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Production And Performance Evaluation Of Bioethanol Fuel From Groundnuts Shell Waste

Nyachaka C.J[1] Yawas D.S[2] Pam G.Y[3]
1. Postgraduate Student Department of Mechanical Engineering Ahmadu Bello University Zaria, Nigeria
2. Department of Mechanical Engineering Ahmadu Bello University Zaria, Nigeria
3. Department of Mechanical Engineering Ahmadu Bello University Zaria, Nigeria

Abstract: - This paper examines the feasibility of bioethanol production from groundnut shells as an important sustainable alternative source of biofuel in Nigeria. Here an experimental attempt has been made to know the level of variation of exhaust emission with a view of minimising the emission of green gases in line with Kyoto protocol treaty. Groundnuts shell where hydrolysed to produce 1.56 mg/ml and 1.09 mg/ml reducing sugar concentration on the first day of batch one and two respectively. Ethanol yield was 6.2 millilitre and 7.9 millilitres on the first and the seventh day of batch one from 420g of substrate. Highest brake power, volumetric efficiency and torque of 9623.40 W, 18.09 % and 62.35 Nm recorded for E40% ethanol/ gasoline blends. Lowest brake power and brake mean effective pressure of 6385.70 W and 8.02 bar respectively was also recorded for sole gasoline. On the other hand exhaust emission from carbon monoxide (CO), nitrous oxide (NOx) decrease greatly as the percentage of the blends increase at point source and 3 metres distance.

Keywords: - *Groundnuts shell, fermentation, ethanol, emissions, gasoline engine*

I. INTRODUCTION

A challenge that humanity must take seriously is to limit and decrease the greenhouse effect Caused by various human activities, a major contributor to the greenhouse effect is the transport sector due to the heavy, and increasing, traffic levels. In spite of ongoing activity to promote efficiency, the sector is still generating significant increases in CO_2 emissions. As transport levels are expected to rise substantially, especially in developing countries, fairly drastic political decisions may have to be taken to address this problem in the future. Furthermore, the dwindling supply of petroleum fuels will sooner or later become a limiting factor.

Groundnut shell (GS), a residue after separation of pod, is available in copious amount in the world. The crop residue is of low economic value and generally used in burning, gasifiers as a fuel source or sometimes as manure to increase the soil conditions. The residue contain a total 54.4 % total carbohydrate content (dry weight) in its cell wall (Raveendran et al., 1995) makes it an appropriate substrate for bioconversion to fuel ethanol.

II. BIOMASS RESOURCES IN NIGERIA

Biomass resources in the country include Agricultural crops, wood, charcoal, grasses and shrubs, residues and wastes (agricultural, forestry, municipal and industrial), and aquatic biomass. Total biomass potential in Nigeria, consisting of animal and agricultural waste, and wood residues, was estimated to be 1.2 PJ in 1990 (Obioh and Fagbenle, 2004). In 2005, research revealed that bio-energy reserves/potential of Nigeria stood at: Fuel wood 13071,464 hectares, animal waste, 61 million tonnes per year, crop residues, 83 million tonnes (Agba et al., 2010)

2.1 Biofuel Potential in Nigeria

Biofuels can be broadly defined as solid, liquid or gaseous fuels consisting of or derived from biomass. At the moment potential crops for biofuel production in the country are cassava, sugar cane, rice and sweet sorghum for bioethanol; palm oil, groundnut, and palm kernel for biodiesel because of their high yield and current production output in the country. Nigeria is the largest producer of cassava in the world and has the

largest capacity for oil palm plantation which serves as a great source for biodiesel (Abiodun, 2007). It is interesting to mention that Nigeria could also be a major player in the biofuel industry given the enormous magnitude of various waste/residues (agricultural, forestry, industry and municipal solid) available in the country. Biofuel may be of special interest in many other developing countries like Nigeria for several reasons. Climate in many of the countries are well suited to
growing biomass. Biomass production is inherently rural and labor-intensive, and thus may offer the prospect for new employment in regions where the majority of populations typically resides. Abila (2010) classified Nigeria as one of the countries with very high potential for energy crops production.

2.2 GROUNDNUT

The **peanut**, or **groundnut** (***Arachis hypogaea***), is a species in the legume or "bean" family (Fabaceae). The peanut was probably first cultivated in the valleys of Peru. It is an annual herbaceous plant growing 30 to 50 cm (1.0 to 1.6 ft) tall (www.eurekalert.org/pub).
Groundnuts were introduced to Nigeria in the 16th centuary and it is extremely grown in West Africa and from Sudan to South Africa. It has been estimated that about 22299 million hectares of land are annually planted with groundnuts. In Africa groundnuts in shell was grown on 746 million hectares with total production of 5794 million tonnes (FAO, 1980).

