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GASEOUS FUEL PRODUCTION BY ANAEROBIC FUNGAL DEGRADATION OF BANANA LEAVES

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ABSTRACT

Anaerobic biodegradation of banana leaves by cellulolytic fungus (yeast) was carried out at optimum operational conditions of temperature (33^0C), P^H (7.3) and slurry concentration ($4g/25cm^3$). The organic component of the gaseous fuel generated was analysed using flame ionization detector (FID). The analysis revealed that the gaseous fuel was rich in methane (CH_4).

Keywords: Anaerobic biodegradation; Micro-organisms; gaseous fuel (biogas).

INTRODUCTION

A sound economic planning and hence industrial development depend to a large extent on the resources available to a nation. This is to say that a nation can automatically develop with the abundance of human and material resources, if the resources could be integrated and judiciously used towards industrialization. On the other hand, industrialization requires a lot of energy for its survival. But the global increase in the prices of improved petroleum products, which are used for energy supply led the world to search for alternative sources of energy for domestic and industrial fuels so as to become less dependent on the improved petroleum products. Developed countries are now concentrating on nuclear and electrical sources of energy, which are cost prohibitive and inaccessible to rural populace in most of the developing countries of Africa as reported by Yusuf (2000). Since energy is one of the basic requirements for industrial development of any country in the world, it is very imperative to think of the ways through which alternative fuels, which are environmentally friendly could be generated at low cost. In view of this, attention has seriously been focused all over the world towards generating fuel from waste and other renewable sources of energy which are cheaper and relatively available, such as solar, wind, geothermal, etc.

A fuel may simply be defined as any substance which on burning or decomposing provides heat. A part from atomic energy, all common fuels are carbon containing compounds, which can be solid, liquid or gas (Robinson,1973). Solid fuels include: wood, peat, lignite, anthracite, coke, e.t.c; liquid fuels include: petrol, diesel oil, kerosene e.t.c; and gaseous fuels include: natural gas, coal gas, water gas, producer gas, town gas, biogas etc Robinson (1973) also reported that fixed weights of different fuels produce different amount of heat when combusted. Therefore, there is the need to have some means of comparing one fuel with another even if they are in the same physical state. One of the essential ways of comparing one fuel with another is its calorific value. The higher the calorific value, the better the fuel, hence the quality of a fuel can be determined in terms of its combustibility and calorific value as pointed out by Baja and Godman (1975); Ababio (1985); Baja et al (1988).

Calorific value of a fuel is simply defined as the amount of heat evolved when 1g or 1kg of the solid or liquid fuel or food is completely burnt in oxygen (Atkison, 1979).Thus; the calorific values of solid and liquid fuels are expressed in terms of Mg/Kg or KJ/g of the fuel while the calorific value of gases is expressed in terms of MJ/litre i.e the amount of heat (in megajoule) produced during the complete combustion of one litre of the gaseous fuel as pointed out by Robinson (1973). A part from calorific value, the choice of a fuel for energy supply must be influenced by many other factors such as cheapness, availability, little ash or smoke when combusted (i.e neatness) and the ash or smoke should not be dangerous to health or harmful to environment and substances of value in the environment. This is in line with the statement of Ariane (1985).

The advantages of using gaseous fuel over solid and liquid fuels include: convenience to handle; the supply of the gas (fuel) can readily be turned off suddenly, and relit in a few seconds; no ash is left as residue; and if the burner is properly adjusted, the gas is a perfect smokeless fuel as reported by Robinson (1973). In addition, it has been reported by Ariane (1985) $1cm^3$ of gaseous fuel (biogas) can cook 3 meals for a family of 5-6; can keep 1 biogas lamp of luminosity equivalent to 60 watts electricity light burning for 6-7 hours; can keep 1 hp internal combustion engine working for 2hours, which is roughly equivalent to 0.6 –o.7 kg of petrol; can drive a 3 tone lorry for 2.8 km; and can generate 1.25 kwh of electricity.

It should be noted that not all sources of fuels are continuous in nature. Some sources of fuels are exhustable and can completely be depleted. Based on this, energy is broadly categorised as renewable and non-renewable. Renewable energy is the energy obtained from the continue or repetitive currents of energy occurring in the natural environment (Twindell & Anthony, 1990). The following are the major alternative sources of renewable energy: hydroelectric power, wind power, geothermal power, solar energy and waste organic substances as reported by Yaro (2010).

