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Anaerobic Fermentation of *Solanum tuberosum* (Potato) Peel Waste for Bio-ethanol Production

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Abstract

In this research work, *Solanum tuberosum* peel waste was used to produce bio-ethanol. Bio-ethanol is an alcohol made by microbial fermentation, mostly from carbonhydrates produced in sugar or starch bearing plants, is one of the bio-energy sources with high efficiency and it's environmentally friendly. The bio-ethanol produced from *Solanum tuberosum* peel waste has a large potential market value. Solanum tuberosum peel wastes contain sufficient quantities of starch, cellulose, hemi cellulose and fermentable sugars that can be used as feedstock for bio-ethanol production. Batches of Solanum tuberosum were washed, sun dried and milled, hydrolyzed (saccarification) with sulphuric acid and then fermented anaerobically with *saccharomyces cerevisiae* (bakers' yeast) to determine the fermentation and ethanol production. From the results obtained, ethanol's yield was one-tenth of every distilled batch. From the results obtained, the bio-ethanol Reid vapour pressure at 37.8^0C was 16.0kpa, specific gravity at 60^0F was 0.791, octane number was 122.2, density was $791.4kg/m^3$, flash point was 26^0C, kinematics viscosity at 20^oC was $1.5mm^2/s$ and its refractive index @ 20^oC was 1.3618. This result shows that *Solanum tuberosum* waste has high potential for ethanol production.

Keywords: *Solanum tuberosum*, wastes, bio-ethanol, potato, anaerobic fermentation.

Introduction

Bioethanol is an alcohol made by microbial fermentation, mostly from carbonhydrates produced from sugar or starch bearing plants. Ethanol fermented from renewable sources for fuel additives are known as bio-ethanol. Additionally the ethanol from biomass – based waste materials is considered as bio-ethanol (Grassi *et al,* 1999). In many parts of the world, bio-ethanol is already in use as addition in some gasoline product instead of toxic MTBE (Methyl Tertiary Butyl Ether) and TAME (EC Report, 2000). The potato plant (*Solanum Tuberosum*) is a perennial plant of the *solanaceae* or nightshade family. It is commonly grown for its starchy tuber and is therefore the world's most widely grown tuber crop and fourth largest plant in South America mainly in the Andes. Potato spread to the rest of the world in the late 1400's and early 1500's. Canada is one of the leading producers presently with 4.7 million tonnes annually and as such amount of potato wastes generated from food and potato processing plants stirring 200rpm – 150rpm each year is managed in a manner that protects the environment. Recently bio-ethanol is produced by using waste potatoes which are co-product of the food industry.

