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Research Paper

Performance of IC Engines Using Chicken Waste as Biofuel, CNT and MnO Nano-Biofuels and Diesel Fuel: A Comparation Study

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Abstract

Biofuel production and its properties improvisation are the wide areas of research in internal combustion (IC) engines. This research derived biofuel from industrial chicken waste. Nano fuels were produced in this study by adding 40 nm sized nanoparticles carbon nano tube (CNT) and manganese oxide (MnO) with the variation of 100 to 200 ppm to the derived oil. Four fuel blends (biofuel (B), B with CNT, B with MnO, and B with CNT+MnO) were compared to the performance of diesel fuel in a 3.5 kW CI engine. The combustion process (peak pressure and heat release), brake thermal efficiency (BTE), and exhaust emissions (CO, HC, NOx, and CO_2) were used as parameters to evaluate the fuel's performance. The result revealed that nano fuel outperformed both diesel fuel and biofuel. The addition of 200 ppm CNT in biofuel enhanced the fuel properties, resulting in higher BTE by 28% and 9.7% compared to diesel fuel and biofuel. The CNT-biofuel also generated less emissions compared to diesel fuel by 26%, 9.4%, and 25% for NOx, HC, and CO gases respectively.

Keywords: Chicken waste biofuel; Nano fuel; CNT, MnO; Nanoparticles

1. Introduction

The properties of fuel to be used for internal combustion (IC) engines are important aspects as they are directly correlated to the engine performance. Therefore, research on enhancing IC engine fuels properties has always been an interest. Basha et al. [1] explained the production of biodiesel from the various vegetable and non-vegetable oils. It is mentioned that vegetable oil-based biodiesel reduces pollution and possibility of failure in the engine. Further, biodiesel has relatively better properties and outcomes for engine performance and combustion. Ramadhas et al. [2] described the production of biofuel from edible and non-edible sources along with the advantages for the usage in the IC engines. IC engine biodiesel can be obtained from animal fat oils like chicken [3], [4], mutton fat [4], pork skin [5], fish oil [6], beef fat oil [7] and vegetables like cashew nut shell oil [8]–[10], neem oil [11] cottonseed oil [12], [13], camphor oil [8]. However, the conversion of waste into desirable products is always preferable [14], [15]. Nataraj et al. [16] considered chicken fat oil as a fuel for the IC engine along with the emission and fuel performance when used in the engine. A 1500 rpm rated speed with 4.23 kW power single cylinder and four-stroke water cooling IC engine with eddy current loading was used to compare the 100% diesel fuel with 20, 40, 60, 80%, and 100%

Nomenclature

B	Biodiesel
BTE	Brake thermal efficiency
CNT	Carbon nanotube
CO	Carbon monoxide
CO_2	Carbon dioxide
HC	Hydrocarbon
ICP	Inner cylinder pressure
IC	Internal combustion
MnO	Manganese oxide
NP	Nanoparticles
NOx	Nitrogen oxide

blends of biodiesel obtained from the chicken oil. The study concluded that chicken oil derived biodiesel led to the best performance and generated the lowest emission when compared to other fuels tested due to its better properties [16]. Kirubakaran et al. [4] studied chicken fat waste biodiesel. The research summarized different feedstocks and the extracting methods. Among other animal fats, chicken fat showed the most preferable result, hence it is concluded that the feedstock is worth considering. The chicken waste-derived fuel has desirable properties like its calorific value, fire point, flash point, kinematic viscosity, density, cloud point, pour point, and cold filter plugging point [4]. Karthik et al. [3] described the relationship between the use of chicken waste biodiesel to the IC engine's performance and emission reduction. A blend of 20% oil obtained from the transesterification technique was used in the IC engine. As a result, it showed a higher efficiency compared to when diesel fuel was used. It was also recorded that the CO and HC emissions were reduced [3]. Gurusala et al. [17] performed research to evaluate the impact of chicken fat biodiesel on the IC engine with exhaust gas recirculation. In the study, the fat was yielded from the chicken skin that was left untreated [17]. Hoque. et al. [7] also studied biodiesel extracted from animals' fat. The oil was produced by applying 100 °C temperature for the heating and n-hexane catalyst to get the highest yield. The oil from this process was filtered to proceed to the transesterification process [7]. Mata et al. [5] investigated the double purified biodiesel from chicken fat, beef fat, and lard by means of esterification with KOH (0.5 g/kg of oil) at 60 °C temperature. Yusof et al. [18] reviewed the significance of nano-sized materials when added to fossil, alcoholic, and vegetable-based oil fuels to the IC engine performance. It is noted that numbers of nanoparticles (NP) such as Ni, Zr, Cu, Zr, CNT, CuO, AgO_2, Al_2O_3, CeO_2, and MnO significantly affect the IC engine performance. The result showed that many combustions advantageous offered, such as higher BTE and less BSFC. Among the aforementioned NP, Al_2O_3 gave the best result because of the higher oxygen quantity present in the compound [18]. Shaafi et al. [19] and Tripathi et al. [20] studied the effect of numerous NP (CNT, metal, metal oxide) in diesel and biodiesel blends in IC engine outcomes. The addition of NP contributed to higher combustion efficiency, decreased ignition delay, amount of fuel needed, and emissions (CO and HC) produced. Also, the NP was able to transform NOx to N_2. This leads to longer engine life due to lower vibration [19], [20]. Lenin et al. [21] mixed diesel fuel with 100 mg/lit of MnO and 100 mg/lit of CuO. As compared, MnO mixed fuel has 2.53 cSt kinematic viscosity, which is less than the diesel fuel has. MnO blend fuel produced the best result owing to the oxygenating quality, and this led to the improvement of the combustion process by reducing the ignition delay. A 4% increase in thermal efficiency was found. Emissions gases namely HC, CO, and NOx were reduced by 1%, 37%, and 4% respectively [21]. Although a number of researchers has been done on the biofuels production, there are very little information available in the literature about the production of biofuel from chicken waste. Therefore, this study have is investigating the experimental studies of engine performance using biofuel from chicken waste and CNT and MnO nano-biofuels and diesel fuel to comparation the performance of internal combustion engine. In order to reduce wasted chicken waste and be reused; this is also in keeping with the United Nations Center for Regional Development's recommendation to practice 3R (Reduce, Reuse, and Recycle).

