

Full Length Research Paper

Comparative study of biogas production from chemically-treated powdered and un-powdered rice husks

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Biogas production was carried out using fresh powdered rice husk (PRH), un-powdered rice husk (U-RH) and a blend of both (CRH) in the ratio 1:1. They were left to degrade for 73 days before pre-decaying in water. The pre-decayed wastes were found to be acidic. Consequently, a concentrated solution of potassium hydroxide (KOH, 50%w/v) in acetic acid (CH₃COOH, 99% v/v) was used to treat the wastes to achieve waste stabilization and neutrality. The pre-decayed, chemically treated rice husks were charged separately as; powdered rice husk (P-RH), un-powdered rice husk (U-RH) and combined rice husks (C-RH) (which is a combination of P-RH and U-RH 1:1) into metal prototype biodigesters of 50 L capacity in the ratio of approx. 2:1 of water to waste. They were all subjected to anaerobic digestion under a 31 day retention period and mesophilic temperature range of 24 to 42°C. Results of volume of gas yield from the different digesters indicated that the P-RH had a cumulative gas yield of 140.60 ± 2.12 L/ total mass of slurry (TMS) while the U-RH system had a cumulative gas yield of 146.3 ± 2.07 L/TMS. When blended and treated the cumulative biogas yield of the C-RH significantly increased ($p \leq 0.05$) to 168.3 ± 2.26 L/ TMS. The different digester systems became flammable at different periods. The biogas from the C-RH system ignited on the 4th day of the digestion period while U-RH and P-RH systems produced flammable gas on the 5th and 6th days, respectively. Generally, the results showed that chemical treatment enhanced the biogas production of the rice husks in terms of cumulative gas yield and onset of gas flammability. The overall results indicate that combining the two types of rice husk gives the best results in terms of those two parameters.

Key words: Powdered rice husk, unpowdered rice husk, biogas production, flammable biogas, cumulative gas yield.

INTRODUCTION

Biogas production from biogenic wastes has been an alternative source of fuel in most developing and developed countries of the world (Isei and Demirer, 2007). Biogas is a mixture of colourless, flammable gases obtained by the anaerobic digestion of organic waste materials. The composition of biogas is typically methane (50 to 70%), CO₂ (30 to 40%) and the rest is made up of traces of elements of hydrogen, nitrogen and hydrogen sulphide (Bori et al., 2007). The Chemistry of the

digestion process leading to biogas involving hydrolysis, acidogenesis/acetogenesis and methanogenesis has been well documented (Kalia et al., 2000; Kozo et al., 1996; Ofoefule et al., 2009). Biogas technology has also been used recently as a means of waste management and environmental pollution control. Agricultural livestock and agro-industrial wastes abound in the rural and sub-urban areas and contribute to the present problems of environmental pollution (Arvanitoyannis et al., 2007; Bori et al., 2007).

Many findings have been reported on the enhancement of gas production through processes such as co-digestion or blending of organic wastes (Parawira et al.,

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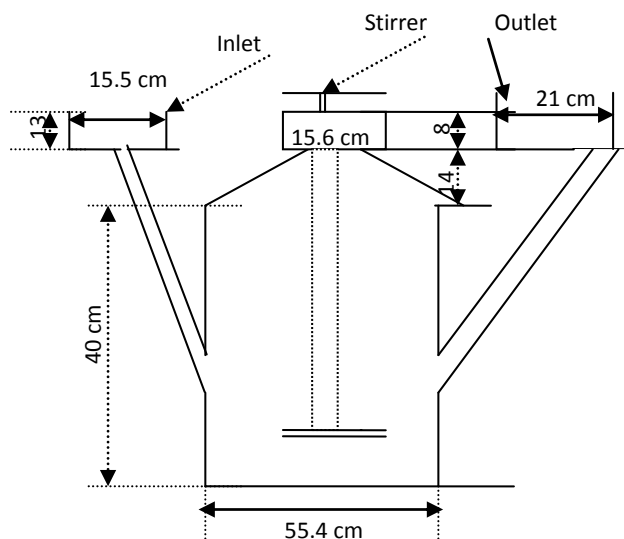


Figure 1. Schematic diagram of the biogas digester.

2004; Uzodinma et al., 2007; Mshandete and Parawira, 2009), reduction of size of organic wastes, addition of chemicals, etc. (Ofoefule and Uzodinma, 2008). The production and utilization of biogas are increasingly felt as the best answer to rural energy needs because it is a decentralized system which can be sealed to suit family as well as community needs. Optimization of biogas yield through co-digestion of organic wastes using rice husks has been reported by several research findings. Eze (1995) reported that the addition of poultry droppings to rice husk at an average temperature of 29.4°C resulted to cumulative biogas yield of 39.70 l/g.TS up from 18.37 l/g.TS gas yield obtained from rice husk alone at the same conditions and within 18 days retention period. Sahota and Rajinder (1997) also reported that the addition of rice husk soaked in water at 20% level to cattle dung digester increased biogas production.

