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# ENVIRONMENTAL AND PERFORMANCE EVALUATION OF BINARY AND TERNARY BLEND RATIOS OF BIODIESEL ON COMPRESSION IGNITION ENGINE

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**ABSTRACT**
Despite the dependable attempts by researchers in the field of sustainable fuels, engines, and emissions, there is a research gap in the area of variations of biodiesel blend ratios with specific fuel consumption of a compression ignition engine as well as the brake thermal efficiency of engines. Therefore, this article has investigated how the blending ratio of biodiesel from jatropha, neem and cotton seeds oil mixed with petrol diesel affects the brake specific fuel consumption of a compression ignition engine and likewise the brake thermal efficiency of the binary and multi-blends of biodiesel with diesel. Three different biodiesel samples were blended with diesel; the biodiesel was achieved through an alkali transesterification reaction. The blending was done for each biodiesel with diesel alone, and that of mixed biodiesel blends with fossil diesel in a definite ratio. The blends were run on a stationary four-cylinder compression ignition engine with an exhaust analyzer to detect CO, NOx, and exhaust temperature ranges. It was recorded that, the combustion of the blends at an engine speed of 1500 rpm, between the Jatropha blend ratios 25 to 30 %, the brake specific fuel consumptions (bsfc) decrease further as against the initial trend shown at 1000 rpm. At 2000 rpm engine speed, the Neem, as well as the mixed biodiesel blends, show entirely different patterns. 25% Jatropha blend gives the best overall performance.

**Keywords***:* Jatropha oil; Neem oil; Diesel engine; Transesterification; Performance; Emission.

## INTRODUCTION

Worldwide fuel demand is spectacularly escalating owing to the rapid industrialization, growing population, increasing municipal activities, and fiscal development globally (Ibrahim *et al*., 2020; Irimiya *et.al.*,2020). For this energy requirement to be accomplished, a huge amount of petroleum is extensively consumed from dissimilar relic wherewithal (Ashraful *et al*., 2014). Biofuels are one of the most reliable, sustainable, renewable, biodegradable, and combustible fuels capable of replacing fossil fuels wholly or partially in internal combustion engines operations ( Kaisan *et.al.*, 2013 ). Researchers have worked on so many aspects of biodiesel for use as a full or partial substitute in compression ignition engines applications. (Hussain *et.al,* 2020) have investigated the Influence of Biodiesel Blends in Nano/Ultrafine/Fine/Coarse Assortment on Particulate and Polycyclic Aromatic Hydrocarbon Emissions from Compression Ignition Engine. They have established that an increase in the blending ratio of biodiesel decreases the exhaust emission of Polycyclic Aromatic Hydrocarbon and particulate matter increases. As the biodiesel blending ratio increased, the particulate matter emissions decreased for the four size ranges of the blends. (Boehman *et al*., 2005) worked on the Influence of Blending Biodiesel on Fossil Diesel Soot and the Rejuvenation of Particulate Sieve. It was established that the results prove the impending effect of blending biodiesel on oxidation owing to the low-temperature characteristics of soot as well as the influence of these soot features on particulate filter rejuvenation. (Durbin *et al*., 2000; Durbin *et al*., 2002) investigated the Influence of Biodiesel Blends, Pure Biodiesel, and a Non-natural Diesel on Exhaust Emission from Light Heavy-Duty Compression Ignition Engine Powered Automobiles and the Influence of Blends of Biodiesel and Arco EC-Diesel on Vehicular Emissions with Light Heavy-Duty Compression Ignition Engine respectively. It was established that Physico-chemical examination confirmed essential and crude carbon as the prime ingredient of the fossil diesel particulate, amounting to 73-80% of the whole throng for the four engines. Pure biodiesel had the maximum organic carbon proportion for all of the test engines. Polycyclic Aromatic Hydrocarbon emissions for the fuel blends were comparatively stumpy, in all probability, this could be as a result of the stumpy fuel Polycyclic Aromatic Hydrocarbon levels. It was further observed that the biodiesel blends from the soy gave lesser emissions disparity more than the experimental vans, together with a little increase in particulate matter emissions. (Ghadikolaei *et al,* 2016) worked on the influence of alcohol blends and fumigation on synchronized and unfettered emissions of internal combustion engines. The authors observed that the addition of alcohols as a substitute fuel in the prescribed engines yielded a diminution of oxides of Nitrogen and Carbon dioxide in most tests and particulate matter in all instances. However, an increase of CO and HC was observed with using alcohols in fumigation mode in most cases. It is noticeable that a diverse effect of alcohol application in blended mode compared to fumigation mode on regulated emissions was recorded in considerable tests except PM. ( Ibrahim *et al*., 2020) investigate the effect of using pentanol blended with biodiesel from moringa oliefera biofuels and results shows considerable engine performance improvement and efficiency ( Kaisan *et al.*, 2020), examine and compare the effect of propanol and camphor on spark-ignition engine performance and emissions, findings show that Sample P0B (100% of pure gasoline and 5 g of camphor) have the best physicochemical properties, the fuel property of the blend has improved by the addition of 5g camphor as an additive, results show a percentage increases of 0.5% for specific gravity, 30.8% viscosity, 5.08% fire point and 21.8%, flashpoint. It also shows improvement in the engine brake thermal efficiency, specific fuel consumptions, and engine brake power. In similar research. ( Kaisan *et al.*, 2020), investigate the effect of camphor and butanol on engine performance and emission, it also shows that the addition of 5g of camphor was the best in improving both the fuel physicochemical properties and engine performance than the addition of butanol, but engine emission reduces with the addition of Butanol.

However, despite the consistent effort of researchers in this sustainable field of study, there is a research gap in variations of blend ratios with specific fuel consumption and brake thermal efficiency of fuels. Therefore, the objective of this article is to investigate how the blending ratio of biodiesel to fossil diesel will affect the brake-specific fuel consumption and thermal efficiency of the binary and multi-blends of biodiesel with diesel.

