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Investigating the Effect of Potato Peel Biocatalyst on Emission Reduction Using Waste Cooking Oil.

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ABSTRACT

Burgeoning global population, growing demand, and rapid consumption for finite fossil fuels have resulted in the depletion of supply reserves, making petroleum fuel more limited and expensive besides contributing to the pollution of the environment due to the emission of greenhouse gases. The production of biodiesel, a different energy source, is an option to solve the issue of this energy source's potential extinction. Using potato peel as a biocatalyst, waste cooking oil (WCO) is transesterified to produce biodiesel. Due to their easy accessibility and environmentally friendly character, bio-based catalysts have started alluring the research community towards the synthesis of biodiesel. The fuel attributes of various WCO mixtures in diesel engines, such as WCB10, WCB20, and WCB30 have been studied. WCB20 has shown better outcomes among the blends than WCB10 and WCB30 when compared with diesel fuel.

Keywords: potato peel biocatalyst, Transesterification process, biodiesel, waste cooking oil, Emission, and performance.

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INTRODUCTION

The world as an entirety is right now dealing with the risk of environmental degradation and the depletion of fossil fuels [1]. Non-renewable energy resources are used to meet energy demand, but it is indisputable that they also pollute the environment. When hydrocarbon products are burned frequently, hazardous gases are released, which pollutes the environment. These fuels provide around 24% of the world's carbon dioxide (CO2) emissions when they are burned [2]. The need for producing affordable, sustainable, and renewable domestic fuels was highlighted by the complex and unpredictable oil price, as well as its scarcity and detrimental environmental effects. The search for better and more environmentally friendly energy sources has started in the field of research [3].

Biodiesel is a renewable energy that can be created from a variety of organic materials, including vegetable oils. In addition, it is more environmentally friendly than energy derived from petroleum. This form of energy can be utilised to replace petroleum-based energy, which increases a nation's need for adequate energy. Biodiesel has minimal greenhouse gas emissions in addition to being more environmentally friendly. According to Karmakar et al. (2018), it is also safer for transportation than fuel derived from petroleum [4]. The simplest and best method for producing biodiesel with improved specifications from a variety of edible and non-edible feedstocks, such as fat and oil from algae, bacteria, fungi, etc., is Transesterification [5]. In order to get the highest yield of biodiesel from this reaction, catalysts are crucial under specified conditions of temperature and alcohol to oil ratio [6].

Wastes from many sources have recently been examined for catalyst products due to their abundance and low cost. Dharmesh R. Lathiya et al. (2018) investigated the feasibility of using bio-waste, such as waste orange peels, for catalyst development, thereby contributing to the manufacture of cost-effective biodiesel [7]. Pineapple leaves, carica papaya stems, banana stems, palm ash from empty fruit bunches, banana peels, and potato peels are just a few examples. The catalyst can be divided into two types based on the nature of the substance used: heterogeneous and homogenous. Despite the homogeneous catalyst's high conversion efficiency, it is not chosen for use due to the trouble of segregation, which contaminates the end product and raises the final product price, Chen et al.(2012)[8]. The simplicity of segregation, the flexibility to be employed for successive cycles, and the comparatively low cost distinguish varied catalysts from homogenous ones. On the downside, these catalysts main drawbacks include their microporosity, lack of active sites, toxicity, filtration, and unfriendliness to the environment, *Omojola Awogbemi et al*(2021)[9].Typically, mixing different catalysts from food or agricultural waste requires the combustion of wastes into ashes. It is also employed directly as a catalyst, or the obtained ash is further calcined in a muffle furnace.

Scanning electron microscopy (SEM) can be used to dissect the face structure and morphology of the biocatalysts used in biodiesel product. This fashion can reveal information about the size, shape, and distribution of active spots on the face of the biocatalyst. Additionally, SEM can provide information about the efficacy of immobilization techniques used to stabilize the biocatalyst, Biswajitnath et al. (2023) [10]. Furthermore, SEM can be used to investigate the structural changes that occur in the biocatalysts during the transesterification process. This can help to determine the factors that affect biocatalyst stability and activity, which are both critical to the overall efficiency of the biodiesel production process. Moreover, SEM techniques become useful in identifying changes in the morphology of biocatalyst due to varying environmental conditions, like pH or temperature, Odetoyeet al.(2021) [11].

