Extraction of Oil and Preparation of Biodiesel using Orange Peel and its Performance and Emission Analysis on CI Engine

Suraj Singh, Devesh Kumar*, Priyankesh Kumar*, Suraj, Santosh Kumar Yadav, Ramji Tripathi

Department of Mechanical Engineering, Madan Mohan Malaviya University of Technology, Gorakhpur Uttar Pradesh, India, 273010

*Corresponding author's e-mail: dkme@mmmut.ac.in, pkchaudhary860@gmail com

doi: https://doi.org/10.21467/proceedings.161.24

ABSTRACT

Although fossil diesel is essential in daily life, it's rapid depletion and environmental impact attract researchers looking for a substitute for fossil diesel (FD). Bio-oil extracted from wastes such as vegetable and fruit peels and converted into biodiesel is essential to filling the energy demand. The present work uses orange peel to extract the oil from it through a Soxhlet apparatus and then convert it into biodiesel (BD) with the help of the transesterification process. Also, three different blending mixtures with orange peel biodiesel (OPBD) were made based on volume. They were named OPBD 0 (fossil diesel 100%), OPBD 10 (10% BD + 90% FD), and OPBD 20% (20% BD + 80% FD), and they were tested on a single-cylinder, four-stroke diesel engine to see how well they worked and how much pollution they gave off. A rope brake dynamometer was used to vary the load from 0 to 5 kg). Performance in terms of brake thermal efficiency (BTE), brake-specific fuel consumption (BSFC), and exhaust gas temperature (EGT) was determined, and emissions such as nitrogen dioxide (NOx), carbon dioxide (CO2), and carbon monoxide (CO), were also analyzed with the help of a gas analyzer. Out of different blending mixtures, OPBD 20 gives the best results in terms of performance and reducing toxic gases. Overall, OPBD 20 can be chosen as an alternative to FD.

Keywords: Orange peel oil, Soxhlet apparatus, transesterification, performance, and emission analysis.

1 Introduction

These days, the price of IC engine fuels (i.e., Petrol and diesel) is increasing daily because of country wars, and simultaneously, the availability of conventional fuel is decreasing continuously. To overcome this problem, the government wants to decrease its dependency on the countries that supply fuel. For this reason, blending biofuel with conventional fuel will reduce dependence on other countries. So, researchers are doing research on renewable and appropriate fuels for the production of biofuel. Diesel plays a significant role in IC engines, generators, commercial and industrial engines, and diesel engine power plants. There are a lot of plant and animal feedstocks available for the production of biodiesel. According to this research, waste orange peel might be a good source for biodiesel production because of its easy availability at zero cost. Karmakar and Halder study provides the different types of first, second, and third-generation feedstock and the different types of oil extraction techniques. Feedstocks from the first generation, such as sunflower, soybeans, rapeseed, and palm oil); feedstocks from the second generation (jatropha, neem, and rubber seed); and also, animal sources such as fats like poultry fat and beef tallow; and feedstock from the third generation is microalgae. Various techniques, such as steam distillation, mechanical extraction, solvent extraction (chemical leaching, Soxhlet extraction), and enzymatic oil extraction, can extract oil from the feedstocks. Some new techniques, such as supercritical fluid extraction, microwave-assisted extraction, and ultrasound-assisted extraction, are used for oil extraction from feedstocks [1]. Vignesh R. *et al.* used orange waste peels dried in sunlight to remove the moisture in the peels. The steam distillation method was applied to obtain pure OP oil from waste orange peel powder. Various fuel properties such as density, kinematic

Proceedings DOI: 10.21467/proceedings.161; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-965621-8-2