2.2.1 Global Situation and Potential Bioethanol Production from Groundnut shell

In Nigeria 1486 million tones of groundnut in shell was estimated from 1.61 million hectares of land (FAO, 1995). Here in Zaria, SAMNUT- 38, was developed at Institute of Agriculture Research Samaru as selection from Virgina bunch with 130-150 days maturity period, Potential yield of 2,500-3,000kg/ha. It has large seed, high oil content, Rosette susceptible, Leaf Spot susceptible and large shell with excellent adaptation in Northern and Southern Guinea savannas.

III. MATERIALS AND METHODS

3.1 MATERIAL

3.1.1 Groundnut Shell

Groundnuts Shell waste for SAMNUT-38 Specie obtained from The Institute of Agricultural Research Samaru Zaria are residue that are cheap and readily available source of lignocellulose after separation of pod and grain were collected and taken to Micro-biology laboratory Ahmadu Bello University Zaria Nigeria.

3.2 METHODOLOGY

3.2.1 Pre-treatment of Lignocellulosic Source

The substrates were washed with distilled water dried for three days at 60^{o} 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 each was weighed, the samples were then soaked in 1% (w/v) sodium hydroxide solution (substrate + solution) for 2hours at room temperature after which it was washed with distilled water and dilute HCL until the wash water was brought to neutral PH free of the chemicals and then set in Memmert oven (Model UE-500 DINI12880) overnight at 60^{o} to dry. The NaOH pretreatment was repeated for each sample according to Amadi (2004).

3.2.2 Samples Collection of producer microorganisms:

Pure culture strains of *Aspergilus niger* and *Saccharomycs cerevesiae* Isolate was provided by the Department of Microbiology Ahmadu Bello University Zaria, Nigeria. This was used for the study. The organism was 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 slant cultures were subcultured and grown on potato dextrose agar (PDA) in petri dishes according to manufacturer specification and sterilized at 121^{o} for 15 mins, samples incubated at room temperature for 5 days. The microscopic feature of pure grown colonies were observed and identified according to procedure described by Bailey et al (2004).

3.2.3 Inoculum Preparation

The organisms were grown on malt extract agar slant at 30^{o}C for 5 days and stored at 4^{o}C with regular sub-culturing. 150 ml of inoculums was prepared for each culture using 5g glucose, 10 g peptone, 5 g 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^{o}C for 48 h before it was used for the fermentation process. Bailey et al (2004).

3.2.4 Preparation of Fermentation Medium

The fermentation medium used for ethanol production consisted of glucose 8% (w/v), peptone 0.1% (w/v), Malt extract0.1% (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 each 500 ml Erlenmeyer flask. The flask were sterilized in autoclave (Model Astell ASB 300) at 121^0C for 15 minutes and inoculated with 15 ml and 4 ml containing growth innocula of *S. cerevesiae* and *A. niger* cells and 2 million spores respectively. (Abouxied, and Reddy,1986). The flasks were incubated on orbital shaker (Model Vineland NJ SH2-526) with an initial agitation rate of 300 rpm at 30^0C for seven days each sample withdrawn at 24 hours interval for distillation.

3.2.5 Determination of Density and Specific gravity

Digital Electronic Balance at Old Chemical Engineering Analysis Lab. Model FA2004 was used. The densities and specific gravities of the solutions were determined using standard procedure and the result recorded. The ethanol concentration was plotted against the number of days.

3.2.6 Determination of Refractive Index Standard Curve:

Refractive Index of ethanol was carried out at Chemical Engineering Unit process Laboratory Ahmadu Bello University Zaria, Nigeria. The refractive index of standard ethanol concentration were 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 samples. (Amadi *et al*., 2004)

3.3 Experimental Setup of PETTERS Spark Ignition Engine & Description

Four stroke single cylinder petrol engine was connected to the electric dynamometer with the help of coupling and mounted on the rigid frame, Tachometer for RPM reading, U tube manometer, air filter, fuel measuring tube. And gas analyzer was arranged.

3.3.1 Experimental Fuels

We used the following fuels in the experiment:

- ► Gasoline purchased at Oando fuel filling station in Samaru Zaria
- ► Ethanol from Groundnut shell

3.3.2 Four-Stroke Engine

A four-stroke, single cylinders, stationary petrol engine, of specification as follows,

Engine Data:

i. Bore = 8.50 cm
ii. Stroke = 8.25cm
iii. Compression Ratio = 6:1
iv. Swept Volume = 468.67 cm
v. Maximum BHP at 1650 rev/min
vi. Maximum speed = 2000 rev/min
vii. Brake Arm = 32.0167 cm
viii. Manometer angle = 15^o
ix. Orifice Size = 1.905 cm
x. Coefficient of Discharge (C_d) = 0.60

3.3.3 Test Procedure on Petters heat engine

Before starting, water circulation to the engine was ensured by first, filling the tank to full capacity. Transformer was switched on so as to supply current to the electrical D.C motor which runs the Petter Paiws test engine as it's 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 is the D.C electrical dynamometer from which relevant data are recorded.