In literature there are some studies on the combustion, performance and emission analysis of internal combustion engines using biodiesel without any modification of engine. According to research by Ashkan Tizvir et al. (2023), adding biodiesel in levels ranging from 0% to 20% decreased the fuel's CO, SOx, and HC emissions while increasing CO2 and NOx emissions. Additionally, while engine power decreased, fuel consumption increased. The composition percentage of 11.5% biodiesel in the gasoline was found to be the point of best performance in order to produce the fewest emissions, use less fuel, and increase output power. [12]. A 20% blended biodiesel blend, or PBD20, enhanced brake thermal efficiency by 1.46% while increasing brake specific fuel consumption by 6.25% when compared to diesel, according to research by Biswajeet Nayak et al.(2023). PBD20 emits 7.72% lower hydrocarbon emissions when compared to diesel at peak loading, with a slight increase in nitrogen oxides of 3.05% [13]. S. Vinodrajet al. (2023) determined that

Juliflora biodiesel exhibits Brake Thermal Performance (BTE) values that are more comparable to diesel fuel at partial and marginal load, with no improvement in BSFC values. The BSFC values for blends B100 were higher (0.34 kg/KWh) at full load strokes than diesel (0.25 kg/KWh). Additionally, there were only very little emissions of HC, CO2, smoke, and CO with a slight increase in NOx emissions [14]. Priyankesh Kumaret al(2023) evaluated that BSFC and EGT for BM20 have increased by 48% and 4.08%, respectively, and BTE has decreased by 14.75% when compared to diesel. BM20's exhaust gas shows decreases in HC of 49.99%, CO of 46.80%, CO2 of 3.23%, and O2 of 28.57% [15]. According to research by C. Adhikesava et al. (2022), biodiesels made from WCOs emit somewhat more carbon monoxide than biodiesels made from fresh oils. The nitric oxide and smoke emissions from biodiesels produced from both old and new cooking oils, however, were comparable. Despite being a degraded feedstock, used cooking oil produces biodiesel that has no detrimental effects on emissions or engine performance [16]. M. Muhammed Niyaset al(2022) evaluated that the heating of coconut, sunflower, and palm oils, respectively, resulted in reductions in the brake thermal efficiency by 0.27%, 0.28%, and 0.52%. Peak heat release rates increased by 2.44 J/deg, 3.43 J/deg, and 2.74 J/deg. NOx emissions increased by 7 ppm, 65ppm, and 60ppm. Smoke opacity decreased by 4.5%, 2.8%, and 1%, respectively. All biodiesel blends were shown to have greater braking thermal efficiency and emissions than diesel, with the exception of NOx [17]. According to Amit Kumar Paswan et al. (2023) investigated that, five different Polanga biodiesel blends—5% (B5), 10% (B10), 15% (B15), 20% (B20), and 25% (B25)—were evaluated in a diesel engine. The maximum values of BTE for B5, B10, B15, B20, and B25 were found to be respectively 33.257%, 33.322%, 33.24%, and 33.121% at an engine speed of 1900 rpm; for diesel fuel, it was 33.31%; and that it then started to decrease with an increase in engine speed. Increases in speed have a positive effect on NOx and PM, while lowering BTE and increasing SO2, according to the current studies. [18].

This analysis looks into hydrocarbon (HC), nitrogenoxides (NOx), carbon monoxide (CO) and opacity as discharge parameters. The research assessed performance indicators included brake-specific fuel consumption (BSFC), brake thermal efficiency (BTE), heat release rate (HRR), and others. This study investigates various biodiesel feed stocks, admixture ratios, and engine operating circumstances to fully comprehend the impact of biocatalysts on biodiesel performance and emigrations in internal combustion engines. The experiment's objective was to make biodiesel using vegetable peels as biocatalysts. Test energies were generated and placed to the tests in a diesel engine, where emigration and performance were recorded.

MATERIALS AND METHODS

Waste potato peels were collected from Visakhapatnam's local hot chip businesses. The biocatalyst was made in a muffle furnace, and SEM and EDX investigations were performed at IIT Madras in Chennai. The biodiesel was prepared at Chennai's Sathyabama Institute of Science and Technology using a biocatalyst. The engine test was overseen by the Sathyabama Institute of Science and Technology's Centre of Research in Chennai.

