# Effect of Butanol and Camphor Blended with Premium Motor Spirit on Performance and Emission of Spark Ignition Engine

Kaisan M.U.*, Sanusi A., Ibrahim I.U. and Abubakar S.

Department of Mechanical Engineering
Ahmadu Bello University
Zaria, Nigeria

*Corresponding email: mukaisan@abu.edu.ng

**Article history**
Received
*15 November 2019*
Revised
*23 May 2020*
Accepted
*1 June 2020*
Published
*15 June 2020*

## ABSTRACT

*To overcome the threat on environment, posed by the use of fossil fuel that leads to global warming, depletion of fossils fuels reserves, etc. Researches are on-going to find the optimum solutions in resolving some of these problems. In this research, the aim is to investigate the effect of camphor and butanol when blended with premium motor spirit (PMS) on the performance and emission of a spark-ignition (SI) engine, taking into account the physicochemical properties of the fuel mixture. A sample of B0B shows the best physicochemical properties as compared to the sole petrol (B0A) having values of 0.7572,1.3 poise, 55℃, 59℃and 1.9% for specific gravity (SG), viscosity (ŋ), flash point, fire point and iodine value (IV), respectively. The performance tests results showed that when the unleaded gasoline was blended with butanol-camphor, the engine performance decreases except for the sample with a small quantity of camphor. At two-constant torques of 3 and 6 Nm, the B0B shows results(in pair) of (468, 867) W for brake power, (1.91, 3.75) bar for brake mean effective pressure, (22.77, 12.99) kgKWh$^{-1}$ for specific fuel consumption and (36, 67) % for brake thermal efficiency, respectively. Also, the CO, CO2, HC and NOx emission concentrations in the engine exhaust also decreases as the percentage of butanol increases in the samples. Sample B15C which consists of 85%petrol, 15%butanol and 10g of camphor shows the least emission of the gases. At the two-constant torques, B15C shows a result of (0.12, 0.13) % for carbon monoxide (CO), (1.23, 1.03) % for carbon dioxide (CO2), (241, 250) ppm for the hydrocarbon (HC) and (242, 253) ppm for nitrogen oxide (NOx), respectively.*

**Keywords**: *Camphor,butanol, SI engine,emissions,gasoline*

## 1.0 INTRODUCTION

In the design and development of internal combustion(IC) engines, the engine performance parameters are very essential. These performances indicate the level of success at which the engine performs its designed task and also the rate at which it converts the fuel chemical energy into useful mechanical work [1]. The combustion of these fuel in an IC engine emits compounds such as HC, CO, NOx, SO2, and solid particles which cause adverse effects on human health and environment [2]. The effects are typically characterized as global warming, depletion of non-renewable energy resources, and environmental deterioration.

In view of finding ways to improve the efficiency and performance of these engines, fuel additives are used.One of the most commonly additives used to improve the fuel performance is oxygenates (i.e., oxygen-containing organic compounds). Many oxygenates have been put to use as fuel additives, such as methanol, ethanol, tertiary butyl alcohol and methyl tertiary butyl ether.

In the 1880s and 1890s amongst all the alcohols, ethanol was the first fuel used to power a vehicle. At the earliest stages of automobile development, Henry Ford selected ethanol to be the fuel of his choice for his automobiles. Presently, one of the alternatives to petroleum-based fuels in automobiles is ethanol. The main reason for advocating the use of ethanol is that, it can be manufactured from natural products or waste materials, unlike gasoline, which is produced from non-renewable natural resources [3]. The use of ethanol, particularly in SI engines, has become more attractive due to its relatively high-octane number and also the fact that it burns clean. It also shows good anti-knock characteristics which makes it a good additive since the early 20$^{th}$century; automotive engineers find out that engines with no knocks run more smoother and more efficient [4]. However, economic reasons still put a limit to its large-scale usage. Thereby, instead of using pure ethanol, now a blend of ethanol with gasoline is becoming more attractive fuel with good anti-knock characteristics [3]. Butanol is another alternative alcohol that could be made from the same raw materials as ethanol without increasing any additional materials, energetic expenditure or cost price. In recent years butanol has become an important alternative fuel for ICs engines, this is mainly due to its eco-friendly production method. It also has some favorable physicochemical properties as compared to ethanol, less hygroscopic, its higher flash point makes it safer in fuel tanks and for storage; it also reduces the corrosion effects in the fuel injection system [5].

The two major problems of an *Otto* cycle engine are the emission of toxic gas and incomplete combustion of fuel (petrol) in the engine. The emission of these gases causes severe adverse effects on human health and environment [6] while incomplete combustion reduces the performance of the engine. To overcome these difficulties, butanol and camphor are blended with premium motor spirit (PMS) to investigate the performance of the engine and its emission.

The main aim of this research study is to investigate the effect of butanol and camphor blended with PMS on spark ignition engine performances and emission. Camphor (*Cinnamomumcamphora*) is a white, crystalline substance with a pungent taste and a strong odor. It is produced from the wood of camphor laurel and some other related trees from the laurel family. By distillation, purification and sublimation camphor are extracted from the woods. Camphor has many applications in pharmaceutical fields, some of which are, topical analgesics, antispasmodic, antiseptic, antipruritic, anti-infective, anti-inflammatory, contraceptive, nasal decongestant, mild expectorant, cough suppressant, etc. [7].

A special note on the aspect of using butanol is described next for its importance as an alternative fuel for the IC engine.

**Butanol**

Due to high demand of environmental security, more concern is being paid to utilizing fuels that have lower emissions and also by optimizing the combustion process. Butanol has since become an important alternative fuel for IC engines this is due to its environmentally friendly production method. When compared to ethanol, butanol has favorable physicochemical properties, it is less hygroscopic, it reduces corrosion in the fuel injection system and is much safer in fuel tanks and storage than ethanol because of its higher flash point as adequately explained in [5]. Butanol is an alcohol with a four-carbon structure with the molecular formula of $C_4H_9OH$ ($C_4H_{10}O$ or $CH_3\,(CH_2)_3OH$ or $CH_3CH_2CH_2CH_2OH$). Butanol has four isomeric structure which are butan-1-ol, butan-2-ol, 2-methypropan-1-ol, 2-methypropan-2-ol [8].

Methods of producing bio-butanol (biological production of butanol) from relatively dry biomass could be sub-divided into several groups [9]:

- By fermentation of sugar substrates (which are directly derived or made from starch)
- Cellulose hydrolysis technology that uses mineral acids, enzymes and other modes then followed by the fermentation of C5/C6 sugars to bio-butanol
- Technology of dehydrating bioethanol to butanol using Sangi hydroxyapatite (HAP) catalysis
- Biomass gasification applied to synthetic gases to produce bio-butanol [10]

Experiments on the effects of camphor ethanol-petrol blends in the SI engines (on both the performance and emissions analysis) were conducted. In this study, a mixture consists of camphor and ethanol with a weight percentage ratio of (20:80) was blended with petrol in three different ratios of: 10%, 20% and 30%. A performance test was carried out on the SI engine at a constant speed. While the torque is varied using an eddy current dynamometer to evaluate the performance parameters between the blended fuel samples and the sole fuel sample, such as engine brake power, specific fuel consumption, brake thermal efficiency and volumetric efficiency, among other important parameters. For all the fuels tested, the values of CO, CO2 and HCs were noticeably reduced in the engine emissions. The addition of camphor and ethanol mixture to petrol resulted in an increase of the brake thermal efficiency (0.37%) for the fuel with 70% petrol plus 30% camphor and ethanol mixture when compared with sole fuel (petrol). Among all the fuels, the fuel consumption and specific fuel consumption against the brake power were less for fuel with 70% petrol plus 30% camphor and ethanol mixture. Further, it is understood from the above study that the heat input against the brake power was also at least 35.50 kW for fuel with 70% petrol plus 30% camphor and ethanol mixture when compared with sole fuel (40.09 kW). Also, the volumetric efficiency was higher for fuel with 80% petrol plus 20% camphor and ethanol mixture followed by fuel with 70% petrol plus 30% camphor and ethanol mixture. Finally, this study demonstrates that if the aim is to get fewer emissions of CO, CO2 and HC and higher brake thermal efficiency with less specific fuel consumption from the SI engine, then a mixture of 70% petrol plus 30% camphor and ethanol mixtureshould be used [11].

