Effects of Propanol and Camphor Blended with Gasoline Fuel on the Performance and Emissions of a Spark Ignition Engine

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ABSTRACT: In this research, the performance and emissions of a four-stroke spark ignition engine fuelled with varying proportion of propanol-camphor and gasoline blends were investigated. The physicochemical properties such as specific gravity, viscosity, fire point, flash point, and iodine value (I.V.) of the blends were determined, and the values obtained conform to the ASTM standard. Sample P0B (100% of pure gasoline and 5 g of camphor) had the best physicochemical property values higher than those of the least sample of P15B by the following percentages: specific gravity (0.5%), viscosity (30.8%), fire point (5.08%), flash point (21.8%), and I.V. sample (0.5%). Also, the engine performance parameters such as brake power, brake thermal efficiency, brake mean effective pressure (BMEP), and specific fuel consumption were generated from the engine-measured parameters. Sample P0B has the best specific fuel consumption for the torque of 3 N m with a value of 22.77 kg/kW h, and sample P0A (100% of pure gasoline) has the best fuel consumption for a torque of 6 N m with a value of 12.52 kg/kW h. For brake thermal efficiency, sample P0B gives the best brake thermal efficiency at the two constant torques with a value of 0.36 for torque 3 N m and 0.67 for torque 6 N m. Sample P15C (85% of gasoline, 15% of propanol, and 5 g of camphor) gives the best BMEP at torque 3 N m with a value of 1.92 bar, and sample P5C (95% of gasoline, 5% of propanol, and 10 g of camphor) gives the best BMEP at 6 N m with a value of 3.85 bar. Exhaust emissions were analyzed for unburned hydrocarbon (HC), carbon monoxide (CO), carbon dioxide (CO2), and nitrogen oxide (NOx). The results showed that increasing the blending percentage reduces the emitted concentration of CO, HC, and NOx. Carbon monoxide emission was found to be lowest at sample P10A (90% of gasoline and 10% of propanol) for torque 3 N m with a value of 0.16, and at torque 6 N m, the sample with the lowest percentage was P15C with a percentage of 0.21.

1. INTRODUCTION

The demand for petroleum product and efficiency in energy conversion devices is increasing because of the increase in industrialization and modernization of the world.1 The excessive use of fossil-derived fuels such as gasoline in spark ignition (SI) engines has been proven to have a negative effect on our environment, which affects our social well-being.13,14 The concern on the increasing air pollution and climate change as a result of exhaust gas emissions has mandated the search for environmentally friendly fuel.5,7–10 Also, considering the energy crises and pollution problems today, the use of gasoline and alcohol fuels blend as an alternative fuel in a gasoline engine is becoming necessary.15–19 The oxygenate fuels sometimes come in the form of an additive and are being introduced into the main gasoline usually in percentage.3,4,6 The use of fuel additives is being introduced to fuel because some additives improve the engine performance and reduce emissions such as smoke, CO, HC, NOx, SO2, and solid particles.35 Oxygenated fuel is used to improve fuel properties, combustion quality, and octane rating in an SI engine.36,37,43–45 The oxygenated fuels commonly used are ethanol, methanol, butanol, propanol, etc.3,4,6 The oxygenates aid the combustion of fuel in an SI engine and consequently reduces the engine emissions.20–27

