Studies on the Influence of Rice Husk on Biomethanation: 1. Optimal Condition for Digestion and the Domestic Use of Stored Biogas.

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ABSTRACT

Studies were carried out to determine the effect of parameters and inoculum on the anaerobic digestion of brewery spent grains. Inoculum was prepared by mixing dried rice husk with water, which was left to decay and used after one month from the time of preparation. The addition of inoculum was found to reduce the number of days the flammable gas was produced by 67days (87th day to 20th day). The comparative study shows that the digester with inoculum (rice husk) gave the highest total gas production of 5.863 m^3, while spent grains alone produced cumulative volume of 3.555m^3 biogas. The gas produced after a period of 11 weeks and 18 weeks respectively were tested using special burners and were found to be combustible, burning with a blue flame. The biogas generated was stored under pressure in special cylinders using a modified compressor.

(Keywords: biomethanation, thermophilic, anaerobic, incubators, innoculum, hemicellulose)

INTRODUCTION

Due to the ever increasing energy demands as well as the tide over the current energy crisis occasioned by over dependence on non-renewable energy sources such as fossil fuels, most countries of the world have now shifted emphasis on the exploitation of renewable energy sources. The exploitation of bio-fermentation energy is one of the steps in this direction (Okogbue, 2003). Interest in the production of biogas from industrial wastes and biomass has stimulated intensive studies of the methane fermentation process (Ezeonu, 2002).

Normal biogas fermentation is impossible without sufficient quantity of biogas microbes. It is these microbes that perform the function of degrading, organic substances anaerobically to yield methane.

Inocula of different sources contain different colonies of biogas microbes. Each of the colonies acts upon some particular materials most efficiently. Reports have shown that addition of bacteria seed or inoculum is known to enrich the bacteria of the digester, which will enhance their action on the substrate and hence on the quantity as well as quality of the biogas generated (Maishanu, 1998). Some inhibitors such as oxygen, high volatile acid and ammonia nitrogen concentration, agricultural chemicals (toxic ones), etc., have to be depleted before the strict anaerobic microorganisms can finally generate methane at the end of the process. (Goodger, 1980).

In addition to the production of biogas as a form of energy, the use of plant waste as raw materials for biogas production is also a plus for sanitation technology. In this study brewery waste (spent grains and rice husk) has been used as raw material for biogas production. The biogas produced was stored under pressure in cylinders using compressor for domestic uses.

AIMS AND OBJECTIVES

(1) The objectives of this study were: to evaluate the anaerobic conversion of spent grain into methane under the influence of inoculum (rice husk).

(2) To assess its effect on biodegradability of the waste after digestion under operating conditions.

EXPERIMENTAL PROCEDURE

(a) **Rice husk** – Adani Rice Mill in Enugu state. In this industry Rice grains are processed and the rice husk is disposed as industrial waste.

(b) **Brewer spent grains (BSG)** - Ama Brewery in Enugu state; in this brewery, barley and sorghum grains are used in an undisclosed proportion for brewing. The spent grains were collected in a dried form for the experiment.

Digester Set-up and Operation: The digestion of waste was undertaken by batch-type anaerobic-digester. In batch fermentation system, a digester is fed once at a time. The gas-yield was monitored until it dropped very low or stopped completely. At the end of its digestion period, it was completely discharged before the digester was charged with fresh waste again.

The fixed dome digester was assessed using different wastes. The quantities of each waste, the inoculum and of course, water were calculated bearing in mind that the volume of the digester was $0.971m^3$. Each waste was mixed in different ratio depending on the nature of the waste (Table 1).

In the first experimental set-up, 48kg of rice husk was pre-decayed for one month and was added to 48kg of spent grains in a drum. 222kg quantity of water was added to the wastes, all were thoroughly stirred to ensure the formation of a homogenous mixture. The whole mixture was transferred to the digester. The total amount of slurry inside the digester was 318kg. As the fermentation began, all the operating parameters were strictly observed.

In the second experimental set-up 170kg of spent grains was mixed with 315kg of water in a drum in the ratio of 1:2. The quantity of slurry charged in the digester was 485kg. Digestion started after 24 hours the waste was charged.

