Bio-Ethanol Production from Rice Husk and Performance Test of Petrol and Bioethanol Blends in a Spark Ignition Engine

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ABSTRACT

In this era of globalization, the increasing demand for energy and the dependence of countries on energy indicate that energy will continue to be relevant in the world. There is therefore, a need to search for alternative and renewable sources of energy. The focus of this research is on rice husk which constitute an environmental waste but has been used in the production of ethanol by simultaneous saccharification and fermentation by co-culture of *Aspergillis niger* and *sacharomyces cerevisiae*. Optimal ethanol yield was obtained on day 7, at 31°C temperature and agitation rate 300 rpm and the performance evaluation from engine test indicate that highest brake power, torque and brake mean effective pressure recorded for E40% blend at 1500 rpm engine speed. Carbon monoxide (CO), Nitrous oxide (NOx) emission decrease as the ethanol blend increases.

Keyword: Bioethanol, Biofuel, Ethanol, Brake power, Brake mean effective pressure, Torque, Specific fuel efficiency, and Specific fuel consumption

1. INTRODUCTION

Energy has been recognized as one of the most important strategic commodities considered to be the lifeline of an economy. Energy is an important factor of production in all economies. The efficient exploitation and development of a nation's energy resources is therefore, of great importance to the progress and well-being of the people.

In this era of globalization, the increasing demand for energy and the dependence of countries

On energy indicate that energy will be one of the biggest problems in the world. There is therefore, a need for alternative and renewable sources of energy.

Energy from different sources would continue to play a determining role especially the non-conventional ones are likely to make significant contribution to the overall national economy.

Currently, 85% of the world's energy demand is met by combustion of fossil fuels which are depletable. The global energy demand is expected to grow by about 50% by 2025, the major part of this increase coming from rapidly emerging countries. Given the growing world population, increasing energy demand per capital and global warming, the need for a long term alternative energy supply is clear. Biofuels offer the advantage of coming from large, mainly under-utilised biomass resources that are sustainable and renewable.

Biofuels apply to solid, liquid or gaseous fuel produced from biological materials (biomass) can be used for the generation of power, heat or fuel for motive power. (Ugochukwu, 2010; Agba et al., 2010). The biomass constitutes the feedstock destined for conversion into biofuels. The use of biomass as a source of energy has two main advantages: First is its nearly unlimited availability and second is the fact that it can be used without essential damage to the environment. In addition, biomass resources are considered renewable as they are naturally occurring and by comparison with other renewable energy resources such as solar and wind, biomass is a storable resource, inexpensive and has favourable energetic efficiency. Biomass resources available in the country include:

Agricultural crops, agricultural crop residues, fuel wood and forestry residues, waste paper, sawdust and wood shavings, residues from food industries, energy crops, animal dung/poultry droppings, industrial effluent/municipal solid waste. (Ugochukwu, 2010 ; Sambo, 2009; Ajueyitsi, 2009; Tayo, 2008).

1.1 Rice hulls (or **rice husks**) are the hard protecting coverings of grains of rice. In addition to protecting rice during the growing season, rice hulls can be put to use as building material, fertilizer, insulation material, chicken incubation and for production for biofuels. (http://esrla.com)

1.2 Production of rice husks

During the milling process, the hulls are removed from the grain to create brown rice, which is then milled further to remove the bran layer, creating white rice.

Rice husk, which accounts for 20% by weight of rice, comes from rice milling process as by-product. Generally, a large amount of rice husk is dumped as waste which results in waste disposal problem and methane emissions. Moreover, the low density of rice husk can cause it to be air-borne easily resulting in breathing problems, if inhaled. Rice husk can be converted to a useful form of energy to meet the thermal and mechanical energy requirement for the mills themselves. This will helps in minimizing the waste disposal problem in addition to converting rice husk to a renewable energy resource.

According to Agricultural Production Survey (APS) conducted annually in the 36 states of the federation and the Federal Capital Terrotory (FCT) by the State ADPs who implement various donor-assisted agricultural development projects show that the overall land area to rice production in Nigeria was estimated at over 1.98 million hactres in 2009. Production figure for rice was over 4.3 million metric tonnes. The national yield average of rice was estimated at 2.18 metric tonne/ hactre. Table 1 show the cultivated area, production, and yield by smallholder farmer.

Table 1: Showing Cultivated area, Production, and Yield by Smallholder Farmers in Nigeria

S/no	Year	Cultivated Area ('000 HA)	Production ('000 Metric Tonnes)	Yield (KG/HA)
1	2004	57.30	110.4	1,926
2	2005	70.96	134.7	1,898
3	2006	67.99	121.9	1,793
4	2007	68.42	122.5	1,882

Source: Agricultural Production Survey (APS, 2010)

Composition of Rice husk waste

The composition of rice husk sample is presented in Table 2 below

Table 2: Showing the Composition of rice husk sample.

Parameters	Result	Basis
C	42.2%	Dry
H	5%	Dry
O	36%	Dry
N	0.7%	Dry
S	*	Dry
Moisture content	11%	Dry
Heating Value	13.79 MJ/kg	Dry

Source: Thipwimon and Suthum (2009).

