JSRT JOURNAL
PAGES: 31-41
11/15/24
JOURNAL OF SCIENTIFIC RESEARCH AND TECHNOLOGY VOLUME-2 ISSUE-11 NOVEMBER

Ultrasonic-Assisted Biodiesel Production From Waste Cooking Oil And Single-Cylinder Diesel Engine Performance Study

Mahesh[1], Dr. Arunkumar B. Jirgi[2]

[1]PG Student, Department of Mechanical Engineering, Poojya Doddappaappa College Of Engineering, Kalaburagi, India. maheshkumartalwar17@gmail.com

[2]Professor, Department of Mechanical Engineering, Poojya Doddappaappa College Of Engineering, Kalaburagi, India. arunjeergi@rediffmail.com

ABSTRACT

India is particularly at risk regarding energy security in the current climate because to its reliance on oil and gas imports from gulf nations to meet its energy demands, as well as the fact that oil prices are shifting and the global energy demand and supply chain is being disrupted. There are a number of obstacles, such as the high manufacturing cost, to the widespread use of biodiesel as a diesel substitute. The manufacturing cost of biodiesel is reduced when waste cooking oil is considered as a cheaper alternative to other feedstocks. It also eliminates the issue of where to put used oil. Examining how various catalysts and process intensification approaches affect the biodiesel output from waste cooking oil (WCO) is the primary goal of this review study. In addition to outlining the global landscape for biodiesel generation from used cooking oil, this review article gives a high-level summary of the situation in India.

As the world's energy supply continues to dwindle and its energy consumption continues to rise, the urgent necessity of developing renewable energy sources has never been greater. Pollutants such as sulfur oxides, nitrogen oxides, particulate materials, and carbon monoxide are released into the atmosphere when fossil fuels are burned. Biodiesel is an alternative fuel that has several benefits over fossil fuels, including being renewable, producing less pollution, and being able to use a range of feedstocks. One possible fuel for biodiesel manufacturing is used cooking oil. Due to its negative effects on the environment, disposing of used cooking oil is a problem in and of itself. For cheap biodiesel generation under moderate reaction conditions, transesterification is the critical procedure. Optimizing transesterification to increase biodiesel output and decrease conversion cost has been the subject of much research. The repeated use of ultrasonic aided technology has the potential to significantly impact both the output and the cost of biodiesel production. An effort at a full examination of the properties of used cooking oil, variables impacting the transesterification reaction, and the use of ultrasonic aided technology to make biodiesel more environmentally friendly is the goal of this submission.

Keywords: **Biofuel, Fossil fuels, Ultrasonic assisted technology, Waste cooking oil, Transesterification, Sustainability, Biodiesel blends**

I.INTRODUCTION

Waste cooking oil is a good biodiesel fuel. Most WCO ends up in garbage cans, drainage systems, or soil. Many environmental issues stem from their disposal. WCO may be used to make biodiesel instead of trash. WCO makes fantastic biodiesel feedstock due to its low cost. WCO is better than edible oils since it is widely available, environmentally friendly, and does not contribute to the food vs. fuel conundrum. Due to its high water and FFA concentration, WCO must be esterified with an acid before transesterification, making the process difficult. Waste cooking oil (WCO) may be converted into biodiesel via pyrolysis, transesterification, ultrasonic assisted technologies, and supercritical methods.

Transesterification, which separates input oil into biodiesel and glycerol, is the most adaptable biodiesel production method. Lowering activation energy with catalysts speeds transesterification processes. The principal catalysts include acids, bases, and enzymes. Corrosion and saponification happened with alkaline and acidic catalysts. By composition, catalysts may be homogeneous, heterogeneous, or enzymatic. Heterogeneous catalysts are cheaper, more corrosion-resistant, simpler to separate, recyclable, longer-lasting, and more sustainable than homogeneous catalysts. Biodiesel production depends on reaction length, temperature, catalyst dose, oil-to-alcohol ratio, stirring speed, and other factors.

The high cost of biodiesel due to feedstock and production expenses is the main barrier to its widespread commercialization. Thus, this study examines old and novel reactor methods for biodiesel generation from spent cooking oil. In biodiesel production from waste cooking oil, tubular/plug-flow reactors (packed bed, fluidized bed, trickle bed, oscillatory flow, and micro-channel reactors), jet stirred, and mechanically assisted transesterification processes are being studied. The detailed material in this page is pertinent to current research on biodiesel production and processing from waste cooking oil and will be beneficial to researchers, specialists, and policymakers.

Technology, energy, and transportation industries grew significantly, increasing the world's oil and energy needs. Due to the uncertain global political climate and fossil fuel price changes, developing countries like India, which depends on other nations for energy, are suffering. India's major energy consumption rose 4% in 2018, 2.3% over the global average, or 35 million tons of oil equivalent. Over 70% of India's fossil fuels are imported.

