

LOAD PERFORMANCE OF A SPARK IGNITION ENGINE USING ETHANOL-GASOLINE BLENDS AS ALTERNATIVE FUEL

¹Surakat Ayodeji Saheed, ¹Bolaji Bukola Olalekan, ¹Olokode Olusegun Sunday and
²Dairo Olawale Usman

¹Department of Mechanical Engineering,

²Department of Agricultural Engineering,

Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

ABSTRACT

In this experimental study, ethanol obtained from three sources (maize, potato and cassava) were used as blend components. The test samples were E10 blends of the three ethanol extracts and pure gasoline (E0) as the reference fuel. A four stroke, single cylinder type spark ignition engine performance test was carried out at rated speed of 3450 rpm at different loads using all four fuel samples and the results obtained showed that Specific Fuel Consumption (SFC) of the test engine when all three ethanol blends were used was lower compared to pure gasoline. The average values obtained using E10 maize, E10 potato and E10 cassava were 22.47, 33.23 and 17.41 % respectively lower than that of E0. Brake Power (BP) obtained using E10 potato, E10 cassava and E10 maize were respectively 6.33% and 3.30% higher and 1.96% lower compared to using E0. The Exhaust Temperatures (ETs) and Brake Thermal Efficiencies (BTE) resulting from the use of the blends were higher compared to using pure gasoline and average values obtained using E10 potato, E10 cassava and E10 maize were 1.31% and 48.81%; 5.39% and 32.40%; 0.56% and 26.98%, respectively higher than that of E0. The results showed that the use of ethanol-gasoline blends performed better than pure gasoline with E10 potato giving the best performance.

KEYWORDS: E10, blends, performance, gasoline, spark ignition engine.

I. INTRODUCTION

Gasoline engines in the transportation and power sectors have carved a niche due to their effective performance and doggedness [1]. They have served as sources of decentralized energy generation for micro electrification plant in the past and present years [2]. In order of prominence, ethanol, methanol, vegetable oils and biodiesel are liquid biofuels closest to being competitive in current market. Over a century, they have been utilized either in one form or another. The search for alternative fuel over conventional petroleum based fuels has been subjected to various studies throughout the world. Since ethanol is a liquid fuel, the storage and dispensing of ethanol is similar to that of gasoline [3-6].

For some time past now, alternatives to fossil fuel had been investigated for the possibility of reduced emission, drop in fuel prices, improved fuel availability and reduced reliance on petroleum [7]. Thermodynamic tests, based on engine performance evaluation have established the feasibility of using a variety of alternative fuels such as hydrogen, alcohols, biogas, producer gas and host of vegetable oils [8]. The simplest approach to the use of alcohols in engines is to blend moderate amounts of alcohols with base fuel [9].

El-Kassaby [10] investigated the effect of ethanol gasoline on the performance of a spark ignition engine. The performance test show that engine power improved with ethanol addition and the maximum improvement occurred when E10 blend was used. On another hand, Abdel-Rahman and

Osman [11] carried out performance tests using varying ethanol percentages in gasoline to prepare its blends. The result showed power improvement with E10 giving the maximum improvement. According to Keith and Trevor [12] use of alcohol as fuel in Spark Ignition (SI) engine will improve the engine's thermal efficiency because ethanol has better anti-knock characteristics compared to gasoline. Koc *et al.* [13] investigated the effect of pure gasoline (E0) and ethanol gasoline blends (E50 and E85) on the performance of a single cylinder four stroke spark ignition engine at two compression ratios. The result of the test showed that ethanol addition to gasoline increased the engine torque, power and fuel consumption. The result also showed that ethanol-gasoline allowed compression ratio (CR) increment without knocking the engine.

Guerrieri *et al.* [14], tested gasoline and gasoline-ethanol blends on six in-use vehicle to determine the effect of ethanol content on fuel economy. Fuel consumption decreased in most vehicles when the ethanol content was increased in the fuel. At the highest ethanol concentration of 40% fuel consumption decreased by about 15%. Wu *et al.* [15], investigated the effects of air-fuel ratios on SI engine performance using ethanol-gasoline blends. The result of engine performance tests showed that torque output was improved on using gasoline-ethanol blends. However, there is no appreciable change on the brake-specific fuel consumption.