1.3 Bio-ethanol Fuel

Bio-fuels are attracting growing interest around the world, with some governments announcing commitment to bio-fuel programmes as a way to both reduce greenhouse gas emissions and dependence on petroleum-based fossil fuels. The United State of America, Brazil, and several European Union (EU) member states have the largest programms promoting bio-fuel in the world.

2.0 Engine Operating Parameters

1. Brake Power (Pb) : It is the actual work output of an engine or the actual work available at the crank shaft. It is usually measured using a dynamometer

$$\textbf{Brake Power (Bp)} = \frac{WN}{5000} \qquad (1)$$

Where,

W = Load reading (lb)

N = Speed (rpm)

2. The **Torque** is obtained by the product of the load applied and the dynamometer arm length

$$\textbf{Torque on Dynamometer (T)} = WR \qquad (2)$$

Where,

W = Load (lb)

R = Torque arm length (m)

3. Brake Mean Effective Pressure (bmep): is a measure of the power produced per cycle as a function of engine size:

$$\textbf{Brake Mean Effective Pressure} = \frac{BP}{LANn} \qquad (3)$$

Where,

Bp = Brake load (lb)

L = Stroke (m)

$A = \frac{\pi D^2}{4}$

N = Speed (rps)

n = Number of cylinder

4. Volumetric Efficiency (η_v): Is the mass of air equal to the density of atmospheric air times the displacement volume of the cylinder

Volumetric Efficiency (η_v) = $\frac{V_a + V_f}{V_S}$ (4)

Where,

V_a = Volume of air = $\frac{m_a R T_a}{P}$ (5)

$\dot{m}_a = 0.866 \sqrt{\frac{Ph}{T_a}}$ (6)

$\dot{m}_a$ = mass of air (kg/s)

h = Manometer reading in (in) = H sinθ

R = Gas Constant = 287 J/KG.K

Note Before: Barometric Readings.

i. Atmospheric pressure (in Hg)

ii. Ambient Temperature (K)

$V_f = \frac{\text{Volume of Sample}}{\text{Rate of consumption}}$

$V_s = V_s N n$

V_s = Swept volume (m^3/s)

3.0 MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Rice Husk

Rice husk was obtained from local rice mill in Samaru market Zaria.

3.2 METHODOLOGY

Pre-treatment of Lignocellulosic Source

Rice husk substrates were washed with distilled water dried for three days at 60° in hot air Memmert oven so as to reduce the moisture content and make them more susceptible to milling. The substrates were milled with motor and pistil, sieved to pass through a 2.2 mm mesh sieve. 1500g was weighed; the samples were then soaked in 1% (w/v) sodium hydroxide solution (NAOH) for 2hours at room temperature. This treatment of lignocellulosic materials caused swelling; leading to an increase in internal surface area, decrease in the degree of polymerisation, decrease in crystallinity, and separation of structural linkages between lignin, carbohydrates and disruption of the lignin structure (Fan *et al*., 1987).

Samples Collection of producer microorganisms:

Pure culture strains of *Aspergilus niger* and *Saccharomycs cerevesiae* isolates were used for this study. The organisms were maintained as direct stocks culture from which inoculates were prepared. Fungal species of *A. niger* and *S. cerevesiae* were originally isolated from soil samples and palm wine respectively, The microscopic feature of pure grown colonies were observed and identified according to methods of Bailey et al (2004).

Inoculum Preparation

The organisms were grown on malt extract agar slant at 30°C for 5 days and stored at 4°C with regular sub-culturing. 150 ml of inoculums was prepared for each culture using 5g glucose, 10g peptone, 5g yeast extract in 1000 ml distilled water. The inoculum was shaken continuously on an environment-controlled incubator shaker (Model 3527-1/34) at 200 rpm and 34°C for 48 hours before it was used for the fermentation process as outlined by Bailey et al (2004).

Preparation of Fermentation Medium

The fermentation medium used for ethanol production consisted of glucose 8% (w/v), peptone 0.1% (w/v), Malt extract 0.1% (w/v), Yeast extract 0.2% (w/v), Magnesium chloride 0.01% (w/v), Calcium carbonate 0.2% (w/v), Ammonium sulphate 0.2% (w/v),and Ferrous sulphate,0.001% (w/v) respectively. 2000 ml medium culture was prepared and 300 ml dispensed into 7 no 500 ml Erlenmeyer flask. The flask were sterilised in an autoclave (Model Astell ASB 300) at 121^{0}C for 15 minutes at 15 psi pressure and inoculated with 15 ml and 4 ml containing growth innocula of *S. cerevesiae* and *A. niger* cells and 2 million spores respectively according to the method of Abouxied, and Reddy (1986). The flasks were incubated on an orbital shaker (Model Vineland NJ SH2-526) with an initial agitation rate of 300 rpm at 30^{0}C for seven days, each sample withdrawn at 24 hours interval for distillation.

Qualitative Analysis of Ethanol Present in the Distillate

Distillation process was carried out and filtered. The filtrate were distilled at 79^{0}C using a rotary evaporator. The qualitative analysis was carried out using ethanoic acid. Two milliliters ethanoic acid was added to 1ml of the distillate and heated in the water bath for 5 minutes until characteristic sweet smell of esters was perceived and recommended by Abouxied (1986).

Determination of Density and Specific gravity

A Digital Electronic Balance, Model FA2004 was used for this. The densities and specific gravities of the solutions were determined using standard procedure as in Amadi et al (2004) and the results recorded. The ethanol concentration was plotted against the number of days.

