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Application of green technology for Biofuel production

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Abstract

Since fossil fuels are becoming less and less accessible, the manufacturing of biofuels from diverse renewable sources is becoming more and more intriguing these days. Several characteristics that make biodiesel a more environmentally friendly fuel include its biodegradability, non-toxicity and reduced pollutant emissions. In the industrial manufacturing of biodiesel, the transesterification process is the most fundamental method. The purpose of this study is to evaluate the processes utilized to produce biodiesel from used cooking oil and various kinds of vegetable oils. Transesterification process is used to produce biodiesel by employing base catalysts (KOH). Among the various feed stock of vegetable oil, coconut oil, orange oil and Sesame seed oil which have different physicochemical characteristics making them a promising feedstock for biodiesel generation. The extracted biodiesel was characterized by acid value, density, viscosity and PH. The effect of type of catalyst and quantity of catalyst on the effectiveness of biodiesel fabrication has been examined.

Key Words:

Biodiesel, biodegradability, Transesterification, density, viscosity

1. Introduction:

By 2050, there will be more than 10 billion people on the planet, according to estimates. Carbon emissions will rise by a staggering 26% by 2030 because of the high rate of population expansion and the resulting daily demand for fossil fuel resources(Pravin et al., 2023, 139724). This suggests that to meet the world's expanding demands, urgent solutions must be found to locate alternative renewable resources. Environmental issues and the world energy crises necessitate a clean, green, sustainable, and inexpensive shift (Khandaker et al., 2022, 112051). All clean energy derived from natural sources, such as biomass, solar, wind, hydropower, and geothermal energy, is referred to as green energy (Csefalvay et al., 2018, 8867). Because they obtain their energy from agricultural residues, perennial grasses, woody biomass, algae, food waste, and livestock manure, biofuels are considered green fuels (Kang et al., 2022, 4). The various generations of biofuels can be distinguished by the constituents that comprise them. For the first generation of biofuels, waste from corn, potatoes, wheat, and sugar cane are used. Because lignocellulosic material is inexpensive and non-edible, it is used as a raw material for the second generation of biofuels. The basic ingredients for biofuels of the third generation are microorganisms. The raw materials for the fourth generation of biofuels are genetically modified microorganisms, including yeast, cyanobacteria, microalgae, and fungus (Gunawan et al., 2023, 101546). When compared to fossil fuels, biofuels create less particulate matter (PM), carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NO_x) (Santana et al., 2021, 9186). Furthermore, biofuels can lessen global warming by preventing the greenhouse effect from forming through CO_2 fixation (Kang et al., 2022, 4).

Modern technology is capable of extracting biofuels in many ways. Biofuels are divided into three groups based on their availability: solid, liquid, and gaseous (Yang et al., 2021, 534-553). Solid biofuels are fuels made from biomass, organic materials, and municipal waste. It is possible to generate thermal and electrical energy using solid biofuels. These renewable fuels come from a variety of sources, including animal carcasses and agricultural and forest waste. Charcoal, wood pellets, wood chips, and firewood are the most well-known solid biofuels (Jabari et al., 2022, 172–192).

Liquid biofuel is the term used to describe any liquid renewable fuel. The main applications for liquid biofuels are in the production of electricity and the transportation sector. Notable examples of liquid biofuels are pyrolysis bio-oil, biodiesel, and bioethanol. Because of their special qualities, liquid biofuels are more widely used than fossil fuels. These advantages include safer transportation, relative cost, storage stability, high energy-to-mass ratios, high combustibility, and fewer greenhouse gas emissions (Devi et al., 2021, 343-353). Bioethanol is an additional alternative fuel that can be utilized for transportation. This fuel can be used straight up or combined with gasoline. Bioethanol fuel has several benefits, including higher efficiency due to its rapid flame speed, high octane number, and high heat of vaporization (Alalwan et al., 2019, 127–139). Bioethanol can be obtained from the fermentation process of simple sugars derived from plant material, such as fructose and glucose (Singh et al., 2022, 125109). Nowadays, crops like sugarcane, beets, wheat, corn, and potatoes are used to make the majority of commercial bioethanol. The top producers of bioethanol are the United States, Brazil, Europe, China, and Canada. Certain biofuels are clean and renewable fuels, but producing them comes with several difficulties, including rising food costs, declining global food security, competition for land and water. These types of biofuels have too many disadvantages to be regarded as a substitute for fossil fuels (Prasad et al., 2019, 588-606).

It is possible to make biofuel from vegetable or animal oils. The fatty acids found in vegetable oils are the best raw materials for the creation of biofuels because they can be processed readily, particularly by transesterification and cracking (Istadi et al., 2021, 100677). Additionally, the kind of raw material used can influence the final biofuel's properties and cost of manufacturing (Kuss et al., 2015, 1013-1020). An alkyl ester combination is what makes up biodiesel as fuel. Alcohol and raw materials that include a high concentration of triglycerides react to produce esters (Gomez-Castro et al.,2023, 113580). There are two recognized processes for producing biodiesel: transesterification and esterification. Transesterification is the process that turns vegetable or animal fats into methyl esters (FAME) (Naghmash et al., 2022, 103532). Vegetable oils and animal fats contain a variety of fatty acid types, including palmitic, myristic, stearic, oleic, linoleic, and linolenic acids (Parida et al., 2017, 556-562). For the purpose of producing biodiesel, the esterification reaction is used to convert free fatty acids (FFAs) into alkyl ester via a reaction with alcohol (Haigh et al., 2012, 1107). Utilizing acid catalysts facilitates the generation of biodiesel with a high free fatty acid (FFA) level (Thanh et al., 2010, 5394-5401). Transesterification processes can be achieved with basic catalysts such potassium hydroxide, sodium hydroxide, or sodium methoxide (Álvarez et al., 2009, 1153). When compared to diesel, biodiesel has a variety of benefits, including a high cetane number, a high boiling point that prevents burning, and excellent combustion efficiency (Changmai et al., 2020, 41626). Pyrolysis bio-oil, exhaustible fuels were created by the earth's pressure and heat millions of years ago from the remains of plants and animals. Pyrolysis is the process of heating plant biomass in an oxygen-free atmosphere to a temperature of 300–900 °C (Panchasara et al., 2021, 794).

