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Full Length Research Paper

Comparative study of the effect of chemical treatments on cassava (*Manihot utilissima*) peels for biogas production

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A comparative study of biogas production from cassava peels treated with different chemicals namely; potassium hydroxide (KOH, 50% w/v) and locally available potash ("akanwu" 50% w/v) was investigated. The untreated peels formed the control. The fresh cassava peels were degraded aerobically for 4 months before the chemical treatment, waste stabilization and charging of digesters took place. The different variants from the treated peels were charged into 50 L metal prototype biodigesters in the ratio of 2:1 of water to waste. The moisture content of the wastes determined the water to waste ratio. They were charged as; Cassava peels treated with KOH (CP-K), Cassava peels treated with potash (CP-P) and untreated cassava peels (CP-U). They were all subjected to anaerobic digestion under a 30 days retention period and mesophilic temperature range of 25 - 37°C. Results obtained showed that while the untreated cassava peels had cumulative gas yield of 68.7 ± 1.03 L/Total mass of slurry (TMS), the peels treated with potash had highest cumulative gas yield of 124.1 ± 2.67 L/TMS, whereas cassava peels treated with KOH had 111.3 ± 2.44 L/TMS. The flash point for the untreated cassava peels was on the 58th day, while that for the CP-K and CP-P were 10 and 7 days, respectively. The general results showed that the biogas yield from cassava peels can be enhanced by chemical treatment. Results further indicated that locally available potash ("akanwu") is a better chemical treatment to be employed in the biogas production of cassava peels.

Key words: Cassava peels, biogas production, cumulative gas yield, onset of gas flammability, lag period.

INTRODUCTION

Since the creation of man, energy has been an important aspect of his activities. Consequently, as the demand for energy is increasing excessively, the entire world has not rested in the search for the different forms of energy that will meet up with his activities. Renewable energy options such as biogas production from anaerobic digestion is a relatively cheap means of providing alternative energy that may serve appropriately for the rural energy needs and to a lesser extent urban energy requirements. Biogas is a colourless, flammable gas produced via anaerobic digestion of animal, plant, human, industrial and municipal wastes amongst others, to give mainly methane (50 - 70%), carbon dioxide (20 - 40%) and traces of other gases such as nitrogen, hydrogen, ammonia, hydrogen sulphide, water vapour, etc. (Maishanu et al., 1990). It is smokeless, hygienic and more convenient to use than other solid fuels (Buren, 1979). Biogas production is a three stage biochemical process comprising hydrolysis, acidogenesis/ acetogenesis and methanogenesis.

$(C_6H_{10}O_5)n + nH_2O \rightarrow n(C_6H_{12}O_6)$ - Hydrolysis
$n(C_6H_{12}O_6) \rightarrow n\,CH_3COOH$ - Acetogenesis/Acidogenesis
$3nCH_3COOH \rightarrow n\,CH_4 + CO_2$ - Methanogenesis

Biogas technology amongst other processes (including thermal, pyrolysis, combustion and gasification) has been

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viewed in recent times as a very good source of sustainable waste treatment / management, as disposal of wastes has become a major problem especially to the third world countries (Arvanitoyannis et al., 2007a). The effluent of this process 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).

The content of biogas varies with the material being decomposed and the environmental conditions involved (Anunputtikul and Rodtong, 2004). Potentially, all organic waste materials contain adequate quantities of the nutrients essential for the growth and metabolism of the anaerobic bacteria in biogas production. However, the chemical composition and biological availability of the nutrients contained in these materials vary with species, factors affecting growth and age of the animal or plant (Wolfe, 1971). Various wastes have been utilized for biogas production and they include amongst others; animal wastes (Nwagbo et al., 1991; Garba et al., 1996; Zuru et al., 1998; Itodo and Kucha, 1998; Alvarez et al., 2006), Industrial wastes (Uzodinma et al., 2007), food processing wastes (Arvanitoyannis et al., 2007b; Arvanitoyannis and Ladas, 2008; Arvanitoyannis and Varzakas, 2008), plant residues (Ofoefule and Uzodinma, 2008). Many are still being researched on as potential feedstock for biogas production.