## MATERIALS AND METHODS

MATERIALS

**Raw materials**

Raw materials used for this research are as follows:

1- Diesel fuel (AGO)
2- Biodiesel samples comprising of 2 liters each from Cottonseed oil, Neem seed oil, and Jatropha seeds oil were sourced. Table 1: Specifications of the Engine Fleet, Manufactured by a company called Cussons Technology, Manchester, UK, 2010

| **Engine Type** | **4 cylinder in-line DOHC Dual Mass Flywheel** |
|---|---|
| Number of Valves | 16 |
| Block | Aluminum |
| Head | Aluminum |
| Horse Power | 81 kW(11OPS) at 4000 rpm |
| Torque | 240-260 NM at 1750 rpm with transient over-boost |
| Displacement | 1560 CC |
| Bore | 75mm |
| Stroke | 88.3mm |
| Compression Ratio | 18:1 |
| Alignment | Transverse |
| Weight | 107 kg |
| Dimensions HXLXW | 600X500X580mm |

## METHODS

### Sample preparation

**Blending**

The blending was done for all the biodiesel samples with petroleum diesel, while that's of heterogeneous biodiesel type (Fractional Blends or Multi Blends) are mixed with petroleum diesel alone. All the biodiesel portions prepaid were blended with fossils diesel fuel in a ratio 5:95, 10:90, 15:85, 20:80, 25:75, 30:70 by volume, and a homogenous sample of all the diesel, as well as a pure mixture of petro-diesel sample, was retained for control reasons. For the pure biodiesel, blends were labeled as B5, B10, B15, B20, B25, B30, B50, and B100 while the homogenous petroleum diesel was label as B0 (M U Kaisan et al., 2013). The blend of cottonseed and diesel was labeled B5c, B10c, B15c, B20c, B25c, and B30c. blends of Jatropha and diesel were labeled B5j, B10j, B15j, B20j, B25j, and B30j. while blends of Neem seed and petro-diesel were also labeled B5n, B10n, B15n, B20n, B25n, and B30n respectively, a lastly multi-blends sample of Cotton, Jatropha, and Neem seed biodiesel with petro-diesel was labeled B5m, B10m, B15m, B20m, B25m and B30m in that order. The samples were kept for more research analyses. ( Kaisan *et al*, 2020 ; Ibrahim *et al* 2020).

*2.2.4 Engine test procedure*

The engine test was carried out on compression ignition engine CI, to measure some performance parameters, like Engine specific fuel consumption, brake power, brake mean effective pressure, and brake thermal efficiency.

This study was carried out to analyze the performance and typical engine exhaust characteristics of a fixed (stationary) four (4) cylinder diesel engine when run on biodiesel/ petrodiesel blends and also on pure diesel fuel. Before starting the test an eddy current dynamometer was attached to the engine, and the engine was to be allowed to operate for about 15 minutes to get wormed. The engine was first tested, with diesel fuel alone, followed by other different blends, to analyze the performances of oil blends and pure diesel fuel these parameters were recorded Brake mean effective pressure, specific fuel consumption (SFC), brake thermal efficiency (BTE). For all the blends, the engine was tested at full load state at varying speeds conditions of 1000 rpm, 1500 rpm, 2000 rpm, and 2500 rpm for all of the blends. Time taken for the engine to finish the fuel is recorded at each engine speed.

With the help of a dynamometer, engine torque was measured, the engine was securely tied to a working bench and the dynamometer rotor was securely attached to the engine output shaft Engine torque was measured with the aid of a dynamometer. The engine was secured to a test bench where its output shaft was coupled to the dynamometer rotor. The rotor was broken by hydraulic and mechanical friction. The energy produced by the engine was a heat change and therefore the dynamometer was adequately cooled. By the use of either balancing weights, springs, pneumatic or electronic means torque (opposing Torque) exerted on the stator was measured. Plates 3.5 to 3.9 displayed the experimental setup. Finally, the remaining engine performance parameters were computed (Kaisan *et al.* 2013).

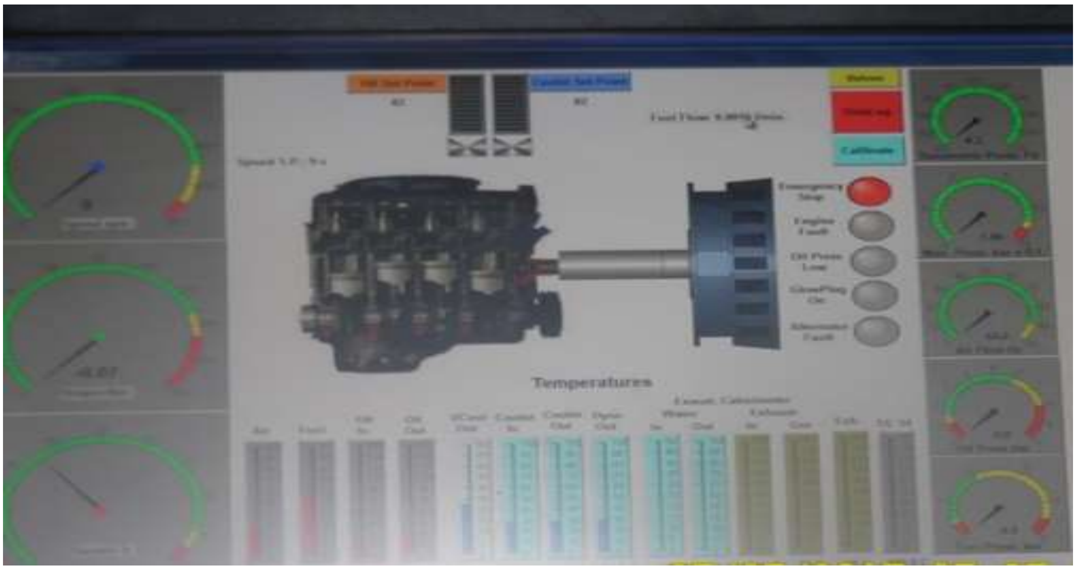

**Plate 1:** PC Monitor Display of the Engine Test Bed

## RESULTS AND DISCUSSION

*Variation of Biodiesel Blend Ratios with Specific Fuel Consumption*

Figures 1 to 8 present the effects of blend ratio on specific fuel consumption.