For instance, potato wastes are used as feed stock in Finland. Shaman Spirits Limited in Tyranava (near Oulu) uses 1.5million kg of waste potatoes per year for ethanol production (Liimatainen et al, 2004). Waste potatoes are produced from 5.20% of crops as by products in potato cultivation (Kimmo and Liisa, 1999). Bio-ethanol offers a valuable energy alternative to gasoline. It’s referred to as a “bio-fuel” since it is generated or manufactured by the fermentation of organic from renewable source using micro-organisms such as yeast. Bio-ethanol is very volatile and will evaporate into air proximately five (5) times faster than MTBE. Like gasoline vapour, bio-ethanol vapour are denser than air and tend to settle in open air areas. Though pure ethanol is poisonous, it is less toxic than the benzene, toluene ethyl benzene and xylene (B.TEX) that are components of gasoline (Gong and Wall, 1997). Bio ethanol has higher ignition temperature than gasoline (approximately 850^0F and approximately 495^0F respectively). When pure ethanol is burned, the flame is less bright than a gasoline flame. Bio-ethanol as fuel is suitable for use in automobile engines, in power plants for process heat generation and as an energy source in fuel cells. It is also appropriate for use by electric utilities as a turbine fuel for peak load requirements (WW1, 2006). Over the years, crude oil prices have increased severally. The dramatic increase in crude oil prices spurred an interest in alternative energy. Alternative energy source ranges from solar, wind, geothermal and ethanol. The first three have the potential to aid electricity, however they do not help to alternate the high fuel prices that have occurred due to high crude oil prices. Ethanol has the potential to become an alternative source of energy, it can also be an additive which will help the world decrease dependency on crude oil and provide a fuel source that can be made from renewable resources. Fossil fuel (crude oil) have done much harm than good since its inception. Its problems far outweighs it gains. Burning fossil fuel such as gasoline, coal, diesel, gas etc. Results in production of carbon dioxide and other green house gases which cause global warming indicated by sea levels rising, hotter temperature and freakish storm weather patterns like tsunamis and hurricanes becoming more and more regular. Ethanol can now replace gasoline in petrol engines. In some part of the world, their cars uses straight ethanol while some other parts maker use of E20 i.e. blend of 20% ethanol and 80% petrol. Therefore, the production of ethanol from biomass as potato peel waste will go a long way to reduce the considerable concern caused by potato peel waste and particularly alleviate the scourge facing the world from fossil fuel.. Ethanol production from agricultural waste as potato peel waste is increasingly becoming important as it also environmental friendly. After burning ethanol, its end products do not posses the adverse effects as that of fossil fuel. In this research work ethanol will be produced from potato peel waste which is utmostly reliable. An efficient ethanol production requires four components fermentable carbohydrates, an efficient yeast strain, a few nutrient and simple culture conditions (Peterson, 1971). Approximately 80% of world supply of alcohol (ethanol) is produced by fermentation of sugar. India present there are (285 distilleries) many distilleries producing ethanol by traditional batch fermentation process (Anon, 2006). In ethanol production of high sugar foods, bacteria as *zymomonas mobilis* and *saccharomyces cerevisiae* were studied extensively, but yeast was found to be more ethanol tolerant and produces more ethanol at sugar concentration 15% (v/v). (Rens and Singh, 2003). The production of ethanol by anaerobic condition is called “Alcoholic fermentation” the fermentation is characterized by development of micro-organisms which converted the present sugar in the agricultural waste material into ethanol, the organism was *saccharomyces cerevisiae*, they are isolated from brewers yeast to grow into sabourand medium. The yeast inoculums were inoculated in yeast extract peptone Dextrose (YPD) fermentation media at pH5.6 and at room temperature in anaerobic condition (Odunfa, 1985). Inoculate the waste potatoes in fermentative media of the dextrose, before adding these waste biomass into fermentative media, Di nitro salicycle Acid (DNSA) was carried for determination of sugar concentration which is present in that particular agricultural waste. The fermentative process should be completed within 48 hours under optimal conditions (Peterson, 1971). Ethanol is separated from broth in continuous stills resembling those utilized for recovery of acetone, butanol and ethanol of 95%. Concentration is obtained by successive distillation in these stills. (Ogunjobi et. al, 2005).

To obtain alcohol concentration greater than 95% however requires special distillation technique because of the ability of alcohol to form an azetrophic mixture containing 5% water. This to prepare ethanol, the 5% water is removed by forming an azetrophic mixture of benzene, water and ethanol which then is distilled with increasing temperate increment. This procedure removes first the azetrophic benzene and water ethanol mixture, then an ethanol benzene azetrophic mixture so that absolute ethanol remains. The absolute ethanol as well as 95% is marketed with and without denaturation (Ogunjobi et. al., 2005). Ethanol has many favourable properties. For example the octane number of ethanol is higher than the octane number of conventional petrol. The octane number influences the anti-knocking number (AKI) and the research octane number (RON) of pure ethanol is 116 and 129 compared to ordinary petrol with 86/87 AKI and 91/92 RON. A high octane number stands for an anti knocking fuel. Knocking describes uncontrolled combustion which puts heavy mechanical and thermal leads on the engine (Paul and Kemnitz, 2006).

On the other hand, the energy yield of ethanol is about one third lower than petrol another property of ethanol is low vapour pressure when stored as a pure fuel, it has lower vapour pressure than gasoline and thus will have fewer evaporative emissions. In cold weather, the low vapour pressure of ethanol will cause cold start problems. Because of the low vapour pressure property, it is sometimes blended with gasoline. This example shows the blends of ethanol and petrol have different properties. Depending on the situation and the desired fuel ethanol is therefore blended with gasoline at any ration. Common ethanol blends are E5, E10, E20, E20, E25, E70, E85, E95 and E100 which contains 5%, 10%, 20%, 25%, 70%, 85%, 95% and 100% ethanol respectively. Also other varying quantities are possible. In European union, so called flexible fuel vehicles (FFV) are currently entering the market. They can run with an ethanol proportion of any mixture up to 85% (WW1, 2006).