CNTs can be produced using a variety of techniques, including chemical vapour deposition (CVD) and arc discharge. These techniques produce carbon nanotubes with diverse characteristics, such as single-walled or multi-walled nanotubes, which may have distinct impacts on the fuel. Carbon nanotubes that have been synthesised must be uniformly disseminated in biodiesel. A steady and homogeneous mixture is required to ensure that the CNTs interact efficiently with the biodiesel [22]. To ensure that the intended characteristics and performance-enhancing features of the nanomaterials are maintained throughout the manufacturing process, strict quality control and characterization of the CNT Nano-Biofuel are required. Safety considerations are critical in any nanomaterial application. Extensive testing and regulatory compliance are required to assure that the CNT Nano-Biofuel is safe for usage and poses no environmental or health dangers [23]. It is vital to note that the development and commercialization of CNT Nano-Biofuel may face cost, scalability, and regulatory approval issues. Furthermore, the potential benefits and impacts of this technology would have to be balanced with considerations for environmental sustainability and safe nanomaterial handling. This study produced biofuel from chicken waste for IC engines. 100 to 200 ppm 40 nm sized nanoparticles namely CNT and MnO were added to biofuel in an aim to improve biofuel properties and performance. The engine performance when each tested fuels applied was used to evaluate the fuel quality.

2. Materials and Method

2.1. *Materials and Reagents*

First, chicken wastes (**Figure 1**) including skin, leg, head, comp, shank, eyes, large intestine, small intestine, and unwanted parts were collected from various places such as kitchens, broiler shops, fast food shops, hotels, etc. Potassium hydroxide (KOH), phenolphthalein, methanol, n-Hexane chromatography grade), ethyl acetate, and Wijs reagent were purchased from Merck local market.

2.2. *Methods*

2.2.1. *Oil Extraction from Chicken Waste*

The collected wastes were rinsed with water and heated at 100 °C for half an hour. The waste parts containing fat were separated and stored in a clean flask. The process was repeated until the maximum yield was achieved. The collected oil was then heated up to 120 °C to remove the moisture content.

2.2.2. *Biofuel production*

A two-liter of moisture-free clear oil from the chicken wastes was prepared for the transesterification process. This oil was set to the heater at a temperature of 65 °C throughout the process, as shown in **Figure 2a**. The heater is also equipped with magnetic agitator to create continuous stirring while heating. Next, 400 ml of methanol was added into the oil, and 10g of KOH was added into the solution with continuous stirring for one hour at a constant temperature. The oil was then cooled at room temperature for one day, which resulted separation of glycerin deposited in the bottom. After removal of the glycerin, the oil was again treated in the same condition with the addition of 10 ml H_2SO_4 into the oil for one hour at the same temperature. Similarly, the oil was cooled for one day afterward, which resulted the final yield of biofuel (shown in **Figure 2b**).

2.2.3. *Nano Fuel Preparation*

Two nanoparticles with an average size of 40 nm, which are CNT (**Figure 3a**) and MnO (**Figure 3b**) were chosen based on some studies [21], [24]. Each combination of nano fuel was added with 200 ppm of NP for every liter of biofuel using a 180 W ultrasonicator (**Figure 3c**).

Figure 1. Cleaned chicken waste collected from various place

Figure 2. Biofuel preparation (a) Transesterification Process (b) Extracted chicken waste biofuel

Three combinations of nano fuel were made in this study to be compared with chicken waste biofuel (B) and diesel fuel with the detail below and properties listed in **Table 1**.

2.3. Combustion, Performance and Emission Testing

Diesel fuel, chicken waste biodiesel, and nano fuels (B with CNT, B with MnO, and B with CNT + MnO) were individually tested in the 3.5 kW IC engine with the rated power of 1500 rpm without modification done to the engine (**Table 2**). The complete experimental arrangement is illustrated in **Figure 4**.