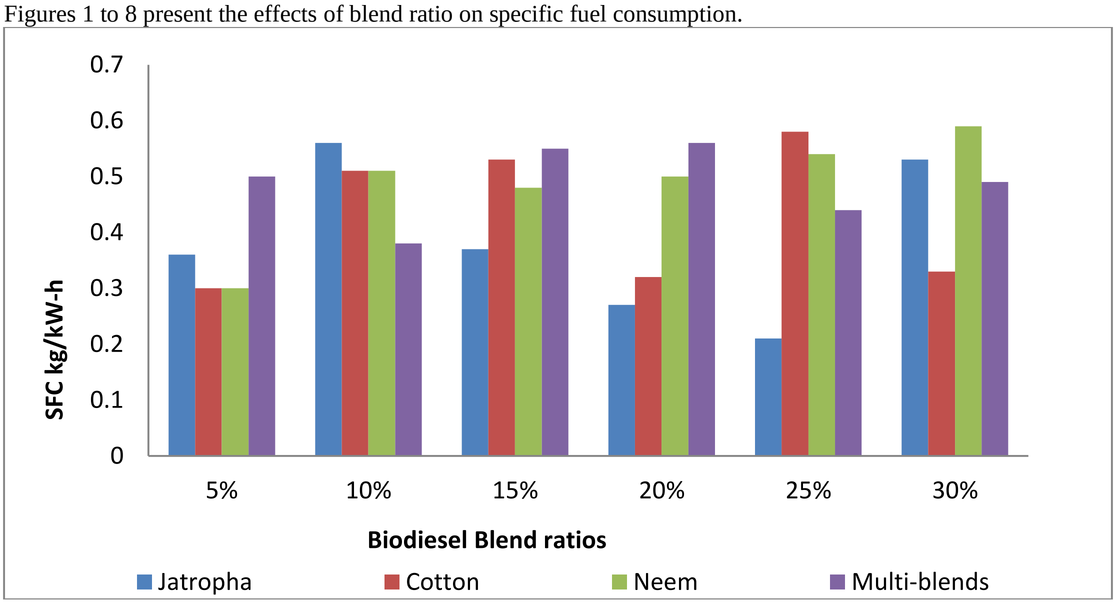


**Figure 1:** Effects of Blend ratio on Specific Fuel Consumption at Engine Speed of 1000 rpm

Figure 1 presents the specific fuel consumptions of different biodiesel blends with blend ratios at an engine speed of 1000 rpm. It could be seen that the specific fuel consumption of Jatropha, cotton, and Neem biodiesel increase with the increase in blend ratio between 5 % and 10 % blend ratio. For Jatropha, the specific fuel consumption values decline between the blend ratio of 10 % and 25 %. The brake-specific fuel consumption (bsfc) reached its minimum value at 25 % and then began to increase further at 30 %. Similarly, cotton has shown a decrease with an increase in blend ratio from 15 % to 20 % where it achieved its minimum value, it then increased further to 25% and declined at a 30 % blend ratio. For Neem biodiesel, however, the decline was between the blend ratios of 10 % to 15 % where it has its minimum value. The multi-blend has shown an adverse trend at this speed, its bsfc has first decreased from 5 % to 10 % blend ratio, and then it started to increase again. The minimum overall bsfc is depicted by Jatropha at a 25 % blend ratio. Factors like volumetric fuel injection, viscosity, the density of fuels, and low heating value affect the bsfc of fuel in CI engine, (Mofijur *et al.*, 2014; Qi *et al.*, 2010). The implication here is that these blend ratios B25J, B25C, and B30C have good values for viscosity and specific gravity as confirmed by Figures 4.1 and 4.4. Hence the quality of atomization, combustion, and air-fuel mixing is very good for these blend ratios.

