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REVIEW PAPER

A BIODIESEL PRODUCTION TECHNOLOGY FROM USED COOKING OIL: A REVIEW

Erwan Adi Saputro* | Achmad Rizaldi | Tahan Simamora | Nove Kartika Erliyanti | Rachmad Ramadhan Yogaswara

[1]Dept. of Chemical Engineering, UPN Veteran Jawa Timur, Surabaya, Indonesia

Correspondence

*Erwan Adi Saputro, Dept of Chemical Engineering, UPN Veteran Jawa Timur, Surabaya, Indonesia. Email: erwanadi.tk@upnjatim.ac.id

Present Address

Faculty of Engineering, UPN Veteran Jawa Timur, Jl. Raya Rungkut Madya, Gunung Anyar, Surabaya 60294, Indonesia

Abstract

Used cooking oil is widely considered waste because it can damage the environment and cause health problems. Meanwhile, used cooking oil can be used as a substitute raw material for Crude Palm Oil (CPO) in Indonesia's national biodiesel program. Indonesia has a remarkable ability to use used cooking oil as a raw material for making biodiesel. If the 1.2 million kiloliters of biodiesel made from CPO raw materials are exchanged with used cooking oil raw materials, it can save approximately Rp. 4.2 trillion. There are various process technologies in making biodiesel, including microemulsion, pyrolysis, and transesterification. Transesterification is a process in which triglycerides and methanol are reacted to create biodiesel and glycerol as a by-product. Transesterification using a homogeneous catalyst has advantages such as lower cost, relatively short processing time, and higher yield of biodiesel products. Transesterification using a homogeneous catalyst has the disadvantage of a more complex separation. This literature study aims to explain the method for biodiesel production and becomes a reference in terms of process selection in biodiesel manufacturing plants, especially from used cooking oil as raw material.

KEYWORDS:

Biodiesel, Homogeneous Catalyst, Used Cooking Oil, Transesterification

1 | INTRODUCTION

The global energy needs, especially in Indonesia, have increased in line with the economic and population growth. Meanwhile, non-renewable energy reserves, such as oil, natural gas, and coal, are reducing year to year, and those fuels have been predicted will be shorted in the following decades. The lack of non-renewable fuels can be reduced by utilizing biodiesel fuel, where the raw material is available and renewable[1]. The utilization of renewable liquid fuel can be used by using biodiesel, the raw material of which is likely to be developed further. As for biodiesel, it can be distinguished into two: from the origin of plants

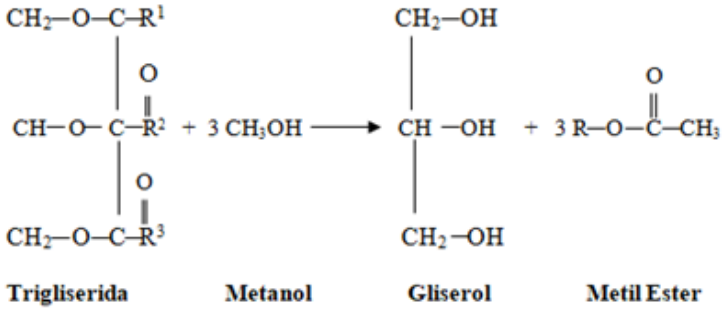

FIGURE 1 The biodiesel reactions,

and animals. Several studies have shown that biodiesel's cetane number (CN) is relatively higher than that of diesel oil (diesel). The cetane number for diesel oil is 45, 62 for those based on palm oil, 51 for jatropha curcas oil, and 62.7 for those based on vegetable oil[2].

Biodiesel also has physical and chemical properties similar to diesel oil. Therefore it can be used as an alternative to diesel-engined mounts. When compared to diesel, biodiesel has unique features : (i) bonding the need for oil imports from foreign countries, (ii) being able to be produced in rural areas, and (iii) being environmentally friendly because biodiesel does not have sulfur elements so there are no SOx emissions, (iv) biodiesel can be obtained from agricultural products, so it can be renewed, (v) safe in storage and transportation because it does not contain toxins, (vi) it has a high cetane number, (vii) it is biodegradable: it is much faster to decompose by microorganisms than petroleum[3]. Biodiesel's physical and chemical properties are similar to those of petro-diesel fuel. Patil and Deng[4] reported that biodiesel is better than petro-diesel in terms of biodegradability, free sulfur content, viscosity, density, flash point, and aromatic content.

2 | PREVIOUS RESEARCHES

Various studies of biodiesel from used cooking oil. Many studies have been carried out, including research using the trans-esterification process method using cooking oil, methanol, and activated zeolite. For the research variables, namely reaction time and zeolite concentration, the best-operating conditions were obtained when the reaction time was 5 hours with a zeolite concentration of 1% and biodiesel yield of 12%[5].