This research investigates the effect using of unleaded gasoline–higher alcohol blends on the performance parameters of a single cylinder four stroke SI engine at different compression ratios. The engine performance tests were conducted at a constant speed of around 2800 rpm. with various fuel blends like gasoline with 5% ethanol content (E5),gasoline with 10% ethanol (E10), gasoline with 5% propanol (Pr5), gasoline with10% propanol (Pr10), gasoline with 5% butanol(B5), gasoline with 10%butanol (B10), gasoline with 5%pentanol (P5), gasoline with 10% pentanol (P10) and then with unleaded gasoline (E0). The performance parameters such as the break specific fuel consumption and break thermal efficiency were also calculated at different compression ratios and then compared with values of E10 and gasoline. After analyzing the results obtained, it showed that the blend with a 10%ethanol-gasoline appeared to be the best for all measured parameters.

A research by Adebayo and Awogbemi(2013) aimed at improving the performance and emission characteristics of SI engines in which the effects of additions of ethanol to gasoline was analyzed[12]. Four sample blends of ethanol-gasoline were prepared such that the first sample is pure ethanol (100% ethanol) and the second, pure gasoline, (100% gasoline),labeled as Samples A and B, respectively. The rest of the two sampleswere prepared with Sample C having 5 % ethanol contents and 95% gasoline, while Sample D has a 10% ethanol and 90% gasoline contents. A physicochemical analysis was conducted on all of the four samples using two-stroke air-cooled SI engine. Samples B, C and D were tested in an effort to determine the performance characteristics of the engine at four different engine speeds of 800rpm, 1000rpm, 1200rpm, and 1400rpm. An exhaust gas analyzer was also put to use so as to analyze the engine emission constituent gases at zero load. Moreover, the results showed that the blending gasoline with ethanol resulted in an increase in engine thermal efficiency, torque and exhaust gas temperature while the specifics fuel consumptions decreases.

Fuel blend with 10% volume ethanol content additions shows best results for the parameters considered at all engine speeds rating.

Pukalskas *et al*. (2009) conducted a research which investigates the mixture of petrol and bio-butanol on *Otto* engines[9]. The research findings explained that, when the *Otto* engine was run with mixture of bio-butanol and petrol, there is a decrease of more than 80% of CO emission compared with similar engines run with pure petrol. It further explains thatthere is an average of 4% decrease in $CO_2$ emission when the engine runs with a mixture of 30% butanol and 70% petrol while in an event where 50% of butanol and petrol mixture blend was used, the $CO_2$ emission in the engine exhaust decreases by 14% compared to the amount released by engines that work with pure petrol. But the amount of hydrocarbon (HC) emission for the engines was decreased by 26% on average when 30% butanol and petrol was used, and 4% on average when a mixture containing 50% of butanol was used compared to the HC amount of the engine working using petrol. To generalize the results of the performed experiment, it is possible to state that the optimal mixture would consist of 70% petrol and 30% bio-butanol.

## 2.0 MATERIALS, EQUIPMENT AND METHODS

### 2.1 Materials and Equipment

The experimental apparatus and materials used during the experiment are:

1. Camphor (60g)
2. Mortal and pistol
3. Petrol (12 *l*)
4. Stop watch
5. Measuring cylinder
6. Bottles
7. Butanol (0.9 *l*)
8. Weight balance
9. Internal combustion engine(SI),*Tecquipment*
10. Gas analyzer

The engine used to carry out the test is a four-stroke single cylinder petrol engine manufactured by *Tecquipment*, Nottingham. The engine specifications are presented in Table 1 which is available at Mechanical Engineering Department, ABU, Zaria, Nigeria. The gas analyzer used was manufactured by Nanhua Guangdong, China (Mainland) and its specifications are presented in Table 2. The analyzer is available at Nigeria Institute of Transport Technology (NITT), Zaria, Nigeria.

**Table 1**: Specifications of the engine model manufactured by *Tecquipment*

| | |
|---|---|
| **Engine type** | 4-stroke single cylinder engine |
| **Weight** | 27 kg |
| **Engine capacity** | 208cc |
| **Net Power** | 4.5kW at 3600 rpm |
| **Net torque** | 12.5Nm at 2800 rpm |
| **Speed** | Approximately 3600 rpm |

**Table 2**: Specifications of the gas analyzer manufactured by Nanhua

| | |
|---|---|
| **Brand name** | Nanhua |
| **Model number** | *NHA-506EN* |

| | |
|---|---|
| **Power supply** | AC220V ±10% 50Hz ±1Hz |
| **Test** | HC, CO, CO2, O and NO |
| **Net weight** | 10 kg |
| **Warm-up time** | 10 mins |

## 2.2 Methodology

### 2.2.1 Sample preparation

Firstly, 60g of camphor was pounded from its solid crystal form to powder form. From this research, a total of 12 different samples were prepared. For the first three samples, 1L of petrol was filled into three different bottles and then 0g, 5g and 10g of camphor was added into each of those samples, respectively. These samples were labeled as B0A, B0B and B0C, respectively. For next three samples, each bottle was filled with 95% of a liter of petrol blended with 5% of a liter of butanol, each of these samples was then filled with 0g, 5g, and 10g of camphor and was labeled B5A, B5B and B5C, respectively. For the next three samples, each bottle was filled with 90% of a liter of petrol blended with 10% of a liter of butanol, each of these sample was then filled with 0g, 5g, and 10g of camphor and was labeled B10A, B10B and B10C, respectively. For the last three samples, each bottle was filled with 85% of a liter of petrol blended with 15% of a liter of butanol, each of these samples was then filled with 0g, 5g, and 10g of camphor and was labeled B15A, B15B and B15C, respectively. Table 3 depicts the nomenclatures of the samples.

**Table 2**:Nomenclatures of the samples

| S/n | Samples code | Compositions of samples | | |
|---|---|---|---|---|
| | | % of petrol per liter | % of butanol per sample | Amount of camphor(g) |
| 1. | B0A | 100 | - | - |
| 2. | B0B | 100 | - | 5 |
| 3. | B0C | 100 | - | 10 |
| 4. | B5A | 95 | 5 | - |
| 5. | B5B | 95 | 5 | 5 |
| 6. | B5C | 95 | 5 | 10 |
| 7. | B10A | 90 | 10 | - |
| 8. | B10B | 90 | 10 | 5 |
| 9. | B10C | 90 | 10 | 10 |
| 10. | B15A | 85 | 15 | - |
| 11. | B15B | 85 | 15 | 5 |
| 12. | B15C | 85 | 15 | 10 |

### 2.2.2 Determination of the physicochemical properties of the samples

The fuel specification that defines and sets the quality standards of the fuel is known as the physicochemical properties of the fuel. These properties include but not limited to: specific gravity, viscosity, calorific value, flash point, cetane number, volatility, and acid value, saponification value as given by Kaisan *et al.*[13-15]. This research determined five physical properties related to the specific gravity, viscosity, flash point, fire point, and iodine value of each blend using the apparatus and equipment in the chemical engineering laboratory of Ahmadu Bello University, Zaria, Nigeria. The procedures to determine these properties are givenas follows:

**1. Specific gravity (SG)**

A small empty bottle wheight was first determined using a digital electronic weighing balance. The weight of the bottle when filled to the brim with water and for each sample (fuel) was also determined using the weighing balance. The value of the SGwas determined using the equation:

$$\text{SG} = \frac{W_2 - W_1}{W_3 - W_1} \tag{1}$$

Where,

$W_1$ : Weight of the empty bottle
$W_2$ : Weight of bottle + fuel
$W_3$ : Weight of bottle + water

**2. Absolute viscosity**

The viscometer was placed in a 1000ml measuring cylinder filled to mark with water and regulated to the appropriate temperature. The tube was then filled up to a graduation mark over the left storage bulb with the sample. The sample was then sucked up to fill the higher storage bulb in the right left of the tube and then released. The time taken for the sample to flow from the upper mark to the lower was observed and calculated. The same procedure was repeated using water which was taken as reference. The relevant equation is:

$$Absolute\ viscosity(\eta) = \frac{t - t_0}{t_0} \tag{2}$$

Where,

$t$ : Time of flow of the sample
$t_0$ : Time of flow of the reference (i.e., water in this case)

**3. Flash point**

An improvised method was used for this determination. A 100ml conical flask was filled to a specific level (10ml) with the sample and was heated at a slow constant rate on the hot plate. The flash point was taken at the lowest temperature when an application of the test flame that caused the vapour above the sample to ignite.

