

# Biogas Generation From Plant and Animal Wastes, Its Purification, Compression and Storage/Usage



## Biotechnology

**KEYWORDS :** Biogas, Scrubbed, Compressed, Adsorption, Mesophilic, Proximate

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### ABSTRACT

*This study focused on biogas production from Irish moss, cattle dung and rice husk, using batch operation method. The slurry of the pre-decayed waste was charged into the biogas digester in different ratios. The proximate analysis of the slurry of the waste showed some variations in the values of the parameters analyzed. Biogas was produced which was scrubbed using chemical and adsorption methods. Biogas was compressed in a different cylinder for home usage. The total viable count of each waste was done. Biogas production was measured for 63 days. The biogas produced from cattle dung was the highest, 973 litres, followed by Irish moss, 496 litres, and then rice husk, 494 liters. The digestion was done under mesophilic temperature. The percentage of the methane component of biogas produced from cattle dung, Irish moss, and rice husk were 83.0 %, 72.7 %, and 52.3 % respectively.*

### Introduction

The anaerobic digestion of dairy manure, agricultural waste and municipal waste produces biogas, a valuable energy resource (Sormana, 1979). The practical technology of biogas digestion has also improved greatly and its application is becoming more and more extensive. It has received special attention in many countries, and it forms an important part of their efforts to exploit solar energy and industrial waste, and to provide better energy resources and fertilizers (Lucas, 1998).

Anaerobic digestion is a microbial process that produces biogas. Rice husk, moss waste and cattle dung are most dominating waste for biogas production (Garba, 1999, Eija, 200). Biomass energy is the use of the stored solar energy inherent in the organic molecules that make up living things. Rice husk, Moss Irish (algae) and cattle dung are potential source of energy for Nigeria (Garba, 1999). Irish moss is another highly nutritious and remarkable gift from the sea. The botanical name for it is *Chondrus crispus* and its family is algae (Encyclopedias, 2011). The research project was aimed at optimizing methane production from rice husk, Irish moss and cattle dung, assessments of the biodegradability of the wastes after digestion and the storage of the biogas. Pilot level trials to compress the biogas have been carried out by a number of earlier investigators working on the subject (Kapdi, 2004, Manilla, 2001, Holmut, 1985). This research work made an effort to improve the quality of biogas by scrubbing CO<sub>2</sub> and H<sub>2</sub>S.

Biogas is an important renewable energy resource for rural areas in Nigeria. Average calorific value of biogas is 20MJ/m<sup>3</sup> (4713K cal/m<sup>3</sup>). The heat value of this gas amounts to 1.3 x10<sup>12</sup>MJ (Ezekoye, 2006, Maishanu, 1990). But in this research work the storage of biogas was successful. The biological processes within an anaerobic digester that lead to biogas are relatively complicated. Methanogenesis has been reported to consist of three or four stages. Recent reports have indicated the process to consist of four steps namely: hydrolysis, fermentation, acetogenesis/acidogenesis and finally methanogenesis (Garba, 1999, Gary, 2004). Gas production from biomass (moss, rice husk and cattle dung) depends on the nature of lignocelluloses substrates and it is greatly assisted by the cellulose and hemicelluloses material in a substrate determines the level of carbohydrate which is one of the chief foods of anaerobic bacteria (Maishanu, 1998).

To guarantee optimum biogas production, it is very important to mix various raw materials in accordance with C/N (Carbon to Nitrogen) ratio requirements of the fermentation. Carbon is utilized by the bacteria for energy and nitrogen for building their cell structures. The pH is a measure of the acidity or alkalinity of aqueous fluid. It has a profound effect on biological activities. Also, the length of time that volatile solids remain in the anaerobic digester is an important factor in the digestion process. The solid retention time (SRT) represents the average time micro organisms spend in the systems, and it depends on the temperature (Thomas, 2007).