Recently, the search for a fuel additive is increasing and lots of additives such as camphor were discovered. Camphor ((C10H16O), cinnamomum camphora) is an organic, white crystalline substance with a strong odor and pungent taste originated from camphor tree, which is found in the Southern United States, China, India, Mongolia, Japan, Taiwan, and Africa.28 Camphor is soluble in alcohols, and it is a flammable compound, transparent with a density of 0.992 g/cm3, has
melting and boiling points of 1750 and 209 °C, respectively, is also soluble in water, and has an autoignition temperature of 166 °C and a flash point of 540 C at the standard state (250 C and 100 kPa). Besides being used as an additive to gasoline fuel, it also has many pharmaceutical applications such as topical analgesic, anti-septic, anti-spasmodic, anti-pruritic, anti-inflammatory, anti-infective, contraceptive, mild expectorant, nasal decongestant, cough suppressant, and so forth.28 Propanol is also considered as one of the alternative fuels for an internal combustion engine for its relatively less toxicity compared to other alcohols and has favorable physicochemical properties.79–32,30 A number of literature studies were reported on the application of oxygenate fuels blended with gasoline. Yusri et al.29 reported that the internal combustion engine has different performance outcomes, but the alcohol fuels are capable of reducing the engine emissions. Kothare et al.14 investigated the effect of unleaded gasoline—higher alcohol blends on the performance characteristic of a single-cylinder four-stroke SI engine at variable compression ratio. Performance tests were conducted at variable compression ratio at a constant speed of around 2800 rpm with various blends such as gasoline with 5% ethanol (E5), gasoline with 10% ethanol (E10), gasoline with 5% propanol (Pr5), gasoline with 10% propanol (Pr10), gasoline with 5% butanol (B5), gasoline with 10% butanol (B10), gasoline with 5% pentanol (PS), gasoline with 10% pentanol (P10), and unleaded gasoline (E0). Brake-specific fuel consumption and brake thermal efficiency were calculated and compared with E10 and gasoline. The result showed that 10% volume ethanol—gasoline blends gave the best result for all measured parameters. Ahmed33 investigated the performance and exhaust emissions of a vehicle fueled with low-content alcohol (methanol) blends and pure gasoline. The engine was run at different loads and methanol blending percentages. It was found that increasing the blending percentage reduces the emitted concentration of carbon oxides and HC. Also, it was found that brake power and brake thermal efficiency are increased with increasing methanol blending percentage because of higher cylinder temperatures. The results showed that the use of 10% volume of methanol blending with the gasoline appeared to be a good option for replacing any oxygenate additives in the gasoline, where CO, CO2, and HC are minimum and the fuel consumption of the blend is lower than that of the commercial gasoline. Silitonga et al.34 evaluated the suitability of biodiesel/bioethanol/diesel blends in a single-cylinder engine. The findings revealed that the brake thermal efficiency is enhanced and the brake-specific fuel consumption is lowered using the biodiesel/bioethanol/diesel blends. The exhaust emissions such as CO and smoke reduced drastically. This implies that oxygenates have the potential to reduce fuel consumption and engine emissions. Shanmugasundaram et al.35 discussed a detailed study on the performance of an SI engine fueled with camphor—ethanol—petrol blends. In this study, a mixture consisting of camphor and ethanol in weight percentage (20:80) was blended with petrol in three different ratios: 10, 20, and 30%. A performance test was carried out on the SI engine at a constant speed while varying the torque to evaluate the performance between the blended fuel and the sole fuel, such as brake power, specific fuel consumption, brake thermal efficiency, and volumetric efficiency. It was inferred from the study that lesser specific fuel consumption, less emissions due to complete combustion of air—fuel of the SI engine, and maximum volumetric efficiency were achieved.

The research on the application of camphor as an additive in gasoline fuel is limited, and concerns were raised on the issue of unregulated application of camphor in SI engines, especially in Nigeria. Thus, this research is aimed at utilizing a specific dosage of camphor as an additive in gasoline fuel to investigate the performance and emission characteristics of an SI engine. This paper is organized as follows: 1. Introduction, 2. Materials and Methods, 3. Results and Discussion, 4. Conclusions, and finally a list of references.