Gaseous biofuels are an additional type of biofuel. It can be noted that two of the most popular gaseous biofuels are syngas and biogas. Gaseous biofuels offer a wide range of uses, particularly in microgrids and the power generation sector. Benefits of using gaseous biofuels include less waste production during usage, ease of control, increased reactivity, and reduced need for oxidants (Maki et al., 2021, 106036). Biogas is natural gas created by burying animals and plants that remain under intense heat and pressure for thousands of years, much like other fossil fuels (Kapoor et al., 2019, 11631–11661). Biogas is a gaseous fuel made from renewable resources. Biogases, which are created when organic materials undergo anaerobic digestion, are a good substitute for natural gases. Biogas involves methane (60–65%) and carbon dioxide (30–35%), with trace amounts of water vapor, hydrogen, and H_2S (Kabey et al., 2022, 2) (Yaqoob et al., 2021, 127250). Syngas is one type of gaseous biofuel. The thermal breakdown or gasification of plant materials yields syngas (Kapoor et al., 2020, 123036).

The Advantages of bioenergy and biofuels: Economic impact: although biofuels have a lower carbon footprint than conventional fuels, they are priced similarly. They offer a superior total economic value for a comparable product over time and are typically more efficient with a lower impact on the environment, less emissions, and fewer bioproducts (Wu et al., 2018, 1-9). Nanotechnology in Biofuel Production. Because of their extraordinary physicochemical properties and distinctive characteristics, nanoparticles have been employed in biofuel Manufacture. They also have a higher potential for recovery, reuse, and recycling [Nizami et al., 2018, 798). High catalytic activity metal oxide nanocatalysts, including magnesium oxide, titanium oxide, calcium oxide, and strontium oxide, have been created for the synthesis of biofuels. Additionally, because of their high surface-to-volume ratio and immobilizing qualities resulting from their nanosize, magnetic nanoparticles have found widespread use in the manufacturing of biofuel. They have the benefit of being easily extracted from the system with the application of an appropriate magnetic field, which makes the method cost-effective for large-scale biofuel production (Antunes et al., 2017, 3-18).

2. The Theoretical Framework

Given the emphasis on alternative fuels and their critical role in mitigating the environmental consequences of emissions resulting from the combustion of fossil fuels, it is imperative to assess current technology for producing biofuels. The area of biofuels has made significant strides recently. Advanced technologies are being created and numerous research projects are being carried out. Biodiesel is a significant biofuel that has the potential to displace petroleum in the future. One solution to the issue of unlawful waste cooking oil (WCO) disposal into rivers and landfills, which causes environmental degradation and energy shortages, is to produce biodiesel from waste cooking oil to partially replace petroleum fuel (Chen et al., 2009,668). Additionally, since waste cooking oil is less expensive than virgin vegetable oils and other feedstocks, it would be a wise choice as a raw material to lower the cost of producing biodiesel (Hameed et al., 2009, 1533).

Transesterification of triglycerides in vegetable oil or animal fats results in the production of biodiesel. The process of replacing alcohol in one ester fat or oil with another is known as transesterification (Srivastava and Prasad, 2000 ,111). Triglycerides high viscosity has been lessened via the widespread usage of this procedure. This process is known as methanolysis if methanol is utilized. One of the reversible processes is transesterification, which basically works by combining the reactants. However, the conversion of fatty acids into ester is accelerated in the presence of a catalyst (Mohamed et al., 2019, 32). The general equation for triglyceride transesterification was shown in Fig. 1.

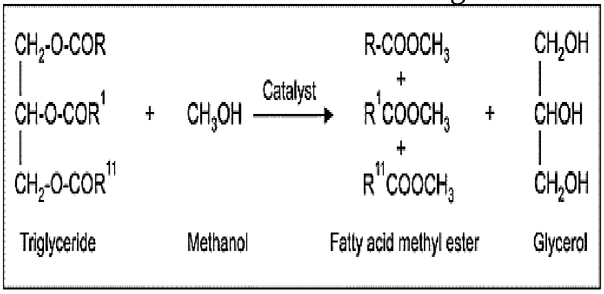


Figure (1): General Equation for transesterification of triglycerides

Triglycerides are trans-esterified to provide glycerol as byproducts and fatty acid alkyl esters. The reaction vessel's bottom is where the glycerol layer eventually settles (Mohamed et al., 2019, 33). The intermediaries in this process are monoglycerides and diglycerides. Fig.2 provides a description of the transesterification mechanism. Because the stepwise reactions are reversible, the equilibrium can be shifted in favor of esters production with a little excess of alcohol. The reverse reaction is determined to be second order and the forward reaction to be pseudo-first order in the presence of excess alcohol. It was also noted that the presence of alkali catalyzes transesterification more quickly (Özcan and Aydın, 2004, 521–524). Several variables influence the transesterification process, contingent on the reaction condition employed (Meher *et al*., 2006, 249).