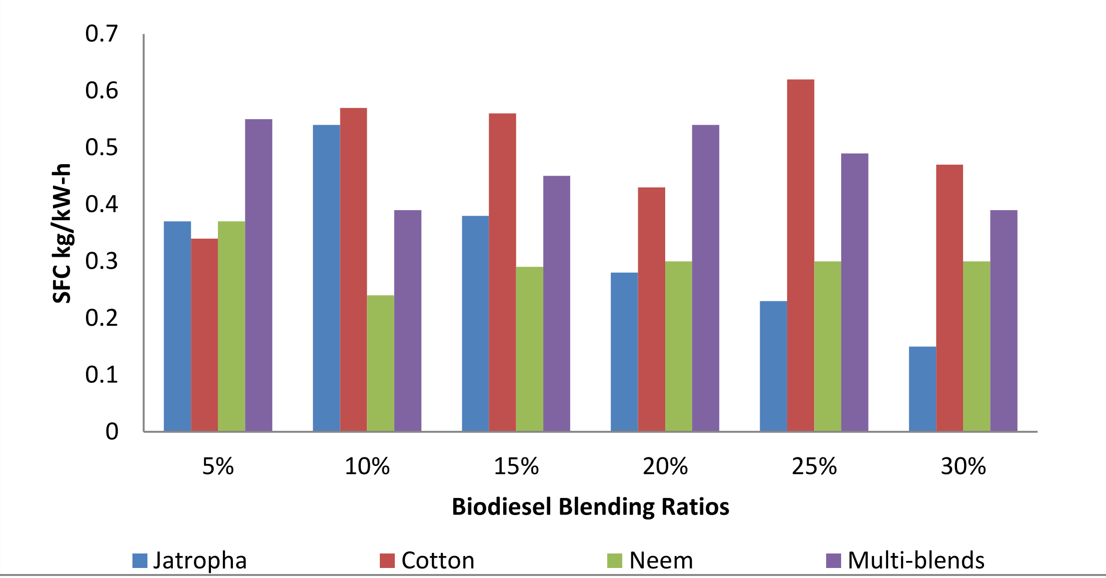


**Figure 2:** Effects of Blend ratio on Specific Fuel Consumption at 1500 rpm Engine Speed

At an engine speed of 1500 rpm as depicted in Figure 2, Jatropha blends (biodiesel) show a similar trend with what is obtainable in Figure 1 only that, between the blend ratios 25 to 30 %, the bsfc decreases further as against the initial trend shown at 1000 rpm. The Cotton biodiesel and the mixed blends have shown a replica of its previous behavior in this Figure. The trends of the cotton biodiesel at 1000 rpm and 1500 rpm are symmetrical. This is contrary to the pattern of Neem biodiesel blend ratios. The bsfc of Neem decreases from the blend ratio of 5 % to 10 % and then increased steadily from 15 % to 30 % blend ratio.

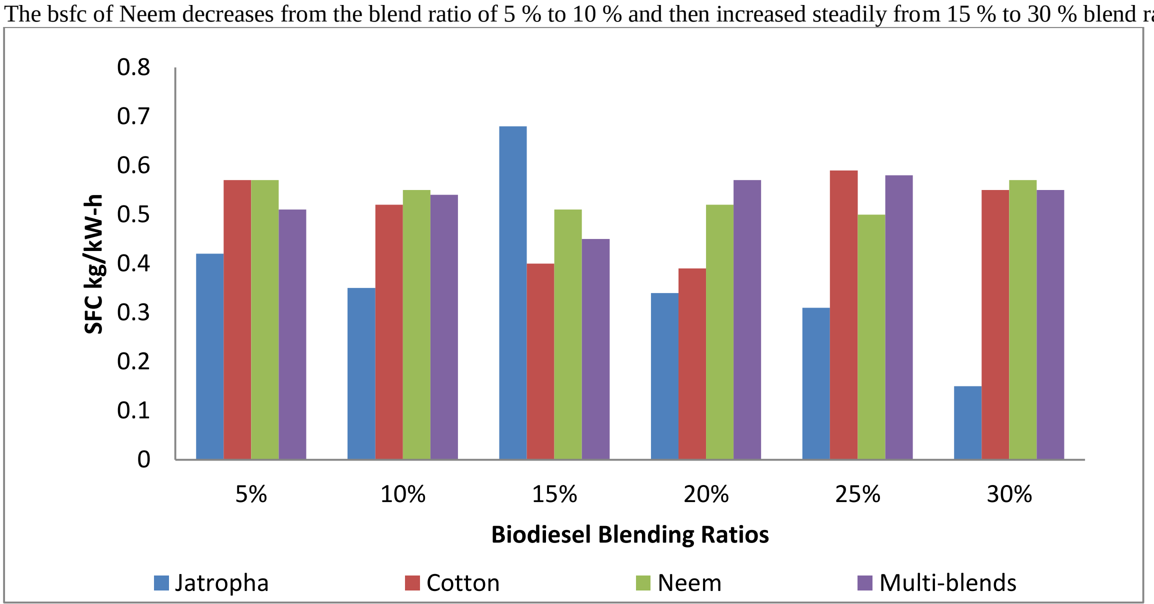


**Figure 3:** Effects of Blend ratio on Specific Fuel Consumption at 2000 rpm Engine Speed

Figure 3 shows the influence of biodiesel blends ratios on bsfc at 2000 rpm engine speed. The Jatropha biodiesel blend shows a pattern that is slightly identical to that shown at 1500 rpm, the lowest bsfc was shown by B30J, followed by B25J. However, Cotton. Neem and the mixed biodiesel blends show entirely different patterns. The bsfc of Cotton decreases with increasing blend ratio between 5 % and 20% and the increased from 20 % to 25 % and decreased again to 30 %. The least value of multi-blends was seen at a 15 % blend ratio and the overall peak value of bsfc was given by B15J.

