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PRODUCTION OF ETHANOL FUEL FROM SELECTED AGRICULTURAL RESIDUES AT DIFFERENT SUGAR CONCENTRATIONS

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ABSTRACT

Frequent increase in price of petroleum products and interest in environmental issues, has led to the demand for in developed countries. Ethanol was produced from 500.0 g each of the grounded residues collected at a dump site near Arada market in Ogbomoso at different sugar contents (10, 20, 30 and 40 mL) by using acid hydrolysis with 4 M H_2SO_4, and simultaneous saccharification and fermentation with Aspergillus niger and distillation. The fuel properties of ethanol produced were also determined using standard procedures in order to determine its suitability as a fuel in automotive engine.

The results show that the volume of ethanol produced from the three residues increases as the amount of sugar content increases. Plantain peels produced the highest volume of ethanol (17.00, 18.20, 20.50 and22.50 mL) while groundnut shells produced the lowest volume (7.00, 8.00, 10.00 and 12.00) at 10, 20, 30 and 40 mL of sugar contents respectively. Calorific values, relative density, viscosity and pH were found to be 28,400, 27,800 and 26,860 kJ/Kg, 0.81, 0.79 and 0.75, 1.59, 1.58 and 1.56 m^2s^{-1} and 2.50, 4.80 and 4.05 for ethanol produced from corn cobs, groundnut shells and plantain peels respectively at 40 mL sugar. Also, the flash and pour points of ethanol produced from corn cobs, groundnut shells and plantain peels were 35.40, 41.40 and 40.50 ^oC and 2.70, 4.70 and 5.55 ^oC respectively at 40 mL. Based on the findings of this study, plantain peels produced more ethanol than the other two residues and the properties of ethanol determined were found to have acceptable fuel properties for use as supplementary fuel in automotive engine engines.

KEYWORDS: Ethanol, Fuel, Residue Sugar, Properties and Fermentation

INTRODUCTION

The progressive depletion of non-renewable fuels and mankind's growing concern regarding climate change and atmospheric pollution, has led to an interest in the use of renewable fuels. Nowadays, 40 % of the total energy consumption worldwide is in the form of liquid fuels such as gasoline and diesel. In fact, transportation is almost fully dependent on these kinds of liquid fuels; special attention has been paid to the potential use of biomass for production of alternative and renewable fuels to be used in vehicles.Liquid bio fuels, especially ethanol, provide one of the few options for fossil fuels substitution in the short to medium terms and are strongly promoted by the European Union. Ethanol derived from biomass has the potential of being an environmental friendly transportation fuel as well as an alternative to gasoline. Several studies have scrutinized the environmental performance of non-renewable energy consumption and greenhouse gas emissions (Farrel et al., 2006, Kim and Dale, 2002, Wang et al., 1999 and Shapouri et al, 1995).

The practice of mechanized farming in Nigeria has led to extensive discharge of agricultural residues that have had negative effects on the environment. The utilization of such residues has been a major concern to many researchers

(Oyenuga 1959; Akpan 1999; Amosun 2000). Therefore, this work was designed to look into the possibility of converting some of the residues of agricultural products into a useful and needed fuel that can partially or completely substitute the existing fossil fuel in transportation. Ethanol is one of such fuel; it is a clear, colourless liquid, which has several common names, such as: alcohol, grain alcohol, grain-spirit, neutral spirit and more commonly, gasohol when used as a blend with gasoline (Berry, 2000). It is also called ethyl-alcohol, pure alcohol, grain alcohol, and it is volatiles and flammable, liquid. It is best known as the types of alcohol found in alcoholic beverages and in thermometers. In common usage, it is often referred to simply as alcohol. Ethanol is a much cleaner fuel than petrol (gasoline). It is a renewable fuel made from plants and it is not a fossil fuel; manufacturing it and burning it does not increase the green house effect. It provides high octane at low cost as an alternative to harmful fuel additives. Ethanol's blends can be used in all petrol engines without modification and dramatically reduce emission of hydrocarbons, a major contributor to the depletion of the ozone layer.