Volatile solids are that portion of the total solid that are organic in composition (Oktay, 2006). Only by frequent stirring of the digester slurry can the raw materials be prevented from settling to the bottom. Stirring ensures an even distribution of raw materials, extends the contact surface of raw materials, with bacteria, and speeds up fermentation, thereby increasing gas yield (Hoerz, 2008, Maurya 1994)

### Mode of Digestion Operation.

There are two basic types of digester operations: the batch and the continuous operations. In batch fermentation system, a digester is fed once at a time, the gas-yield is monitored until it drops very low or stops completely. Once the digestion is complete, the effluent is removed and the process is repeated. The type of digester used for this research work is fixed dome-type digester which has the capacity of 76.912 litres

### Materials and Methods.

Cattle dung, Rice husk and the Irish moss used were collected from the community. The plant and animals waste were pre-decayed for 30 days.

### Preparation of the samples.

After cattle dung was pre-decayed, it was ground into smaller particles using pestle and mortar. The cattle dung was mixed in the ratio of 1:2 (that is waste to water). The samples were measured with a weighing balance. The weighing balance used was "five goats" brand, model 2051599 and was graduated in imperial and metric scale of 0-110Lb and 0-50.0 kg respectively before using the weighing balance zero error of the instrument was corrected. The sensitivity was ensured. It could also measure fraction up to the nearest 0.02 kg. The ratio used for cattle dung implies that a total of 16 kg of cattle dung was mixed with 32 kg of water giving a total mass of 48 kg of slurry. Both waste and water were thoroughly mixed in a small drum, ensuring that no solid (hard) material which was not decomposable was present before introducing the mixture into the digester. The digester was kept open throughout the loading until the waste occupied about 74 % of the digester. The remaining part i.e. 26 % was left for gas collection. After introducing the waste all openings were close. After one day of charging, biogas generation commenced as shown in figure 6. The biogas becomes combustible as from the 20th day to the end of digestion. The slurry of the moss was obtained by diluting the solid moss with water in the ratio of 1:5 (Waste: water). This implies that 8 kg of waste was mixed with 40 kg of water. A total mass of 48 kg of slurry was introduced into the digester and all openings were closed. After one day of charging the gas generation commenced as shown in figure 6 below. The biogas becomes combustible from the 43<sup>rd</sup> day to the end of digestion. The temperature range was within the mesophilic range (20-32°C).

The slurry of the rice husk was obtained by mixing the dried rice husk with water in the ratio 1:3 that is (waste to water). This implies that 12 kg of waste was mixed with 36 kg of water. A total mass of 48 kg of slurry was introduced into the digester. After

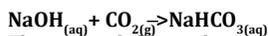
one day of charging the biogas generation started as shown in figure 6. They become combustible from the 34<sup>th</sup> day to the end of digestion. The total volume of biogas produced was 494 litres.

### Instrumentation.

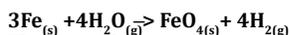
When each waste was charged, the thermo-hygro was used to measure the ambient temperature and the slurry temperature every day. Throughout the days, the wastes were digestered. An instrument called thermo-hygro was used. The measuring range for temperature was 0°C-50°C and the measuring range for humidity is 2% RH-98% RH. The biogas was analyzed using Gas Analyzer Sperian. Bio system multiple model number was SM66429 made in USA. The materials used for biogas scrubbing was iron filling and sodium hydroxide. pH meter was used to measure the pH value every week. The volume of the gas produced was measured by downward displacement of water. The pressure was measured using pressure gauge.

