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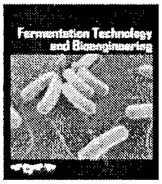

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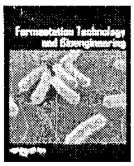

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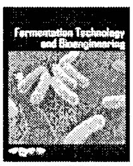

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Evaluation of Sorghum Stalks, Wood and Food Wastes in Mini Pilot Plant Biogas Production

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ABSTRACT

Conventional biodegradable agricultural and household wastes (sorghum stalks, sawdust, rice and beans wastes) have been biodegraded in a mini pilot bio-digester at 33°C. The volume of biogas formed in each of the systems was determined and the relative degradability of the substrates compared. When ranked, the substrates performed as follows: softwood sawdust > maize stalk > guinea corn stalk > hardwood sawdust > beans alone > beans/rice mix.

Keywords:
Assorted wastes,
mini pilot biodegradation.

1. Introduction

Affordable energy for cooking/heating and lighting purposes remains a problem of great concern in many developing nations. The low income rural dwellers of Sub-Saharan Africa constitute a significantly disadvantaged group in terms of access to affordable energy. In Nigeria, currently ranked 6th in world production and export of crude petroleum products, the story is no different. The now frequent and practically uncontrollable petroleum products price hike (gasoline and kerosene in particular) has brought about once again increased use of fuel wood, a situation that had declined substantially during the past several years. Use of fuel wood on a regular basis as a source of energy for cooking/heating implies tree felling on a continuous basis, without the corresponding tree planting for replacement. Tree felling is among the many factors (e.g. bush burning, overgrazing, over-cultivation, etc) that promote dsertification[1]. There are reports of the Borno state government of Nigeria, and the Chad Republic passing laws to outlaw tree felling[2]. As far back as 2003, a report expressed the pessimism that investments by the Nigerian Northern and Eastern state governors to fight desert encroachment and erosion might be in vain[3]. This was as a result of

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kerosene price hike witnessed at the time, which, according to the reporter, would prompt Nigerian rural dwellers to fell more trees. In the interim, kerosene price has witnessed fluctuations, and a recent report (Jan. 2011) is about kerosene price-hike once again[4]. For many Nigerian rural inhabitants today, kerosene, a downstream product of the petroleum industry, has become a luxury even for lighting purpose. For this class of Nigerians, even as the petroleum industry continues to flourish, a viable, affordable and renewable energy resource is most likely to be found in the abundant biomass materials in the environment: plant and animal wastes as well as cooked food and agricultural wastes. These are readily convertible to gaseous fuels and oils.

There is appreciable literature on the conversion of various biomass materials to gaseous bio-fuels and oils[5-12]. While much of the technology on biogas production so far has utilized animal waste principally as substrate, other biomass materials, e.g. grasses, wood and food wastes, are also receiving attention.

We had earlier reported on the importance of availability of appropriate microorganisms for the anaerobic biodegradation process. Also, an earlier reported study of the elephant grass biodegradation observed reaction enhancement by a number of micro-nutrients[13]. It was observed, among others, for example, that mixed microorganism cultures could be just as effective as the pure cultures. Similarly, a recent study by Nawa[14] has shown that an equal volume mixture of cow dung, vegetable and kitchen waste is more effective than cow dung alone in increased formation of biogas. This finding is particularly significant in any planned development of a simple, inexpensive biogas production technology that is affordable to the most needy – the rural populace.

The hitherto generation of biogas solely from animal waste has certainly had its limitations. Clearly, large animal breeding farms would be required to produce adequate amounts of waste for biogas generation. Our studies spanning many years have in fact revealed that a number of biomass materials generate far more biogas than animal waste on a comparable weight basis.

In this paper, our findings of a mini pilot scale biodegradation of maize and guinea corn stalks, hard and soft wood saw dust as well as cooked food waste (beans alone and mixed beans/rice waste) are discussed.