The hand wheel provided on top of the balance frame was use to adjust the height of the balance arm. This should always be horizontal when taking brake horsepower readings from the dynamometer.

The fuel consumption was obtained from the measuring jar on the engine by noting the fit for consumption of a known quantity of fuel using stop watches.

The inlet and exhaust temperatures of the water coolant were obtained by deepening thermometers into a bore on the inlet and outlet water pipe.

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

The experimental analysis commenced by using 100% gasoline as a reference and later with the gasoline – ethanol fuel blends (E10, E20, E30, E40, E50). The results obtained was recorded.

3.3.4 IMR 1400 gas analyzer

This is an equipment to sample emission product directly from the combustion chamber, it Measures and calculates in addition to the above mentioned parameters 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)

The IMR gas analyzer is design to work under strict adherence to the operating manual and within stipulated temperature.

Procedure

Petters Heat Engine was 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.

3.4 CHEMICAL COMPOSITION

GS used in this investigation with chemical composition 35.7% cellulose and 18.7% hemicelluloses which constitutes total carbohydrate content (TCC) of 54.4% on dry solid (DS) basis is presented in Table 1 below.

Table 1: Chemical composition of groundnut shell

Components	% dry weight
Ash	5
Cellulose	38
Hemicellulose	36
Lignin	16
Moisture	5

Source: (Raveendran et al., 1995)

IV. RESULTS AND DISCUSSIONS

4.1 RESULT

The result of the test conducted was recorded in tables and plotted in figures 1, 2, 3, 4, 5, 6,7 and 8 below.