### The purification of biogas.

Raw biogas contains about 55-85% methane (CH<sub>4</sub>), 30-45% carbon dioxide (CO<sub>2</sub>), traces of hydrogen sulfide (H<sub>2</sub>S) and fractions of water vapor. The active or main flammable component of biogas is methane (Virendra, 1985, Thipwimon, 2004). The presence of H<sub>2</sub>S gas in biogas makes it corrosive to metal part. Hydrogen sulphide concentration depends on the sulphur content of the raw material being digested and lies in the range 0.15-0.5 vol; % (Kapdi, 2004, Virendra, 1985). The scrubber was constructed with a metal can through which a hose passed. The first metal can contained the dry sodium hydroxide which removes carbon dioxide (CO<sub>2</sub>) through chemical processes. When the entire gas is passed through sodium hydroxide (NaOH), carbon dioxide reacted with the sodium hydroxide to produce sodium hydrocarbonate (NaHCO<sub>3</sub>).



This type of chemical reaction is called combination reaction (Manilla, 2001, Wojciech, 2012). In this way carbon dioxide and water moisture were removed from the entire gas. The second metal can was filled with iron filling (Fe). As the gas passed through iron filling, it removed the hydrogen sulphide (H<sub>2</sub>S) which had offensive odor like that of a rotten egg.



This type of chemical reaction is called Reversible reaction

### Determination of total viable count (TVC):

Determination of microbial load in a given test sample was done using the method of surface viable count, required to determine viable count of the bacteria (see table 3)

### Biogas composition by percentage.

To identify and quantify the different components of biogas produced, gas analyzer was used.

### Storage of biogas.

A gas compressor is a mechanical device that increases the pressure of a gas by reducing its volume, which obeys Boyle's law. Biogas was compressed by two pistons into the storage cylinder. It is powered by electricity. Biogas was stored to be used at home. The stored biogas was passed to the gas burner and it burnt with blue flames. Biogas from cattle dung, rice husk and Irish moss were stored in different cylinders of net weight 13.6 kg. The capacity of the compressor used was 1/5 horsepower, which was made in Scotland. Each cylinder was able to compress biogas of 2.4 bars of pressure.

Proximate analysis of the waste is the determination of the major components of the waste. The method of meynell and microkjeldahi by pearson were used (Ieshita, 2013, Gary, 2004) (see table 5).

### Result and Discussion

Results of this work are summarized in tables 1 and 2; and is noted that the cattle dung, rice husk and Irish moss produced considerable quantity of biogas. From table 1, It can be observed that the total quantity of biogas obtained in 63 days were 978li-

tres, 494 litres and 496 litres respectively. The research work was done between the months of August and October. At the initial stage the temperature conditions were not favorable for the production of biogas because it was raining period (season). In table 2, it was recorded that the flammability time for cattle dung, rice husk and Irish moss was 20<sup>th</sup>, 34<sup>th</sup> and 43<sup>th</sup> which shows that the waste did not become combustible on time because of initial cold weather, but toward September ending the temperature condition became favorable and it was within the mesophilic range (20-35°C) The relative humidity during the production of biogas falls between the range (30-58%). The pH of the batch operation digesters varied slightly, but remained within the optimum range of (4-7) quoted in the literature (Kucha, 1998. In table 3 the total viable count determination for bacteria that acted on the waste within the mesophilic range was recorded. The original cell population was 8.5x10<sup>7</sup> cfu/ml, 1.4x10<sup>8</sup> cfu/ml and 5.0x10<sup>7</sup> cfu/ml for Irish moss, rice husk and cattle dung respectively. This viable count of the bacteria was favorable for the biodegradation of the waste.

**Degradation of volatile solid:** At the end of the experiment, the reduction in volatile solids of the substrate ranged from 2 to 14% for the batch digesters. These values are within the range reported by others. The degradation of total solid of the waste ranged from 13 to 18% for the batch digester/operation (See table 5). Table 4 illustrates the performance of the batch operation digester in terms of gas production. Comparison between the rates of gas production from the three waste types showed that the cattle dung produced more gas than the rice husk and Irish moss. The mean methane content of the biogas from cattle dung, rice husk and Irish moss was 83.0%, 52.3% and 72.7% respectively. These methane yields are comparable to those reported for other waste types (Maurya, 1994).