The largest potential feedstock for ethanol is lignocellulosic biomass, which includes materials such as agricultural residues (e.g. Corn Stover, crop straws, sugar cane bagasse), herbaceous crops (e.g. alfalfa, switch grass), woody crops, forestry residues, waste paper and other waste (Seungdo and Bruce, 2008). The large quantities of agricultural residues produced in Nigeria can play a significant role in meeting her energy demand. The availability of these residues is important, but the techniques of their efficient utilization are of more importance **(**Oladeji, *et al*. 2009). Most of these solid residues are biomass, which contain enormous amount of energy (Wilaipon, 2008). However, it is unfortunate that in Nigeria, the current farming practice is to burn these residues or they are left to decompose. This burning, not only results in health risk to both human and ecology, but more than that, it is a waste of available energy. Also the heat produced from burning them result in killing some of the organic nutrients required to improve the fertility of the soil.This work is therefore, based on one of the techniques of converting agro-residues into improved or higher-grade biomass energy, which is in form of liquid fuel. This is because there is the need to improve and supplement liquid fuel at cheaper and more affordable cost.

Apart from providing a suitable alternative to fossil fuels, ethanol forms the major raw material in most industrial sectors of every economy including pharmaceutical and entertainment establishments. Furthermore, the use of agricultural residues would also improve our waste management as well as improve the economy of rural dwellers as these residues will be a source of income for them.

MATERIALS AND METHODS

These agricultural residues: Plantain peels, Groundnut shells and Corn cobs samples were collected in three different sacks at a dump site near Arada market in Ogbomoso. The materials were transported to the Laboratory where the experiments were performed.

Physical pretreatment was applied to the samples of the residues which involved sun dried, mechanical size reduction by grinding and milling. The grounded samples of the residues were sieved using standard sieve of about 1.0 mm to obtain smooth powdered particles of uniform sizes. Five hundred grammes (500 g) of the powdered sample of corn cobs each were placed into four different glass jars containing 1000 ml of distilled water and properly mixed by vigorously shaking the jar and their contents. The content in each glass jar were sterilized by autoclaving at 121 ^{o}C for about 15 minutes and allowedto cool while the remaining batch meant for spontaneous fermentation was left un-autoclaved.

Dilute sulphuric acid (H_2SO_4) of 4 Moles was added to each glass jar of liquid corn cobs samples for the hydrolysis. The raw sugar purchased from the market was processed to syrup of 0.5 gmL^{-1} by dissolving 500 g of the sugar in 1 litre of warm water and allow it to cool down to room temperature. The sugar concentrations of the contents in each glass jar were varied by adding 10, 20, 30, and 40 mL of the syrup. The contents in each glass jar were filtered and the culture of Saccharomyces cerevisiaewas then added to the filtrate. The reaction was allowed to stand for about 4 hours after which the solution was tested for the concentration of ethanol.

The fermented corn cobs liquid samples were filtered individually using cheese cloth to obtainliquid ethanol for distillation. Distillation is the process of separating ethanol from the mixture of ethanol and water and other residual solids after fermentation. This was done by boiling off ethanol from the rest of the solution in a distillation column apparatus. The volumes of ninety-five percent (95 %) ethanol solution produced at four different concentrations of sugar were determined and recorded. The above procedure were repeated using the same quantities of groundnut shells and plantain peels instead of plantain peels and the volumes of ethanol produced were determined and recorded in each case. Plates 1, 2 and 3 show the pictorial diagrams of the plantain peels groundnut shells and corn cobs respectively.

