weight of the crucible + sample was taken. The crucible was then dried in the oven at 100ºC for 24 hours to constant weight (by reweighing after every 4 hours then after 30 minutes until a constant weight was obtained). The weight was taken and the % moisture content calculated as shown,

% moisture content = 100 x weight of sample - weight of crucible + sample after drying/ Weight of sample taken

3. Results and discussions

Table 1: Result of Proximate analysis of the substrates (Cow dung and Poultry droppings)

S/N	Properties	(Cow dung)	(Poultry droppings)
1	Ash content (%)	1.74	3.40
2	Crude fat (%)	0.50	0.70
3	Moisture content (%)	83.56	68.42
4	Crude fibre (%)	6.90	8.0
5	Carbon content (%)	7.0	6.5
6	Protein content (%)	3.25	5.68
7	Nitrogen (%)	0.014	0.012
8	Phosphorus (%)	0.72	0.66
9	pH	8.0	6.2
10	Energy value (Kj/kg)	14,734.50	13,559.89

From Table 1, it could be observed that the samples contained ash, crude protein, moisture, nitrogen, crude fat, energy value and carbon. The result also showed that the two feeds tocks contained energy yielding nutrients but at varying concentrations.The cow dung substrate is alkaline in nature; which implies that the substrates will likely yield biogas.

From table 3.1 it was observed that the ash content, crude fat, crude fibre and protein content of poultry droppings were 3.40, 0.70, 8.0 and 5.68%, whereas that of the cow dung was 1.74, 0.50, 6.90 and 5.25 these may be attributed to the higher carbon content of the substrate cow dung. The moisture content of the cow dung was 83.56% and that of poultry droppings was 68.42%. The pH and energy value of the substrates were recorded as 8.0 and 14,734.50Kj/kg for cow dung, whereas that of poultry dung were 6.2 and 13,559.89Kj/kg.The significant concentrations of energy yielding nutrients in the substrates suggests that the substrates may be used as feedstock to provide sufficient energy for microorganisms to live and sustain the process and this agrees with the work of Ukpabi *et al*. (2017) [19].

Table 2: Result of X-Ray Fluorescence (XRF) Analysis of Poultry droppings & Cow dung

S/N	Elements	Poultry droppings	Cow dung
		Concentration (wt %)	**Concentration (wt %)**
1	Na_2O	0.365	5.363
2	MgO	4.101	0.764
3	Al_2O_3	3.275	3.680
4	SiO_2	16.587	52.764
5	P_2O_5	14.524	12.383
6	SO_3	7.249	4.631
7	Cl	5.195	2.227
8	K_2O	14.940	4.057
9	CaO	25.568	9.816
10	TiO_2	0.393	0.338
11	Cr_2O_3	0.012	0.011
12	Mn_2O_3	1.114	0.223
13	Fe_2O_3	5.926	3.654
14	ZnO	0.656	0.056
15	SrO	0.097	0.033

It was observed from Table 3.2 that P content found in the poultry droppings (14.52wt %) is higher than that of cow dung (12.383wt %). The K, Mg, S, Cl, Ca and Zn contents are higher in poultry droppings than cow dung as shown in Table 3.2. The Al, Na and Si contents are higher in cow dung than poultry droppings. The traces of heavy metals contents such as Cr, Mn, Fe, and Ti found in the poultry droppings are higher than that of cow dung. The higher concentration of P, K, Mg, Ca, N and Zn found in poultry droppings act as inhibitor to anaerobic digestion of the substrate thus reduced the volume of biogas likely to be produced from the substrate.

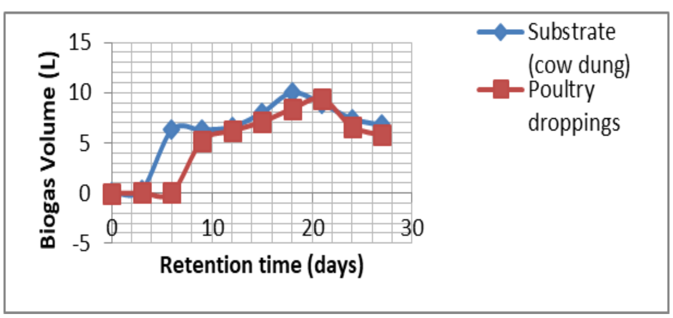

Fig 1: Graph biogas yield versus retention time (days) from cow dung poultry droppings