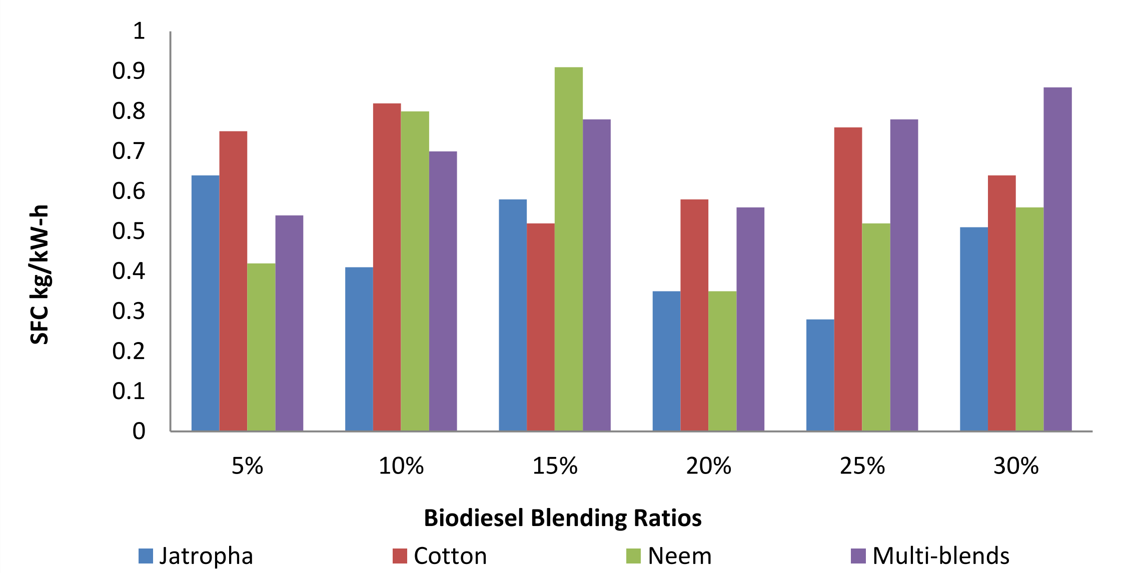


**Figure 4:** Effects of Blend ratio on Specific Fuel Consumption at 2500 rpm Engine Speed

Figure 4 has shown the variation of bsfc at 2500 rpm with biodiesel blend ratios. The blend ratios of Jatropha biodiesel have shown a dissimilar trend from the previous curves in that, the bsfc reduces from 5 % to 10 % blend ratios. The 25 % blend of Jatropha gives the overall minimum value for bsfc at 2500 rpm. All other biodiesels have incremental values of bsfc from 5 % to 10 % blend ratios, then a uniform decline of bsfc to 15 % blend ratio for Cotton and 20% blend ratios for Neem and Multi-blends before the curves make a turn to show an increasing trend in bsfc in each case.

Furthermore, Figures 5 to 8 present the effects of the blend ratio of on brake thermal efficiency at engine speeds of 1000 rpm, 1500 rpm, 2000 rpm, and 2500 rpm.

*3.2 Variation of Biodiesel Blend Ratios with Brake Thermal Efficiency*

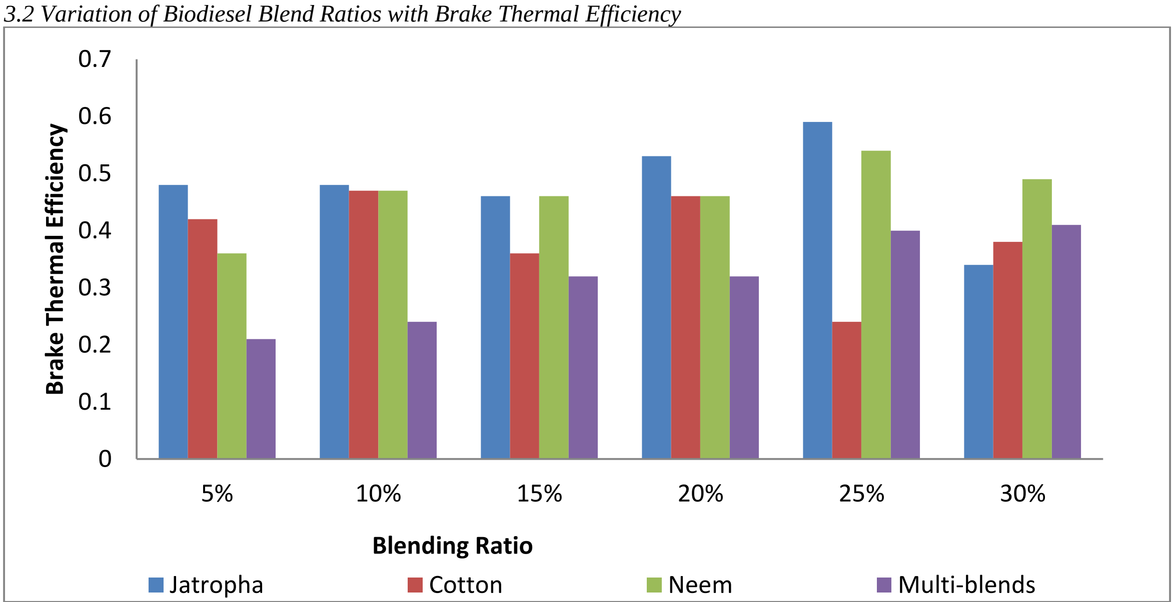


**Figure 5:** Effects of Blend ratio on Brake Thermal Efficiency at Engine Speed of 1000 rpm

Figure 5 presents the influence of blend ratio on brake thermal efficiencies of biodiesel from Cotton, Jatropha, and Neem at 1000 rpm. The Jatropha blend B25J with a blend ratio of 25 % has the peak value of brake thermal efficiency at 1000 rpm. The blend ratios of Jatropha, Neem, and the multi-blends show an increasing trend at 5 % up to 25 % blend ratio before declination in bte by Jatropha and Neem between 25 % to 30 %. However, the Cotton blends show a meandering effect in brake thermal efficiency at each interval of the blend ratio. The higher the brake thermal efficiency of a Compression Ignition Engine, the higher the compression ratio, (Prasath *et al.*, 2012), The implication here is that there will be a greater advantage in using B25J in CI engine because compression ratio is a desired parameter for the engine.

