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RESEARCH ARTICLE

DEVELOPMENT OF A BIOGAS PLANT FROM COW DUNG, SWINE DUNG AND POULTRY DROPPING.

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Abstract

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Over dependent on crude oil in African countries call for the need for alternative source of renewable energy. A biogas digester of 56 liters capacity was locally designed, fabricated and tested at the workshop of Agricultural and Bio-Environmental Engineering Department of Rufus Giwa Polytechnic, Owo, Nigeria. The major components of the biogas include the digestion chamber comprising of stirrer which can be manually or electrically powered, a thermometer to measure the temperature variations of the digester and the hygrometer to measure the relative humidity of the environment. Investigations were made into the production of biogas from the mixture of three different substrates of cow dung, swine dung and poultry droppings. The proximate analysis showed that volatile solid, total solid and moisture content for the mixed substrates at the initial stage were; 64.7%, 83.5% and 13.5 % similarly at the digestion stage the volatile solid, total solid and moisture content were 54.1% 22.6% and 74.4%. As the decomposition proceeded, the pH value gradually increased up to 7.2 and 7.4 indicating the stability of organic matter. Moisture content on wet basis was 13.5%. These values latter increased to 74.4%. On the average, 15 kg of mixed substrates with 25 liters of impure water produced biogas within 25 days of digestion. The gas produced from mixed substrates became flammable with blue flame after 16 days of production, indicating that the ratio of methane gas generated with three mixtures of fresh animal waste was higher than other gases produced. In conclusion, the mixed substrates produced faster than other substrates in mixture when compared to literatures. The cost of production was ₦ 38,805.75, this price is considered been to be afforded by small and medium scale entrepreneurs.

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Introduction:-

The rising cost of petroleum products is a serious problem facing most developing countries of the world including Nigeria which dwell on electricity for 98% of their source of Nigeria (Famuyide *et al.*, 2004, CBN 2000). Again, excessive energy demands from both rural and urban dwellers imply that other natural sources of energy have to be explored. Hence, conversion of agricultural wastes into biogas could be a leeway to solving some of these energy

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problems (Ofoefule and Uzodinma, 2009). However, due to epileptic electricity supply in Nigeria which has greatly reduce our daily income and lead to abnormal hike in foreign currency on daily market stock (Fagbenle *et al.*, 2006), it is therefore important that Nigerian should embrace an alternative way by which electricity and cooking gas can be generated. According to Akinfiresoye *et al.* (2018) our environments are subjected to pollution and contamination leading to outbreak of killer diseases due to improper disposal of our domestic waste products. Rather than allowing this pollution to continue unabated, they can be converted through recycling into biogas production useful for our communities and nation. Nwaokocha and Giwa (2016) discovered in a related research that poor developing countries' households use wood, charcoal and other solid fuels to cook in open fires or poorly functioning stoves. It's a great challenge finding a means of expanding its energy resources especially to the rural households and also addressing the health risks and environmental consequences associated with over dependence on such fuels for cooking. While high consumption of firewood can lead to destruction of forest, the excessive smoke emitted can cause respiratory disorder when inhaled (Kehinde *et al*., 2014). Therefore, the need to utilize more animal dungs or agricultural wastes as an alternative energy source is apparent. Recently, diversification on the use of energy has increasingly become an important issue because the oil sources are costly and leads to pollution. Up till now, Nigeria focus more on petroleum, the existing PHCN power generation plants operate at far below their installed capacity as many of them have units that need to be rehabilitated, retrofitted, and upgraded (Imo, 2008). The percentage of generation capability from hydro turbines is 34.89%; from gas turbine, 35.27%; and from steam turbines, 29.84%. The relative contribution of the hydropower stations to the total electricity generation (megawatt per hour) is greater than that of the thermal power stations (Oyedepo, 2012), therefore, an alternative source of energy is needed to solve the power challenge of Nigeria. In the study carried out by Zaher *et al.* (2009), Cow manure when urea or glucose is added produced methane with Carbon/Nitrogen (C/N) ratio between 15.5 and 19. Similarly, for swine manure, the greatest methane production is achieved when its C/N is adjusted to 25/1. The researcher found out that adding urea and glucose cannot be an economically sustainable method to facilitate methane generation from large scale digesters. Therefore, the productivity of anaerobic digestion process can be enhanced by optimizing the substrate C/N ratio through the addition of other agricultural waste products such as maize husks, cassava peels, livestock dungs. The benefit of co-digesting plant material with animal manure can provide buffering capacity and a wide range of nutrients while the added plant materials with high carbon content can improve the C/N ratio of the feedstock, thus potentially improving methane yields (Kayhanian, 2004).