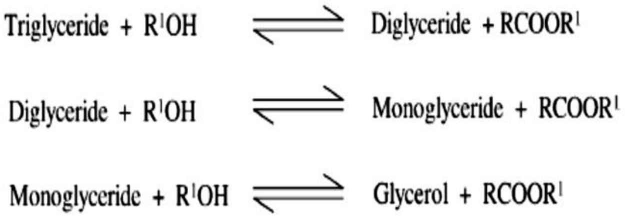


Figure (2): Triglyceride transesterification

Homogeneous catalysts have been the subject of several studies on the manufacture of biodiesel; however, they are highly costly and unfriendly to the environment. Conversely, heterogeneous catalysts are environmentally benign and less expensive during manufacture. Waste cooking oils were transesterified using zeolite ore as a solid heterogeneous catalyst to produce biodiesel (Saad et al., 2023, 15836). Using waste cooking oil and two different catalyst types: potassium hydroxide and ion exchange resin Amberlite 15 biodiesel is created through a transesterification process (Ulukardesler, 2023, 2035). Heteropoly acid $H_3PW_{12}O_{40}$ ($6H_2O$) [PW12] is employed as an effective catalyst to produce biodiesel from waste cooking oil (Cao et al., 2008, 93). $NaOH/CoFe_2O_4$ magnetic nanoparticles are used as an effective catalyst for the transesterification reaction between WCO and methanol (Bousba et al., 2024, 118021). Biodiesel was fabricated from wasted vegetable oil using heterogenous nanocatalysts based on Al_2O_3 and Fe_2O_3(Abati et al., 2024 130847). 2D carbons have been employed as catalysts in the synthesis of biodiesel, such as derivatives of graphene via esterification and transesterification reactions (Roy et al., 2021, 101053). Pongamia oil is converted into biodiesel with the use of sodium hydroxide as basic catalyst and methanol (Naveen et al., 2021, 218). Biodiesel was generated by esterification of wastewater that contains fats, oils, and grease (Ahmed et al., 2022, 1). Using a solid acid catalyst and the esterification process, olive pomace oil was utilized to create biodiesel (Ayadi et al., 2021, 120678). Biodiesel produced from coffee byproducts, such as wet coffee (coffee pulp or peeled) and dry cherry coffee bean processing residues (Sugebo, 2022, 91). Using KOH as a catalyst, the coconut fatty acid distillate was utilized as a new feedstock for biodiesel (Rajesh et al., 2021, 1424). As a catalyst, Ce-KIT-6 assisted by Cs-exchanged tungstophosphoric acid (Cs-TPA/CK) is used to produce biodiesel from amla and almond oils (Ganesan et al., 2024, 256). Biodiesel synthesis using a new $Na/SiO_2/TiO_2$ heterogeneous catalyst from nonedible wild olive oil (Khan et al., 2022, 123828). The transesterification process converting waste frying oil (WFO) into biodiesel uses a unique heterogeneous catalyst called potassium carbonate/orange peel-derived activated hydrochar (KC/OAH) (Mawlid et al., 2024, 140947). Sesame seed oil is one of the many vegetable oils that may be used as feedstock to produce biodiesel because of its distinct physicochemical characteristics (Roy, 2021, 619). Biodiesel was made from the oil that was taken from the seeds of the castor plant (Khudhair et al., 2023, 293). Consequently, the purpose of this study was to propose a method employing environmental cost accounting principles for lowering emissions, fuel costs to produce biofuel from waste cooking oil. Biodiesel generated via transesterification of waste cooking oil (WCO) with methanol in the presence of KOH catalyst. Additionally different kinds of vegetable oils are used to production biodiesel.

3.Methods of Research and the tools used

Materials: Waste cooking oil (WCO), Orange oil, Sesame oil, Coconut oil, Potassium Hydroxide (KOH) and Methanol (CH_3OH).

Tools: Graduated cylinders, Pipettes, bursts, beakers, thermometer, separating funnel, balance, Hot plates with stirring, pH meter and viscometer.

Procedure of biodiesel production: Firstly, waste cooking oil is filtered to remove all food impurities. After that, 60 mL of waste cooking oil measured out and added to a big beaker. The oil is heated to 60°C on hotplate with contentious stirring. After that 12 ml of methanol was added to 0.2 g of KOH and mixed well to form methoxide. The methoxide solution is then added to the oil and keep the mixture at 60°C for 60 minutes. After 60 minutes glycerol, the darker layer, should be accumulating on the bottom, while biodiesel, the lighter layer, should be floating on top. It will take many hours to overnight for the reaction mixture to completely separate. Following the biodiesel and glycerol separation process, the biodiesel was cleaned to get rid of any leftover catalyst. The biodiesel was repeatedly washed with distilled water to guarantee that all the base, leftover alcohol and glycerol had been removed. When the initial pH of the distilled water was comparable to the pH of the water after extraction, the washing procedure was terminated. Following this washing procedure, the biodiesel was heated to 90°C with the purpose of evaporating any remaining water and alcohol (Saad et al., 2023, 559). The refined product was then weighed. Similarly, biodiesel is produced by using different vegetable oils (coconut oil, orange oil and Sesame oil) by the above steps. Vegetable oils are used without any purification. Fig. 3 shows the steps of preparation of biodiesel from waste cooking oil. Fig.4 illustrates the biodiesel manufacture from orange oil. Fig. 5 clarified the biodiesel generation from coconut oil. The production of biodiesel from sesame oil is obvious in **Fig. 6.**