viscosity, flash point, fire point, and calorific value of diesel, OPO100, OPO20 were measured. For optimization, the Central Composite Design (CCD) and Response Surface Methodology (RSM) approaches were adopted, in which CCD was adopted to know the parameters that have the best effect on the performance of a diesel engine. These factors were taken as entry parameters for the Response Surface Methodology (RSM) approach [2]. Temilola T. Olugasa *et al.* prepared an orange peel biodiesel blend with cashew nutshell liquid. After the performance analysis and emission characteristics of blending mixtures of cashew nutshell liquid and orange peel biodiesel, it was found that Cashew nutshell liquid was a favourable additive that improved the performance of orange peel biodiesel [3]. Parvesh Kumar and Naveen Kumar transformed OP oil into orange peel (OP) oil methyl ester, which was optimized using response surface methodology. The CCD technique of Response surface methodology (RSM) was adopted to achieve optimal reaction conditions. After optimization, it was observed that the yield of orange peel oil methyl ester (OPOME) increased by more than 2% using RSM [4]. Hiba Shaghaleh *et al.* investigated a microwave pre-treatment procedure at atmospheric pressure using a microwave oven. The citrus peel shredder removed the orange peels from the fruit. The steam distillation process was applied to extract oil from these orange peels. Scanning electron micrography (SEM) was performed for the chemical analysis of the orange peel oil [5]. M.A. Asokan *et al.* adopted a steam distillation process for the oil extraction from the waste orange peels. They prepared the different orange peel oil blends with diesel, such as B100, B20, B30, and B40), in which B100 refers to pure biodiesel, B20 refers to 80% fossil diesel and 20% orange peel biodiesel, B30 refers to 70% fossil diesel and 30% orange peel biodiesel, and B40 refers to 60% fossil diesel and 40% orange peel biodiesel [6]. P Akpan *et al.* (2014) told that orange fruit has been part of the human diet for ages because of its nutritional and medicinal value. Still, the consumption of orange fruit generates waste in the form of orange peel. If it is not properly handled, it can contribute significantly to the pollution of the larger environment. According to the researcher, waste orange peels might be a good option for waste-to-energy (WTE) energy extraction [7]. Mohsen Gavahian *et al.* reviewed the recent findings on the suitability, merits, and demerits of orange oil extraction methods for orange peel valorization [8]. S. Abdul Sheriff *et al.* used lemon peel oil (LPO) and orange peel oil (OPO) to prepare biodiesel. Cerium oxide (CeO_2) and carbon nanotube (CNT) nanoparticles were used as nano additives to enhance the properties of prepared biodiesel. Cerium oxide nanoparticles were obtained through CO-precipitation (CPM), and carbon nanotubes were prepared by the chemical vapour deposition (CVD) method. The ultrasonication process synthesizes cerium oxide and Carbon nanotubes nanofluids [9]. B. Ashok *et al.* used Steam distillation apparatus to obtain the OP oil from waste orange peels. During the distillation process, it was observed that 20% blending orange peel oil with mineral diesel does not change the distillation temperature and it provides a blend of decreased density and almost the same cetane index. During experimentation, the hydrostatic head principle was used to evaluate the fuel consumption of all fuel samples [10]. Alex Y *et al.* used mechanical crushing to get the desired size of the dried orange peels. The prepared powder size was kept between 1-5mm. Utilizing the Soxhlet extractor apparatus, the oil solvent extraction process and the preparation of the biodiesel transesterification process were both used. The GC-MS and FTIR tests were adopted to study the fatty acid composition of the feedstock [11]. Rajaraman *et al.* used diethyl ether (DEE) as an additive in the orange peel oil biodiesel. By using diethyl ether, NO_x and HC emissions decrease and increase, respectively [12]. Mahesh Kumar *et al.* effectively utilized the orange oil as a fuel for diesel engines. The tailpipe emissions of diesel engines were reduced for the fuel blend nanoemulsion orange oil methyl ester (OOME). A smoke meter was used to measure the smoke opacity, and a gas analyzer was used to measure the exhaust gases [13]. Nataraj Ganesan and Senthilkumar Masimalai studied the results of mixing antioxidant additives with orange peel oil (OPO) BD to reduce the exhaust emissions in a diesel engine. The produced BD (OB20) was blended with 5% and 10% antioxidant additives (L-ascorbic acid) [14]. Saini *et al.* prepared corn oil biodiesel and prepared eight samples which are characterized by carbon-hydrogen-nitrogen-sulphur analyzer (CHNS), FTIR and (GCMS) analysis [15]. Ahmad and Saini (2023) prepared mango seed biodiesel by using butanol as an additive to enhance the properties of mango seed biodiesel. Butanol is selected because it is highly volatile, safely combustible, and has less viscosity. Uncertainty analysis was adopted to assess the errors during the experiments [16]. Md. A. Hossain *et al.* used coconut as a feedstock for biodiesel preparation and measured the properties of biodiesel and blending mixtures by measuring heating value, viscosity, and flash point. The heating value was observed to be the maximum for diesel and the minimum for neat biodiesel. Good biodiesel must have less viscosity. During the analysis, it was observed that B100 was a very dense fuel, and the viscosity of B100 fuel was higher than that of fossil diesel. It results in existing diesel engines requiring some modifications [17]. Periasamy *et al.* used a split injection CRDI engine to perform emission and performance tests for different orange peel biodiesel blends with additives. K-type thermocouples were used to measure the temperature of gases and water at various loads. Engine performances like brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), brake power (BP), cylinder pressure, and mechanical effectiveness were determined [18]. R. Siva *et al.* used orange peels to prepare biodiesel and blend mixtures to determine diesel engine performance and emission characteristics. Emissions like unburned hydrocarbons (HC), CO, nitrogen oxide (NO_x), and smoke opacity were determined by the gas analyzer [19]. C. Banerji *et al.* extracted orange oil from waste orange peels by distillation. A new approach has been tried to enhance the ignition pattern of orange peel oil by mixing Di-tetra-butyl-peroxide (DTBP) as a cetane improver [20].

Overall, the literature investigation showed that different researchers utilized various forms of fuel for BD production and to test its impacts on diesel engines, with relatively few researchers using the orange peel for oil extraction and BD preparation.

In the current investigation, oil was extracted from wasted orange peel using a Soxhlet system, and BD was prepared by transesterification and tested on a diesel engine.