The setup has fuel and airflow sensors to measure and control the flow rate of fuel and air individually. In-cylinder pressure during the combustion process is measured by the pressure transducer. Engine loading is given by an eddy current dynamometer. The system is associated with the data acquisition system (DAS). The combustion and performance results were obtained from the DAS. The exhaust emissions gases were obtained through an AVL gas analyzer which help to recognize the emissions of CO, CO_2, HC and NOx.

3. Results and Discussion

3.1. Biodiesel Production from Chicken Waste

Methyl ester conversions from chicken waste in a transesterification process of 96.6%. This reaction performance can be explained by the solvent extracting various types of lipids and fats as well as contaminants that could interfere with the reactive system's ability to produce FAME [25]. This analysis should also take into account the fact that the content and properties using heterogeneous biomass due to internal fluctuations in the manufacturing process, which affects biodiesel generation. These findings also indicated that the method used to collect chicken waste could have an impact on biodiesel production, indicating that an integrated analysis based on both economic and environmental consequences should be done to choose the best biomass processing approach.

Figure 3. Nano fuel preparation: (a) CNT (b) MnO (c) Ultrasonicator equipment

Table 1. Properties of the fuels

Properties / Fuels	D	B	B with CNT	B with MnO	B with CNT + MnO	ASTM D6751
Cetane number	49	56	62	59	60	47 minimum
Density in kg/m^3	835	892	850	860	865	860-880
Flash point in °C	54	139	151	164	149	Min. 130
Fire point in °C	79	148	160	173	165	-
Calorific Value in kJ/kg	41950	38120	41932	40979	40026	35000 minimum
Kinematic viscosity @ 40 °C in cSt	3.2	5.5	4.1	4.3	4.5	1.9-6.0

B & CNT –100% biofuel and 200 ppm CNT
B & MnO – 100% biofuel and 200 ppm MnO
B & CNT + MnO – 100% biofuel and 100 ppm CNT + 100 ppm MnO

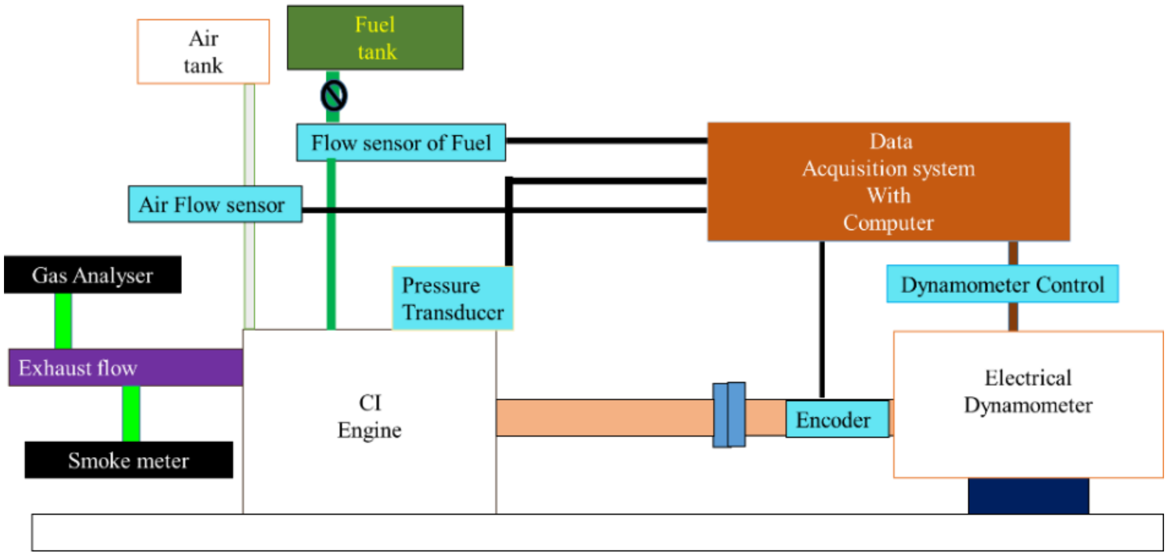

Figure 4. Experiment arrangement

Table 2. Technical specifications of the engine

Type	Specifications
Injection system	Direct injection
Number of cylinder	One
Type of cooling system	Water-cooled
Cylinder bore (mm)	87.5 mm
Stroke (mm)	110 mm
Max. Power	3.5 kW
Max. engine speed (rpm)	1500 rpm

3.2. *Combustion of Diesel Engine*

Figure 5 shows the relationship between the inner cylinder pressure (ICP) and crank angle variations to compare the fuel performance. The peak pressure performance of biodiesel, B with MnO, B with CNT+MnO, and B with CNT are 10.0%, 12.8%, 23.8%, and 32.0%, correspondingly, and the result is higher than the pure diesel. The peak pressure of nano fuels performance was compared with base fuel (B). The results demonstrated that B with MnO, B with CNT+MnO (hybrid), and B+CNT are 2.5%, 12.5%, and 20.0% respectively, higher than the peak pressure performance of base fuel (biodiesel). With this, CNT blend fuel was then noted to be the best fuel, outperforming diesel fuel, biofuel, nano fuel, and hybrid nano fuel. These variations were formulated by the nano particle used in the fuel which led to the augmented properties (**Table 1**). NP enhanced the heat transfer in the convection mode, especially CNT hence led to the widespread of combustion [18], [19], [21].