Again, Uzodinma et al. (2007) reported that blends of rice husk with brewer's spent grain, cassava waste water and carbonated soft drink sludge increased biogas yield by over 240, 250 and 40% respectively while also reducing significantly the time taken for gas flammability to set in. However, Iyagba et al. (2009) reported that when rice husk was co-digested with cow dung at levels of 1:1 and 1:4, there was an observed increase in biogas yield different from that of the rice husk alone. This increased biogas yield was attributed to the cow dung, with the rice husk contributing nothing to the biogas production. Rice is a staple food crop in the tropics and the husks are readily available at rice mills in large quantities and sometimes in heaps of pyramidal shape either as powdered or un-powdered. Consequently, the wastes have not been fully utilized in biogas production.

The un-powdered rice husk is obtained from the rice mill after the parboiling process and subsequent milling to

de-hull the rice, while the powdered rice husk is normally obtained after the firing process which converts some of the husks into "ash" to give the product known as "rice husk ash". Moreover, the by-product of the anaerobic digestion of wastes generally (and in this instance rice husk) is a residue rich in essential inorganic elements like nitrogen and phosphorus needed for healthy plant growth known as biofertilizer which when applied to the soil, enriches it with no detrimental effects on the environment (Bhat et al., 2001). Previous study carried out on biogas production from rice husk showed that the waste has the potential to generate biogas but with low cumulative gas yields and slow onset of gas flammability as a result of the presence of lignin in the cell wall of the plant bringing about slower rate of degradation and hydrolysis with consequent acidic environment (Uzodinma et al., 2007).

This study was undertaken to investigate the effect of chemical treatment on these two parameters (cumulative gas yield and onset of gas flammability) of both powdered rice husk (P-RH) and un-powdered rice husk (U-PH) including the blend of the two – combined rice husk (C-RH) (1:1), by treating them with potassium hydroxide solution (KOH, 50% w/v).

MATERIALS AND METHODS

The powdered and un-powdered rice husks used for this study were procured from a rice mill at Adani, an Agricultural Center in Enugu state of Nigeria. The chemicals were used as procured without further purification. The KOH (99% purity), a product of Avondale Laboratories England and the Acetic acid (99% purity) made by Sigma-Aldrich Laboratories, Germany. The digesters used were the metal prototype digesters of 50 L capacity constructed at the National Center for Energy Research and Development, University of Nigeria, Nsukka (Figure 1) and the study was carried out between February and July 2008 at the same Research Institute.

Other materials used for the study include:

Top loading balance (50 kg, "5 goats", model no Z051099), plastic water bath for soaking the wastes, water trough, graduated transparent plastic bucket (for measuring gas production), thermometer (-10 to 110°C), digital pH meter (Jenway, 3510), hose pipes, biogas burner fabricated locally for checking gas flammability.

Digestion studies

Preparation of wastes

The fresh wastes used for this study were allowed to degrade for about two and a half months to reduce the toxicity of the wastes. They were then soaked in a plastic water bath for five weeks to allow for partial decomposition of the wastes by aerobic microbes (Fulford, 1998). The pH of the variants were monitored throughout this period and were still found to be acidic (Figure 2), hence the need for treatment since acidity is known to hinder biogas production. 12 kg of each of the wastes were weighed and soaked with 27 kg of water, giving water to waste ratio of approx. 2:1. The combined waste was done in the ratio of 1:1 of the pure wastes to make up 12 kg and soaked differently with 27 kg of water.

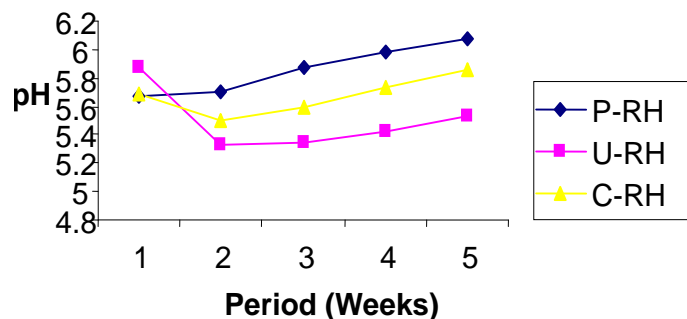


Figure 2. pH monitoring of the soaked wastes.