Biodiesel research uses the transesterification process method made from Crude Palm Oil (CPO), methanol, and $CaCO_3$ heterogeneous catalysts. The research variables were the molar ratio of methanol to CPO 9:1, reaction temperature of 70C, reaction time of 1.5 hours, and CaO concentration of 1.5%. Biodiesel conversion obtained is 74.60%[6].

Research on biodiesel production from beef tallow by transesterification process with NaOH catalyst. With a reaction time of 30 minutes, a reaction temperature of 50°C, and a catalyst concentration of 0.8%, producing a yield of 95.67%[7].

The most commonly used biodiesel production process is transesterification. The raw material used in this process is triglycerides (such as used cooking oil). The transesterification process, in general, is the reaction of triglycerides with alcohol with the help of a catalyst to produce fatty acid methyl esters and glycerin. Fatty acid methyl ester or FAME (Fatty Acid Methyl Ester). The transesterification reaction can be seen in Fig. 1 .

Biodiesel is produced from fatty acid triglycerides. Several other types of vegetable oils, such as sunflower, corn, and olive oil, are abundant in many areas, along with some wastes, such as cooking oil and animal fats, which are attractive for biodiesel production[5]. Used cooking oil is a type of vegetable oil left over from various types of cooking oil, such as oil from vegetables, corn, and others. The definition of used cooking oil is oil that has been used for frying more than two or three times and is categorized as waste because it can cause environmental and health problems. Residual cooking oil is commonly found in household activities and the food processing industry, such as restaurants and fast-food restaurants. Generally, the waste oil is

TABLE 1 Palm cooking oil consumption data (Adaileh, 2012).

Year	Quantity (tons)
2012	2.289.582
2013	2.219.296
2014	2.421.120
2015	2.864.155
2016	3.058.992
2017	3.480.087

brown in color, thick in texture, and contains large amounts of free fatty acids (FFA). Used cooking oil can contain carcinogenic compounds and is harmful to the body. Therefore, cooking oil can no longer be used for processing, a useless waste.

So far, used cooking oil is just thrown away and becomes waste. However, used cooking oil can be used as a substitute for CPO oil in the Indonesian biodiesel state program. Not only innovative and economical, but this step can also minimize environmental waste, impact the economy, both for health, and reduce greenhouse gas emissions to support regional development. Research from Smith et al.[6] proved that waste cooking oil and fat have significant potential and can reduce the final price of biodiesel because the raw material is lower than pure vegetable oil.

Indonesia has a high potential to utilize used cooking oil as raw material for biodiesel production. The rest of Indonesia's cooking oil consumption is relatively high because the European Union produces 22.7 million tons, the United States approximately 16 million tons, India 23 million tons, and Indonesia 18.422 million tons. Unfortunately, only 18.5 percent can be collected as raw material for used cooking oil. The benefit, in terms of costs for production, saves 35% more. If 1.2 million kiloliters of biodiesel derived from CPO oil were transferred to used cooking oil collected, it could save approximately IDR 4.2 trillion.

According to Pertamina's Vice President of Strategic Planning[8], the utilization of used cooking oil and its processing into biodiesel requires the management of integrated material flow, information flow, and money flow. All flow will involve parties such as consumers of cooking oil, waste cooking oil collector, biodiesel processor, Pertamina, and biodiesel consumers. Each one has different roles and interests. This also needs to be considered so that the biodiesel supply chain system can be overcome by considering the interests of all involved.

As seen in Table 1 , the data consumption of palm cooking oil from 2012 to 2017 has increased. From these data, a lot of used cooking oil will be wasted, so efforts are needed to utilize used cooking oil as biodiesel fuel. Utilization of New and Renewable Energy (EBT) in the transportation sector shows that biodiesel is starting to develop rapidly in line with the application of the mandatory biofuel policy, which requires a mixture of biofuel to fuel as much as 30% (B30)[9].

3 | MATERIAL AND METHOD

The biodiesel manufacturing process with the transesterification process uses a homogeneous base catalyst. It starts with entering all raw materials such as oil with methanol in the reactor assisted by a catalyst NaOH. This works to anticipate the reaction transesterification. The process is divided into three parts. They are as follows.

3.1 | Raw material Preparation Stage

Used Cooking Oil is accommodated in a holding tank, heated by steam. The raw material for used cooking oil is still high in FFA. We put it into the mixer with added activated carbon to reduce the FFA levels so that the transesterification reaction can run optimally and minimize the saponification reaction. It then flowed to the filter press to separate the used cooking oil, which had reduced its FFA content with activated carbon. Then the used cooking oil was poured into the reactor with the addition of a solution of Methanol and NaOH, which had previously been mixed in Mixer I.