Cassava processing is generally considered to contribute significantly to environmental pollution and aesthetic nuisance. The major wastes from cassava processing in Nigeria include; cassava peels, cassava wastewater, sievates and offal (wastes from “foo-foo” production). Cassava peels, which are usually discarded after the processing rot, could pose a disposal problem in the future especially with increased industrial production of cassava products such as cassava flour and dried cassava “foo-foo” (Ekundayo, 1980) including bioethanol production. Products of fermentation of cassava peels from such heaps include foul odour and sometimes poisonous and polluted air, which when inhaled by man or animals, may result to infection and diseases that may take a long time to manifest. Likewise, vegetation and soil around the heaps of cassava peels are rendered unproductive and devastated due to biological and chemical reactions taking place between continuously fermenting peels, soil and surrounding vegetation. Since these peels could make up to 10% of the net weight of the roots, they constitute an important potential resource if properly harnessed bio-technologically (Obadina et al., 2006). Initial digestion studies carried out on cassava peels showed that the peels are poor producers of biogas, probably as a result of their content of toxic cyanogenic glycosides (Okafor, 1998). As a result, they require treatment to enhance their yield of biogas and onset of gas flammability. One treatment method for this feedstock that has been carried out was by blending it with some animal wastes (Ofoefule and Uzodinma, 2009). The blending was reported to have a positive effect on the waste by enhancing the biogas yield and improving the onset of gas flammability. This study was undertaken to investigate the effect of chemical treatment on those two parameters by using locally available potash and traded KOH. The peels were treated with these two chemicals (50% w/v) as Cassava peels with Potash (CP-P), Cassava peels with KOH (CP-K) while untreated Cassava peels (CP-U) formed the control.

MATERIALS AND METHODS

The cassava peels used for this study was collected from one of the local processors of “garri” (a staple food in the Eastern part of Nigeria). The potassium hydroxide (KOH, 99% purity), made by Avondale laboratories England was purchased from a supplier at Nsukka town while the local potash (“akanwu”) was purchased from the market also at Nsukka town. These chemicals were used as procured without further purification. Other materials used for the study include metal prototype digesters of 50 L capacity constructed at the National Center for Energy Research and Development of the University (Figure 1), and the study was carried out between June and July 2008 at the same Institute. Other materials used were top loading balance (50 kg capacity, “Five goats”, model no Z051599), plastic water bath for soaking the peels, water trough, graduated transparent plastic bucket for measuring volume of gas production, thermometer (-10 - 110℃), digital pH meter (Jenway 3510), hosepipe, biogas burner fabricated locally for checking gas flammability.

Digestion studies

Preparation of wastes

The Cassava peels were allowed to dry up and were degraded for four months to reduce the toxicity of the waste. They were then soaked in a plastic water bath for two weeks to allow for partial decomposition of the peels by aerobic microbes which have been reported to aid faster digestion (Fulford, 1998) while monitoring the pH. 12 kg of each of the different samples; CP-U, CP-K and CP-P were weighed and soaked with 27 kg of water giving water to waste ratio of approximately 2:1. For the CP-K, 300 ml of potassium hydroxide solution (50% w/v) was utilized for the treatment, while 75 ml of acetic acid was used to correct for pH when alkalinity was exceeded. For the CP-P, 1.89 kg of potash (“akanwu”) was utilized for the treatment.

Charging of digesters

The different variants were charged into the 50 L metal prototype digesters as originally weighed out. 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. Gas production measured in liter/total mass of slurry was obtained by downward displacement of water by the gas.

Analyses of wastes

Physicochemical analysis

Ash, moisture and fibre contents were determined using AOAC

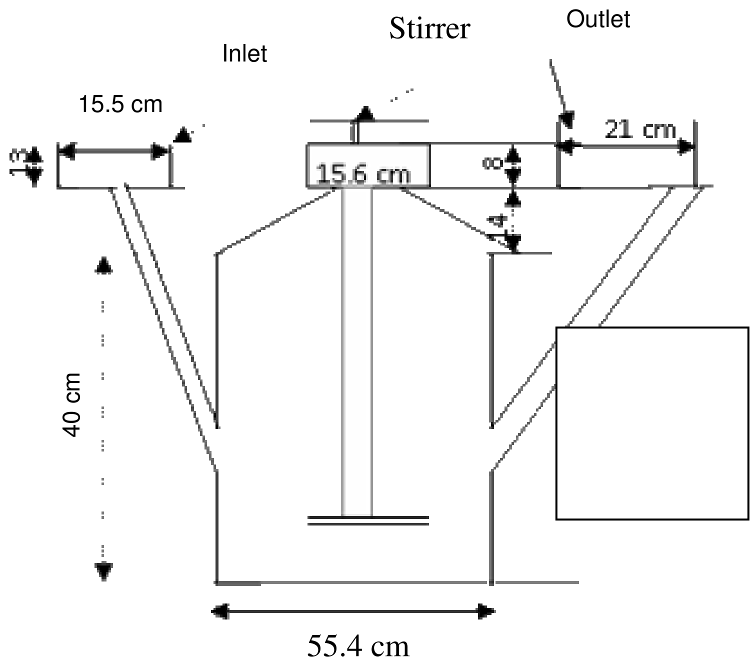

Figure 1. Schematic diagram of the biodigester.

method of 1990. 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 AOAC method described in Onwuka (2005) while total and volatile solids were determined using Meynell (1976) method.

