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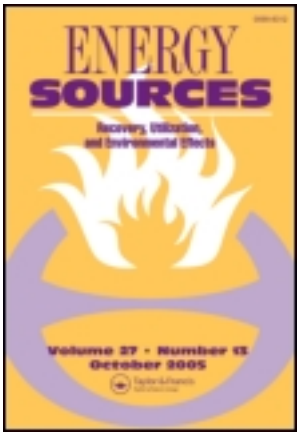

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The Production and Characterization of Ethanol Fuel from Agricultural Products as an Alternative Fuel for Gasoline

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Abstract *The concern for efficient use of clean and alternative sources of energy other than fossil fuel has gathered rapid momentum all over the world. The most interesting development is the growing realization that ethanol is an alternative source to fuel and lubricants derived from the liquid fuel. This work, therefore, focuses on the experimental conducts in producing ethanol fuel from agricultural products (corn, guinea corn, and millet shaft) that are an easy source in Nigeria and to compare the performance of the fuel with gasoline based on the characteristics of the ethanol fuel produced. The agricultural products (corn, guinea corn, and millet shaft) were hydrolyzed using an alkaline treatment and acid hydrolysis; subsequent fermentation of simple sugars obtained from hydrolysis by yeast (*Saccharomyces cerevisiae*) produced bio ethanol and CO_2. Results obtained revealed that the production of bio-ethanol was successfully carried out. One hundred grams each of the three samples gave yields of 65, 52, and 45 cm^3 from corn, guinea corn, and millet shaft hydrolyzed, respectively. About 99.2% of anhydrous ethanol was achieved at the end of the drying process using charcoal (adsorbent), which is close to the theoretical value of 99.9% ethanol. The properties that the bio-ethanol have been tested for are relative density, flash point, sulphur content, vapor pressure, viscosity, latent heat of vaporization, and heat of combustion. The results obtained are relative density of 0.966, flash point is 55°C, and sulphur content of the ethanol fuel is 0.0251%, while the vapor pressure of the produced fuel is 25.7%. Other properties of the produced ethanol fuel are viscosity, which is 1.24 (cp) at 20°C, latent heat of vaporization is 635.3 kj/kg, while the latent heat of combustion of the produced ethanol fuel is 31300.23 kj/kg. These experimental values are relatively close to gasoline.*

Keywords charcoal, corn, ethanol, gasohol, gasoline, guinea corn and millet shaft

1. Introduction

The energy crises all over the world is a very big challenge in recent times and this is due to the inability of government and energy sectors to balance the supply of energy with the increase in human population and growth in demand for energy by the industries (Anderton and Kingwell, 2008; Sánchez and Cardona, 2008; Du and Hayes, 2009;

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Balat and Balat, 2009; Lambert and Middleton, 2010). This, therefore, calls for the urgent development of alternative energy sources that will compete well with the fossil fuel. Obviously, such alternative source(s) should be a clean burning, cost-effective, and environmentally friendly fuel. Alcohol has been suggested as possessing such potential as an alternative source of energy with emphasis on ethanol majorly due to the ease of production from different sources that are easily available in developing countries like Nigeria.

Ethanol is made from grains (mainly corn) or other renewable agricultural or forestry products, such as wood, brewery waste, potatoes, cheese whey, paper waste, beets, or vegetable wastes, etc (Huang et al., 2009; Yamashita et al., 2010). Its isolation as a relatively pure compound was first achieved by Persian alchemists who developed the art of distillation during the Abbasid caliphate, the most notable of whom was Al Razi. Absolute ethanol was first obtained in 1796 by Johann Tobias lowitz, by filtering distilled ethanol through charcoal. The basic advantage of ethanol as a duel source derives from its ability to burn clearly. Ethanol also has a long history as a fuel, including as a fuel for internal combustion engines. It is classified as a primary alcohol, meaning that the carbon to which hydrogen atoms is well attached. Ethanol as an oxygenator contains an oxygen atom bonded to a hydrogen atom in the hydroxyl radical, as opposed to octane with no oxygen. During ethanol combustion, the hydroxyl group combines with a hydrogen atom from a molecule of water (Sánchez and Cardona, 2008; Felix and Tilley, 2009). In the atmosphere, it is predicted that ethanol will be oxidized quickly; the half-life ranges between 0.5 and 5 days, while the half-life of ethanol in the soil is in the range of up to 2.1 days. The main advantage associated with the use of ethanol as a fuel oxygenate is its high oxygen content and short half-life in the environment relative to other oxygenates. Furthermore, ethanol exhibits low human toxicity at the estimated exposure levels from the accidental releases of ethanol-gasoline into the environment (Yamashita et al., 2010). Ethanol, therefore, has far fewer standard regulator pollutants, such as carbon monoxide and hydrocarbons, compared with plain gasoline in equivalent tests.