**4. Fire point**

An improvised method was also used for this determination. A conical flask of 100ml capacity was filled to a certain specific level (10ml) with the sample was heated at a constant slow rate on a hot plate. The fire point was recorded at the lowest temperature at a point when an application of tests flame that caused the sample to ignite and burn.

**5. Iodine value (IV)**

Several methods are available for iodine value determination but the *Hanus* method (association of an analytical chemist in 1975) was used in this work. 1g of the sample was put in a 250ml conical flask followed by 30ml *Hanus* solution and the flask stoppered. The contents were mixed and kept in a drawer for exactly 30 mins. It was then titrated against a 0.1$Na_2S_2O_3$ until the whole solution becomes light yellow. A 2ml of 1% starch indicator was again added and titration continued until the blue color of the starch indicator dissappeared. A blank determination was also carried out under the same conditions and the IV calculated as thus:

$$\text{IV} = \frac{(B - S) \times 12.69 \times N}{W} \tag{3}$$

Where,

| | | |
|---|---|---|
| *B* | : | Blank titre |
| *S* | : | Sample titre |
| *N* | : | Normality of $Na_2S_2O_3$ |
| *W* | : | Weight of the sample |

### 2.2.3 FTIR analysis of camphor

Fourier transform infrared (FTIR) spectroscopy, which is also known as FTIR analysis or simply FTIR spectroscopy. This technique can be used to determine the structural changes and thermal stability of organic, polymeric, and in some cases an inorganic material[16]. For these works, FTIR was used to assess the chemical properties of the camphor. When carrying out the test, a little sample of powder camphor was dropped on the machine (*Agilent Technologies Cary 630* FTIR) and then the result for the test was displayed by the machine. The test was carried out in the Department of Chemistry Science (multi-user laboratory), Ahmadu Bello University, Zaria, Nigeria.

### 2.2.4 Experimental procedure for performance and emission tests

A four-stroke single cylinder petrol engine was used to carry out the performance and emission tests. To carry out the performance, a dynamometer rotor was coupled to the engine output shaft which was braked by the application of mechanical friction;the energy generated from the engine was converted to a heat energy, therefore the dynamometer has to be kept adequately cooled. The opposite torque exerted on the stator was being measured by an electronic device Before initiating the tests, the engine was started after it has been filled with 100ml of pure petrol and then it was run and allowed to be warmed for about 10 mins. To start the engine, the power was first switched on and then the choke lever was pushed down to close the choke, and the engine throttle was slightly opened and the starting handle at the left of the engine was pulled until the engine was fired.

To test the emission and performance of the samples, the engine was tested at a pair of constant torques of 3 and 6Nm. For sample B0A, 8ml of it was filled to the engine and then the first test condition (i.e., 3Nm) was set by opening the engine throttle and also increasing the flow of water into the dynamometer until the engine attained the torque. When the condition has stabilized, the readings of the performance parameters and the emission gases were taken. The throttle was further opened until the torque reached 6Nm before it was then stabilized and the reading was also recorded. These procedures were repeated for all the samples and their readings taken. The parameters measured for the engine performance are brake power, brake mean effective pressure (BMEP), specific fuel consumption, thermal efficiency and temperature of the exhaust air. For the emission test, the gases measured were HC, CO, $CO_2$ and $NO_X$. A schematic diagram of the experimental set-up can be sen in Figure 1.

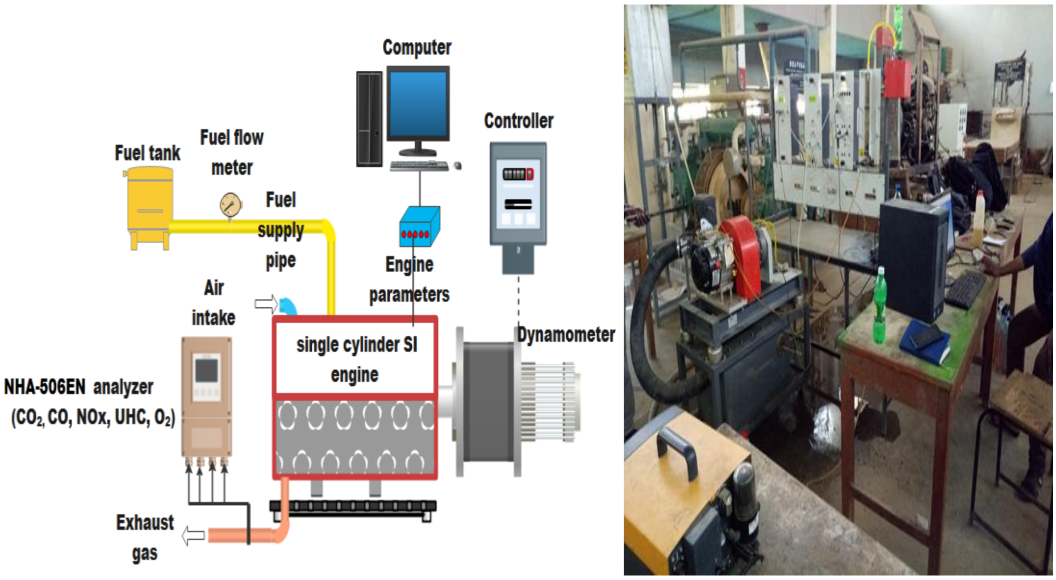


**Figure1**: Schematic diagram and the experimental setup

## 3.0 RESULTS AND DISCUSSION

### 3.1 FTIR Results for Camphor (Naphthalene Ball)

To determine the functional groups of camphor, the FTIR experiment was performed. The FTIR result obtained from the experiment is shown in Figure 2.

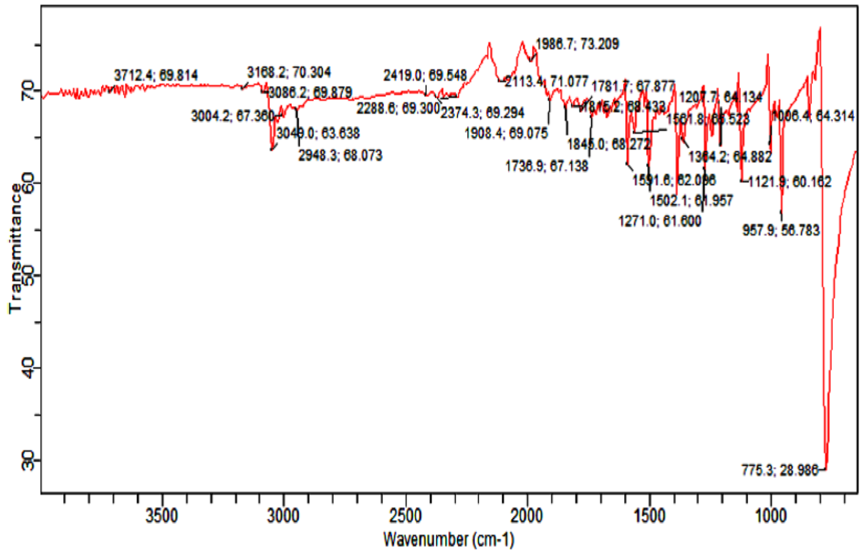


**Figure 2**: FTIR result for the camphor

Using a simplified infrared chart, it is seen from Figure 2that the functional groups for camphor at 775.3, 957.9, 1006.4, 1121.9, 1271.0, 1364.2, 1591.6, and 3049.0 peak wave numbers show that the sample consists of C-H, C-O, N-H, C-N, S=O and C-X bonds.