Biodiesel may replace diesel because to its renewable resources, diesel-like structure, sulfur-free content, and lower emissions of hydrocarbons, carbon dioxides, carbon monoxide, and suspended particles. Biodiesel is produced by reacting animal and vegetable feedstock alkyl ester fatty acids with alcohols like methanol, ethanol, etc. utilizing homogeneous, heterogeneous, or enzymatic catalysts. Biodiesel has high production costs, poor cold flow behavior, high viscosity, and poor oxidation stability. However, some researchers have improved oxidation stability using antioxidants and metals. They are also studying feedstocks to reduce viscosity to diesel levels.

Second-generation biofuels from non-edible oils have replaced edible oil for ethical and commercial reasons. Current food crop use will be affected by biodiesel production. India's new biofuel policy promotes biodiesel production from non-edible oil seed crops such Karanja, Neem, Castor, Jatropha Carcus, Callophylum Innophylum, Simarouba Glauca, and Hibiscus Cannabbinus. However, nonedible oil is acidic and needs a lot of space owing to its high free fatty acid content. As a feedstock, Waste Cooking Oil (WCO) has financial and environmental benefits. By 2026, the worldwide cooking oil market might reach Rs 773.5 million. Waste cooking oil (WCO) might fuel biodiesel manufacturing in poor countries like India. It solves two problems: waste oil disposal and biodiesel production's lower cost than alternative feedstocks.

Transesterification is accelerated by catalysts' lower activation energies. The reaction equilibrium may be altered by a catalyst to produce the desired result. Acids, bases (alkaline), and enzymes are catalysts. Alkaline and acidic catalysts often saponify and corrode. Depending on composition, catalysts are homogeneous, heterogeneous, or enzymatic. Heterogeneous catalysts are cheaper, more sustainable, easier to separate, reusable, and last longer.

Fossil fuels dominate most nations' energy sectors due to their widespread use in industry, transportation, and agriculture. The imminent depletion of fossil resources concerns India. In 2018, oil accounted for 41% of global energy consumption, or 9.938 Mtoe (Figure 1).Non-renewable energy sources provide most of a nation's energy. Due to demand, industrialization, and scarcity, fossil fuels are depleting swiftly. Therefore, the best alternative to these old fuels must be found promptly. Biofuels are a good fossil fuel alternative since they are renewable, cheap, and emit fewer hazardous emissions.

II. LITERATURE SURVEY

1) A.E. Atabani, A.S. et.al, A comprehensive review on biodiesel as an alternative energy resource and its characteristics, Renew. Sustain. Energy Rev. 16(4) (2012) 2070-2093.

In order to keep up with the times and keep the economy growing, energy is a crucial component. The transportation sector uses 30% of the world's supplied energy, making it the second-biggest energy consumer behind industry. Over the last three decades, this industry has grown at a consistent rate. From 2005 to 2035, the world's transportation energy consumption is projected to rise at a rate of 1.8% year. Almost every fossil

2) A.L. Ahmad, et.al, Microalgae as a sustainable energy source for biodiesel production: A review, Renew. Sustain. Energy Rev. 15(1) (2011) 584-593.

It is evident from the above overview that feedstocks that do not cause land clearance, do not compete with food crops, and reduce greenhouse gas emissions should be the emphasis of the search for good biodiesel sources. If biodiesel wants to help mitigate climate change and ensure food security in the long run, it needs biofuel regulations that are consistent and take into account the socioeconomic circumstances around agricultural production. It has been shown that microalgae might theoretically serve as a source.

3) I.M. Atadashi, et.al, Refining technologies for the purification of crude biodiesel, Appl. Energy 88 (2011) 4239-4251

An important part of making biodiesel is the process of purifying the finished product. A critical analysis of current research on biodiesel refining technology is presented in this article. The most up-to-date biodiesel membrane refining technology is discussed with more traditional methods. In terms of biodiesel output and quality, the findings achieved by membrane filtration showed some promise. There was a decrease in wastewater discharges and water usage due to membranes. As a result, research into and use of membrane technology for crude biodiesel purification is essential. Additionally, researchers and industry may be encouraged to strive for high-quality, environmentally friendly biodiesel fuel that may substitute non-renewable fossil fuels for many uses if membrane technology proves effective in purifying crude biodiesel.

4) U. Schuchardt, et.al, Transesterification of vegetable oils: A review, J.Braz. Chem. Soc. 9 (1998) 199-210.

Environmental concerns will soon force the replacement of homogeneous catalysts used in industry with heterogeneous catalysts. Exciting new heterogeneous catalysts with strong bases are still in the works. Zeolites with strong basicsites 98 might be one option. The utilization of organic polymer-anchored guanidines was highlighted here. The guanidine must be doubly attached to the polymers in order to prevent its leaching. Guanidine encapsulation in a suitable inorganic matrix is another potential alternative. Due to its relatively small ore system diameter, the Y zeolite is unsuitable for this application as it hinders the diffusion of fatty acid triglycerides.

5) A. Kalva, et.al, Physical mechanism of ultrasound assisted synthesis of biodiesel, Indust. Eng. Chem. Res. 48(1) (2009) 534-544.