Determination of Refractive Index

The refractive index of standard ethanol concentration was determined using Abbe Refractometer (Model 2WAJ) at 28^{o} C. The refractive index of same volume of distilled water was also determined. The refractive index values recorded for each of the samples as suggested by Amadi *et al* (2004).

3.2.1 Engine Test Experiment

A petters spark ignition four stroke single cylinder petrol engine was connected to an electric dynamo-meter with the help of a coupling and mounted on a rigid frame. A Tachometer was used for engine measurement. A U tube manometer, air filter, fuel measuring tube, and a gas analyser were arranged.

Experimental Fuels

The following fuels where used in the experiment:

- ► Petrol
- ► Ethanol from rice husk

Table 3

Baseline Engine conditions:

Parameters	Description
Bore	8.50 cm
Stroke	8.25 cm
Compression Ratio	6:1
Swept Volume	468.67 cm
Maximum BHP	1650 rev/min
Maximum Speed	2000 rev/min
Brake Arm	32.0167 cm
Manometer angle	15^{o}
Orifice Size	1.905 cm
Coefficient of Discharge (C_d)	0.60 cm

Test Procedure on Petters heat engine

Before starting, water circulation to the engine was ensured. The Transformer was switched on so as to supply current to the electrical D.C motor which runs the Petter Paiws test engine as it is a motor start engine. The loads were released, the field and start switches were switched on. On operating the starting lever, the motor runs the test engine until it fires, thereafter the test engine powers the D.C motor which operates the D.C electrical dynamometer from which relevant data were recorded.

Readings were taken on the rate of fuel consumption, speed, load coolant and exhaust temperatures of every fuel sample.

The experiment commenced with 100% gasoline as a reference and later with the gasoline – ethanol fuel blends (E10, E20, E30, E40, and E50). The results were recorded.

IMR 1400 gas analyzer

This is equipment for analysing emission products directly from the combustion chamber. The IMR 1400 is a state-of- the- art combustion gas analyser that was used for the experiment.

4.0 RESULTS AND DISCUSSIONS

IMR 1400 model measures and calculates the following:

-Flue Gas Temperature

- Carbon dioxide (CO_2)

-Carbon monoxide (CO) (Corrected to 0%O_2)

-Nitrogen dioxide (NO_x, Corrected to 0%O_2)

-Sulfur dioxide (SO_x, Corrected to 0%O_2)

Procedure

After all preliminary inspection for starting the Heat engine was observed, PETTER Engine started and allowed to idle and set to 1200 revolution per minute. The duct was then connected through the gas sampling probe to the analyzer, The gas sampling probe was initially at ambient air during the zero calibration and the unit turned on to start the zero calibration which took 180 seconds before measurement started. Fuel type, engineering unit (PPM) was selected on the display screen through the selection menu. Exhaust duct valve turned open and readings were recorded for each set of experiment at point source and at 3meters measured distance.

Interval of one minute was observed before next reading was taken, and after each run the dust filter and the sensor removed and cleaned free of soot and readings recorded in table.

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4.1 RESULTS OF ETHANOL PRODUCTION

The results of the test conducted were recorded and plotted in figures (1), Glucose Concentration Vs Number of days (2), Ethanol yields Vs Number of days (3), Ph value Vs Number of days and (4), Refractive index Vs Number of days