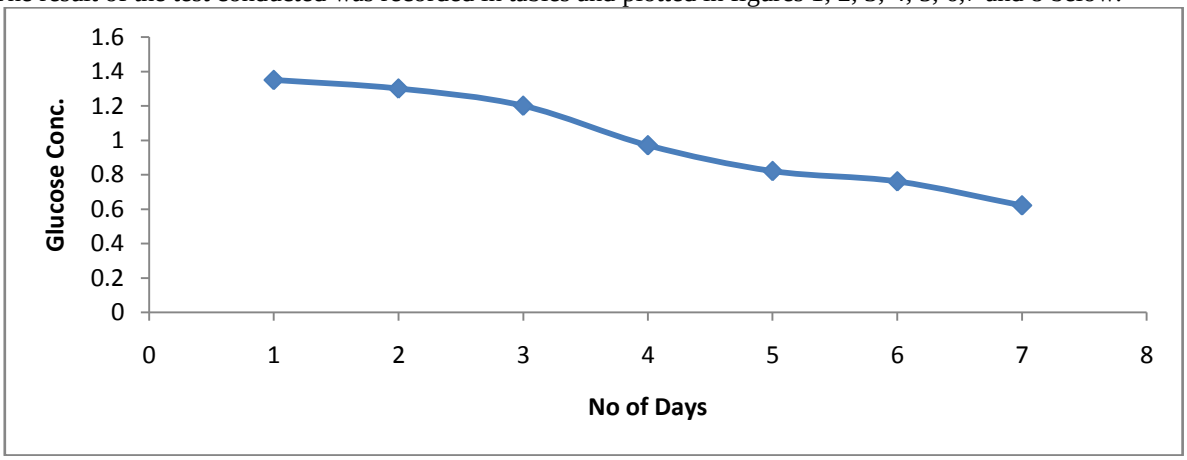


Figure 1: Glucose concentration Vs No of days

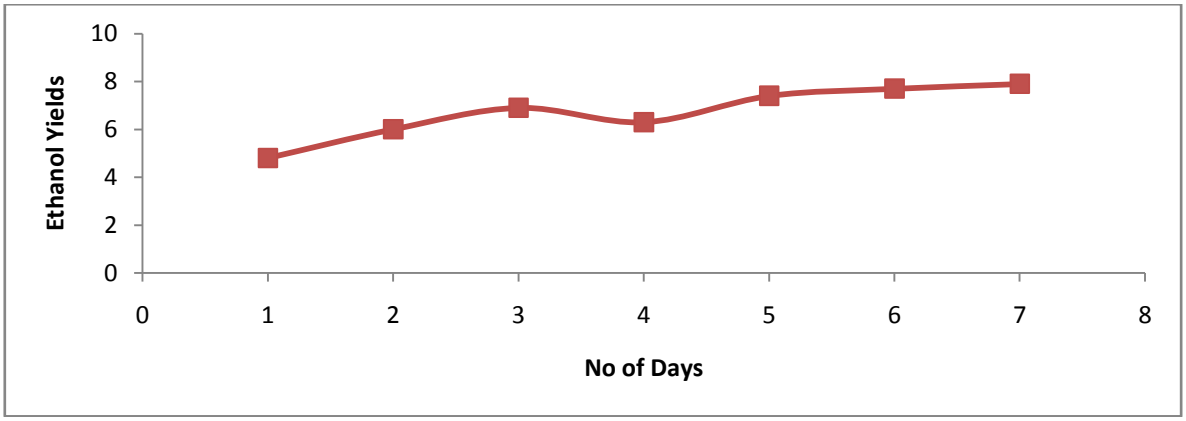


Figure 2: Ethanol yields Vs No of days

Reducing Sugar Concentration Obtained from Groundnut Shell Wastes

The ability of the *Aspergilus niger* and cellulose to breakdown groundnuts shell waste into reducing sugar. Groundnut shell was hydrolyzed to produce 1.56 mg/ml reducing sugar concentration on the first day and 0.46 mg/ml on the seventh day of batch one 1.09 mg/ml, 0.96 mg/ml, 0.85 mg/ml for first, second and third day of batch two. Batches three, four and five of the experiment show similar result. Thus, reducing sugar concentration decreases gradually as the fermentation period increases.

Result of Ethanol obtained from fermentation of organic waste

On the first day of batch one, substrate produced 6.2 millilitre of ethanol, as the fermentation period increase ethanol yield also increase 9.2 milliliter on the seventh day respectively. Total ethanol yield obtained from 420g of substrate groundnut shell is 55.8 millilitres. Batch two indicates slight decrease from the same quantity as the fermentation period increases. Thus, total ethanol yields was 45.60 millilitre, while in batch three, ethanol yield Groundnut shell was 43.76ml 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 groundnut shell was 1.3361 day one to 1.3409 day seven respectively.

The calculated result of densities of ethanol was, 756.4 kg/m^3

Specific gravity of ethanol obtained was, 0.7564. pH values of the ethanol obtained from groundnut shell wastes also decreases as the concentration increases. The pH values of ethanol obtained from groundnut shell decreases from 6.79 on the first day to 6.49 on the seventh day respectively.

Volume of ethanol produced from 420 g substrate groundnut shell was approximately 60 ml. As in literature by Mathewson (1980), that a ton of fermentable sugar substrate can produce 70 – 100 gallons of ethanol. The approximate ethanol yield of (50 – 80) ml obtained in this experiment also agrees with the report of Akpan and Adamu (2008), that substrate of 2500 g of fermentable sugar can produce a maximum ethanol yield of about 0.65 litres.

RESULT OF CALORIFIC VALUE OF THE BLENDS

The calorific values, density and specific gravity for the blends where determined and the result obtained was tabulated in table 2 below.

Table 2: Table of Calorific Value of Blends

S/No	SAMPLE ID (%)	GROSS HEAT (MJ/Kg)	INITIAL TEMPT. (°C)	FINAL TEMPT. (°C)	SAMPLE WEIGT. (g)	DENSITY (kg/m^3)	SPECIFIC GRAVITY
1	E0	480.2916	23.806	26.6705	0.0001	703.5	0.7035
2	E10	459.0396	24.1860	25.4115	0.0001	712.3	0.7123
3	E20	437.6421	23.9670	24.1783	0.0001	724.2	0.7242
4	E30	364.1139	24.9673	25.3214	0.0001	737.9	0.7379
5	E40	230.6567	25.3219	26.5336	0.0001	746.7	0.7467
6	E50	203.2716	24.7362	25.4693	0.0001	758.6	0.7586

4.3 EXPERIMENTAL CALCULATION/ ENGINE PERFORMANCE

The values obtained from the experiment were used to determine the various engine parameters as outlined below. These engine parameters were calculated for the E0%. E10%, E20%, E30%, E40% and E50% base on full throttle opening.

