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FUEL PROPERTIES OF BIOETHANOL PRODUCED FROM SWEET POTATO PEELS

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ABSTRACT
In this work, some fuel properties of locally produced ethanol from sweet potato waste were experimentally determined to establish their suitability for use in compression ignition(CI) engines. Five blends (E_5, E_{10}, E_{15}, E_{20} and E_{30}) of ethanol with petrol (by volume) were used. The properties determined were Density (0.754kg/m^{3}), Boiling point (73), Flash point (35), Pour Point (15), Viscosity (1.0mPas), Cloud point(-8), Fire point (30), Calorific value (35086.78kJ/kg). These results showed that both the density and viscosity of the blends decreased as the ethanol content in the blends increased. The Cloud Point was found to be -8 for all the blends and gasoline, while the Pour Point of 15 was obtained for gasoline and blends with E_5, E_{10}, E_{15}, $E_{20}$and E_{30} ethanol content, respectively. Flash point of 35 was obtained for diesel and the ethanol-gasoline blends with E_5, E_{10}, E_{15}, E_{20}, E_{30} ethanol respectively. Calorific value of 35086.78, 33744.65, 30315.77, 30238.10 and 27,969.16kJ/kg were obtained for ethanol-gasoline blends. Based on the findings of this study, blends with E_5, E_{10}, E_{15}, E_{20}, E_{30} percent ethanol content were found to have acceptable fuel properties for use as supplementary fuel in CI engines. The volume of ethanol produced from 500g of the sample was 730cm^{3}.

Keywords: *Bioethanol, Potato waste, Compression Ignition (CI) engines, Calorific value, Fire point.*

INTRODUCTION
Today, the world relies heavily on fossil fuels for both domestic and commercial energy needs. The depletion coupled with the environmental effects of these fossil fuels has influenced research in the development of alternative energy sources. One of the alternative sources of energy is bioenergy (Abba *et al.,* 2014). A worldwide interest in the utilization of bioethanol as an energy source has stimulated studies on the cost and efficiency of industrial processes for ethanol production. Human activities generate large amounts of waste such as crop residues, solid waste from

mines and municipal waste. They may become a nuisance and sources of pollution. It is therefore important to handle them judiciously to avoid health problems, since these wastes may habour pathogenic microorganisms. Agricultural wastes including wood, herbaceous plants, crops and forest residues as well as animal wastes are potentially huge sources of energy. In Nigeria, large quantities of these wastes are generated annually and vastly underutilized (Oyeleke and Jibrin, 2009).
Utilization of organic waste materials for renewable energy is currently one of the hottest topics in the market. One of the demanded intermediate products for renewable energy (e.g. bioethanol and biobutanol) is fermentable sugar. Therefore, the need for cheap biosugars supply such as glucose has recently increased remarkably and one of the potential sources to generate a considerable amount of biosugars would be the potato processing wastes (Sulaiman*et al.,* 2014).

Potato is yet to gain global recognition as an energy crop although its importance in this regard is known in several places. Therefore, our efforts reported in this paper, point at its capability as a potent source of ethanol and its potential to gain a recognizable presence in global energy economies. Finding such an important use for potato waste would help to reduce the current almost total reliance on wood and expensive fossil fuels as industrial energy sources in Nigeria (Adelekan, 2010). Ethanol has wide spread use as a solvent of substance intended for human consumption, including scents, flavouring, colourings and medicine, Ethanol acts as an antifreeze in the engine performance. This high quality and high octane fuel is capable of reducing air pollution and improving automobile performance. In chemistry, it is both an essential solvent and a feedstock for the synthesis of other products. Bioethanol is a microbial way of converting simple sugar into ethanol (C_2H_5OH) and carbondioxide (CO_2). Bioethanol is a principal fuel that can be used as petrol substitute for vehicles. It is a renewable energy source produced mainly by sugar fermentation process, although it can also be manufactured by the chemical process of reacting ethylene with steam. Due to gradual decrease in fossil, bioethanol has got the attention of many researchers to use it as alternative source of energy across the world. Ethanol fuel trends are widely sold in the United States. The most common blend is 10% ethanol and 90% petrol (E_{10}) vehicle engines requires no modification to run on E_{10} and vehicle warrantees as unaffected. Also ethanol derived from biomass is the only liquid transportation fuel that does not contribute to green house gas effect (Oyeleke*et al.,* 2012).