Al-hassan [16], conducted experiments on a four stroke four cylinder SI engine using gasoline-ethanol blends in different proportions. The variable engine speed was between 1000 and 4000 rpm. The experiments were conducted at three-fourth throttle opening position. The range of ethanol percentage added to the gasoline is from 5% to the maximum of 30%. The study concluded that the performance of the engine improved with gasoline ethanol blends. Yucesu *et al.* [17] and Topgul *et al.* [18], used unleaded gasoline (E0) and unleaded gasoline-ethanol blends (E10, E20, E40 and E60) in a single cylinder, four-stroke, spark-ignition engine with variable compression ratio. It was found that blending unleaded gasoline with ethanol slightly increased the brake torque.

There had also been a suggestion to use artificial neural network (ANN) to determine engine power, torque, specific fuel consumption, brake thermal efficiency and volumetric efficiency based on different ethanol-gasoline blends and speeds. Experimental demonstrations revealed that brake power marginally increased while specific fuel consumption decreased when ethanol-gasoline blends were used. The brake thermal efficiency and volumetric efficiency also increased. Analysis of the experimental data by the ANN showed there is a befitting correlation between the ANN-predicted results and the experimental data [19].

From above literature, it is evident that ethanol gasoline blended fuels can perform as substitutes to pure gasoline because of increased brake power, reduced specific fuel consumption and increased brake thermal efficiency without modification to the fueling system of the engine. It therefore suffices to evaluate performance of a single cylinder four stroke spark ignition engine fueled with blends of gasoline and ethanol sourced from the following crops: maize, potato and cassava as alternative to pure gasoline for conformity and possible performance disparities between the ethanol sources. The performance parameter of the SI engine working with this alternative fuels were evaluated and compared with those of gasoline.

II. MATERIALS AND METHODOLOGY

2.1 Fuel Samples For Tests

Four fuel samples were used for this study. E10-cassava (10% cassava ethanol-90% gasoline), E10-potato (10% potato ethanol-90% gasoline), E10-maize (10% maize ethanol-90% gasoline) and E0 (100% gasoline as control). Some of their properties are shown in Table 1.

Table 1: Some properties of the fuels samples used for engine test

Samples	Density of the blends @ 20°C (kg/m ³)	Heating value (MJ/kg)
E0	848	52
E10 maize	769	42
E10 cassava	770	46
E10 potato	786	48

2.2 Preparation of Samples

Ethanol obtained from the three sources was colorless. Gasoline was used as baseline fuel in this study. It was obtained from local petrol station. Blends preparations were produced by pouring gasoline and ethanol constituents into a container and thoroughly mixing them together. 10% ethanol to 90% gasoline by volume of the three ethanol was prepared as fuel test samples. No modifications were made to the engine.

2.3 Experimental Set Up

The experimental set up consists of a four strokes, single cylinder carburettor SI engine coupled to hydraulic type dynamometer for load control. Also in position, is the instrumentation unit mounted beside the engine. In addition to the instruments for measuring the engine performance, are the air consumption box viscous flow meter and an inclined manometer, thermocouple connected to temperature meter. Torque, engine speed, airflow, fuel mass flow rate, exhaust temperature were measured. Experimental set up is shown in figure 1 while the test engine specification is shown in Tables 2.