Figure 6 points out the discrepancy of the heat release rate established on the crank angle deviations. The heat release performance of fuels was compared with pure diesel fuel. As a result, it showed that B (12.0%), B with MnO (15.8%), B with CNT+MnO (23.2%), and B with CNT (44.8%) fuels have higher heat release performance than diesel fuel. The heat release performance of base fuel (biofuel, B) was also compared to B with MnO, B with CNT+MnO, and B with CNT. The result showed that the fuels resulted in higher heat release performance than the base fuel by 3.4%, 10.0%, and 29.3%, respectively. The same as peak pressure performance, CNT nano performed better than other fuels in terms of heat release performance. This variation was influenced by the fuel properties like higher cetane number and lesser viscosity of the base fuel [4], [16], [17]. CNT nanotubes can promote finer fuel atomization during the injection process. Finer fuel droplets result in better air-fuel mixing, leading to more efficient and complete combustion, potentially contributing to a higher cetane number [26]. he NP addition to the base fuel corresponds to a greater heat release rate due to the augmentation of the energy content on the fuel [24]. These help to increase the combustion with maximum possible oxidation [20], [21].

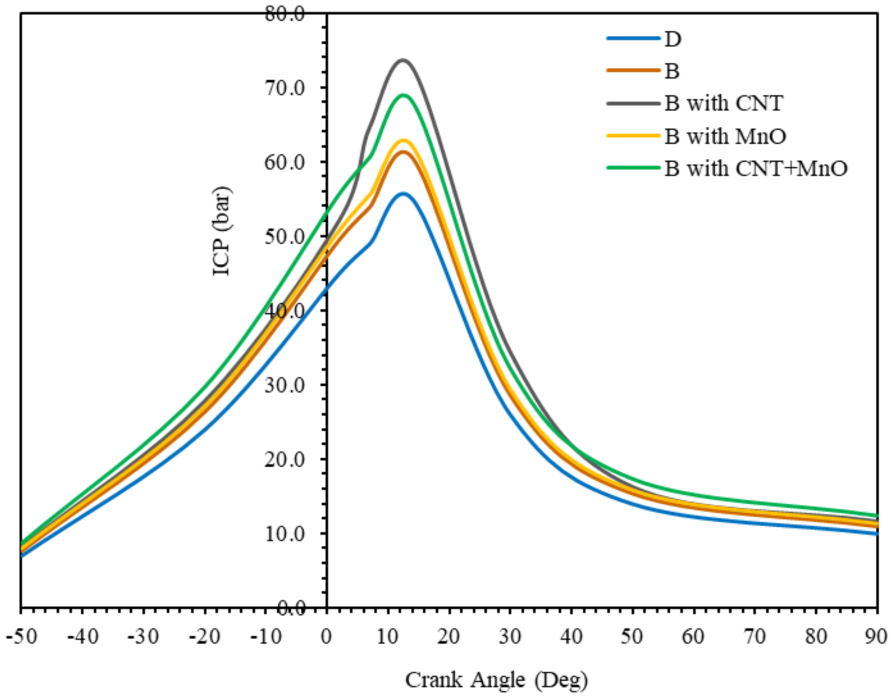

Figure 5. Relationship between in-cylinder pressure, ICP (bar) with crank angle variations (degree)

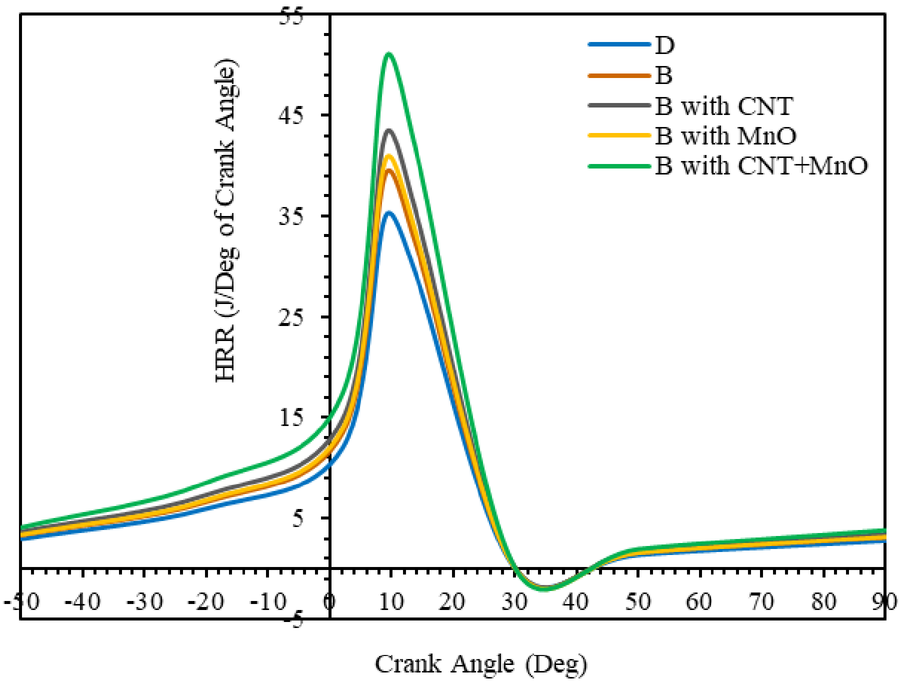

Figure 6. Relationship between heat release rate (J/DCA) with crank angle variations (degree)

