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# SYNTHESIS OF BIO- ETHANOL/GASOLINE BLENDS AND ITS EFFECT ON THE PERFORMANCE OF A SPARK IGNITION ENGINE

****Obi, A. I., **Amaghionyeodiwe, C. A., *Ogbeifun, S. and *Dauda, M**

**Department of Mechanical Engineering, Ahmadu Bello University, Zaria*
***Department of Mechanical Engineering, Michael Okpara University of Agriculture, Umudike*

## ABSTRACT
Bio-ethanol produced from pineapple and pawpaw peels through biochemical reaction called fermentation by *Aspergillus niger* and *Saccharomyces cerevisiac* was investigated for its suitability in running petrol engines. Gasoline blended with 10-50% of the extracted ethanol at intervals of 10% was compared with pure gasoline. Some physical and chemical properties of viscosity, calorific value, specific gravity, octane number and flash point of the bio-ethanol gasoline blends were determined. The performance characteristics and exhaust emission test were also conducted using Petter Paiw single cylinder spark ignition engine and IMR 1400 gas analyzer on the blended fuel samples. It was found that higher fuel consumption and reduced volumetric efficiency were observed with increase in the blended fuel compared with the reference fuel and a marginal increase in brake thermal efficiency and reduction in the exhaust gases of CO, $NO_x$, $SO_x$ and HC.

## 1.0 INTRODUCTION
The combustion of petroleum products causes environmental pollution and the emission of greenhouse gases generally believed to be responsible for global warming. The Internal Combustion (IC) Engine (a common automobile engine used in Nigeria and other developing countries) is an engine that converts chemical energy in a fuel into mechanical energy, usually made available on a rotating output shaft. ICEs generate undesirable emissions during the combustion process. The emissions discharged into the surroundings pollute the atmosphere and cause the following problems: global warming, acid rain, smog, odors, respiratory and other health hazards. The causes of these emissions are non-stoichiometric combustion, dissociation of nitrogen and impurities in the fuel and air, releasing dangerous gases like: unburnt hydrocarbons (HC), oxides of carbon ($CO_x$), oxides of nitrogen ($NO_x$) oxides of sulphur ($SO_x$) and solid carbon particulates into the atmosphere. The trend now therefore is to reduce over dependence on petroleum products in order to cut down the effects of global warming. Other possible advantages of phasing out petroleum products are the presence of sources available from renewable resources which do not require the use of heavy equipment for extraction, long distance transportation and distribution.

Ethanol blended with gasoline and diesel in various fractions is already in use in many countries. An E10 blend represents 10% bio-ethanol in 90% gasoline while an E20 blend represents 20% bio-ethanol in 80% gasoline. Research has shown that alcohol based fuel is of high quality, low cost and has exceptional engine performance (RFA, 2001). Ethanol blended fuels account for approximately 30% of all automotive fuels sold in the U.S. and ethanol acts as antifreeze in the engine during winter (RFA, 2001). This high quality and high-octane fuel is capable of reducing air pollution and improving automobile performance (Wei-Dong et al., 2002; Al-Hasan, 2003). Road transportation is the dominant means of moving goods and services in developing countries like Nigeria and the demand for road transportation fuel will continue to rise due to increasing population, urbanization, industrialization and socialization, the result being increased environmental problems/ pollution. In 1980, Nigeria emitted 18.9 million metric tons of carbon and since then, carbon emission has been on the increase with 23.5 million metric tons and 27.7 million metric tons emitted in 2001 and 1996 respectively (DPR Nigeria, 2005), hence the necessity to source friendly alternatives. Part of the objectives of this research work includes the extraction of bio-ethanol from pineapple and pawpaw peels, production of E10, E20, E30, E40 and E50 bio-ethanol blends, determination of some Physical and Chemical properties of the produced blends, performance evaluation of the bio-ethanol blends produced on a Spark Ignition (SI) engine and exhaust emission analysis of E10, E20, E30, E40 and E50 blends driven SI engine.

## 2.0 MATERIALS AND METHOD

### 2.1 Procedure for Extraction of Bio-ethanol from Pineapple and Pawpaw Peels

Ripe pineapple and pawpaw obtained from the local Samaru market, were purchased and the peels were collected and taken to the Microbiology Laboratory of Ahmadu Bello University Zaria, where the peels were washed and their outer coat removed, cut into smaller pieces using a knife and then blended with sterile distilled water using electric blender, and stored in a refrigerator prior to use.