1. **Brake Power** 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. It is given by

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

Where,
W = Load reading
N = Speed

2. Torque Is a good indicator of an engine ability to do work. It is define as force acting at a moment distance.

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

W = Load
R = Torque arm length

3. Brake Mean Effective Pressure It is the mean effective pressure which would have developed power equivalent to the brake power if the engine were frictionless for a four – stroke engine, it is given by

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

L = Stroke
$A = \frac{\pi D^2}{4}$
N = Revolution per second
n = Number of cylinder = 1

4. Volumetric Efficiency Is the mass of air equal to the density of atmospheric air times the displacement volume of the cylinder per each cycle.

$$\textbf{Volumetric Efficiency } (\eta_v) = \frac{\mathbf{V_a + V_f}}{V_S} \quad (4)$$

Where,

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

$$\dot{\mathbf{m}}_\mathbf{a} = \mathbf{0.866}\sqrt{\frac{\mathbf{Ph}}{T_a}} \quad (6)$$

$\dot{m}_a$ = mass of air
h = Manometer reading in (in) = H sinθ
θ = 15°
R = Gas Constant

Note Before: Barometric Readings.

i. .Atmospheric pressure = 27.80 inHg
ii. Ambient Temperature = 29.96 °C = 302.96 K

$$\mathbf{V_f} = \frac{\textbf{Volume of Sample}}{\textbf{Rate of consumption}} \quad (8)$$

$$\mathbf{V_s = V_s Nn} \quad (9)$$

V_s = Swept volume

V. RESULTS OF PERFORMANCE OF SI ENGINE

From the result of the performance of the Petters Spark Ignition Engine the behaviors of parameters of Brake Power, Torque, Brake Mean Effective Pressure, and Volumetric Analysis Vs Engine Speed are presented in Figures 5, 6, 7 and 8 below.

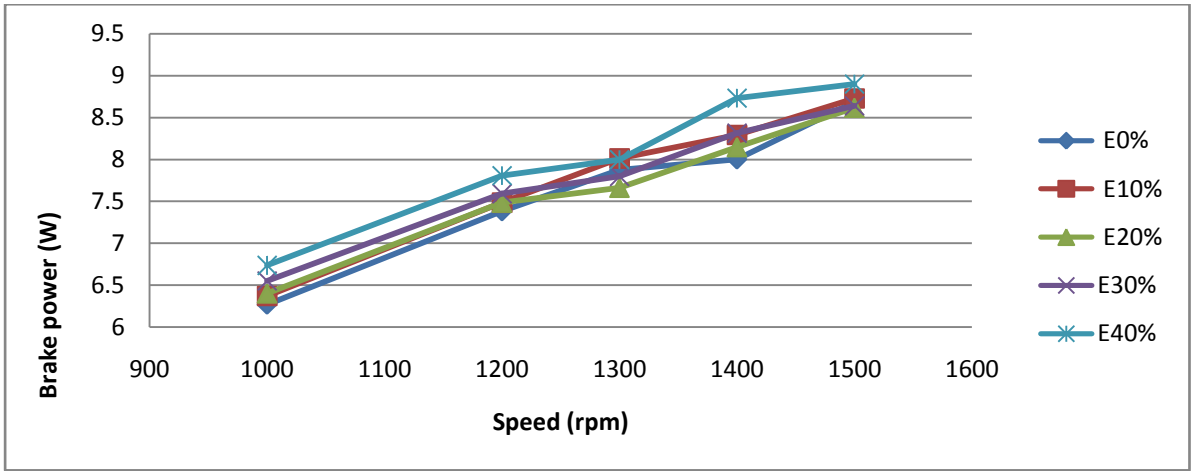


Figure 5: Brake power Vs Speed (Groundnuts shell)

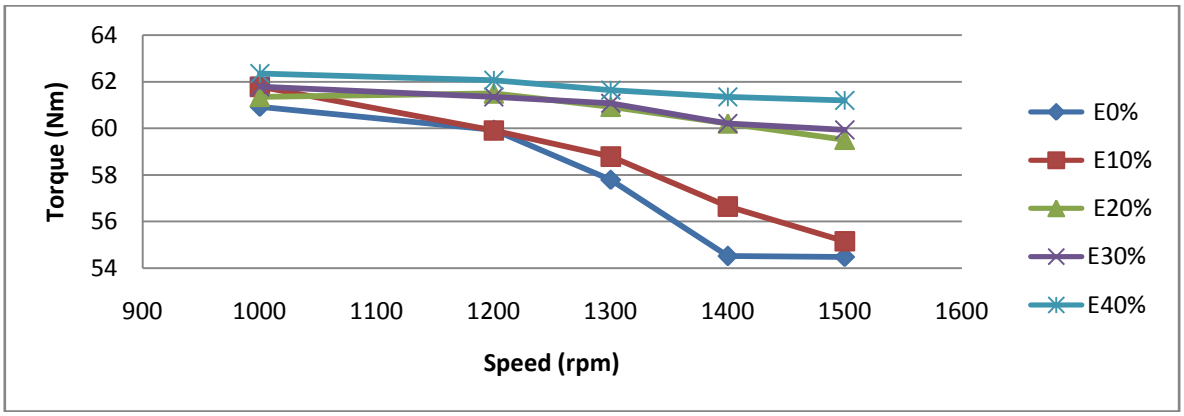


Figure 6: Torque Vs Speed (Groundnut shell)