Preparation of Bio Catalyst

Figure 1: Waste potato peel

The biocatalyst was made from waste potato peels, which were pure and free of dirt or contaminants. Any face contaminants or pollutants were removed by completely rinsing them with water and not using any chemicals. The potato peels were dried in the sun's lighting as shown in figure 1 to get rid of the moisture. The dried potato peels had been crushed. The fine powdered potato peels were calcined at 650°C for 3hours before being let to cool overnight [19]. The ash as shown in figure 2 produced during the calcination process was used as a biocatalyst.

Figure 2: Calcined potato peel catalyst

SEM ANALYSIS

Catalyst characterization was determined by SEM and EDX Analyses at IIT Madras (SAIF). It was used to determine the morphological analysis and the essential component of the catalysts. The morphology of the potato peels catalyst as disported in a Table 1 and Figure 3. Figure 4 depicts that the presence of potassium. It is planned to conduct a micro-structural analysis of several heterogeneous credentials such as calcium and potassium products. The key qualities of the catalyst include viscosity, form and size, stability, and strength. The potassium- revealing components will be dissected in the microscope examination.

Table 1: EDX analysis of potato peel catalyst

Element	Wt%	At%
PK	01.69	02.13
KK	97.00	96.61
CaK	01.31	01.27

Figure 3: SEM image of potato peel catalyst

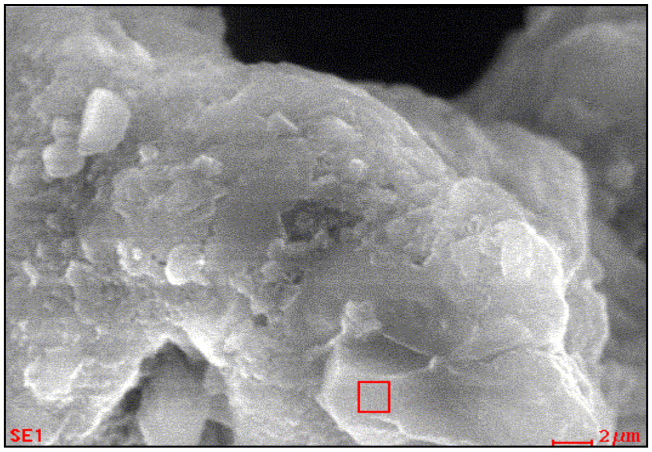
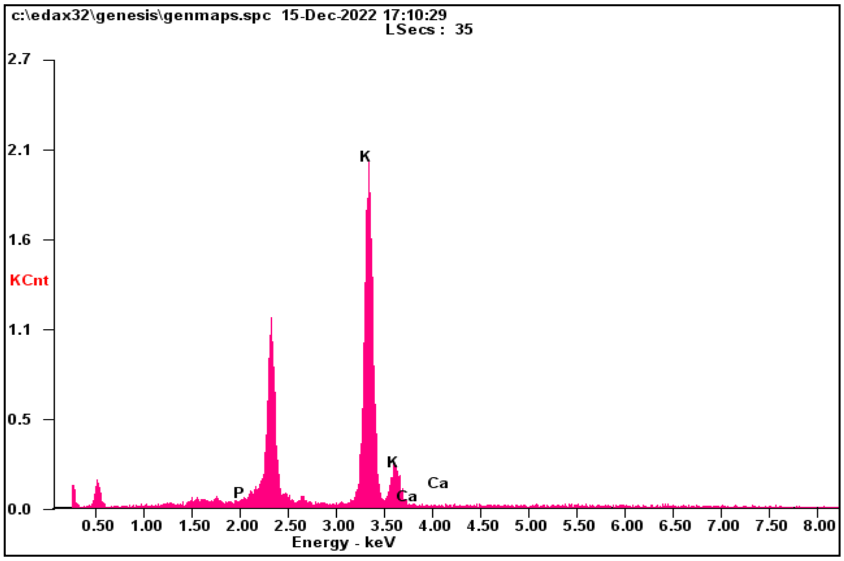


Figure 4: EDX spectra of potato peel catalyst



To examine the number and quality of these attributes, various field image analysis algorithms have been developed, Nirandaimaryetal.(2022b) [20]. High percentage of potassium and calcium as shown in table 1 improves the reaction of the oil. This helps to increase the productivity of the biodiesel and lower reaction time, Ural (2021)[21].