#### 2.1.1 Microorganism Culturing

Pure culture strain of *Aspergilus niger* and *Saccharomyces cerevisiae* were isolated and used throughout this study. These organisms were maintained as direct stocks culture from which inoculates were prepared. Fungal spieces of A. niger and S.cerevesiae were originally isolated from soil samples and palm wine respectively, the slant cultures were sub-cultured and grown on potatoes dextrose agar (PDA) in petri dished according to manufacturer's specification, and sterilized at 121$^0$C for 15mins, Samples were then incubated at room temperature for 5 days.

#### 2.1.2 Preparation of Growth Medium

The growth medium used for preparing the *Aspergillus niger* inoculum (obtained from garden soil) consisted of 150g of the blended pineapple and pawpaw peels (substrate), peptone, 0.1%; malt extract, 0.1% (w/v), yeast extract, 0.2% (w/v), calcium carbonate 0.2% (w/v), and ferrous sulphate respectively. *Saccharomyces cerevisiae* (obtained from ripped pineapple peels) growth medium was prepared using yeast-malt broth at pH 5.5 (Abouzeid and Reddy 2006).

#### 2.1.3 Preparation of Inocula and Fermentation Procedure

*Aspergillus niger* inoculum was prepared in 250cm$^3$ cotton- plugged conical flask containing 100cm$^3$ of different substrates growth media. The flasks were sterilized and inoculated with 0.11 (OD) *Aspergillus niger* spores. Each of the flasks was incubated on an environment- controlled incubator shaker (Model 3527-1/34) shaker with agitation rate of 300rpm at 30$^0$ C for five days. *Saccaharomyces Cerevisiae* inoculum was prepared in the same way as the *Aspergillus niger* inoculum except that yeast malt broth was used. The growth medium was inoculated with 0.08 (OD) yeast cells and incubated for 24hours. The fermentation medium used for ethanol production was identical to the growth medium. Ethanol fermentation was carried out in 1000cm$^3$ conical flasks each containing 300cm$^3$ of medium. The medium was sterilized and inoculated with 5% (v/v) growth media containing *Aspergillus niger* and *Saccaharomyces Cerevisiae* and incubated on a shaker with an agitation rate of 300rpm at 30$^0$C for seven days.

### 2.2 Bio-ethanol Blends Preparation

Bio-ethanol generally has some lower physical and chemical properties compared to gasoline. Hence, for smooth and efficient performance of engines, the bio-ethanol produced was blended with gasoline in different ratios. The bio-ethanol blends were prepared using direct blending method and the blends produced include: E10, E20, E30, E40 and E50 which represent 10% bio-ethanol in 90% gasoline, 20% bio-ethanol in 80% gasoline, 30% bio-ethanol in 70% gasoline, 40% bio-ethanol in 60% gasoline and 50% bio- ethanol in 50% gasoline respectively. This was done by mixing 10ml, 20ml, 30ml, 40ml and 50ml of the bio-ethanol produced with 90ml, 80ml, 70ml, 60ml and 50ml of gasoline respectively in a transparent bottle.

### 2.3 Determination of the Physical and Chemical Properties of the Blended Fuel

The properties of the bio-ethanol blends tested include: Calorific value, Viscosity, Specific Gravity, Octane number, Flash point and Density.

### 2.3.1 The Calorific Value

The calorific values of the bio-ethanol and gasoline blends were measured using a bomb calorimeter. A known amount of fuel was placed in the crucible. The crucible was then placed over a ring and a fine magnesium wire touching the fuel sample was stretched across the electrodes. The lid was tightly screwed and the bomb was filled with oxygen up to 25 atmosphere pressure. The initial temperature was recorded. The electrode was then connected to a 6 V battery and the circuit was completed. As soon as the circuit was completed and current was switched on, the fuel in the crucible burnt with the evolution of heat. Heat liberated by burning of the fuel increases the temperature of water and the maximum temperature attained was recorded.