Ethanol is also increasingly used as an oxygenated additive for standard petrol as a replacement for methyl tertiary butyl ether (MTBE). MTBE is usually mined with petrol as an additive to improve the octane number. Because MTBE has toxic properties and is responsible for considerable groundwater and soil contamination. MTBE is more and more frequently replaced by ETBE (Ethyl tertiary butyl ether) ETBE is produced from bio-ethanol and may be mixed at maximum quantities of 15% with petrol. The Denver metropolitan area is the first region in the United State to implement the use of oxygenated fuel in an effort to reduce ambient carbon monoxide

(Anderson et. al., 1994). This was because the majority of the fuel sold contained 8% MTBE, since 1988, for this reason the addictive has gradually shifted from MTBE to ethanol (Anderson et. al., 1994). For the combustion of petrol, usually spark ignition engines are used. They are internal combustion engines where the fuel air mixture is ignited with a spark. These engines differs from a compression ignition engines where the heat and pressure from compression alone ignites the mixture. A spark ignition engine can either be two-stroke or four –stroke (an otto cycle engine). Originally the fuel spark ignition engine mixes outside the cylinder as opposed to compression-ignition engine where the fuel is mixed inside the cylinder. However spark-ignition engines are increasingly designed with direct injection eliminating this distinction. Generally, all spark-ignition engines can run with bio-ethanol as well. In 1876 Nicolas otto, developer of otto cycle is said to have described 'ethanol' as the proper fuel for his four stroke internal combustion engine. (Cheremisnoff, 1979). If 10-25% ethanol is mixed with gasoline, typically no engine modifications are needed. Along modern cars can run on these mixtures very reliably. But the higher the ethanol component of blended petrol becomes the lower is its stability for standard car engines. This is due to certain characteristics of bio-ethanol (WWI, 2006). Despite farmers enthusiasm for the fuel, the effort because bio-ethanol could not compete economically with the fair less expensive petroleum derived gasoline. However for the cost soon became too restrictive and thereby resulted in the end of ethanol usage. Ethanol resurges again as a motor fuel option during the late 1970's when oil price rose dramatically (Lorenzetti, 1991). The energy balance of bio ethanol depends on the energy input for processing bio-ethanol during the life cycle in comparison to the energy content of the final fuel. Typically life cycles of different bio-fuels can be used very different and depends on feedstock type, agricultural practices, regional feed-stock productivity, process technology and final driving efficiency. Therefore attention has to be paid when using data about energy balances of ethanol. Generally they are valid only for dedicated cases which can vary considerably. Although there exist studies in which the energy balance of different methods in many of these studies assumption and data on agricultural and industrial conversion technologies are not updated. More recent studies are based on new technologies (Schmitz et. al., 2005).

Noteworthy, the estimate of fossil energy balance of ethanol (Cellulose where potato wastes fall) is 21 – 36 and the bio ethanol from sugar cane was found out to be the best energy balance which is the only ethanol that exceeds that of the potato waste (Cellulosic Feedstock), but the technology is not yet in commercial operation significantly, all types of bio ethanol not only have better energy balances than fossil petrol but even have energy larger than one (Schmitz, et al, 2005). Schmitz et al (2005) again investigated and analysed several studies for energy balances of ethanol by using absolute values in MJ/L instead of output/input ratios. They found that in older studies, the energy input for producing one-litre ethanol is between 21-36MJ/L. Since the energy content of one litre ethanol is 21.2MJ/L, the result of most of these studies showed a negative net energy balance based on absolute values. The fault of these studies was that co-products were not considered in contrast to these older studies. Schmitz et al (2005) showed that more recent studies are based on actual technical developments and assume lower energy inputs between 18 and 29 MJ/L. The IEA even predicts energy inputs of 13MJ/L for future technologies. One of the major drivers of bio-fuel promotion worldwide is the concern about climate change and the potential of bio-fuels to reduce green house gas (GHG) emissions. Although it is incontestable that the use of bio ethanol is able to reduce GHG emissions significantly when compared to fossil fuels assessments of quantified. GHG reductions are useful and necessary. However, the GHG balance for bio-ethanol is highly variable and includes emissions of cultivation, transport, conversion process and distribution. Further, the GHG reduction potential depends on type of feedstock, agricultural practices, site productivity, conversion technology and finally on the whole design of the study (WWI, 2006).