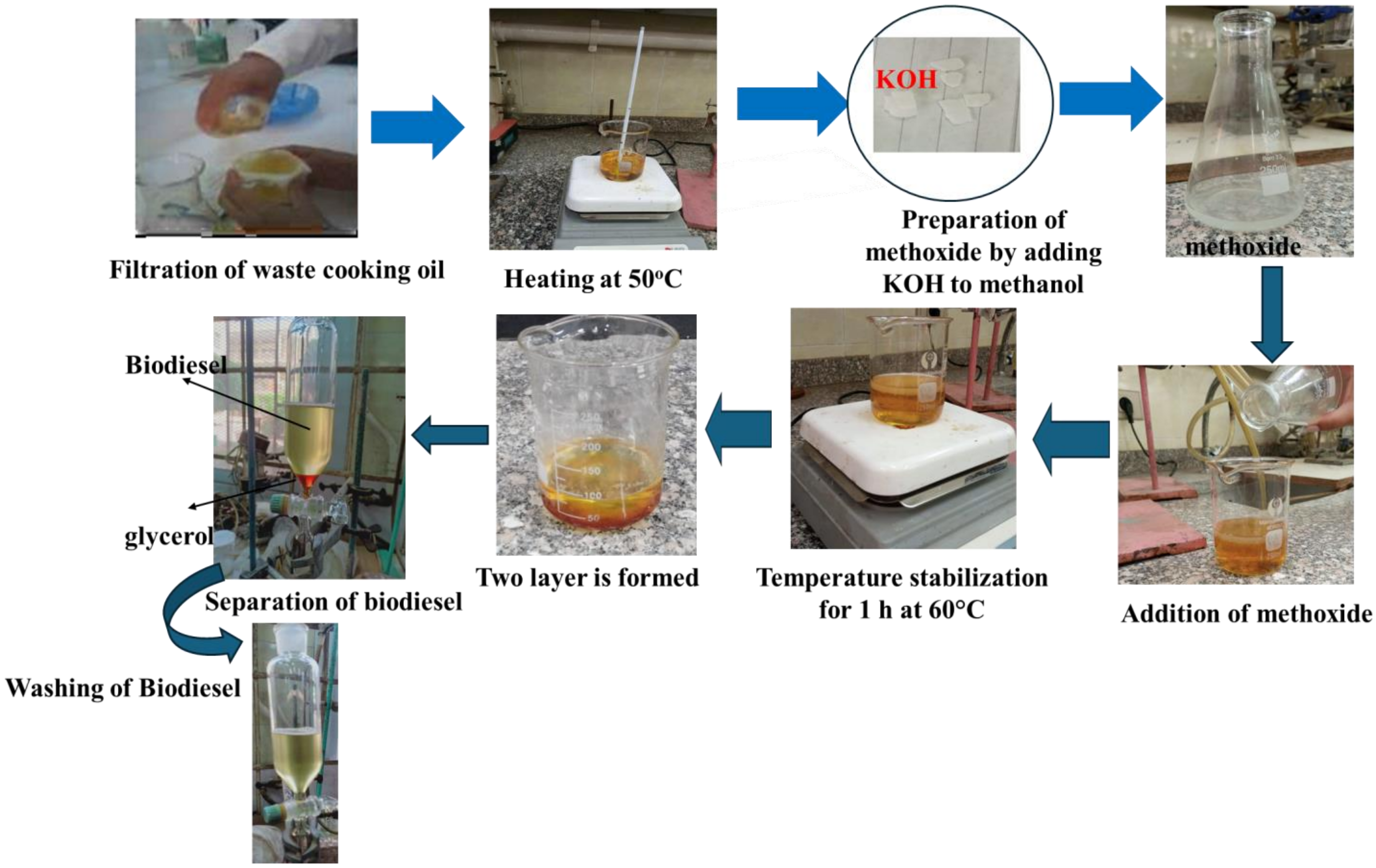
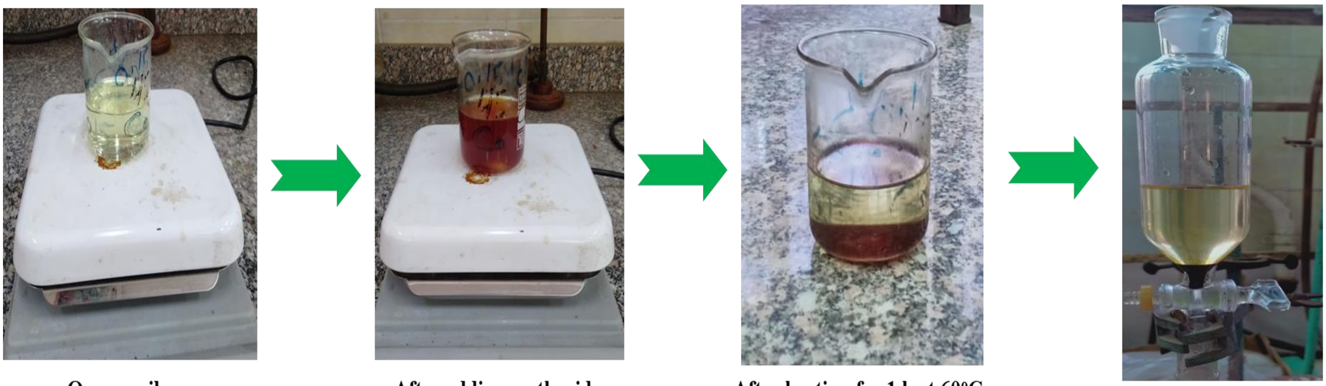


Figure (3): A diagram summarizing the process of producing biodiesel from waste cooking oil.