### 2.3.2 The Viscosity

The viscosity of the samples was determined using a glass capillary kinematic viscometer at 40 $^{0}$C (Sivaramakrishnan and Ravikumar 2011). The viscometer was tightly clamped on a retort stand. 100g of each sample was collected into a Pyrex beaker and was gradually heated to a temperature above 40$^{0}$C. The sample was then transferred into the viscometer through the larger opening of the capillary tube and the fluid was allowed to cool until a temperature of 40$^{0}$C was reached. Thereafter, suction was applied to the other end of the capillary tube to draw the fluid to the mark on the upper meniscus level of the capillary tube.

The fluid was allowed to run freely to the lower meniscus mark in the capillary tube.

The efflux time for the fluid to flow from the upper meniscus mark to the lower meniscus mark was determined with the aid of a stopwatch. The test was triplicated for each sample and the kinematic viscosity was calculated using equation (2.1).

$$\text{Kinematic Viscosity} = kt \quad (2.1)$$

Where k = Constant of the viscometer expressed in $mm^2/s^2$

t = Flow time in seconds of the liquid.

### 2.3.3 Test for Specific Gravity

The specific gravity of the samples was measured at room temperature using a Fisher brand hydrometer (size 0.795-0.910, accuracy 0.001). The measurement was performed according to the method adopted by (Coronado et al., 2009).

### 2.3.4 Test for Octane number

The octane number of the blended fuels was determined to ensure that the produced bio-ethanol and gasoline blends have octane numbers complying with octane numbers of motor fuel, as calculated by research method (ASTM D2699) and motor method (ASTM D2700) standards. This was achieved using OCTANE-IM portable octane meter used in refineries to control quality of fuel components and their blends, fuel checking during transportation, storage and consumption.

### 2.3.5 Test for Flash Point

Flash points of the samples were determined using the setup apparatus comprising an electric heater, beaker and thermometer. 80ml of each sample was introduced into a transparent Pyrex beaker placed on an electric heater. The beaker was fitted with the thermometer, clamped on a retort stand. Heat was applied gradually by turning the knob of the electric heater until the observed movement of the particles increased. A flame was constantly brought near the surface of the beaker until “a catch and disappearing” of flame on the surface of the hot liquid occurred. The temperature was noted as the flash point.

### 2.3.6 Density

The densities of the blends produced were determined at ambient temperature (28$^{0}$C). A density bottle of mass 50ml was weighed on the analytical balance and the initial weight of the bottle was noted. The samples were then put in the density bottle, the spillage was cleaned and dried, and the bottle was weighed on the analytical balance. The process was repeated twice and the average value was determined as the result. Density of each sample was then computed using equation (2.2) below.

$$D = \frac{W_2 - W_1}{V} \quad (2.2)$$

Where D = Density in g/cm³
W₂ = Weight of bottle and sample (g)
W₁ = Weight of bottle only (g)
V = Volume of the Liquid (cm³)

### 2.4 Experimental Setup of Peter Paiw Spark Ignition Engine for Performance Evaluation of the Produced Fuel Blends

The engine performance and exhaust emissions tests were carried out on a Peters PAIW carburetted single cylinder four-stroke research SI engine. This was done by connecting a four stroke single cylinder petrol engine to the electric dynamometer with the help of coupling. Tachometer for speed reading rpm, U tube manometer, air filter, fuel measuring tube and gas analyzer were arranged as shown in Figure 2.1.

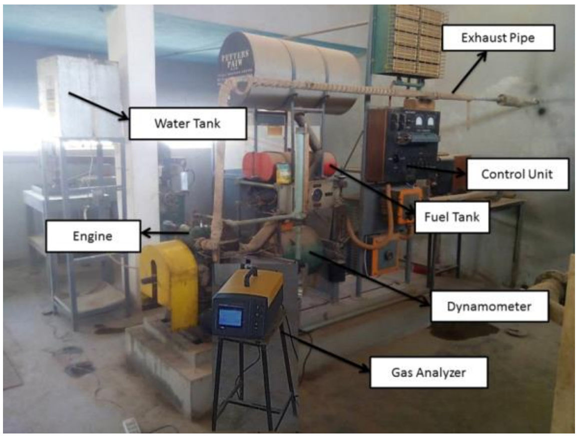


*Figure 2.1: Experimental setup of Petters Engine*

#### 2.4.1 Determination of Engine Torque and Brake Power

Torque is the engine's ability to do work. The torque applied by the engine on the dynamometer, T was determined using equation (2.3).