### 3.2 Results of the Physicochemical Properties of the Samples

The physicochemical properties test of the sampleswas carried out and the result for each sample was presented and discussed in the following sub-sections. The physicochemical properties tested are the specific gravity, viscosity, flash point, fire point and iodine value.

#### 3.2.1 Specific gravity

This is the ratio of the specific weight of the liquid/fuel to the specific weight of a standard fluid as given in [17]. The SGresult obtained from the procedure stated is presented in Figure 3.

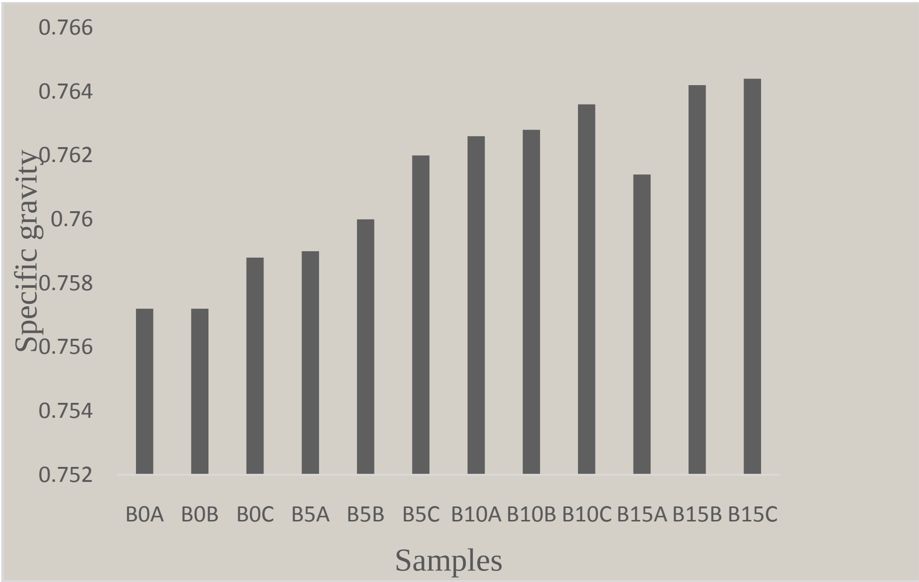


**Figure 3**: SG of the samples

From Figure 3, it can be seen that the sample with the least SGare the first two samples B0A and B0B with a value of 0.7252. This is because the SG of petrol is less than the SGof both butanol and camphor.

The inference at this point is that, the eminence of atomization of the petroleum fuel, mixing of the fuel, incineration and fuel precipitations can be improved in the petrol engine by using these butanol and camphor blends. This is in concordance with the verdicts reported in [18-21]. In all cases, the SG rate of the pure fuel was lesser than that of the clean biofuel and mixtures. This infers that mixing the butanol and camphor in petroleum fuels increases the SG of the fuel, indicating that the gasoline blends provide improved atomization, ignition, and air-fuel intermingling tendency than pure petrol.

Additionally, the SG of the fuels increases with the increase in the concentration of butanol and camphor in the blends. This is obvious in the blend of B0C, B5A, B5B, B5C, B10A, B10B, B10C, B15A, B15B, B15C although with a slight drop in SG of B15A which has 15% butanol but with no camphor additive. This is as a result of the circumstance shown earlier, since butanol has greater density than the standard gasoline, then the combination will continually have greater density than the gasoline fuel, and hence, this accounted for the higher SG values in the blend. These results are antagonistic to the outcomes of Rahman *et al*. (2018) where the density of rice bran oil biodiesel was lower than the density of the fossil diesel [22]. The likely reason for the drop in the SG of B15A is the increase in concentration of the butanol which may lead to some shifts in equilibrium of the mixture. Additionally, the absence of camphor which could have served as a stabilizer may be the second reason why there is a drop in the SG of that sample.

#### 3.2.2 Viscosity

This is the property of a fluid which determines its resistance to shearing stresses. It is also defined as the measure fluid internal friction which causes resistance to the flow [17]. The viscosity results obtained from the procedure stated is presented in Figure 4.

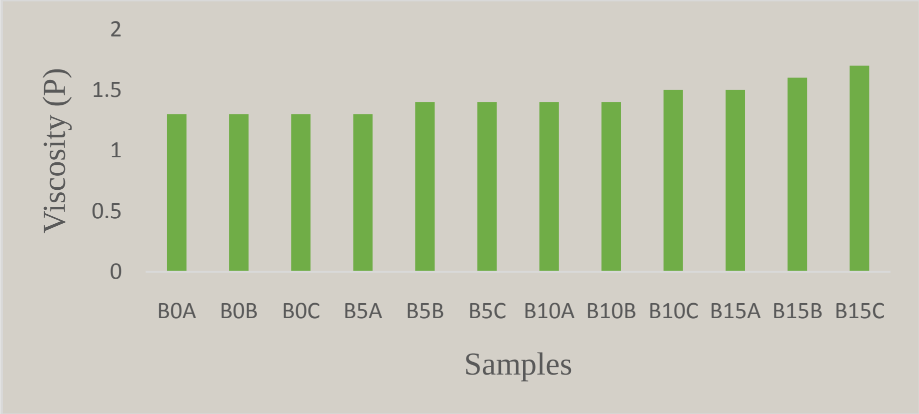


**Figure 4**: Viscosity of the samples

From Figure 4, it can be seen that the samples with the least viscosity are B0A, B0B, B0C and B5A with a value of 1.3poise.This is because the viscosity of petrol is less than the viscosity of butanol. Hence, the mixture of these two compounds increases the viscosity of the sample.

The kinematic viscosity of the fuels and blends are close in values to those of the pure gasoline fuel. The implication here is that these blends will burn perfectly in spark ignition engines with sufficient fuel atomization devoid of any effect on the operation of fuel injection system, formation of suites of engine deposits. The average low viscosities of B0A, B0B, B0C, and B5A make it possible to pump and achieve fuel droplets in the injection system of the diesel engine. These findings are consistent with the results and analyses in [21-25].Thekinematic viscosity is the most important property of fuel because it influences the operation of the fuel injection system[26]. In real life engine, viscosity is determined by measuring the quantity of fuels passing through the orifice of specified diameter.

### 3.2.3 Flash point

This is known as the lowest temperature, at which the vapor of the samples will momentarily caught with fire in the form of a flash under the specific condition of test. The flash point was determined using the procedure stated and the result is in Figure 5.

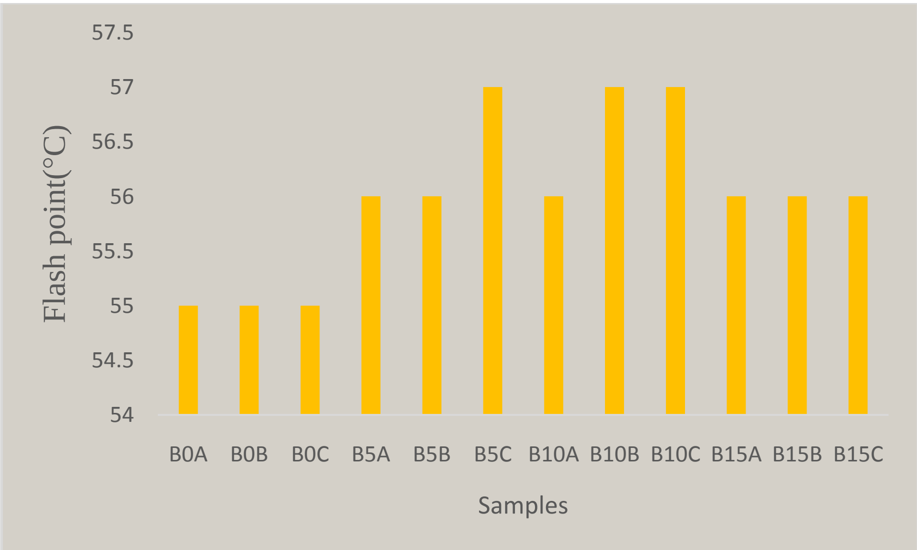


**Figure 5**: Flash point of the samples

From Figure 5, it can be seen that the samples with the quickest flash point are B0A, B0B and B0C with a flash point temperature of 55℃.