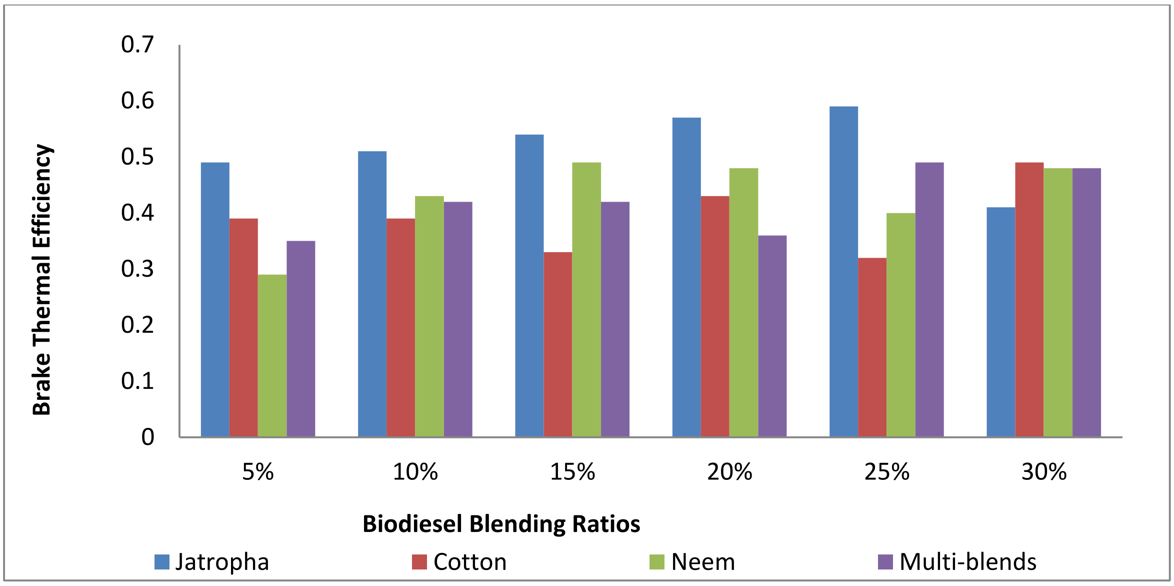


**Figure 6:** Effects of Blend ratio on Brake Thermal Efficiency at 1500 rpm Engine Speed

Figure 6 presents the influence of blend ratios on bte of Jatropha, Neem, Cotton, and mixed blends at 1500 rpm. Jatropha blends show an increasing trend from 5 % up to 25 % blend ratio and decline between 25% and 30% blend ratio, this is similar to the Neem blend ratios which shows a decline between 15 % through 20 % up to 20 % and then made a turn between 25% and 30%. The B25J Jatropha blend ratio shows the peak value of brake thermal efficiency at 1500 rpm. Cotton and multi-blends however have shown an irregular pattern for brake thermal efficiency. The lowest value of brake thermal efficiency was recorded by B25C which is a cotton blend ratio of 25 %.

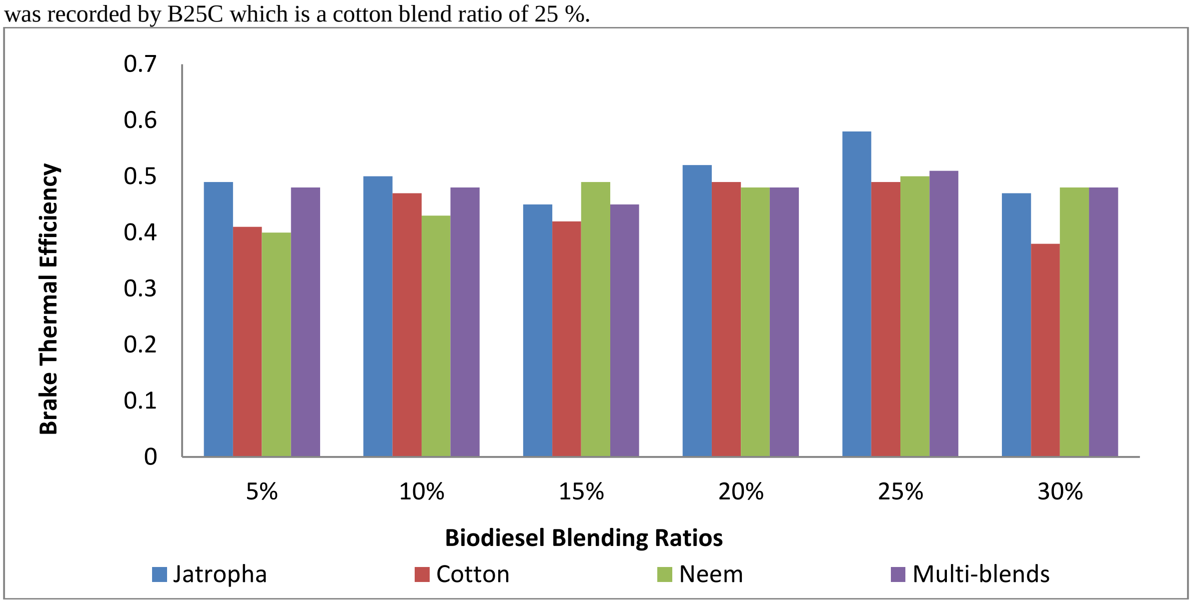


**Figure 7:** Effects of Blend ratio on Brake Thermal Efficiency at Engine Speed of 2000 rpm

Figure 7 presents the effects of blend ratios on brake thermal efficiency of Jatropha, Cotton, Neem, and mixed blends at 2000 rpm. Jatropha blends show an increasing trend from 5 % to 10 %, decreases at 15 % and increased up to 25 % blend ratio and then declined between 25 % to 30 % blend ratio, this is dissimilar to the Neem blend ratios which only shows a slight decline between 15 % t\to 20 % but increases steadily between 5 % and 30 %. The B25J Jatropha blend ratio shows the peak value of brake thermal efficiency at 1500 rpm. The multi-blends however have shown an increasing pattern for brake thermal efficiency but with a slight decline at a 15 % blend ratio. The lowest value of brake thermal efficiency was recorded by B30C which is a cotton blend ratio of 30 %.