$$T = W \times R \quad (2.3)$$

where,
W= Load
R= Torque arm length

Brake power is the useful power at the output shaft. For different engine loads. brake power increases with the increase of engine speed due to increase of engine friction. The brake power $P_B$, delivered by the engine and absorbed by the dynamometer was determined using equation (2.4).

$$BP = \frac{WN}{5000} \quad (2.4)$$

where,
W = Load reading
N = Speed

#### 2.4.2 Determination of Brake Mean Effective Pressure

Mean effective pressure ($P_m$) is that hypothetical constant pressure which is assumed to be acting on the piston during its expansion stroke producing the same work output as that from the actual cycle. The brake mean effective pressure (BMEP) of an engine is the average (mean) pressure which, if imposed on the pistons uniformly from the top to the bottom of each power stroke, would produce the measure (brake) power output. BMEP is calculated from equation (2.5).

$$BMEP = \frac{BP}{LANK} \quad (2.5)$$

where,
Bp = Brake Power
L = *Length of Stroke*
*A = Area of the piston ($m^2$)*
*N = Speed in R.P.M and*
*K = Number of Cylinders*

#### 2.4.3 Determination of Volumetric Efficiency

Volumetric efficiency (VE) of an engine is the actual amount of air the engine ingests compared to the theoretical maximum. VE of the SI engine was determined from equations (2.6) – (2.10).

$$(V_E) = \frac{V_a + V_f}{V_s} \quad (2.6)$$

where:

$$V_a = \text{Volume of air} = \frac{M_a R T_a}{P} \quad (2.7)$$

$M_a$= Mass of air

$$M_a = 0.866 \sqrt{\frac{Ph}{T_a}} \quad (2.8)$$

h = Manometer reading = H Sin $\theta$
$\theta = 15^0$
R = Gas Constant = 287

$$V_f = \frac{\text{Volume of sample}}{\text{Rate of consumption}} \quad (2.9)$$

$$V_S = V_C N_n \quad (2.10)$$

$V_C$ = Cylinder Swept Volume
$N_n$ = Number of cylinders

### 2.5 NHA- 506EN Automotive Emission Analyzer

This equipment was used to investigate emission products directly from the combustion chamber. The NHA- 506EN gas analyzer is a combustion gas analyzer designed to work under strict adherence to the operating manual and within stipulated temperature and was used for this work. It measures and calculates the Flue Gas Temperature, Excess Air, Carbon dioxide ($CO_2$), Carbon monoxide (CO) (Corrected to 0% $O_2$), Nitrous oxide ($NO_x$) (Corrected to 0% $O_2$), Combustion efficiency and Heat loss.

## 3.0 RESULTS AND DISCUSSION

### 3.1 Result of Physical and Chemical Properties test of the Produced Fuel Blends

Results of the calorific value, viscosity, specific gravity, Octane number, Flash point and density of the bio-ethanol blends and the unblended gasoline sample (designated E0) obtained are tabulated in Table 3.1 below

From Table 3.1, the calorific values of the blends decrease with an increase of bioethanol in the blends except for E0 and E10 which have the same calorific value; this is because, with 10% of bio-ethanol in the blend, the quantity of bio-ethanol in the blend is not enough to alter the calorific value of the blend. From the result of the viscosity, the unblended gasoline gave a viscosity of 0.61mm$^2$/ s at 40$^0$C. There was increase in viscosity with corresponding increase in bioethanol percentage in the blends. Hence, E10 has a viscosity of 0.65mm$^2$/s, E20 has 0.68mm$^2$/s, E30 has 0.69mm$^2$/s, E40 has 0.70mm$^2$/s and E50 has 0.72mm$^2$/s. The specific gravity of the blends increased from 0.7840 for E0 to 0.7952 with E50. This result affirms that bioethanol is heavier than gasoline. This explains why when a mixture of bio-ethanol gasoline is allowed to settle and viewed inside a transparent container; ethanol is seen to settle at the middle sandwiching gasoline on top and water at the bottom.