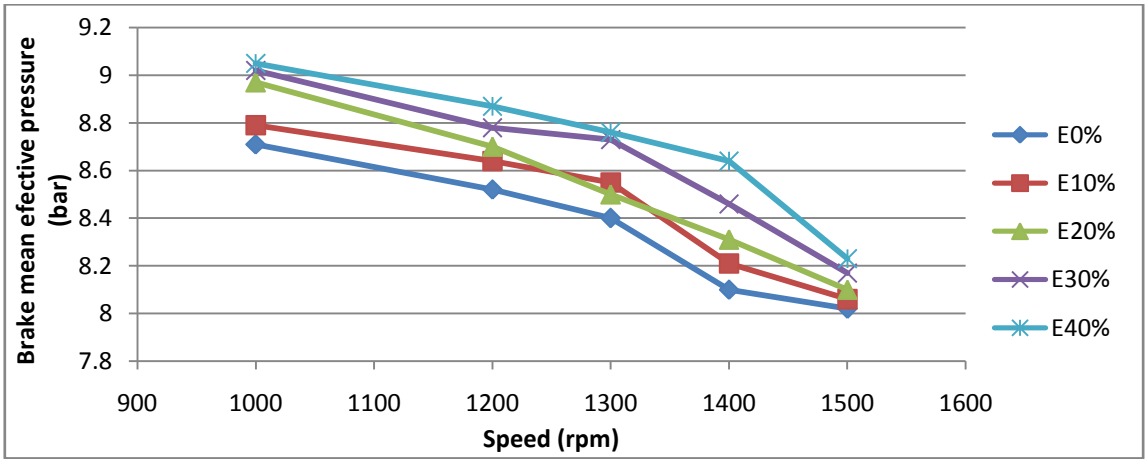


Figure 7: Brake mean effective pressure Vs Speed (Groundnut shell)

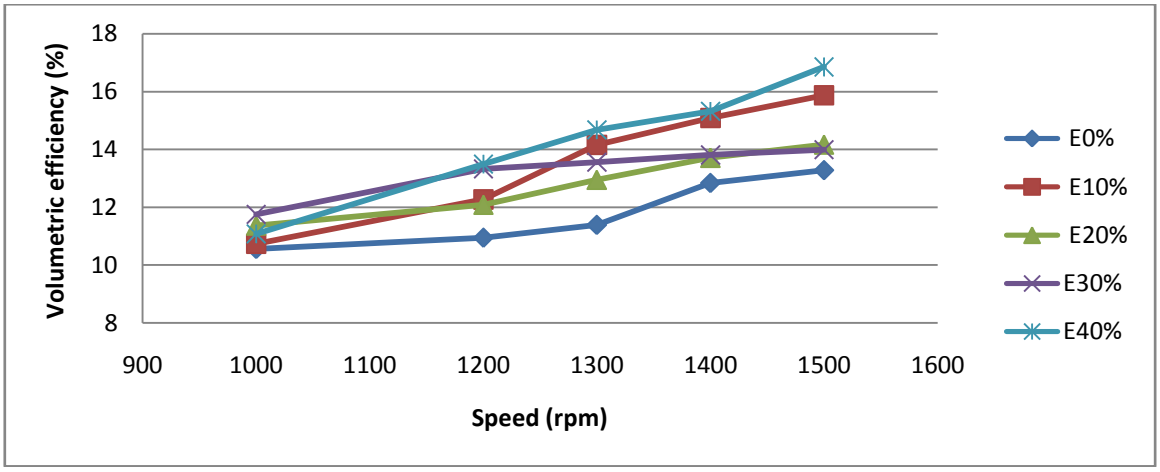


Figure 8: Volumetric efficiency Vs Speed (Groundnut shell)

VI. DISCUSSION OF RESULT FOR ENGINE PERFORMANCE TEST.

5.1 DISCUSSION

5.1.1 Brake Power

Brake Power was found to be relatively equal at lowest engine speed of 1000 rpm as shown, it shows that Brake Power increase with increase in speed, At the highest speed of 1500 rpm E40% developed the highest brake power followed by E30%, E10% and E20% while gasoline developed the lowest brake work, this may be due to better combustion condition of the engine, power increase when more ethanol is added to gasoline.
Due to oxygen in ethanol composition the combustion process improves in the engine this is in agreement with the findings by Alvydas and Saugirdas (2003).

5.1.2 Torque

From the graphs of Torque Vs Speed (Fig. 6).Torque is good indicator of an engine ability to do work. Torque decreases with increase in engine speed for all the blends for groundnuts shell. 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 Nm 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).