Bio-ethanol fuel is mainly produced by the sugar fermentation process (Silalertruksa and Gheewala, 2009; Pereira and Ortega, 2010; Yamashita et al., 2010), although it can also be manufacture by the chemical process reacting ethylene with steam. Ethanol is described as a high octane fuel and has replaced lead as an octane enhancer in petrol. At the moment, fuel blends are widely used in most parts of the world and the most common blend is 10% ethanol and 90% petrol (E10) (Silalertruksa and Gheewala, 2009). Vehicle engines require no modifications to run and vehicle warranties are unattested also, only flexible fuel vehicles can run on up to 85% ethanol and 15% petrol. Today, almost half of Brazilian cars are able to use 100% ethanol as fuel, which includes ethanol only engines and flex-fuel engines (Smeets et al., 2008). Flex-fuel engines are able to work with all ethanol, all gasoline, or any mixture of both. Brazil supports this population of ethanol burning automobiles with a large national infrastructure that produces ethanol from domestically grown sugarcane. Sugarcane not only has a greater concentration of sucrose than corn (by about 30%), but it is also much easier to extract (Chandel et al., 2009; Pereira and Ortega, 2010; Yu et al., 2010; Bahera et al., 2010). The bagasse generated by the process is not wasted, but is utilized in power plants as a surprisingly efficient fuel to produce electricity. This work is focused on the production of bio-ethanol fuel from the shaft of corn, millet, and guinea corn using an alkaline treatment to eradicate the pollution effect of these shafts on the environment (water and soil pollution) since they are a pollutant. It also intends to blend the bio-ethanol produced with gasoline (Premium Motor Spirit) to obtain gasohol (E10).

2. Experimental

2.1. Materials and Equipments

All the chemicals used in this study are of analytical grades (95–99.5%). They include Fehling solution, calcium hydroxide, acetic acid, iodine solution, potassium hydroxide, and distilled water. Other materials are shaft from corn, shaft from guinea, shaft from millet, vitamin B complex, and yeast (*Saccharomyces cerevisiae*). The list of equipment includes distribution apparatus (Pyrex), viscometer (Cannon fenske), pH meter (307/Fenway), flash point (Pen sky-martens), thermometer (sedim), digital weigh balance (CT 1200/OHAUS), water bath (WE 4105/Clifton), and electric heater.

2.2. Production of Bio-ethanol

The feed stock, corn, millet, and guinea corn (100 g) were pre-treated by thoroughly cleaning in water after which they were soaked in water for about 3 days. The soaked cereals (corn, guinea corn, and millet) were then grinded to obtain homogeneity of each of the cereals. The grinded cereals texture was smooth, which makes it easy to sieve. The objective of sieving is to separate the shaft from the wort. The sieved cereals were then dried in an oven at 80°C to remove the moisture content in the sample and were further processed using equal reagents and chemicals.

The next step is the mashing (meal slurried with water) and alkaline treatment of starch. Mashing prepares the starch for fermentation softening, gelatinizing, and the subsequent hydrolysis of the starch into simple sugars. One hundred grams of each dried shaft was measured and was transferred into a conical flask of known weight. One thousand cm^3 of distilled water was heated to a temperature of 50°C and the shaft powder was mixed with the water and thoroughly agitated for 10 min so as to get a homogenous mixture. After the agitation, 2 cm^3 of the mixture was measured in a test tube and iodine solution was added dropped wise and stirred to test for the presence of starch. The starch obtained was placed on a hot plate stirrer operating at a temperature of 95°C for 30 min; stirring is carried out during boiling to avoid the formation of lumps. The sample is set aside to cool for 60 min, while stirring continues. After cooling, the sample is then ready for hydrolysis (saccharification). One hundred cm^3 of 0.054 M potassium hydroxide was added to the sample and immersed in a water bath at a temperature of 75°C and maintained for 30 min. One hundred cm^3 of 0.05 M ethanoic acid was added to the mixture between 3.6–4.0 pH level, then calcium hydroxide and phosphoric acid were added to maintain the pH level. The mixture was filtered into a different conical flask and the filtrate wort was collected, weighed, and the volume was measured. About 100 cm^3 of distilled water was used to wash the wort in the residue.