Materials and Methods:-

Materials used for the fabrication of the biogas plants were selected based on their availability locally, suitability for the research and the cost. Cow dung (CD), Poultry dung (PD) and Swine dung (SD) were collected from Akure butchers plant along Ado Ekiti Road while PD was collected from Federal University of Technology poultry farm in Akure, Nigeria.

Machine Conception

The biogas plant was made up of cylindrical shaped chamber divided into the storage and digester units. It has a shaft carrying the stirrer suspended on two roller bearings at the ends of the chamber. There are controlled inlet and outlet valves at the upper part of the chamber and pressure gauge to determine the amount of gas produced. It also has an outlet at the base where the mixture of effluents and substrate is being released from the tank for further use in crop fertilization.

Design Consideration

Biogas reactor unit is a convectional machine that would interact with different waste such as plant and animal waste and also micro-organism in the process of production, with some high degree of strength, pressure and precision with consideration for cost and maintainability. Mild iron steel was used for the digestion chamber due to its strength, durability and resistance to corrosion. Low carbon mild steel was used for the shaft due to its ability to resist fatigue when mixing the waste inside the chamber and its toughness and strength to withstand loads.

Design Analysis

The major parts of the plant were designed as follows:

Biogas plant digester capacity

The volume, V of the cylindrical shape of the digester unit was designed according to the relationship in equation 2.1 by Allen *et al.,* (2009)

$$V = \pi r^2 h \qquad (2.1)$$

Where π is 22/7 (constant), r is the radius of the tank which is 255 mm, h is the height of the tank which is 275 mm. Therefore,
$V = 3.142 \times 255^2 \times 275 = 5618.25\, mm^3 = 56.2\, ltrs$

Shaft design
The diameter of the shaft was determined using equation 2.2 according to Khurmi & Gumpta (2005).

$$d^3 = \frac{16}{\pi S_s}\sqrt{(M_t k_t)^2 + (M_b k_b)^2} \quad (2.2)$$

Where d is the diameter of the shaft (mm), (M_b) is the maximum bending moment (Nm), (M_t) is the torsional moment (Nm), K_b is the combined shock = 1.5, Kt is the fatigue factor = 1.0 and S_s is allowable shear stress = $55x10^6 MN/m^2$

The biogas planter designed and fabricate is shown in figure 2.0

Fig 2.0:-Biogas plant

Biogas Plant Operations
The biogas digester unit is filled through the controlled inlet valve with the mixture of 5 kg each of CD, PD and SD with impure 25 liters of water as shown in figure 2.1.

Fig 2.1:-Loading of the Biogas Plant

The stirrer which can be manually or electrically powered through 1.5 Hp electric motor mixes the content together to a slurry form and allowed to ferment via anaerobic digestion for fourteen days. The stirring was repeated thereafter while the outlet valve is opened for the collection of gas produced. Temperature of the digester was maintained within the allowable temperature ranges for optimum gas production being; mesophilic, cycrophilic and thermophilic temperature ranges. A thermocouple was used to measure the temperature of the slurry.

Results and Discussion:-

Results

The results of the Physico-chemical property of the mixed substrates over a period of 25 days is as shown in Table 3.1 and Figure 3.0. While the effect of temperature on the pH of the substrates is presented in Table 3.2 and the chart of Figure 3.1.