It seems that ultrasonic aided transesterification, which involves reducing the process duration and stages of operation, is a potential method for transesterifying Jatropha oil into biodiesel. The catalyst loading, methanol to oil molar ratio, reaction temperature, and reaction duration were some of the process factors studied for their effects on biodiesel production from Jatropha oil. Under these conditions—50? C, 9:1 methanol to oil molar ratio, 30 minutes reaction time, and 1% catalyst/oil wt.%—the conversion was more than 93%. Using ultrasound-assisted synthesis as its foundation, this work presents a kinetic analysis of Jatropha oil transesterification. An equation for the rate that was found is also given.

III. CHARACTERISTICS OF WASTE COOKING OIL

The chemical reactions that occur during frying lead WCO to vary in appearance from fresh oil. But WCO has the same density, acid value, kinematic viscosity, and iodine value as biodiesel, therefore it meets all the quality standards. Because it contains more free fatty acids (FFAs) than vegetable oil, WCO is a better catalyst to use in the manufacturing process. Conditions with high FFA concentrations limit large-scale biodiesel synthesis because of soap manufacturing. Kinematic viscosity, saponification, flash point, moisture content, and free fatty acid values are all very high for WCO. Both the yield and quality of biodiesel are affected by these chemical properties. It will be difficult to inject gasoline from the fuel tank without atomization if the oil has a high viscosity.

The processing expenses are significantly reduced due to the fact that WCO is two to three times cheaper than fresh vegetable oil. Since the cost of raw materials makes up a significant portion of the entire cost of making biodiesel—anywhere from seventy-five to ninety percent—its commercial price is greatly affected by these factors.

IV. TRANSESTERIFICATION OF WASTE COOKING OIL

Synthesizing biodiesel from discarded cooking oil mostly involves a transesterification process. The transesterification process may take place with or without a catalyst, and it involves the interaction of feedstock oil with alcohol. Both the output and quality of the biodiesel are significantly impacted by the catalysts. As will be discussed later on, catalysts may be further categorized as either homogeneous or heterogenous: -

4.1. One step transesterification

For waste cooking oil with low free fatty acid (FFA) concentration, a one-step transesterification procedure including alcohol and a catalyst is enough to directly transesterify WCO. synthesize biodiesel from used cooking oil with several methanol to oil ratios (4.5:1, 6:1, and 9:1) and catalysts (potassium hydroxide, sodium hydroxide) available. Conditions of 25 °C, 30 minutes of reaction time, 1% KOH/g acid, and a 6:1 molar ratio of methanol to oil produced the highest conversion. Using a methanol to oil molar ratio of 6:1, 1% KOH, a reaction period of 90 minutes, and reaction temperatures of 25 °C, it was further asserted that high-quality biodiesel could be produced from used cooking oil. tested a variety of catalyst concentrations (0.5% and 1%w/w), oil-to-methanol ratios (3:1, 6:1, and 9:1), reaction temperatures (25 °C and 65 °C), and alcohol-to-catalyst ratios (varying) and found that none of them affected biodiesel conversion from waste cooking oil. A molar ratio of 6:1, a catalyst of 1% w/w KOH, and a reaction temperature of 65 °C were the optimal conditions that produced the highest yield of around 98.16 percent. At the same time, it was noted that the conversion rate of KOH was 1% higher than that of NaOH.

4.2. Two-step transesterification

If the oil has significant FFA, it must be base-treated. Feedstock water and FFA levels greatly affect alkali catalysts. For WCO purification, column chromatography, steam injection, neutralization, vacuum filtering, and film vacuum evaporation are used. Steam distillation and alcohol extraction need high temperatures and large solvent quantities, making biodiesel production less efficient and harder. Esterification of FFA using sulfuric acid as a catalyst lowered WCO FFA concentration.

This method works with heterogeneous and homogeneous acid catalysts. Solid acidic catalysts outperform homogenous catalysts in advantages. Some studies have lowered WCO FFA using acidic ion-exchange resins. The reduction in catalyst activity is the major drawback with this method. Ideal conditions for esterification with iodine catalyst: 1.75:1 molar ratio of methanol to oil, 80 °C reaction temperatures, 3 hr reaction time, and 1.3 wt.% catalyst. The data show that this catalyst may be reused and reduce FFA to < 2%. Using glycerol as a catalyst and acidic raw material at 200 °C to pre-treat waste oil is new. This creates monoglycerides and diglycerides from glycerol and FFA. Biodiesel generation is achievable since FFA content is reduced. Without alcohol, water evaporated from the mixture as the reaction started. These pretreatment methods enhance biodiesel production costs. Slow reaction rate and saponification-induced methyl ester and glycerol separation are the biggest issues in acidic and alkaline catalysis transesterification. Two-step acid and alkali catalysed transesterification is used by many scientists to solve these problems.