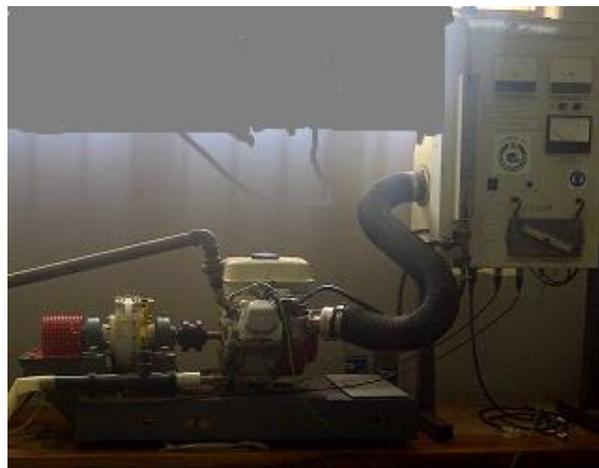


Figure 1: Experimental setup (the engine, dynamometer and instrumentation unit).

Table2: De-damak (GX200) engine specifications

Engine type	4-stroke, single-cylinder
Rated power	4.8 kW at 3600 rpm
Maximum torque	1.35 kg-m/2500 rpm
Bore/Stroke	68.00 mm/54.00 mm
Displacement vol.	196 cc
Compression ratio	8 : 1
Engine cooling	air cooled
Fuel	Gasoline

2.4 Performance Parameters

The engine performance parameters such as brake power, total fuel consumption, brake mean effective pressure, brake thermal efficiency, brake specific fuel consumption were evaluated using the following equations [16]:

Brake power (bp):

$$bp = 2\pi NT \quad \dots \quad (1)$$

Brake mean effective pressure (*bmep*):

$$bmep = \frac{2bp}{ALNn} \quad \dots \quad (2)$$

Brake thermal efficiency (η_{BT}):

$$\eta_{BT} = \frac{bp}{m_f \times Q_{net,v}} \quad \dots \quad (3)$$

Specific fuel consumption (*sfc*):

$$sfc = \frac{m_f}{bp} \quad \dots \quad (4)$$

where,

N = the speed of the engine (rpm)

T = the torque of the engine (N-m)

A = surface area of the piston (m²)

L = length of the stroke (m)

n = number of cylinders

\dot{m}_f = mass of fuel consumed per unit time (kg/s)

$Q_{net,v}$ = calorific value of the fuel (MJ/kg)

bp is the brake power of the engine (kW)

III. RESULTS AND DISCUSSION

3.1 Torque

Figure 2 shows torque developed by the test engine on various loads. Torque exhibited an increasing trend for all test fuels as load increases. Average torques of 5.46, 5.36, 5.81 and 5.64 Nm were obtained for the studied load range using E0, E10 maize, E10 potato and E10 cassava, respectively.

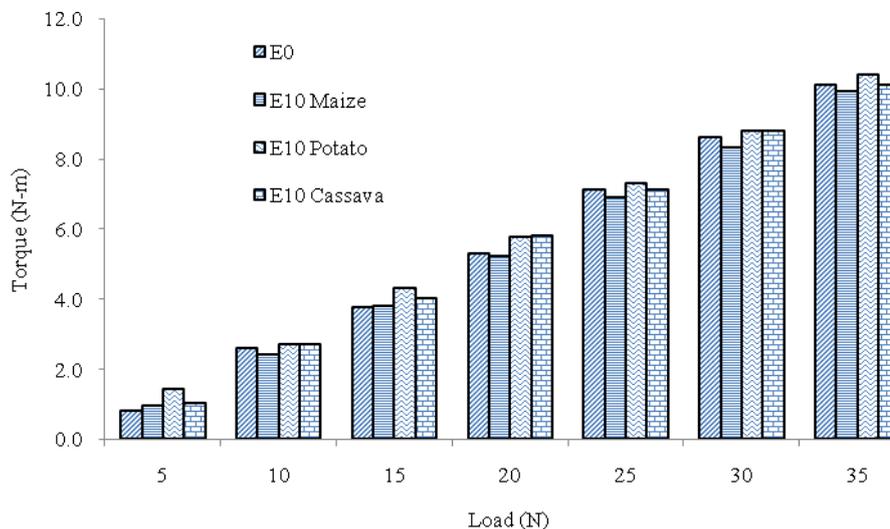


Figure 2: Engine torque against load

3.2 Brake Power (BP)

Figure 3 shows Brake Power (BP) developed by the test engine on various loads. BP exhibited an increasing trend for all test fuels as load increases. At an applied load of 15 N, BP for E10 maize, E10 potato and E10 cassava were higher by 0.8, 14.06 and 6.1 %, respectively compared with gasoline (E0). Average BPs of 118.47, 116.15, 125.97 and 122.38 kW were obtained for the studied load range using E0, E10 maize, E10 potato and E10 cassava, respectively.