As a locally produced renewable fuel, ethanol has the potential to diversify energy portfolios, lower dependence on foreign oil, and improve trade balances in oil importing nations. Replacing petroleum with biofuel can reduce air pollution, including emissions of fine particles and carbonmonoxide (Rabah*et al.,* 2011). The study to determine the production of ethanol from potato waste is therefore expected to reawaken the awareness about the importance of potato waste in Nigeria not only as food but possible feedstock for biofuel production (Obueh*et al.,* 2014). The aim of this research work was to produce bioethanol from potato peel and evaluating the suitability of using the peels of potato for bioethanol production.

MATERIALS AND METHODS

COLLECTION OF SAMPLE

The potato tubers used was bought from Ega market, Idah Local Government, Kogi State, Nigeria.

PREPARATION OF SAMPLE FOR FERMENTATION

The potato tubers were peeled and rinsed in a clean water. The samples were weighed in two replicates of 500g. Afterwards, the weighed potato peels were soaked in clean water. The potato peels were then placed on a clean tray in the laboratory and allowed to dry naturally for 4 h .After dewatering , the potato peels were transferred to a mortar where they were mashed using a pestle to attain a sufficient size reduction. The mash was then transferred into a plastic bucket. 500 mL of petroleum ether was added to the suspension to aid fermentation. The mash was thoroughly stirred to achieve an even mixture with the petroleum ether. I L of water was added to the sample and stirred thoroughly in another plastic bucket. It was then covered and left undisturbed in the laboratory at room temperature for 8days.

PREPARATION OF SAMPLE FOR DISTILLATION

The fermented mash was poured onto a sieve placed over a clean plastic bowl. The potato peel mash was then completely squeezed to dryness while the liquid filtered through the sieve. The filtered liquid was afterwards transferred to the distillation apparatus. The collected liquid was poured into a glass dish and then gradually heated at 79 □ for 5-10 h to ensure complete evaporation of any trapped CO_2 remaining in it. Afterwards, the finial liquid was allowed to cool normally in the laboratory and its mass, volume and other properties were measured and determined. A measuring cylinder was used to measure the volume of the distillate.

PREPARATION OF THE DISTILLATE FOR BLENDING

Gasoline was used as reference fuel in this study. The petroleum fuel is a volatile, flammable liquid obtained from a local fuel petroleum station at Idah, Kogi state, Nigeria. Five blends of bioethanol produced blended with gasoline were used. They were obtained by mixing bioethanol and gasoline by volume in the following proportions:

E_5 = 5 percent bioethanol + 95 percent gasoline
E_{10} = 10 percent bioethanol + 90 percent gasoline
E_{15} = 15 percent bioethanol + 85 percent gasoline
E_{20} = 20 percent bioethanol + 80 percent gasoline
E_{30} = 30 percent bioethanol + 70 percent gasoline.

FUEL PROPERTIES

Fifty milliliters density bottle described in Pearson (1976) was used for density determination. Cloud and Pour points of fuel samples were determined as per 1S : 1448 [P: 10]: 1970 using the Cloud and Pour points apparatus at National Centre For Energy Research and Development, University of Nigeria, Nsukka, Enugu state. Flash and Fire points / Boiling point of the fuel samples were determined as per 1S : 1448 [P:32]:1992 using a Pensky Martin flash point (closed) apparatus at National Centre for Energy research and Development, University of Nigeria, Nsukka, Enugu state. Viscosity of the fuel sample was determined with digital viscometer –Searchtech, England.Calorific value was determined using Oxygen Bomb calorimeter (model: XRY-1A).

Determination of Relative Density

Specific gravity bottle method as described by Eze,2009 using density bottle and electronic weighing balance was used for the determination.