Biogas, an approximately 60:40 (V/V) mixture of methane and carbon dioxide is produced by anaerobic fermentation of cellulosic biomass materials. Biogas can be used to generate high pressure steam, which through coupling to a rotating turbine would lead to electricity generation[15]. Small scale bio-digesters of various shapes have been used in India and China. While about 1.8 million cattle dung digesters were installed in India by mid-1996, a third of these were no longer operational by 2000. Insufficient dung and difficulties in the organization of dung deliveries were identified as the major problems.

2. Materials and Methods

Experimental

Substrate Pre-treatment

Maize and guinea corn stalks were obtained from farming areas within the university community. Similarly, the food wastes were leftovers of the food services facilities within the university. The maize and guinea corn samples were washed, chopped into small pieces; oven-dried at 100°C for 2h, cooled and finally ground to < 250µm particle size. The food waste was size-reduced with the help of a mortar and pestle. Hardwood (mahogany) and softwood (gmelina) samples were obtained from the carpentry/woodwork industrial estate of the city of Jos. These were similarly oven-dried at 100°C and further treated as described above for maize and guinea corn.

Substrate – H_2O slurries for biodegradation were of the order of 2: 5 (w/v) in all cases. The systems were generally un-buffered; the initial pH of the slurries was about 7.3 in most cases.

In the case of the food wastes, pig dung was added as inoculum. For the other systems, the processed substrates were pre-exposed for a minimum of 24h at ambient laboratory air temperature for direct organism build-up prior to slurry preparation

The Digester

The mini pilot digester, made of brass material, was constructed by the Equipment Maintenance Centre (EMC) of the University. It was cylindrical in shape, 21cm deep, had 20cm internal diameter and 10 liter capacity. It was fitted with a manual stirrer, slurry loading and gas exit nozzles at the top, and a sludge discharge at the bottom. It was dome-shaped at the top. This enhanced gas pressure build-up at the exit nozzle. By the process of downward displacement of water in a burette sealed at the top and connected to the digester, the gas evolved in the biodegradation was monitored daily and its volume recorded. The digester was stirred on a daily basis

Isolation of Organisms

In order to isolate organisms involved in the process, small portions of spent slurry (sludge) from each of the food wastes were collected in a sterile bottle by means of a clean glass rod. The samples were then transferred to the incubation hood and cultured on blood agar, MacConkey agar (MCA), and Sabourauds dextrose agar (SDA). The SDA was used for yeast isolation to ascertain the presence or otherwise of fungi. The plates of blood agar and MCA which were inoculated were incubated both aerobically and anaerobically at 37°C. Also, small portions of samples were placed in meat infusion broth, which is a special growth medium for clostridium. The SDA was incubated at room temperature at about 25°C. The plates were all examined for growth after 24h. The SDA plates were further left for 7 days at ambient laboratory temperature for possible fungal growth.

Yeasts were identified by their fermentation test and bacterial isolates by the Gram and biochemical reactions[16].

Biodegradation

For the biodegradation, the substrate-water slurry (prepared as described above) was charged into the digester; the system was then sealed air-tight and placed in a water bath with temperature regulation. Runs in triplicate for each sample were at 33°C. The process was batch-wise; each set up for the fermentation was allowed to proceed to the point of zero gas production. Thereafter, the digester was cleaned and recharged with the next sample slurry.

3. Results and Discussion

Figures 1 – 3 show the performance of the various biomass materials in terms of the volume of gas generated on a daily basis: maize and guinea corn (Fig. 1); beans alone and beans/rice mixture (Fig. 2); hardwood (mahogany) and softwood (gmelina) sawdust (Fig.3).

In Fig. 1. biogas generation for each of maize and guinea corn is zero on day one. This rises to approximately $2.5x10^{-4}m^3/kg$ for both on day two. The daily production progressively attains a maximum on day three for guinea corn (3.8×10^{-4} m^3/kg) and day four for maize ($5.8 \times 10^{-4}m^3/kg$). Both systems gradually attain their minimum gas production on day twelve (zero for guinea corn and approx. $1.8x10^{-4}m^3/kg$ for maize)