Table 3.1:-Physicochemical Property of Substrates

PARAMETERS	FRESH SUBTRATES	SUBTRATES AFTER DIGESTION
Total Solids (%)	83.5	22.6
Moisture content (%)	13.5	74.4
Volatile solids (%)	64.7	54.1
Ash content (%)	34.6	45.6
pH	6.6	7.2
Temperature (^{O}C)	30.3	29.5

Table 3.2:-Effect of temperature on pH level of the substrates

Days	pH	Temp (^{o}c)
1	6.7	31.8
2	7	31.6
3	7	31
4	6.9	32.5
5	6.8	32
6	6.7	32.5
7	6.9	33.3
8	7.4	30.3
9	7.2	28
10	7	28.5
11	7.1	29.5
12	7.2	31
13	7	33

14	7	33.5
15	6.9	30
16	6.8	29
17	6.7	28.5
18	6.7	30
19	6.94	31
20	6.8	29
21	6.7	29
22	6.8	30
23	6.7	29
24	6.8	30
25	6.82	30
Mean	6.9	29.26

Discussion:-

Analysis and Physicochemical Properties of the Substrates

As presented in Figure 3.0, it was observed that there was a decrease in the total solids, volatile solids and temperature of the fresh substrates and after digestion.

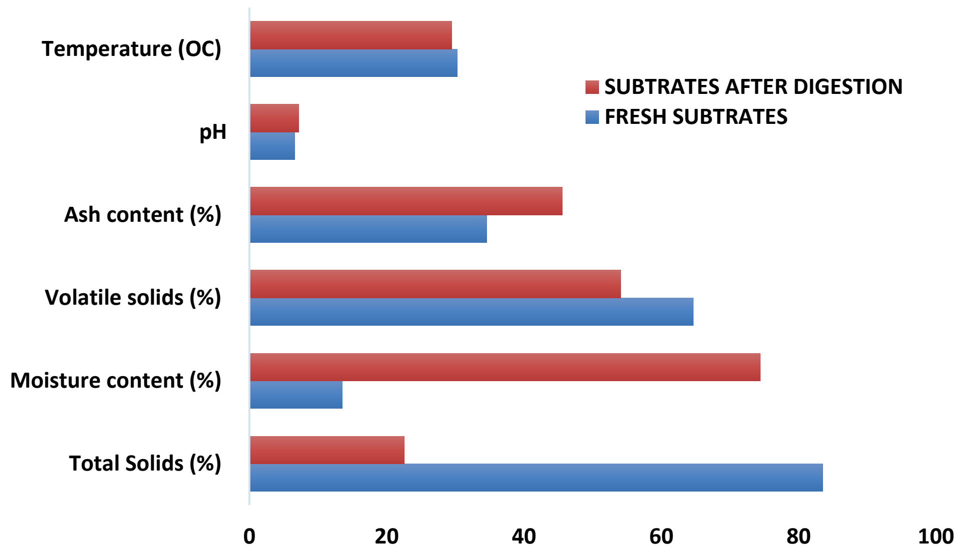

Fig. 3.0:-Physicochemical properties of biogas substrates

The total solid waste reduced from 83.5 % to 22.6%, also, the volatile content reduced from 64.7 % and 54. 1 % and that of temperature from 30.3^{o}c to 29.5^{o}c, this may be due to the utilization of the wastes by the microorganisms which agrees with the reports of Oyeleke *et al*., (2003), who stated that, the total solids and volatile solids reduce as methane yield increases. Whereas, the ash content increases from 34.6% to 45.6% and the pH level moves from 6.6 to 7.2 which is in agreement with the work of Hansen (2001) who reported that pH range of 6.8 through neutral to 7.4 is required for optimum biogas. It was also observed that as the temperature increases, the gas production increases as well, this was also the observation of Lawal *et al.*, (2001) that biogas production is favored with an increased temperature and as temperature drops, so the rate of biogas production declines. The retention period for biogas production was twenty five days. This may be due to the accumulation of acids, exhaustion of nutrient or production of auto toxic substances by the microbes because this process is a batch culture system.

