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Improving Gasoline Efficiency through Blending with Bio-Ethanol Produced from Saw Dust

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ABSTRACT- This research work investigated the suitability of blending bio-ethanol produced from saw dust with gasoline as a source of automobile fuel. The bio-ethanol was produced using fermentation and distillation processes and prepared for blending by making it conform to the American Standard of Testing and Material (A.S.T.M). Engine trails involved combinations of various ratios of gasoline/bio-ethanol as fuel in a small unmodified gasoline engine connected to a dynamometer. The vapour pressure, octane number, flash point, specific gravity and calorific value of various compositions of the blends were evaluated. Other physical observations suggest that to successfully run a gasoline engine with bio- ethanol-gasoline blends above E10 some modifications would have to be done on the engine, including advancing of ignition timing, provision of air tight fuel conduit network, and modification of piston heads to improve pre-combustion fuel homogenisation. Hence biomass energy systems can become much more efficient and competitive sources of renewable electricity/transportation fuel by improving its efficiency through blending in gasoline (UNEP, 1991).

INDEX: Mm – Mass of saw dust, Qb – Quantity of slurry, RI – The specific yield in l/kg RON - Research Octane Number, E - Bio-ethanol, X – Percentage of bio-ethanol in the blend, and RVP – Reid vapour pressure

1 INTRODUCTION

Alcohols have been used as fuel for engines since 19th century. Among the various alcohols, bio-ethanol is known as the most suited renewable, bio-based and eco-friendly fuel for spark-ignition (SI) engines. The most attractive properties of ethanol as an SI engine fuel are that it can be produced from renewable energy sources such as sugar cane, cassava, saw dust and many types of waste biomass materials, corn and barley. In addition, ethanol has higher evaporation heat, octane number and flammability temperature therefore it has positive influence on engine performance and reduces exhaust emissions which cause environmental pollution and enhance ozone layer depletion. (EPA US, 2000)

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Compared with conventional unleaded gasoline, bio-ethanol is a particulate-free burning fuel source that combusts with oxygen to form carbon dioxide, water and aldehydes. Gasoline produces 2.44 CO_2 equivalent kg/l and ethanol 1.94. Since ethanol contains 2/3 of the energy per volume as gasoline, ethanol produces 19% more CO_2 than gasoline for the same energy. The addition of bio-ethanol in gasoline reduces carbon monoxide emissions. The additive MTBE is currently being phased out due to ground water contamination hence bio-ethanol becomes an attractive alternative additive to gasoline in order to enhance environmental friendliness. When compared to gasoline, depending on the production method, Bio-ethanol releases less greenhouse gases. (UNEP, 1991)

1.2 CHARACTERISITICS OF BIO-ETHANOL-GASOLINE BLENDED FUELS

Blending ethanol with gasoline has multiple effects. Ethanol increases the heat output of the unleaded gasoline, which produces more complete combustion resulting in slightly lower emissions from unburned hydrocarbons. The higher the concentrations of ethanol, the more the fuel has polar solvent-type characteristics with corresponding effects on conducting fire suppression operations. However, even at high concentrations of ethanol, minimal amounts of water will draw the ethanol out of the blend away from the gasoline. Ethanol and gasoline are very similar in specific gravity. The two differing fuels mix readily with minimal agitation, but the blend is more of a suspension than a true solution. Ethanol has a greater affinity for water than it does for gasoline. Over time, without agitation, gasoline will be found floating on a layer of an ethanol/water solution. The resulting ethanol/water solution is still flammable since the concentration of ethanol is still fairly rich.

Phase separation can occur in fuel storage systems where water is known to be present. Blending these fuels together alters the physical and chemical characteristics of the original fuels. However, the resulting changes may be unnoticeable to emergency responders, because gasoline is used in the blend, E-85 is considered potentially carcinogenic. One of the noticeable differences in the blended fuel versus unblended gasoline is the visual difference of the smoke and flame characteristics. Higher concentrations of ethanol produce less black smoke and decreased visible flame colour. These characteristics may be masked by other substrates that may also be burning such as vehicle tires. Another noticeable difference of ethanol-blended fuels under fire conditions is that when foam or water has been flowed on the burning product, the gasoline will tend to burn off first, eventually leaving the less volatile ethanol/water solution which may have no visible flame or smoke. (Nafaji 2002)