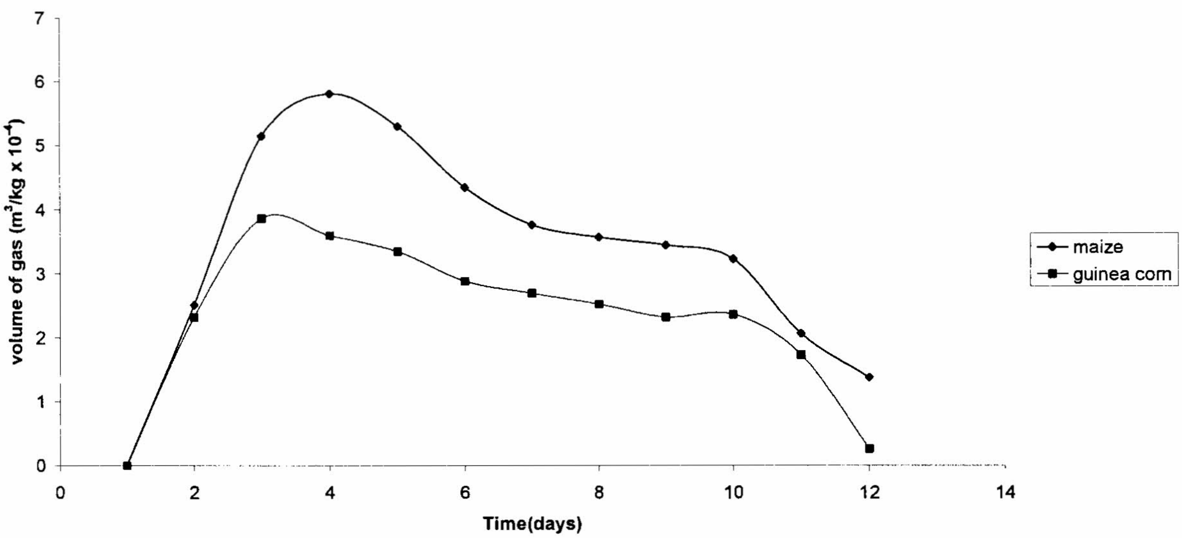

Fig 1 : Performance of maize and guinea corn stalks in biodegradation

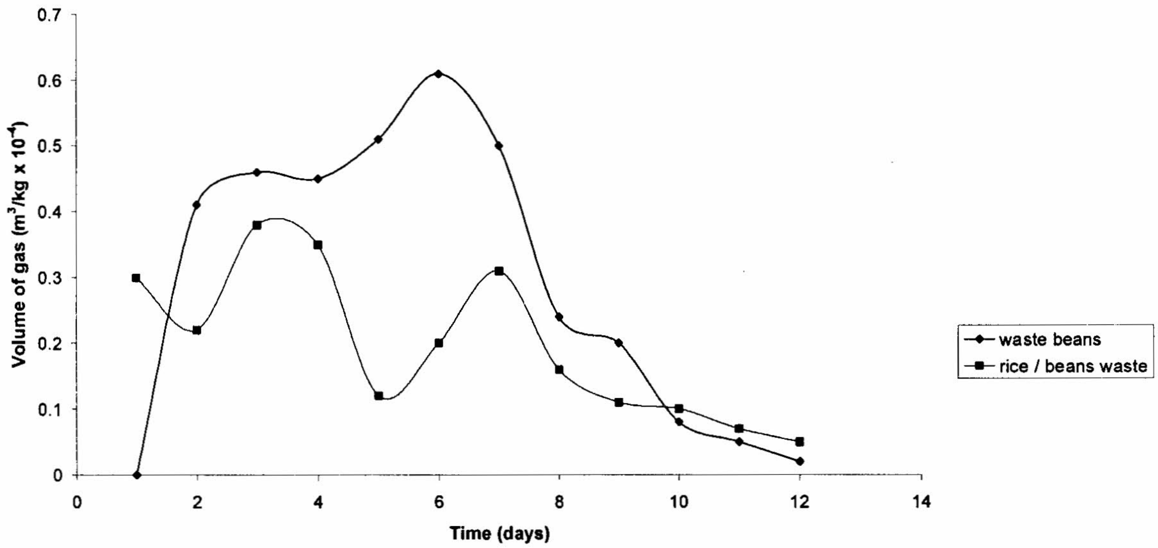

Fig 2 : Performance of beans waste alone and mixed rice/beans waste in biodegradation