2 Material and Methods

2.1 Collection and powder preparation

We know orange peels are thrown into fields. In our project, waste orange peels were collected from fruit shops and marriage halls. The collected orange peels were dirty because they were thrown into the dustbin. So, we cleaned these orange peels in a water-filled plastic tub, as shown in figure 1. Then these waste orange peels are dried in the presence of sunlight to remove the moisture contained in the orange peels shown in below figure 2.

These peels are dried for 15 days to remove the moisture in the orange peels shown in figure 3. After the waste orange peels were dried, they were converted into powder form with the help of a mixer grinder. The

Figure 1: *Cleaning of OP*

Figure 2: *Drying of OP*

Figure 3: *Dried OP*

Figure 4: *OP powder*

size of the orange peel powder is kept between 1 to 3 mm, as shown in figure 4. Then an oil extraction technique is applied to extract the pure orange peel oil.

2.2 Oil extraction technique (Soxhlet extraction, steam distillation)

The Soxhlet and steam distillation apparatus are used for the oil extraction of orange peel powder. Soxhlet apparatus can be addressed separately into three sections (i.e., upper, middle, and lower). In the upper section, there is a condenser consisting of two pipes for the condensation process: an inlet pipe and an outlet pipe with water supplies in it. In the middle section, an extraction chamber is attached to tubes, one is a vapour tube, and another is a syphon tube. A thimble is made using filter paper to extract oil from the powder. A vapour tube is attached to carry the solvent's vapour. And a siphon tube is attached to carry the mixture of extracted oil and solvent. The lower section contains a round bottom flask and heating mantle; the solvent is put into the round bottom flask of the soxhlet apparatus, and the heating mantle provides heat to the round bottom flask. The soxhlet apparatus is shown in figure 5.

A steam distillation unit is used to separate pure oil and solvent. The steam distillation apparatus is shown in figure 6. The steam distillation apparatus consists of two parts: one is a round bottom flask (containing a mixture of oil and solvent), and another is a condenser.

In the oil extraction process, two steps are performed. A thimble containing orange peel powder was kept in the extraction chamber in the first step. N-hexane was used as a solvent in a round bottom flask because of its low boiling point (i.e., 69 °C). Using a heating mantle, N-hexane boils and goes into the condenser via a vapour tube; after condensation, it falls into the extraction chamber, extracts the oil, and goes into the round bottom flask again via a syphon tube; this process takes 8–10 cycles until the N-hexane's colour appears white again in the extraction chamber.

In the second step, a mixture of orange peel oil and n-hexane obtained from a round bottom flask is kept in the steam distillation apparatus. Heat is supplied to the round bottom flask of the steam distillation apparatus, and water is supplied to the inlet of the condenser. Further, due to the difference in boiling temperatures between orange peel oil (OPO) and n-hexane, n-hexane boils and is stored in the container, and pure OPO is left out into the round bottom flask.

Figure 5: *Soxhlet extraction*

Figure 6: *Steam distillation*

2.3 Transesterification process

The transesterification process is the most commonly used method for the preparation of biodiesel. As it can lower the viscosity of the feedstock/vegetable oils to a level closer to that of standard fossil-based diesel fuel, transesterification is a crucial step in manufacturing biodiesel. For the transesterification process, the most common form uses methanol (converted to sodium methoxide) to produce methyl ester. In making OPOBD, pure orange peel oil, methanol (CH_3OH), and sodium hydroxide (NaOH) pellets were used to produce biodiesel. In the first step, with the help of a weighing machine, 0.7 grams of NaOH (solid form), 12.5 ml of methanol, and 50 ml of OP oil were measured using a measuring flask. The second step was mixing the OP oil at 60 °C with the help of a magnetic stirrer (shown in figure 7). A stir bar (magnetic beads or a flea) is immersed in liquid to spin quickly. It employs a rotating magnetic field and provides a heat supply to the flask. After the transesterification process, the prepared solution is kept into the separating funnel (shown in figure 8) for more than 24 hours to get methyl-ester and glycerol.

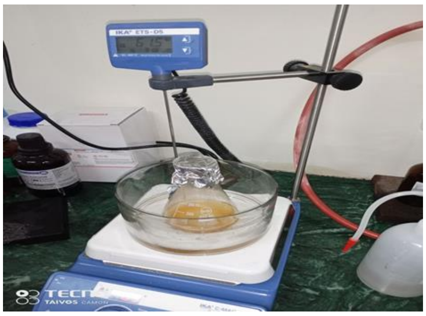

Figure 7: *Magnetic Stirrer*

Figure 8: *Separating funnel*

3 Theory and Calculation

A 4-stroke single-cylinder diesel engine (shown in below figure 9) and gas analyzer are used at the automobile and IC engine labs at MMMUT, Gorakhpur, Uttar Pradesh, India.