1.3 WOOD A SOURCE OF BIOMASS

Wood energy is derived both from direct use of harvested wood as a fuel and from wood waste streams. The largest source of energy from wood is pulping liquor or “black liquor,” a waste product from processes of the pulp, paper and paperboard industry. Waste energy is the second-largest source of biomass energy. The main contributors of waste energy are municipal solid waste (MSW) such as wood, manufacturing waste, and landfill gas. (Klose, Damm, and Wiest, 2000). Virgin wood consists of wood and other products such as bark and sawdust which have had no chemical treatments or finishes applied. New second generation technologies are being developed which are capable of producing a range of liquid or gaseous transport fuels (bio fuels) from woody material. (Gerez and Miller, 1985)

Table 1.1 Some Basic Data on Plant Biomass

Principal Component	Wood (%)
Cellulose	40 – 45
Hemicellulose	10 - 15
Lignin	20 - 35
Ash	Up to 1

1.4 BIO-ETHANOL FROM WOOD

Cellulosic ethanol is a bio-fuel produced from wood, grasses, or the non-edible parts of plants. It is a type of bio-fuel produced from lignocelluloses, a structural material that comprises much of the mass of plants. Lignocellulose is composed mainly of cellulose, hemicellulose and lignin. Corn stover, switch grass, miscanthus, woodchips and the by-products of lawn and tree maintenance are some of the more popular cellulosic materials for ethanol production. Production of ethanol from lignocellulose has the advantage of abundant and diverse raw material compared to sources like corn and cane sugars, but requires a greater amount of processing to make the sugar monomers available to the microorganisms that are typically used to produce ethanol by fermentation.

1.4 CONVERTING WOOD INTO TRANSPORTATION FUELS

Wood can also be used to produce transportation fuels, such as ethanol, methanol or biodiesel. Ethanol is produced through a process called fermentation in which wood is exposed to microorganisms. As these microorganisms decompose the wood, enzymes are produced. These enzymes trigger a chemical reaction that exposes and breaks down the sugars in the wood. Certain microbes can then be added to the sugar solutions to convert them into ethanol, a colourless alcohol, and other by-products (Kumar and Kotiya, 2004). Once processed, ethanol can be used in combination with gasoline to make E-10 or E-85 to power vehicles equipped to burn it. E-10 contains 90% gasoline and 10% ethanol and can be used in most modern vehicles; E-85 contains 15% gasoline and 85% ethanol and can be used in engines modified to run on higher concentrations of ethanol, such as flexible-fuel vehicles that is vehicles designed to utilize blended fuels.

1.6 PHYSICAL AND CHEMICAL PROPERTIES OF BIO-ETHANOL AND GASOLINE

Selected chemical and physical properties of gasoline and ethanol are shown in table 1.2, when ethanol is blended with gasoline, larger amounts are needed in the blend in order to match the oxygen content of the blend. In general, as the ethanol concentration increases so does the blend's specific gravity. Fuel blends with higher alcohols are slightly denser than those with lower alcohols for given oxygen mass contents of 2.5% and 5.0%. The energy-mass density for each blend is predicted by summing up the mass weighted heating values of the neat components. The higher the oxygen contents in the blend, the lower its energy mass-density value. The decrease in the heating value is almost the same for blends with matched oxygen content. The energy-volume density for each blend is computed by multiplying its energy-mass density and its specific gravity. Blends with higher alcohols have larger energy volume densities, when compared to those with lower alcohols for the given oxygen mass contents of 2.5% and *5.0%*. For the Same operating conditions, engines burning a stoichiometric mixture need to consume more alcohol-gasoline blend than neat gasoline. (Furey, 1998)

Table 1.2 Properties of Gasoline and Bio-Ethanol

Properties	Gasoline	Ethanol	Unit
Formula	C8-H18	C2H5OH	
Mole weight	100 – 105	46.07	
Spec grav.	0.72-0.78	0.794	
Boiling temp	80-437	172	^{o}C
Freezing point	-40	-173.2	^{o}C
Vapour pressure	8-15	2.2	psi
Calorific value	125000	76000	cal/gm
Octane rating	87	122	
Flash point	-45	55	^{o}C