Detailed summaries of studies, indicating GHG reductions by using neat or blended bio ethanol are given by WWI (2006) and OECD/IEA (2004). They show reductions of up to 96% for anhydrous bio-ethanol in Brazil (Macedo et al, 2003). The major part of engine exhaust streams during ethanol combustions consists of the components nitrogen, carbon dioxide and water. All these components are non-toxic to human health. However about 1.4% petrol engines exhaust emissions are composed of more or less harmful substances to health. Apart from the above mentioned emissions, fuel combustion emits particulate matter (PM), volatile organic compounds (VOCs), Nitrogen oxides (NO_x) carbon monoxide (CO) and variety of other toxic air pollutants. These are criteria pollutants of the environment and the VOCs and NOx are precursors for tropospheric ozone. (Sincero and Sincero, 2006). Therefore, the objectives of this work are production of bio-ethanol from potato peels waste using the anaerobic fermentation process; production of absolute ethanol by distillation method; characterization of the bio-ethanol and comparing it properties with gasoline; and to compare the bio-ethanol produced with the ASTM specifications and standard.

MATERIALS AND METHODS

Description of Study Area

The research was carried out at the Chemical/Petrochemical Engineering Laboratory of Rivers State University, Port Harcourt, Nigeria.

Source of Material Used

The primary raw material for this experiment, potato peel waste or potato waste was gathered and collected from a local food vendor at the back gate of the university premises who fried potato for consumers need. Ordinarily her ignorance of applied technology would cause her to gather the waste and dispose them in the refuse bin. Large amount of the potato waste were collected for usage.

Other materials such as Bakers' yeast (*saccharomyces cerevisiae*), bioreactor, Dual purpose distillation Apparatus, molecular sieves, sulphuric acid and flasks for distillating and receiving were all gotten from the Chemical/Petrochemical laboratory of the Rivers State University of Science and Technology, Port Harcourt, Nigeria.

Methodology

The production of bio-ethanol from potato waste was done by "Anaerobic Fermentation" a chemical reaction caused by the action of yeast or bacteria changing sugar into alcohol (ethanol) in the absence of oxygen. For this method is most economical and widely used way of producing bio-ethanol as a product more than its advantage as operations are simple, stable and energy consumption is low. The potato waste was washed, sun dried milled and inoculated in a fermentative media (bioreactor) and from study, potato waste being a cellulosic biomass comprising of lignin, cellulose and hemicellulose thus sometimes called lignocellulose material must be converted to six carbon sugar (glucose) before they can ferment and be converted into ethanol. This process is known as saccarification.

Saccarification could be done either by acid hydrolysis or enzymatic hydrolysis but it is more difficult to hydrolise a cellulosic biomass as potato waste because cellulose molecules consist of long chains of glucose molecules as do starch but have different structural configuration. Therefore this structural characteristic plus the encapsulation of lignin made us incure acid hydrolysis for saccarification so as to breakdown completely this cellulosic biomass into sugar. Dilution was done with water as the solution was afterwards left to ferment using baker's yeast to speed up the rate of fermentation. Fermentation was done for a period of three days.

The bakers' yeast (*saccharomyces cerevisiae*) was used because it is the most frequently used to ferment glucose to ethanol. The solution after fermentation was distilled in batches to yield ethanol.

Physical Pre-treatment (milling)

On collecting the potato peel waste from the local food vendor the waste biomass was thoroughly washed and afterwards sun dried for 4 days and taken to the market for milling into the finest form.

Milling was done because the waste in massive form would take a longer time to ferment causing an uneven breakdown of the cellulosic material into sugar.

Saccarification

The breaking down or conversion of the milled biomass into sugar (glucose) by acid hydrolysis. The apparatus used includes: Bioreactor (Fermentative media), The milled biomass (potato waste), sulphric acid. The Procedure are: The bioreactor is cleaned, weighed and recorded, The milled biomass is put into the reactor and both were weighed, 20ml of sulphric acid is added to the milled biomass to break its cellulosic constituents into sugar (glucose).

The Chemical Treatment carried out includes: The dilution of the mixture in the reactor with water into the bioreactor 300ml of water was added and properly stirred to dilute preparation for fermentation for a relatively high ethanol yield.

Fermentation process:

100g of Bakers' yeast (*saccharomyces cerevisiae*) was added to the solution for complete fermentation to take place. The fermentation was done anacrobically to enable the yeast develop microbes faster which eventually converts the present sugar in the solution into ethanol. The solution was left to ferment for a period of 72hours at room temperature. The bioreactor was made air tight to avoid entry of oxygen. Within this time range, micro organisms helped in yielding ethanol during the fermentation as the yeast was there to serve as a catalyst thereby increasing the activities of the micro-organisms in the bioreactor.