The actual production of ethanol took place during fermentation. The enzymes, invertase (maltase), and zymase contained in the used yeast, as well as diastase contained in the Malt (i.e., partially germinated barley) acted on monosaccharide and disaccharide produced during mashing and in the process degrades the saccharides to ethanol and CO_2. An amount of 15 g of baker's yeast was measured and added to the yeast nutrient (Ammonia); this was then added to each of the mixtures. The flask was corked with a rubber cork. The opening in the flask was blocked and was allowed to ferment for a period of 12 days. To test for the presence of alcohol, 3 cm^3 of the mixture was transferred into a test tube, iodine and sodium hydroxide was added, and the mixture was maintained at 40°C. Yellow precipitate was formed indicating the presence of ethanol.

Distillation was carried out after fermentation. This is done so that the ethanol fuel can be collected because the ethanol produced during fermentation was contained in a mixture of water and unfermented spent materials. The distillation was carried out to first separate the liquid from the spent materials and then to concentrate the alcohol produced. The distillate was further purified by the use of lime (calcium oxide). Lime, a basic oxide, was added to the ethanol, an alkaline solution. The calcium hydroxide formed was separated from the ethanol by further distillation, which leaves absolute ethanol. The ethanol produced from the cereals was mixed with gasoline to produce the ethanol bio-fuel. The various tests conducted on the resulting bio-fuel are relative density, flash point, sulphur content, vapor pressure, viscosity, latent heat of vaporization, and heat of combustion.

3. Results and Discussion

The urgent need for alternative sources of energy to the present source of available fuel is very high. The harm caused by the combustion of fossil fuel has led to the pragmatic effort to source for a more environmental friendly fuel (Du and Hayes, 2009). The alternative energy source must be clean, safe, and cost effective, and alcohol fuel possess these qualities. Among the available alcohol fuels, ethanol provides the best qualities and can be easily sourced from the agricultural product. Also, blending bio-ethanol with petrol (Premium Motor Spirit) will help extend the life of the diminishing oil supplies and ensure greater fuel security, avoiding heavy reliance on oil as the main source of foreign exchange. In this article, ethanol fuel is produced and characterized from agricultural products (corn, guinea corn, and millet shaft) that are easily available in Nigeria and the results of various analysis conducted on the bio-fuel produced are presented in Tables 1–4. Table 1 shows the quantity used in the production of material, while the results of various analyses conducted on the produced bio-ethanol after twelve days of fermentation are presented in Tables 2–4.

The major operations during the production of ethanol were mashing fermentation. During the gelatinization, however, the interest was in the hydrolysis reactions involving the conversion of complex network of glucose in the starch to simple sugars. Also important is the conversion of protein present to amino acids that can also be metabolized by the yeast cells, while the reaction of interest during fermentation is the synthesis of

Table 1
Quantity of materials used in production of ethanol

Materials	Quantity
Shaft from corn	100 g
Shaft from guinea corn	100 g
Shaft from millet	100 g
Distilled water	1,000 cm^3
Potassium hydroxide	0.054 M (100 cm^3 used)
Acetic acid	0.05 M (100 cm^3 used)
Vitamin B complex	10 g
Yeast	15 g
Calcium hydroxide	5 g

Table 2
pH requirement

pH	Observed	Expected
Mashing	3.6–4.0	5.4–5.6
Fermentation	4.5–4.7	5.9–6.1

Table 3
Quantity of ethanol produced from agricultural products

Samples	Weight of shaft, g	Volume of ethanol collected after distillation, cm^3
Shaft from corn	100.0	65.0
Shaft from guinea corn	100.0	52.0
Shaft from millet	100.0	45.0

Table 4
Characteristics of the bio-ethanol produced from agricultural products

Experiment	Experimental value of the ethanol fuel sample	Standard value of ethanol	Gasoline
Relative density	0.969	0.79	0.695
Flash point (°C)	55	12–13	65
Sulphur content (%)	0.0251	0.045	0.5
Vapor pressure (kpa)	35.7	16.0	48–100
Viscosity at 20°C (cp)	1.24	1.20	0.503
Latent heat of vaporization (kj/kg)	635.3	921.4	349
Heat of combustion (kj/kg)	31,300.23	25,120	43,961

ethanol by the degradative action of the yeast cells on the simple sugars and amino acids from the starch hydrolysis during mashing. The pH of the starch solution was observed to be acidic before and during mashing. The result observed for the pH values were 3.6–4.0 as shown in Table 2, the result was found to be close to the expected pH values. The little difference in the results can be attributed to experimental errors and environmental factors. Effectiveness of mashing was checked by the response of the sample to test for simple sugars and unhydrolyzed starch. Fehling's solution result was indicative of the considerable level of conversion of the starch to simple sugars, which gave a blue black coloration on the addition of iodine solution showing the presence of unconverted starch even after mashing. Incomplete conversion of starch was a result of imbalance in pH requirement during milling and may also have resulted from the use of incorrect proportions of the reagent for the 100 g of each shaft used. Fermentation was run for 12 days and the pH value during fermentation was 4.5.