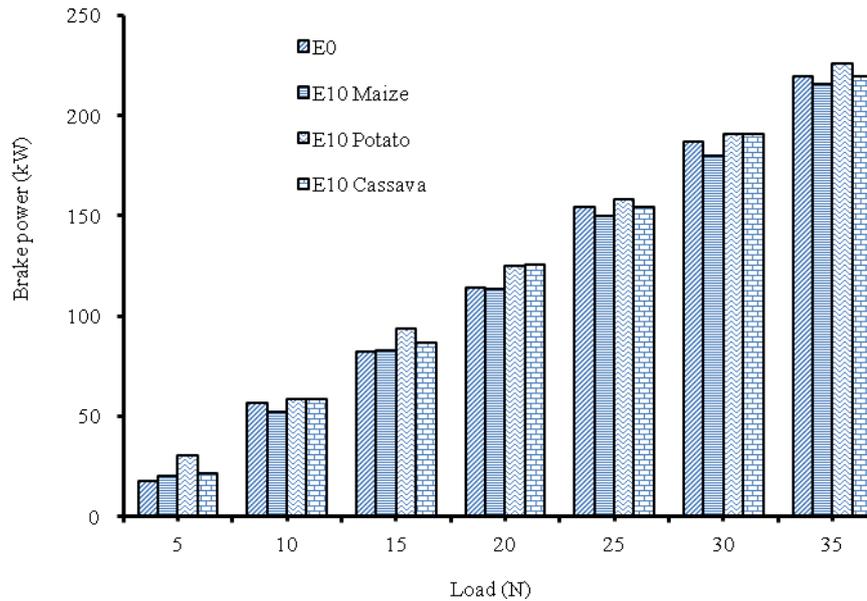


Figure 3: Brake power using ethanol blends against load

3.3 Specific Fuel Consumption (Sfc)

In figure 4, the engine Specific Fuel Consumption (SFC) decreased as applied load increased for all test fuels. Also, for all loads applied in this study, SFC reduced when compared to E0. At an applied load of 20 N, SFC for E10 maize, E10 potato and E10 cassava decreased by 18.36, 21.17 and 16.61 %, respectively compared to E0. Average SFCs of $6.32E-10$, $4.90E-10$, $4.22E-10$ and $5.22E-10$ kg/kWh were obtained using E0, E10 maize, E10 potato and E10 cassava, respectively.