Distillation/Dehydration Process:

Ethanol produced by fermentation results in a solution of ethanol in water. For ethanol to be used fuel, water must be removed by a method known as distillation. Though the purity is limited to 95-96% due to formation of low-boiling water –ethanol azeotrope i.e the liquid mixture of ethanol and water retaining the same composition in the vapour state as in the liquid state when distilled or partially evaporated under certain pressure. Therefore, a special distillation technique was used to attain maximum dehydration level of ethanol. The apparatus used are: Dual purpose distillation apparatus which consists of Condenser, Valves, Distillation columns; Distillation flask (500ml); Heating mantle; Thermometer; Receivers; Molecular sieves; Hoses; Retort stand (2)

The Procedure used: The apparatus was mounted using retort stands to hold it at both ends and hoses connected to the inlet and outlet of the condenser taking water in and out. The function of the condenser is to trap the ethanol in vapour form that leaves the solution from the distillation flask and when it is cooled by the water going in and out, it drops as liquid into the receiver. Also, 500ml sample of the fermented solution was poured into the distillation flask and cocked to the dual purpose distillation apparatus at one end. With the receiver (a round bottom flask) at the receiving end of the apparatus (cocked to it). The heating mantle set at an appreciable distance from the bottom of the distillation flask is lighted up so as to heat up the solution.Noteworthy, the heating mantle has a regulator to regulate so as to control the heat generated in heating up the solution. Ethanol is very volatile (lighter than water and less dense than water) and with it's boiling point between 70-85^{0}C. With the aid of the thermometer, at about 78^{0}C, ethanol leaves the solution and visibly moves upward through the distillation column then to the condenser where it is cooled and drops as liquid into the receiver. The distillate (ethanol) has azeotropic mixture in it. Distillation was done with increment in the temperature of the heating mantle to first remove the azeotropic water –ethanol mixture so that absolute ethanol remains. Noticeable fermented residues in the distillate were equally removed using molecular sieves to trap them. Distillation was done at room temperature for each batch for six consecutive times.

RESULTS AND DISCUSSION

Saccarification and Dilution

Weight of container = 143g

Weight of container + Biomass = 441g

Mass of the biomass (potato milled waste)

= (441 – 143g)

= 298g

With 20ml of sulphuric acid to hydrolise the medium and dilution with 3000ml of water, Ratio of biomass to water was approximately

= 1:10

Fermentative Stage

After fermentation of 72 hours, the solution was discovered to have a lot of microbes in it making the solution have an offensive smell and noticeable odour of ethanol in the solution. Indeed, the sugar has been broken down into ethanol.

Distillation Yield of Ethanol

After several distillation, it was discovered that about one-tenth of the samples distilled yielded anhydrous ethanol. This yield is relative to the pH of the solution at the time of distillation. This is as a result of saccarification done by acid hydrolysis making the medium an acidic one.

Ethanol yield $= \frac{1}{10} \times 500$

= 50ml approximately

For 6 batches, 500ml each;

= 0.1 x 500 x 6 batches

= 300ml approximate

At an acidic pH (about 6.7), ethanol yield is relatively is high compared to a basic medium where micro-organisms won't survive nor grow to boost ethanol production in the solution.

Analysis/Characterization of Bio-Ethanol

To satisfy high performance of automotive engines ethanol must meet specification, some of which are varied according to location and base on temperature of attitude:

(i) The fuel must evaporate easily and burn completely

(ii) The fuel must be chemically stable i.e. does not easily decompose

(iii) It should not form gums or other polymeric deposit precursors

(iv) There should be no particulate contaminants or entrained water.

The properties which are generally used to characterize and specify gasoline (petrol) are those related to performance and meet the ASTM standards most importantly. They include: Vapour pressure, Specific gravity, Octane number, Density, Flash point, Viscosity, Refractive Index and Volatility. These properties were used to characterize the ethanol yield in the experiment carried out.

Reid Vapour Pressure (RVP)

This is the vapour pressure exerted by the vapour when the vapour is in equilibrium with the liquid or solid. The Reid vapour pressure is an absolute pressure at 37.8^{o}C (100^{o}F).