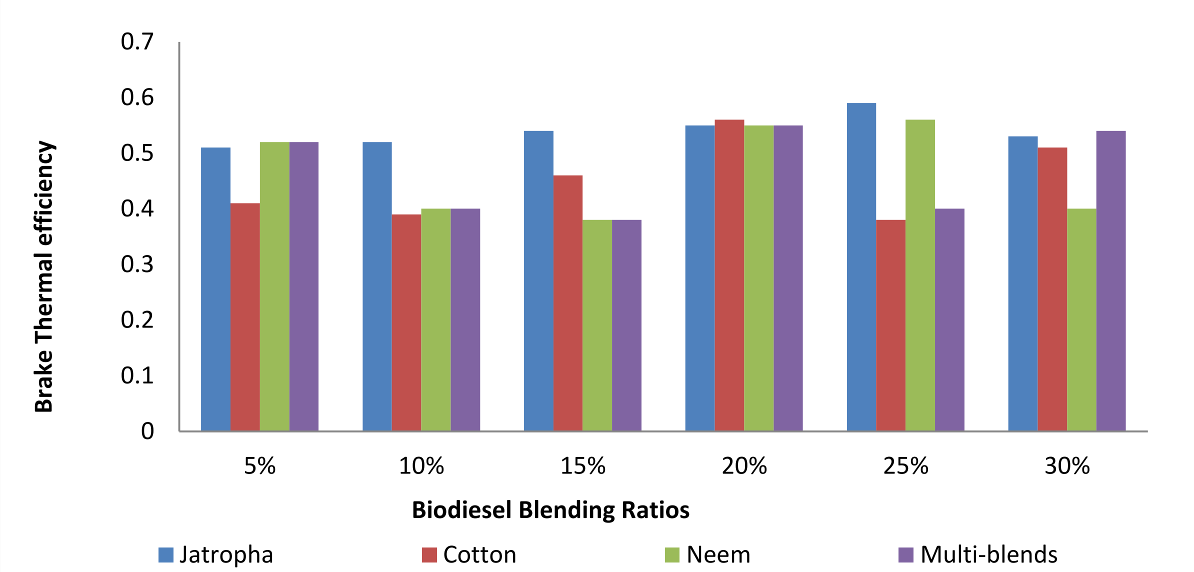


**Figure 8:** Effects of Blend ratio of Brake Thermal Efficiency at Engine Speed of 2500 rpm

Figure 8 presents the effects of blend ratios on brake thermal efficiency of Cotton, Jatropha, Neem, and multi-blends blends at 2500 rpm. Jatropha blends show an increasing trend from 5 % up to 25 % blend ratio and decline between 25% and 30% blend ratio, this is similar to the performance of Jatropha blend ratios at 1500 rpm. The Neem and multi-blend ratios move consistently together from 5% and show a decrease in brake thermal efficiency through 10 % up to 15 % blend ratio and made a sudden rise to 20 % blend ratio where the duo separated from one another. The B25J Jatropha blend ratio shows the peak value of brake thermal efficiency at 2500 rpm. This is contrary to the findings of (Chauhan *et al.*, 2012) who state that brake thermal efficiencies of Jatropha methyl ester and its blends with diesel were very low, and brake specific energy consumption was very high. The Cotton values for brake thermal efficiency decrease from 5 % to 10 % blend ratios, increases between 10 % and 20 %, declined at 25 %, and made further increases at 30%.

*Variation of Biodiesel Blend Ratios with CO and NOx Emissions*

The exhaust emission of various blend ratios of 5%, 10%, 15%, 20%, 25%, and 30% biodiesel from Jatropha, Cotton, and Neem as well as the mixture of the three with diesel at the peak engine speed of 2500 rpm are presented in Tables 2-7 respectively.

**Table 2: Exhaust Emission of 5 % Biodiesel Blends at 2500 rpm**

| $B5_{Jatropha}$ | | $B5_{Cotton}$ | | $B5_{Neem}$ | | $B5_{Mixed}$ | |
|---|---|---|---|---|---|---|---|
| Temperature $^0C$ | | Temperature $^0C$ | | Temperature $^0C$ | | Temperature $^0C$ | |
| Gas | 55 | Gas | 69 | Gas | 64 | Gas | 55 |
| Room | 41 | Room | 29 | Room | 39 | Room | 39 |
| Flue Gases $g/M^3$ | | | | Flue Gases $g/M^3$ | | Flue Gases $g/M^3$ | |
| CO | 0.271 | CO | 0.696 | CO | 0.573 | CO | 0.371 |
| $NO_X$ | 0.220 | $NO_X$ | 0.296 | $NO_X$ | 0.407 | $NO_X$ | 0.280 |

**Table 3: Exhaust Emission of 10 % Biodiesel Blends at 2500 rpm**

| $B10_{Jatropha}$ | | $B10_{Cotton}$ | | $B10_{Neem}$ | | $B10_{Mixed}$ | |
|---|---|---|---|---|---|---|---|
| Temperature $^0C$ | | Temperature $^0C$ | | Temperature $^0C$ | | Temperature $^0C$ | |
| Gas | 56 | Gas | 65 | Gas | 64 | Gas | 58 |
| Room | 41 | Room | 29 | Room | 39 | Room | 41 |
| Flue Gases $g/M^3$ | | Flue Gases $g/M^3$ | | Flue Gases $g/M^3$ | | Flue Gases $g/M^3$ | |
| CO | 0.251 | CO | 0.489 | CO | 0.398 | CO | 0.351 |
| $NO_X$ | 0.168 | $NO_X$ | 0.290 | $NO_X$ | 0.358 | $NO_X$ | 0.198 |

Table 4: Exhaust Emission of 15 % Biodiesel Blends at 2500 rpm

| $B15_{Jatropha}$ | | $B15_{Cotton}$ | | $B15_{Neem}$ | | $B15_{Mixed}$ | |
|---|---|---|---|---|---|---|---|
| Temperature $^0C$ | | Temperature $^0C$ | | Temperature $^0C$ | | Temperature $^0C$ | |
| Gas | 57 | Gas | 66 | Gas | 55 | Gas | 59 |
| Room | 41 | Room | 29 | Room | 39 | Room | 41 |
| Flue Gases $g/M^3$ | | Flue Gases $g/M^3$ | | Flue Gases $g/M^3$ | | Flue Gases $g/M^3$ | |
| CO | 0.063 | CO | 0.139 | CO | 0.420 | CO | 0.043 |
| $NO_X$ | 0.133 | $NO_X$ | 0.197 | $NO_X$ | 0.271 | $NO_X$ | 0.163 |