Figure 1: Fresh Plantain Peels

Figure 2: Corn cobs

Figure 3: Groundnut Shells

The following fuel properties of ethanol produced from the three residues at 40 mL sugar concentrations were determined and the resultscomparedwith ASTM standards

Percentage Concentration by Volume of the Distilled Ethanol

The apparatus used includes, specific gravity bottle, pipette, measuring cylinder and weighing balance. A sample of ethanol was pipetted into a specific gravity bottle of known weight andthe volume of ethanol was estimated and weighed. The weight of equal volume of water wasalso determined and the specific gravity of ethanol at room temperature was determined using equation 1.

$$\text{Specific gravity} = \frac{\text{weight of ethanol}}{\text{weight of an equal volume of water}} \qquad (1)$$

Viscosity of Ethanol

The dynamic viscosity of the sample of ethanol was determined by using a U tube saybolt viscometer. The experiment was performed at room temperature. The dynamic viscosity was calculated from the equation (Ajav and Akingbehin, 2002).

$$\eta = 0.073134\,dt - \frac{5.94458\text{d}}{\text{t}} \qquad (2)$$

Where: η= Dynamic viscosity in MPa.s

d= Density of the fuel sample in g/mL

t = Flow time, in second

Calorific Value of Ethanol

The calorific or heating values of the samples of ethanol were determined by using a Gallenkamp ballistic bomb calorimeter. A known quantity of the sample was burnt in the bomb andthe maximum deflection of the galvanometer on the control box on the bomb calorimeter was noted and recorded. The effective heat capacity of the system was determined using the same procedure but with pure and dry benzoic acid, as the test fuel. The calorific value was calculated using equation (4) (Ajav, and Akingbehin, 2002)

$$\text{C.V} = \frac{(a_3 - a_1)Y}{Z} \qquad (3)$$

Where C.V = Calorific value of the sample in kJ/kg

a_1 = Galvanometer deflection without sample

a_3= Galvanometer deflection with sample

Y = calibration constant

Z = Mass of fuel sample in g

The calibration constant (Y) is given by

$$\text{Y} = \frac{6.32\text{w}_1}{\text{a}_2 - \text{a}_1} \qquad (4)$$

Where: W_1 = Mass of benzoic acid in g

a_2 = Galvanometer deflection with benzoic acid

Density of Ethanol

A pyknometer (specific gravity bottle) was used to determine the density of ethanol. The weight of an empty, clean and dry specific gravity bottle wasdetermined by weighing and recorded as $W_{o.}$ The bottle was then filled with the sample of ethanol at the room temperature, weighed and recorded as W_1. The weight of the sample only was obtained by

$$W_2 = W_1 - W_o \tag{5}$$

Therefore the density ρ of the sample is given by;

$$\text{Density} = \frac{\text{Mass of the sample}}{\text{Volume of the sample}} \tag{6}$$

Cloud and Pour Points

These were determined using the Baskeyl seta point cloud and pour point apparatus in Texaco, Lagos, Nigeria.

Flash Point

Flash point of the sample of ethanol was measured by using the Pensky Martens flash point closed apparatus also in Texaco, Apapa Lagos.

RESULTS AND DISCUSSIONS

Figure 4 shows the volume of distilled ethanol extracted at different sugar contents from corn cobs, groundnut shells and plantain peels respectively.