2. MATERIALS AND METHODS

2.1. Sample Preparation. Before initiating the blending, 60 g of camphor was pounded from its solid crystal to powder form. For the first three samples, 0, 5, and 10 g of camphor were added into three different bottles and then 1 L of petrol was filled into each of those samples as seen in Table 3. These samples were labeled P0A, P0B, and P0C, respectively. For the next set, each bottle was filled with 95% of a liter of petrol blended with 5% of a liter of propanol, added to each of these samples, then 1 L of petrol was filled into labeled P5A, P5B, and P5C respectively. For the third three samples, each bottle was filled with 10% of a liter of propanol, added to each of these samples, and labeled P10A, P10B, and P10C, respectively. For the next set, each bottle was filled with 95% of a liter of petrol blended with 5% of a liter of propanol, added to each of these samples, then filled with 0, 5, and 10 g, and labeled PSA, PSB, and PSC respectively. For the third three samples, each bottle was filled with 10% of a liter of propanol, added to each of these samples, and labeled P15A, P15B, and P15C, respectively. For the next set, each bottle was filled with 95% of a liter of petrol blended with 5% of a liter of propanol, added to each of these samples, then filled with 0, 5, and 10 g, and labeled PSA, PSB, and PSC respectively. For the third three samples, each bottle was filled with 10% of a liter of propanol, added to each of these samples, and labeled P15A, P15B, and P15C, respectively.

Table 1. Specifications of the Engine Fleet Manufactured by Tecquipment Technology

| engine parameters | specifications |
|-------------------|---------------|
| engine type       | four-stroke single-cylinder SI engine |
| weight            | 27 kg         |
| engine capacity   | 208 cc        |
| net Power         | 4.5 kW at 3600 rpm |
| net torque        | 12.5 N m at 2800 rpm |
| speed             | 3600 rpm      |

Table 2. Specifications of the Gas Analyzer Manufactured by Nanhua

| equipment             | measured variables | range         | uncertainties |
|-----------------------|--------------------|---------------|---------------|
| NHA-506EN emission analyzer | HC                | 0–9999 ppm    | ±12 ppm       |
|                       | NOx               | 0–5000 ppm    | ±1 ppm        |
|                       | CO                | 0–10 vol %    | ±0.06 vol %   |
|                       | O2                | 0–25 vol %    | ±0.1 vol %    |
|                       | CO2               | 0–18 vol %    | ±0.1 vol %    |

Table 3. Nomenclature of the Samples

| s/n | nomenclature of samples | % of petrol per liter | % of propanol per sample | amount of camphor (g) |
|-----|-------------------------|-----------------------|--------------------------|-----------------------|
| 1   | P0A                     | 100                   |                          |                       |
| 2   | P0B                     | 100                   |                          | 5                     |
| 3.  | P0C                     | 100                   |                          | 10                    |
| 4   | PSA                     | 95                    |                          | 5                     |
| 5   | PSB                     | 95                    |                          | 5                     |
| 6   | PSC                     | 95                    |                          | 10                    |
| 7   | P10A                    | 90                    |                          | 10                    |
| 8   | P10B                    | 90                    |                          | 5                     |
| 9   | P10C                    | 90                    |                          | 10                    |
| 10  | P15A                    | 85                    |                          | 15                    |
| 11  | P15B                    | 85                    |                          | 15                    |
| 12  | P15C                    | 85                    |                          | 10                    |
of propanol and 90% of a liter of petrol and then filled with 0, 5, and 10 g of camphor. These samples were labeled P10A, P10B, and P10C, respectively. For the last three samples, each bottle was filled with 0, 5, and 10 g of camphor and then 85% of a liter of petrol blended with 15% of a liter of propanol was added to each sample. These samples were labeled P15A, P15B, and P15C, respectively.