2 EXPERIMENT

Bio-ethanol is produced through a process called fermentation in which wood is exposed to micro-organisms. As these micro-organisms decompose the wood, enzymes are produced. These enzymes trigger a chemical reaction that exposes and breaks down the sugar in the wood. Certain microbes can then be added to the sugar solutions to convert them into ethanol (a colourless alcohol) and other by-products. Bio-ethanol today is utilized as an alternative fuel for it can be blended with regular gasoline. It increases the octane number and improves the emission quality of burnt gasoline. Bio-ethanol can be blended with gasoline to produce alternative transportation fuels.

Table 2.1 List of Chemicals Used for this Study

Table 2.1 List of Chemicals Used in this Study

Chemicals	Manufacturer
18M Sulphuric acid	BDH Prolabo
6.0M Sodium hydroxide	BDH Prolabo
Fehling solution	GRG Mistral
Yeast	Kunimed
Vitamin B complex	Emzor

Table 2.2 List of Apparatus/Equipment used in this Study

Apparatus	Equipment
Measuring cylinder	p H meter
Beaker	Fermenter
Cornical flask	Rotary evaporator
Funnel	Refractometer
Filter cloth	Bomb calorimeter
	RON analyser
	Hydrometer
	Dynamometer

2.1 BIO-ETHANOL–GASOLINE BLENDING PROCEDURE

The refractometer method was used to determine the reasonable accuracy and purity of the ethanol being blended for fuel. It checks the refractive index of the product, which should be within certain limits to be suitable for use in gasoline. The purity of the ethanol produced as determined by the refractometer was 99.86% and ethanol/gasoline (p.m.s) blend was achieved by preparing 5mls ethanol to 95mls gasoline, 10mls ethanol to 90mls gasoline, 15mls ethanol to 85mls gasoline and 25mls ethanol to 75mls gasoline and the physico -chemical properties of the various blends determined.

2.2 MEASUREMENT OF PHYSICO-CHEMICAL PROPERTIES OF THE BLEND

The specific gravity of the various samples was determined by use of a hydrometer at 24°C and it was corrected using the ASTM conversion table at 15/4°C. The distillation of the various blends was carried out using a distillation bath and the vapour pressure of the sample was carried out by use of a Reid vapour pressure bath. Pensky Martens (ASTM D93) method was used to determine the flash point. The test cup was filled to a specific level with a sample of bio-ethanol/gasoline blended fuel. The temperature of the sample was increased rapidly at first and then slowly as the flash point was approached. At 20 °C, a small test flame was passed across the cup. At a point, the vapour above the surface of the testing sample was ignited with the aid of the test flame and the temperature at this point was noted and was recorded as the flash point.

2.3 ENGINE PERFORMANCE USING DYNAMOMETER

During the engine trails, various ethanol-gasoline blends were used as fuel to run a small gasoline engine attached to a dynamometer and the break power developed by the engine was computed using the torque output and the maximum engine speed developed. Before this was done it was necessary to calibrate the equipment using gasoline only as fuel. The equipment used was a 4 hp engine attached to a dynamometer of the type Power Lab PL 100D. This dynamometer consisted of a fined rotor mounted in cradle housing. The engine being tested was attached to drive the fine rotor section as described in the PL-D dynamometer laboratory and technical manual. During tests water was introduced into the dynamometer under pressure into the water absorption unit mounted in an adjustable bracket system. As the engine being tested had to pump the water, this placed a load on the engine and the load was varied by decreasing or increasing the water in the system. The outward movement of the water caused the housing to rotate in its cradle and a scale attached to the housing enabled the torque to be measured using a load cell and a bourdon tube gauge. The said system was designed to measure brake horsepower and torque at various data points throughout the speed range of the engine being tested. The mechanical energy of the engine was converted into heat energy in the form of hot water. As the hot water left the dynamometer, the system was cooled and therefore no auxiliary cooling was required. The values obtained during calibration were taken, as standard values so that the readings obtained using different fuel combinations would be compared to these.