Results obtained on the production of bio-ethanol from agricultural products, i.e., corn (maize), guinea corn, and millet, as presented in Table 3, shows that the corn shaft yielded more ethanol than the guinea corn shaft, which in turn yielded more ethanol than millet. The quantity of ethanol yielded by fermentation of starch contained in the sample was considered in the course of this experiment. At the end of the 12 days, the total volume was 800 cm^3 from each sample. The degree of purity of the fuel (ethanol) during distillation is determined by the temperature range it takes for a particular quantity of the ethanol to be vaporized. The volumes of ethanol produced are 65, 52, 45 cm^3 corresponding to 0.65 cm, 0.52, and 0.45 cm^3 of ethanol per gram of the cereals from the corn shaft, guinea shaft, and millet shaft, respectively. This shows that the shaft from corn has a higher composition of carbohydrate and reducing sugar than the rest of the samples. In other words, to assess the suitability of the bio-ethanol as an alternative source of fuel, the ethanol produced was blended with gasoline to form the ethanol bio-fuel, the basic fuel test was conducted, and the results obtained are presented in Table 4. The result obtained on the relative density of the bio-ethanol fuel was found to be 0.96, which deviated from the literature values of 0.79 and 0.695 for ethanol and gasoline, respectively. The variation can be attributed to the concentration of the bio-ethanol fuel. The flash point of the produced bio-ethanol fuel was 55°C; this is an indication that the bio-ethanol fuel will give off less quantity of vapor when compared with the gasoline that has the flash point of 65°C. Though results obtained revealed that the flash point of the bio-ethanol is less than that of the gasoline, it is also an indication that the produced fuel is safer to handle than the gasoline. Also investigated is the viscosity of the bio-fuel. Viscosity is a very important characteristic of fuel; it influences the flow of fuel through the nozzles, injection pipe, and orifice (Abdulkareem et al., 2010). Viscosity is the measure of the friction that opposes the motion of the fuel. The viscosity of the bio-ethanol fuel is 1.24, which is higher than that of the gasoline. The variation between the two fuels suggests that a little adjustment may be required in the nozzles, injection pipe, and orifice. Results obtained on the vapor pressure of the bio-ethanol, as shown in Table 4, indicates that the vapor pressure of the bio-ethanol is 35.7 kpa. This is an indication that the fuel produced was volatile and there is the possibility that the sample will give off enough fuel vapor for the carburetion. The experimentally determined vapor pressure of the bio-ethanol is lower than that of the gasoline, which is in the range of 48–100 kpa, and the difference can be attributed to the presence of a small amount of water in the sample. The sulphur content of the bio-ethanol produced is 0.0251%, while that of gasoline fuel is 0.5%. The difference in the value of the sulphur content of the two fuels can be attributed to the fact that the gasoline is a petroleum derivative, while the bio-ethanol is produced from the ethanol, which contains fewer amounts of sulphur or sulphur-related compounds. The latent heat of vaporization of the produced bio-ethanol fuel is 635.5 kj/kg and it is the property of the fuel that is responsible for the charge cooling. This value is higher than that of the gasoline, which is 349 kj/kg; this is an implication that the charge of cooling will be greater when using the bio-fuel than when gasoline is used in the engine. One of the most important properties of any fuel is the amount of energy obtained from it when it is combusted, which is referred to as the heating value of the fuel, measured on a unit basis (weight or volume). It is this property that gives an indication of the potential work than can be expected from a machine as a function of the fuel efficiency. The value of the heat of vaporization of the bio-ethanol produced is 31,300.23 kj/kg, which is lower than that of the gasoline. Results obtained on the various analyses conducted on the bio-ethanol fuel compared favorably with gasoline. The little variations are attributed to the sources of the properties and on the experimental error.

4. Conclusion

Based on the experimental result, it can be deduced that the agricultural products (corn, guinea corn, and millet shaft) employed in this work produced ethanol that can effectively serve as an alternative for the fossil fuel, with the highest yield from the corn shaft. Blending of the alcohol produced with gasoline to obtain gasohol shows that the use of shaft for the production of ethanol increases its utilization, not just for animal food but also serves as an alternative or substitute for the production of motor fuels. The ethanol bio-fuel has the advantage of being a non-polluting source of energy; therefore, it will help in reducing the emission of greenhouse gases into the atmosphere.

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