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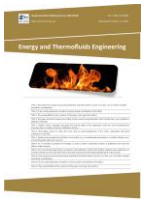

Extraction and characterization of biodiesel from waste cooking oil: An investigative approach based on the number of times used

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Abstract: In the era of rising atmospheric pollution and carbon dioxide emissions, environmentally sustainable energy sources are essential. This study seeks to address this challenge by examining the potential of biofuels, namely biodiesel derived from discarded waste cooking oil. The primary objective was to employ substantial quantities of wasted cooking oil, often generated by households and companies, in order to produce a biodiesel substitute that has a diminished environmental footprint in comparison to conventional diesel fuel. The procedure involved the synthesis of biodiesel through the transesterification of waste cooking oil samples, utilizing Methyl alcohol (CH_3OH) and Sodium hydroxide (NaOH) as a catalyst. The collected biodiesel samples were analyzed for important parameters, such as kinematic viscosity, flash point, and density. The kinematic viscosity values for the 10th, 20th, and 30th samples were 5.59 centistokes, 5.46 centistokes, and 4.91 centistokes, respectively. The flash points were determined to be 164.4 °C, 165.4 °C, and 148.4 °C, with densities of 0.8889 g/cc, 0.8891 g/cc, and 0.8891 g/cc, respectively. This study conducts a comprehensive examination and comparison of the characteristics of several biodiesel samples to ascertain the most advantageous choice. Moreover, a comparative assessment is carried out to determine the environmental benefits of the biofuel produced, as compared to conventional diesel. The findings offer crucial perspectives for the discourse on sustainable energy sources, emphasizing the potential of utilizing waste cooking oil-derived biodiesel as a viable and eco-friendly alternative to fossil fuels. By transforming waste cooking oil into biodiesel and carefully assessing its properties during synthesis, this research takes an innovative method.

1. Introduction

The increasing global population has led to a significant rise in the consumption of limited fossil resources. This circumstance highlights the urgent need for further research and development in the field of renewable fuels, with biodiesel emerging as a highly promising option (Yaakob et al., 2013). At the same time, the increasing price of petroleum, growing concerns about vehicle emissions and their impact on the environment, changes in local weather patterns, and a growing preference for diesel engines, which are known for their better performance compared to gasoline engines, all contribute to the growing importance of biodiesel as an alternative fuel source (Hosseini et al., 2012).

The increasing dependence on fossil fuels and petroleum derivatives is becoming more prevalent. According to (Suzihaque et al., 2022), the worldwide demand for diesel

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fuel made from petroleum has significantly increased during ten years, rising from 3.5 million tons in 2010 to 3.9 million tons in 2019. More precisely, in the Asia-Pacific area, which includes countries like China, Japan, and Malaysia, the consumption of diesel fuel had a significant rise from 1.1 million tons in 2010 to 1.4 million tons in 2019. This increasing pattern emphasizes the urgent requirement for feasible substitutes to diesel in order to tackle the growing global usage. Global warming, the depletion of non-renewable fossil fuels, and environmental contamination are all problems that the world is facing right now. Fossil fuels are responsible for the vast majority of manmade greenhouse gas emissions (Endalew et al., 2011; Tshizanga et al., 2017).

Finding sustainable, affordable, and environmentally acceptable alternative energy sources is crucial for addressing the challenges associated with the growing dependence on fossil fuels. Biodiesel is emerging as a prominent alternative to tackle these issues. As a potential replacement for traditional fossil fuels, biodiesel shows promise due to its ability to break down naturally and safely. Its low carbon dioxide emissions stem from photosynthesis's capacity to recycle fuel, thereby reducing the contribution of biofuel combustion to the greenhouse effect (Brito et al., 2007; Chung et al., 2008; Körbitz, 1999). The use of biodiesel is advantageous, producing cleaner exhaust gas emissions (Glisic & Orlović, 2014). Originating from non-fossil fuel sources positions biodiesel as a feasible substitute for conventional petroleum diesel. Extensive research has explored biodiesel's potential as an alternative energy source to traditional petroleum-derived diesel, consistently highlighting its exceptional qualities, including enhanced biodegradability, minimal toxicity, and improved environmental performance. Compared to petroleum diesel, biodiesel offers various benefits, such as reduced combustion emissions and a closed carbon cycle that limits its impact on global warming. Its compatibility with current diesel engines is particularly remarkable, necessitating few or no alterations and resulting in negligible reductions in performance (Fazal et al., 2011). Research consistently emphasizes the positive effects of biodiesel on exhaust emissions, demonstrating substantial decreases in CO, CO_2, SO_2, hydrocarbons, particulate matter, and smoke. This favorable outcome is attributed to the abundance of oxygen in biodiesel, facilitating thorough combustion and leading to reduced emissions compared to traditional diesel fuel (Ahmad et al., 2011).