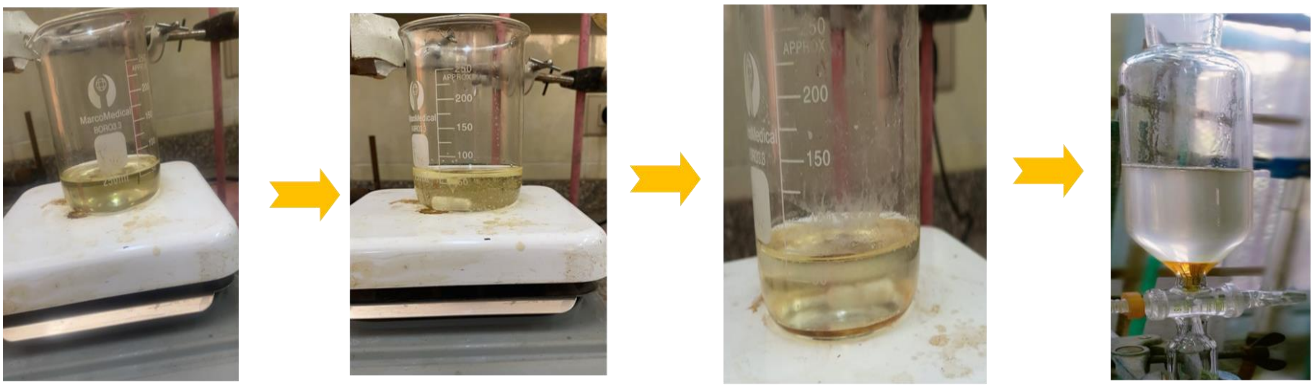
Orange oil

After adding methoxide

After heating for 1 h at 60°C
Two layer is formed

Separation of biodiesel

Figure (4): Biodiesel manufacture from orange oil.



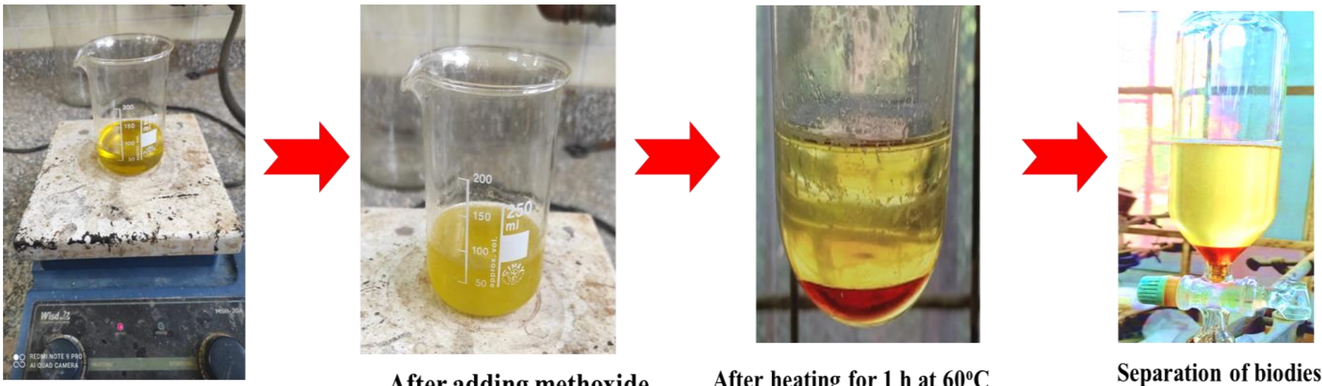
Coconut oil

After adding methoxide

After heating for 1 h at 60°C
Two layer is formed

Separation of biodiesel

Figure (5): Biodiesel generation from coconut oil.



Sesame oil

After adding methoxide

After heating for 1 h at 60°C
Two layer is formed

Separation of biodiesel

Figure (6): Biodiesel production from sesame oil.

Measuring the biodiesel density:

Biodiesel density is calculated by gravimetric analysis, weighing the sample on an electronic scale and using a glass cylinder to hold a volume of biodiesel. The density determined using equation:

$$\rho = \frac{m}{v}$$

There, the sample's weight is expressed as m [g], and its volume is expressed as v [cm^3].

The measurement of biodiesel viscosity

A viscosimeter was used to measure relative viscosity (Figure 7). A measurement was made of the oil or biodiesel sample's time flow through the viscometer's capillary. kinematic viscosity (mm^2/s) is calculated by divided the relative viscosity on the density value as mentioned on the following equation (Adekunle et al., 2020, 2867):

$$\nu = \mu / \rho$$

where μ = relative viscosity (kg/ms); ν = kinematic viscosity (mm^2/s); ρ = density (g/cm^3).

