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# Production of Biodiesel from Waste Cooking Oil in Laboratory Scale: A Review

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***Abstract***— *A contemporary process from biomass is used for derived biofuel from biomass such as plant or algae material or animal waste. As such feedstock material can be replenished readily; biofuel is considered a renewable energy source. Biodiesel is the most famous biofuel as it is commonly produced and easily derived from available raw materials. It can be generated from vegetable oil or animal fat. The most common way to produce biodiesel is the trans-Esterification method which refers to a catalyzed chemical reaction involving oil and alcohol to yield fatty acid alkali esters and glycerol.*

***Keywords***— *Biodiesel, Biofuel, Fatty Acid Alkali Esters, Glycerol, Transesterification, Waste Cooking Oil, Yield*.

## I. INTRODUCTION

Biofuels are defined as fuels that are derived from a variety of sources of biomass. Mainly, it can be classified as biodiesel, bioethanol, and biogas. Biofuels are used for plant materials, certain types of crops, recycled or waste vegetable oils. Mainly, biofuels are dominant with energy, and biofuels are power sources from energy. Renewable fuels like hydropower, wind, solar, biomass, and biofuels are represented around 7% of the total energy demand [1]. Biofuel production offers many advantages, such as reducing greenhouse gas emissions, contributing to the security of energy supply, providing a boost to the agriculture industry, and promoting renewable energy. This mini-review mainly discussed the biodiesel production process and the most important parameters of biodiesel. This fuel can be produced from vegetable oil or animal fat. However, small-scale producers generally use vegetable oil, and it can be used in traditional diesel engines. Also, biodiesel can be blended with diesel fuel [2].

Biodiesel and conventional hydrocarbon-based diesel blends are most commonly distributed for use in the retail diesel fuel marketplace [2]. This society uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix as follows;

- 100% biodiesel is referred to as B100
- 20% biodiesel, 80% petro-diesel is labeled B20
- 5% biodiesel, 95% petro-diesel is labeled B5
- 2% biodiesel, 98% petro-diesel is labeled B2

Biofuels can be classified into two categories like primary and secondary biofuels. The primary biofuels are natural which directly produced from firewood, plants, forests, animal waste, and crop residues. The secondary can directly generate from plants and microorganisms and be further divided into three generations, as shown in Table 1 [3]. The first generation of biofuels is ethanol production from food crops having starch like wheat, barley, corn, potato, sugarcane, etc. Biodiesel can be manufactured from soybean, sunflower, and animal fat [4]. While the second generation of biofuels is the production of bioethanol, and biodiesel which can generate from several species of plants such as Jatropha, Soybean, Palm, Rapeseed, Cottonseed, etc. The third generation of biodiesel is manufactured from microalgae and microbes.

TABLE 1. Classifications of biofuels [4], [5]

| **Primary Biofuel** | **Secondary Biofuels** | | |
|---|---|---|---|
| | First Generation | Second Generation | Third Generation |
| Animal wastes, Wood chips, Pellets, Firewood, Forest and crop residues, landfill gas. | Bioethanol or butanol by fermentation of starch (from Corn, Barley, Wheat, Potato) or sugars (from sugar beet and sugarcane) Biodiesel by Transesterification of oil crops (Sunflower, Soybean, Palm, Rapeseed, Coconut, Animal fats, Tallow and Used Cooking oil) | Bioethanol and biodiesel produced from ordinary technologies but based on novels like starch, oil and sugar crops such as *Jatropha, cassava* or *Miscanthus*.Bioethanol, biobutanol, produced from lignocellulosic materials (e.g.:- straw, wood and grass) | Biodiesel from microalgae: Bioethanol from microalgae and seaweeds. Hydrogen from green microalgae and microbes. |

Biodiesel is described as an alternative, biodegradable, and renewable diesel fuel [6]. Transesterification of vegetable or animal fats and short-chain alcohols like methanol or ethanol is used to make biodiesel. Biodiesel is a biofuel designed to be used in regular diesel engines. Biodiesel can use as it is or in combination with petro-diesel at any rate. These mixtures can also be used as heating oil. Biodiesel is produced by a transesterification reaction of diverse feedstock like Edible, Non-edible, and Waste oils [6].