Biochemical analysis

The pH of the Cassava peels soaked in water and treated were monitored for two weeks during which further treatment was effected for the stabilization of the waste, while the ambient and influent temperatures were monitored daily throughout the retention period.

Microbial analysis

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

RESULTS AND DISCUSSION

All experiments were carried out under daily mean ambient temperature range of 24 - 37°C throughout the period of gas production. Daily biogas production from the untreated cassava peels and the treated variants are graphically shown in Figure 2. Each of the biogas systems produced non-flammable biogas within 24 h of charging the digesters, whereas the flammable gas production as shown in Table 2 commenced at different time lags (which is from the time of charging the waste to the onset of gas flammability). Results in Table 2 shows that the untreated cassava peel (CP-U) had the longest time lag of 58 days and lowest cumulative gas yield. This may be as a result of the acidity of the untreated cassava peels (Figure 3). Figure 3 which display the pH changes, shows that the pH was mainly from acidic to slightly acidic for a long period. One of the major problems associated with biogas production from cassava tuber wastes (cassava wastewater, cassava solid waste and cassava fresh tuber) is low pH (Kozo et al., 1996; Barana and Cereda, 2000; Anunputtikul and Rodtong, 2004).

The thin brownish outer membrane of cassava root consists of lignified cellulosic material while the white inner portion comprises parenchymateous material known to contain most of the toxic cyanogenic glycosides and linamarin in the entire cassava root (Okafor, 1998). The linamarin is broken down with the production of the hydrocyanic acid during the processing. The low pH of the pure cassava peels indicated the need for the peels to be treated for enhanced gas yield and faster onset of gas flammability. This is also because the methanogens that convert wastes to flammable biogas are highly pH sensitive and operate optimally at a pH range of 6.5 - 8.5 (Anonymous, 1989). Hence, in most of the work done in biogas production using cassava wastes, inoculums and neutralizers have been applied to the slurry to bring about neutrality in the biogas system (Anunputtikul and Rodtong, 2004). Moreover, treatment of the waste with KOH is expected to de-lignify the cassava plant structure, since acids and bases are known to be used to delignify

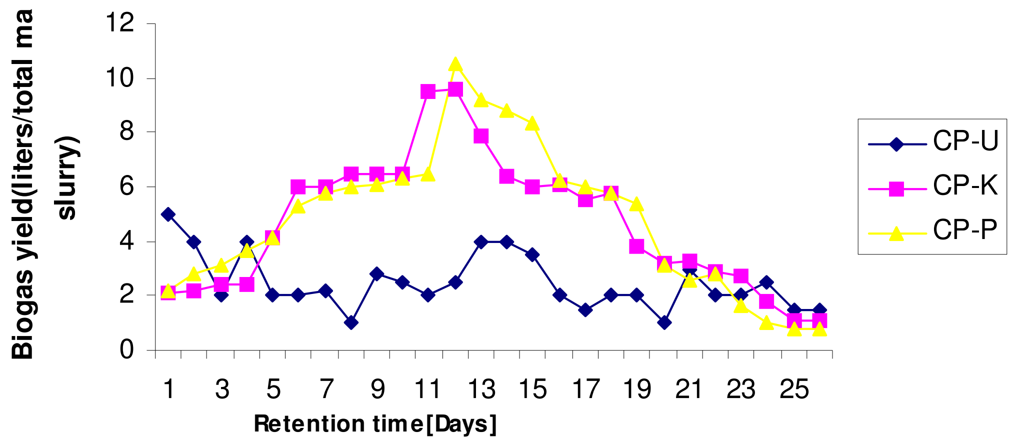

Figure 2. Daily biogas yield for pure and treated CP.

Table 2. Lag period, cumulative and mean volume of gas production for cassava peels.

Parameter	CP-P	CP-K	CP-U
Lag period (days)	7	10	58
Cumulative gas yield (L/ total mass of slurry	124.1	111.3	68.7
Mean volume of gas production (L/ total mass of slurry)	4.97	4.45	2.39
Standard deviation	± 2.67	± 2.44	± 1.03

CP-P= Cassava peels with potash, CP-K= Cassava peels with KOH, CP-U= Cassava peels untreated.