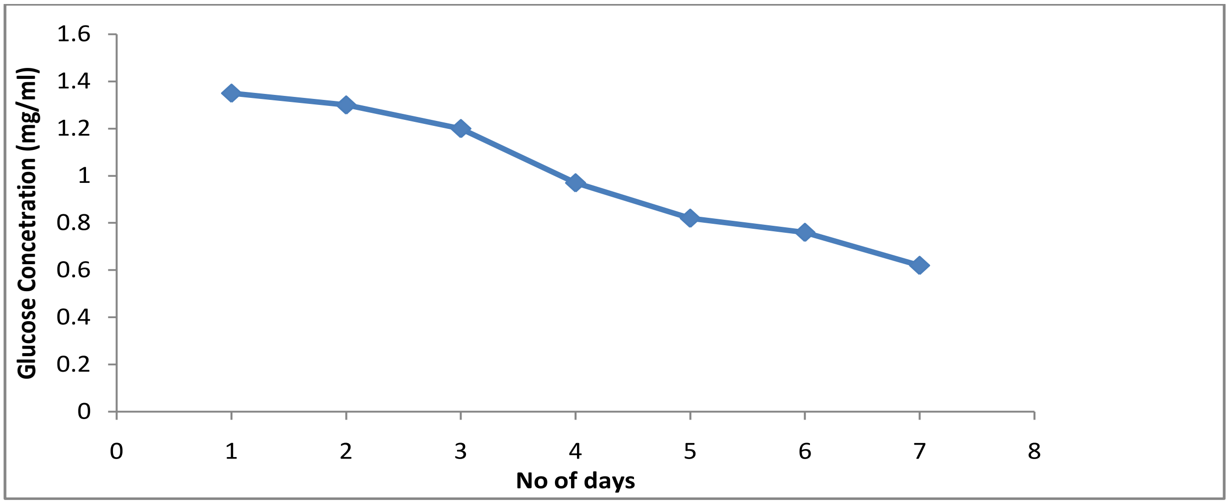

Fig 1: Glucose Concentration Vs Number of days

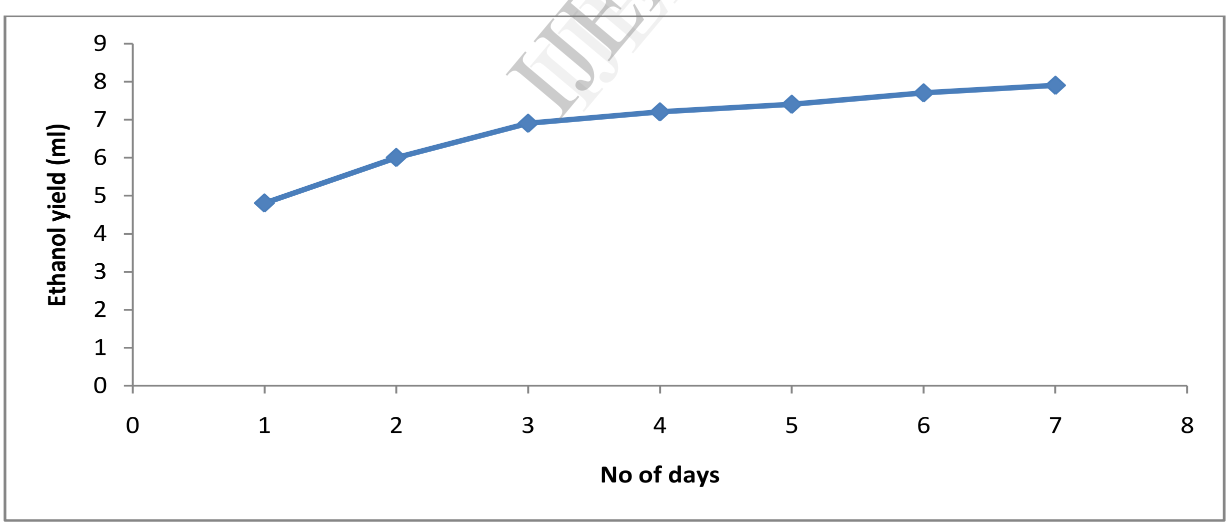

Fig 2: Ethanol yields Vs Number of days

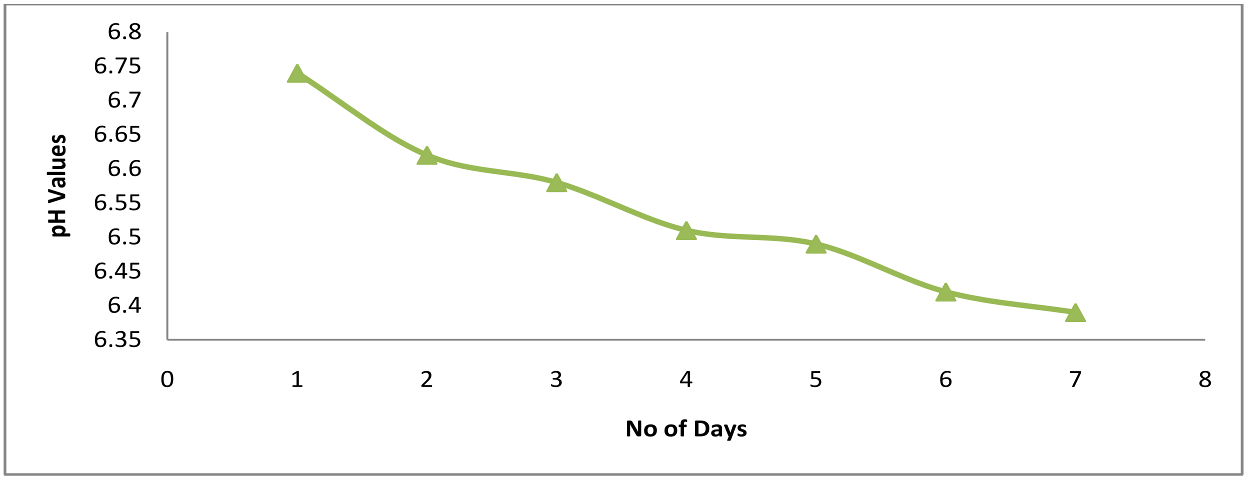

Fig 3: PH value Vs Number of days

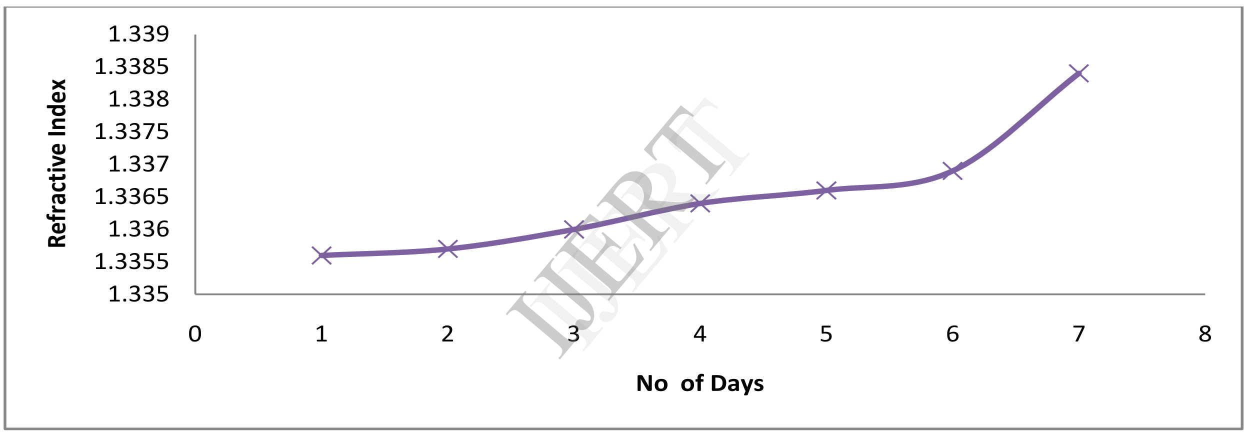

Fig 4: Refractive Index Vs Number of days

4.2 RESULTS OF PERFORMANCE OF SI ENGINE

4.2.1 Result of Brake Power Vs Engine Speed