The implication of the above analyses is that, all the blends are safe to handle and camphor blends are deemed the safest. This conforms to the findings in [20, 25-28] on similar experiments with biodiesel fuel blends. According to Salaheldeen *et al*. (2015),a flash point is the measure of flammability of fuel; high flash point indicates low volatility [29]. The high flash point leads to the formation of carbon deposits and inferior cooking [30]. Therefore, the camphor blended fuels have higher tendency of being safely handled and combusted in in spark ignition engines devoid of volatility, inferior cooking, and carbon deposits and can be transported safely with less flammability.

### 3.2.4 Fire point

This is the also the lowest temperature but at which the sample gets ignited and burns out under specified condition of the test. The fire point was determined using the procedure stated and the result is presented in Figure 6.

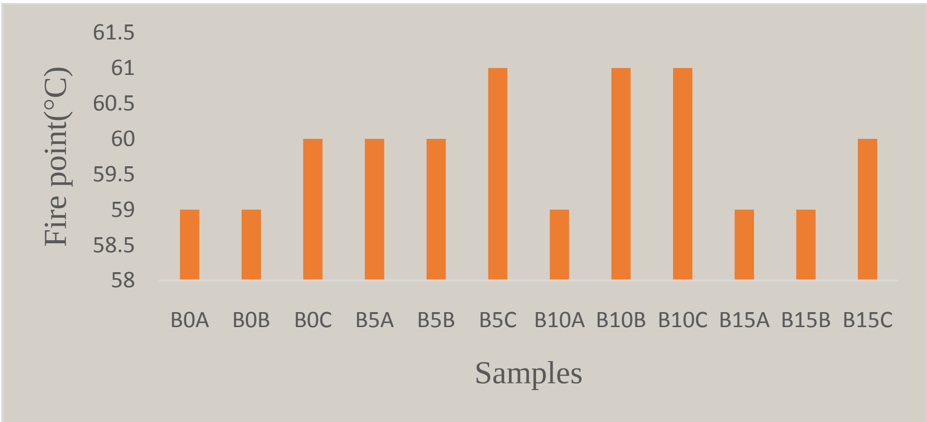


**Figure 6**: Fire point of the samples

From Figure 6, it can be seen that the samples with the quickest fire point are B0A, B0B, B10A, B15A and B15B with a flash point temperature of 59℃.

### 3.2.5 Iodine value

This is the amount of unsaturation in the fuel (petrol). This unsaturation is in form of a double bond. The higher the iodine number or value the more C=C bonds in the sample. Figure 7shows the iodine value in the samples.

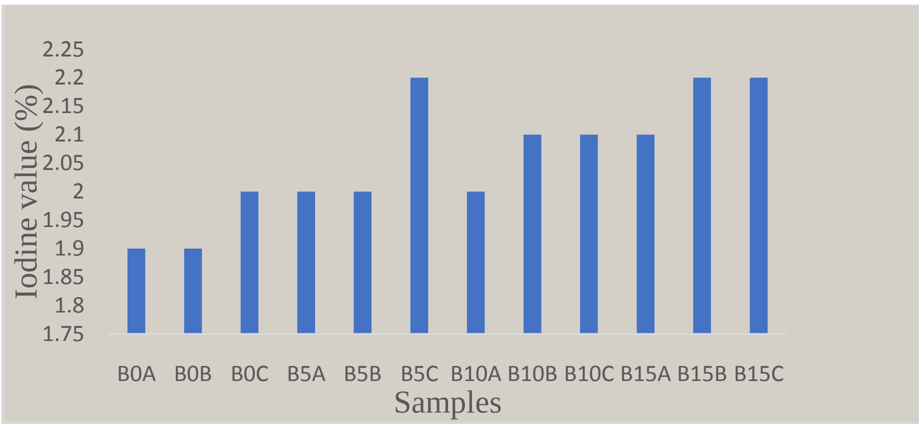


**Figure 7**: Iodine value of the samples

From Figure 7, it can be seen that the samples with the highest iodine value are B5C, B15B and B15C with the percentage of 2.2%.

### 3.3 Results ofthe Engine Performance

The engine performance test of the sample was carried out at two constant torques and the result for each of the samples at these torques is presented and discussed in the following sub-sections. The engine performances tested are brake power, brake mean effective pressure, specific fuel consumption, thermal efficiency and exhaust temperature.

#### 3.3.1 Brake power

Brake power is the main usable power output of an engine, excluding the power required to fuel, lubricate, heat the engine, circulate coolant to the engine, or operate after-treatment devices. The effect of the camphor-butanol-petrol blends on the brake power at the two constant torques (3and 6Nm) is shown in Figure 8.

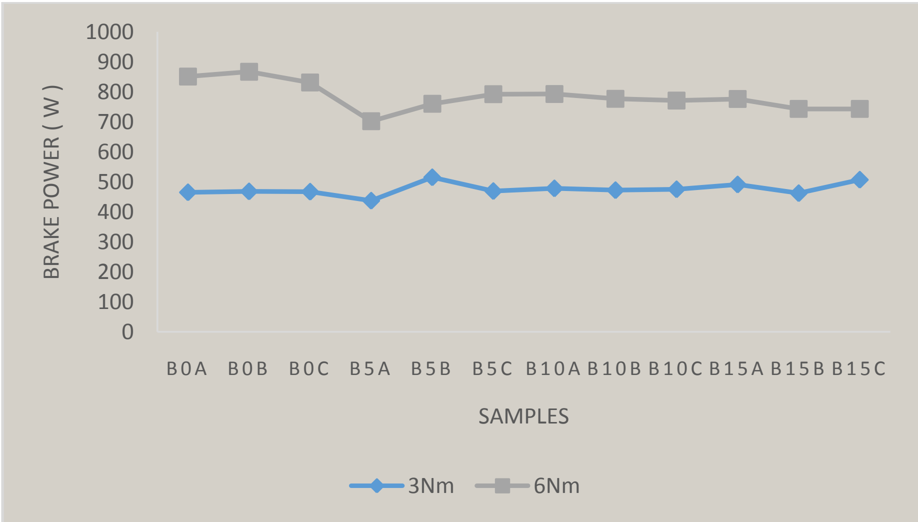


**Figure 8**: Brake power of the samples at 3and 6Nm

From Figure 8, it is evident that with small amounts of camphor to the PMS the higher the value of the brake power. Butanol at the other end, reduces the brake power as can be seen from Figure 8that the brake power of the sole petrol is much greater than those blended with some percentage of butanol. Also, from the results obtained, the sample with the highest brake power at 3Nm is B5B with a value of 515W, while the sample with the highest brake power at 6Nm is B0B with a value of 867W.

#### 3.3.2 Brake mean effective pressure (BMEP)

This is an average or mean pressure which, if applied uniformly on the piston from top to bottom of each power stroke, would produce the measured power output. The effect of the camphor-butanol-petrol blends on the BMEP at the two constant torques (3and 6Nm) is shown in Figure 9.