To measure the engine performance and emission characteristics of prepared orange peel BD (OPOBD) and its blending mixtures,

Figure 9: *4-stroke Diesel engine*

Diesel Engine Performance Parameter

Brake thermal efficiency (BTE)

$$BTE = \frac{BP}{TFC \times CV} \times 100 \quad (1)$$

BP = Brake power kw

$$BP = \frac{2\pi NT}{60 \times 1000} \quad (2)$$

N = RPM of the Crankshaft, T = produced torque in N-m,

TFC=Total fuel consumption (kg/hr)

$$TFC = \frac{P \times Xcc \times s}{t} \quad (3)$$

Where s = specific gravity of fuel,

Xcc= Total volume of fuel consumed (10 ml),

$\boldsymbol{P}$ = density of fuel (kg/m^3)

t = time taken for 10 ml fuel at each power output condition
CV=calorific value in kJ/kg.
Brake Specific fuel consumption

$$BSFC=\frac{TFC}{BP}\ [kg/(kW\text{-}hr)] \quad (4)$$

4 Result & Discussion

This research extracted 530 ml of (OP) oil from the WPO. From the transesterification process, orange peel oil biodiesel and glycerol are obtained as 43 ml and 7 ml, respectively, as shown in figure 10.

Figure 10: *Orange peel oil biodiesel and produced glycerol*

Figure 11: *Prepared Blending Mixtures*

Two blending mixtures are prepared using orange peel oil biodiesel and fossil diesel, as shown in figure 11. The total amount of orange peel oil biodiesel yield can be calculated as,

$$\text{Orange Peel Oil Biodiesel (OPOBD) Yield (\%)} = \frac{Total\ weight\ of\ oil\ in\ methyl{-}esters}{Total\ weight\ of\ oil\ in\ sample} \times 100$$

$$\text{Orange Peel Oil Biodiesel (OPOBD) Yield (\%)} = \frac{43}{50} \times 100$$

$$\text{Glycerol Formed} = 7\ ml$$

4.1 Fuel Properties

OP oil and OP oil biodiesel (OPOBD) fuel properties like density, flash point, fire point, and calorific value (given in table 4.1) are measured at the Suyash Institute of Information Technology, Gorakhpur, Uttar Pradesh, India.

Table 4.1: *Fuel properties of fossil diesel, OP oil and OP oil biodiesel (OPOBD)*

S. No.	Fuel Properties	Orange peel oil (OPO)	Orange peel oil biodiesel (OPOBD)	Diesel	Measuring Instruments
1.	Density kg/m^3 (@15 ºC)	845	890	830	Hydrometer
2.	Flash Point (ºC)	58	66	64	Pensky Martens
3.	Fire Point (ºC)	62	70	69	Pensky Martens
4.	Calorific Value (kJ/Kg)	32200	33764	45000	Bomb calorimeter

Proceedings DOI: 10.21467/proceedings.161
ISBN: 978-81-965621-8-2

Series: AIJR Proceedings
ISSN: 2582-3922

4.2 Engine Performance

Engine performance and emission characteristics are performed in the mechanical engineering department's automobile and IC engine labs at Madan Mohan Malaviya University of Technology, Gorakhpur, Uttar Pradesh, India.

4.2.1 Brake thermal efficiency (BTE):

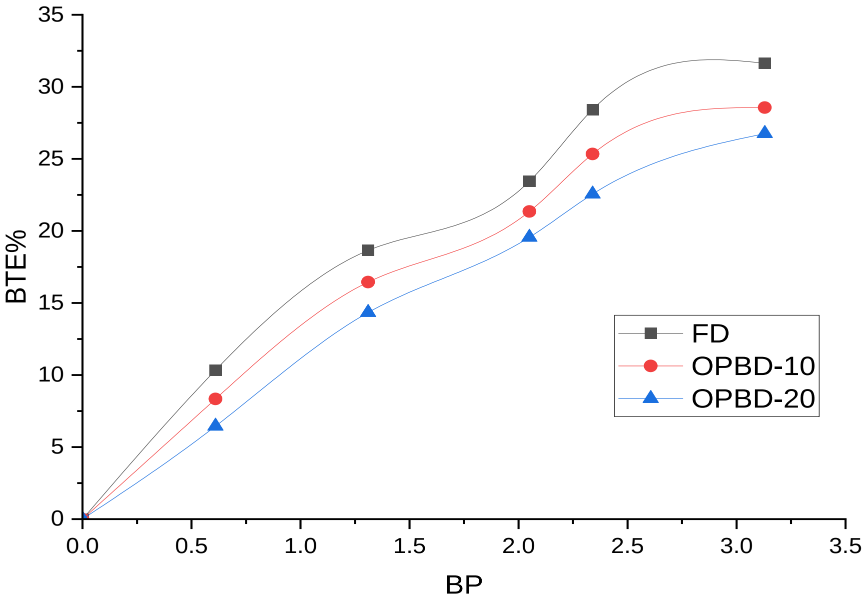

Figure 12: *brake thermal efficiency (BTE) variation Vs brake power (BP)*

The figure 12 shows the effect on brake thermal efficiency (BTE) on varying brake power (BP). When the brake power reaches above 3 kW, fossil diesel shows maximum BTE, i.e., 31.6%, while orange peel biodiesel (OPBD) at 10% blending shows 28.56%, and OPBD at 20% blending mixture shows 26.76%. It is observed that brake thermal efficiency increased by increasing the load for both the blending mixtures of biodiesel and fossil diesel.