**Table 5: Exhaust Emission of 20 % Biodiesel Blends at 2500 rpm**

| $B20_{Jatropha}$ | $B20_{Cotton}$ | $B20_{Neem}$ | $B20_{Mixed}$ |
|---|---|---|---|
| Temperature $^0C$ | Temperature $^0C$ | Temperature $^0C$ | Temperature $^0C$ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Gas | 54 | Gas | 42 | Gas | 98 | Gas | 56 |
| Room | 31 | Room | 29 | Room | 47 | Room | 31 |
| Flue Gases g/M$^3$ | | Flue Gases g/M$^3$ | | Flue Gases g/M$^3$ | | Flue Gases g/M$^3$ | |
| CO | 0.021 | CO | 0.125 | CO | 0.032 | CO | 0.022 |
| $NO_X$ | 0.074 | $NO_X$ | 0.129 | $NO_X$ | 0.358 | $NO_X$ | 0.079 |

**Table 6: Exhaust Emission of 25 % Biodiesel Blends at 2500 rpm**

| $B25_{Jatropha}$ | | $B25_{Cotton}$ | | $B25_{Neem}$ | | $B25_{Mixed}$ | |
|---|---|---|---|---|---|---|---|
| Temperature $^0$C | | Temperature $^0$C | | Temperature $^0$C | | Temperature $^0$C | |
| Gas | 47 | Gas | 44 | Gas | 65 | Gas | 47 |
| Room | 31 | Room | 32 | Room | 29 | Room | 31 |
| Flue Gases g/M$^3$ | | Flue Gases g/M$^3$ | | Flue Gases g/M$^3$ | | Flue Gases g/M$^3$ | |
| CO | 0.179 | CO | 0.123 | CO | 0.461 | CO | 0.269 |
| $NO_X$ | 0.062 | $NO_X$ | 0.166 | $NO_X$ | 0.316 | $NO_X$ | 0.092 |

**Table 7: Exhaust Emission of 30 % Biodiesel Blends at 2500 rpm**

| $B30_{Jatropha}$ | | $B30_{Cotton}$ | | $B30_{Neem}$ | | $B30_{Mixed}$ | |
|---|---|---|---|---|---|---|---|
| Temperature $^0$C | | Temperature $^0$C | | Temperature $^0$C | | Temperature $^0$C | |
| Gas | 89 | Gas | 56 | Gas | 55 | Gas | 57 |
| Room | 31 | Room | 32 | Room | 29 | Room | 31 |
| CO | 0.633 | CO | 0.190 | CO | 0.604 | CO | 0.333 |
| $NO_X$ | 0.392 | $NO_X$ | 0.127 | $NO_X$ | 0.314 | $NO_X$ | 0.292 |

From tables 2-7, it may be abstracted that, change in blend ratios leads to a corresponding change in exhaust emission values. From Table 2, at a 5% blend ratio and an engine speed of 2500 rpm, the Jatropha blend has the least value of carbon monoxide and nitrogen oxide emissions. Let us define exhaust temperature range (ETR) as the difference in exhaust temperature and room temperature during the experimental combustion of the fuels. The exhaust range for Jatropha is 14 $^0$C, and for cotton, neem and multi-blends are 40 $^0$C, 23 $^0$C, and 16 $^0$Crespectively. This implies that the combustion of 5% Jatropha blend is the most environmentally friendly as compared with cotton and neem. Interestingly, the mixed blend was next to the Jatropha blend. This implies that the mixing of three biodiesel reduces the quantity of flue gases as well as the temperature range of the exhaust gases.

Similarly, from Table 3, at a 10% blend ratio and an engine speed of 2500 rpm, the Jatropha blend leads to the emission reduction pattern. However, this is in contrast to the results in Tables 4-7. At 15% blend ratio as shown in Table 4, while the Jatropha blend maintained the lead in terms of NOx reduction, the cotton blend has the lead in reduction of CO emission of 0.139 g/m$^3$ and neem blend in terms of Exhaust Temperature Range of 16 $^0$C.

Furthermore, from Table 5, the cotton biodiesel blend ratio of 15% gave the least CO emission, least NOx emissions, and the lowest ETR. This is like the findings in Table 6 at 20% blend ratio, the only exception in Table 6 is that Jatropha blend has the lowest NOx emissions.

Finally, in Table 7, the cotton biodiesel blend of 30% led with the lowest CO and NOx emissions of 0.19g/m$^3$ and 0.127g/m$^3$ respectively. The ETR was 24$^0$C for cotton biodiesel as against58$^0$C, 26$^0$C, and 26$^0$C or Jatropha, Neem, and Mixed blend respectively. Therefore, the cotton biodiesel blend is the best in CO, NOx, and ETR reduction at a higher blend ratio from 20-30%. While at Lower blend ratios, Jatropha blend gives higher emission reduction and ETR reduction tendencies.

## CONCLUSION

The biodiesel blend ratio has direct effects on performance parameters of compression ignition engine, a. The minimum overall bsfc is depicted by Jatropha at a 25 % blend ratio. Factors like the volumetric fuel injection, viscosity, density of the fuel, and low heating value affect the bsfc of fuel in the CI engine, at 1000 rpm, the blend ratios B25J, B25C, and B30C have good values for viscosity and specific gravity. Hence the quality of atomization, combustion, and air-fuel mixing is very good for these blend ratios. The Jatropha binary blend ratio B25J shows the peak value of brake thermal efficiency at 1500 rpm. The multi-blends however have shown an increasing pattern for brake thermal efficiency but with a slight decline at a 15 % blend ratio. The B25J Jatropha blend ratio shows the peak value of brake thermal efficiency at 2500 rpm.

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