Non-renewable energy is the energy obtained from the static store of energy that remains bound unless released by human interaction (Twindell & Anthony 1990). Petroleum (crude oil), coal and natural gas are the examples of non-renewable energy resources available in Nigeria.

The production of gaseous fuel from organic substrates (banana leaves inclusive) is an anaerobic microbial process, which involves the combined action of different micro-organisms in four different stages as reported by Khandelwal and Mahdi (1986). The first stage is the degradation of higher molecular weight substances like cellulose, starch fats, proteins in organic materials into low molecular weight compounds like fructose, glucose etc.

$$n(C_6H_{10}O_5)_{(S)} + nH_2O_{(l)} \xrightarrow{\text{Enzymatic hydrolysis}} nC_6H_{12}O_{6\,(aq)}$$

In the second stage, the product of the first stage is converted into organic acid and by-products like CO_2, H_2O, H_2, NH_3, etc by a group of bacteria known as acetogens.

$$nC_6H_{12}O_{6\,(aq)} \xrightarrow{\text{Acetogenes}} 3nCH_3COOH_{(aq)}$$

The third stage is the conversion of hydrogen and simple carbon compounds produced in the second stage into ethanoic acid by a group bacteriab called homoacetogens.

$$4H_{2\,(g)} + 2CO_{2\,(g)} \xrightarrow{\text{Homoacetogenes}} CH_3COOH_{(aq)} + 2H_2O_{(l)}$$

The fourth stage is the conversion of ethanoic acid and some other compounds like CO_2 and H_2 into CH_4, by a group of bacteria known as methanogens.

$$\left.\begin{array}{l} CH_3COOH_{(aq)} \xrightarrow{\text{Methanogenes}} CH_{4\,(g)} + CO_{2\,(g)} \\ \\ CO_{2\,(g)} + 4H_{2\,(g)} \xrightarrow{\text{Methanogenes}} CH_{4\,(g)} + 2H_2O_{(l)} \end{array}\right\} \text{gaseous fuel (biogas)}$$

Specific Objectives of the Research

The objectives of this research for using banana leaves as a raw materials for gaseous fuel generation will involve: the provision of a renewable energy; determination of hydrocarbon type in the gaseous degradation product (gaseous fuel); and reducing environmental problems associated with the dumping and burning of wastes.

MATERIALS AND METHODS

Preparation of sample The substrate (banana leaves) was prepared by drying in an oven at 105^0C for 3 hours, ground using pestle and mortar and sieved to a mesh size of <250µm.

Preparation of slurry The slurry was prepared by dissolving 4.0g of the prepared sample of banana leaves in 25cm^3 of distilled water containing 0.18g yeast.

Production and Collection of Gaseous Fuel

The prepared slurry was placed in a Vuchner filter flask (as reactor). The reactor was made airtight using plastic stopper and the outlet of the reactor was connected to a balloon using PVC tube. The degradation temperature was maintained at 33^0C using water bath within which the reactor and it content were placed. The degradation process was allowed to continue for 7 days, with the reactor being shaken periodically. The gaseous degradation product (gaseous fuel) generated was collected in a balloon. The experiment was carried out in triplicate.

In order to evaluate the volume of gaseous fuel generated, 3 parallel set ups under the same conditions were made in which the out let of each of the reactor was connected to an inverted measuring cylinder filled with brine (28% NaCl solution), which prevents the gaseous fuel generated from dissolving. The volume of the brine displaced in each of the measuring cylinder served as a measure of the volume of gaseous fuel generated in each of the set ups. The average volume of the gaseous fuel generated was evaluated and recorded.

Analysis of the Gaseous Fuel generated

In order to identify the individual components of the C_1 – C_4 of the hydrocarbons in the gaseous fuel generated a gas-liquid chromatograph (glc) fitted with the porapark Vz7 (dimension 8m x 3mm) column made of stainless steel was used. The column was kept at 150^0C, the flame ionization detector (FID), which was maintained at 220^0C was used. Helium was used as carrier gas (flow rate 50cm^3/min and pressure 5kg/cm^2). The quantity of the sample used (in micro litre) was 8, which was injected into glc at 100^0C injection temperature. The component was identified using its glc retention time (RT), which was compared with the RT of liquefied petroleum gas (LPG) obtained from crude oil distillation.