As a possible replacement for traditional fossil fuels, biodiesel seems promising. Biodiesel is an alternative fuel that can be broken down naturally and safely, with its low carbon dioxide emissions coming from photosynthesis's ability to recycle the fuel. By doing so, the contribution of biofuel combustion to the greenhouse effect is reduced (Brito et al., 2007; Chung et al., 2008; Körbitz, 1999). The use of biofuel is beneficial because it produces cleaner exhaust gas emissions (Glisic & Orlović, 2014). Its origin from non-fossil fuel sources makes it a possible substitute for conventional petroleum diesel. Extensive studies have investigated the potential of biodiesel as a feasible alternative energy source to traditional petroleum-derived diesel. These studies continually emphasize the exceptional qualities of biodiesel, including its enhanced biodegradability, little toxicity, and improved environmental performance. Compared to petroleum diesel, biodiesel offers a wide range of benefits, including less combustion emissions and a closed carbon cycle that helps limit its impact on global warming. The compatibility of biodiesel with current diesel engines is particularly remarkable, as it necessitates few or no alterations and results in very negligible reductions in performance (Parawira, 2009). Research constantly highlights the positive effects of biodiesel on exhaust emissions, demonstrating substantial decreases in CO, CO_2, SO_2, hydrocarbons, particulate matter, and smoke. The favorable finding is ascribed to the abundance of oxygen in biodiesel, which facilitates thorough combustion and leads to reduced emissions in comparison to traditional diesel fuel (Ahmad et al., 2011).

Biodiesel is synthesized through the transesterification process, utilizing methyl alcohol (CH_3OH) and the catalyst lye (NaOH) as the final components. An expeditious and consistent combustion test was performed on the diesel fuel. The lubrication of the diesel appears satisfactory. Subsequent laboratory tests will determine the comparative quality of the biodiesel concerning the qualities of conventional diesel. Biodiesel is a highly efficient and less harmful fuel that offers numerous advantages, including cleaner combustion and reduced emissions of soot and air pollutants. Furthermore, biodiesel is devoid of sulfur, so preventing the emission of sulfur oxides into the atmosphere, which are known to contribute to the formation of smog and acid rain. Biodiesel, derived from bio-sources, exhibits a net negative carbon cycle. Avoiding any emission of CO_2 as a greenhouse gas is a driver of global climate change. It can

be used as a direct substitute for petroleum diesel in any diesel engine application, including vehicles, generators, and heating systems.

The transesterification process, which uses edible oil or animal fat as substrate using an enzyme or catalyst, has been the primary area of biodiesel production research (Asakuma et al., 2009; Atabani et al., 2012; Demirbas, 2005; Lee et al., 2011; Olutoye et al., 2011; Yagiz et al., 2007). Since heavy virgin oils like sunflower, soybean, olive, etc. are required to make biodiesel, the feedstock oil accounts for 60-80% of the total cost of the fuel, making it more costly than petroleum fuel (Christopher et al., 2014; Parawira, 2009). Because of this, the commercialization of biodiesel has stalled (Talebian-Kiakalaieh et al., 2013).

Waste cooking oil (WCO) and non-edible oils are being increasingly used as poor feedstock in biofuel production as a result of rising food commodity prices and waste discharge (Shu et al., 2007; Wang et al., 2011; Zhang et al., 2003). These oils have garnered a lot of interest as a potential feedstock for the manufacture of biofuels since they are both clean energy and accessible, which reduces manufacturing costs. Although the manufacture of biodiesel from WCO has been widely documented in the literature, the feedstock's characteristics, such as its high quantities of FFA, pose significant challenges to the use of standard homogeneous-catalyzed transesterification. There are several problems associated with making biodiesel using a homogenous catalyst and WCO. These problems include corrosion of equipment, soap formation, and excessive catalyst use (Shu et al., 2007).