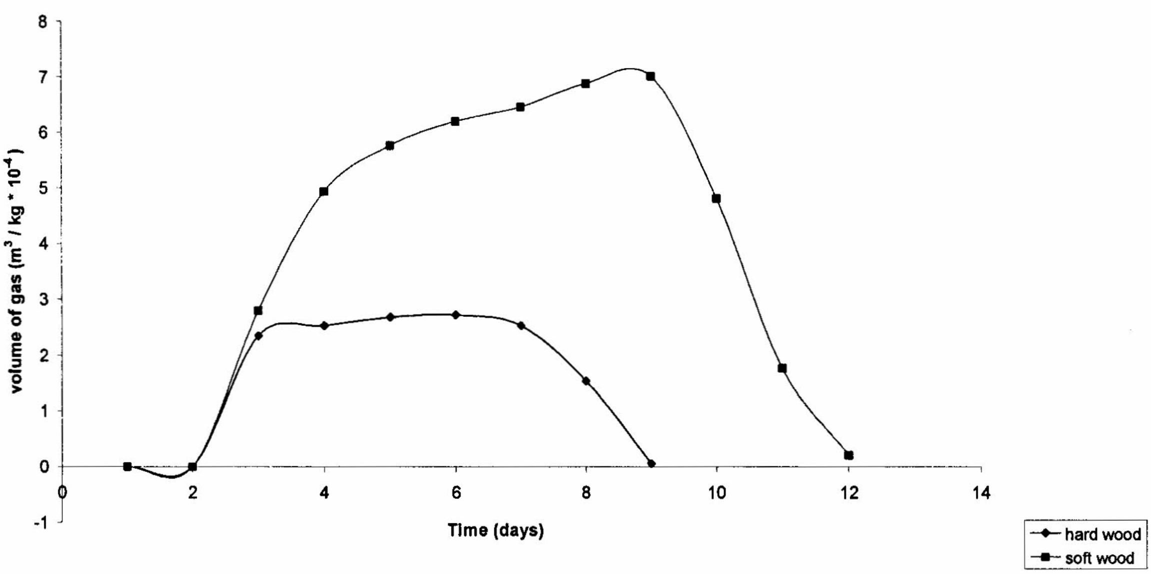

Fig 3: Performance of hard and soft wood saw dust in biodegradation

By all accounts, maize stalk performed significantly better than guinea corn stalk. This confirms our previous observations in the laboratory scale studies.

The results of Fig. 2 follow a pattern similar to the maize/guinea corn systems, the beans alone clearly producing more biogas than the combined beans/rice system. Comparatively, the beans alone produces a maximum of $0.6x10^{-4}m^3/kg$ on day six, the rice/beans mix only as much as $0.3x10^{-4}m^3/kg$ on day seven. Both systems experience a production drop thereafter, each producing less than $0.1x10^{-4}m^3/kg$ by day twelve.

It is to be noted, however, that the actual daily volumetric biogas produced in these systems is an order of magnitude lower than those of the separate maize and guinea corn systems.

In Fig. 3.0, it is observed that biogas generated is practically zero in the first two days for both hardwood and softwood. On day three, the biogas produced is comparable for both systems; this is, approximately, $2.3x10^{-4}m^3/kg$ for hardwood and $2.7x10^{-4}m^3/kg$ for softwood. Hardwood produces a maximum biogas of approx. $2.8x10^{-4}m^3/kg$ on day six; for softwood, the maximum is as much as $7.1x10^{-4}m^3/kg$ by day ten. Thereafter, both substrates tend towards zero production levels. For hardwood, this is attained by day nine; for softwood by day twelve.

Hardwood biodegradation is significantly low; the maximum daily gas production of about $2.8x10^{-4}m^3/kg$ obtained on the sixth day is less than half of that of softwood ($7.1x10^{-4}$ m^3/kg) obtained on day nine.

When the substrates are ranked on the basis of their biodegradation efficiency, we have: softwood sawdust > maize stalk > guinea corn stalk > hardwood sawdust > beans alone > beans/rice mix.