A density bottle of 10 mL capacity was washed, cleaned, dried and weighed (w_b). It was then filled with water, and weighed again (w_1). The density bottle was emptied, cleaned with ethanol and dried. It was later filled with the sample (bioethanol), and weighed (w_2) . All the determinations were carried out at 28 □

$$R.D = \frac{w_2 - w_b}{w_2 - w_b}$$

Viscosity

This was done with a digital viscometer (Searchtech, England). The appropriate spindle was selected and fixed in the instrument. The spindle was inserted in the sample to be analysed till the level mark in the spindle reach the surface of the sample. Enter botton on the instrument was pressed and the viscosity of the sample was displayed on the screen.

Cloud and Pour Points

The cloud and pour point of fuel samples were determined as per IS:1448[P:10] 1970 using the cloud and pour point apparatus. The glass tube containing fuel sample was taken out from the jacket at every 10 □ interval as the temperature fell and was inspected for cloud / pour point. The pour point was taken to be the temperature 10 □ above the temperature at which no motion of fuel was observed for 5 *s* on tilting the tube to a horizontal position.

Flash and Fire Points

The flash and fire points of the fuel samples were determined as per 1S:1448[P:32]: 1992. A Pensky Martin flash point (closed) apparatus was used to measure the flash and fire point of the fuel samples. The sample was filled in the test cup up to the specified level and was heated and stirred at a slow and constant rate. At every 10 □ temperature rise, flame was introduced for a moment with the help of a shutter. The temperature at which a flash appeared in the form of sound and light was recorded as flash point. The fire point was recorded as the temperature at which fuel vapour catches fire and stayed for minimum of 5 *s*. The temperature was measured with a thermometer.

Calorific (heating/combustion) Value Determination using Oxygen Bomb Calorimeter (Model: XRY – 1A)

The outer canister of the bomb calorimeter was filled with water. The inner canister was filled with 3 litres of distilled water. Then 1g of an anhydrous biethanol/ gasoline sample to be evaluated was measured and placed in a mould (small metal crucible). 10cm ignition thread (wire) connected to the electrodes of the oxygen bomb, was placed and allowed to keep in touch with the sample. The bomb was filled in with oxygen at a pressure of 2.8 – 3.0 mPa and then transferred into the inner canister (filled with 300cm^3 of distilled water). The necessary wires were connected and the temperature sensor was placed in the inner canister. The power was switched on and the water inside the inner canister was stirred for about 2 min and the initial temperature of the water was noted and denoted T_o. The Bomb calorimeter was fired and the final temperature (T_f) was recorded when the time got to 31 min. Length of the pieces of unburnt firing wire was measured (l) and the inner lining of the oxygen bomb and crucible were washed with distilled water into a conical flask. The wash solution was titrated against 0.0709N $Na_2S_2O_3$, using 2 drops of methyl red indicator.

Calorific values of the samples were calculated from the expression:

$$W = \frac{E\Delta T - \Phi - V}{m}$$

where w = heat of combustion of sample (calorie/g)

m = mass of sample to be evaluated (g)

E = 13,039.308 calories/g , Benzoic acid standard

T = change in temperature = $T_f - T_o$

Φ = 2.3l (where l = length of the unburnt wire)

V = volume of alkali ($Na_2S_2O_3$ solution) cm^3

The combustion value were converted to Joules from the expression

1 calorie = 4.148 Joule

Boiling Point Determination

Ten milliliters of the liquid was placed in a test tube. A capillary tube was sealed at one end and placed into the test tube with one end upwards. The test tube was clamped to a stand and a thermometer was immersed into the test tube. A 250mL beaker was filled to three quarter of its volume with water and placed on the heating mantle. The test tube with the thermometer were carefully lowered into the 250mL beaker of water so that the test tube was immersed halfway in the water. The water in the heating mantle was heated slowly. As the liquid approaches its boiling point, few bubbles were observed flowing out of the open end of the capillary tube. The heating mantle was turned off when a steady stream of bubbles were observed. The test tube was allowed to cool. The capillary tube was observed carefully. The boiling point was recorded when the liquid began to flow into the capillary tube.