Transesterification Process

The first step is to clean the WCO of contaminants such as solid particles, free fatty acids, and water in preparation for transesterification. WCO, methanol, and the prepared potato peel biocatalyst are then combined in a reactor. The methanol to waste cooking oil ratio is typically approximately 3:1. To speed up the reaction, the mixture is heated and stirred. In the presence of the potato peel biocatalyst, the transesterification reaction occurs between WCO and methanol. The reaction usually happens at high temperature, about60◦ C and takes 90 minutes to complete, Alrobaian et al. (2020)[22]. The mixture must be allowed to settle or stand after the transesterification reaction in order to separate the glycerol and biodiesel phases. Glycerol sinks to the bottom because it is denser, whereas biodiesel floats on the top. This separating procedure may take several hours. Excess alcohol, catalyst residue, and soap formation are all removed from the separated biodiesel.

Properties of oils

Waste cooking oil biodiesel has several properties that make it a viable alternative to conventional diesel fuel. Waste cooking oil biodiesel generally produces fewer greenhouse gas emissions compared to traditional diesel fuel. It has lower sulfur and particulate matter levels, which can help reduce air pollution. Biodiesel derived from waste cooking oil typically has a high cetane number as shown in table 2, which indicates good ignition quality. This can result in smoother engine operation and improved cold-start performance. It can be blended with conventional diesel fuel in various proportions, such as WCB10 (10% biodiesel), WCB20 (20% biodiesel) and WCB30 (30% biodiesel).

Table 2: Properties of pure diesel, waste cooking oil, and biodiesel mixtures

S.No.	Parameter	ASTM	EURO VI DIESEL	Waste cooking oil	WCB10	WCB20	WCB30
1	Density	800-900	820-845	879	835	840	845
2	Kinematic Viscosity@40ºC	1.9-6	2-4.5	5.85	4.36	4.53	4.69
3	Flash point PMCC method	130-170^{0}C	35^{0}C	182^{0}C	50^{0}C	64^{0}C	79^{0}C
4	Fire point PMCC method	100-170^{0}C		191^{0}C	145^{0}C	150^{0}C	155^{0}C
5	Calorific value kj/kg		42500	37293.12	41979	41458	40978

Sonication of Test Fuels

The sonicator used in this work is GT SONIC professional ultrasonic cleaner which has the tank size of 150* 140*100 (mm), ultrasonic power of 50W, heating power of 100W, time ranging from 1-99 minutes and temperature ranging from 0-80^{0}C.The sonication method normally entails placing the liquid sample in a suitable container and positioning it within the sonicator bath. Necessary amounts of WCO and pure diesel fuel are mixed in a container. Three blends are prepared. These are WCB10 (10% of WCO and 90% of pure diesel), WCB20 (20% of WCO and 80% of pure diesel) and WCB30 (30% of WCO and 70% of pure diesel). The containers containing the biodiesel-diesel mixture is placed in the sonicator bath. It is to be checked whether the liquid level is lower than the sonicator's maximum fill line. The sonicator is activated to emit high-frequency sound waves into the liquid. These sound waves induce fast pressure changes in the liquid, resulting in cavitation, the production, and the implosion of small bubbles. Cavitation causes significant mixing and agitation in the liquid by generating localised high temperatures and pressures. This promotes proper blending by dispersing and homogenising the biodiesel and diesel mixture. The temperature is room temperature and the time for the process is 10 minutes, Jitjamnong et al.(2020)[23]. The mixture is examined for a visually consistent appearance, which indicates that the biodiesel and diesel fuel have been well blended.