2.2. Experimental Procedure. The prepared blends were tested in a four-stroke single-cylinder petrol engine manufactured by Tecquipment, Nottingham. The engine is available at the Department of Mechanical Engineering, Ahmadu Bello University, Zaria, Nigeria. Experiments were performed on a four-stroke, single-cylinder SI engine at a constant speed. The experimental layout (shown in Scheme 1) and the materials used consist of the internal combustion engine (SI) tecquipment, fuel supply system, data acquisition system, emission analyzer, camphor (60 g), stopwatch, plastic bottles, weight balance, propanol (1.8 L), mortal and pistol, gasoline (15 L), and measuring cylinder. The engine output shaft was coupled to the dynamometer rotor, which was braked by mechanical friction. Before initiating the tests, 100 mL of pure petrol was charged into the engine before it was started and it was then allowed to warm up for about 10 min. To start the engine, the power switch was first turned on, then the choke was closed by pushing it to lever down, and the throttle was opened slightly. The starting handle was then pulled until the engine fired. At constant torques of 3 and 6 N m, the emission and the performance of the samples were recorded simultaneously. For the first sample (P0A), 8 mL of it was filled to the engine and then the first test conditions (i.e., 3 N m) was set by opening the throttle and increasing the flow of water to the dynamometer until the engine attained the torque. When conditions stabilized, the readings of the performance parameters and the emissions were taken. The throttle was further opened until the torque reached 6 N m and it was then allowed to stabilize before the reading was also recorded. Readings were taken at an engine speed of 1500 rpm and an air–fuel ratio of 0.58. This procedure was repeated for all the samples and their readings were taken. Interestingly, the engine torque is varied using an in-built dynamometer. The output of the engine such as brake power, brake-specific fuel consumption, and thermal efficiency was obtained using a personal computer (PC) system as shown in Scheme 1, while the exhaust emissions (HC, CO, CO₂, and NOx) were measured using the gas analyzer. The readings were recorded at an interval of 5 min, and for each sample, five readings were taken when the average was used and the deviation was shown as the error bars.

2.3. Determination of Physicochemical Properties of Samples. The physicochemical properties of the fuel are the fuel specifications that define and set the quality standard. In this research, five physicochemical properties were determined including specific gravity, viscosity, flash point, fire point, and iodine value (I.V.) of each blend using apparatus and equipment available at Chemical Engineering Ahmadu Bello University, Zaria Nigeria.

2.3.1. Fire Point. A method developed by Kaisan et al. was followed to determine the fire point of the samples. To determine the fire point, 10 mL of the sample was heated in a 100 mL conical flask at a slow constant rate on the hot plate. The fire point temperature was taken at the temperature when an application of the test flame caused the sample to ignite and burns.

2.3.2. Flash Point. A 100 mL conical flask was filled to a specific level (10 mL) with the sample and 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 caused the vapor above the sample to ignite.

2.3.3. Absolute Viscosity. The viscometer was placed in a 1000 mL 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 the reference. The absolute viscosity can be calculated from eq 1 as given by Kaisan et al.
\[ \eta = \frac{t - t_0}{t_0} \] (1)

where \( t \) = time of flow of the sample, \( t_0 \) = time of flow of the reference (water in case).

2.3.4. Iodine Value. To determine the I.V., 1 g of the sample was placed in a 250 mL conical flask, followed by 30 mL of Hanus solution and the flask was stoppered. The content was mixed and placed in the drawer for exactly 30 min. It was titrated against 0.1 Na\(_2\)S\(_2\)O\(_3\) until the solution becomes light yellow. 1% starch indicator (2 mL) was added and titration continued until the blue color just disappears. A blank determination was also carried under the same conditions and the I.V. was calculated as given by Kaisan et al.\(^{11}\)

\[ \text{I. V.} = \frac{(B - S) \times 12.69 \times N}{W} \] (2)

where \( B \) = blank titer, \( S \) = sample titer, \( N \) = normality of Na\(_2\)S\(_2\)O\(_3\), \( W \) = weight of the sample.

2.3.5. Specific Gravity. The specific gravity, also known as the relative density, is the ratio of the density of a material at a given temperature to the density of an equal volume of water at the same temperature.\(^{12}\)

\[ S, G = \frac{W_2 - W_1}{W_5 - W_1} \] (3)

where \( W_1 \) = weight of the empty bottle, \( W_2 \) = weight of the bottle + fuel, and \( W_5 \) = weight of the bottle + water.