Due to their high viscosity, diesel engines cannot run on direct vegetable oils (DVO). The transesterification process reduces the viscosity of DVOs (Ehsan & Chowdhury, 2015). Free fatty acid (FFA) levels are lower in biodiesel made from edible oils and greater in biodiesel made from non-edible oil sources (Diwani et al., 2009). Recycling the WCO produced by restaurants, and other food industries every day, anywhere in the globe, might be a possible alternative raw material for biodiesel production (Demirbas, 2009), given the retail price of biodiesel from vegetable oil is still greater than that of diesel. Food restaurants in Bangladesh appear to be in a particularly advantageous position: they use a great deal of WCO in the cooking process, and they must frequently use emergency generators, which require them to spend money on diesel fuel even though they are not directly generating electricity. Producing biofuel from WCO and utilizing it to replace some of the diesel feed might be an alternative for boosting plant profits and ensuring a reliable power supply. It may be possible to further ameliorate the situation by eliminating the disposal charge of the WCO and profiting from the biofuel sediments (Ehsan & Chowdhury, 2015).

This research focuses on producing biodiesel from WCO by the transesterification process accomplished in the presence of homogeneous catalysts such as CH_3OH and NaOH as suggested in a research paper (Ehsan & Chowdhury, 2015). Moreover, the properties of the produced biodiesel have been investigated to compare its quality with the biodiesel from crude oil.

This study is notable for its deliberate use of WCO, which is easily accessible in many areas, as the main raw source. This intentional decision efficiently tackles both the environmental difficulties linked to the inappropriate disposal of WCO and the economic obstacles in the production of biodiesel. This study enhances the field of biofuel research by providing insights into the distinct properties of WCO and suggesting novel methods for utilizing catalysts. Moreover, the essay emphasizes the worldwide need to shift from fossil fuels to sustainable energy sources, highlighting recent industry changes as the complete use of biofuel by Malaysian airlines. The results of this study not only enhance academic comprehension but also provide practical guidance for the advancement of ecologically sustainable and financially feasible techniques for producing biodiesel, especially in areas with a surplus of waste cooking oil.

2. Mechanism of Biodiesel Production

2.1. Transesterification Reaction

The combination of an ester molecule with an alcohol molecule, where the alcohol has a different structure from the primary alcohol in the ester, leads to the creation of a unique ester group. The reaction described by Sivasamy et al. (2009) entails replacing the original alcohol molecule with a different alcohol molecule. Triglycerides, which are the main components of vegetable oils, undergo a sequence of reductions to generate mono- and di-glycerides before finally converting into glycerol. The catalytic reaction pathway is illustrated in Figure 1, with fatty acids denoted by the symbols R's. The procedure involves the reaction of a single component, WCO, with three times the amount of methanol. This reaction results in the formation of three times the amount of methyl esters and an equal amount of glycerol, as explained by

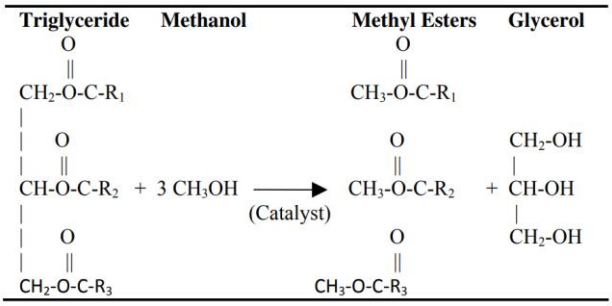

Fig. 1. Triglyceride transesterification mechanism using methanol {reproduced from (Sivasamy et al., 2009) with permission from John Wiley and Sons.}

research finding (Ehsan & Chowdhury, 2015). This synthesis process highlights the complex changes that occur in triglycerides during biodiesel generation and has implications for improving the efficiency of the transesterification process.

2.2. Experimental process of biodiesel production

Laboratory-scale biodiesel production from waste cooking oil used methanol and Sodium Hydroxide as a catalyst. Transesterification occurs in a 500ml flask on a magnetic stirrer. Heat the waste cooking oil to the reaction temperature before adding methanol and catalyst lye to the flask. Methanol and NaOH were mixed in the flask for 8–10 minutes. After adding the methyl-oxide solution to the WCO, the reaction mixture was vigorously stirred for 6–10 minutes. After adding 2500 ml of waste cooking oil, the mixture was heated to 65˚C transesterification was done by stirring the reaction mixture for the required duration.