Experimental Set-up

Specifications of the Engine

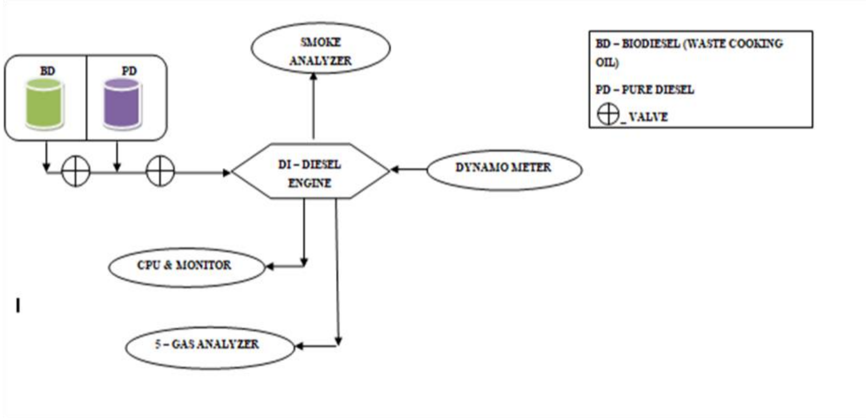


Figure 5: Experimental set-up of testing engine

The Kirloskar 4-stroke DI Diesel engine set up as shown in figure 5; with an eddy current dynamometer has been used to evaluate biodiesel with a biocatalyst. The power output is 5.2 KW. Five gas analyzers were used to monitor knockout gases such as carbon dioxide (CO2), nitrogen oxides

(NOx) hydrocarbons (HC), and carbon monoxide (CO) at a stable speed of 1500 rpm and a compression ratio of 17.5.

RESULTS AND DISCUSSION

Emissions

Carbon monoxide (CO)

Figure.6 depicts the Changes in carbon monoxide exposure relative to the load. The graph shows WCB10 and WCB20 dropped emigrations by8.8% and13.23% compared with neat diesel fuel and Compared to pure diesel at full loading, WCB30 increased it by 3%. The drop in CO is due to decent combustion. Ayhan Uyaroglu et al (2021) investigated that a lack of oxygen during combustion results in the production of carbon monoxide emissions [24].

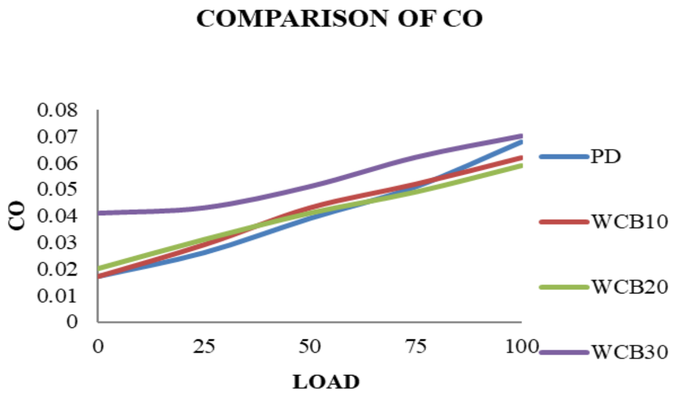


Figure 6: CO Variation as a Function of Load

Hydrocarbon (HC)

Figure.7 illustrates Load related hydrocarbon emissions. WCB10 and WCB30 have higher 33.33% and 42%. Compared with to diesel, WCB20 increases slightly on the first charge and decreases by another 9% at full load condition. This is due to as a result of operating the engine with a lean air-fuel combination under heavier loads, the cylinder temperature drops and HC emissions rise. SarthakBaweja et al (2021) investigated that decreased HC emissions as a result of improved fuel combustion compared to other fuels. Higher loads cause the engine to operate with a lean air-fuel mixture, which lowers cylinder temperature and increases HC emissions. Due to its higher oxygen content compared to other blends and pure diesel, blend WCB20 emits less HC emissions when compared to all other blends and pure diesel [25].

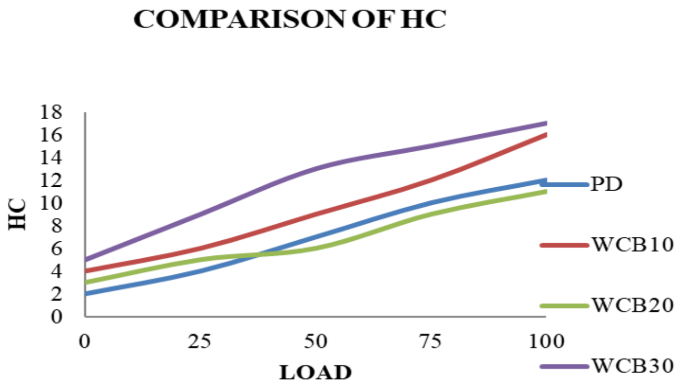
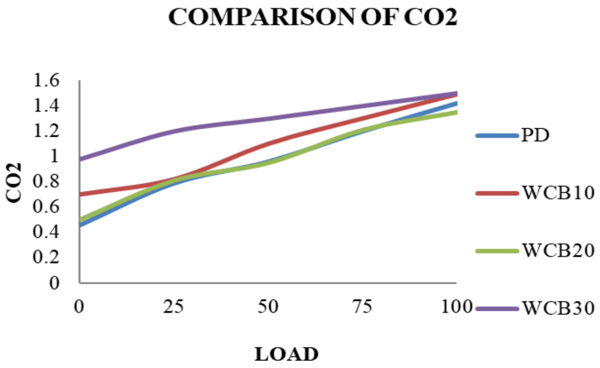