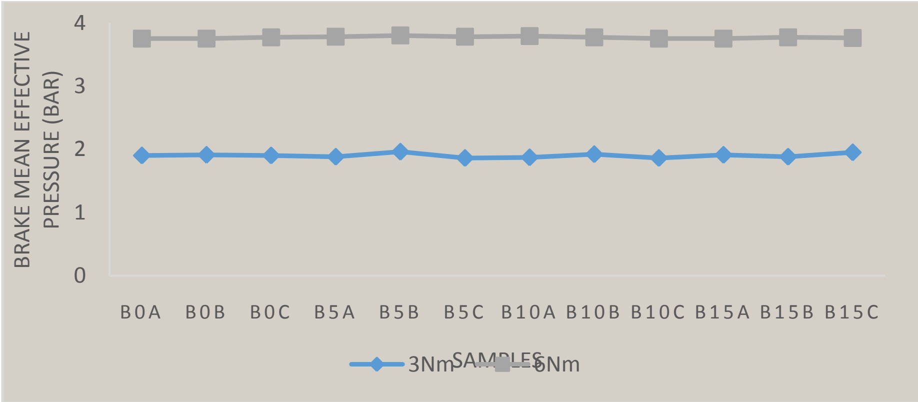


**Figure 9**: Brake mean effective pressure of the samples at 3 and 6Nm

From Figure 9, it is seen that the higher the torque supplied by the engine, the higher the BMEP is produced. Also, the smaller the amount of camphor in the blend causes a higher BMEP. Meanwhile, the higher the percentage of butanol results in the correspondingly higher BMEP. From the results obtained, sample B5B shows the highest BMEP at the two constant torques with a value of 1.96 and 3.8 bar, respectively.

### 3.3.3 Specific fuel consumption

This is the ratio of fuel mass flow rate into the engine to the engine brake power. The effect of the camphor–butanol-petrol blends on the specific fuel consumption at the two constant engine torques (3 and 6Nm) is shown in Figure 10.

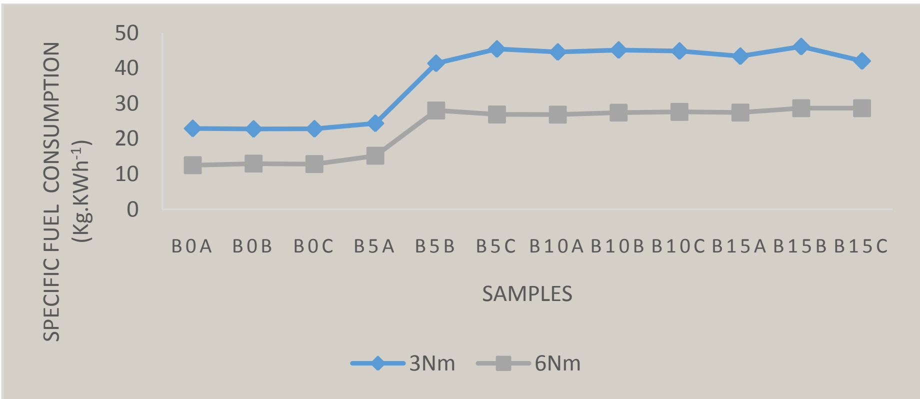


**Figure 10**: Specific fuel consumption of the samples at 3 and 6Nm

From Figure 10, it is evident that the sample with the minimum specific fuel consumption at 3Nm torque is the sole petrol sample (B0A) with a value of 22.72 kg $kWh^{-1}$ whiles at 6Nm, sample B0B has a value of 12.52 kg $kWh^{-1}$. These show that the addition of these blends to the sole petrol increases the specific fuel consumption of the engine.

### 3.3.4 Brake thermal efficiency

This is the ratio of engine brake power to the fuel energy input. Figure 11 shows a graphical presentation of brake thermal efficiencies of respective blends at 3 and 6Nm.

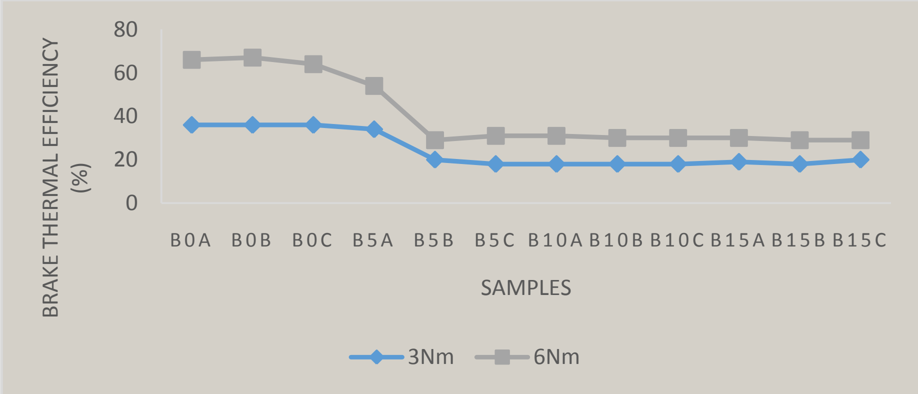


**Figure 11**: Brake thermal efficiency of the samples at 3 and 6Nm

From Figure 11, it is evident that engine brake thermal efficiency is greatly reduced as the percentage of butanol increase. It was also observed that for a small amount of camphor, there was a little increase in the brake thermal efficiency. From the results, it was found that the sample with the highest brake thermal efficiency is sample B0B with a brake thermal efficiency of 45 and 67% at the torques of 3 and 6Nm, respectively.

### 3.4 Emissions Test Results

The emission test was carried out using a gas analyzer which measured the concentration of the exhaust gases at two constant torques. The test was carried out on all the samples and the readings for some of the emitted gases were recorded. The gases recorded are CO, $CO_2$, HC and $NO_X$ and the results obtained were plotted and discussed in the following sections.

#### 3.4.1 Carbon monoxide (CO)

CO is produced in an internal combustion engine due to insufficient oxygen to produce $CO_2$.The effect of camphor–butanol-petrol blends on CO emission is shown in Figure 12.

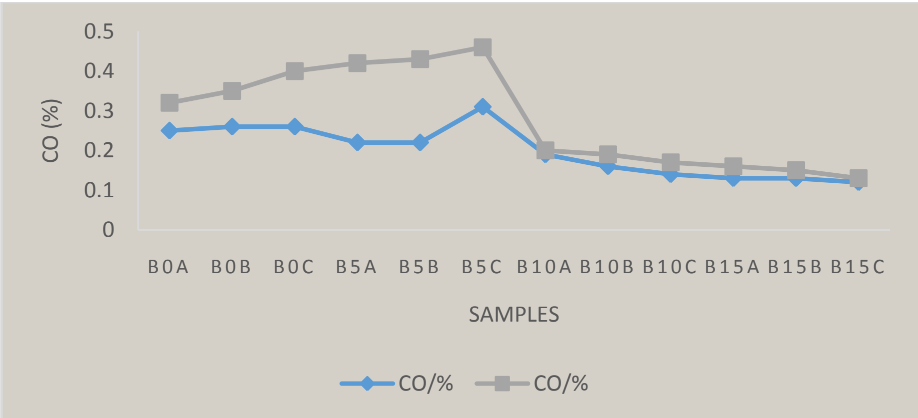


**Figure 12**: CO emission of the samples at 3 and 6Nm

It is seen from Figure 12that the percentage of CO increases for the first three samples (B0A, B0B and B0C) at the two constant torques. This is due to the addition of camphor to the sole petrol which increases the carbon content of the sample. For the next three samples (B5A, B5B and B5C) at a constant torque of 3Nm, the percentage of CO of these samples decreases at first due to the high percentage of butanol which contains some percentage of oxygen, but as the percentage of camphor increases in these samples the percentage of CO increases simultaneously. For the 6Nm torque, the percentage of CO increases throughout the samples. Further, it is obvious from Figure 12 that the CO emission for the remaining samples followed a very close trend, i.e., it decreases as the percentage of butanol increases. Finally, the best sample with the least CO emission was found to be B15C with a CO emission of 0.12% and 0.13% at 3and 6Nm, respectively.

### 3.4.2 Carbon dioxide ($CO_2$)

The formation of $CO_2$in the emitted gases indicates the complete combustion of the fuel in the combustion chamber. The effect of the camphor-butanol-petrol blends on the $CO_2$ is shown in Figure 13.