FFA levels are reduced to less than 1% by transesterifying waste cooking oil with alkaline catalysts after esterification with acidic catalysts. Biodiesel production from recycled canola oil using two-step acid and alkali catalysis. The molar ratio of alcohol to oil (4.5:1–18:1), catalyst concentration, reaction duration, and reaction temperature for acidic catalysed esterification were considered first. Ideal conditions were 40:1 molar methanol to oil and 5% H_2SO_4. At 55 °C for 1.5 h, FFA dropped 96.3% from 11% to 0.41%. After esterification, transesterification was done using 6:1 methanol-to-oil and 1% potassium hydroxide. The two-step transesterification process included sulfuricacid, ferric sulphate (2–0%), and potassium hydroxide (1.0%) as catalysts. Data showed that the one-step approach converted well at 90%. A 20:1 molar methanol-to-oil ratio, 10-hour reaction time, and 95 °C were excellent. The two-step method was unique. Under optimal circumstances of 10:1 methanol to oil molar ratio, 4-hr reaction time, and 95 °C reaction temperatures, the highest conversion rate was 97.22%. These results revealed that two-step systems offered several benefits over single-step reactions, including high efficiency, no acidic waste treatment, economical equipment, and easy catalyst recovery. Numerous studies demonstrate that two-step transesterification is better than one. Two-step biodiesel synthesis from WCO yielded 90% conversion compared to 50% for alkali catalysed transesterification. Also found that two-step WCO transesterification reaction converts 30% more than single-step. Two-stage transesterification yields 98% methyl ester vs 86% in a single step. Use Response Surface Methodology to optimize two-stage transesterification. The optimal reaction conditions were 60 °C, 3 hour, and 7:1 molar methanol to oil ratio, yielding 81.3%. A reaction temperature of 65 °C for the acid transesterification reaction and 50 °C for the base transesterification reaction, a molar ratio of 3:7 (v/v) for methanol to oil, a mixing speed of 400 rpm, and a catalyst of 1% w/w H_2SO_4 were ideal for producing biodiesel from WCO with a high FFA Conversion was 90.6% for transesterification and 21.5% for esterification. Most studies advocate two-step transesterification since it yields more and can be turned into biodiesel. However, removing the catalyst in both stages is the hardest part of this process. After neutralizing the acid catalyst, additional alkaline catalyst must be used to cure the problem. Extra catalyst boosts biodiesel production costs. Leftover catalysts may damage engines. Transesterification Double Step Process (TDSP) produced biodiesel from multiple feedstocks. The first step's shorter reaction time, less catalyst, and direct mixing of acid solution and methanol without cooling produced amazing results. To assess product quality, 1H NMR and biodiesel analytical methods are used. High conversion rates (97% and 98% for waste cooking oil). High yields of 87.5%, 92.3%, and 93.3% for spent cooking oil.

V. STUDY OF PERFORMANCE CHARACTERISTICS OF THE ENGINE

The performance test began with pure diesel loads of 2kg, 4kg, 6kg, 8kg, and 10kg. After getting the performance test results in Excel, began testing blends B20, B30, and B40. Performance tests employed 16:1, 17:1, and 18:1 compression ratios. The computer performance test findings for various fuels were as follows.

1) Mechanical Efficiency

Figure 1 plots brake power on the x-axis and mechanical efficiency on the y-axis. Compare various diesel blends from graph Diesel and all biodiesel mixes have similar mechanical efficiency. This shows that all biodiesel mixes convert input energy to output movement efficiently.

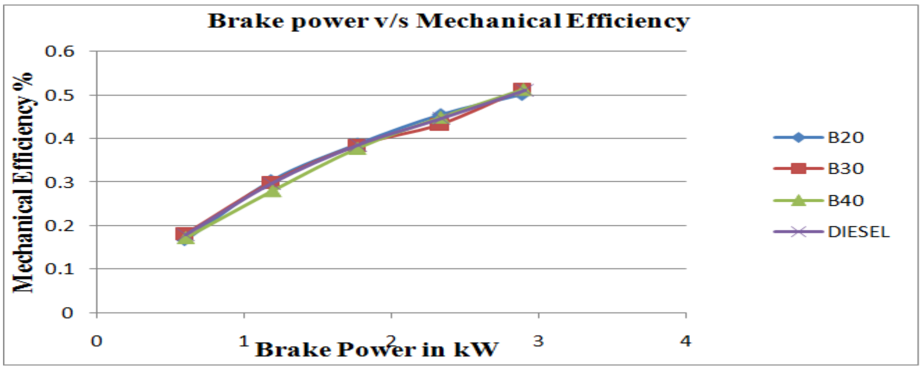

Fig 1 Mechanical Efficiency v/s Brake power

2) Brake Specific Fuel consumption (BSFC)

The x-axis in figure 2 below shows brake power, while the y-axis shows BSFC. Blend B40 has the lowest fuel usage out of all the mixes, as seen in the figure. B40 blend has the highest brake thermal efficiency of any blend since it uses the least amount of gasoline. More gasoline is used up because of the low compression ratio.