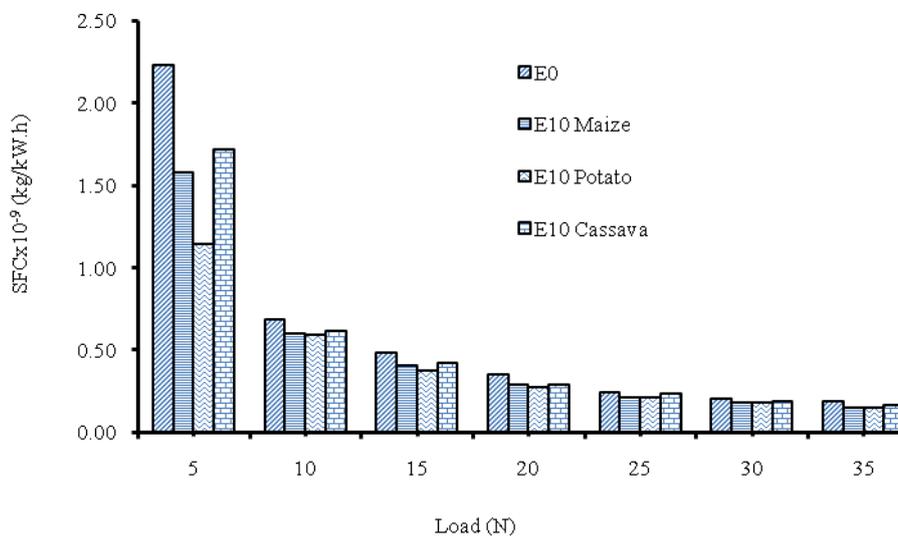


Figure 4: BSFC of ethanol blends against load

3.4 Brake Mean Effective Pressure (Bmep)

The Brake Mean Effective Pressure (BMEP) acting on the piston of the test engine increases as the load increases on the engine for all test fuels as shown in Figure 5. At applied loads 10, 20, 25, 30 and 35 N, BMEP for E10 maize reduced when compared to E0, E10 potato and E10 cassava. Average BMEP of 350.05, 343.18, 372.20 and 361.58 kN/m² were obtained using E0, E10 maize, E10 potato and E10 cassava, respectively.

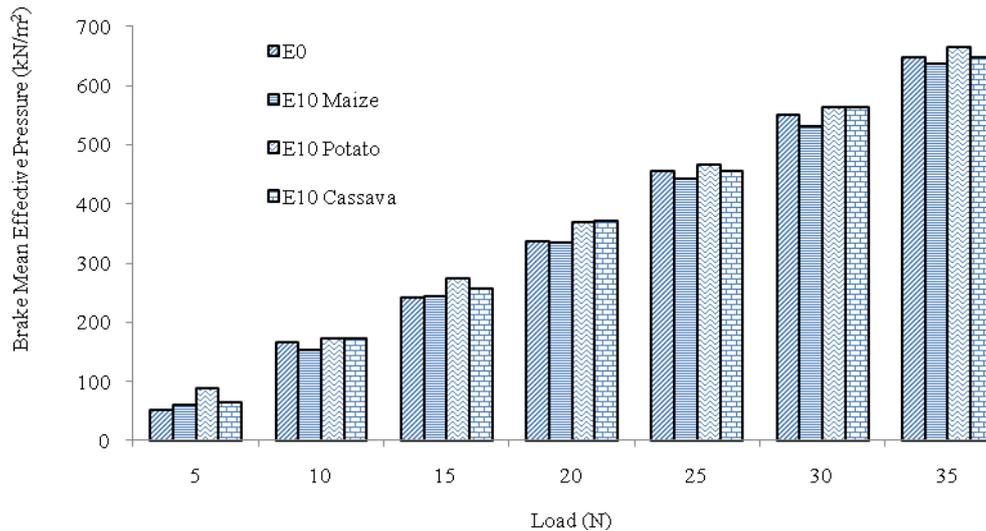


Figure 5: BMEP of ethanol blends against load.

3.5 Exhaust Temperature (ET)

Exhaust Temperature (ET) against all loads applied to test engine for E0, E10 maize, E10 potato and E10 cassava are presented in Figure 6. The ET at applied load 35 N increased for E10 maize, E10 potato and E10 cassava by 1.49, 5.97 and 1.49% respectively when compared to E0. Average ETs of 668.75, 677.50, 704.79 and 672.5°C where obtained using E0, E10 maize, E10 potato and E10 cassava, respectively.