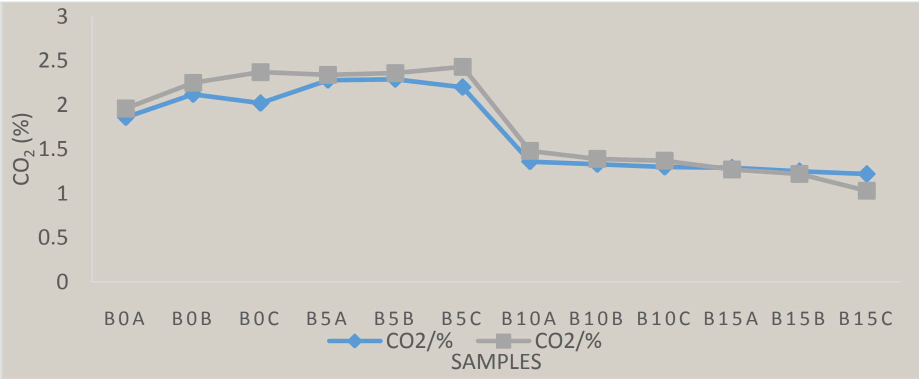


**Figure 13**: $CO_2$ emission of the samples at 3 and 6Nm

It is evident from Figure 13 that the higher the percentage of butanol, the lower the amount of $CO_2$ isemitted. It is also seen that, the higher the amount of camphor in the sample, the higher is the $CO_2$emission. From the result, it was found that the sample with the least emission of $CO_2$ for the two constant torques was for sample B15C which has a value of 1.22 and 1.03% of $CO_2$ for 3and 6Nm torques, respectively.

### 3.4.3 Hydrocarbons (HC)

HCs are organic compounds that consist of entirely two mean elements (i.e., hydrogen and carbon). The emitted HCs in the engine emissions are as a result of the unburned HCs, which were not combusted during the combustion process of the fuel (petrol) in the engine in the combustions chamber. The effect of the camphor-butanol-petrol blends on HC is shown in Figure 14.

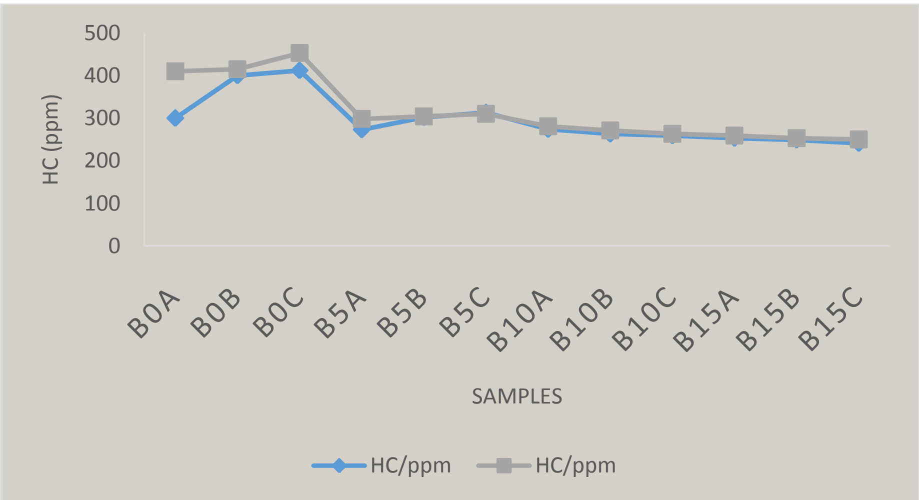


**Figure 14**:HC emission of the samples at 3 and 6Nm

From Figure 14, it is shown that the higher the percentage of butanol the lower the amount of HC emitted. It is also seen that, the higher the amount of camphor in the sample the higher the emission of HC. From the result, it was found that the sample with the least emission of HC for the two constant torques was for sample B15C which has a value of 241 and 250 ppm of HC at 3and 6Nm torques, respectively.

### 3.4.4 Nitrogen oxide (NOx)

This is a general term used to define nitrogen oxides that are most relevant for causing air pollution; they are nitric oxide (NO) and nitrogen dioxide ($NO_2$). $NO_X$ is produced in SI engine due to the combustion of air which contains some percentage of nitrogen and oxygen. The effect of the camphor-butanol-petrol blends on the emission of nitrogen oxide is shown in Figure 15.

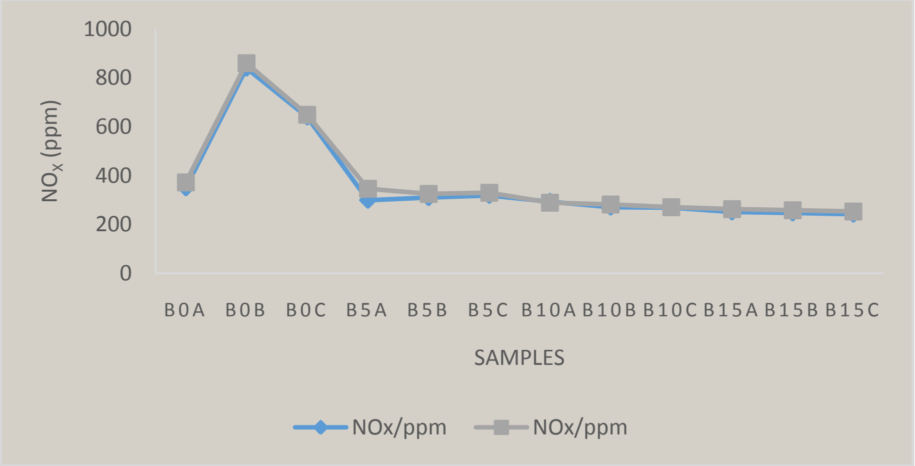


**Figure 15**: $NO_x$ emission of the samples at 3 and 6Nm

It is evident from Figure 15 that the higher the percentage of butanol and camphor in the blend, the lower the emission of $NO_x$. Also, it was observed that the amount of $NO_x$ emitted was insignificantly dependent on the torque run by the engine. Hence, from the result obtained, the sample with the least emission of $NO_x$ was for sample B15C with a value of 242 and 253 ppm at 3and 6Nm, respectively.

## 4.0 CONCLUSION

In this research study, the experiments were carried out using blends of butanol and camphor with gasoline. Subsequently, physiochemical, performance and emission analysis were conducted and the results were equally discussed. It was based on the experimental results that the following major conclusions have been made. From the physiochemical test, it was evident that the blends increase the physiochemical properties of the blends. Hence, the sample with the best physicochemical properties was sample B0A (100%petrol-0%butanol-0g camphor) with the recorded values of 0.7572, 1.3poise, 55℃, 59℃ and 1.9% related to the specific gravity, viscosity, flash point, fire point and iodine value, respectively.

The performance test shows that all the blends significantly decreases the performance of the engine except for sample B0B which has better engine performance at the two constant torques compared to the sole petrol condition. For the tests based on a pair of constant torques,sample B0B shows a result of (468, 867) W for the brake power, (1.91, 3.75) bar for the brake mean effective pressure, (22.77, 12.99) $kgKWh^{-1}$ for specific fuel consumption and (36, 67) % for brake thermal efficiency, respectively.

The emission test shows that there is a significant decrease in the emission of blends containing a high percentage of butanol. Sample B15C which consists of 85%petrol, 15%butanol and 10g of camphor shows the least emission of the gases. At the two-constant torques, B15C shows a result of (0.12, 0.13) % for carbon monoxide (CO), (1.23, 1.03) % for carbon dioxide ($CO_2$), (241, 250) ppm for hydrocarbon (HC) and (242, 253) ppm for nitrogen oxide ($NO_x$), respectively. Hence, in order to reduce effect of global warming, depletion of fossil fuel reserves, and environmental deterioration sample B15C could be used as an alternative source of fuel.