The relationship between the ambient temperature and slurry temperature was determined using a basic linear regression graph in figures 6, 7, and 8. If the measured maximum and minimum ambient temperature is known, the minimum and maximum slurry temperature can be determined from Y=0892x+3.513 for Irish moss, Y=0.996x+1.246 for cattle dung and Y=1.135x-2.335 for rice husk. The equations R<sup>2</sup> =0.629, R<sup>2</sup>=0.533 and R<sup>2</sup>=0.693 show the coefficient of determination which explains proportion of the two variables. In all the waste, it shows that the straight line is a good line to explain the relationship by 62%, 53% and 69% respectively.

The coefficient of correlation was deduced from the coefficient of determination R<sup>2</sup>. The correlation coefficient between slurry temperature and ambient temperature for cattle dung, rice husk and Irish moss was 0.73, 0.83 and 0.79. It indicates that for an increase in ambient temperature there will be an increase in slurry temperature.

The biogas stored by compressing and filling it into cylinder after scrubbing and drying. It was obvious that when the gaseous mixture of the biogas was passed through the first scrubber which contained sodium hydroxide, it reacted with the carbon dioxide inside biogas to produce sodium hydrocarbonate. Through this process the carbon dioxide which is not combustible was scrubbed out of the biogas produced. The second scrubber which contained iron filling absorbed hydrogen sulphide and water moisture and produced iron sulphide and iron oxide. After passing the biogas through these scrubbers, the quality of biogas was improved and was compressed in the cylinders which made biogas transportable. With this method the scrubbing, compressing and subsequent storage of biogas for wider application was made possible.

Biogas from cattle dung, rice husk and Irish moss was stored in different cylinders of net weight 3016 or 13.6kg. Each cylinder was able to compress/store biogas of 2.4 bars of pressure. Figure 1 and 2 shows the fluctuation of ambient and slurry temperature with retention time for the 3 different waste. From the graph the ambient temperature falls between (20.0-30.0)°C and slurry temperature falls between (21.0-35.0)°C which was within mesophilic range (Bruce, 2012)

Figure 3 shows the variation in the daily biogas produced from the three different wastes. Figure 4 shows the effect of relative humidity on biogas production. Figure 5 shows the cumulative biogas generation during fermentation. From the graph, the highest cumulative gas produced was from cattle dung and the lowest was 494 litres from rice husk. Table 5 shows the analysis of slurry before and after digestion of the different in the concentration of various elements. Nitrogen, phosphorous and potassium increased after digestion. This shows that the biofertilizer has useful properties for better crop production (Mais-hanu, 1998).

**Conclusion**

In this study, mesophilic fermentation bacteria initiated the anaerobic digestion in cattle dung, rice husk and irish moss. The fermentation occurred in the mesophilic range of 20.0°C – 35.0°C, this is the temperature range in which the digesting bacteria are most productive in terms of production rates, growth rates and substrate degradation performance. The Cattle dung yielded biogas faster than plant wastes. Nitrogen content of Irish moss after digestion was greater than that of cattle dung and rice husk. The three substrates have enough carbon and nitrogen elements that meet the C/N ratio for optimum biogas yield. Irish moss was found to be better biofertilizer because of the higher values of N.P.K in the digested waste compared to those of the cattle dung and rice husk.