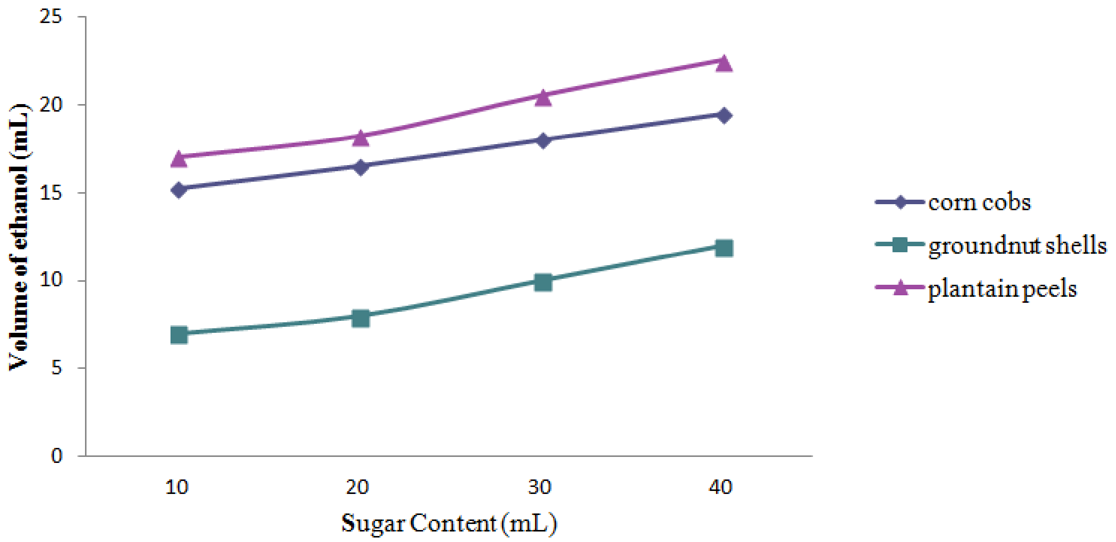

Figure 4: Volume of Ethanol Produced against Sugar Contents

The volume of distilled ethanol produced from corn cobs at different sugar concentrations increases as the sugar contents increases. The maximum and minimum volumes of ethanol produced are 19.5 mL and 15.2 mL respectively (Figure 4).The volumes of ethanol produced from both groundnut shells and plantain peels were also found to increase as the sugar concentrations increases.The maximum volumes of ethanol produced from groundnut shells and plantain peels were 12 mL and 22.5 mL respectively and the minimum volumes of ethanol produced were 7 mL and 17 mL respectively. This shows that plantain peels processed at 40 mL produced the highest volume of ethanol while groundnut shells processed at 10mL produced the lowest volume. This implies that plantain peels have ability to produce highest volume of ethanol compared with the other two residues. Again, it is evident from Figure 1 that volume of ethanol produced in all the residues increases with amount of sugar contents, meaning that increase in sugar content of the biomass will favour the production of ethanol.

Table 1 show the fuel properties of ethanol produced from corn cobs, groundnut shells and plantain peels at 40 mL sugar content.

Table 1: Fuel Properties of Ethanol from Corn Cobs at 40 Ml Sugar Concentrations

Parameter	Corn Cobs	Groundnut Shells	Plantain Peels
Calorific Value(kJ/Kg)	28,400	27,800	26,860
Flash Point (^oC)	35.40	41.40	40.50
Pour Point (^oC)	2.70	4.70	5.55
Ph	2.50	4.80	4.05
Viscosity(m^2s^{-1})	1.59	1.58	1.56
Relative Density	0.81	0.79	0.75

The relative density of ethanol produced from corn cobs, groundnut shells and plantain peels at 40 mL sugar concentration are 0.81, 0.79 and 0.75 respectively. The flash point and pour point of ethanol obtained from corn cobs, groundnut shells and plantain peels at 40 mL sugar concentration are 35.40, 41.40 and 40.50 and 2.70, 4.70 and 5.55^oC) respectively. The pH values of the ethanol obtained from corn cobs, groundnut shells and plantain peels were found to be 2.50, 4.80 and 4.05 respectively at 40 mL sugar concentration.

The ethanol obtained from corn cobs and plantain peels produced the highest (1.59 m^2s^{-1}) and lowest (1.56 m^2s^{-1}) viscosities respectively. The calorific values of the ethanol produced from the three residues were found to be 28,400, 27,800 and 26,860 kJ/Kg.

CONCLUSIONS

The results obtained show that Plantain peels which is one of the agricultural residues produced more ethanol than the other two. Reasonable amount of ethanol is present in plantain peel. The volume of ethanol produced from plantain peels, groundnut shells and corn cobs increases as the amount of sugar contents increases with plantain peels producing the highest volume (22.50) mL and groundnut shells producing the lowest volume (12.0) mL of ethanol at 40 mL sugar. The ethanol produced was found to have acceptable fuel properties for use as supplementary fuel in automotive engine engines.

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