5.1.3 Brake Mean Effective Pressure

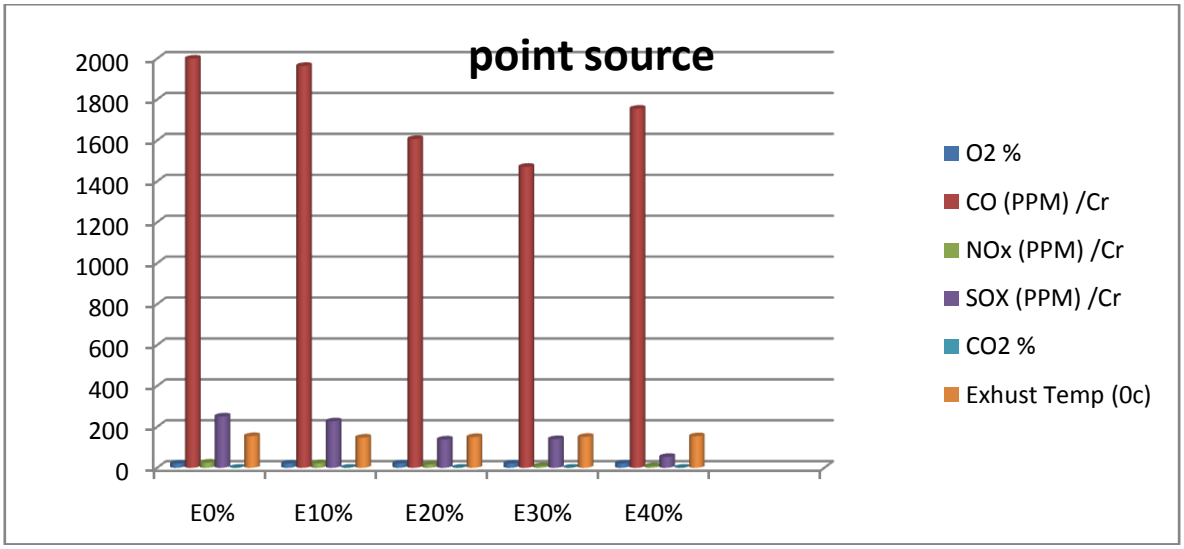
As shown in Equation (3), Brake Mean Effective Pressure is directly proportional to the torque developed by the engine. Graph 7, shows slightly higher torque and BMEP at speed of 1000 rpm for blend and sole fuel (gasoline). Lowest BMEP of 7.92 bar for gasoline (E0%) was recorded at 1400 rpm engine speed. At low engine speeds the higher heating value of gasoline is responsible for high BMEP.

5.1.4 Volumetric Efficiency

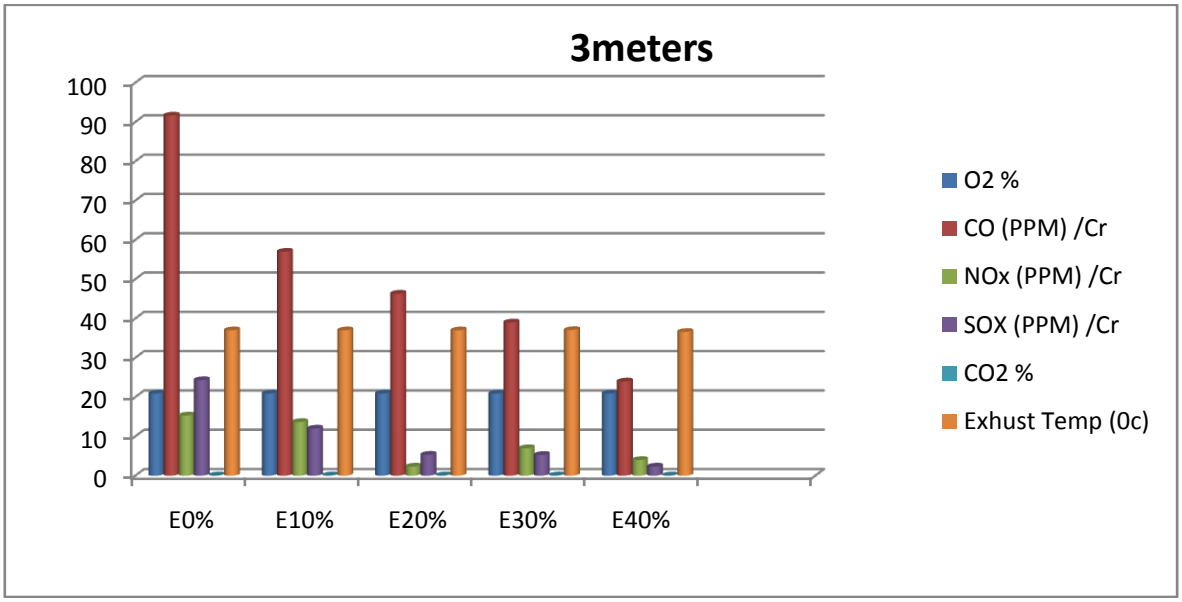
Graph 8 show that Volumetric efficiency is slightly affected by increase in blends of gasoline – ethanol. Peak Volumetric efficiency of 22.35% was recorded at 1200 rpm engine speed and lowest volumetric efficiency of 10.09% for gasoline (E0%). This is in agreement with Andreas (2003), that volumetric efficiency is inversely proportional to engine speed, increasing the compression ratio, decreases the clearance volume and hence a higher volumetric efficiency is obtained.