3.3. *Performance Characteristics of Diesel Engine*

The performance analysis of the engine contains details of the brake thermal efficiency and heat release rate related to the different loads. Brake thermal efficiency variations with respect to the biofuel and nano fuels are depicted in **Figure 7**. The comparison shows that diesel fuel has low brake thermal efficiency in all loads applied while the other fuels have higher brake thermal efficiency considering the higher calorific value they own and cetane number of the base fuel [5], [7]. The brake thermal efficiency of the four fuels was compared to diesel fuel. As result, B, B with MnO, B with CNT+MnO, and B with CNT show higher efficiency than pure diesel by 17%, 21%, 25%, and 28%, respectively. The brake thermal efficiency of nano fuels also competed with the base fuel (biofuel, B). These CNT+MnO help increase the cetane number by promoting faster ignition. They can modify the chemical composition of the fuel, allowing it to ignite more easily when exposed to the high temperature and pressure in the engine's combustion chamber [27]. In rank, the result showed that CNT fuel (9.7%), B with CNT+MnO (7.2%), and B+MnO (4.6%) are higher than biodiesel. This is achieved due to the oxidation property that led to the proper oxidation of the fuel during the combustion process [19], [20].

The variation of the load was used to compare the engine performance when specific fuel is subjected. As shown in **Figure 8**, it is observable that diesel fuel has the lowest brake-specific fuel consumption in all load variations. The other fuels consumed more for the same operating condition applied. The combustion-based properties of the comparable fuel were found to be better than diesel fuel, as summarized in **Table 1**. This is, of course, correlated to more fuel consumption. The fuel consumption performance of the control and experimental groups was tested at a full load condition. Compared to diesel, other fuels were consumed lesser than that of diesel fuel by 4.5%, 9.8%, 13.4%, and 19.7% respectively for B, B with MnO, B with CNT+MnO, and B with CNT. In comparison to the base fuel (biofuel, B), other nano fuels consumed lower than the base fuel by 5% for B with MnO, 8.5% for B with CNT+MnO,

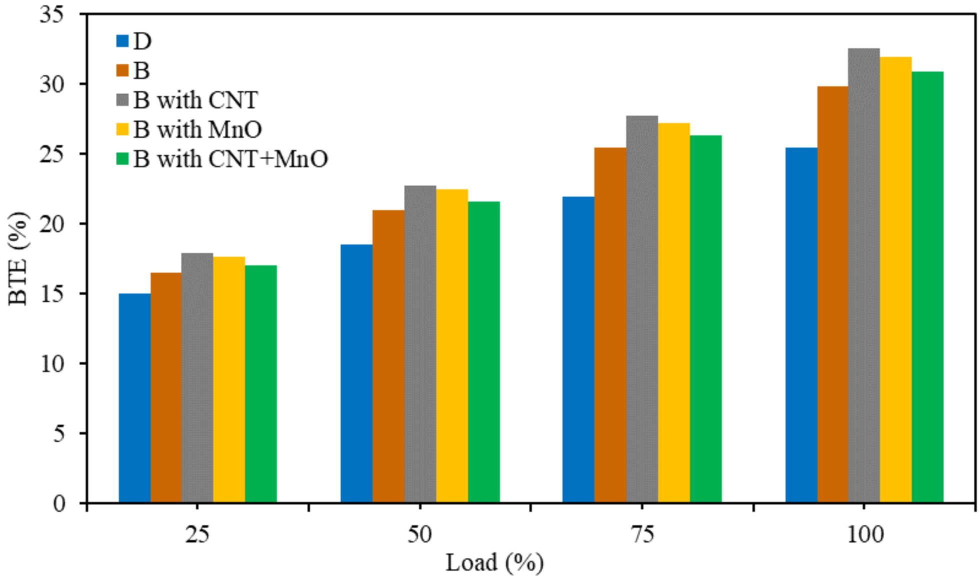

Figure 7. Performance comparison of brake thermal efficiency (%) related to a given load