From the result of the performance of the Petters Spark Ignition Engine the behaviours of parameters of Brake Power Vs Engine Speed is presented in Fig 5

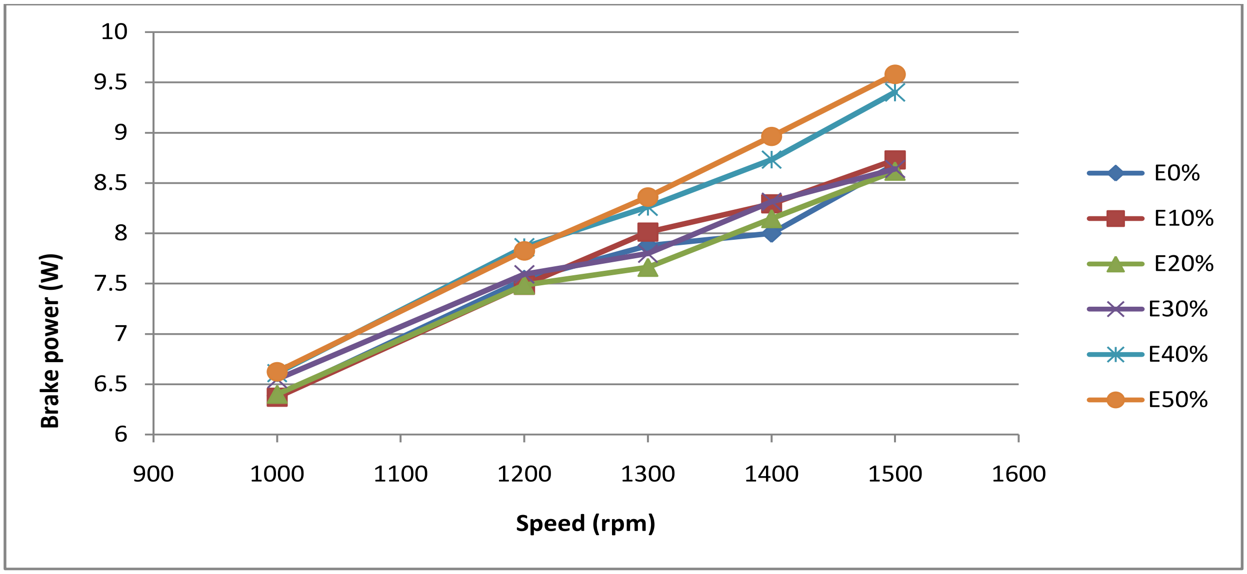

Fig 5: Brake Power Vs Speed

Result of Torque Vs Engine Speed

From the result of the performance of the Petters Spark Ignition Engine the behaviours of parameters of Torque Vs Engine Speed are presented in Figure 6 below.