Figure 7: viscosimeter

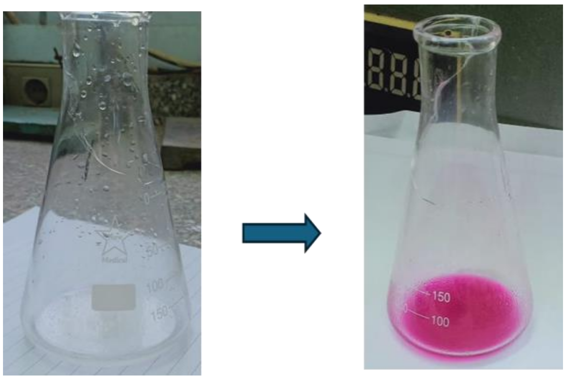


Fig.8: Determination of the Acid Value

Figure 9: pH meter

Volumetric titration was used to determine the acid value. The oil and biodiesel sample weighed one gram and was placed in a conical flask, then added 10 ml of solvent (iso propyl alcohol) and 2 drops of phenolphthalein indicator. The mixture after that is titrated with a potassium hydroxide solution (0.02 M) until pink color is formed (Fig.8). The following equation was used to compute the acid values of the oil and biodiesel (Adekunle et al., 2020, 2866):

Acid value (A.V)

$$Acid\ value = \frac{Titrate\ value\ (ml)\ x\ \ M\ x\ 56.1}{Weight\ of\ oil\ (g)}$$

where 56.1 is the molar mass of KOH and M is its molarity.

pH measurement

The pH of oil and biodiesel is measured by using pH meter as demonstrated in Fig. 9.

Table 1: Biodiesel yield using different types of oil.

Type of oil	Biodiesel yield (% Conversion)
Waste cooking oil (WCO)	75.88
Orange oil	74.20
Coconut oil	72.70
Sesame oil	60.99

Table 2: Physical and chemical properties of the different types of oils.

Property	WCO	Orange oil	Coconut oil	Sesame oil
Density (g / cm^3)	0.99	0.828	0.91	0.91
Kinematic viscosity (mm^2 / s)	17.27	4.24	10.99	13.08
pH	8.88	4.24	5.1	4.45
Acid value (mg KOH /g oil)	1.35	1.23	1.46	1.79

Table 3: Comparison of fuel properties of biodiesel produced in our work from WCO, orange oil, coconut oil and sesame oil with American & European biodiesel standards and also compared with other works.

	Property			
	Density (g / cm^3)	Kinematic viscosity (mm^2 / s)	pH	Acid value (mg KOH /g oil)
Biodiesel from WCO	0.901	6.02	6.67	0.11
Biodiesel from orange oil	0.878	3.14	6.80	0.22
Biodiesel from coconut oil	0.865	5.75	6.22	0.22
Biodiesel from sesame oil	0.872	5.96	7.1	0.45
ASTM D 6751 for biodiesel (Saad et al., 2023)	0.875-0.90	1.9-6	…….	<0.8
Europe EN 14214 (Saad et al., 2023)	0.86-0.90	3.5-5	…….	< 0.5
Petro Diesel (Ganesan et al., 2024)	0.83	2.98	…….	0.35
Mawlid et al., 2024	0.890	4.3	…….	………
Kambiz et al., (2011)	0.864	5.5	…….	……..
Moreira et al.2009	0.878-0.885	4.52-6.13	…….	0.091-0.24

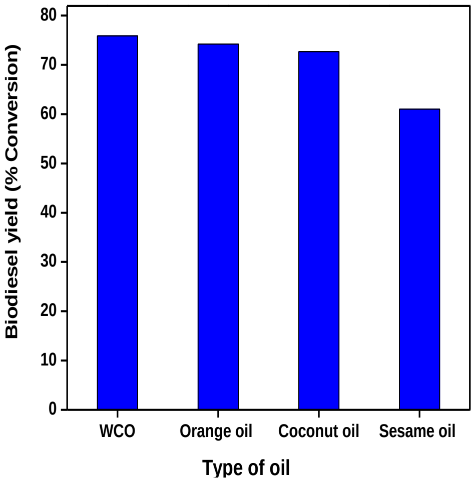


Figure 10: **The percentage yield of biodiesel produced with each type of oil**

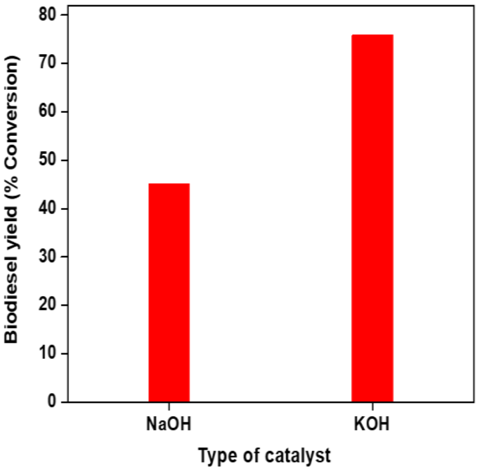


Figure 11: **Effect of type of catalyst on the conversion of WCO to biodiesel**

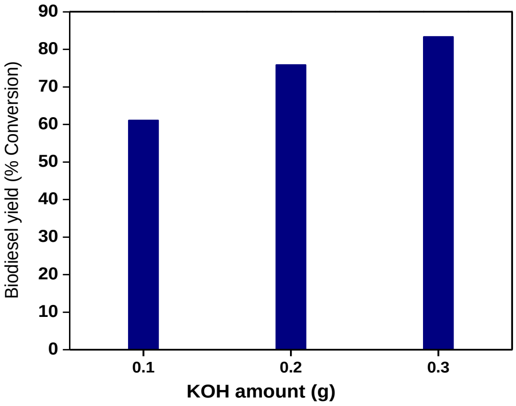


Figure 12: **The effect of KOH amount on the conversion of WCO to biodiesel**

5. Interpretation of Results

5.1. Biodiesel yield

From an economic standpoint, the yield of biodiesel production is critical. The following equation was used to compute the percentage of biodiesel yield (Adekunle et al., 2020, 2865).