The Operating Conditions of Biogas Digestion: Biogas digestion is a microbial process and therefore requires the maintenance of suitable growth condition for biogas-producing bacteria. The provision of nutrient, an optimum temperature pH and other environmental factors are vital for the activity of living bacteria. Only if these conditions are met will the normal bacterial activity and subsequent gas production be assured. (Goodge, 1980). There are seven main conditions required by methane-producing bacteria mixtures.

Strict Anaerobic Environment: All microbes that play an important role in biogas digestion are strictly anaerobic. They include acid-producing bacteria and methane producing bacteria. The latter are so sensitive to oxygen that digestion would be inhibited by even the slightest trace of oxygen. With the charging of spent grains/rice husk, a lot of oxygen enters the digester. During an initial stage of fermentation (aerobic phase) oxygen was quickly exhausted by oxygen-loving bacteria, resulting in attainment of an anaerobic environment. The addition of rice husk as seeding or “starter” further aided in establishing an anaerobic environment in the digester.

Table 1: The Mixing, Charging, and Quantity of the Waste Charged in the Digester.

Waste	Mixing Ratio	Quantity of waste (kg)	Quantity of water (kg)	Charging ratio percent	Total vol. of gas produced (m^3)
Spent grains	1:2	170	315	100	3.555
Spent Grains / Rice Husk	1:2.5	96	222	50:50	5.863

Compounding Suitable Fermentation Substrates: All organic materials, except mineral oil and lignin, are suitable substrates for biogas fermentation. The lignin content will decrease the rate of digestion of carbohydrates (cellulose and hemicellulose). The rice husk used in this experiment as seeding material was pre-rotten for one month. This made the wax to disintegrate and the cellulose to become soft and loose. Rotting rice husk and spent grains increased the wettability and hence the weight of rice husk and spent grains so that they did not float and form surface scum in the digester. The pre-rotting wastes raised the temperature of the slurry to (20.2 – 36.0^{0}C) and killed off insects, parasites and undesirable microbes in rice husk and spent grains. To guarantee optimum biogas production, the raw materials were mixed in accordance with C/N (Carbon to Nitrogen) ratio.

The C/N ratio reflects the relative proportions of these two elements in the digester charge. The C/N ratio of spent grains was 8: 1, while that of spent grains/rice husk was 4:1. Carbon (in form of carbohydrates) and nitrogen (as protein, ammonia, etc.) are the chief nutrients for anaerobic bacteria.

Maintaining an Optimum Temperature: There are two groups of bacteria that digest organic matter: Those that work at high temperature (described as thermophilic bacteria) and those that work at relatively lower temperature (described as mesophilic bacteria).In this experiment the gas production occurred within the mesophilic temperature range of (20.7 – 36^{0}C) and the cumulative gas production for spent grain was 3.555m^3 of digester volume and for spent grains, it was 5.863 m^{3}m^3 of digester volume. The effect of temperature was limited to the quantity and not the extent of digestion of raw material.

Maintenance of Optimum pH: The symbol pH is a measure of the acidity or alkalinity of aqueous fluids. From the experimental study it has been shown that the optimum pH for biogas fermentation from spent grain was 5.44 – 7.78 and from spent grains/rice husks it was 5.00 – 6.78.

Enrichment with "Starter" Bacteria: Biogas production is a result of the interaction of various groups of microbes, which make methane. Among other things, pre-rotting enriches the raw material with microbe before it entered the digester. When fresh spent grains enter the digester with only a few starter–bacteria, the fermentation period was 126 days and biogas production was very slow and incomplete.

The methane content was zero after 86 days of fermentation. When pre-rotten rice husk was used, the methane content increased very quickly and at the 20th day, the gas became combustible.

Frequent Stirring of Digester Slurry and Evacuation of Gas Produced: It was essential to stir the digester slurry every day to prevent thickening and caking of the scum. This prevented the gas from escaping into the gas holder. There was an inbuilt stirrer in the digester used for this experiment and the stirring was done once every day. Stirring ensured an even distribution of spent grains and rice husk, the extent of the contact surface of raw materials with bacteria and sped up fermentation, thereby increasing gas yield. It was discovered that the over-all volume or quantity of gas produced was increased with repeated evacuation.