The advantages of using waste cooking oils to produce biodiesel are low-cost effectiveness and prevention of environmental pollution [7, 8]. Generally, if waste oil is disposed of, it has many problems like water and soil pollution, human health concerns, and disturbances to the amphibious ecosystem. Anastasia Kharina et al. [9] study the detrimental effects of consuming used cooking oil. Many toxic substances are easily absorbed in food when we use waste oil, and root cause for many serious diseases such as Stroke, Alzheimer's, Parkinson's, and Huntington's diseases [9]. Despite inclining it and harming the environment, it can be used as an effective and cost-efficient feedstock for biodiesel production as it is readily available and easily approachable [10]. If we use the fat of animal lipids, it has many significant facts in clarification, and processing has some technical problems also. Furthermore, if we are consuming used cooking oil can happen to increase LDL ("bad" cholesterol) and reduce HDL ("good" cholesterol) [9].

WCO collected can also prepare soaps and additives for lubricating oil using glycerine, a by-product of biodiesel production. Several kinds of researches have definitive that the production of biodiesel from cooking oil successful. Vegetable oil encloses saturated hydrocarbons (triglycerides), which consist of glycerol and esters of fatty acids. In some places, WCO from main restaurants was reselling to street sellers, and they use it to fry their food; and this waste oil is termed as second - used cooking oil, and it can also be exploited by converting to biodiesel [10].

Waste vegetable oils are used to economize the need for biodiesel production crops and the competition with food. The chemical and physical properties of WCO vary from those of fresh oil because some changes in chemical reactions - such as Oxidation, Acidity content, Hydrolysis, Polymerization, and material transfer between food and vegetable oil exist during the frying process. WCO is a low-cost feedstock that requires simple processing to make biodiesel [9]. The properties of WCO are given in Table 2.

TABLE 2. Properties of WCO [11]

| Property | Method | Standard Value |
|---|---|---|
| Density at 16°C (g/mL) | ASTM D4052-91 | 0.9 – 0.92 |
| Kinematic Viscosity at 40°C ($mm^2s^{-1}$) | ASTM D445 | 1.9 – 6.5 |
| Flash Point ($T_F$) | ASTM D93 | 180.5 |
| Acid Number (mg KOH/g) | ASTM D664 | ≤ 0.50 |
| Saponification Value ($S_V$) | ASTM D5555-95 | < 312 |
| Iodine Number (g $I_2$/100g of oil) | Hanus Method | <120 |
| Cloud Point (°C) | ASTM D2500 | -3 to 12 |
| Pour Point (°C) | ASTM D2500 | -15 to 10 |
| Distillation Curve | ASTM D1160 | |
| Cetane Index | Willard, 1997 | >47 |

The American Society for Testing and Materials (ASTM) standards and the European Specification (EN Standard) for biodiesel and typical diesel were used to compare the study of different oil characteristics, fuel characteristics, and process parametric assessment studies of WCO. Also, these tastings are using for providing an international standard by various industries which maintain regulatory commonality for quality control, contamination identification, formulation, trace analysis, investigative analysis, and more [12], [13].

The oil quality is expressed in terms of chemical properties such as Acid value, Saponification value, Iodine value, etc. According to the study [14], biodiesel has a higher Cetane number than diesel fuel, no aromatics, almost no sulphur, and contains 10% to 11% oxygen by weight. Another essential factor about the WCO is Free Fatty Acid Content (FFA), and it may be the critical value for producing biodiesel from any feedstock. Mainly, many kinds of researches show and describe how much it is worth. This FFA value is based on the acid value on the WCO. Instead, we can get the FFA value by dividing the acid value by two.

People worldwide use edible oil for cooking which is discarded. When study on the fatty acid profiles, it included Oleic, Linoleic, Lauric acids, and other essential acids in percentages. The widely used vegetable oils for frying purposes are generally olive, sunflower, and peanut oil. Those oils are saturated with the fatty acid composition, which is dominated by oleic and Linoleic fatty acids and a small portion of stearic and Palmitic acids [15].

According to the research [16], the reaction is completed by giving a high percentage yield of biodiesel that reached 97%. Because the Waste Vegetable Oil (WVO) was first filtered using filter cloth or any filtration system to remove waste food residues using a funnel. It was then designed to be used in an acid-catalyzed Esterification process with a FFA level of less than 1 mg KOH/g. However, it can see a lower percentage yield of biodiesel as it reached 80 – 88% in that study [17] because its FFA content was lower than 2 mg KOH/g. WCO can be used as an alternative feedstock for biodiesel production as it is highly efficient and cost-effective. Thus, the conversion of WCO into biodiesel is a winning approach to manage and minimize domestic waste while helping to solve the global energy challenge. In addition to producing biodiesel, WCO could produce soap and additives for making lubricant oils. Furthermore, using WCO to produce biodiesel decreases crop production and solves the food security issue [18].