**Table 3.1 Calorific value, viscosity, specific gravity, octane number, flash point and density of blends of gasoline and bioethanol produced from pineapple and pawpaw peels.**

| Blends | Calorific Value KJ/Kg | Viscosity@ 40 (mm$^2$/ s) | Specific gravity (Kg/L) | Octane number | Flash Point ($^o$C) | Density (Kg/m$^3$) |
|---|---|---|---|---|---|---|
| E0 | 42932 | 0.61 | 0.7840 | 90 | 28.7 | 784.0 |
| E10 | 42932 | 0.65 | 0.7852 | 92 | 29.1 | 785.2 |
| E20 | 41510 | 0.68 | 0.7896 | 93 | 29.2 | 789.6 |
| E30 | 40341 | 0.69 | 0.7907 | 94 | 29.4 | 790.7 |
| E40 | 39450 | 0.70 | 0.7924 | 96 | 29.6 | 792.4 |
| E50 | 37872 | 0.72 | 0.7952 | 97 | 29.8 | 795.2 |

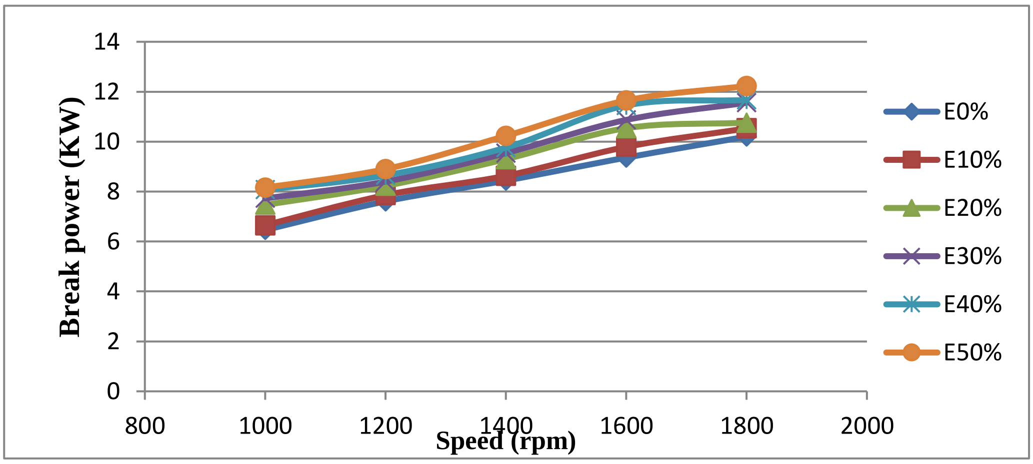


*Figure 3.1: Graph of Break Power against Speed*

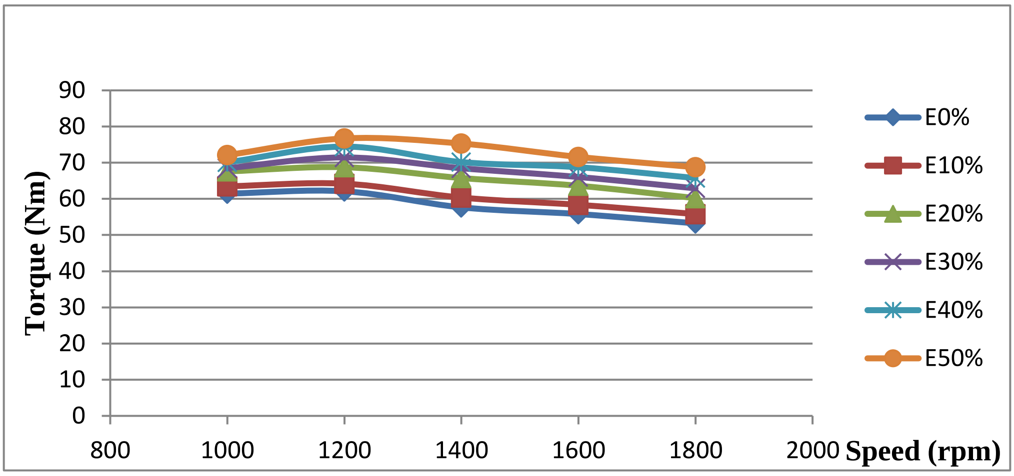


*Figure 3.2: Graph of Torque against Speed*

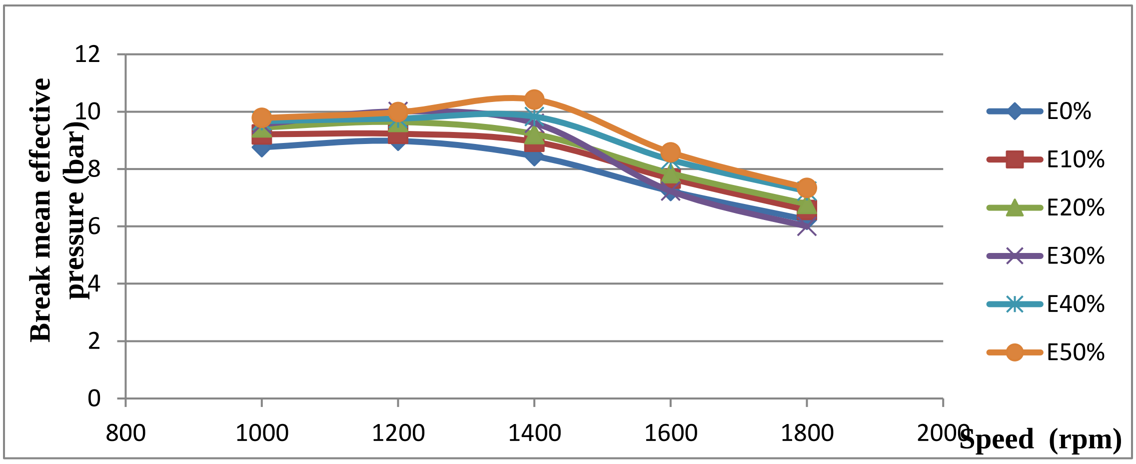


*Figure 3.3: Graph of Brake Mean Effective Pressure against Speed*

The immiscibility of the blends with higher bio-ethanol fractions seems to be responsible for the unsteady engine production noticed during the tests. The octane number increases from 90 for E0 (100% gasoline) to 97 for E50. Octane number of a fuel indicates its ability to resist pre-ignition and burn evenly. The flash point increases from 28.7 for E0 to 29.8 for E50. The flash point indicates the temperature at which the fuel can vaporize to produce an ignitable mixture with air.

The flash point gives some indication on the flammability of the liquid showing that with the addition of ethanol fractions to gasoline the burning characteristics of the mixture reduce. It is important to note that the higher the flash point of a fuel the more difficult it is to start the engine. For example, the flash point of E50 ($29.8^0$C) means it will be difficult to start an engine. Hence, as much as we desire to reduce the harmful emissions associated with combustion of gasoline, other factors such as flash point, octane number, etc should be considered in choosing the optimal blending ratio for the most efficient and safe engine operation.