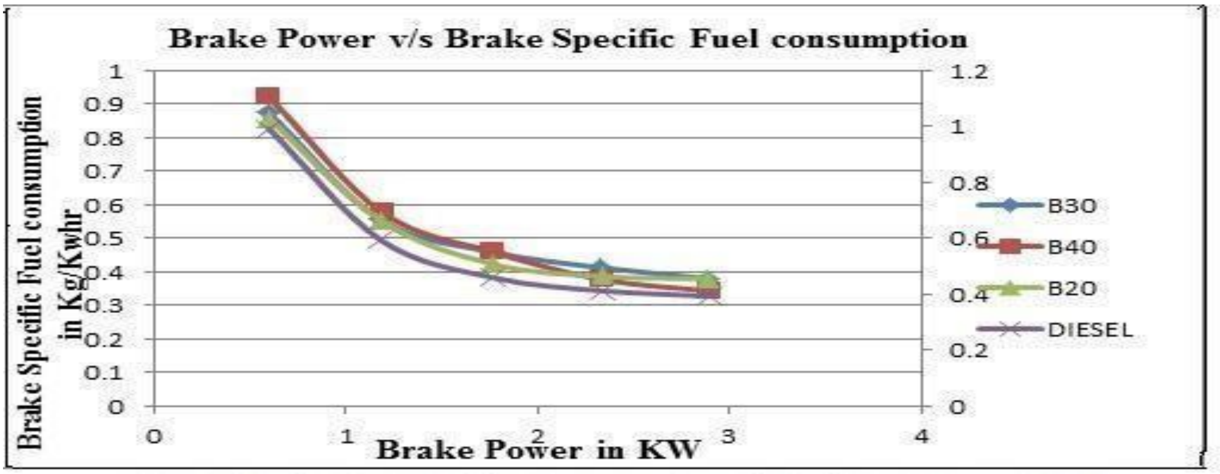

Fig 2 BSFC Vs BP

3) Brake Thermal Efficiency

Figure 3 shows the relationship between brake power and brake thermal efficiency, with the former represented along the x-axis and the latter along the y-axis. Increases in braking power result in improvements in the engine's brake thermal efficiency, according to graphs comparing various diesel blends. Blend B40's BTE is closest to that of Diesel. This proves that blend B40 outperforms all other blends in terms of efficiency.

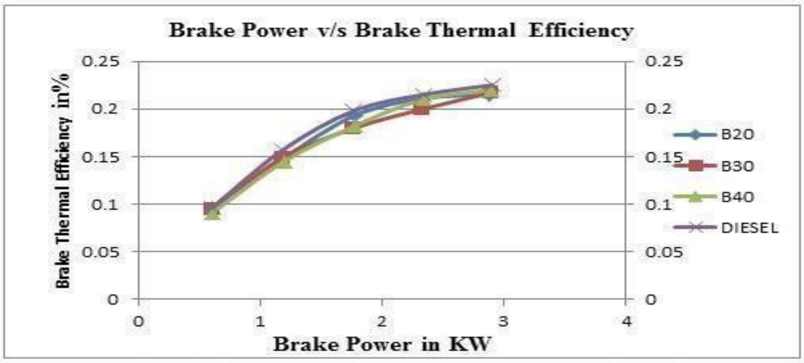

Fig 3 BTE Vs BP

4) Indicated Thermal Efficiency

The x-axis in figure 4 shows brake power, while the y-axis shows suggested thermal efficiency. Then I compared several diesel blends. The graph shows that when the braking power increases, the engine's thermal efficiency falls. Diesel and Blend B30 have the same ITE levels. Blend B30 outperforms all other blends in terms of efficiency, according to this data.