Proximate Analysis and Physicochemical Properties

The proximate analysis showed that at fresh state the volatile solid, total solid and moisture content for mixed substrates were; 64.7, 83.5 and 13.5 respectively and after the experiment the analysis also showed volatile solid, total solid and moisture content were; 54.1, 22.6 and 74.4 respectively. As the decomposition proceeded, the pH value gradually increased from 6.0 up to 7.4 indicating the stability of organic matter. Earlier studies have showed that pH range of 5.5 - 9.0 was suitable for microbial decomposition of organic materials, while the compositing process was most effective at pH values between 6.5 and 8.0 (Kalia and Singh, 1996; Philip and Itodo, 2001).

Flammability of the gas

An increase in the pressure of the biogas plant digester was observed on the seventh day of fermentation. This was attributed to biochemical reaction arising from the microbial activities of the substrates. Combustibility tests carried out shows blue flame with pop sound which was repeated and found positive after 24 days of digestion without any black fume.

pH and Temperature

As represented in the trend chart of Figure 3.1, it was discovered that the slurry changed from acidic to basic state. It was also observed that the acidity in the digester at the first week of the experiment produced low yield of biogas. During the early stage of decomposition, the acid forming bacteria were found to be breaking down the substrate with volatile fatty acids produced. This changed the values of the general acidity for the digesting material with the value of the pH falling below neutral. These changes assisted the microorganisms in the system to perform well which led to increase in the production of the biogas. The result was corroborated by related research carried out by Akintunde (2014).

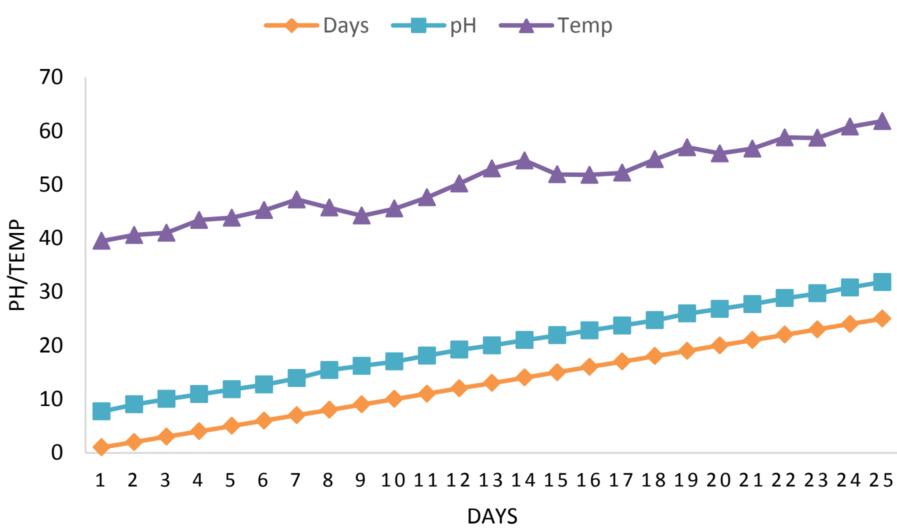

Fig 3.1:-Variation of combine pH and slurry temperature with retention time (Days)

Conclusion:-

A biogas digester that consist of inlet opener, outlet opener, a stirrer handle, spikes and cylindrical chamber has been designed, fabricated and evaluated. The result of this research showed that many of the micro-organisms associated with the fermentation of cow dung', swine dung' and poultry dropping originated from the substrate used. The biogas yield was dependent on the temperature of the environment where the digester was placed. The higher the temperature, the higher the methane gas produced. The pH on the other hand was affected by the activities of micro-organism, as the waste decomposes, the pH value gradually increased from 6.0 up to 7.4 indicating the stability of organic matter. A blue flame methane gas was produced when ignited after 25 days of the process which can be used for cooking. This research showed that waste products of livestock can be converted to gas for cooking and other domestic purpose.

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