Decreasing Internal Pressure: It has been found that if the internal pressure of digester is too high, the rate of gas production slows down. In this experiment, the gas pressure gauge was mounted along the gas delivery line before the outlet valve so that the gauge pressure could be recorded before exhausting or evacuating the gas. The highest pressure for spent grains was 0.06 bars (1 bar = 10^5 Nm^{-2}) while that of spent grain/rice husk was 0.22 bars.

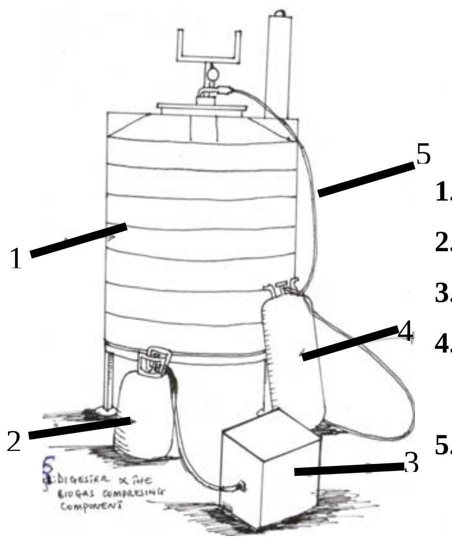
ANALYTICAL

About 0.05kg weight of each waste was collected and analysed in the laboratory for determination of concentration of different components of the slurry before and after digestion (Table 2)

Composition of Biogas: After 19th and 86th day, the two samples started to produce combustible gas. Biogas was compressed under pressure into cylinders with the aid of gas compressor. Gas compressed in each cylinder was 2.4 bars. (Figure 1) (Ezekoye, 2006). The analysis of the biogas from spent grain and spent/rice husk was done using Orsat Apparatus. The result obtained was tabulated in Table 3. The capacity of the compressor used was 1/5 horsepower, which was made in Scotland.

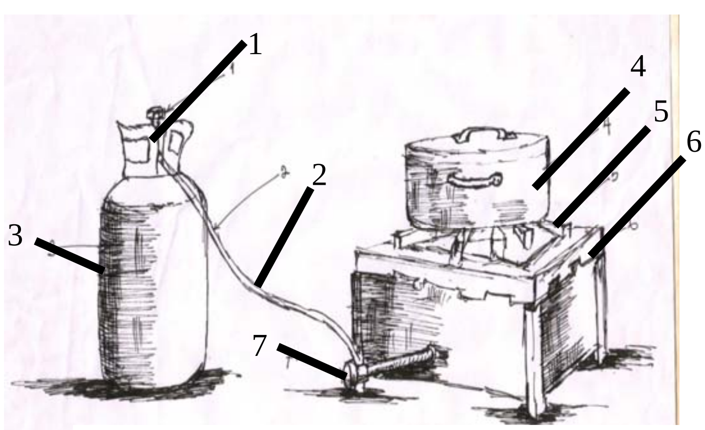
Table 2: Proximate Analysis of Spent Grains and Spent Grains/Rice Husk.

Parameters	Spent Grains		Spent Grains/Rice Husk	
	Before Digestion (%)	After Digestion (%)	Before Digestion (%)	After Digestion (%)
Nitrogen	4.53	4.70	4.53	4.95
Carbon	6.59	7.50	6.59	8.94
pH	6.5	5.71	5.93	7.79
Ash	0.9	1.0	0.9	0.38
Moisture	86.5	89.4	86.5	95.3
Phosphorus	0.08	4.49mg/100g	0.05	0.068
Potassium	120ppm	14.42mg/100g	120ppm	125ppm
Volatile solid	94.1	92.90	91.91	93.2
Total solid	88.76	9.28	95.8	87.86



1. **Digester**
2. **Gas Cylinder where the Biogas was stored**
3. **Gas Compressor**
4. **Gas Cylinder through which the Biogas was sucked out from the Digester**
5. **Rubber Hose**

Figure 1: Digester and the Biogas Compressing Component.