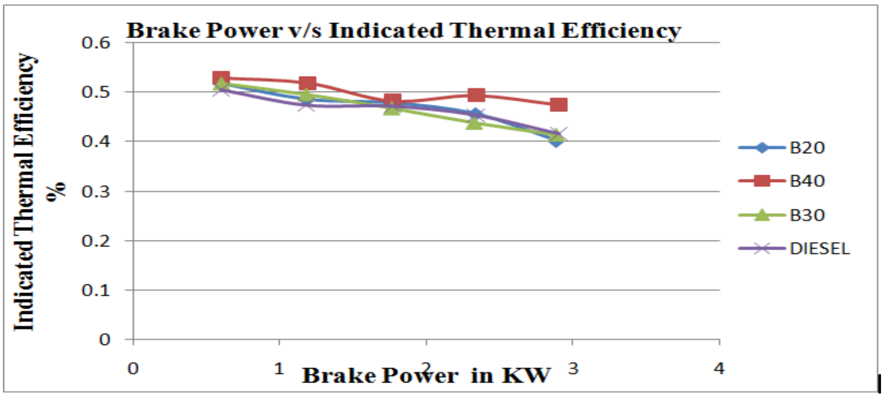

Fig 4 ITE Vs BP

5) Indicated Power

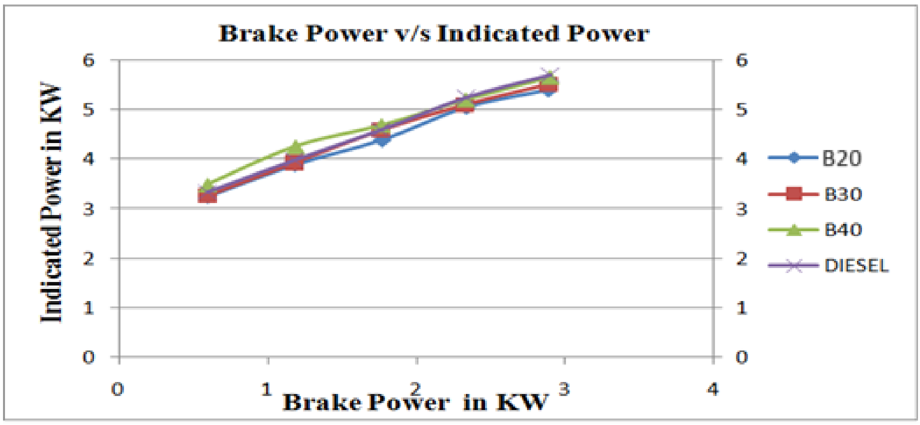

Fig 5 IP Vs BP

Figure 5 displays the relationship between brake power and indicated power along the x-axis and along the y-axis, respectively. Then I compared several diesel blends. The graph clearly demonstrates the pattern of stated power; as the braking power rises, so does the indicated power. Diesel has the closest IP to Blend B40. This proves that blend B40 outperforms all other blends in terms of efficiency.

6) Carbon monoxide

To confirm the general behavior of pollutant levels according to each fuel mix and operating mode, this section illustrates the emissions characteristics of the fuels studied. In Figure 6, we can see the fuel mixes' carbon monoxide (CO) emissions.

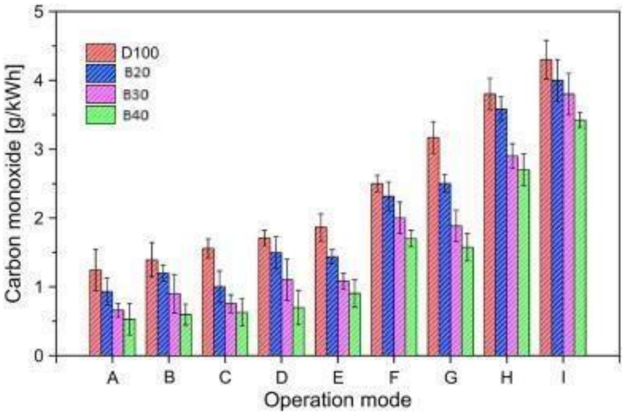

Fig. 6. CO levels of the tested fuels.

The amounts of CO emissions are lowest in B40 and B30 fuel mixes, and greatest in normal diesel. The chemical composition confirms, as this trend shows, that adding ethanol to the biodiesel mix of used cooking oil lowers the carbon level. Overall, as compared to regular diesel, B20, B30, and B40 fuels reduce CO emissions by 6.98%, 11.63%, and 15.39%, respectively. This pattern makes sense given that ethanol causes more thorough and efficient burning, which in turn reduces CO emissions. Ethanol, in other words, makes CO compound conversion to CO2 easier during combustion oxidation. Experimentation with various biodiesel blends revealed a consistent pattern of decrease for this sort of emissions.

7) Carbon dioxide

Carbon dioxide (CO2) emissions varied throughout the chosen modes of operation, as seen in Fig. 7.

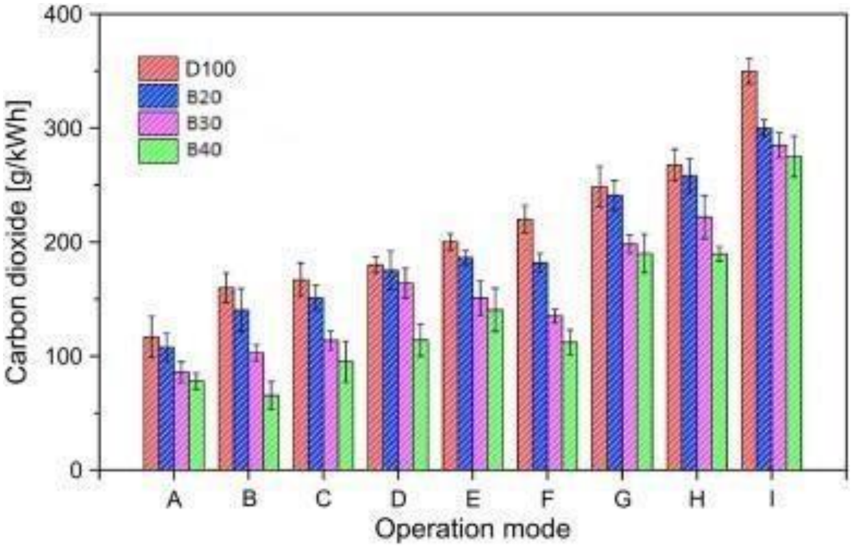

Fig. 7. CO2 levels of the tested fuels.

Adding ethanol to gasoline mixes reduces CO2 emissions, as seen in the results. In addition, the maximum amount of carbon dioxide emissions is produced by diesel engines operating independently. When compared to B20, B30 and B40 fuels reduced CO2 emissions by an average of 20.26% and 24.68%, respectively. In particular, the amount of oxygen, carbon-to-hydrogen ratio, and carbon atoms determine the nature of these emissions. Because of its low carbon to hydrogen ratio and very little quantity of carbon, ethanol will immediately reduce CO2 emissions when used in this process. A drop of 1.60% in the C/H ratio relative to the B20 biodiesel mix is responsible for the decreased CO_2 emissions seen in B30 and B40 ethanol blends. Studies using biodiesel blends have shown comparable outcomes.