5.2 COMBUSTION ANALYSIS OF THE OF BIOFUEL BLEND AND GASOLINE

Graph 9, below shows the combustion analysis of petters engine at Point and 3 metre source.



Graph 9: Exhaust emission at point source Vs Blend Ratio (Groundnut shell)



Graph 10: Exhaust emission at 3 m dis. Vs Blend Ratio (Groundnut shell)

VII. SUMMARY

From the result of this research, using fungus microorganism *A.niger* and *S. cerevisiae* that can convert xylose and other pentose to bioethanol will convert 420g substrate Groundnuts shell to produce approximately 50 – 80 ml ethanol yield.

The test result and graphs have demonstrated the possibility of using bioethanol obtained from organic wastes to run gasoline engine with little or no modification. Result from the test carried out showed that blends of ethanol: gasoline from banana peel developed the highest maximum torque of 63.19 Nm, and the highest brake power of 9578.64 W, compared to sole gasoline with 60.92 Nm torque, and 8683.4 4W. However maximum fuel consumption was noticed from ethanol: gasoline blends when compared with that of sole gasoline.

VIII. CONCLUSION

The result of the experiment conducted shows that Cellulosic agricultural wastes particularly groundnuts shell is a potential substrate which can be exploited in industries for bioethanol production on a commercial scale as they are cheap and more importantly renewable. Available data support the conclusion that environmental impact associated with dedicated production of cellulosic biomass appears to be generally acceptable and can be positive.

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 has 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

REFERENCE

[1] Abila N. (2010). Biofuels adoption in Nigeria: Preliminary Review of Feedstock and Fuel Production Potential, Dept. of Industial Management, University of Vaasa, Vaasa, Finland. pp 1-11.

[2] Abiodun O. (2007). Biofuel Opportunities and Development of renewable energies Markets in Africa: A paper presented during the biofuel market Africa 2007 conference, Cape Town, South Africa.

[3] Akpan, U G.; Alhakim, A. A. and Ijah, J. J (2008) *Production of ethanol frm organic food waste*

[4] Adeniyi, O. D.; Kovo, A.S.; Abdulkarim, A. S. Chukwudozie, *Ethanol production from cassava as a substitute for gasoline. J. Dispersion Sci. Technol.(2007)*

[5] Akande, F. H. and Mudi, K. Y., *kinetic Model for Ethanol production from cassava starch by saccharomyces cerevisiae*. *proceedings of the 35th Annual Conference of NSChE, Kaduna, Nigeria(2005)*

[6] Agba A.M., Ushie M.E., Abam F.I., Agba M.S., Okoro J. (2010). Developing the Biofuel Industry for Effective Rural Transformation. European Jornal of Scientific Research, Vol. 40 No. 3, pp 441-449.

[7] Ajueyitsi O.N (2009). Optimization of Biomass Briquette Utilisation, a Fuel for Domestic use. PhD Research Proposal Seminar, Dept. of Mechanical Engineering, FUTO.

[8] Amadi, B.A., Agomo, E.N and Ibegbulem, C.O (2004). Research method in biochemistry. Supreme publishers, Owerri, Nigeria pp. 93-99

[9] Bailey, B., and Russell, J. (2004). Emergency Transportation fuel investigation: Properties and Performance. SAE Papers 81044.

[10] Elijah I.O. (2010). Emerging Bio-ethanol Projects in Nigeria: Their Opportunities and Challenges. Energy Policy Reviews. Vol 38, Issue 11, pp 7161-7168.+ http://www.eurelertk

[11] Obioh I. and Fagbenle R.O. (2009). Energy Systems:Vulnerability Adaptation Resilience (VAR). Hello International

[12] Ogwueleke T. (2009). Munucipal Solid Waste Characteristics and Management in Nigeria. Iran Journal Of Environmental Health Sci. Eng, Vol 6,N0.3, pp 173-180.

[13] Raveendran, K., Anuradda, G. and Kartic, CK., "Influence of mineral matter on biomass pyrolysis characteristics", Fuel, 1995, 74, 1812-1822.