2.3. Article structure

Figure 2 shows the biodiesel production process. Two access locations are possible for this process. Vegetable oils with less than 2.5% free fatty acid (FFA) do not need esterification (Mohd Zamberi et al., 2011). Here are the trans-esterification steps: Warming oil to 65°C; titrating WCO to determine NaOH; combining methanol and NaOH to make methoxide; combining methoxide concentration with WCO; emptying glycerol; and cleaning and drying biofuel. The cafes in the study generate 80 liters of WCO every week, but they need 150–200 liters of fuel per day to power their 180-kVA backup generator during the 4-5 hours of daily power outages. The hotel manager says this WCO must be properly disposed of at a "Disposal Expense" of 25000 Tk per week (Ehsan & Chowdhury, 2015). This "Disposal Cost" rises when glycerin is extracted with biofuel particles.

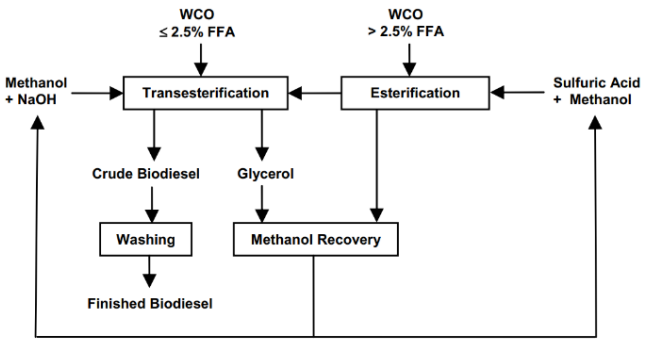

Fig. 2. Flow process of the plant for biodiesel production {reprinted from (Ehsan & Chowdhury, 2015), copyright (2015) with permission from Elsevier}.

2.4. Methodology

The main objective of this study is to produce biodiesel from WCO. The research will primarily focus on implementing fieldwork and conducting a numerical survey. After synthesizing biodiesel from WCO, a thorough series of chemical tests was conducted according to the specified approach. The chemical solution was prepared by combining methyl alcohol (CH_3OH) and sodium hydroxide (NaOH) as a catalytic lye. This solution was then applied to the WCO samples under carefully controlled conditions. Following the initial stages, the fuel and glycerol were separated into separate layers. Subsequently, chemical analysis was performed in controlled laboratory conditions to determine the characteristics of the biodiesel that was created. This work enhances the scientific discussion by providing a detailed account of the methods used to produce biodiesel from WCO, highlighting the crucial chemical processes involved, and reporting data obtained from extensive laboratory analyses.

In this experiment, the WCO was collected from five different domestic restaurants. This study involved a thorough examination of cooking oil usage in five different restaurants in order to identify trends and differences in cooking methods.

Table 1 shows the data collected from different restaurants. Treat Dee, Hotel Hasan International, and Dui Kabab and Restaurant primarily used vegetable oil and mustard oil, with usage frequencies ranging from 30 to 50 times, 12/13 times, and 10 to 20 times a day, respectively. Hotel Hasan International stands out by using olive oil in its culinary operations. The Vai Vai Hotel, which specializes in

Table 1. Data Collection from Different Restaurants.

Restaurant Name	Oil Type	Oil Brand	Oil Uses	Food Items	Daily oil use
Treat Dee	Vegetable oil, mustard oil	Basundhara, Pushti	30 (min–50 (max) times	chicken, rice, biriyani, Chinese, French fry, potato wedges, etc.	5-liter average
Hotel Hasan International	Vegetable oil, mustard oil, olive oil	Pushti	12/13 times per day	French fry, Wonton, salad, chicken fry etc	5 to 10 liters average
Vai Vai Hotel	Palm oil	Super	8/9 times per day	Samucha, Shingara, Jilapi, etc. (street food)	10 liters average
Alif Food	Vegetable oil	Basundhara	30–50 times	Burger, crispy chicken, roll, wings	10 to 15 liters
Dui Kabab and Restaurant	Vegetable oil, mustard oil	Pushti, Radhuni	10 to 20 times	Kabab and daily meals	10 to 20 liters

street food, solely relies on palm oil as its primary cooking oil, consuming an average of 10 liters a day. Alif Food, renowned for its burgers and crispy chicken, exclusively usesvegetable oil, using it 40 to 60 times a day, resulting in a daily consumption of 10 to 15 liters. By employing this analytical technique, a thorough comprehension of the cooking oil preferences and practices in each restaurant was achieved, hence facilitating a detailed comparative analysis.