It is an important physical property to volatile liquids used to determine the vapour at 37.8^{o}C of volatile liquids with initial boiling point above O^{o}C (32^{o}F).

Vapour pressure is critically important for both automotive and aviation gasoline as it:

(i) Affects starting, warm up and tendency to vapour lock with high operating temperatures of high altitude

(ii) Vapour pressure is also used as an indirect measure of the evaporation rate of volatile solvents

(iii) Vapour pressure is important to the producers and users for general handling.

In determination of the RVP of bio ethanol, the RVP apparatus is used which consists a vapour chamber/manometric guage and liquid chamber, also an electric water bath and bath thermometer were used.

The vapour chamber is heated to 37.8^{o}C in a bath then the liquid chamber is filled with the sample of ethanol and made air tight with a trade tape to the manometric guage. It is shaken to allow the sample run into the air chamber and initial pressure reading is taken. It is then immersed in the bath at a standard temperature of 37.8^{o}C monitored and brought to share at intervals until a constant pressure reading is observed. The reading suitable is reported as the Reid vapour pressure.

With the test method of ASTM D-6378, the RVP of ethanol @ 37.8^{o}C is 0.16bar (16.0kpa).

Specific Gravity

Specific gravity also known as relative density is the ratio of the mass of a given volume of liquid at a specific temperature to the mass of an equal volume of pure water at the same temperature. Accurate determination of density, relative density or API gravity of fuel is necessary for the conversion of measured volumes to volumes or masses or both at standard reference temperatures during custody transfer. Density, relative density (specific gravity) is a factor governing the quality and pricing of fuel.

To determine the specific gravity of ethanol fuel, a thermometer, hydrometer and measuring cylinder are used some sample (test portion) of ethanol is put in the measuring cylinder/hydrometer cylinder and the appropriate hydrometer is lowered into the test portion and allowed to settle. The hydrometer scale is then read and temperature of the test portion is taken. The observed hydrometer reading is reduced to the reference temperature by means of petroleum measuring tables.

Specific gravity G = $\frac{\delta_e}{\delta_w}$

Where,

G = Specific gravity

δ_e = Density of ethanol

δ_w = Density of water

Thus, the specific gravity of ethanol with ASTM D – 1298 test method is 0.7914 (@ 60^{o}F).

Density

The density of a substance is a ratio of the mass of that substance to the volume of the same substance but specific gravity was given to be the ratio of the density of a substance to the density of water at the specific temperatures.

Therefore, the density of ethanol here is

$$\delta_e \quad \frac{M_e}{V_w}$$

Where,

δ_e = density of ethanol

M_e = Mass of ethanol

V_w = Volume of ethanol

But specific gravity, G = $\frac{\delta_e}{\delta_w}$

Where G = 0.7914

δ_e = ?

δ_w = 1000kg/m^3

The δ_e = $G\delta_w$

Density of ethanol (δ_e) = 0.7914 x 100

= 791.4kg/m^3

in g/cm^3 = 0.791g/cm^3

Flash Point

This is the temperature at which a liquid or volatile solid gives off vapour, sufficient to form an ignitable mixture with air near the surface of the liquid or within the test vessel. To determine at what temperature the vapour pressure of ethanol sample becomes inflammable, a thermometer, flash cup, electric heater and flash point apparatus were used. Firstly, the test cup is cleaned up and filled with sample of ethanol to an indicated mark on the test cup. Put the test cup/thermometer into position in the apparatus, the heater is the put on and the temperature at which ignition occurs is observed.

With the test method of ASTM D1500 ethanol's flash point was 26^{o}C.

Octane Number

This is a standard laboratory measured of a fuel's ability to resist knock during combustion. It provides a means of defining the anti-knock quality of a fuel.

In determining the octane number of ethanol, test bottles and a comparative fuel research (CFR) engine is used. The ethanol sample is put in a test bottle and the bottle is put in a freezer to cool a little and allowing the CFR engine to steam and attain temperature of about 100 to 120^{o}F. Then the ethanol sample was turned into the machine and flush the stream with a little of it. The machine is allowed to knock at a specific temperature and the anti-knocking reading is taken. Thus it was observe to be 122.2 (RON) with a test method of ASTM D2699 in place.

Viscosity

Viscosity is the frictional force in liquid and is the ability of the liquid to resist motion. Using a viscometer, at 20^{o}c, the kinematics viscosity of bio-ethanol is observed to be 1.5mm^{2}/s.