### 3.2 Result of Performance Test of the Produced Blends on SI Engine

The brake power, torque, brake mean effective pressure and volumetric efficiency of the various blends were plotted against engine speed and the results presented in Figures 3.1 to 3.4 below.

Figure 3.1 shows that brake power increases with increase in engine speed. This is due to increase of engine friction. At the highest speed of 1800rpm, E50 fuel blend developed the highest power followed by E40, E30, E20 and E10 respectively while, gasoline

(E0) developed the lowest brake work as shown in (Fig 3.1). Due to bio-ethanol addition to gasoline, the engine operation enabled leaning effects and improves engine combustion and more power is produced thereby, increasing engine performance as explained by (Al- Hasan, 2003).

Figure 3.2 shows decrease of torque as speed increases. The maximum decreasing percentage in torque occurs for gasoline. This is the result of addition of alternative fuel which caused the octane number to rise. This effect is particularly important as it improves the anti-knock quality of the engine (Kumbhar and Patil, 2013).

From Figure 3.3, the BMEP of the various blends are seen to increase with a corresponding increase in engine speed until the engine speed gets to 1400rpm where the BMEP starts decreasing. BMEP is 10.01% at 1200rpm for E30 while, minimum value of the BMEP is about 7.34% for E50 as against 6.25% compared to gasoline. At, low engine speeds the higher heating value of gasoline is responsible for high BMEP. This is in agreement with the result obtained by (Nyachaka, 2013).

Finally, Figure 3.4 shows that the value of volumetric efficiency increases with increase in the bio-ethanol content of the blends due to the lower heating value of the ethanol. This reduces the charge temperature of the intake manifold as confirmed by (Al-Hassan, 2003). However, the volumetric efficiency starts to decrease when bio-ethanol content is more than 30%.