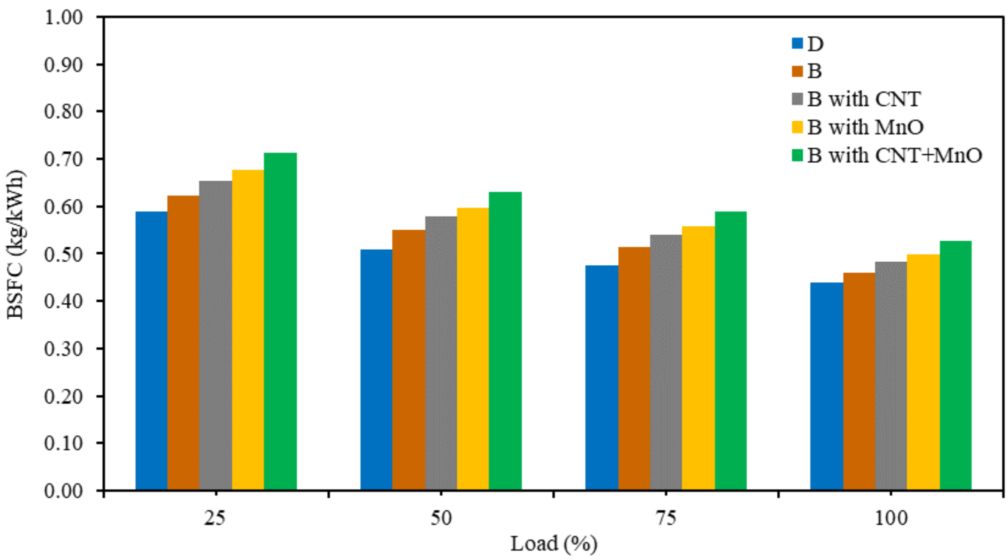

Figure 8. Performance comparison of brake-specific fuel consumption (kg/ kWh) and load (%)

and 14.5% for B with CNT. Among the three, B with CNT fuel consumed the least. This deviation was possibly happened by means of NP's oxidation ability and therefore needs more fuel to have appropriate oxidation in combustion [18]–[22]. The exhaust emission measurement by an AVL gas analyzer shows the CO, HC, CO_2, and NOx emissions of the engine when each fuel is applied with different loads. **Figure 9** presents the relationship between the number of emissions produced and load. Diesel fuel generated the highest CO emission while the lowest generated by B and CNT fuel in all load variations.

3.4. *Emission Characteristics of Diesel Engine*

Different load conditions were applied to test carbon monoxide produced by all fuels. The lowest emission was obtained when B with CNT was used in all load variations, lower by 27% from pure diesel fuel, followed by B with CNT+MnO (20%), B with MnO (17%), and B (15%). When compared to the base fuel, B with CNT also contributed less emission by 11%, while B with MnO and B with CNT+MnO by 5% and 2% respectively. The oxygen content in the biofuel is more than the diesel fuel has, and it creates the maximum conversion of the CO emission into the CO_2 by the oxidation during combustion [20], [21].

Figure 10 shows the result of HC in ppm of fuels when different loads were applied. In comparison to the diesel fuel, B with CNT fuel produced the lowest emission (9.4% less than pure diesel fuel), followed by B with CNT+MnO (5.3%), B with MnO (5.2%), and B (1.7%). Meanwhile, comparing nano fuels to base fuel (biofuel, B), lower emissions found in all variations applied generated by B with MnO, B with CNT+MnO, and B with CNT by 7%, 10%, and 14%. The B with CNT fuel produced the least emission because the oxidation properties of NP convert the unburn hydrocarbon by oxidation [18], [19].

Carbon dioxide was also set as the fuel performance indicator in this study. **Figure 11** provides data on the CO_2 generation of all tested fuels in the given load. Diesel fuel produced the lowest emission while the highest resulted in from B with CNT burning. A higher emission was obtained when B, B with MnO, B with CNT+MnO, and B with CNT by 10%, 37.5%, 48.5%, and 54% fuels were used. Nano fuels were compared to base fuel (biofuel, B) to see CO_2 generation at the same given loads. Turned out, B with MnO, B with CNT+MnO, and B with CNT fuels were responsible for more emission production by 25%, 36%, and 41%. Hence the CO_2 emission by CNT Nano-fuel found lower than diesel fuel, Biofuel, Nano fuel and Hybrid Nano-fuel. These variations were created due to two main reasons. One is the oxygen content availability of the base fuel [3], [4] and the second one is the oxidation property of the nano particles [20], [24]. CNT could reduce the ignition delay of biodiesel. The time period between the start of injection and the actual start of combustion is referred to as ignition delay. Higher cetane levels are connected with shorter ignition delays [28]. So, the maximum conversion

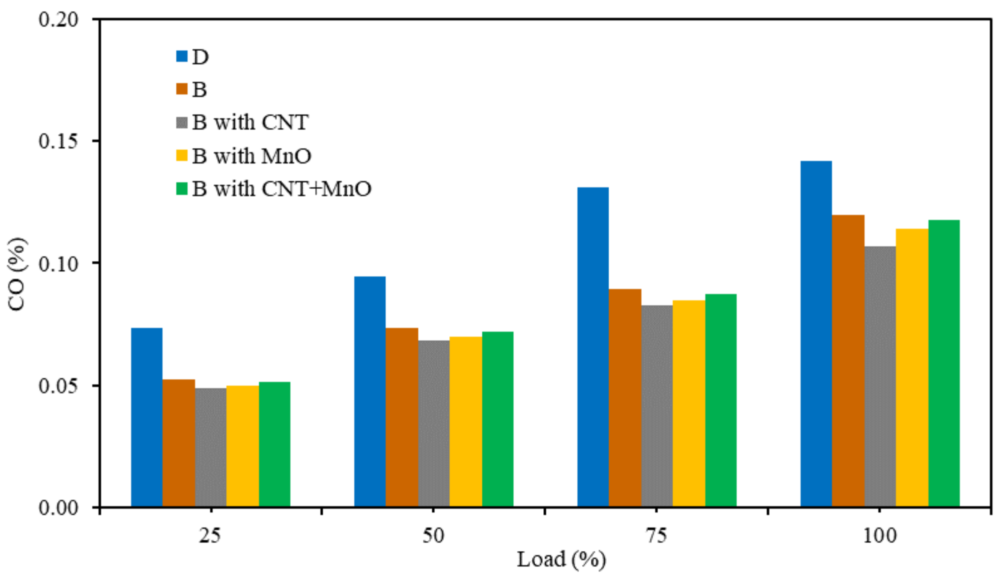

Figure 9. Relationship between exhaust emission, Carbon monoxide (%) and load (%)