Viscosity is necessary for optimum performance of spark ignition engines as too low viscosity causes excessive high pressure in the engine. As such the flow of ethanol in the hoses, pipes of spark ignition engine system is a function of viscosity.

We can therefore say,

$$\eta = 2\,\frac{(\Delta P)\, g a^2}{v}$$

Where η = viscosity

ΔP = difference in density of spherical shaped viscometer and ethanol

g = acceleration due to gravity

a = Reading of sphere (viscometer)

v = velocity of ethanol flow (mm/s)

Refractive Index

Refractive index is carried out using a refractometer the refractive index is used to know the purity of bio ethanol as a fuel and it strictly depends on the temperature. This is done when the hinge and prism surfaces of the instrument are carefully cleared with acetone. After cleaning, a drop of ethanol is dropped on the surface of the prism and clamped. This is viewed through the telescope and the reflection are observed. The refractive index read directly from the scale which was through the telescope where reflection was high.

Refractive index $R = \frac{v}{v_p}$

Where,

V = speed of light area

V_p = momentum of refractive ray

Refractive index of bio-ethanol @ 20^{o}C was 1.3618.

Volatility

This test method covers the atmosphere distillation of fuel product in automotive spark ignition engine fuels using laboratory batch distillation unit to determine its boiling range. Since this test method has been in use a tremendous number of historical data bases exist for estimating end use sensitivity on products and processes.

The distillation (volatility) characteristic of ethanol has an important effect on their safety and performance especially in the care of bio-ethanol and solvent.

The boiling range gives information on the composition, the properties and the behaviour of the fuel during storage and use. Distillation characteristic is thus important for ethanol, affecting starting, warm up and tendency to vapour lock at high operating temperature or at high attitude or both.

The table below shows percentages of volume of ethanol evaporated at varying temperature reading.

Table 1.0 : Volatility table

% Vol Evaporated	**Temperature (°c)**
Initial boiling point	74
10	78
20	78
30	78
40	78
50	78

60	78
70	78
80	78
90	78
End boiling point	78

Thus, from the volatility table, some properties can be obtained, from this test methods, they are:

(i) Distillation profile

(ii) Vapour liquid ratio

(iii) Vapour lock index evaporated at 70^{o}c

(iv) Drivability index using temperatures at fixed distillation point.

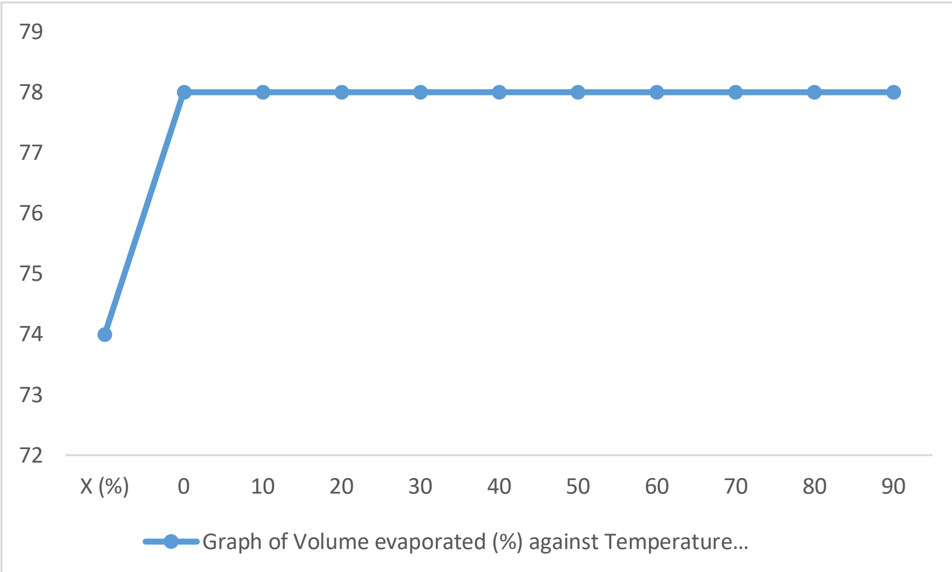

Fig 1.0: Distillation profile of ethanol

Vapour Lock Index

In an otto cycle engine (spark ignition), the fuel must be in the vapour state for combustion to take place. Vapour lock index is used to control vapour lock and other hot-fuel handling problems (hard starting and no starting after a hot soak and poor throttle response)

With the percentage of (evaporated ethanol sample at 70^{o}c to be zero (o); And using the formulae

$$VLI = 10V_p + 7\ (T70)$$

Where,

VLI = Vapour lock index

V_p = Vapour pressure as 16kpa

T70 = Temperature at 70^{o}c is 0

= VL1 = 10 (16) + 7 (0)

$\underline{\underline{160}}$

At this vapour lock index, the normal standard range is met.