The net combustible gas (CH_4) yield per kg of substrate was not determined in the present study, although such information is available from our laboratory scale studies on the elephant grass, maize and guinea corn stalks[13].Net biogas yield is obtained by removal of CO_2 as a carbonate.

For the elephant grass, biogas production on the laboratory scale is observed to be significantly higher than that obtained in the mini pilot scale, the order of reactivity being: elephant grass > maize > guinea corn stalk[17].

The higher biogas formation on the laboratory scale relative to the mini pilot scale is readily explained by the relatively larger volume of substrate in the mini pilot and the non-comparable surface area exposure, as the reaction rate is known to be a function of the surface area of exposure of the substrate, among others. Furthermore, the extent of organism availability for biodegradation in the mini pilot scale may be inadequate compared to the laboratory scale.

A number of biodegrading microorganisms were identified and their specific roles are currently being studied, but we had observed and reported previously that mixed rather than pure microorganisms hold much promise for bio-fuel generation[13], and this is important in indigenous technology development, which is the focus of this study.

Oyagade and Opumu[18] in an anaerobic digestion of cassava peel mixed with pig waste for biogas and biofertilizer generation isolated *Cellumonas sp, Bacillus sphaericus, Proteus vulgaris* and other organisms from the digested sludge. Similar studies on the elephant grass over a number of years have demonstrated significant activity of *Penicillium spp* and *Curvularia spp* but not *Aspergillus niger, Fusarium spp* and *Enterobacter aerogenes* [13]

These observations will guide our on-going studies; in particular, it would be necessary to re-examine our present digester design by considering the possibility of increasing the exposed substrate surface area.

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4. Discussion

In this present study, the moisture content of all the ten maize samples was significantly higher than the recommended 13% level for safe storage[7]. Moisture content higher than 13% level recommended for effective storage of maize grains has also been reported in stored grains[11]. This high moisture content is probably due to the combined effects of the prevailing climatic conditions[21] and the practice of non-scientific method of handling grains during harvesting, shelling and drying. High moisture content may also be due to the storage of maize grains in synthetic bags which trap moisture and hence, an increase in the moisture content of maize grains. The high moisture content of the maize grains, its rich nutritional composition coupled with favourable prevailing temperature of Iwo, make it an ideal substrate for microbial growth and this further deteriorates the grains very quickly during storage[6]. Deterioration often results in high economic loss due to the development of colour, odour. Hence, safe and scientific method of drying maize should be adhered to so as to minimize deterioration and increase or extend the shelf life of stored maize grains.

All the fungi isolated from these maize grains have been previously reported [14, 16, 15&4]. The high incidence of organisms from Sample S2 and S7 coupled with their high moisture content probably suggests the bad handling of grains during the pre-and post-harvest periods. High incidence of species of *Fusarium*, *Cladosporium* and *Botrydiplodia* from Sample S2 and S8 suggests the high incidence of fungal infection of these maize samples prior harvesting since these fungi are known to be plant pathogens. Bankole and Mabekoje[16] also documented the possibility of cross contamination since the warehouses are usually used to store more than one type of agricultural products.

The relatively high number of species of *Fusaruim, Penicillium* and *Aspergillus* in these maize grain samples is of high importance since these organisms are known to produce toxic chemical substances known as mycotoxins[22]. Apart from producing mycotoxins, some of these organisms like *Aspergillus* sp also cause allergic reactions and aspergillosis in humans and animals (17).

Various reports [11, 23&22] have emphasized the importance of rapid drying of maize grains prior to storage so as to minimize post-harvest loss resulting from mould contamination.

The results of the correlation co-efficient revealed a positive correlation between the numbers of fungal isolated and the moisture content of the maize samples. This could be as a result of the fact that microorganisms especially fungi, require high moisture content for growth and effective metabolism [24].

In conlusion, based on the results of this study, good practice of pre- and post-harvest management strategies are necessary to minimize mould infestation of maize grains and also to reduce the possible health risk resulting from the consumption and exposure of humans and animals to mould contaminated maize grains in Iwo, Osun state Nigeria.

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