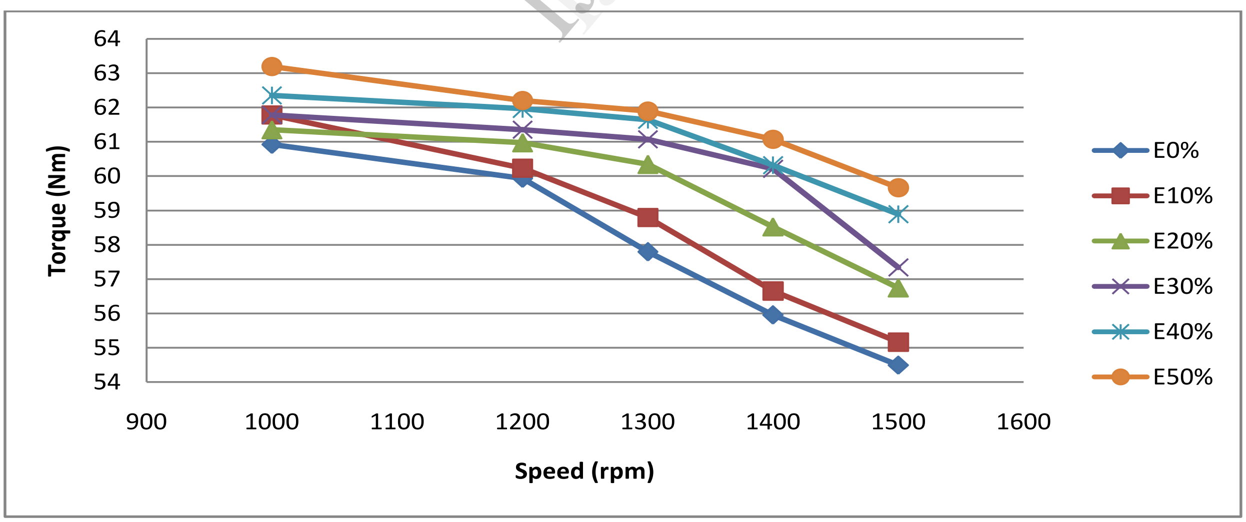

Fig 6: Torque Vs Speed

Result of Brake Mean Effective Pressure Vs Engine Speed

From the result of the performance of the Petters Spark Ignition Engine the behaviours of parameters of Brake Mean Effective Pressure Vs Engine Speed are presented in Figure 5

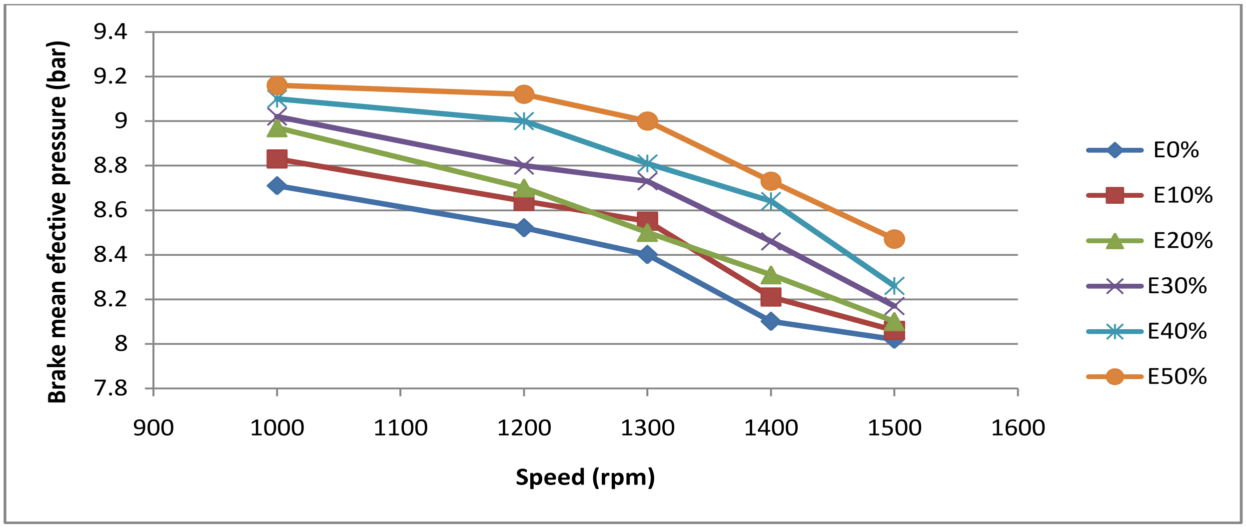

Fig 7: Brake Mean Effective Pressure Vs Speed

Result of Volumetric Efficiency Vs Engine Speed
From the result of the performance of the Petters Spark Ignition Engine the behaviors of parameters of Volumetric Efficiency Vs Engine Speed are presented in Figure 8.