3 RESULTS

Table 3.1. Ethanol Production from Saw Dust

Tempt °C	Mass of Saw Dust (kg)	Quantity of Slurry (L)	Quantity of Ethanol (cl)	Ethanol Yield (cl/L)
30	2.0	7.9	45	5.7
34	2.0	7.9	49	6.0
38	2.0	7.9	46	5.8

Table 3.2 Properties of Gasoline Fuel Blended with various Percentages of Bio-Ethanol

Parameters	E0	E5	E10	E15	Unit
Spec grav.	0.8014	0.751	0.752	0.754	
Calorific val.	11218	11214	11211	11202	Cal/gm
Reid vap. press.	2.21	2.30	2.39	2.10	psi
Flash point	- 63	-45	- 30	-24	°C
RON	90	91	92	93	

Table 3.3. Variation of Engine Power with various Loads for E10 Blend

Engine Load	Power (watts)
0	170
0.25	172
0.5	220
0.75	224
1.0	160

Table 3.4. Variation of Engine Power with various Loads for E20 Blend

Engine Load	Power (watts)
0	40
0.05	46
0.15	51
0.2	55
0.25	61

3.1 DISCUSION OF RESULTS

Results of specific bio-ethanol yield from saw dust are shown on table 3.1. Analysis of the ethanol production from sawdust shows that a kilogram of this sawdust would produce about 45cl of the ethanol. The maximum yield of alcohol for sawdust is about 6.0 cl/L at a temperature of 34°C. The first, second and third distillation produced 45cl at a temperature of 30°C, 49cl at a temperature of 34°C and 46cl at a temperature of 38°C ethanol respectively. The final ethanol product had a specific gravity of 0.8014 indicating a volume of 1.4lt ethanol product.

Before transferring the three samples into the fermenter it was ensured that the temperature of the slurry was varied between 30-38°C this was done in order to determine the temperature at which the highest yield of ethanol will be produced. The ideal temperature is between thirty and forty degrees Celsius within the fermentation chamber, as this is the temperature range at which anaerobic bacteria are most active. (FAO, 2004)

After three days of fermentation, the alcohol yield dropped considerably for all the three substrates. This can be explained by the fact that after three days of fermentation, oxidation reactions proceed in the formation of acetic acid and ethanoic acid, thereby decreasing the alcohol yield. The alcoholic fermentation was catalysed by yeasts.

Five blends of ethanol- gasoline mixtures were used. The blends are usually referred to as EX, where E represented bio-ethanol and X represented the percentage of the bio- ethanol in the blend. For example, E5 means a blend composition in which bio- ethanol is 5% by volume and gasoline is 95% by volume. The various properties of the bio-ethanol produced and gasoline used for the blending are shown in table 1.2 above.

The measured properties of the various blends are shown in Table 3.2. Blending these fuels together altered the physical and chemical characteristics of the original fuels. Bio-ethanol and gasoline are very similar in specific gravity, the two differing fuels mix readily with minimal agitation.

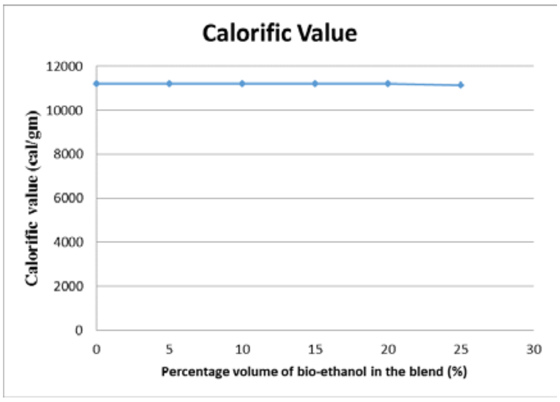

Figure 3.1 Variation of Calorific value with Percentage volume of Bio-ethanol in the blend

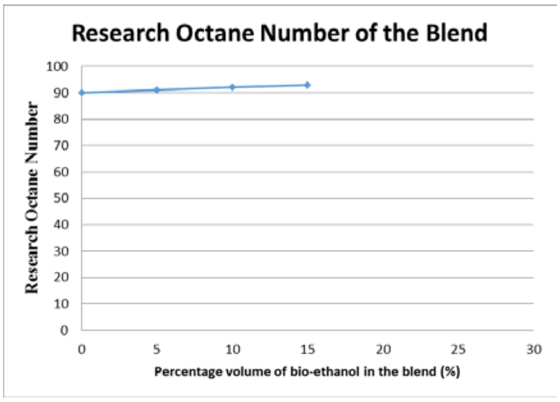

Figure 3.2 Variation of Research Octane Number with Percentage of Bio-ethanol in the blend