### 3.3 Results of Exhaust Emission of SI Engine for the Various Fuel Blends

The exhaust emission for each of the blends when tested on a SI engine (running at 1200rpm) were determined and the result shown in figures 3.5 and 3.6

From figure 3.5, pure gasoline (E0) emits less $CO_2$ compared to the blended fuel samples. Hence, the amount of $CO_2$ emitted increases as the concentration of ethanol in the samples increases. This is because of the additional oxygen content of ethanol. Also as combustion becomes more efficient, CO gets converted into $CO_2$ (Kumbhar and Patil, 2013). Consequently, CO emission continuously decreased with increase in the ethanol concentration of the blends (Mugal *et al.*, 2012).

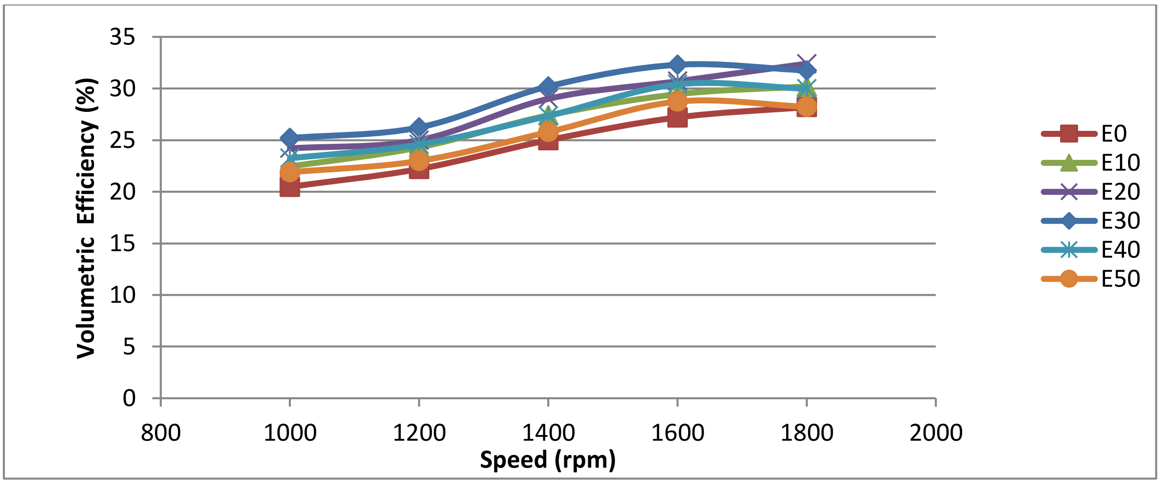


*Figure 3.4: Graph of Volumetric efficiency against Speed*

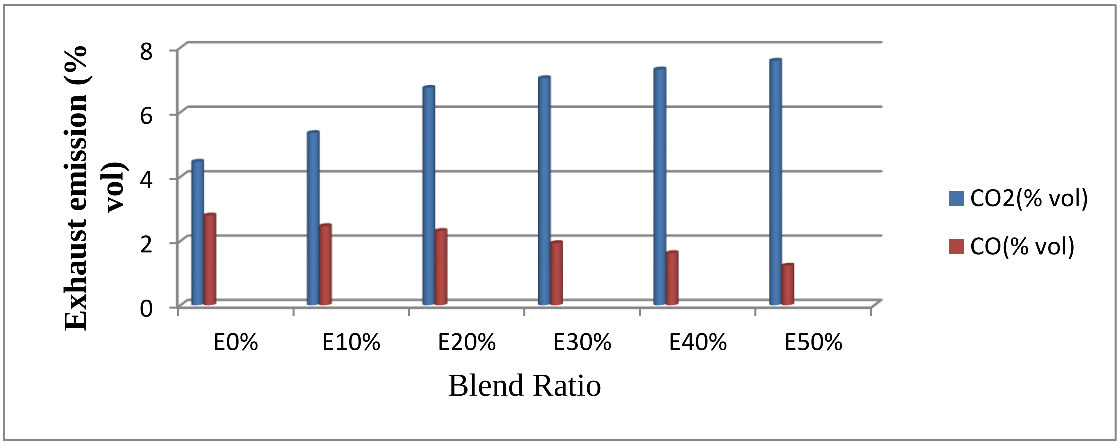


*Figure 3.5: Bar Chart of Exhaust emission against Bio-ethanol blends*

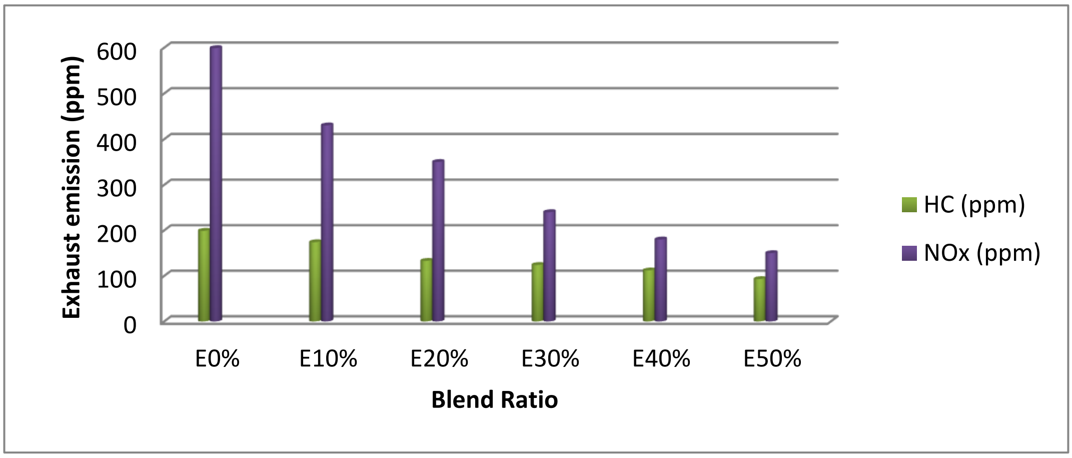


*Figure 3.6: Bar Chart of Exhaust emission against Bio-ethanol blends*

The effect of bio-ethanol percentage in the HC emission is shown in (fig 3.6). In all the blends there is decrease in the HC emissions when compared to sole gasoline as a result of hydrocarbon oxidation. This is in agreement with (Laminu *et al.*, 2014), that reduction of the carbon atoms concentration in the blended fuel, high molecular diffusivity and high flammability limits improve mixing process and hence there is better combustion. Generally, NOx formation is increased when an engine runs at its most efficient/hottest part of the cycle. However, it can be seen from figure 3.6 that addition of ethanol to gasoline decreases NOx emission. This is due to lower heating value of the blends compared to pure gasoline. This confirms the investigation made by (Ananda and Saranana, 2010), that lower heating value decreases the combustion heat energy and lowers the combustion temperature in the cylinder. Hence, E50 blend releases the least amount of $NO_x$ (150ppm).