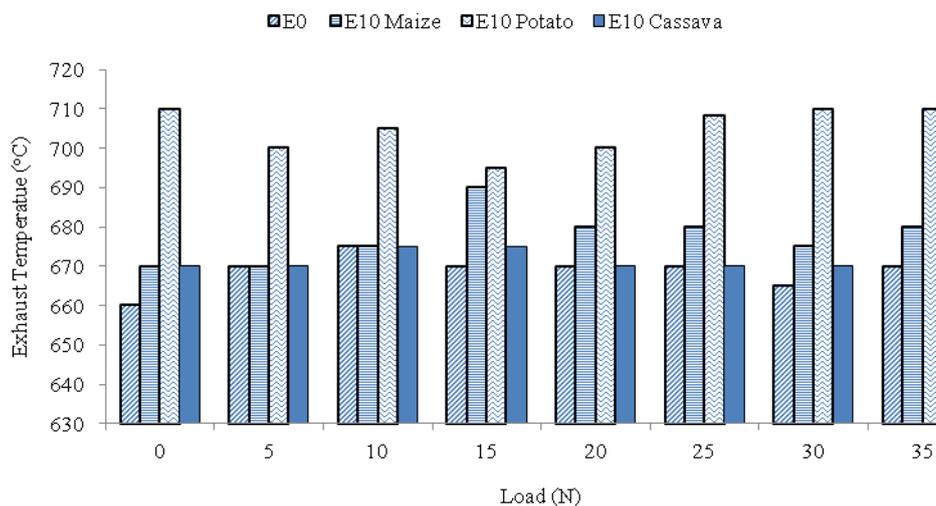


Figure 6: Engine ET versus load.

3.6 Brake Thermal Efficiency (BTE)

Figure 7 presents the effect of using fuels E10 maize, E10 potato, E10 cassava and E0 on BTE. This figure clearly indicates that BTE increases as the load on the engine increases for all test fuels. At an applied load of 35 N, BTE for E10 maize, E10 potato and E10 cassava decreased by 56.45, 34.96 and 25.90% respectively, compared to E0. Average BTE of 26.46, 39.38, 35.04 and 33.60% where obtained using E0, E10 maize, E10 potato and E10 cassava, respectively.

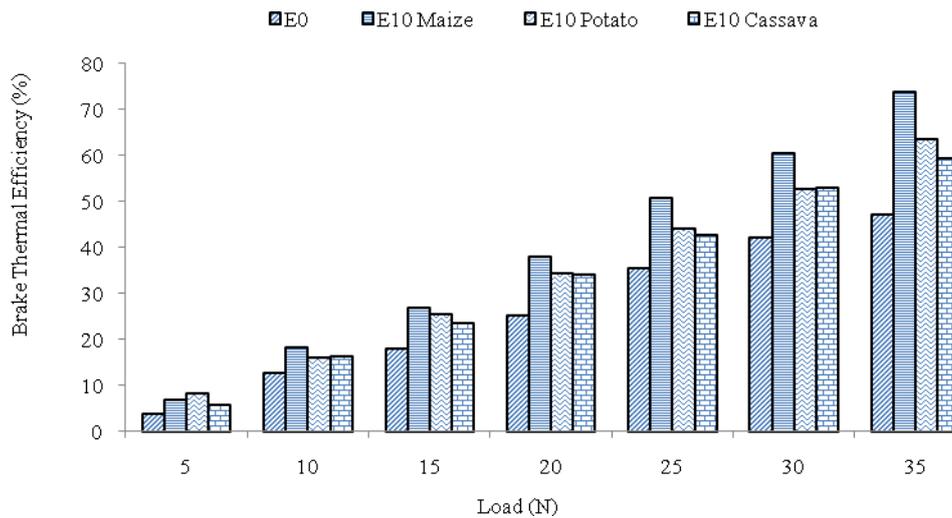


Figure 7: Variation of brake thermal efficiency with load.

3.7 Effect of Engine Torque on Specific Fuel Consumption.

Figure 8 shows the graphical relationship between engine torque and engine Specific Fuel Consumption (SFC). The figure exhibits similar trends for all test fuel samples. E0 gave maximum value of SFC to be 2.238×10^{-9} kg/kWh at torque of 0.8 N-m and minimum value of SFC to be 1.89×10^{-8} kg/kWh at torque of 7.1 N-m. E10 maize gave maximum value of SFC to be 1.58×10^{-9} kg/kWh at torque of 0.93 N-m and minimum value of SFC to be 1.49×10^{-8} kg/kWh at torque of 9.93 N-m. E10 potato gave maximum value of SFC to be 1.44×10^{-9} kg/kWh at torque of 1.4 N-m and minimum value of SFC to be 1.51×10^{-8} kg/kWh at torque of 10.4 N-m. E10 cassava gave maximum value of SFC to be 1.722×10^{-9} kg/kWh at torque of 1.0 N-m and minimum value of SFC to be 1.69×10^{-8} kg/kWh at torque of 10.1 N-m.