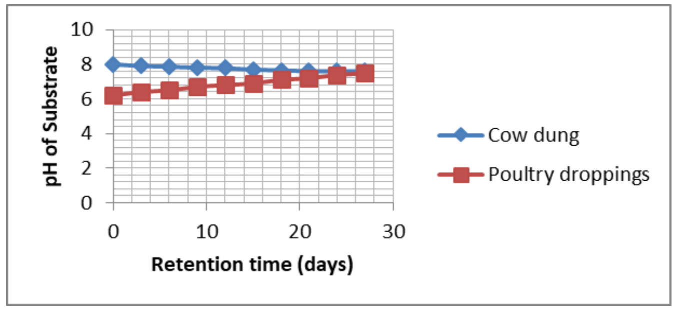

Fig 2: Graph of pH profiles during anaerobic digestion of cow dung and poultry droppings

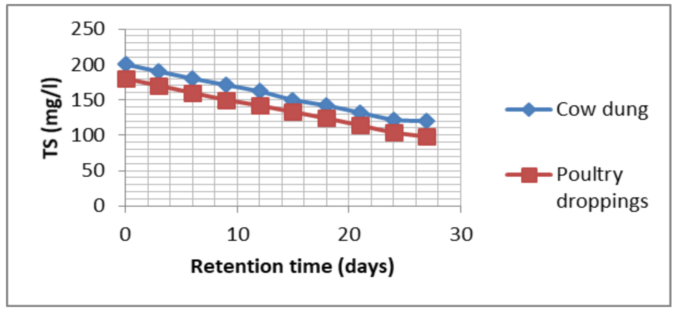

Fig 3: Total solid profile of cow dung and poultry droppings substrate

Suyog (2011) [16] and Meres *et al*. (2004) [17] were of the opinion that biogas production from wastes is partly dependent on pH and the volume of the slurry in the digester. The anaerobic bio-digesters were charged on 5th of May, 2017 and the retention time was 30 day. It could be observed from Fig.3.2a that biogas production actually started after the 3rd day for the substrate cow dung and 6th day for poultry droppings). This may be because biogas production rate in batch condition is directly equal to specific growth of methanogenic bacteria (Nopharatana, *et al*., 2007) [21]. Also, the alkaline nature of cow dung allows the growth of methanogenic bacteria in the first 3 days and slight acid nature of poultry dropping hinder the early activity of methangenic bacteria and hence prolong the biogas yield from the substrate up to the 6th day. During the first 8 days, there was slow biogas production and this is mainly due to the lag phase of microbial growth Fig. 3.2a. Between the 9th to 21st days, biogas production increased substantially due to exponential growth of methanogens. The pH of cow dung substrate was found to be basic and later became neutral as the retention days increased, whereas the pH of the poultry droppings was slightly acid and later became alkaline as observed in Fig. 3.2b. The unregulated pH region may lead to increase/decrease in concentration of ammonia nitrogen and this might be assumed to inhibit the process. It was reported by Chen *et al*., (2008) [20] that high concentration of ammonia nitrogen is toxic to anaerobes, which will decrease the efficiency of the digestion and upset the process. The biogas production started decreasing after 15th day of production for the cow dung substrate and 21days for the poultry droppings and this could be as result of decreased in the total soluble solid of substrate as degradation process continued. It was obvious from Figure 3.2a that cow dung was better feed stock

for anaerobic digestion and equally has higher biogas yield than poultry dropping and this could be attributed to the higher total soluble solid (TSS)
Fig. 3.2c, volatile solid (VS) and carbon content table 3.1 of the cow dung. However, both substrates could significantly enhance the biogas production. Also, this may be attributed to the difference in the feed they were fed on which reflected in the carbon contents of the dung. Similar result was reported by Umar *et al*., (2012) and Sadaka and Engler (2000) [22] for sample (cow dung).

4. Conclusion

This work successfully characterized and investigated biogas production using cow dung and poultry droppings. High calorific cow dung substrate had a better biogas yield; therefore, the calorific content of substrate affects biogas production. Also the cow dung was alkaline which showed that pH of the substrate would determine the effectiveness of biogas production. In addition, the presence of traces of heavy metals in large amounts in poultry droppings acts as inhibitor to anaerobic digestion of the substrate thus reduced the volume of biogas likely to be produced from the substrate.

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