4.2.2 Brake Specific Fuel Consumption (BSFC):

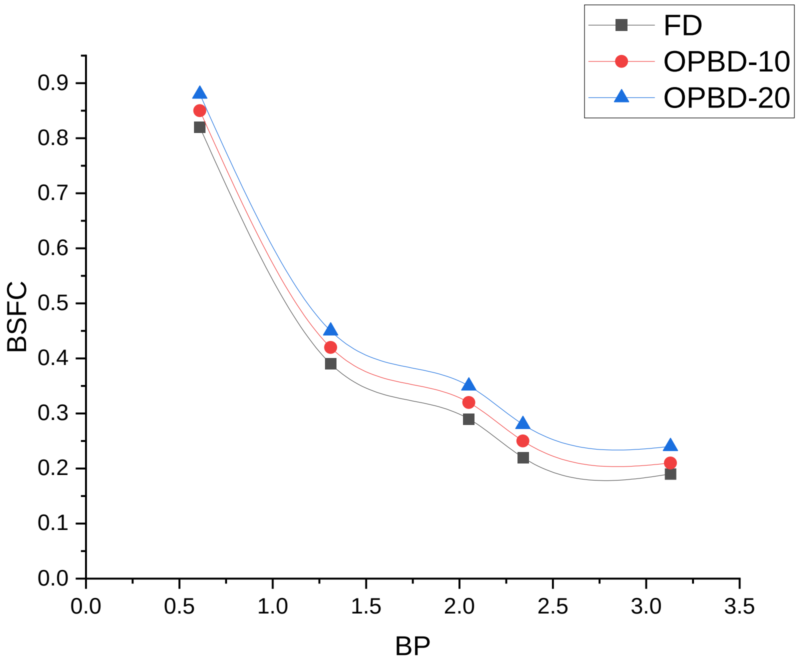

Figure 13: *Brake Specific Fuel Consumption (BSFC) variation Vs brake power (BP)*

The figure 13 shows the effect on brake-specific fuel consumption (BSFC) on varying brake power (BP). When the brake power reaches above 0.6 kW, fossil diesel shows the minimum BSFC, i.e., 0.82 kg/kW-hr, while orange peel biodiesel (OPBD) at 10% blending shows 0.85 kg/kW-hr, and OPBD at 20% blending mixture shows 0.88 kg/kW-hr. It is observed that BSFC is decreased by varying the different loads—the calorific value, density, and viscosity of mixtures made from biodiesel and fossil diesel impact BSFC [21].

4.2.3 Exhaust Gas Temperature (EGT):

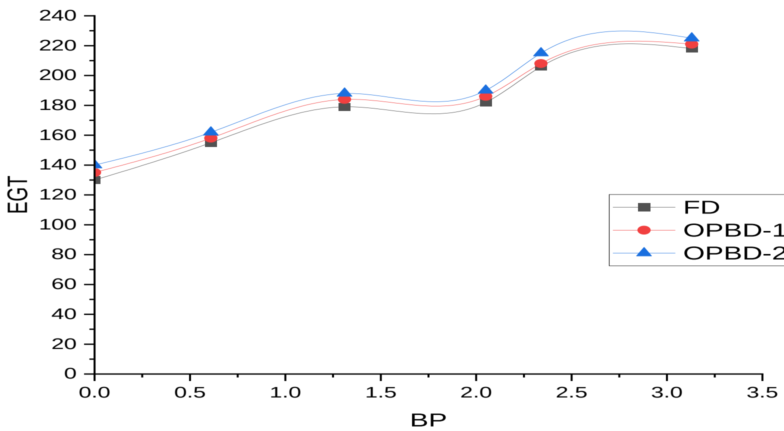

Figure 14: *Exhaust Gas Temperature (EGT) variation Vs brake power (BP)*

The figure 14 shows the effect on exhaust gas temperature (EGT) on varying brake power (BP). It is observed that exhaust gas temperature increases with increasing the biodiesel percentage in the fossil diesel blend. When the brake power reaches above 3.13 kW, fossil diesel shows the minimum EGT, i.e., 218 ^{o}C, while orange peel biodiesel (OPBD) at 10% blending shows 221 °C and OPBD at 20% blending mixture shows 225 °C.