RESULTS AND DISCUSSION

The results of all the analysis carried out in this work are shown in the Tables below:

Table 1: Daily and Cumulative Average Volumes of Gaseous Fuel Obtained

No. of days	Average Volume (cm^3)
01	45.00
02	22.00
03	14.00
04	0.00
05	0.00
06	0.00
07	0.00
Cumulative average volume after seven days	**81.00**

Table 2 – Analysis of Gaseous Fuel Generated and LPG used

Component	RT	Area	Height	Mole %	Factor
* CH_4	2.230	3201799	429396	99.691	1.000
CH_4	2.246	56534	8618	1.145	1.000
C_2H_6	2.423	257741	37917	5.222	1.000
C_3H_8	2.730	878316	109247	17.796	1.000
C_4H_{10}	3.193	625767	69407	12.679	1.000
C_5H_{12}	3.530	1515640	128395	30.710	1.000
C_6H_{14}	4.833	945643	66118	19.161	1.000
C_7H_{16}	5.480	654173	39516	13.225	1.000
C_8H_{18}	6.736	1541	143	0.031	1.000

* Component identified in the gaseous fuel

DISCUSSION

The daily average volume of gaseous fuel generated in this work is as shown in Table 1. From the results, the cumulative volume of gaseous fuel generated was 81.00cm^3 . This shows that gaseous fuel can be generated from banana leaves.

The results of the respective glc analyses of the gaseous fuel and LPG carried out are shown in Table 2. From Table 2, it could be seen that the organic component identified in the gaseous fuel was * CH_4 while the components identified in the LPG were CH_4, C_2H_6, C_3H_8, C_4H_{10}, C_5H_{12}, C_6H_{14}, C_7H_{16} and C_8H_{18}. This shows that the gaseous fuel generated was of the same chemical nature with natural gas because methane (CH_4) is the main component of natural gas as pointed out by Murray (1977).

Comparison of the results shown in Table 2 has shown that the peak of CH_4 in the gaseous fuel generated shown on Figure 1 corresponded to the peak of CH_4 found in LPG and shown on Figures 2. Furthermore, the respective retention times (RT) of CH_4 in the gaseous fuel generated and LPG used were 2.230 and 2.246 as shown on Figures 1and 2 respectively. This implies that the gaseous fuel generated in this work was almost of the same physical and chemical properties with LPG. This shows that the gaseous fuel (biogas) obtained could have good fuel value as LPG. The results of the analysis carried out also show that the gaseous fuel generated was of good fuel value and low environmental problems, since for a biogas to be of good fuel value, its CH_4 content must exceeded 60% and CO_2 below 40% as reported by Khandelwal and Mahdi (1986).

From the percentage of CH_4 per mole of the gaseous fuel generated (Mole %) shown in Table 2, it could be said that the gaseous fuel generated contains 99.691% CH_4, which is combustible. This implies that the fuel generated would be highly combustible and of high calorific value because the combustibility and calorific value of a fuel depend on its combustible component(s) as pointed out by Baja and Godman (1975); Ababio (1985); Baja et al (1988).

CONCLUSION

The research revealed the idea through which gaseous fuel could be generated from organic wastes and crops residues, which would in turn help in reducing environmental pollution and over-reliance on petroleum products, which are relatively scarce, expensive and environmentally-unfriendly. The research also revealed that the fuel generated was of high calorific value considering the percentage molar concentration of its CH_4 content.

Recommendations

- Research should be conducted on the Calorific Value determination of gaseous fuel (biogas).
- Analysis of the liquid degradation product (bioliquid) from banana leaves should be carried out.
- The use of nutritive additive should be employed in order to enhance the production of the gas (gaseous fuel).
- Government at all levels should lay emphasis on conversion of wastes and crops residues into gaseous fuel for energy generation, biofertilizer production and promote environmental sanitation.
- Government, non-governmental organizations (NGOs) and donor agencies should employ experts for public enlightenment about the importance and the potential health hazards associated with the inappropriate dumping of wastes and crops residues.