As a result of difficulties in obtaining WCO directly from restaurants, the study opted to create representative WCO samples by simulating domestic cooking behaviors, notably frying birds and French fries. There were six separate samples created, each representing different usage frequencies that mirror real-life situations. Sample 5th experienced around 5 usage cycles, while Sample 10th, Sample 15th, Sample 20th, Sample 25th, and Sample 30th underwent roughly 10, 15, 20, 25, and 30 usage cycles, respectively. This method tackles the difficulties of acquiring genuine WCO from restaurants, guaranteeing that the artificially produced samples accurately represent the various conditions seen in culinary environments. The thorough recording of usage frequencies enhances the precision and significance of the research, establishing a basis for further examination and discourse on the characteristics and consequences of biodiesel created from these domestically sourced waste cooking oil samples.

2.5. Biodiesel Production

The WCO is produced at home. Different samples from different WCO based on the times it was used in cooking. The whole process was conducted at home. The initial WCO sample was obtained from a stove that was heated to a maximum temperature of 148 °F. During this procedure, it is crucial to ensure that the temperature does not surpass 148 °F. Failure to do so could result in a volcanic eruption occurring when the oil is combined with the chemical solution**.**

2.5.1. Methyl-Oxide Solution Preparation

The chemical solution has been prepared. Using a magnetic stir plate, 50 ml of methyl alcohol (CH_3OH) and 4 grams of catalyst lye (NaOH) were combined in a flask. The dissolution of lye into methanol and the formation of the methyl-oxide solution required around 3–4 minutes.

2.5.2. Mixing the Waste Cooking Oil into the Methyl-Oxide Solution

The WCO sample was mixed into the prepared methyl-oxide solution in the magnetic stirring plate as shown in Figure 3 to perform the transesterification process. After mixing the solution properly, the solution was kept for 24 hours at rest to allow it to separate into two different layers.

Fig. 3. Transesterification Reaction Occurring in the mixture of the Waste Cooking Oil and the Methyl-Oxide Solution.

Fig. 4. The Final Product of the transesterification process i.e., biodiesel.

The transesterification procedure entailed combining the WCO sample with a carefully produced methyl-oxide solution, using a magnetic stirring plate for assistance. After complete mixing, the solution was left undisturbed for 24 hours to allow for spontaneous separation into two different layers. The temporary period of rest was essential, as it facilitated the separation of the synthesized solution into its individual components, specifically the biodiesel and glycerol phases. This procedural step guarantees the thoroughness of the transesterification process and establishes the foundation for further evaluations of the characteristics and effectiveness of the resulting biodiesel.

2.5.3. The Final Product of the Transesterification Process

After allowing the solution to settle for 24 hours, it underwent phase separation, resulting in the formation of two distinct layers. The top substance is bio-diesel, whereas the bottom substance is glycerol as shown in Figure 4.

2.6 Property Testing of the Produced Biodiesel

In order to do the laboratory analysis of biodiesel, three distinct samples of the manufactured biodiesel were chosen to ascertain the essential characteristics, including kinematic viscosity, flash point, and density. The chosen samples were ranked as the 10^{th}, 20^{th}, and 30^{th}.

2.6.1 Kinematic Viscosity Testing

The Institute of Fuel Research & Development (IFRD) of Bangladesh Council of Scientific and Industrial Research (BCSIR) investigated biodiesel kinematic viscosity at 40°C and 100°C using ASTM-D 445-65. The biodiesel sample was collected in a viscometer from Tube-1's vent tube. To put the sample's meniscus between bulb-A's two lines, the lower bulb, was the goal. The viscometer was then placed vertically in a thermos-like bath at a set temperature. Full submersion of bulb-C (spherical) took around 5 minutes to reach the correct temperature. After gently pumping the sample to the middle of the bulb, bulbB recorded the sample's fall time.