1. **Cooking Valve**
2. **Rubber Hose**
3. **Gas cylinder**
4. **Iron pot**
5. **Iron Seater**
6. **The Burner**
7. **Valve**

Figure 2: Using Stored Biogas for Cooking.

Table 3: Percentage of the Components of Biogas from the Samples.

Waste	Carbon dioxide (CO_2) (%)	Hydrogen sulphide (H_2S) (%)	Carbon monoxide (CO) (%)	Methane and Other Components (%)
Spent grains	17.5	0.8	9.0	72.7
Spent grain / rice husk	30.7	2.1	9.9	52.3

It is clear from the tables below that over five months period, the average daily gas production was 3.555m^3 for spent grains and 5.863 m^3 for spent grains/rice husk.

Calculation of Percentage Solid Degradation and Specific Gas Production: The weight of the dry solids from each digester was measured and the percentage solid degradation achieved in each digester was calculated using the following formula:

$$\frac{Vo - Ve}{Vo} x \frac{100}{1}$$

where Vo = weight of the sample before digestion and Ve = weight of the sample after digestion.

The specific gas production rates were calculated for the two samples using the following formula:

$$\text{Specific gas production} = \frac{\text{Volume of gas produced}}{\text{Retention time X vol. of digester}}$$

Volume of gas produced refers to the cumulative gas production in each digester and retention time is the time taken for the waste to digest until it generates no more gas. Volume of the digester in this experiment was 0.97 m^3 (Maishanu, 1998).

Table 4: Gas Production by Spent Grains Classified by Months.

Month	Average amount of gas produced (m^3)
April	0.760
May	0.825
June	0.880
July	o.965
August	0.125

Table 5: Gas Production by Spent Grains/Rice Husk Classified by Months

Month	Average amount of gas produced (m^3)
August	0.006
September	0.2158
October	0.3225
November	0.2638

Table 6: Specific Gas Production and Percentage Solid Degradation.

Waste	Retention Time	Cumulative Gas Production (m^3)	Average Daily Gas (m^3)	Specific Gas Production	Solid Degradation (%)
Spent grains	126	3.555	0.028	0.029	38%
Spent grains/rice husk	80	5.863	0.073	0.076	70%

RESULTS AND DISCUSSION

As has been noted, biogas fermentation is a microbial process. The determination of microbial load in given test sample was done using the method of surface viable count, required to determine viable count of both bacteria and fungi. The total viable count (TVC). Determination for bacteria in spent grains was (18×10^6 cfu/ml) and for fungi it was (13×10^6 cfu/ml) where (cfu means colony-forming units).

Dilution of organic waste with water and seed is a prerequisite condition for biomethanation. Table 1 shows the quantity of wastes, water, charged ratio and cumulative biogas yield of digester after a retention time of 80 days and 126 days. From the table, the digester with spent grains/rice husk having a charging ratio of 1:2.5 had the highest gas yield of approximately $5.863m^3$, followed by digester with spent grain of ration 1:2, which produced about $3.555m^3$ of gas. Among the two different wastes used in this study, a mixture of spent grains/rice husk proved better for biogas generation. From table 2 the optimum carbon – nitrogen ratio mixture desired for Brewers spent grains (BSG) biomethanation are 8:1 for spent and 4:1 for spent grains/rice husk. This shows that the anaerobic bacteria use up carbon 8 times and 4 times faster than nitrogen.

Results obtained from the study have indicated inoculum age influential in cumulative gas production and average daily gas production. Seeding the digester with one month-old inoculum (rice husk) generated a total of $5.863m^3$ of biogas within a retention time of 80 days. From table 6 the average daily gas production was calculated to be $0.073m^3$. The mean weekly temperature was found to be in the range of (20.7 – 36.0^0C) which was low mesophilic range of temperature.

When the specific gas production rates were calculated for all the digesters (Table 6) they were $0.076m^3m^{-3}d^{-1}$ for spent grains/rice husk and ($0.029\ m^3m^{-3}d^{-1}$) for spent grains. The percentage degradation was indicated higher figure for digester fed with one-month inoculum (70%) while the lowest figure (38%) was achieved by the digester which was fed with spent grains alone. The effect of bacterial population in the inoculum which was added to the spent grains might have been responsible for the enhanced gas production in this digester; as well as the reduction in the retention time to 80 days. In this investigation, the addition of rice husk to the digester enhanced the start up of the fermentation process and eliminated the lag phase. The inoculum (rice husk) resulted in fast establishment of anaerobic micro flora.