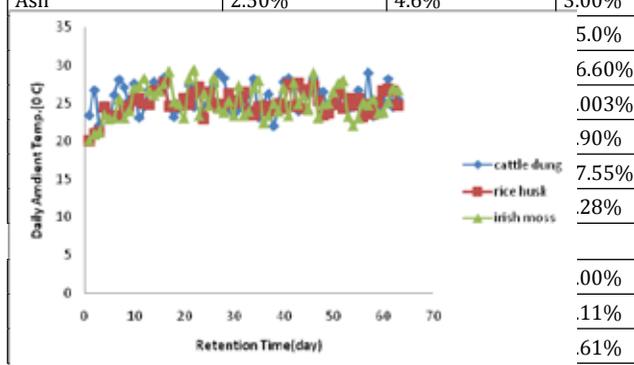
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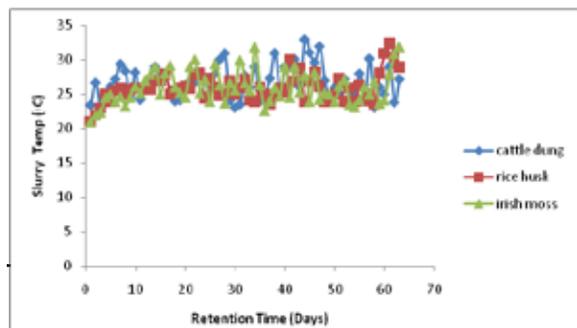
Cattle dung	14.6	0.4	2.4	83.0
Rice husk	30.7	2.1	9.9	52.3
Irish moss	17.5	0.8	9.0	72.7

**Table 5: Proximate Analysis of Cattle Dung, Rice Husk and Irish Moss.**

Parameters	Cattle dung		Rice husk		Irish moss	
	Before digestion	After digestion	Before digestion	After digestion	Before digestion	After digestion
Nitrogen	0.57%	0.74%	0.53%	0.82%	0.63%	0.98%
Carbon content	2.94%	6.29%	2.55%	4.19%	2.76%	10.47%
pH	5	7	4	7	5	7
Ash	2.50%	4.6%	3.00%	4.35%	4.50%	7.30%



**Figure 1: change in daily ambient temperature during fermentation**



**Table 1: The Mixing Ratio and Quantity of Waste Charged in the Digester.**

Waste	Mixing ratio	Quantity of waste (Kg)	Quantity of water (Kg)		Total vol. of biogas produced
Cattle	1:2	16	32	100	978
Rice husk	1:3	12	36	100	494
Irish moss	1:5	8	40	100	496

**Table 2: Day of Flammability and Total Biogas Produced**

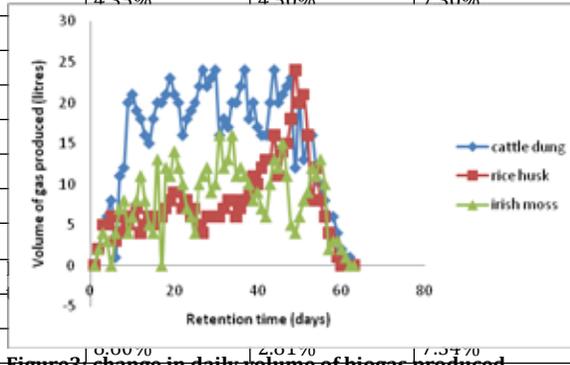
Waste	Retention time (days)	Flammable time (Days)	Total volume of biogas produced(L)
Cattle	63	20	978
Rice husk	63	34	494
Irish moss	63	43	496

**Table 3: Total Viable Count Determination for Bacteria**

Waste	Mean drop count	Dilution factor	Vol./drop (ml)	Total viable count(cfu/ml)
Cattle dung	10	10 <sup>-5</sup>	0.02	5.0x10 <sup>7</sup>
Rice husk	27	10 <sup>-5</sup>	0.02	1.4x10 <sup>8</sup>
Irish moss	17	10 <sup>-5</sup>	0.02	8.5x10 <sup>7</sup>

**Table 4: Percentage of the Components of Biogas from Three Different Wastes Using Gas Analyzer.**

Waste	Carbon dioxide (CO <sub>2</sub> )%	Hydrogen sulphide (H <sub>2</sub> S)%	Carbon monoacid (CO)%	Methane and other components (%)
Cattle dung	0.0070	0.0070	0.0070	0.0070
Rice husk	4.0170	0.0070	0.0070	0.0070
Irish moss	7.5470	0.0070	0.0070	0.0070