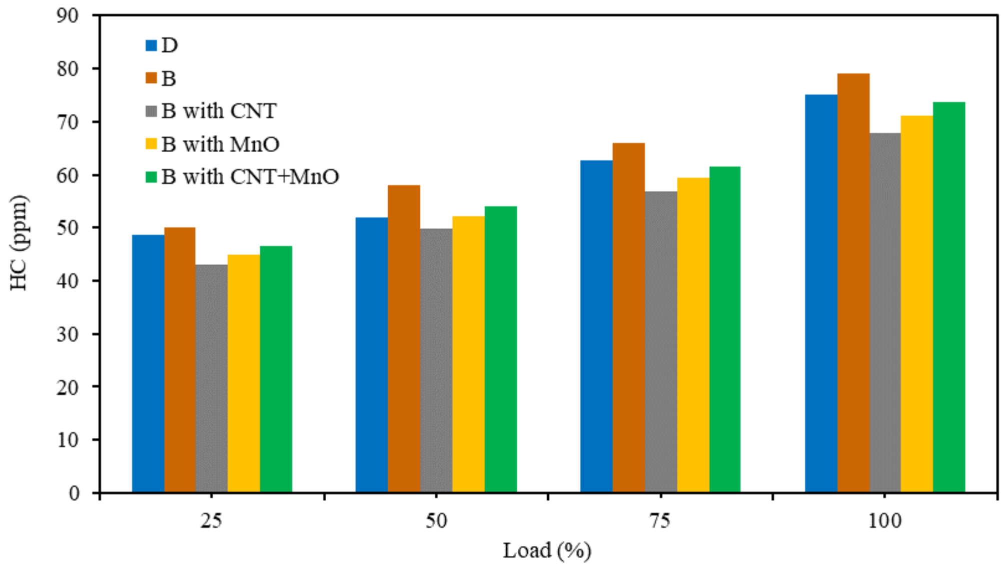

Figure 10. Exhaust emission of hydrocarbons (ppm) variation for the different load (%)

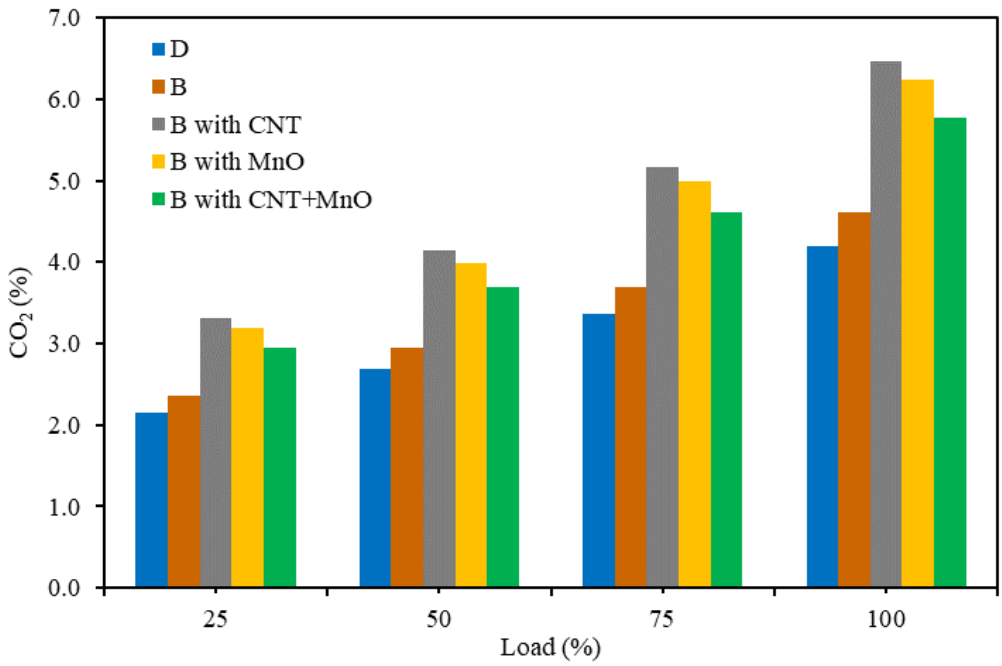

Figure 11. Exhaust emission of Carbon dioxide (%) variation for the different load (%)

of the HC emission and CO emission has led to the increase of the Carbon dioxide emission in the exhaust. But Carbon dioxide is lesser pollutant than CO emission so this is the preferable one.