$$\% \text{ Conversion} = \frac{\text{Mass of biodiesel produced}}{\text{Mass of used oil}} \times 100$$

Table 1 Shows the percentage yield of biodiesel produced by different oil. Figure 10 illustrated the % conversion of biodiesel using the different types of oils. From table 1 and Figure 10 it is observed that the high biodiesel yield is achieved by using waste cooking oil as a raw material for transesterification reaction. These outcomes offer more benefits as consuming cooking oil waste is bad for the environment and the health of the consumer. It is thought that using fried food will result in cancer due to the toxic compounds produced when the oil oxidizes. Therefore, one suggestion to address these problems is to use the WCO as the raw material for more affordable and environmentally beneficial biodiesel (Suzihaque et al., 2022, 491). Additionally, using used cooking oil as a raw material for the creation of biodiesel is far less expensive than using other types of vegetable oils.

5.2. Impact of catalyst type on waste cooking oil conversion efficiency to biodiesel

There were two different kinds of catalysts used: potassium hydroxide (KOH) and sodium hydroxide (NaOH) as illustrated in Figure 11. When converting from sodium methoxide to potassium methoxide as a basic catalyst for transesterification reaction of waste cooking oil, it is demonstrated that the greatest conversion rate using KOH is 75.88%, while the lowest conversion rate utilizing NaOH is 45.2%. The results indicate that using potassium hydroxide is much better than using sodium hydroxide. The reason for this is the difficulty of dissolving sodium hydroxide in methanol, which has negative effects on the conversion process, because part of it does not react, which is the main reason for this discrepancy. Therefore, potassium hydroxide is better than sodium hydroxide in producing biofuels (Slani et al., 2008, 2712-2719) (Encinar et al., 2007, 516).

5.3. Effect of catalyst amount on biodiesel yield

The effect of the quantity of KOH on the conversion of waste cooking oil to biodiesel has been investigated. Figure 12 demonstrates the impact of varying KOH amount (0.1, 0.2, and 0.3 g). Using catalyst amounts of 0.1, 0.2, and 0.3 g, the influence of the KOH catalyst quantity on the transesterification process of waste cooking oil was examined. A key factor in maximizing the transesterification reaction yield is catalyst concentration. Figure 12 explains that when the quantity of catalyst increased from 0.1 to 0.3 g the biodiesel yields increased. This can be attributed to the enhancement in the active catalytic sites of the catalyst with raising quantity (Negm et al.,2017,160). It was found that 0.3 g of catalyst was the ideal quantity, yielding 83.36% of biodiesel. According to literature (Rasyid et al.,2018, 012025), an increase in catalyst amount will result in an increase in the number of molecules that collapse and an increase in reaction rate. It was reported that the amount of biodiesel produced decreased with further catalyst addition. This may be understood as the reaction medium's viscosity increasing, which reduces the catalyst-reaction component contact and, as a result, leaves some of the catalyst unutilized (Negm et al.,2017,160). Moreover, the production of soap caused by the extra catalyst has somewhat decreased the biodiesel output (Saad et al., 2023, 560).

5.4. Oils physical and chemical characteristics, as well as the biodiesel it produced.

The various chemical and physical characteristics of the biodiesel, including its density, kinematic viscosity, pH and acid value, were calculated and compared to ASTM D6751 standards. Also, studies on the characteristics of oils have been conducted. Tables 2 and 3 display the results. Kinetic viscosity and density are the metrics that biodiesel and diesel fuel standards need since they are fundamental fuel properties for diesel engines.

kinematic Viscosity

The capacity of a fluid to flow at a specific temperature is determined by its viscosity. One of the factors that most influences an automotive engine's performance and emission characteristics is kinematic viscosity (Onyezeka et al., 2020, 52). For liquid fuels, increasing fluid viscosity corresponds to increased fluid mobility (Kurdi et al, 2021, 485). Liquid fuel is sprayed into compressed air and atomized into tiny droplets close to the nozzle exit of a diesel engine. The liquid fuel's viscosity influences the atomization quality, size of the fuel drop, and penetration. Excessive viscosity wears down fuel pump components and injectors, increases engine deposits, impairs fuel atomization during spraying, and requires more energy to pump. Because viscosity rises with decreasing temperature, high viscosity also leads to additional issues in cold weather (Alptekin and Canakci, 2008, 2624).