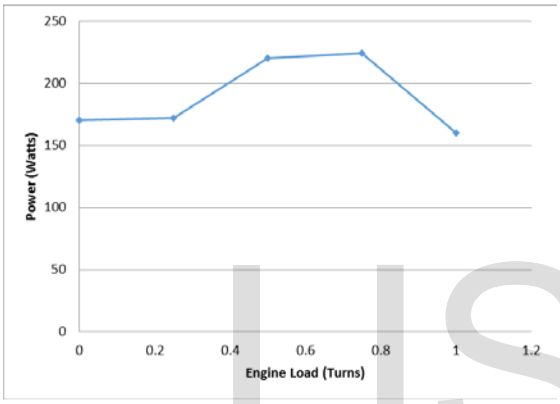

Figure 3.3 Behaviour of engine power with load of E10 blend

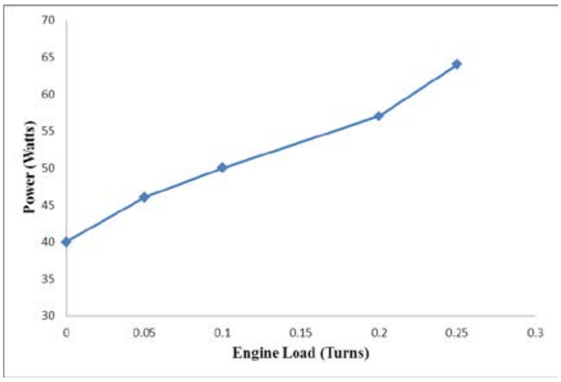

Figure 3.4 Behaviour of Engine Power with load of E20 blend

From figure 3.1 the calorific value of the blended fuel decreased from 11214kcal/kg for E5 to 11156 for E25 as ethanol concentration increases this implies more fuel is consumed per mile as the ethanol fraction in the blend increases. As the calorific value of the blended fuel decreases the octane rating increases. This is because when the octane number is raised by blending the gasoline with bio-ethanol, energy content per volume is reduced thus making the fuel to burn in a controlled manner, rather than exploding in an uncontrolled manner. This energy content is the quantity of heat released per unit quantity of fuel, when it is burned completely with oxygen and the products of combustion returned to ambient temperature.

Comparing the results of the calorific values on table 3.2 with that of table 1.2 it is clear that the calorific value of gasoline decreases considerably as the percentage of bio-ethanol in the blend increases this is shown on figure 3.1. From figure 3.1 the calorific value decreases from E0 to E25.

The flash point increases from -59 at E0 to -17°C with E25. The flash point indicates the temperature at which the fuel can vaporise to produce an ignitable mixture with air. At the flash point an applied flame gives momentary flash instead of some steady combustion. Therefore the flash point gives some indication on the flammability of the liquid. This shows that with the addition of ethanol fractions to gasoline the burning characteristics of the mixture reduces. It is important to note that the higher the flash point of a fuel the more difficult it is to start the car. For example, the flash point of E25 was found to be -17°C meaning that starting will be very difficult at temperatures of about -59°C. Therefore a gasoline engine converted to an E25 engine would need to use pre heater plugs in winter.

The specific gravity of the blends increased from 0.751 for E5 to 0.769 with E25. This was expected especially as bio-ethanol is heavier than gasoline. This explains why when a mixture of hydrous bio- ethanol gasoline is viewed inside a transparent container; ethanol is seen to settle at the middle sandwiched by gasoline on top and water at the bottom, but for anhydrous ethanol there is no such observation. This shows that addition of bio-ethanol to gasoline produces a fuel blend denser than gasoline. The specific gravity of a fuel is the weight of the fuel compared to the weight of the same volume of distilled water at a given temperature. It gives an indication of the purity of a fuel. When fuel is contaminated with another liquid, the specific gravity will either increase or decrease depending on the specific gravity of the contaminant, that is, the specific gravity of the contaminant alters that of the fuel. In this research work, the specific gravity of the blend increased because bio-ethanol is heavier than gasoline.