## II. PROCESS OF SYNTHESIZING BIODIESEL

Used vegetable oil is a 'renewable fuel' since it does not emit any more carbon dioxide gas into the environment, unlike fossil fuels. The conversion of pure triglyceride to fatty acid methyl ester is high. The reaction time is relatively short; vegetable oil from plant sources is the ideal starting material for producing biodiesel. Trans-Esterification is the most prevalent method for biodiesel, which refers to a catalyzed chemical reaction involving vegetable oil and alcohol to yield fatty acid alkyl esters and glycerol [8].

When it follows biodiesel production research [8], their different processes can be applied to synthesize biodiesel, such as direct use and blending, microemulsion process, thermal cracking process, and the most convenient way trans-Esterification process. It is the most common process in biodiesel production. Biodiesel and glycerol are produced by combining alcohol and vegetable oil in the presence of a catalyst. The biodiesel produced has a lower viscosity, preventing several engines' damages because of incomplete combustion and poor fuel atomization [19].

### *Direct Use and Blending*

Direct use of vegetable oils or as a blend of vegetable oil with petro-diesel generally has been considered to be not satisfactory and impractical for diesel engines because of their unique inherent failings. In this case, biodiesel fuel needs a chemical change (modification) before using it. In past

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decades, some researches in a vast range have been done about this. However, it has experimented for almost a hundred years. Besides, some diesel engines can run with pure vegetable oils as turbocharged to Diesel engines like trucks. There is the same energy consumption when using pure vegetable oil to the diesel engine [20], [13].

*Micro-Emulsion Process*

According to Zahan K. A. [13], the study explained the micro-emulsion biodiesel production process. It means the vegetable or animal oil was dissolved in a solvent and surfactant until the required viscosity is achieving. We can highlight a simple process as an advantage of using this process. Also, High viscosity, low stability, ability to sticking, incomplete combustion, and carbon deposition can be a disadvantage of this process [20], [13].

*Thermal Cracking (Pyrolysis)*

Pyrolysis means that the Vegetable or Animal oil was separated by using elevated temperature until it decomposed, whether the catalyst is present or not. In this case, gas and liquid products were analyzed based on their boiling point. This process is effective, not required to wash or filter, and there is no waste can get as advantages are expensive equipment, and required high temperature to separation system [20], [13].

*Transesterification*

Vegetable or Animal oil was reacted with Alcohol like Methanol or Ethanol in this process. There is used Sodium Hydroxide (NaOH) or Potassium Hydroxide (KOH) as the catalyst to increase reaction speed, increase product weight and increase the yield of the final product. Then the Methyl Ester or Ethyl Ester was separated with glycerol layer when divide as two layers in the target was sent through the purification step for further steps [8], [13].

This method has been frequently employed to minimize the high viscosity of triglycerides. [20]. A catalyst is usually used to improve the reaction rate and yield. Transesterification is a reversible reaction that is carried out by mixing the reactants. In this process, one mole of triglyceride reacts with three moles of alcohol to produce three moles of mono-alkyl ester and one mole of glycerol [13]. However, the presence of a catalyst will accelerate the reaction. In this case, KOH as the catalyst to triglyceride reaction with methanol is present in Figure 1. [8]. The process starts with a sequence of three consecutive reversible responses [20], wherein triglycerides are converted to diglycerides, are converted to monoglycerides, and monoglycerides are converted to glycerol [19].

Transesterification of triglycerides and methanol with the help of catalyst produces methyl ester and glycerol. After the settling part, the glycerol layer settles down at the bottom layer in the separation funnel. Transesterification is one of reversible reactions and proceeds by mixing Triglycerides and Methanol reactants. Because there was excess alcohol, the forward reaction is first order, and the reverse reaction is the second-order reaction [21].