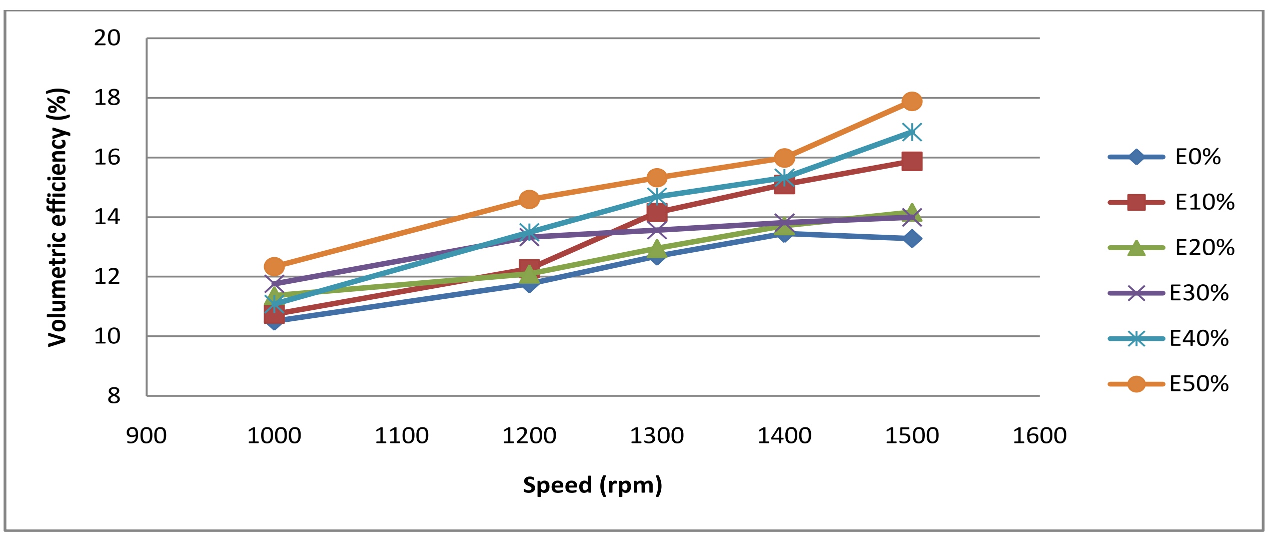

Fig 8: Volumetric efficiency Vs Speed

4.3 DISCUSSION

4.3.1 Discussion of Result of Reducing Sugar Concentration Obtained from Agricultural Wastes

From figure 1, the ability of A. *niger* and cellulase to breakdown rice husk into reducing sugar in terms of amount of reducing sugar (mg/ml) produced at 24 hour intervals for seven days. Rice husk was hydrolysed to produce 1.35 mg/ml, and 0.62 mg/ml reducing sugar concentration respectively on the first day and seventh day of batch1. In batch two, 1.32 mg/ml, 1.29 mg/ml, and 0.47 mg/ml was hydrolysed on the first, second and seventh day. The reducing sugar concentration decrease gradually as the fermentation period increases.

The calculated result of densities of ethanol from rice husk was, 720.8 kg/m^3

Specific gravity of ethanol obtained from rice husk is 0.7208

pH values of the ethanol obtained from rice husk wastes also decreases as the concentration increases. Values obtained presented in table 4 & 5 above.

Fermentation of rice husk

The rate of ethanol yield increases as the fermentation period increase. Thus, 4.20 ml, 4.50 ml and 5.40 ml was produced on first, second and the seventh day respectively as recorded in table. Total ethanol yield obtained from 420g of substrate of rice husk is 55 ml. Batch two indicates a decrease of yield to 34.54 ml and 42.94 ml respectively.

From the result, it was observed that as the concentration of the distillate increases, the refractive index also increase which implies that ethanol concentration is directly proportional to its refractive index. The refractive index of the ethanol obtained from rice husk ranged from 1.3356 to 1.3384 batch one, and 1.3352 to 1.3403

Discussion of Result for Engine Performance Test.

Brake Power

Brake Power was found to be relatively equal at lowest engine speed of 1000 rpm as shown Figure 5, it shows that Brake Power increase with increase in speed, At the speed of 1500 rpm, E50% developed the highest brake power followed by E40%, E30%, E10% and E20%. Gasoline developed the lowest brake work, this may seen that due to better combustion condition the engine power increase when more ethanol is added to gasoline

Due to oxygen in ethanol composition the combustion process improves in the engine which is in agreement with the findings by Alvydas and Saugirdas (2003).

Torque

From the graphs of Torque Vs Speed Figure 6, Torque is good indicator of an engine ability to do work. Torque decreases with increase in engine speed. On the other hand, slightly higher torque is produced by the gasoline –ethanol blends at low engine speed. Gasoline (E0%) developed the lowest torque of 54.49 N-m at engine speed of 1500 rpm. This is because the engine is unable to ingest a full charge of air at higher speed, also because friction loss increases with speed as explained by Pulkrabek, (2003).

Brake Mean Effective Pressure

Brake Mean Effective Pressure (BMEP) is directly proportional to the torque developed by the engine. Figure 7 showed slightly higher torque and BMEP at speed of 1000 rpm for blend of banana peel, groundnut shell and rice husk and sole fuel (gasoline). Lowest BMEP of 7.92 bar for gasoline (E0%) was recorded at 1400 rpm engine speed. At low engine speeds the higher heating value of gasoline is responsible high BMEP.

Volumetric Efficiency

Figure 8, showed that volumetric efficiency is slightly affected by increase

in blends of gasoline – ethanol. Peak Volumetric efficiency of 22.35% was recorded f at 1200 rpm engine speed and lowest volumetric efficiency of 10.09% for gasoline (E0%). This is in agreement with Andreas (2003), that volumetric efficiency is inversely proportional to engine speed, increasing the compression ratio, decreases the clearance volume and hence a higher volumetric efficiency is obtained.