Figure 3 shows the change in pressure during fermentation. The range in pressure was between 0.02 – 0.09 bar for spent grains while for spent grains/rice husk it was between 0.02 – 0.2 bars (1 bar = 10^5 NM^{-2}). Figures 4 and 5 show the change in ambient temperature fermentation and slurry temperature during fermentation.. The two temperatures fall within the mesophilic range.

Figure 6 illustrates the regression temperature between the slurry and ambient temperature. For spent grains substitute the values of $X = 34.9^0$C for maximum ambient temperature and $x = 21.1^0$C of the minimum ambient temperature on the prediction equation $Y = 0.8994\ x + 2.8854$. The predicted maximum and minimum slurry temperatures were 34.27^0 and 21.86^0C. The equation $R^2 = 0.7054$ shows the coefficient of determination which explains proportion of two variables. For example in spent grains $R^2 = 0.7054$, it means that the relationship between the maximum and minimum temperatures of ambient and slurry temperatures is 70.5%. The co-efficient of correlation was deduced from the coefficient of determination R^2, for spent grains, it was 0.839. The correlation coefficient between slurry temperature and ambient temperature was $r = 0.84$. This was used to support the claim that the increase in the ambient temperature could be attributed to the increase in slurry temperature.

Figure 7 shows the daily volume of gas produced by spent grains and spent grains/rice husk. From table 3, methane is the most valuable component of biogas. It was 72.7% and 52.3% for the two different wastes. It was also found out that the pH was initially high, dropped and then rose again, and eventually became constant (Figure 8).

CONCLUSION

Biotechnology of biomass utilisation for biogas production integrated essential aspects of feedstock preparation and fermentation brought about through the choice of the best working conditions.

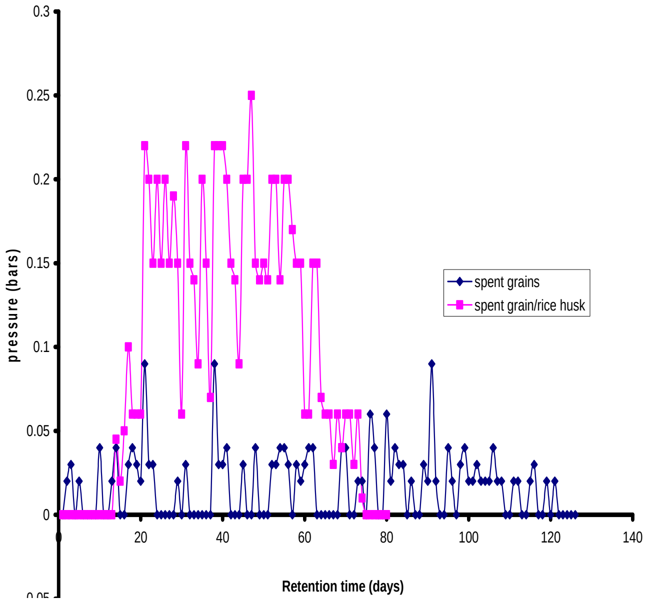


Figure 3: Change in Pressure During Fermentation.