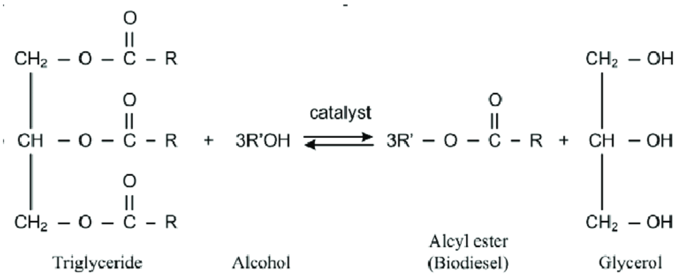

Fig. 1. A schematic representation of the transesterification reaction [18]

## III. Biodiesel Production Process

The production process of biodiesel is represented in Figure 2.

Biodiesel, which is made from biological resources, is a sustainable fuel that has recently gotten much attention. The chemical makeup of biodiesel is a fatty acid methyl ester [8]. First of all, the selected WCO was filtered to remove food residues and other suspended matters to complete the filtration process. Then it was heated at a high temperature to remove the soluble impurities and moistures. According to the study of M. Farooq et al. [22], the washed WCO was treated with silica gel to remove the water content. Then the critical physicochemical properties of the WCO were determined using standard methods, as shown in Table 2 [22]. Even the [23] paper said that they used CO for the pre-treatment step after filtered to remove impurities from local restaurants. The same research [18], said that the oil is filtered to remove any chunks of food particles passing the oil through a cotton cloth.

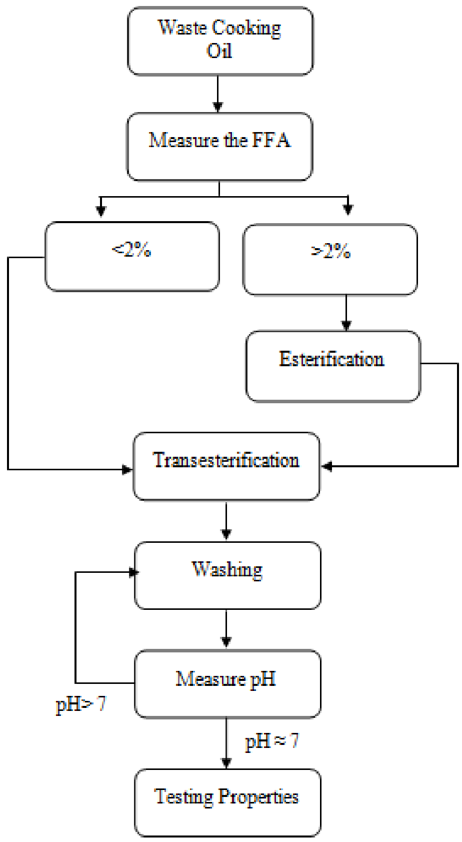

Fig. 2. A schematic process of biodiesel production [21].

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The acid number/acid value of the WCO should be measured to get the FFA value. The literature says, it is said that the acid number/acid value means the mass of KOH in milligrams that are required to neutralize one gram of chemical substances [10]. As follows, the acid number was measured by direct titration. A known amount of sample was dissolved in an organic solvent (like Isopropyl alcohol). Then, it was titrated with potassium hydroxide solution with a known concentration, and phenolphthalein is used as an indicator. The above procedure was used to determine the acid number of cooking oil for two samples with known quantities that included waste cooking oil and a blank sample (sample 3) that only included isopropyl alcohol and phenolphthalein indicator [10]. The acid number is a measurement of the quantity of acid in a solution. It is expressed in milligrams of potassium hydroxide required to neutralize the acidic constituents in 1g of the sample [24].

The biodiesel was synthesized from WCO using a two-step catalyst process, namely the Esterification process with ferric sulphate and transesterification step with KOH. Also, the addition of catalysts can increase the yield of biodiesel production. The purpose of pre-treatment and Esterification methods are to identify and reduction of the FFA value in WCO. In that case, it can reduce the FFA value using several methods, namely steam distillation, extraction by alcohol, and Esterification by acid catalysts [25]. However, the standard pre-treatment method is the Esterification of FFA with methanol in the presence of an acidic catalyst (usually sulphuric acid) [26]. Those catalysts can be homogenous or heterogeneous acid catalysts [21], [27].