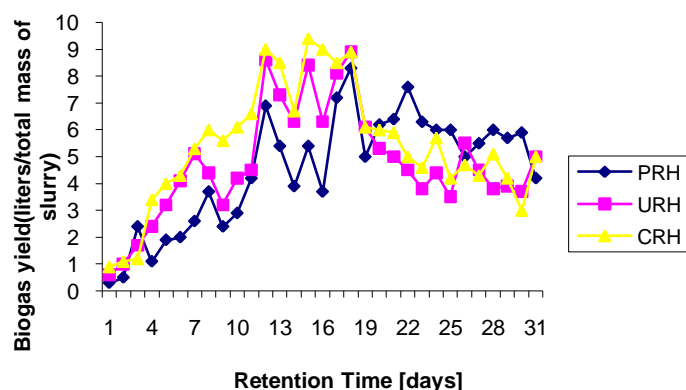


Figure 3. Daily biogas production for the pure and waste blends.

Each of the wastes was treated with 200 ml of KOH solution (50% w/v). 75 ml of acetic acid (CH_3COOH) was added to correct for pH when alkalinity was exceeded. The contents were stirred adequately to ensure homogenous dispersion of the chemicals in the mixture. They were left to stand for 1 week to ensure waste stabilization before charging into digesters.

Charging of the wastes

The wastes were charged in the metal prototype digesters of 50 L capacity in the ratio of approx. 2:1 water to waste. The moisture content of the waste determined the water to waste ratio. The digester contents were stirred adequately and on a daily basis to ensure homogenous dispersion of the chemicals in the mixture. Daily gas production measured in liter/ total mass of slurry (TMS) was obtained by downward displacement of water by the gas and recorded.

Analyses of wastes

Physicochemical analyses

Ash, moisture and fiber contents were determined using AOAC (1990) method. Fat, crude nitrogen and protein contents were determined using Soxhlet extraction and micro-Kjedhal methods described in Pearson (1976). Carbon content was done using Walkey and Black (1934) method, energy content was carried out

using the AOAC method described in Onwuka (2005) while total and volatile solids were determined using Renewable technologies (2005) method.

Biochemical analysis

The pH of both the soaked and treated wastes was monitored on weekly basis (Figure 2) using Jenway, 3510, digital pH meter. Ambient and slurry temperatures were also monitored and recorded daily using liquid in glass thermometer (-10 to 110°C).

Microbial analysis

Total viable counts (TVC) for both the pure and the waste blend slurries were carried out to determine the microbial load of the samples using the modified Miles and Misra method as described in Okore (2004). This was carried out at four different periods during the digestion; At the point of charging the digester, at the point of flammability, at the peak of gas production and at the end of digestion.

Statistical analysis

The data obtained from the volume of biogas production was subjected to one-way analysis of variance. The significant difference in the mean was determined at $p \leq 0.05$ using Genstat software package (Discovery edition 3).

RESULTS AND DISCUSSION

The experimental study was carried out within ambient and influent temperature ranges of 24 to 37°C and 28 to 42°C, respectively. Daily biogas production from P-RH, U-RH and C-RH systems is graphically shown in Figure 3. Biogas production commenced from all the systems within 24 h post-charging period (Figure 3). Flammable biogas production from each of the systems took place at different times during the digestion. For a biogas to be useful and effective for cooking and lighting, it must be combustible. If it burns, it means that the methane content is more than 45% (Anonymous, 2003). If it does not burn it means that the methane content is less than 45%, has more of CO_2 and other gases and may be useless to the end user for the purposes of energy utilization.

Ordinarily, untreated rice husk takes about 3 to 4 months before flammable biogas production commences (Uzodinma et al., 2007). This is because hydrolysis of rice husk and other plant wastes is very slow as a result of the hard structure of the plant and it has been reported that plant materials especially crop residues are more difficult to digest than animal manure because of the presence of lignin and consequent acidic nature of the wastes. Consequently, hydrolysis of cellulosic materials of crop residues can be a major rate determining factor in anaerobic digestion process (Kozo et al., 1996). More so, the imbalance in ratio of carbon to nitrogen of the plant raw material can limit the rate of organic conversion into

Table 1. Physicochemical composition of undigested wastes.

Parameters	P-RH	U-RH	C-RH
Moisture (%)	7.55	7.90	6.70
Ash (%)	13.90	12.80	11.20
Fiber (%)	32.40	47.60	42.80
Crude Nitrogen (%)	0.70	1.12	0.84
Crude Protein	4.38	7.00	5.25
Fat Content (%)	1.05	1.50	2.70
Total Solids (%)	92.45	92.10	93.30
Volatile Solids (%)	48.55	79.30	22.10
Carbon content (%)	40.60	20.30	21.15
Energy (Kcal/mol)	4.29	4.35	4.32
C/N ratio	57.93	18.13	25.18
pH at soaking	6.07	5.53	5.86
pH at charging (after treatment)	6.94	7.03	7.16

P-RH = Powdered rice husk, U- RH = Unpowdered rice husk, C-RH = Combined rice husk. The C-RH was combined in the ratio P-RH: U-RH (1:1).