Figure 7: HC Variation as a Function of Load

Carbon dioxide (CO_2):

Figure 8 depicts the CO2 emissions. At full load, WCB10 and WCB30 raise CO2 emissions in comparison to diesel fuel by 4.9% and 5.6%, respectively. When compared to pure diesel, WCB20 reduces it by 4.9% at full load. This is due to reason that increased engine load, complete combustion results in an overall increase in CO2 generation. Upendra Rajak et al (2021) evaluated that the Full combustion causes a rise in CO2 production with engine load. Diesel fuel's main source of CO2 emissions is during burning, and according to reports, the amount of CO2 emissions increases as the percentage of biodiesel increases [26].

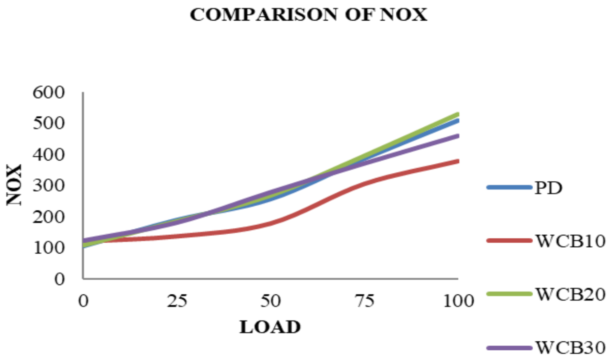
Figure 8: CO_2 Variation as a Function of Load



Nitrogen oxide (NOx)

Figure 9 depicts NOx emissions. When compared to pure diesel fuel, WCB10 and WCB30 both lower NOx emissions at full load by 25% and 10%, respectively. WCB20 increases it by around 4% over pure diesel at full load. This is due to the reason that the increased cylinder temperature causes increased NOx emissions. Ashish Dubey et al (2022) evaluated that the sufficient oxygen present in WSCO biodiesel, proper fuel oxidation takes place. As a result, the cylinder temperature rises, and the quicker ignition time permits less time for heat transfer cooling [27].

Figure 9: NO_x Variation as a Function of Load



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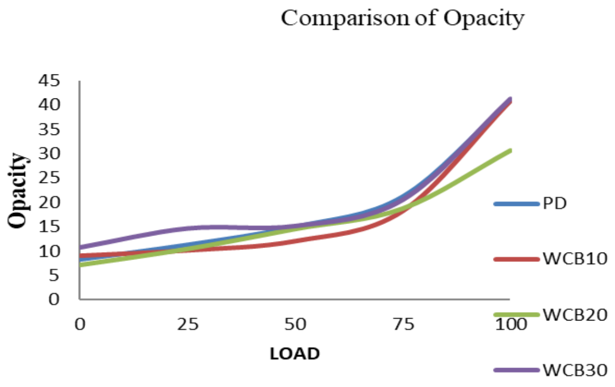
Opacity

Figure.10 illustrates Load related opacity. Compared with pure diesel, the opacity of WCB10 and WCB30 gives almost similar results but WCB20 decreases opacity by 25%. This is due to the reason that, with increasing load, more fuel is pushed for a given amount of air, which slows the oxidation process and increases smoke formation. Addisu Frinjo Emma et al(2022) investigated that As a result of incomplete combustion, a lack of oxygen, self-ignition, and fuel atomization, smoke opacity forms in the exhaust gas. [28].