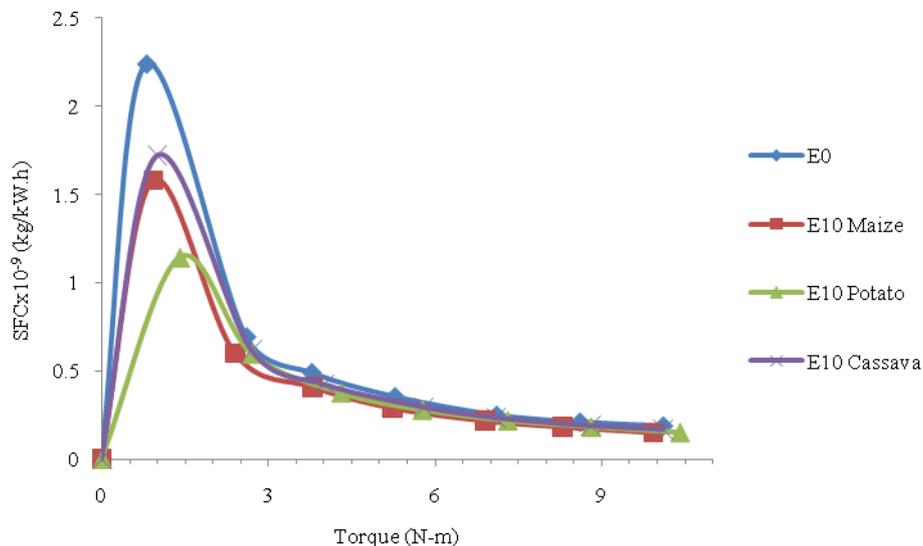


Figure 8: Effect of engine torque on specific fuel consumption.

3.8 Effect of Engine Torque on Brake Thermal Efficiency.

Figure 9 show the relationship between engine torque and Brake Thermal Efficiency (BTE). The figure exhibits almost similar trends for all test fuel samples. E0 gave maximum value of BTE to be 47.19% at torque of 10.1 N-m and minimum value of BTE to be 3.98% at torque of 0.8 N-m. E10 maize gave maximum value of BTE to be 73.84% at torque of 9.93 N-m and minimum value of BTE

to be 6.98% at torque of 0.93 N-m. E10 potato gave maximum value of BTE to be 63.69% at torque of 10.4 N-m and minimum value of BTE to be 8.43% at torque of 1.4 N-m. E10 cassava gave maximum value of BTE to be 59.42% at torque of 10.4 N-m and minimum value of BTE to be 5.84% at torque of 1.0 N-m.