2.6.2 Flash Point Testing

Flashpoint analysis of biodiesel samples from the 10th, 20th, and 30th batches were performed at the Institute of Fuel Research and Development (IFRD) of the Bangladesh Council of Scientific and Industrial Research (BCSIR) according to ASTM-D93. A Pen-sky-Martens closed-cup device determines a test substance's flash point according to ASTM-D93. The flash point testing machine meets ASTM-D93 and other requirements. ASTM-D93 procedures A, B, and C can be chosen based on test temperature, liquid type, or low melting solid. Process A involves distillate fuels like diesel, biodiesel blends, kerosene, heating oil, turbine fuels, and new and used lubricating oils. Procedure B tests leftover fuel oils, cutback residue, used lubricating oils, petroleum liquid-solid combinations, and petroleum liquids that form a surface film. Procedure C governs biodiesel. Since manual observation is difficult, automated equipment with electronic flash point detection can precisely measure residual alcohol in biodiesel. These tests can detect volatile or flammable chemicals in non-volatile materials. It is possible to determine the flash point above 250°C, although the precision is unknown. Precision for residual fuel flashpoints above 100°C and accuracy for contemporary lubricating oils have not been determined. Several standards show that the D93 lowest flash point is below 40°C; however, precision below this temperature is unknown.

2.6.3 Density Testing

The ASTM-D 1298 test standard is used to determine the density, relative density (specific gravity), or API gravity of crude oil, petroleum products, or mixtures of crude oil and non-petroleum products. This test is conducted in a laboratory using a glass hydrometer, and it applies to liquids with a Reid vapor pressure (RVP) of 101,325 kPa or lower. During the experiment, the sample was heated to a specific temperature, and a piece of the sample was then transferred to a hydrometer cylinder that had been heated to a similar temperature. Furthermore, a suitable hydrometer was submerged into the sample and left to stabilize at a comparable temperature. Once thermal equilibrium was achieved, the temperature of the test part

was measured using the hydrometer. The hydrometer reading was adjusted to the reference temperature using the Petroleum Measurement Tables. If required, the hydrometer cylinder and its contents were placed in a temperature-controlled bath to prevent significant temperature fluctuations in accordance with the testing standard ASTM-D 1298.

3. Results and Discussion

After combining the chemical solution with the heated cooking oil, the resulting mixture underwent phase separation, resulting in the formation of two separate layers. The upper layer consisted of biodiesel, while the lower layer consisted of glycerol as shown in Figure 5. This process is depicted in the accompanying diagram. This division was a crucial turning point, facilitating the extraction of the specific biodiesel from the top layer.

The study involved the creation of six biodiesel samples, each made from different WCO (vb) samples, which were identified by their unique frequencies of use. Moreover, the effectiveness of the synthesized biodiesel was confirmed by conducting a burning test, as demonstrated in the accompanying visual representation as shown in Figure 6. This comprehensive technique enhances the scientific comprehension of biodiesel synthesis from WCO and emphasizes the significance of thorough testing to evaluate its practical feasibility.

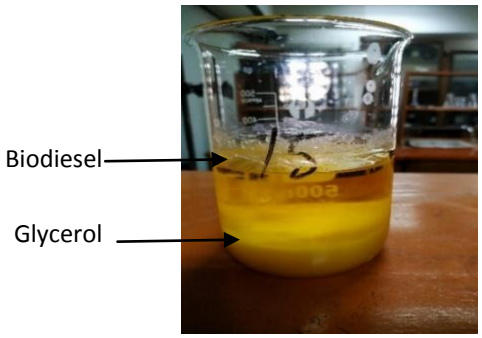

Fig. 5. Biodiesel and Glycerol were separated into Two Layers at the end of the work.

Fig. 6. Burning test of the produced biodiesel.

The examination of biodiesel samples, specifically focusing on sample IDs 10th, 20th, and 30th, demonstrates significant discrepancies in important attributes, as outlined in Table 2. Sample ID 30 exhibits the highest-quality biodiesel values across multiple parameters and demonstrates superior performance compared to the other samples.

The density, which is a crucial parameter for assessing the quality of biodiesel, is found to be the same for sample IDs 20th and 30th, measuring 0.8891 g/cc. This value exceeds the density of sample ID 10th, which is 0.8889 g/cc. Increased density is typically correlated with enhanced biodiesel quality. Therefore, both sample IDs 20th and 30th are identified as ideal selections according to this criterion.

Upon further examination of the flash points, it is evident that sample ID 30th, with a flash point of 148.4°C, exceeds the flash points of sample ID 10th (164.4°C) and sample ID 20th (165.4°C). A lower flash point can indicate improved biodiesel performance in terms of ignition properties. Therefore, sample ID 30th is identified as the optimal choice in regards to flash point.