Free fatty acids will be converted to biodiesel by direct acid Esterification, and the water needs to be removed [25]. Also, the FFA causes corrosion and low oxidation stability in WCO [27]. One of the studies [18] showed that Esterification could convert the FFA to biodiesel and reduce the FFA, as shown in Figure 3. In this reaction, FFA reacts with alcohol in the presence of a catalyst to give fatty acids. The most commonly used alcohol in these processes is methanol because of its low cost [19].

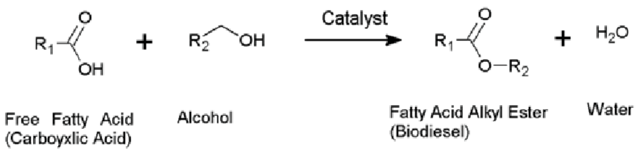


Fig. 3. A schematic representation of the Esterification reaction [18]

The Esterification step aims to minimize the acid value of Waste Cooking Oil. Usually, the Esterification process is an acid catalyzed homogenous process in which acids as sulphuric acid and hydrochloric acid. The research study of [25] said that if the acid value of the oil is very high, one-step Esterification may not reduce the FFA because of the high content of water produced during the process. So thus, the mixture of sulphuric acid and alcohol can be added to the oil three times as three-step Esterification. Furthermore, this reaction is slower than the base catalyzed trans-Esterification reaction, as described earlier [7].

As described in the Esterification procedure, we aimed to reduce the FFA value of WCO to a value of less than or equal to 2% [28].

First, 1 wt. % Conc. Sulphuric acid (0.05g con. $H_2SO_4$/ 1g of FFA in oil) was mixed with a large amount (2 g $CH_3OH$/1g FFA) of methanol [29]. Then the mixture was added to oil with high FFA and stirred while maintaining the temperature at a constant temperature in the range of 50 – 55°C for 2 hours. Finally, the mixture was kept for 24 hours to settle down to two layers of ester and aqueous [27]. Then the ester layer (bottom layer) was separated to measure FFA value, and for further alkaline Esterification, the aqueous layer (top layer) was discarded after the settle down. If not the FFA value of the ester layer is less than 2%, the above process must be repeated until it gives FFA content less than 2% [27], [29]. According to the previous study [30], they have used 1 wt. % of sulphuric acid to Esterification and 1.5 wt. % of sodium methoxide to the trans-Esterification steps.

## IV. Biodiesel Testing

Calorific Value, pour point, Flash Point, Kinematic Viscosity, and Cetane number are the most critical and significant fuel properties that take action in applying non-edible biodiesels in diesel engines. Many researchers have reported that the fuel properties of non-edible biodiesels depend on their fatty acid and chemical composition [31]. Therefore, before using non-edible-based biodiesels in diesel engines, measuring the fuel properties of selected biodiesels is essential. The fuel properties of biodiesels are specified by different standardization methods like ASTM D6751 and EN14214.

### *Calorific Value*

Calorific value is the measure of the heat energy content of fuel [31]. A higher calorific value of fuel means it releases higher heat and consequently improves engine performance during combustion. Biofuel usually has a lower calorific value than diesel fuel because of its higher oxygen content. According to the study of Mahmudul et al. [32], the calorific value is a fundamental property of fuels that use for combustion in an engine because the power output is pretty much dependent on calorific value. Different biodiesel fuels have different calorific values. This Calorific value is measured from EN 14214 or ASTM D 4868 test methods [33], [34]. Many researchers have reported that biodiesel fuel from different sources has a lower calorific value than diesel fuel [34], [35]. According to the study of Ashraful et al. [31], it is said that biodiesel from Jojoba seeds has the highest Calorific Value of 47.38 MJ/Kg through all biodiesel species from other crops.

### *Flashpoint*

Flashpoint is the most important property that must be considered in analyzing the overall flammability [31]. At this temperature, the gas stops burning when the flame exposes to the Biodiesel vapour. Each biodiesel has a unique flashpoint. Many factors affect the change in biodiesel flashpoint, while residual alcohol content being one of the factors [31].

Moreover, flashpoint is influenced by several key factors, such as the chemical compositions of the biodiesel, including the number of double bonds and the number of carbon atoms [36]. The flashpoint of biodiesel is measured using the ASTM D93 and EN ISO3697 test methods [36].