4.3 Emission characteristics

4.3.1 NO_x emission:

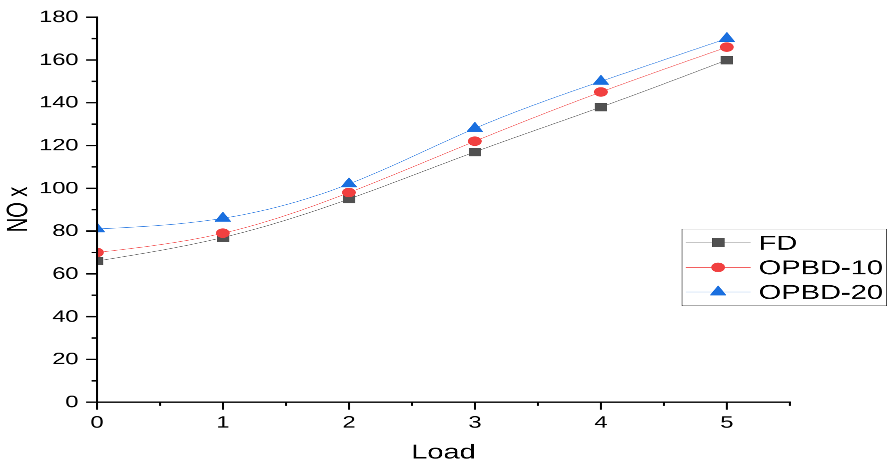

Figure (15): *Oxides of Nitrogen (NO_x) gas emission variation Vs load*

The figure (15) shows the effect on nitrogen oxides (NO_x) on varying the load. NO_x emissions occur because of the higher temperature in the engine cylinder. It is noted that when a full load of 5 kg is applied to the engine, fossil diesel shows the minimum NO_x emission, i.e., 160 ppm, while orange peel biodiesel (OPBD) at 10% blending shows 166 ppm and OPBD at 20% blending mixture shows 170 ppm.

4.3.2 CO emission

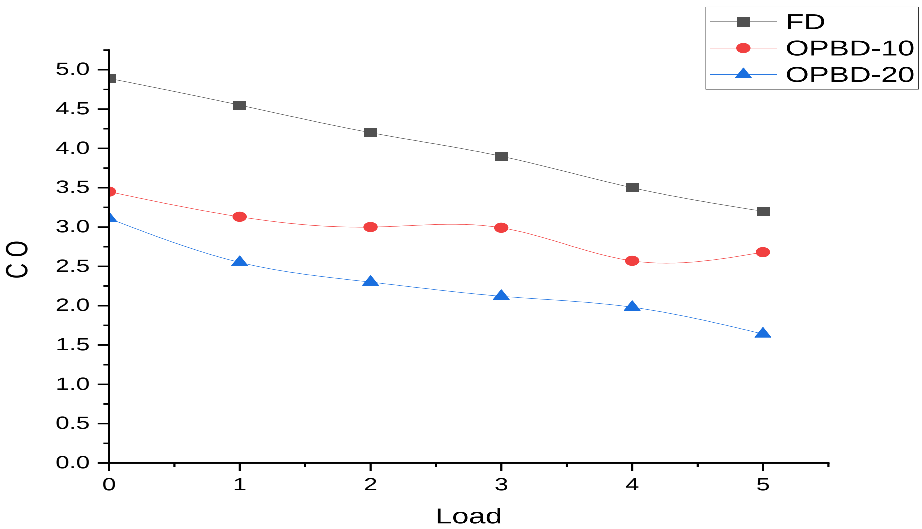

Figure (16): *Carbon monoxides (CO) gas emission variation Vs load*

The figure (16) shows the effect on carbon monoxide (CO) gas emissions on varying loads. Carbon monoxide emissions occur because less oxygen (O_2) is present in fossil diesel. It is noted that when a full load of 5 kg is applied to the engine, fossil diesel shows the maximum CO emission, i.e., 3.2%, while orange peel biodiesel (OPBD) at 10% blending shows 2.68% and OPBD at 20% blending mixture shows 1.64%.

4.3.3 CO_2 emission

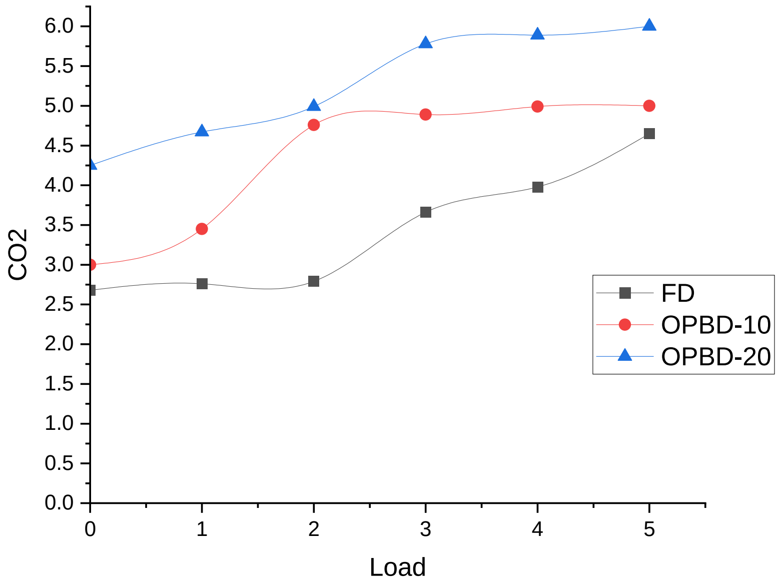

Figure (17): *Carbon dioxide (CO_2) gas emission variation Vs load*

The figure (17) shows the effect on carbon dioxide (CO_2) gas emissions on varying the load. CO_2 emissions are increased by increasing the blending percentage with fossil diesel. It is noted that when a full load of 5 kg is applied to the engine, fossil diesel shows the minimum CO_2 emission, i.e., 4.65%, while orange peel biodiesel (OPBD) at 10% blending shows 5% and OPBD at 20% blending mixture shows 6%.