RESULTS

The results of the fuel properties of bioethanol produced from potato peel are shown in Table 1.

Table 1:**Results of Fuel properties of Bioethanol produced from potato peel**

Fuel Properties	E_5	E_{10}	E_{15}	E_{20}	E_{30}
Density(m/v)	0.754	0.746	0.739	0.73	0.728
Boiling point (□)	73	75	79	85	92
Cloud Point (□)	-8	-8	-8	-8	-8
Pour Point (□)	-15	-15	-15	-15	-15
Fire Point (□)	30	35	40	60	65
Flash Point (□)	35	39	45	63	67
Viscosity (mPas) at 30□	1.0	1.0	1.0	1.2	1.2
Viscosity (mPas) at 40□	0.7	0.7	0.8	0.9	0.9
Calorific value (kJ/kg)	35086.78	33744.15	30315.77	3.0238.10	27969.16

The comparison of the fuel properties of anhydrous ethanol with Gasoline(Petrol) is shown in Table 2

Table 2: **Fuel properties of anhydrous ethanol and comparison with petrol**

Property	Ethanol	Petrol
Density(kg/m^3)	794	750
Lower heating value (m/kg)	26.7	42.9
Boiling point(□)	78	80.225
Flash point (□)	13	-42

Sources: JEC, 2005; Joseph 2007; EERC, 2008.

Volume of Bioethanol produced by a quantity of sweet potato is shown in Table 3.

Table 3: **Volume of Bioethanol produced from the quantity of sweet potato waste**

Mass of the waste	Volume of the ethanol
500g	730cm^3

DISCUSSION

Flash Point

Flash point indicates the temperature at which a fuel can vapourize to reduce ignitable mixture with air. Flash point gives some indication of the flammability of a liquid. At the flash point, an applied flame gives momentary flash instead of some steady combustion. It is the temperature at which liquid (fuel)starts to burn. The composition of flash point produced from sweet potato wastes were 35, 39, 45, 63 and 67□ for E_5, E_{10}, E_{15}, E_{20} and E_{30}.

The standard flash point of anhydrous ethanol and petrol are 13□ and -42□ respectively. From the chemical composition of bioethanol produced, it was observed that the flash point obtained from sweet potato were 35, 39, 45, 63 and 67□, respectively. This shows that the flash point of bioethanol produced was higher than the standard flash point of ethanol and petrol.

The flash point obtained from sweet potato waste would therefore will form ignitable mixture and is enough to burn the liquid. Blending of 90% of petrol and 10% ethanol will help it to burn more completely and reduce emission pollution.

Cloud Point

Cloud point is the temperature at which solidification of heavier components of fuel resulting in a cloud or wax crystal within the body of the fuel first appeared. The value of the cloud point for the blend is -8□. The cloud point typically occurs between 8□ and 5□ above that of the pour point. Higher cloud point can affect the performance of the engine under cold climatic condition. The cloud point of bioethanol produced increased as the percentage of the ethanol increased. This showed that at a very high percentage of ethanol, the cloud point would also increase and cloudy appearance of haze would also increase.

The bioethanol produced would therefore replace fuel as it has better cloud point.

Pour Point

Pour point is the temperature at which on further cooling of fuel, results in the increase in size and number of the crystals and eventual coalescent of the fuel to form a rigid substance of structure. This temperature helps to know the behaviour of fuel in cold weather. The pour point of bioethanol produced was -15□. It is the temperature at which no motion of a liquid is observed. The result of the analysis carried out showed that bioethanol produced has better pour point than that of the standard ethanol and petrol.

Calorific value

Calorific value is the amount of heat released during the combustion of a specified amount of substance. It is the quantity of heat released during combustion of a specified amount of liquid particularly petrol. The calorific value of the ethanol produced were 35086.78, 33744.65, 30315.77, 30238.10 and 27969.16kJ/kg for E_5, E_{10}, E_{15}, E_{20} and E_{30} respectively. The calorific value of bioethanol produced decreased as the blending or percentage of ethanol increased. This shows that the higher concentration of ethanol, bioethanol will release lesser amount of heat.