2.4. Fourier Transform Infrared Analyses of Camphor. Fourier transform infrared (FTIR) spectroscopy, also known as FTIR analysis or FTIR spectroscopy, was performed. The structural changes and thermal stability of an organic, polymeric, and in some cases inorganic material can be analyzed using this technique. For this research, FTIR is used to assess the chemical properties of camphor. A little sample of powder camphor was placed 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 (multiuser laboratory), Ahmadu Bello University Zaria, Nigeria.

3. RESULTS AND DISCUSSION

The findings of the research include the results of the gas chromatography–mass spectrometry analysis, FTIR analysis, the engine emissions, and the performance index.

3.1. FTIR Spectroscopy Result for Camphor. The FTIR result obtained from the experiment is shown in Figure 1.

From Figure 1, absorptions were observed at 3004 and 2948.3 because of the C−H asymmetric and symmetric vibrations, respectively. The absorptions at 1581.8 and 1591.6 are due to the C=C stretch.

3.2. Result of Physiochemical Properties of the Samples. 3.2.1. Specific Gravity. The specific gravity, also known as the relative density, is the ratio of the density of a material at a given temperature to the density of an equal volume of water at the same temperature.\(^{12}\)

From Figure 2, the result shows that the first two samples P0A and P0B have the least specific gravity with a value of 0.7572 each. This is because the specific gravity of gasoline is lesser than the specific gravity of camphor and propanol. Sample P10C appeared to have the highest specific gravity with a value of 0.7610. These values agree with the findings of Kaisan et al.\(^{11}\) and conform to the ASTM D4052 standard.

3.2.2. Viscosity. Viscosity measures the resistance of the fuel to flow.\(^{12}\) From Figure 3, the result shows that the samples with the least viscosity are P0A, P0B, and P0C with a value of 1.3 P

Figure 1. FTIR result on camphor.

Figure 2. Specific gravity of the samples.
each. As the amount of propanol increases, the viscosity of the samples also increases, and the samples with the highest viscosity are P15B and P15C with a value of 1.7 P. Camphor addition did not influence the viscosity of the samples. The viscosity values obtained are within the ASTM D455 standard.

3.2.3. Fire Point. The fire point is the lowest temperature at which the sample gets ignited and burns under the specified test condition. From Figure 4, the result shows that the samples with the least fire point are P0A and P0B with a temperature of 59 °C each and the addition of propanol further increases the fuel fire point with P15C having the highest temperature of 62 °C. This conforms to the ASTM D93 standard and agrees with the results of Sani et al.20

3.2.4. Iodine Value (%). I.V. is an indicating parameter of the degree of saturation in fuel, which influences the fuel viscosity and cold filter plugging point. Figure 5 shows the I.V. of the samples. From Figure 5, the result shows that the samples with the highest value are P15B and P15C with a percentage of 2.4 each and the samples with the least I.V.s are P0A and P0B with a percentage value of 1.9 each. The results obtained conform to the ASTM D6751 standard.

3.3. Engine Performance Test. 3.3.1. Brake Power. At a torque of 3 N m, it was noticed that there is a slight change in brake power with and without the camphor addition up to a blend of 10% propanol and 10 g of camphor (P10C) as shown in Figure 6 and this blend also portrayed the least engine brake power. This shows that addition of camphor to the volume of 10 g has effects on fuel quality, such as high density, high autoignition temperature, and high viscosity. With propanol content increased to 15%, a better and an improved engine brake power was recorded as regard to P10C, and this shows that addition of more propanol improves the quality of the fuels, thereby yielding much better engine brake power. Similar results were also obtained at 6 N m torque but with a much better engine brake power than at 3 N m. This finding agrees with the results of Shanmugasundaram et al.33