NOx as one of the exhaust emissions gases was also considered in this study to evaluate the fuel's performance. As shown in **Figure 12**, for the same load applied, chicken waste biofuel produced the highest NOx pollutant, 23% higher compared to diesel fuel. The nano fuels, however, generated fewer emissions by 8% (B with CNT+MnO), 14% (B with MnO), and 26% (B with CNT). Compared to biofuel, 40%, 30%, and 25% lesser NOx were produced by B with CNT, B with MnO, and B with CNT+MnO nano fuels respectively. These results were possible happened because of the in-cylinder temperature [6], [17] and the maximum oxidation of the fuel in the combustion [19], [21]. CNT Nano-Biofuel might potentially lower emissions of greenhouse gases and hazardous pollutants such as particulate matter, nitrogen oxides (NOx), and hydrocarbons by promoting greater combustion and fuel efficiency. The overall impact, however, would be determined by the fuel's whole life cycle, including production, distribution, and end-of-life issues [29].

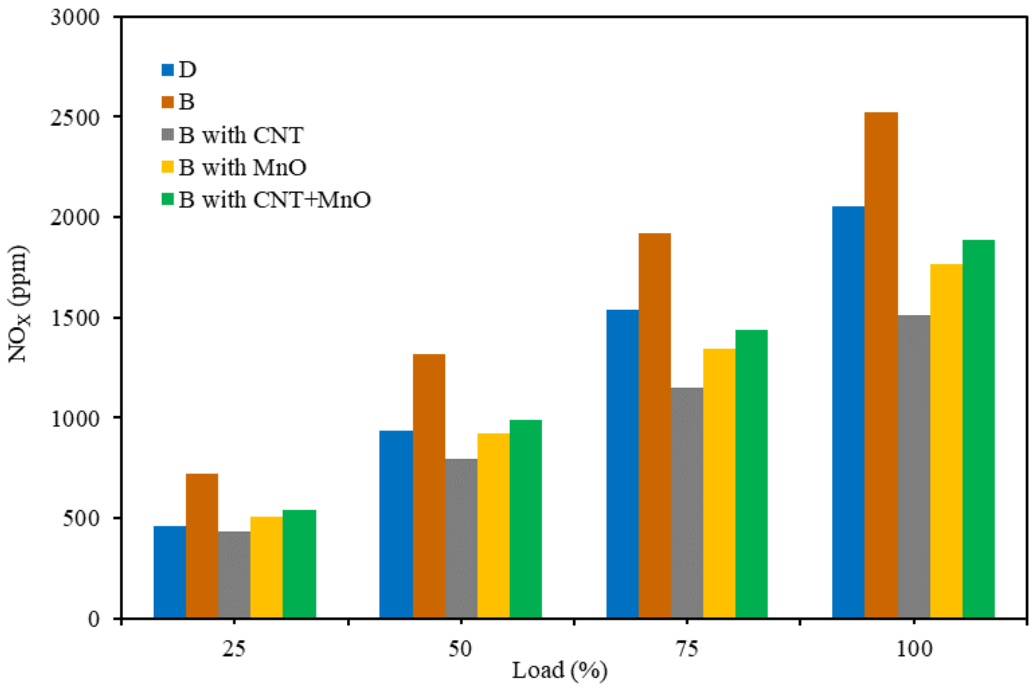

Figure 12. Exhaust emission of NOx (ppm) variation for the different load (%)

4. Conclusion

This study extracted oil from industrial chicken wastes to produce high-grade nano fuels for CI engines. The base fuel (biofuel, B) was added with nanoparticles (CNT and MnO), resulted in the following combinations: Biofuel (100% biofuel or B), Biofuel with 200 ppm CNT (B with CNT), Biofuel with 200 ppm MnO (B with MnO), Biofuel with 100 ppm CNT and 100 ppm MnO (B with CNT+MnO). To evaluate the compatibility for CI engines and to see the emissions generated, biofuel and nano fuels were compared to diesel fuel. The results of applying different crank angle variations and loads are summarized below:

a. Biofuel extracted from chicken waste via the transesterification process is potential to be used as IC engines fuel.
b. The addition of CNT and MnO (either combined or separated) to biofuel improved the combustion performance, and engine efficiency. Regardless that the addition of nanomaterials increased the CO_2 production, other emissions gases (CO, NOx, and HC) production was reduced and is preferable because the characteristic of CO gas is more harmful than CO_2.
c. Among other nano fuels studied, CNT fuel has better performance compared to diesel fuel and biofuel: Higher BTE by 28% than diesel fuel and 9% than biofuel; Slighty higher BSFC; Better combustion process; Lesser HC production (9.4% than diesel fuel, 14% than biofuel); Lesser CO production (25% than diesel fuel, 11% than biofuel); Lesser NOx production (26% than diesel fuel, 40% than biofuel); Higher CO2 production (54% than diesel fuel, 41% than biofuel)
d. The order of nano fuels performance: B with CNT > B with CNT+MnO > B with MnO.

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Author's Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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Availability of data and materials

All data are available from the authors.

Competing interests

The authors declare no competing interest.

Additional information

No additional information from the authors.

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