Figure 10: Opacity variation as a function of load

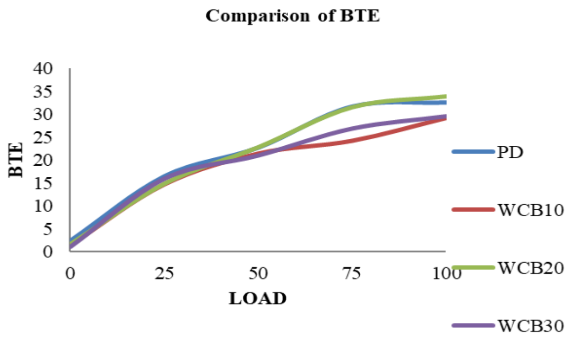


Performance

Brake thermal efficiency (BTHE)

The change of BTE with regard to load is shown in Figure 11. When initially loaded, pure Diesel fuel, WCB10, WCB20, and WCB30 all exhibit comparable performance. At full load, the WCB20's maximum BTE is 4.6%, which is greater than the BTE of pure Diesel fuel. WCB10 and WCB30 both reduce BTE by 10% and 9% when compared to pure diesel fuel, respectively. This is due to reason that the Poor combustion characteristics, decreased fuel atomization, and fuel vaporisation as a result of this state lead to a fall in BTE. Lekidelu Asrat Ayalew et al (2022) investigated that the higher viscosity and lower heating value than diesel; biodiesel blends have a poorer brake thermal efficiency than diesel [29].

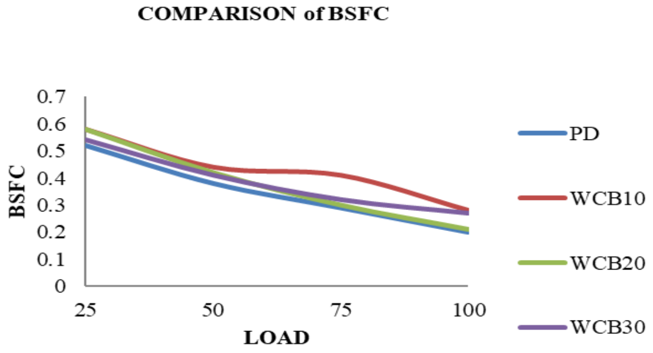
Figure 11: BTE Variation as a Function of Load



Brake specific fuel consumption (BSFC)

Figure.12 depicts the relationship between BSFC and load. WCB10, WCB20, WCB30 and pure diesel show similar results of specific fuel consumption at initial load. At the full load condition BSFC of WCB10 and WCB30 increase by 40% and 35%, when compared with pure diesel but WCB20 shows similar results. This is due to reason that the biodiesel has lower heating values than regular diesel fuel is the cause of BSFC increase. ZulfuTosun et al (2022) evaluated that the amount of specific fuel consumed depends on the fuel's quantity, density, viscosity, and heating value. Due to its low calorific value, biodiesel requires more fuel to produce the same quantity of energy. This results in higher brake specific fuel consumption than diesel fuel use [30].

Figure.12: BSFC Variation as a Function of Load



CONCLUSION

This study has researched the effectiveness of biocatalyst in the physic of biodiesel. Waste potato peel was used as a biocatalyst in the biodiesel production of WCO. WCO mixes were tested on a Kirloskar 4-stroke DI diesel engine. This research yielded the following conclusions:

- Using potato peels, normally considered waste, promotes sustainable practices by reducing food waste and turning it into a valuable resource. Abraded potato peels are readily available as a by-product of food processing, and may be less expensive than commercial catalysts.
- The emissions of the engine powered by WCB20, namely CO, HC, CO_2, and Opacity have decreased by 13.23%, 9%, 4.9%, and 25% but NOx has increased slightly by 4%.
- The BTE of WCB20 increased by 4.6% in comparison to pure diesel when operating at full load.
- WCB10, WCB20, WCB30, and pure diesel all displayed comparable values for initial load. When compared to pure diesel, the BSFC of WCB10 and WCB30 increases by 40% and 35% at full load, respectively, and WCB20 exhibits similar results.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Nomenclature

WCO- Waste cooking oil
WCB10- Waste cooking oil biodiesel 10%
WCB20- Waste cooking oil biodiesel 20%
WCB30- Waste cooking oil biodiesel 30%
SEM-Scanning electron microscopy
EDX- Energy Dispersive X-ray Analysis
CO - Carbon monoxide
HC- Hydro carbon
CO_2- Carbon dioxide
NOx - Nitrogen oxides
BTE- Brake thermal efficiency
BSFC- Brake-specific fuel consumption (BSFC)

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