3.3.2. Specific Fuel Consumption. Figure 7 shows the specific fuel consumption of the fuel blends at torques of 3 and 6
N m. At a 3 N m torque, it was observed that P0B has the best specific fuel consumption with the lowest value of 22.77 kg/kW h. In addition, at 6 N m, it was observed that P0A has the best fuel consumption with a value of 12.52 kg/kW h. This implies that increasing the quantity of camphor and propanol leads to an increase in fuel consumption. This is attributed to the lower viscosity, density, and calorific value of the oxygenate fuel.14

3.3.3. Brake Thermal Efficiency. Figure 8 shows the graphical representation of brake thermal efficiency at torques 3 and 6 N m.

It can be observed that at torque 3 N m, the brake thermal efficiency was highest in P0A, P0B, P0C, and P5C with a value of 0.36. In addition, at a torque of 6 N m, it can be seen that P0B and P0A have higher brake thermal efficiency with values of 0.67 and 0.66, respectively. Therefore, the best brake thermal efficiency at higher engine torque was achieved by applying P0B in the engine. However, when considering the brake thermal efficiency at the lower torque, P0A, P0B, P0C, and P5C are the best. This implies that the brake thermal efficiency decreases with an increase in the quantity of propanol and camphor in the blends. The addition of the oxygenated lowers the calorific value of the blends.44

3.3.4. Brake Mean Effective Pressure. From Figure 9, it can be seen that as the torque of the engine increases, the brake mean effective pressure (BMEP) increases. Also, the fuel blends do not seem to have a significant effect on BMEP. After all, one of the most important factors that affect BMEP is the intake air density/pressure (turbo boost), which is not affected in this research, but the slight changes shown in the results are as a result of changes in the physicochemical properties of the fuels as the results of addition of both camphor and propanol. From the result obtained at torque 3 N m, the sample with the highest BMEP is P15C with a value of 1.92 bar, and at a torque of 6 N m, the sample with the highest BMEP is P5C with a value of 3.85 bar.

3.4. Engine Emission Results. 3.4.1. Hydrocarbon. Figure 10 shows the effect of the emission of hydrocarbon (HC) in a petrol propanol blend with camphor in an SI engine.

From Figure 10, the result shows how the emission of HC increased and then decreased. At P0A, P0B, and P0C, the emission of HC increases from 300 to 412 ppm at a torque of 3 N m and 410 to 453 ppm at torque 6 N m because of the increase in carbon content, which is present in camphor. The addition of propanol leads to a decrease in HC emissions.1 Because propanol is an oxygenated fuel, it can improve the combustion efficiency and hence reduces the concentration of HC emission in the engine exhaust.47 This is similar to the work of Shanmugasundaram.33 From the result, it can be seen that at a torque of 3 N m, the sample with the lowest emission of HC was P15C with a value of 243 ppm, and at a torque of 6 N m, the sample with the lowest emission of HC was P15C with a value of 249 ppm. Engine performance results for P15C shows that the blend has a high brake power at 3 N m torque, while at 6 N m torque, its brake power was slightly less than that of the P0A. P15C appeared to have high fuel consumptions at both engine torques as a result of its physicochemical properties, which are entirely different from the rest of the fuel blends because it contains the highest percentage of both propanol and camphor which affect the fuel quality.

3.4.2. Nitrogen Oxide. Figure 11 shows the emission of nitrogen oxide in gasoline—propanol blends with camphor in an SI engine.

From Figure 11, the result shows an increase in nitrogen oxide because of an increase in a small amount of camphor, but as the quantity of camphor increases, the emission of nitrogen reduces. Also, blends PSA, PSB, and PSC show a decrease in NOx emission because of the increase in the percentage of propanol. The propanol addition led to the reduction of combustion temperature as a result of the excess oxygen content. At torques 3 and 6 N m, it can be seen that the sample with the lowest emission of nitrogen oxide was P15C with a value of 249 and 253 ppm, respectively. Therefore, it can be understood that the addition of camphor and propanol reduces the NOx emissions.
3.4.3. Carbon Monoxide. Figure 12 shows the exhaust gas analyses of the gasoline—propanol blend with camphor in an SI engine.