The analysis of kinematic viscosity provides additional evidence of the improved performance of sample ID 30th. At 40°C, the viscosity of the sample is 4.91 cSt, and at 100°C, it is 1.96 cSt. This is better than sample ID 10th, which has viscosities of 5.59 cSt and 2.15 cSt at the respective temperatures, as well as sample ID 20th, which has viscosities of 5.46 cSt and 2.05 cSt at the respective temperatures. A decrease in kinematic viscosity suggests better performance of biodiesel, further supporting the

Table 2: Parametric values of the produced biodiesel found in the experiments.

Parameter		**Method / Instrument**	**Results**		
			Sample ID: 10th	**Sample ID: 20th**	**Sample ID: 30th**
Density (g/cc)		ASTM-D 1298	0.8889	0.8891	0.8891
Flashpoint (°C)		ASTM-D 93	164.4	165.4	148.4
Viscosity cSt	at 40 °C	ASTM-D 445	5.59	5.46	4.91
	at 100 °C		2.15	2.05	1.96

Table 3: The Comparison between the value of the sample ID 30th and the value of the actual diesel.

Fuel Property		Actual Diesel	Biodiesel
Density g/cc		0.80–0.90	0.8891
Flash Point °C		60–80	148.4
Kinematic Viscosity	at 40 °C	1.3–4.1	4.91
	at 100 °C	1–1.5	1.96

selection of sample ID 30 as the preferred option. When comparing the biodiesel's density, flash point, and kinematic viscosity in sample ID 30th with the real diesel values (Table 3), noticeable patterns emerge. The combustion efficiency of biodiesel is not compromised despite its increased density, which is influenced by parameters like fatty acid content and molar mass. Higher density, in reality, signifies effective atomization and thorough combustion within the engine, hence promoting a longer lifespan for the engine.

Furthermore, the increased flash point of biodiesel, which is a consequence of enhanced intermolecular attractions, diminishes the probability of unforeseen fire risks. Despite having a higher flash point than regular diesel, biodiesel derived from sample ID 30th can be efficiently utilized as Heavy Fuel Oil (HFO) in the Stratified Charge Engine. In this engine, the fuel-to-air combination is intentionally made richer near the spark plug.

The increased kinematic viscosity of biodiesel compared to regular diesel is related to the longer molecular chain length of biodiesel molecules. The heightened quantity of dispersion forces within biodiesel chains leads to a greater molecular closeness, which in turn affects viscosity. Notwithstanding the variation, sample ID 30th demonstrates outstanding performance, confirming its potential as a sustainable alternative to conventional diesel fuels. These studies provide vital insights into the possible applications and benefits of biodiesel produced from waste cooking oil.

4. Conclusion

In conclusion, the investigation into biodiesel generation from various types of spent cooking oil, focusing on their frequency of usage, has yielded valuable insights. The methodical sequence of experiments and thorough analysis facilitated a rigorous evaluation of the synthesized biodiesel samples. These samples, derived from different waste cooking oil sources, underwent comprehensive testing, including a burning test, to confirm their effectiveness.

Significant discrepancies in key attributes among the biodiesel samples, particularly sample IDs 10th, 20th, and 30th, were observed. Sample ID 30th emerged as the top performer, demonstrating superior characteristics in density, flash point, and kinematic viscosity. This indicates its potential as an environmentally friendly fuel substitute.

Comparisons with genuine diesel fuel (Table 3) further underscored the superiority of biodiesel, especially from sample ID 30th, in terms of flash point, kinematic viscosity, and density. Despite its increased density, biodiesel from sample ID 30th maintained combustion efficiency and posed reduced fire risks, making it suitable for applications such as HFO in the Stratified Charge Engine.

The outstanding performance of sample ID 30th confirms its potential as a sustainable alternative to conventional diesel fuels. These findings provide crucial insights into the applications and benefits of biodiesel produced from waste cooking oil, emphasizing the significance of thorough testing to evaluate its practical feasibility and promote environmental sustainability in the energy sector.

Disclosures

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Conflict of interest

The authors declare that they have no conflicts of interest in publishing this research work.

Nomenclature

υ	Kinematic viscosity [cSt]
K	Viscometer constant [mm²/s]
t	Down flowing time of a liquid [s]
ρ	Density [g/cc]
HFO	Heavy Fuel Oil
WCO	Waste Cooking Oil

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