**Figure 3: change in daily volume of biogas produced**

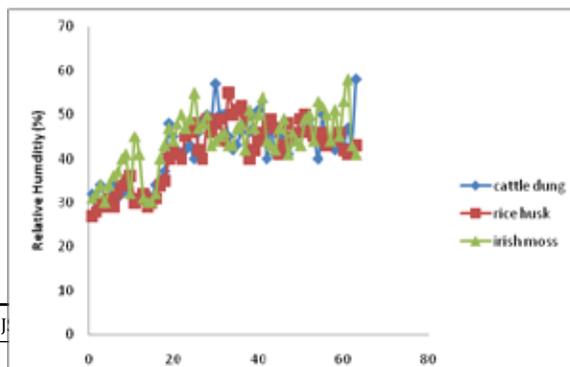


Figure 4: variation of relative humidity during fermentation

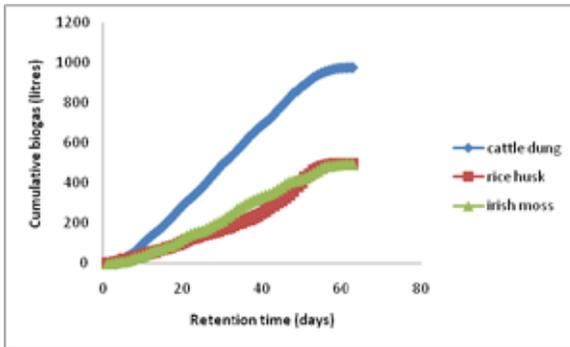


Figure 5: Cumulative biogas produced during fermentation

Figure 7: maximum ambient versus slurry temperature

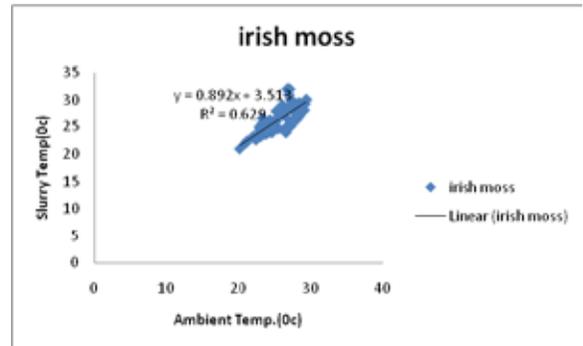


Figure 8: maximum ambient versus slurry temperature

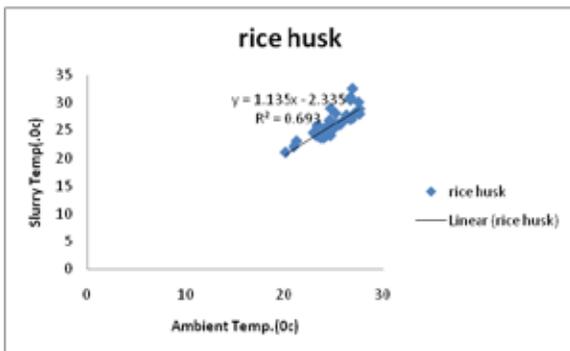
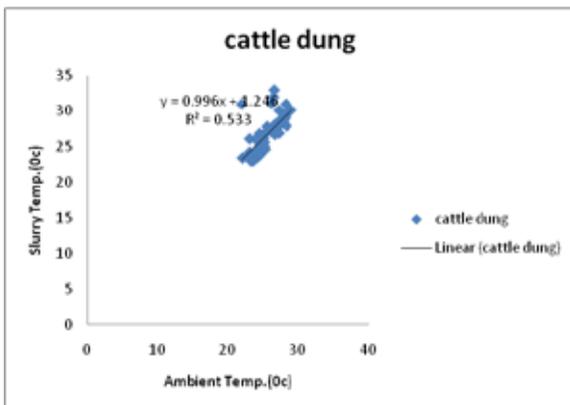


Figure6: maximum ambient versus slurry temperature



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