- Large scale production should be employed and encouraged by federal government in order to have mass consumption of wastes and at the same time generate fuel, which could be used for domestic and industrial purposes.

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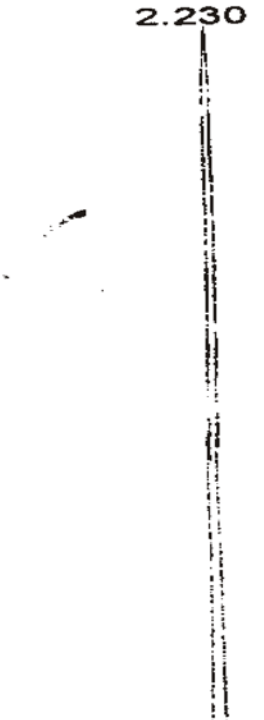

Fig 1 GC-Chromatogram of Biogas (Gaseous Fuel)

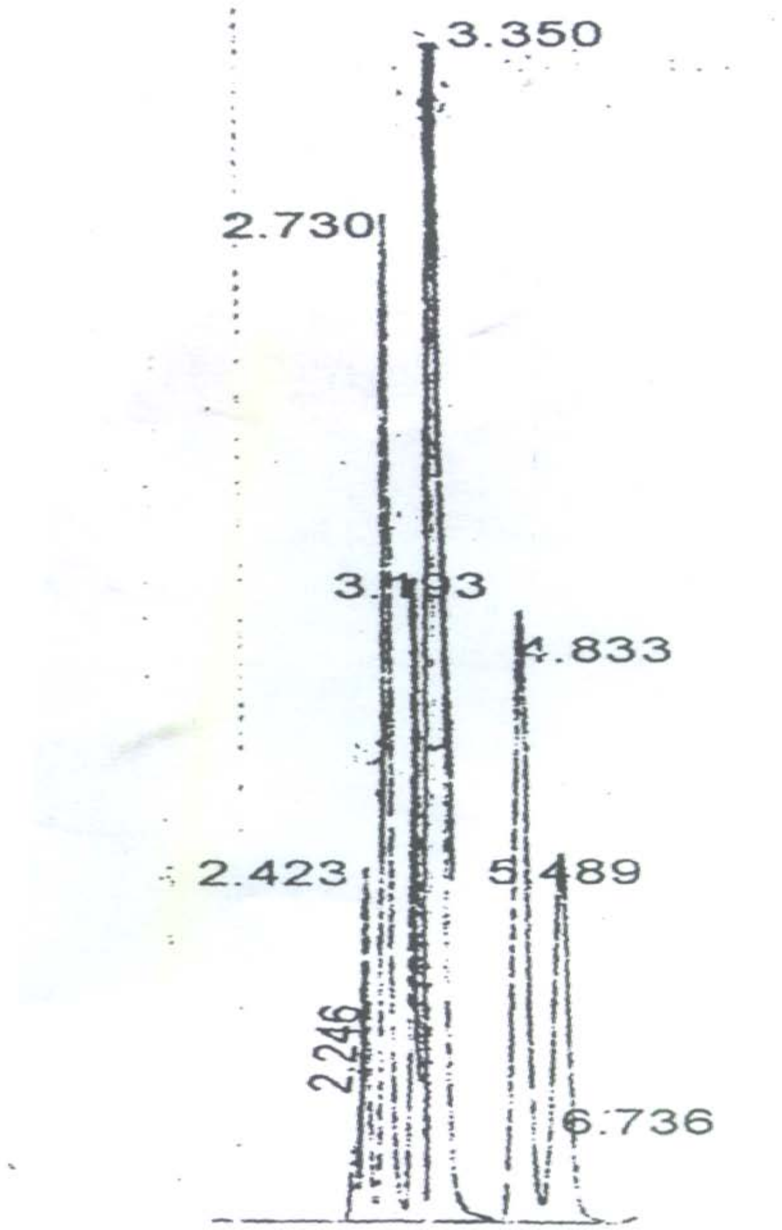

Fig 2 GC-Chromatogram of LPG