8) Hydrocarbon

See Figure 8 for a breakdown of the various fuel mixes' unburned hydrocarbon (HC) emissions.

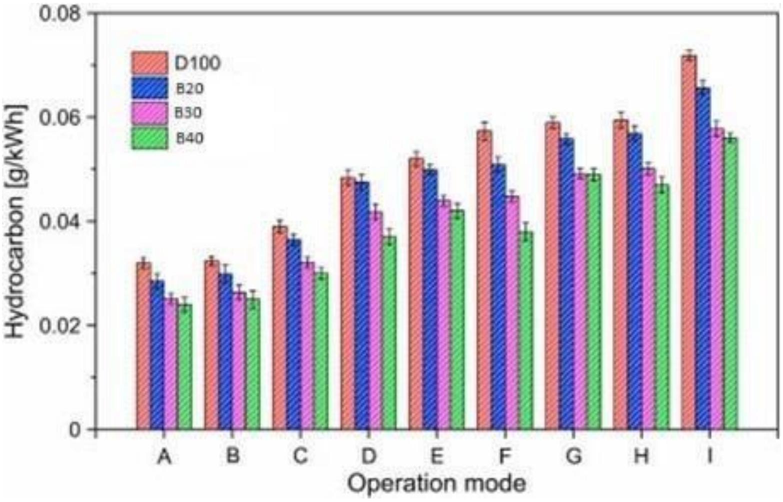

Fig. 8. Hydrocarbon emissions of the fuel blends.

With an increasing amount of ethanol in biodiesel, HC emissions were shown to decrease. When compared to regular diesel, the average reduction in HC emissions for B20, B30, and B40 fuels was 8.66%, 15.62%, and 19.07%, respectively.

There is almost twice as much oxygen in the B30 and B40 ethanol blends as there is in the Waste frying oil biodiesel. The addition of ethanol increases the oxygen concentration, which in turn promotes the combustion of hydrocarbons and reduces HC emissions.

9) Oxides of nitrogen

Figure 9 displays the nitrogen oxide emissions for all of the tested fuels. The major reason why NOx emissions have intensified is because combustion temperatures have been increased.

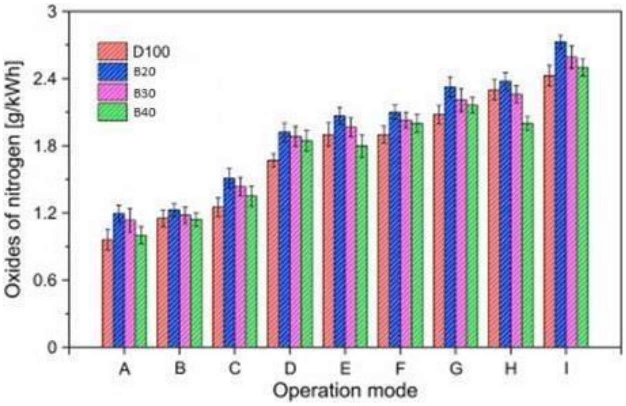

Fig. 9. NOx emissions of the tested fuels.

As compared to diesel alone, the data show that the B20 mix may increase NOx emissions by as much as 12.4%. The NOx emissions are reduced by 5% and 8.3%, respectively, when 2% and 4% ethanol are added to the preceding blend (B20). The high latent heat of ethanol vaporization causes a substantial quantity of heat to be absorbed inside the combustion chamber, which in turn lowers the combustion temperature. This is the reason for this pattern. This limits the production of NOx. The biodiesel blend made from waste cooking oil (B20) proved that the increased oxygen content of fuels B30 and B40 might promote the creation of NOx emissions; nevertheless, the aforementioned condition compensates for this. Nox emissions for various biodiesel mixes that enhance combustion oxidation follow a similar pattern.

10) Smoke opacity

Values of smoke opacity for each of the tested fuels are shown in Figure 10. Incomplete combustion is the primary cause of smoke opacity.

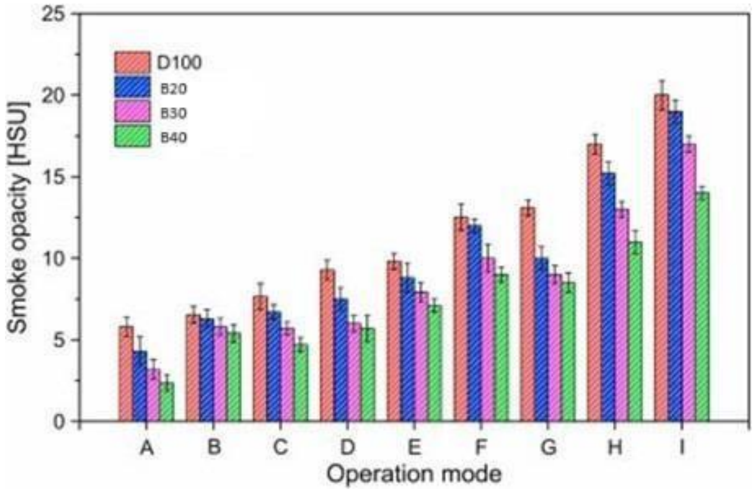

Fig. 10. Smoke opacity levels of the tested fuels.