4.4 RESULT OF EXHAUST EMISSIONS OF SI ENGINE FOR BLENDS

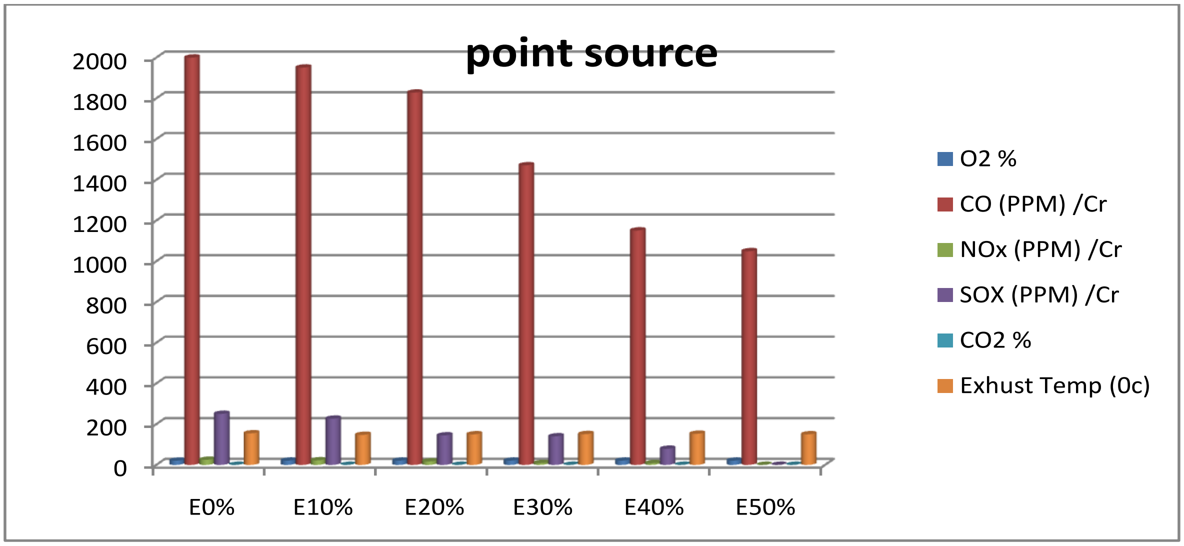

Fig 9: Exhaust emission at point source Vs Blend Ratio

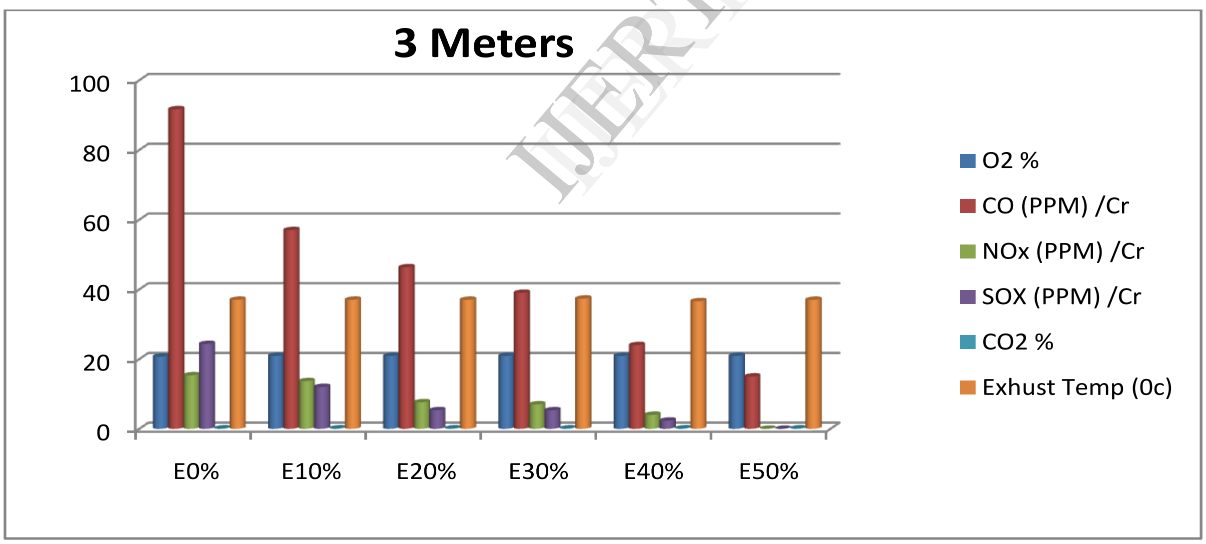

Fig 10: Exhaust emission at 3m distance Vs Blend Ratio

EMISSION

The effects of gasoline – ethanol blend with sole gasoline showed that the amount of carbon monoxide (CO) emitted decrease greatly as the percentage of blend increase, NOx emission slightly decrease as the blend increase, at point and 3m measure distance. At point source an overflow > 2000 ppm was recorded, and 9% reduction of CO emission at 3m distance and engine speed of 1200 rpm. Thus, ethanol decrease the amount of CO emission in the engine exhaust, this is because the fuel mixture combust better and the amount of incomplete combustion product decreases (Alvydas and Saugirdas 2003).

5. CONCLUSION

From the results and discussion on the study, the following conclusion can be drawn:

►The result of the experiment conducted showed that Cellulosic agricultural wastes particularly rice husk is a potential substrate which can be exploited for bioethanol production on a commercial scale as it is cheap and more importantly renewable.

►Ethanol is a relatively clean – burning liquid, as the amount of gasoline blended with ethanol decreases. Ethanol is compatible with at least some fuel cell configurations, offering the potential for dramatic reductions in air pollution as well as high efficiency.

►Ethanol blends with gasoline causes significant improvement in engine performance, indicating parameters like Brake power, Torque, Brake Mean Effective Pressure, Volumetric Efficiency and Fuel consumption been observed for various additives. Addition of 50% ethanol – gasoline was feasible though with difficulty in starting but there was significant reduction in exhaust emission as engine speed increase. Values of CO, NOx, SOx, emission decreases dramatically as a result of leaning effects caused by ethanol addition.

►It was observed that the load decreases as the speed of the engine increase, Brake Power increases as the speed of the engine increase, Torque decrease as the speed increase. However fuel consumption increase with addition of alcohol in the blended fuel, exhaust gas temperature is found to increase with alcohol addition to gasoline.

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