The study of Silitonga A.S. et al. [33] has said that the flashpoint is the temperature at which it ignites when the vapour is exposed to a flame or a spark. Flashpoint and the fuel's volatility are inversely proportional. Generally, biodiesel has a higher flashpoint usually varies around100°C-170°C while the commercial flash point of diesel fuel is 55°C–70°C. Therefore, biodiesel is safe for transportation, handling, and storage purposes compared with pure Petroleum Diesel. Blending a modest quantity of biodiesel with diesel can enhance the final mixture's flashpoint [37].

*Cloud Point and Pour Point*

The study of A. S. Silitonga et al. [33] has said that Cloud point and Pour point are essential for fuel for low-temperature applications. The cloud point is described as the temperature at which a cloud of wax appears when the fuel cools to a lower temperature. Pour point is defined as the temperature at which it ceases to slow [32]. In general, biodiesel has a higher cloud point and pour point than diesel fuel [38]. The cloud point and pour point of non-edible biodiesel vary with the fatty acid compositions in the feedstock. Usually, high saturated fatty acid produces biodiesel with higher pour points [31]. This Cloud point and Pour point are tested using ASTM D2500 and ASTM D97 in Celsius degrees [33].

*Kinematic Viscosity*

Kinematic viscosity is the most crucial property of fuel that must be considered to maintain engine performance [31]. High viscosity causes a poor fuel flow in the engine combustion chamber during the intake stroke and takes a long time to mix with air. Therefore, it results in delayed combustion. The viscosity of fuel has been proved to decrease with the increase in temperature. Kinematic viscosity is determined using the ASTM D445 and EN ISO 3104 test methods [31]. According to the study of Silitonga A. S. et al. [33], The resistance of a liquid to flow is known as kinematic viscosity. It refers to the thickness of the oil and is determined by measuring the amount of time taken to pass through cleavage of a specified size as No. 1 & No. 2 for given oil type [39]. High viscosity may lead to the formation of carbon and engine deposits due to inadequate fuel atomization. Furthermore, decreased viscosity makes it easier to pump and inject till the final drop [38].

Demirbas A. et al. [38] have studied that biodiesel has viscosity close to diesel fuels. According to that research, the Kinematic viscosity of biodiesel decreases clearly after the alkali-catalyzed transesterification process.

*Cetane Number*

Cetane Number is the most critical property of fuel that directly affects its combustion quality [31]. It can measure the Ignition quality of fuel in a powerful diesel engine. There is a shorter ignition delay if the Cetane number is low. The Cetane Number of pure diesel fuel is lower than that of biodiesel. It is higher in Biodiesel because of its longer fatty acid carbon chains and the presence of saturation in molecules. It is based on two compounds, namely, hexadecane and heptamethylnonane. The Cetane Number is measured using the ASTM D613 and EN ISO5165 test methods [31].

Mahmudul H. M. et al. [32], mentioned that Another key attribute to identify the ignition quality of any fuel at a relevant condition is the Cetane number [33]. When utilizing biodiesel-based fuel, a higher Cetane number provides significant benefits for engine performance and emissions, allowing the engine to run smoothly and quietly. Biodiesel fuel has a higher Cetane number than diesel fuel [38]. Biodiesel is an oxygenated fuel and endowed with a shorter ignition delay due to higher Cetane Number [40]. The fuel having a lower Cetane number takes time to start and causes higher Hydro Carbon (HC) and Particular Matter (PM) emissions in the selected diesel engine. Biodiesel with high amounts of saturates has a higher Cetane Number, while the biodiesel with high amounts of unsaturated has a low Cetane Number. For example, the Cetane number of different fuels are as follows; palm biodiesel is 54.6, Sunflower is 49, Soybean is 37.9, Rapeseed is 54.4 and diesel fuel is 48 [32], [41].