The blending of varying volumetric ratios of bio-ethanol generally increased the volatility of the base fuel (gasoline). This is apparent in view of the fact that 5% ethanol blend increased the Reid vapour pressure to 2.30 psi.

The vapour pressure of the blends decreases from E15 to E25. The vapour pressure of a liquid is very important because it affects the starting and warm up of spark ignition engines (Davis et al., 2002). At high altitudes and during high operational temperatures the cause of vapour lock in fuel pumps depends on the vapour pressure of the fuels. Therefore blending bio-ethanol with gasoline beyond E10 negatively affects the ease of starting the engine. Hence beyond E10 there must be engine modification for higher ranges of bio-ethanol-gasoline blend.

Figure 3.2 shows the variation of research octane number with percentage bio-ethanol in the blend. The octane number increases from 90 at E0 (100% gasoline) to 93 with E15. Octane number of a fuel indicates its ability to resist pre- ignition and burn evenly. The Octane number of pure bio-ethanol is

129. This shows that the addition of bio-ethanol to gasoline improves considerably, the Octane number of gasoline.

A fuel with a higher octane rating can be run at a higher compression ratio without causing detonation. Compression is directly related to power and to thermodynamic efficiency, so engines that require higher octane rating usually deliver more motive power and do more work for a given calorie of fuel. Engine power is a function of the fuel, as well as the engine design, and is related to octane rating of the fuel. Power is limited by the maximum amount of fuel-air mixture that can be forced into the combustion chamber. When the throttle is partially open, only a small fraction of the total available power is produced because the manifold is operating at pressures far below atmospheric.

Engine Performance using various Gasoline-Bio-ethanol Mixtures

The observations made using various ratios of gasoline-bio ethanol mixture were as follows. There was normal starting of the engine from E5 to E10 while delayed starting of the engine was noted as the bio-ethanol concentration increased from E15 to E20. However If the octane rating was improved further, there would have been uncontrolled ignition. Uncontrolled ignition in an internal combustion engine is very undesirable because it leads to reduced power, no matter the energy density of the fuel. Therefore for an increase in the octane number to produce an advantage, the engine has to be modified to advance the timing and also increase the compression ratio.

Figure 3.3 and 3.4 above shows the behaviour of the engine with different bio-ethanol-gasoline ratios as fuel. It was noted that the engine developed the fastest speed with a fuel composition of 100% gasoline and 0% ethanol (E0). The maximum engine power using the compound fuel was obtained with E10. E20 also gave some good results but the maximum was E10 after which the engine performance was no longer satisfactory. However E10 gave the best engine increasing power without vibrations. As seen on Figure 3.3 the curve for E10 is smooth tolerating a wide range of load variations. E10 has also been recommended by (Ceviz and Yüksel, 2005).

4.0 Conclusion

The main conclusions drawn from this research work are as follows:

1. Wood can also be used to produce transportation fuels, such as bio-ethanol.
2. Environmental pollution from wood chips can be reduced drastically by using it for the production of bio-ethanol.
3. Bio-ethanol's specific gravity is 0.79, which indicates it is heavier than gasoline
4. Bio-ethanol-gasoline blends with up to 10 percent ethanol will not have any significant negative effects on the wear and performance of the engine.
5. No significant difference was seen in regulated emissions when comparing the use of blended fuel (with up to 10% bio-ethanol) to the use of neat gasoline.
6. Anti-fuel properties of higher bio-ethanol blends such as E20 and above calls for serious engine modifications to avoid knock and unwanted emissions.

7. Bio-ethanol blended with gasoline makes it burn more completely, thus increasing combustion efficiency and reduces carbon monoxide emissions.
8. While the octane number is raised by blending in ethanol, energy content per volume is reduced.
9. Burning fuel with a lower octane rating than required by the engine often reduces power output and efficiency one way or another.
10. For the Nigerian Automobile Transportation System to be environmentally sustainable, it is expected to undergo reform and restructuring to allow for the use of bio fuels as energy carrier.

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