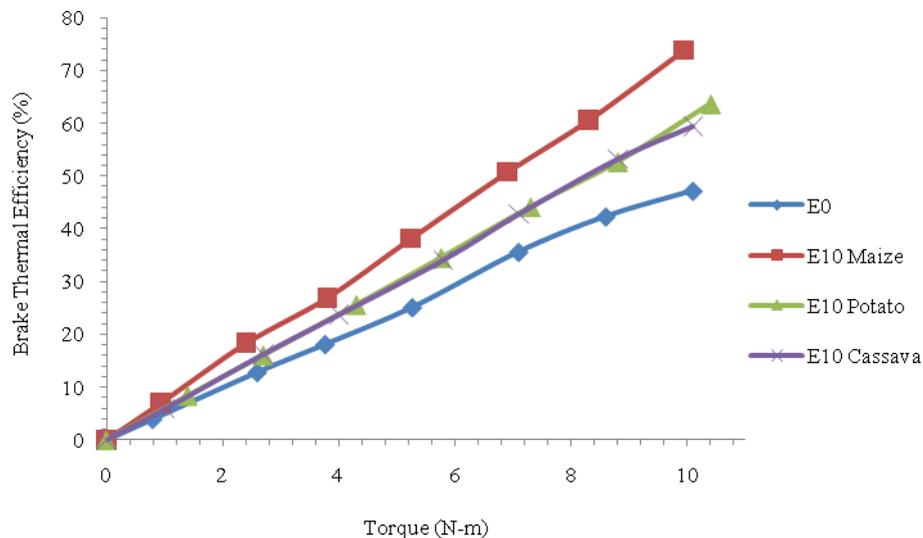


Figure 9: Effect of engine torque on brake thermal efficiency.

IV. CONCLUSION

Experimental investigations were carried out on a 4-stroke, single-cylinder, air cooled DE-DAMAK (GX200) super general engine to determine its performance parameters. In the present research, engine tests were carried out in a steady state and varying load conditions. Engine performances working with ethanol-gasoline blends as fuel were compared with its performance when it was fuelled with pure gasoline. The results obtained showed that torque output of the test engine gave an increasing trend for all test fuels. Comparatively, E10 potato gave the highest torque. Also, the test engine exhibited highest average brake power when E10 potato was used to power it than when the other fuel samples were used. Specific Fuel Consumption (SFC) decreased as the load applied on the engine increased for all fuel samples, but ethanol-gasoline blends exhibited lower SFC than pure gasoline. The least SFC was obtained using E10 potato. The highest average Brake Mean Effective Pressure (BMEP) of 372.20 kN/m² was obtained using E10 potato, while the average BMEP obtained using E0, E10 maize and E10 cassava were 350.05, 343.18 and 361.58 kN/m², respectively. The highest average brake thermal efficiency (BTE) of 39.38% was obtained using E10 maize, while the average BTEs of 26.46, 35.04 and 33.60 % were obtained using E0, E10 potato and E10 cassava, respectively in the engine. Conclusively, ethanol-gasoline blended fuels performed better than pure gasoline and the best performance was obtained using E10 potato in the engine.

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SHORT BIOGRAPHY

Surakat Ayodeji Saheed was born in Lagos State, Nigeria. He received the Bachelor in Engineering degree from the Federal University of Agriculture, Abeokuta, Nigeria in 2008 and the Master in Engineering degree from the Federal University of Agriculture, Abeokuta, Nigeria in 2013, both in Mechanical Engineering. He is to commence a Ph.D. degree with the Department of Mechanical Engineering, Federal University of Agriculture, Abeokuta, Nigeria. His research interests include material science, renewable energy and thermofluid. He is a graduate member of the Nigeria Society of Engineers and an affiliate member of National Society of Black Engineers, United State of America.



Bolaji, Bukola Olalekan is an Associate Professor of Energy and Thermo-fluid. He holds a PhD degree in Mechanical Engineering (Building Services Option). He is a Registered Engineer and member of the Nigerian Society of Engineers, Environment Behaviour Association of Nigeria and Member, Southern African Association for Energy Efficiency. He has trained a lot of students in the areas of solar thermal systems, thermo-fluids, renewable energy and environmental engineering at both undergraduate and postgraduate levels. He has consulted in a variety of industries in Nigeria on refrigeration, air-conditioning and solar power systems for over fifteen years. Currently, he is the Head of Department of Mechatronics Engineering, College of Engineering, Federal University of Agriculture, Abeokuta, Nigeria.



Olokode, Olusegun Sunday is a Senior Lecturer and Acting Head of Mechanical Engineering Department, Federal University of Agriculture, Abeokuta. He holds a PhD degree in Mechanical Engineering (Material Sciences Option) from Imperial College, London and Federal University of Agriculture, Abeokuta.



Dairo, Olawale Usman is a doctorate degree holder in Agricultural Engineering. He specializes in crop processing and utilization with more than 35 publications areas of drying kinetics, energy from crop and biomass, crop processing and food products. He is presently a senior lecturer in the Federal University of Agriculture, Abeokuta, Nigeria.