Therefore, bioethanol produced would release heat more easily at low pressure and temperature when compared to heat released by petrol combustion. Bioethanol produced from sweet potatoes waste would be good enough to replace petrol used in transportation, since it was found to have lower heat of combustion even at a higher concentration.

Density

The density helps to determine the purity of a liquid. It was observed that when the percentage of the ethanol blends increased, the density decreased. This is due to the fact that the ethanol has a lower density and as such will lower the density when mixed with petrol. The relative density of bioethanol produced from sweet potato waste are 0.784, 0.746, 0.739, 0.730 and 0.728kg/m^3 for E_5, E_{10}, E_{15}, E_{20} and E_{30}.

The standard density of petrol is 750(m/v) while that of ethanol is 794(m/v). Comparing the density of the ethanol produced with that of the standard ethanol and petrol, it was observed that the density of the ethanol produced was lower than the standard ethanol and petrol.

However, the higher the temperature, the lower the density. Bioethanol produced from sweet potatoes waste would therefore, be advantageous because at lower density, bioethanol can be purified while petrol can be purified at higher density.

Viscosity

Viscosity is the resistance to the flow exhibited by fuels. It increases slightly with an increase in the average molecular weight and in the degree of unsaturation of ethanol. It is the measure of the resistance to gradual deformation by shear stress or tensile stress. It is also the ability of a liquid to resist deformation by mechanical stress. The viscosity of bioethanol produced at 30℃ were 1.0, 1.0, 1.0, 1.2and 1.2mPas, for E_5, E_{10}, E_{15}, $E_{20}$and E_{30} while that at 40℃ were 0.7, 0.7, 0.8, 0.9 and 0.9mPas respectively. The viscosity at 30℃ and 40℃ changed but at a very low rate. This shows that as the temperature increases the viscosity also increases at a very low rate. Bioethanol produced had a high resistance to gradual deformation by stress more than the standard.

Fire Point

Fire point is the temperature at which fuel vapour catches fire and stays for the minimum of five seconds. It can be measured with the help of thermometer. The fire point of bioethanol produced from sweet potato waste were 30, 35, 40, 60and 65℃ for E_5, E_{10}, E_{15}, $E_{20}$and E_{30} respectively. At a high percentage of ethanol, the fire point increased, which increases the rate at which fuel will catch fire. Bioethanol produced would be advantageous when compared to that of petrol, because Bioethanol produced can catch fire at the minimum of five seconds while petrol catches fire beyond five seconds.

Boiling Point

Boiling point is the temperature at which liquid will start to vapourizeinto atmosphere. The boiling point of a liquid is also known as the boiling temperature. Boiling point of ethanol is 78℃. Boiling point of ethanol produced from sweet potato wastes are 73, 75, 79, 85 and 92℃for E_5, E_{10}, E_{15}, $E_{20}$and E_{30} respectively.

The standard boiling point of petrol is 80-225℃, while that of ethanol is 78℃. Comparing the boiling point of bioethanol produced with the standard, it was observed that the boiling point of standard petrol and ethanol were higher than that of bioethanol produced from sweet potato wastes. Bioethanol produced from sweet potatoes waste would be good fuel substitute because it has lower boiling temperature compared to the standard boiling point of petrol.

CONCLUSION

From the results the following conclusions could be made:

- It is possible to produce bioethanol from potato peel.
- The cloud and pour points of the bioethanol conforms with that of petrol.

- For the tropical countries, one of the options should look in the direction of tremendously raising the production of potato as a potent source in the production of ethanol fuel for the supply of energy.
- This will serve as a two pronged strategy namely first raising the production of ethanol biofuel and secondly mitigating the negative environment impacts of wastes so produced by producing another fuel from it.

The increased cultivation of potato and the production as well as use of ethanol derived from it is recommended particularly in the tropical regions of the world.

- The viscosity of bioethanol produced was less than that of conventional fuel.

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