Drivability Index (DI): Volatility is a good characteristic drivability index of a gasoline. Drivability describes how an engine starts warms up and runs. It is the assessment of a vehicle's response to easily accelerate idle smoothly and respond to changes in throttle position as expected.

To predict cold-start and warm up, a derivability index (DI) has been developed using temperatures for the evaporated percentage at 10 percent (T10), 50 percent (T50) and 90 percent (T90). At this evaporated percentages, we had the temperature reaching to be 78^{o}C, 78^{o}C, 78^{0}C respectively.

Using the formulae D1 = 1.5(T10) + 3.0 (T50) + .T90

We have (DI) of ethanol = 1.5(78) + 3.0(78) + 78

$$= 117 + 234 + 78$$

$$= 429^{o}c$$

This drivability index falls within the standard range of ($375^{o}c$ to $625^{o}c$) which implies that ethanol will start/drive a car.

Other Analytical Properties Of Ethanol

Acidity

With the hydrolysis carried out with sulphuric acid, the test of the distillate (ethanol) has it acidity (as a acetic acid and % mass at maximum) as 0.0025 with a test method AMSE 1114.

pH

The distillate when tested for level of acidity or alkalinity with blue litmus paper its gave a noticeable red colour, i.e. the distillate is acidic with pH measure 6.7.

Appearance/Colour

After distillation was done till no traceable impurities was found in the distillate, ethanol in colourless and appearance seem to be clear without particles.

Analysed bio-ethanol specifications in comparison to ASTM bio-ethanol standards

Property	Specific Values	ASTM Methods	ASTM (Ethanol Standards)
RVP @ 37.8°C	16.0kpa	ASTM D -6378	-
Specific gravity (@ 60°F)	0.7914	ASTM D-1298	0.7915
Octane Number	122.2	ASTM D2699	129
Density	791.4kg/m^3	-	791.5kg/m^3
Flashpoint	26°C	ASTM D1500	> 21°C
Viscosity(@ 20°C)	1.5mm^2/s	-	-

Refractive index @ 20^{o}C	1.3618	-	-
Acidity (as acetic acid)	0.0025	AMSE 1114	0.003
pH	6.7	-	6.5 – 9.0

Parameters of bio-ethanol in comparison with gasoline (petrol)

	Density (kg/m^3)	**Viscosity (mm^2/s)**	**Flash point (^{0}C)**	**Octane No (RON)**	**Caloric value (MJ/L)**	**Fuel equivalence (L)**
Petrol	760	0.6	26	88.2	32.45	1
Bio-Ethanol	791	1.5	26	122.2	21.17	0.65

CONCLUSION

The production of bio-ethanol from potato waste is very possible..

There are several potentially important benefits from developing a viable and commercial cellulosic ethanol process,

(i) Access to a much wider array of potential feedstock types, potato waste (and other cellulosic crops as grasses and trees), opening the door to greater ethanol production.

(ii) A much greater displacement of fossil energy per litre of fuel, due to nearly completely biomass –powered system.

(iii) Much lower net well-to-wheels greenhouse gas emissions than with grain–to-ethanol processes primarily powered by fossil energy.

(iv) Greater avoidance of conflicts with land used for food and feed production.

Also, after analyzing some physio–chemical test on the bio-ethanol produced from potato waste it reveals that ethanol as fuel in an internal combination engine (spark – ignition engine is possible as it meets various conditions and standards of the ASTM like the gasoline (petrol) but preferably more acceptable because of the friendliness of its end products to the environment.

In conclusion: Production of ethanol should encourage. The government should support farmers, provide them with needed subsidy to enable them produce more potatoes and other Ethanol producing crops so as to be on the safer side in case oil (petroleum) thus run out. Besides if this is done, there will be more jobs opportunity and feeds for live stocks.

Also, Government should also make public through electronic, print media, seminars etc to inform the educate motorist as well as the general public on the importance of ethanol over gasoline (petrol) so as to convince them on its usage thus commencing commercial production and sale.

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