5 Conclusion

Two blending mixtures of orange peel oil are prepared (i.e., BD10 and BD20). From the determination of fuel properties, engine performance, and emission characteristics, it is concluded that:

- The calorific value, density, and viscosity of the mixtures made from blending biodiesel and fossil diesel all impact it. For both the prepared blending mixtures of biodiesel and fossil diesel, brake thermal efficiency increases by increasing the load. And BSFC decreases by varying the load.
- NO_x emissions occur because of the higher temperature in the engine cylinder. It increases by increasing the blending of mixtures of biodiesel with fossil diesel. Exhaust gas temperature is increased by increasing the blending mixture of biodiesel and fossil diesel.
- Carbon monoxide emissions occur because less oxygen (O_2) is present in fossil diesel. It decreases by increasing the mixture of biodiesel with fossil diesel, and CO_2 emissions increase by increasing the blending percentage with fossil diesel.

Abbreviation

SME or SOME	Soy Methyl Ester
RME	Rapeseed Methyl Ester
PME	Palm Methyl Ester
FAME	Fatty Acid Methyl Esters

Proceedings DOI: 10.21467/proceedings.161
ISBN: 978-81-965621-8-2

Series: AIJR Proceedings
ISSN: 2582-3922

FAEE	Fatty Acid Ethyl Esters
ULSD	Ultra-Low Sulphur Diesel
CO_2	carbon dioxide
OP or OPO	orange peel oil
OPBD or OPOBD	orange peel oil biodiesel
PMFs	poly methoxy flavones
KOH	Potassium hydroxide
NaOH	Sodium hydroxide
FFAs	free fatty acids
FD	Fossil diesel

6 Declarations

6.1 Competing Interests

The authors declare no conflict of interest.

6.2 Study Limitations

There are no limitations that significantly affect the research outcome.

6.3 Acknowledgements

The authors would like to thank the mechanical and chemical engineering department of MMMUT Gorakhpur for providing laboratories to conduct experiments smoothly and successfully.

6.4 Warning for Hazard

The "Extraction of oil and preparation of biodiesel using orange peel and its performance and emission analysis on CI engine" does not involve any chemicals, procedures, or equipment with unusual hazards.

6.5 Ethical Approval

Ethical approval is not required for this study.

6.6 Informed Consent

No human or animal subjects were involved in this research; hence no informed consent was obtained.

6.7 Publisher's Note

AIJR remains neutral with regard to jurisdictional claims in institutional affiliations.

How to Cite

Singh *et al.* (2023). Extraction of Oil and Preparation of Biodiesel using Orange Peel and its Performance and Emission Analysis on CI Engine. *AIJR Proceedings*, 209-220. https://doi.org/10.21467/proceedings.161.24

References

[1] Karmakar, Bisheswar, and Gopinath Halder. "Progress and future of biodiesel synthesis: Advancements in oil extraction and conversion technologies." *Energy Convers. Manag.*, vol.182, pp 307-339, 2019. https://doi.org/10.1016/j.enconman.2018.12.066

[2] Vignesh, R., B. Ashok, A. K. Jeevanantham, Ashwin Jacob, Raunak Devdatta Prabhu Bhembre, Shlok Shreedhar Sharma, and Kartik R. Bhat Hire. "Enhancement of idling characteristics using multi-objective approach in light-duty diesel Vehicle fuelled with orange peel biofuel." *Fuel,* vol 291, 2021. https://doi.org/10.1016/j.fuel.2021.120222

[3] Olugasa, Temilola T., Michael L. Adekanbi, and Samson K. Fasogbon. "Performance and emission characteristics of compression ignition engine running on a blend of cashew nutshell liquid and biodiesel produced from orange peel." European Journal of Sustainable Development Research, vol 6, no. 4 : em0197, 2022. https://doi.org/10.21601/ejosdr/12233

[4] Kumar, Parvesh, and Naveen Kumar. "Process optimization for production of biodiesel from orange peel oil using response surface methodology." Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, vol.43, no. 6 : pp 727-737, 2021. https://doi.org/10.1080/15567036.2019.1631909

[5] Shaghaleh, Hiba, Xu Xu, Mohammed Al-Azem, and Yousef Alhaj Hamoud. "Investigation on the utilization possibility of orange (Citrus sinensis var. Valencia) oil extracted by microwave pretreatment-improved steam distillation as natural flavoring agent based on its characteristics analysis." Journal of Essential Oil Bearing Plants 21, no. 2 : pp 298-316, 2018. https://doi.org/10.1080/0972060X.2018.1467283

[6] Asokan, M. A., S. Senthur Prabu, S. Prathiba, Devansh Sunit Sukhadia, Varshit Jain, and Suruchi Madan Sarwate. "Emission and performance behavior of orange peel oil/diesel blends in DI diesel engine." Materials Today: Proceedings, vol.46, pp 8114-8118, 2021. https://doi.org/10.1016/j.matpr.2021.03.060

[7] Akpan, Patrick, and Paul Ozor. "An estimation of orange oil (Biodiesel) quantity from orange peel in Nigeria." In NIIE 2014 conference proceedings, 2014. http://dx.doi.org/10.13140/RG.2.1.3796.2721