Table 2. Lag period, cumulative and mean volume of gas production for the pure and waste blend.

Parameters	P-RH	U-RH	C-RH
Lag periods (days)	5	4	3
Cumulative gas yield (liter/total mass of slurry)	140.60	146.30	168.30
Mean volume of gas production (liter/total mass of slurry)	4.53	4.72	5.43
Standard deviation	±2.12	±2.07	±2.26
Treatment mean	13.89	14.63	16.84
Standard error	0.38	0.37	0.41

Treatment least significant difference (l.s.d): 3.163 at 5% confidence level. P-RH = Powdered rice husk, U- RH = Unpowdered rice husk, C-RH = Combined rice husk. The C-RH was combined in the ratio P-RH: U-RH (1:1).

methane.

Figure 2 shows the pH monitoring of the waste when soaked for a period of five weeks which necessitated the treating of the wastes before charging. Treating the wastes with KOH reduced the time taken for flammable biogas to commence (Table 2). This is because acids and bases are known to de-lignify plant cell structures (Matthewson, 1980). The KOH was expected to have assisted in facilitating this break down, neutralizing the acidic waste and releasing trapped nutrients for the microbes to feed on. This indicates that any local and cheaper source of potash like salt petre etc. can be used to achieve the treatment. The powdered rice husk (P-RH) had the least cumulative gas yield (Table 2). The undigested P-RH has high carbon content (Table 1). As a result, the carbon/nitrogen (C/N) ratio was much higher than the optimal level required for effective biogas production which has been given to be in the range of 20 to 30:1 (Dennis and Burke, 2001).

This is against 57.93 obtained for P-RH. Besides, it had least crude fibre, protein and energy contents (Table 1).

Anaerobic bacteria consume carbon roughly 30 times faster than nitrogen.

A higher ratio will leave carbon still available after the nitrogen has been consumed, starving some of the bacteria of this element. These will in turn die returning nitrogen to the system but slowing the process down (Energy commission of Nigeria, 1998). All these may have contributed to relatively low gas production of P-RH waste system. The U-RH had a cumulative gas yield that was slightly higher than that of P-RH and as such there was no significant difference between their biogas yields (Table 2). The raw U-RH waste had the highest fibre content (Table 1). This gives an idea of the materials that are indigestible in U-RH. Biogas production from less biodegradable wastes results to lower gas production (Energy commission of Nigeria, 1998).

The carbon content of the undigested U-RH was also low (Table 1), its cumulative gas yield was relatively higher than that of P-RH which may be due to availability of nutrients and highest energy content (Table 1). The lag period for this system was also shorter (Table 2).

Table 3. Total viable count (TVC) for pure and waste blend.

Period	P-RH	U-RH	C-RH
At charging	1.20 X 10 ⁶	5.67 X 10 ⁵	1.12 X 10 ⁶
At point of flammability	1.68 X10 ⁷	3.48 X10 ⁷	1.23 X10 ⁷
At peak of production	2.42 X 10 ⁵	4.33 X10 ⁵	1.78 X10 ⁶
Towards end of study	9.50 X10 ⁶	6.90 X10 ⁶	4.60 X10 ⁶

P-RH = Powdered rice husk, U- RH = Unpowdered rice husk, C-RH = Combined rice husk. The C-RH was combined in the ratio P-RH: U-RH (1:1).

Blending the two rice husks and chemically treating it brought about a significant increase ($p \leq 0.05$ within 85% confidence level) in the biogas production from the C-RH. The C-RH had the shortest onset of gas flammability and highest cumulative gas yield (Table 2). Some of the physicochemical properties of the undigested C-RH such as volatile solids, C/N ratio (at optimum range), fibre and energy contents were relatively high enough and would have contributed to the performance of C-RH system.

A count of the total viable microbial load for the different systems during the digestion period (Table 3) indicated that the highest number of microbes were available at the point of flammability, while at the end of digestion, the methanogens would have died ultimately reducing generation of biogas (Elango et al., 2007).

Conclusion

This study has shown that when rice husks are pre-treated, flammable biogas can be produced to serve both community and rural energy needs. The combined rice husk had the best onset of gas flammability and cumulative gas yield due to the synergy that existed between the combined wastes. This expected to provide a lee-way for local rice millers to utilize these wastes which are generally left to rot. It will also bring about an integrated system with reduced cost of operation and consequent increased earnings while providing better esthetics and healthier environment.

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