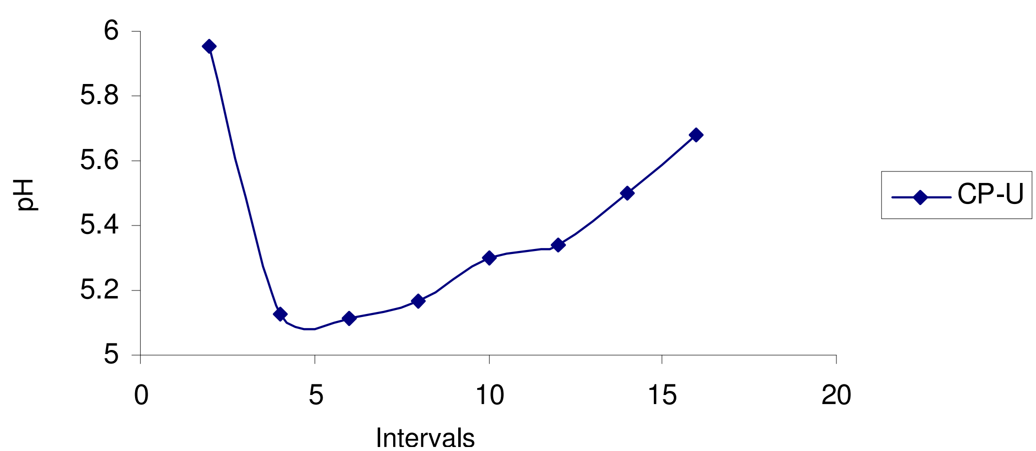

Figure 3. pH changes for the CP-U.

cellulose plant materials (Mathewson, 1980). This is also expected to expose / release the trapped nutrients in the plant to the microbes as well as creating a neutral environment for their activity with consequent increase in gas production. The treatment which was effected, evidently affected the behavior of the cassava waste (Table 2). The treatment reduced the lag period drastically to 10 and 7 days while it increased the yield by 62 and 81%, respectively for the CP-K and CP-U. The physicochemical properties of the treated wastes showed improvements on the untreated one (Table 1). For instance, the volatile solids (which is the biodegradable portion of the waste), Energy and Fat were higher.

The CP-P had the shortest onset of gas flammability and highest biogas yield. This may be attributed to the highest energy content, volatile solids, nutrients, C/N ratio, etc. These are the major physicochemical factors that affect biogas production. Even though the CP-K had a lower yield and slower onset of gas flammability, its performance was significantly better than the untreated

Table 1. Physicochemical properties of the wastes.

Parameter	CP-P	CP-K	CP-U
Moisture (%)	1.6	1.5	14.25
Ash (%)	10.2	10.2	21.9
Fiber (%)	11.2	11.2	32
Crude nitrogen (%)	0.98	1.21	1.4
Crude protein (%)	6.13	7.58	8.74
Fat content (%)	2.2	1.4	0.75
Total solids (%)	98.4	98.5	68.25
Volatile solids (%)	70.77	64.35	33.87
Carbon content (%)	30.01	35.13	41.27
Energy (Kcal/mol)	4.25	4.09	3.50
C/N ratio	31.60	29.03	30

CP-P = Cassava peels with potash, CP-K= Cassava peels with KOH, CP-U = Cassava peels untreated.

Table 3. Total viable count (TVC) for the waste slurries.

Period	CP-P (cfu/ml)	CP-K (cfu/ml)	Cp-U (cfu/ml)
At the point of charging	1.3×10^4	6.75×10^5	1.13×10^3
At the point of flammability	5.75×10^6	8.33×10^6	1.59×10^6
At the peak of production	4.6×10^7	2.58×10^7	1.45×10^7
Towards the end of production	2.17×10^6	7.5×10^5	2.05×10^6

CP-P = Cassava peels with potash, CP-K= Cassava peels with KOH, CP-U = Cassava peels untreated.

CP. The total viable microbial count (TVC) of the slurries during the digestion displayed in Table 3 shows the progression of the microbes. The TVC for the CP-U had the least load throughout the digestion period when compared with the treated wastes, indicating that the treatment also affected the microbial load positively.

Conclusion

The overall results indicate that the low biogas yield and slow onset of gas production/flammability of cassava peels under anaerobic digestion can be enhanced when treated with KOH and potash (50% w/v). The potash-cassava peel system had the shortest onset of gas flammability and highest cumulative volume of gas production. Hence, this treatment could be a cheaper source of waste management and or energy option to industrial cassava processors and the rural dwellers.

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