In this investigation, the oil kinematic viscosity is listed in table 2. The biodiesel kinematic viscosity, which was determined in this investigation, ranged from 3.14 to 6.02 mm^2 /s as mentioned in Table 3. The value of biodiesel kinematic viscosity on our work is in compliance with the ASTM D6751 standard (1.9 – 6.0 mm^2/s) and European Union standards (EN 14214) (3.5–5.0 mm^2/s) (Saad et al., 2023, 564). This data shows that biodiesel has a significant molecular mass than petroleum diesel since the kinematic viscosity is higher than those of petroleum diesel (2.98mm^2/s) (Ganesan et al., 2024, 263). Furthermore, the kinematic viscosity of the current work conformed with that of the previous writers (Mawlid et al., 2024) (Kambiz et al., 2011) and (Moreira et al., 2009).

Density

One important fuel attribute that has a direct impact on engine performance is density. Numerous performance metrics, such heating value and cetane number, are dependent on the density (Tat and Gerpen, 2000, 115). Diesel fuel injection systems, on the other hand, measure the fuel by volume. Because of the varying mass of gasoline injected, variations in fuel density will thus affect engine output power (Alptekin and Canakci, 2008, 2624). The mass of an item divided by its volume yields its density. Biodiesel typically has a density of 0.868 to 0.901 g/cm^3 as clarified in Table3. Because the densities of methanol and oil are similar to the density of the generated biodiesel, it has been noted in several investigations that the density of biodiesel has not altered much. Based on the information presented in Table (3), density values of generated biodiesel are in accordance with the ASTM D6751 standers 0.875-0.90 cm^3/gm and European Union standards (EN 14214) 0.86-0.90 cm^3/gm (Saad et al., 2023, 564). Diesel fuels have lower density than biodiesel fuels as noticed in Table 3(Ganesan et al., 2024, 263). Although the density of biodiesel is much greater, the energy content of which is lower both on a mass and a volume basis compared to diesel fuel (Alptekin and Canakci, 2008, 2626). Density for the current study was comparable to prior findings (Mawlid et al., 2024) (Kambiz et al., 2011) and (Moreira et al.2009). However, the purity and content of the fatty acids in biodiesels will affect their densities (Alptekin and Canakci, 2008, 2627).

Acid value (AV)

The quantity of unreacted acids in the final fuel is known as the acid value, alternatively known as acid number. It is the amount of KOH (measured in milligrams) required to neutralize the free fatty acids in one gram of lipid at room temperature. An effective parameter for biodiesel is the acid value. High acid value biodiesel has the potential to corrode oil tanks and other pertinent parts. The fuel oxidative potential can also be determined by the acid value (Adekunle et al., 2020, 2867). An essential test to evaluate the quality of a specific biodiesel is acid value determination. The AV of the raw material can have a significant impact on the end product's free acid methyl ester %FAME (Ismail and Ali, 2015, 5). Because ester bond hydrolytic breakage caused by the presence of free fatty acids affects fuel aging, ASTM standard D6751 stated the maximum amount of AV for pure biodiesel is 0.8 mg KOH / g oil and European Union standards (EN 14214) is 0.5 mg KOH / g oil (Saad et al., 2023, 564). Tables 2 and 3 demonstrate the AV (mg KOH / g oil of oil and biodiesel produced. The produced biodiesel's AV ranged from 0.11 to 0.45 which is compatible with ASTM and EN value. Sesame oil biodiesel has the highest acid value at 0.45 and waste cooking oil biodiesel has the lowest AV 0.11. Moreover, the low acid value indicates a minimal probability of fuel tank corrosion from the oil. The oils that are used in the production of biodiesel have acid values ranging from 1.23 to 1.79. The acid value is agreed with the previous work (Moreira et al., 2009).

pH value

Tables 2 and 3 present the results of determining the pH of biodiesels and oil raw materials. The pH range of the biofuel generated from various types of oil is around 6.22 to 7.1. This data is reasonably close to the findings of earlier studies for (Anisah et al., 2019, 8) which demonstrated that biodiesel has pH 7, pH is ranged from 6.5 to 9 according to (GHANIMI et al., 2024, 642) pH is ranged from 6.5 to 9 according to (GHANIMI et al., 2024, 642). The pH is found to be 6.23 (Ogunsuyi, 2012, 21).

6. Conclusion

Biodiesel is a special type of biofuel. It is a sustainable and biodegradable fuel that is produced using recycled restaurant grease, animal fats, or vegetable oils. It was possible to economically make biodiesel from waste cooking oil, which also lessened the environmental damage caused by diesel fuel derived from petroleum. This Study has been done on the use of waste cooking oil (WCO) and other vegetable oils such as orange oil, coconut oil and sesame oil in the creation of biodiesel by transesterification reaction by using KOH. It is concluded that the biodiesel formed by using waste cooking oil has the highest value among the other oils that were used in the study 75.88%. The study demonstrates that, by utilizing little energy during the transesterification procedure, waste material may be transformed into a useful product. The impact of the catalyst type in waste cooking oil conversion to biodiesel is investigated, it is found that Potassium hydroxide is better than sodium hydroxide in transesterification reactions. Furthermore, an examination on the effect of KOH concentration reveals that an increase in KOH content improves WCO conversion to biodiesel. Several physical and chemical characteristics of the biodiesel produced, including density, kinematic viscosity, pH, and acid value, have been examined in the current study. These characteristics are also compared with the data gathered by earlier works, European Union standards (EN 14214), and ASTM D6751 standards. According to the physical and chemical properties of produced biodiesel, waste cooking oil, orange oil, coconut oil and sesame oils have the potential to be a perfect, and readily available feedstock for the advancement of sustainable biodiesel manufacturing technologies.

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