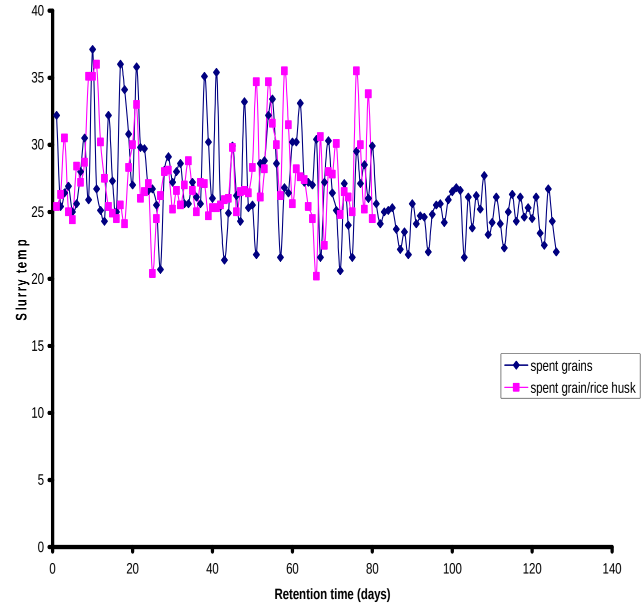


Figure 5: Daily Change in Slurry Temperature During Fermentation.

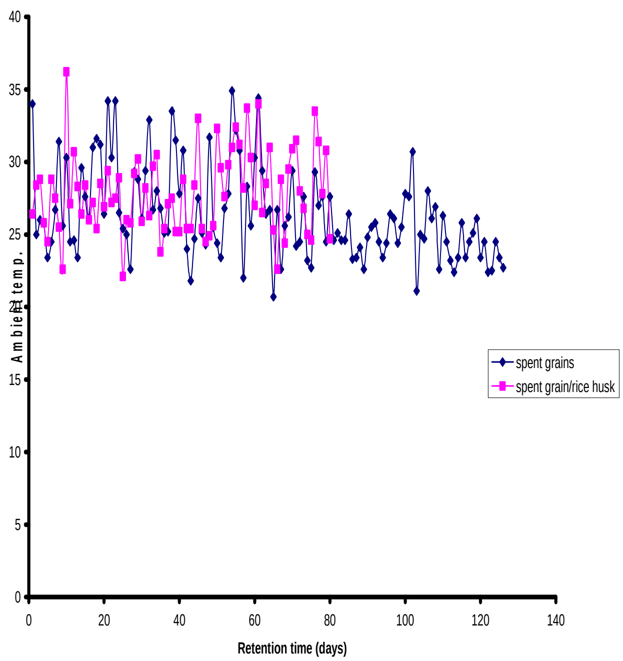


Figure 4: Daily Change in Ambient Temperature During Fermentation.