[8] Gavahian, Mohsen, Yan-Hwa Chu, and Amin Mousavi Khaneghah. "Recent advances in orange oil extraction: An opportunity for the valorisation of orange peel waste a review." International Journal of Food Science & Technology 54, vol. no. 4, pp 925-932, 2019. https://doi.org/10.1111/ijfs.13987

[9] Sheriff, S. Abdul, Indrala Kishan Kumar, Petluri Sai Mandhatha, Samraj Sunder Jambal, Raja Sellappan, B. Ashok, and K. Nanthagopal. "Emission reduction in CI engine using biofuel reformulation strategies through nano additives for atmospheric air quality improvement." Renewable Energy, vol. 147, pp 2295-2308, 2020. https://doi.org/10.1016/j.renene.2019.10.041

[10] Ashok, B., K. Nanthagopal, D. Arumuga Perumal, J. M. Babu, Anmol Tiwari, and Akhil Sharma. "An investigation on CRDi engine characteristic using renewable orange-peel oil." Energy conversion and management vol.180, pp 1026-1038, 2019. https://doi.org/10.1016/j.enconman.2018.11.047

[11] Alex, Y., Jobie Earnest, Anoop Varghese, and Aneesh Achankunju. "Synthesis and Testing on Engine Characteristics of Bio-diesel Obtained by Orange-Peel Oil Methyl Ester Blended with Conventional Diesel Fuel." International Journal of Recent Technology and Engineering (IJRTE) vol 9, no. 1, pp 2091-2099, 2020. http://dx.doi.org/10.35940/ijrte.F9535.059120

[12] Rajaraman, Kavitha Kutuva, Nivin Joy, Jayaprabakar Jayaraman, Madhubalini, Avuth Spandana, P. Sivashankari, and J. Lilly Mercy. "Comparative study of performance and emission characteristics with addition of DEE on orange peel biodiesel." In AIP Conference Proceedings, vol. 2311, no. 1, p. 020019, 2020. https://doi.org/10.1063/5.0034491

[13] Kumar, AR Mahesh, M. Kannan, and G. Nataraj. "A study on performance, emission and combustion characteristics of diesel engine powered by nano-emulsion of waste orange peel oil biodiesel." Renewable Energy, vol.146, pp 1781-1795, 2020. https://doi.org/10.1016/j.renene.2019.06.168

[14] Ganesan, Nataraj, and Senthilkumar Masimalai. "Experimental investigation on a performance and emission characteristics of single cylinder diesel engine powered by waste orange peel oil biodiesel blended with antioxidant additive." Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, vol. 42, no. 11, pp 1412-1423, 2020. https://doi.org/10.1080/15567036.2019.1604856

[15] Saini Prashant, Chandan Gupta, and Ravi Shankar. "Characterization of corn oil biodiesel and its application in diesel engine." Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, pp 1-15, 2019. https://doi.org/10.1080/15567036.2019.1679913

[16] Ahmad, Khurshid, and Prashant Saini. "Effect of butanol additive with mango seed biodiesel and diesel ternary blends on performance and emission characteristics of diesel engine." Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, vol. 44, no. 4, pp 9988-10005, 2022.
https://doi.org/10.1080/15567036.2022.2143954

[17] Hossain, Md A., Shabab M. Chowdhury, Yamin Rekhu, Khandakar S. Faraz, and Monzur Ul Islam. "Biodiesel from coconut oil: a renewable alternative fuel for diesel engine." International Journal of Chemical and Molecular Engineering, vol. 6, no. 8, pp 524-528, 2012.

[18] Periasamy, Somasundaram, Jegadheesan Chinnasamy, Jeyaprakash Natarajan, Saravanan Ravirajan, and Dhavaneeswaran Nagharajan. "Study on performance and emission characteristics of split injection CRDi engine fueled with orange peel oil and diethyl ether." In IOP Conference Series: Materials Science and Engineering, vol. 1055, no. 1, p. 012043. 2021. doi:10.1088/1757-899X/1055/1/012043.

[19] Siva, Ramasamy, Dinesh Babu Munuswamy, and Yuvarajan Devarajan. "Emission and performance study emulsified orange peel oil biodiesel in an aspirated research engine." Petroleum Science, vol. 16, no. 1, pp 180-186, 2019. https://doi.org/10.1115/1.4031834

[20] Banerji, C., and S. Roji. "Detailed analysis on exploiting the low viscous waste orange peel oil and improving its usability by adding renewable additive: waste to energy initiative." Biomass Conversion and Biorefinery, pp 1-13, 2022. https://doi.org/10.1007/s13399-022-02870-x

[21] Kumar, Priyankesh, Devesh Kumar, Ravi Shankar, Sachin Kumar, Prashant Saini, and Narendra Kumar. "Effect of synthesized lemongrass biodiesel on the performance and emission characteristics of a CI engine." Sustainable Energy Technologies and Assessments, vol. 57, 103221, 2023. https://doi.org/10.1016/j.seta.2023.103221