## REFERENCES

1. Kaisan M.U., Anafi F.O., Nuszkowski J., Kulla D.M. and Umaru S., 2017a. Calorific Value, Flash Point and Cetane Number of Biodiesel from Cotton, Jatropha and Neem Oil Binary and Multi-Blends with Diesel, *Biofuels*, 8(4):1-7.
2. Senthil R., Arunan K., Silambarasan R., Pranesh G. and Samuel P., 2015. Effect of Fuel Additives on Performance Improvement and Emission Control in Diesel Engines, *International Journal of Applied Engineering Research*, 10(38): 29345-29350.
3. Al-Hasan M., 2003. Effect of Ethanol–unleaded Gasoline Blends on Engine Performance and Exhaust Emission, *Energy Conversion and Management*, 44: 1547–1561.
4. Nadim F., Zack P., Hoag G. and Liu S., 2001. United States Experience with Gasoline Additives, *Energy Policy*, 29: 1-5.
5. Sattar J., Andrew P. and Yusaf T., 2018, The Impact of Injector Hole Diameter on Spray Behaviour for Butanol-Diesel Blends, *Energies*, 1-12.
6. Guttikunda S., 2009. Daily Dose of Air Pullution. Retrieved from: http://urbanemmissions.blogspot.com. [Accessed on 1 December 2019].
7. Hamidpour R., Hamidpour S., Hamidpour M. and Shahlari M., 2013. Camphor (Cinnamomum camphora), a Traditional Remedy with the History of Treating Several Diseases, *International Journal of Case Reports and Images*, 86-89.
8. Pubchem, 2018 June 6. Retrieved from: http://pubchem.ncbi.nlm.nih.gov/compound/1-butanol. [Accessed on 1 December 2019].
9. Pukalskas S., Bogdanovičius Z., Sendžikiene E., Makarevičiene V. and Janulis P., 2009. The Mixture of Biobutanol and Petrol for Otto Engines, *Transport*, 24(4): 301-307.
10. Sankar S., Praveen M., Manivarma K., Abhilash O., Akhil D. and Manivarma K., 2016. Experimental Study on the Effects of Camphor Ethanol Petrol Blends in a Spark Ignition Engine, *Performance and Emissions Analysis*, 6(1): 19-28.
11. Kothare C., Kongre S. and Bhope D., 2016. Experimental Investigation of Effect of Gasoline Higher Alcohol Blend on Performance Characteristic of Four Stroke Spark Ignition Engine at Variable Compression Ratio, *Procs. of International Conference on Electrical, Electronics, and Optimization Techniques*, 27-33.
12. Adebayo A. and Awogbemi O., 2017. Effects of Fuel Additives on Performance and Emission Characteristics of Spark Ignition Engine, *European Journal of Engineering Research and Science*, 2: 30-35.
13. Kaisan M.U. and Pam G.Y., 2013. Determination of Engine Performance Parameters of a Stationary Single Cylinder Compression Ignition Engine Run on Biodiesel from Wild Grape Seeds/ Diesel Blends, *Journal of Energy, Environment & Carbon Credits*, 15-21.
14. Kaisan M.U., Anafi F.O., Nuszkowski J., Kulla D.M. and Umaru S., 2017b. Calorific Value, Flash Point and Cetane Number of Biodiesel from Cotton, Jatropha and Neem Oil Binary and Multi-Blends with Diesel, *Biofuels*, 8(4):1-7.
15. Kaisan M.U., Anafi F.O., Nuszkowski J., Kulla D.M. and Umaru S., 2017c. Performance Evaluation of Binary and Multi-Blends of Biodiesel from Cotton, Jatropha and Neem Oils in Multi Cylinder CI Engine, *African Journal of Renewable and Alternative Energy*, 2(1).
16. Slqsarczyk A., Paluszkiewicz Z. and Czeslewa P., 2005. FTIR and XRD Evaluation of Carbonated Hydroxyapatite Powders Synthesized by Wet Method, *Journal of Molecular Structure*,11:658-660.
17. Rajput R., 2011. *Fluid Mechanics and Hydraulic Machines*, Delhi: S.Chand & Company Ltd.

18. Kaisan M.U., Anafi F.O., Nuszkwoski J., Kulla D.M. and Umaru S., 2017c. Exhaust Emissions of Biodiesel Binary and Multi-Blends from Cotton, Jatropha and Neem Oil from Stationary Multi Cylinder CI Engine, *Transportation Research Part D: Transport and Environment*, 53(2017): 403-414.
19. Sani S., Kulla D.M., Kaisan M.U. and Liman B.M., 2017. Production of Citrullus Lanatus Derived Biodiesel and Gas Chromatography Mass Spectroscopic Analyses, *African Journal of Renewable and Alternative Energy*, 2(3).
20. Kaisan M.U., Abubakar S., Ashok B., Dhinesh B., Narayan S., Ivan G., Nadica Stojanovic N., 2018. Comparative Analyses of Biodiesel Produced from Jatropha and Neem Seeds Oil using Gas Chromatographic and Mass Spectroscopic Technique, *Biofuels*, 1-12.
21. Bragadeshwaran A., Kasianantham N., Ballusamy S., Tarun K.R., Dharmaraj A.P., Kaisan M.U., 2018. Experimental Study of Methyl tert-butyl ether as an Oxygenated Additive in Diesel and Calophyllum Inophyllum Methyl Ester Blended Fuel in CI Engine, *Environmental Science and Pollution Research*, 25(33) 33573-33590.
22. Rahman M.J., Ambigaipalan P. and Shahidi F., 2018. Biological Activities of Camelina and Sophia Seeds Phenolics: Inhibition of LDL Oxidation, DNA Damage, and Pancreatic Lipase and α-Glucosidase Activities, *Journal of Food Science*, 8(1): 237-245.
23. Kaisan M.U., Anafi F.O., Nuszkwoski J., Kulla D.M. and Umaru S., 2017. Fuel Properties of Biodiesel from Cotton, Jatropha Binary and Multi-Blends with Diesel, *Nigerian Journal of material Science and Engineering*, 7(1): 55-61.
24. Ashok B., Jeevanantham A.K., Nanthagopal K., Saravanan B., Senthil Kumar M., Johny A., Kaisan M.U., Abubakar S., 2019. An Experimental Analysis on the Effect of n-pentanol- Calophyllum Inophyllum Biodiesel Binary Blends in CI Engine Characteristics, *Energy*, 173: 290–305.
25. Sani S., Kaisan M.U., Kulla D.M., Ashok B. and Nanthagopal K., 2018. Determination of Physico Chemical Properties of Biodiesel from Citrullus Lanatus Seeds Oil and Diesel Blends, *Industrial Crops and Products*, 122(2018): 702-708.
26. Atabani A.E., Mahlia T.M.I, Badruddin I.A., Masjuki H.H., Chong W.T. and Lee K.T., 2013. Investigation of Physical and Chemical Properties of Potential Edible and Non-edible Feedstocks for Biodiesel Production, A comparative Analysis, *Renew. Sust. Energ. Rev.*, 21:749-55.
27. Kaisan M.U., Anafi F.O., Nuszkwoski J., Kulla D.M. and Umaru S., 2017. Cold Flow Properties and Viscosity of Biodiesel from Cotton, Jatropha and Neem Binary and Multi-Blends with Diesel, *African Journal of Renewable and Alternative Energy*, 1(1): 80-89.
28. Ashok B., Kasianantham N., Kaisan M.U. and Madhu D., 2018. Influence of Injection Timing and Exhaust Gas Recirculation (EGR) Rate on Lemon Peel Oil – Fuelled CI Engine, *Env. Sci.& Pol. Res*, 25(33): 33573-33590.
29. Salaheldeen M., Aroua M., MariodA., Cheng F., Abdelrahman M. and Atabani E., 2015. Physicochemical Characterization and Thermal Behavior of Biodiesel and Biodiesel–diesel Blends Derived from Crude Moringa Peregrina Seed Oil, *Energy Conversion and Management*, 92: 535-542.
30. Shanmugasundaram S., Maruthur P., Kumaresan M., Abhilash O.P., Akhil Das K. and Maluf A., 2016. Experimental Study on the Effects of Camphor Ethanol Petrol Blends in a Spark Ignition Engine: Performance and Emissions Analysis, *International Journal of Energy Engineering*, 6(1): 19-28.