Figure 10 shows that the smoke quality of the flue gases was improved with the addition of ethanol. Fuels B30 and B40, in particular, were shown to lower smoke opacity by 10.52% and 20.31%, respectively, as compared to fuel B20. This latter property promotes thorough and clean burning and may be linked to an increase in oxygen concentration and a decrease in viscosity. It has been shown via fuel characterisation study that adding ethanol to a mixture of palm and sunflower oil (B20) decreases the fuel's viscosity by 0.56%. The results of this study are consistent with previous ones that have looked at smoke emissions modified by ethanol additives.

VI. CONCLUSION

WCO's high FFA value necessitates pretreatment, although it does lower feedstock cost. When making biodiesel from WCO, it's crucial to use the right catalysts and process intensification methods. As a potentially inexpensive feedstock for biodiesel manufacturing, developing nations like India might make use of the abundantly accessible used cooking oil. As an added bonus, it will aid India in reaching its SDGs. This research draws conclusions from a number of previously conducted reviews.

Waste cooking oil and India

India consumes 225 lakh tons of vegetable oil annually, with 30% of that amount going to waste, according to the Food Safety and Standards Authority of India (FSSAI). The manufacturing of biodiesel may rely on it as a raw feedstock. In their biofuel strategy for 2018, the Indian government aims to eliminate the reuse of WCO for cooking and create a system to collect leftover cooking oil to guarantee a supply for biodiesel manufacturing. Putting effort into making biodiesel more economical while maintaining its excellent fuel attributes makes it one of the best fuel alternatives. What follows is a synopsis of the most important aspects of my work:

- Increasing the biodiesel output via the use of ultrasonic aided technology is a primary focus in the transesterification reaction, the main route in process biodiesel synthesis.
- The components of the feedstock or substrate used to produce biodiesel have a significant impact on both the efficiency and the final output of the manufacturing process.
- Using leftover cooking oil helps lower the costs of biodiesel manufacturing. Heating oil, however, changes its properties in a negative way, increasing its water and FFA content and perhaps introducing other pollutants.
- Producing biodiesel from waste cooking oil isn't without its challenges, which drives up the price of the separation and purification process.
- As the alkali catalysts are very sensitive to the free fatty acid (FFA) and water levels in the raw material, the traditional method of biodiesel production—transesterification—has serious problems with purification.
- Although FFA and water have no effect on acid-catalyzed reactions, the synthesis procedure takes more time.
- Despite their effectiveness, enzyme catalysts are too costly for commercial biodiesel production, despite the fact that they produced great results.
- Extremely high temperatures and pressures are required for the supercritical or non-catalyst method, which is plainly out of reach financially.
- After undergoing extensive improvements to its mechanical qualities and technical materials, the engine will function at an exceptional level.
- The results of this investigation pave the way for the next stage of alternative fuel research, and using biodiesel in engines has shown to be effective.

Ultrasonic technology is primarily focused on the reuse of heterogeneous acidic and basic catalysts in the production of biodiesel. The ability to reuse catalysts is the most important attribute for commercial manufacturing in a continuous process since it reduces costs. To cut down on production costs, reaction durations, catalyst, and alcohol demand, transesterification systems have used a number of ways. Processes using immiscible phases that work well in the lab often have trouble scaling up to commercial scale because of mass and heat transfer constraints. However, there has been great promise in recent years for technologies such as the oscillating flow reactor (OFR), ultrasonic technology, microwave irradiation, and co-solvent to circumvent this limitation. In addition to being more energy efficient than traditional heating techniques, these technologies increase the mixing intensity and heat and mass transfer rates, which speeds up the transesterification process.

REFERENCES

[1] A.E. Atabani, A.S. Silitonga, I.A. Badruddin, T.M.I. Mahlia, H.H. Masjuki, S. Mekhilef, A comprehensive review on biodiesel as an alternative energy resource and its characteristics, Renew. Sustain. Energy Rev. 16(4) (2012) 2070-2093.

[2] A.L. Ahmad, N.H.M. Yasin, C.J.C. Derek, J.K. Lim, Microalgae as a sustainable energy source for biodiesel production: A review, Renew. Sustain. Energy Rev. 15(1) (2011) 584-593.

[3] I.M. Atadashi, M.K. Aroua, A.R. Abdul Aziz, M.N. Sulaiman, Refining technologies forthe purification of crude biodiesel, Appl. Energy 88 (2011) 4239-4251.

[4] M. Berrios, R.L. Skelton, Comparison of purification methods for biodiesel, Chem. Eng.Jour. 144 (2008) 459-465.

[5] M. Canakci, The potential of restaurant waste lipids as biodiesel feedstocks, Bioresour. Technol. 98 (2007) 183-190.

[6] M.C.G. Albuquerque, I. Jiménez-Urbistondo, J. Santamaría-González, J.M. Mérida-Robles,
R. Moreno-Tost, E. Rodríguez-Castellon, et al., Cao supported on mesoporous silicas as basic catalysts fortransesterification reactions, Appl. Catal. A: Gen. 334 (2008) 35-43.

[7]