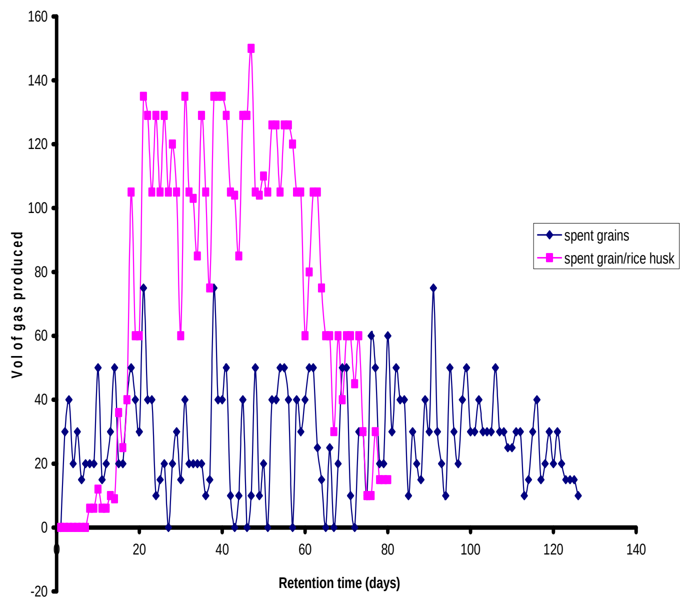


Figure 6: Daily Volume of Gas Produced

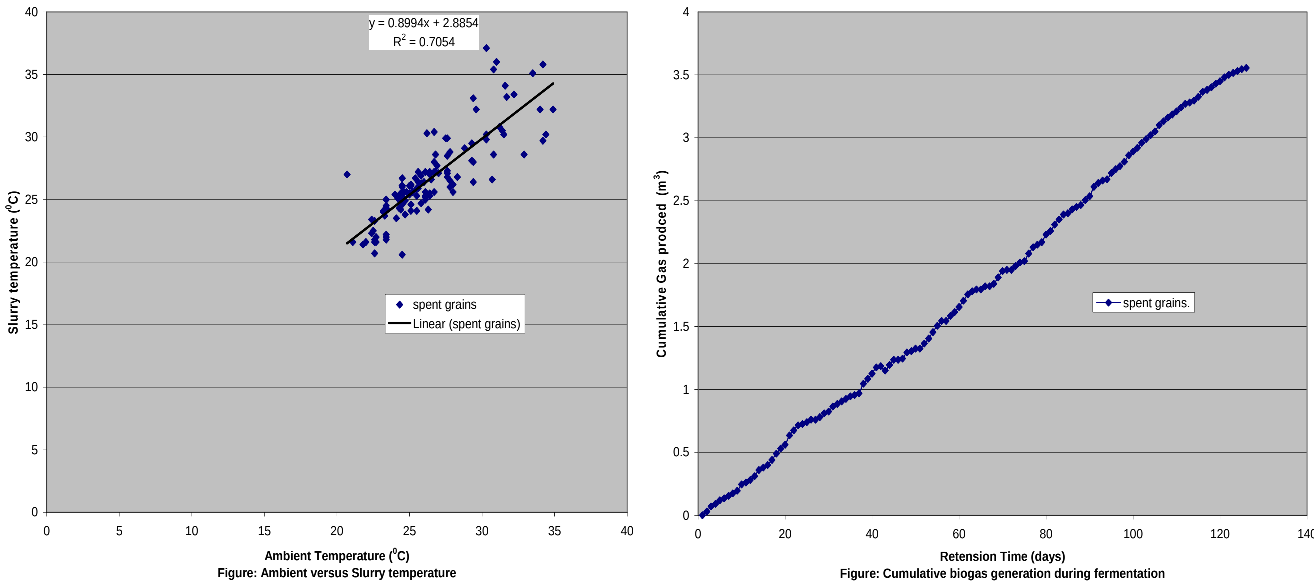


Figure 7: Temperature and Gas Measurements.

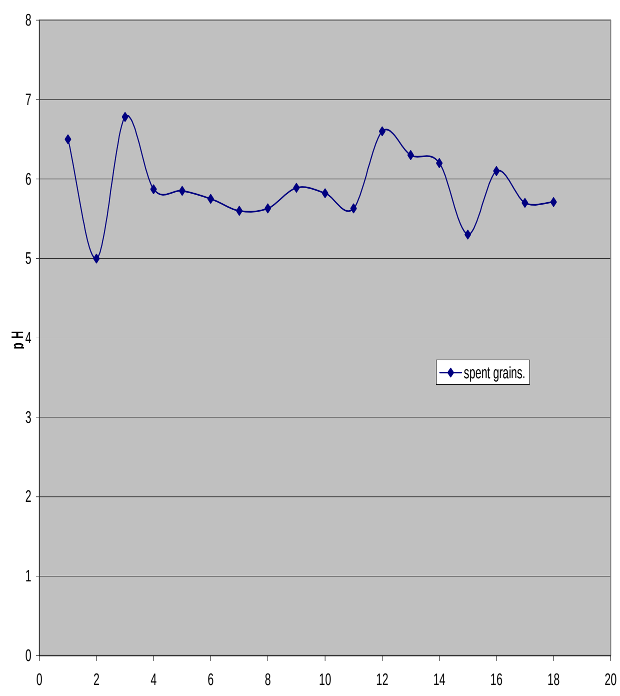


Figure 8: Change of pH During Fermentation.

The seven main conditions required by the methane-producing bacteria mixture greatly enhanced gas production in the whole experiment. Rice husk is the best seeding material which was found to be influential especially in specific gas production, cumulative gas production and retention time of solid particles.

The lots of rural populace could be tremendously improved energy- wise, by introducing such a local technology that turns spent grains and spent grains/rice husk into wealth, more so, when the raw material for biofermentation energy is in abundant supply in the rural and sub-urban settings.

RECOMMENDATION

(1) Rice husk is recommended as the best seeding material so far.

(2) A 1:2:5 feedstock to water ratio is therefore recommended for optimal digestion of B.S.G.

To encourage the use of biogas requires an awareness of the potential users of the process.

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