*Engine Performance*

The study of biodiesel production from WCO is not complete since it is tested in commercial diesel engines. Many studies have been to that test the biodiesel performance obtained from WCO compared with the commercialized petroleum diesel fuel. Mainly, in terms of emissions engine performance, and fuel consumption was tested under quality evaluation. The study of Murillo S. et al. [42] described the Engine performance with the different blends of diesel and biodiesel, as well as its emission characteristics, largely depends on the combustion chamber and air turbulence, actual start of combustion, injection pressure, injector nozzle design, air-fuel mixture quality, and many other particularities that make test results differ from one engine to another. Besides, each engine parameter varies with load and speed. Therefore, emissions will be studied in different operational points, including specific ISO test methods for determining the overall emissions. Jayashri et al. [2] studied this Engine Performance and Emission Characteristics of Biodiesel used as a blend in different portions of petroleum diesel in GHG emissions [13]. The level of Carbon Monoxide (CO), Carbon dioxide ($CO_2$), Smoke, and Particular Matter (PM), etc., reduce consequently when Nitrogen ($NO_X$) species was increased. A study by Marcelino et al. [43] said that biodiesel has similar properties to diesel and can be used in internal combustion engines without significant modification to its characteristics. It can replace diesel purely or blended to it in any portion, with minor losses in performance in internal combustion engines. As compared to diesel, it is using biodiesel (net or blended with diesel) lowers the emissions of Hydro Carbons (HC), Carbon Monoxide (CO), and Particular Matter (PM). Furthermore, it is highly biodegradable, non-toxic, no aromatic compounds, and lower sulfur content. However, if we use biodiesel can cause higher emission of

NOx, which can affect respiratory problems [44], [43]. Also, they conduct their experiments by using an engine-generator set composed of a diesel internal combustion engine (brand Perkins, model 1104, with direct injection, 4-cylinder and 4.4 L, power band of 50–106kW), coupled with an adapted generator with a maximum power of 100kV A, 200V, tri-phase, 60Hz, 1800rpm.

According to the study of Jinlin Xue et al. [45], kinds of literature are illuminating the effect of biodiesel on engine power. There are several kinds of literature to study the effect of pure biodiesel on engine power, such as Hansen et al. [46] that mentioned that the difference in heating value (13.3 percent), density, and viscosity resulted in a 9.1 percent braking torque loss of B100 biodiesel compared to B2 diesel at 1900rpm. Moreover, Murillo et al. [42] found that on a 3-cylinder, natively aspirated (NA) submarine diesel engine at maximum load, biodiesel lost 7.14 percent of its output compared to diesel. On the other hand, biodiesel lost roughly 13.5 percent of its heating value compared to diesel.

The study of Murillo et al. [42] has highlighted that the variations when engine power at full load with different fuels. The rated power measured (although slightly slower) is closed to that declared by the manufacturer at rated speed (approximately 3450rpm). According to this study, as the percentage of biodiesel in the fuel grows, engine power decreases. In the same case of pure biodiesel (B100), the power loss is higher than 1kW and accounts for 7.14% of rated power. In this case, the power obtained is similar to B10 and B30 blended diesel when the engine's speed is low. If the speed is increased to 2500rpm, then the power obtained is much lower, with a loss of more than 2kW (12.5%) at the rated speed.

Hansen A. C. et al. [46] Studied the diesel Engine Performance and NOx Emissions from the selected diesel engine. A 10% blended ethanol and two soybean methyl ester biodiesels (B2 and B100) with volume percentages of 2 and 100 were used. In addition, a blend of 95% biodiesel with 5% ethanol (BE5) was produced. The biodiesel was measured from ASTM D6751 testing method. Fuel samples of B2 and B100 were analyzed. The biofuel was blended onsite and stored in 55-gallon drums.

## V. CONCLUSION

The advantages of using WCO to produce biodiesel are the cost-effectiveness and prevention of environmental pollution. Street sellers reused WCO from local restaurants to fry their foods, and this waste oil is termed as second - used cooking oil, can also be utilized by converting to biodiesel. If we reused more than one-time fried waste cooking oil, it could become a carcinogen enzyme. Any chemical, radionuclide, or radiation that promotes carcinogenesis, or the production of cancer, is referred to as a carcinogen.

In the modern world, this fuel is created from vegetable oil or animal fat. However, small-scale producers generally use vegetable oil. Also, this biodiesel is used by blending with diesel fuel, and biodiesel can be produced in small or large quantities. Biodiesel is named as a renewable and alternative fuel for diesel engines. There are mainly two parts in this biodiesel production name as acid Esterification and alkaline Esterification (Transesterification). Firstly, we must measure the FFA content of WCO used in this production. If this FFA value is less than or equal to 2, conduct the transesterification process directly. If not, we must take it into the Esterification process to reduce the FFA content (mg KOH/g) to a value less than or equal to 2. Transesterification is commonly used to reduce the viscosity during the production of biodiesel. Widely used catalysts are acids and bases. However, the transesterification is dependent on the molar ratio of alcohol and the weight basis of KOH that we use as the catalyst.

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