## 4.0 CONCLUSION AND RECOMMENDATIONS

### 4.1 Conclusion

Pineapple and Pawpaw peels were obtained washed and their outer coats removed and cut in small pieces using a knife. Ethanol was extracted from the peels through a biochemical reaction called fermentation. The bio-ethanol produced was blended with gasoline in different ratios to produce E10, E20, E30, E40 and E50 blends which represent 10% bio-ethanol in 90% gasoline, 20% bio-ethanol in 80% gasoline, 30% bio-ethanol in 70% gasoline, 40% bio-ethanol in

60% gasoline and 50% bio- ethanol in 50% gasoline respectively.

Some physical and chemical properties of the blends were determined and compared with those of pure gasoline. The samples were further subjected to engine test to determine their performance on a four stroke, single cylinder Peter Paiw SI engine. Also $CO_2$, CO, HC and $NO_X$ exhaust emissions for each of the blends when tested on the SI engine (running at 1200rpm) were determined and compared with emissions from the engine when run with pure gasoline. The findings of this study show that pineapple peels and pawpaw peels are potential substrates which can be exploited in industries for bio- ethanol production on a commercial scale as they are cheap and more importantly renewable.

## 4.2 Recommendations

Based on the study the following recommendations are made:

- Proper waste management committee should be set up which will religiously collect pineapple and pawpaw peels from consumers, sellers, farmers and fruit juice producers to store the spoilage and post-harvest losses and peelings for bioethanol production.
- Further research is recommended to vary the different bioethanol substrates from pineapple and pawpaw separately on different engine parameters.

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