From the above figure, the samples with the lower percentage of carbon monoxide at a torque of 3 N m are P10A and P15C with percentages 0.16 and 0.19, respectively, which give the best least emissions. In addition, at a torque of 6 N m, the samples with the best emission are P15B and P15C with percentages 0.29 and 0.21, respectively. From the graph, there was an increase in the emission of carbon in P0A, P0B, and P0C because of an increase in camphor, and with an increase in the percentage of propanol, carbon emission tends to reduce because of the fact that both camphor and propanol are oxygenated compounds, so CO was reduced to CO2; this agrees with the findings of Mourad and Mahmoud.1 These samples that have the least emission of CO appeared to have a good engine performance, especially P15C, which has high engine brake power.

3.4.4. Carbon Dioxide (CO2). Figure 13 shows the emission of CO2 in a gasoline—propanol blend with camphor in an SI engine.

From Figure 13, at a torque of 3 N m, the sample with the higher percentage of CO2 is P15B with a percentage of 2.63%, and at a torque of 6 N m, the samples with the higher percentage are P5B and P10C with percentages 2.70 and 2.65%, respectively, which are the best for the efficiency of the engine. This guides us that addition of these oxygenated compounds reduces engine emission at the expenses of some engine performance parameters.

4. CONCLUSIONS

Experiments were conducted in a four-stroke single-cylinder SI engine using blends of propanol—camphor with gasoline fuel to investigate the engine performance and emissions. Based on the experimental results obtained, the following conclusions were drawn:

1. The physicochemical properties conform to some literature results and fall within the ASTM standard, which shows the feasibility of utilizing the fuel in an SI engine.

2. It was established that sample P0B has the best specific fuel consumption at an engine torque of 3 N m with a value of 22.77 kg/kW h and sample P0A has the best specific fuel consumption for higher torque of 6 N m with a value of 12.52 kg/kW h.

3. It was established that the higher percentage of the blends in the gasoline brought about an increase in the brake power. Sample P15C gives the best brake power at 3 N m with a value of 490 W and sample P0B gives the best brake power at 6 N m with a value of 867 W.

4. It was shown that the best brake thermal efficiency at a torque of 6 N m was sample P0B with 0.67, and at the engine torque of 3 N m, samples P0A, P0B, P0C, and P5C have the best brake thermal efficiency with a corresponding value of 0.36. Also, the sample with the highest BMEP at 3 N m was P15C with a value of 1.92 bar. Similarly, at 6 N m, the sample with the highest BMEP was P5C with a value of 3.85 bar.

5. From the engine emission analysis, it was seen that the increase in the percentage of propanol in the gasoline—camphor blend leads to a decrease in the emission of HC and NOx. This is because propanol is an oxygenated fuel; it, therefore, improves the combustion efficiency and hence reduces the concentration of HC and NOx emission in the engine exhaust. At torques 3 and 6 N m, it was noticed that the sample with the lowest emission of nitrogen oxide and HC was P15C with values 249, 253 and 243, 251 ppm, respectively. The emission of carbon dioxide was found to be highest for sample P15B at a torque of 3 N m with a percentage of 2.63, and at a torque of 6 N m, the sample with the highest percentage of carbon dioxide is P5B with a percentage of 2.70. Carbon
monoxide emission was found to be lowest at P10A for torque 3 N m with a value of 0.16, and at a torque of 6 N m, the sample with the lowest percentage was P15C with a percentage of 0.21.

6. In the future, the influence of the higher percentage of propanol and the camphor blend can be investigated.

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**Notes**
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