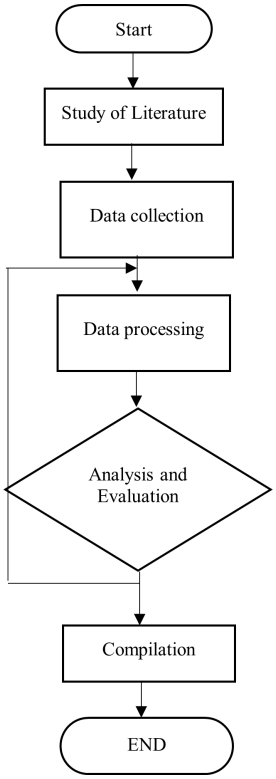

FIGURE 2 The research block diagram,

3.2 | Reaction Stage

Inside the reactor, the Triglycerides contained in the used cooking oil then react with 98% methanol which causes the reaction transesterification to form a methyl ester product (Biodiesel) and glycerin by-products with a conversion reaction of 97%. Furthermore, Methyl ester products, glycerin, water, FFA, NaOH and methanol, and residual triglycerides were separated using a decanter and distillation column.

3.3 | Purification Stage

The Methyl Ester product mixture that comes out of the reactor enters the decanter to be separated from the glycerin. Glycerin, NaOH, and water will come out as under-flow products and then be stored in a holding tank. Meanwhile, the methyl ester, which still contains FFA, triglycerides, and residual methanol, is separated using a distillation column. Materials with lower boiling points will evaporate as the top product (Methanol and triglycerides). Meanwhile, the products of methyl ester and FFA will come out as the bottom product to be cooled first, use a cooler until the temperature is and then flow into the holding tank methyl ester products. The methanol triglyceride mixture is then separated using distillation column II to purify methanol. Triglycerides, the bottom product, are channeled to the Waste Treatment Plant (WTP)[10].

The methodology used in this research is a literature study where data is obtained from previous research through journals and books regarding biodiesel. Everything that is done, from problem formulation to decision making, is modeled in a flow chart in Fig. 2 , which is expected to explain the steps to be taken.

The literature study focuses on collecting literature references that would be used as a reference to be discussed. The second step, data collection, collects data obtained from previous research. In the third step, data processing, all data that has been obtained would be processed in such a way that the data obtained is easily understood and understood by the reader. The fourth step is analysis and evaluation. The analysis process consists of three main objectives, i.e. finding biodiesel parameters according to SNI, discovering various production processes, and identifying various purification substances in the process of making biodiesel. After that, the evaluation carried out was to determine the biodiesel production process that had the best results and

TABLE 2 The physical and chemical properties of biodiesel (SNI)[13].

Test Parameter	Test Method	Requirements	Unit Min/Max
Cetane number	SNI 7182:2015	51	Min
Acid number	SNI 7182:2015	0.4	Mg-KOH/g, maks
Iodine number	SNI 7182:2015	115	%-mass (g-I2/100 g), maks
Flashpoint (covered bowl)	SNI 7182:2015	130	°C min
Sulfated ash	SNI 7182:2015	0.02	%-mass, maks
Carbon residue in the original sample or i0% distillation dregs	SNI 7182:2015	0.05;0.3	%-mass, maks
Distillation temperature 90	SNI 7182:2015	360	°C maks
Total glycerol	SNI 7182:2015	0.24	%-mass, maks
Sulfur	SNI 7182:2015	10	Mg/kg, maks
Phosphor	SNI 7182:2015	4	Mg/kg, maks
Copperplate corrosion (3 hours at 50°C	SNI 7182:2015	Number1	
Glycerol free	SNI 7182:2015	0.02	%-mass, maks
Density (40°C)	SNI 7182:2015	850-890	Kg/m3
Methyl ester content	SNI 7182:2015	96,5	%-mass, min
Kinematic viscosity (40°C	SNI 7182:2015	2,3-6,0	mm2/s (cSt)
Oxidation stability	SNI 7182:2015	600	Minute
Induction period	SNI 7182:2015	45	Minute
Monoglycerides	SNI 7182:2015	0.55	%-mass, maks
Metal II (Ca+Mg)	EN 14538	5	Mg/kg, maks
Water content	ASTM D-6304	350	Ppm, maks
CFPP	ASTM D-6371	15	°C maks
Color	ASTM D-1500	3	Maks
Metal I (Na+K)	EN 14108/14109, EN 14538	5	Mg/kg, maks
Total contaminants	ASTM D 2276; ASTM D 5452;ASTM D 6217	20	Mg/liter, maks

Source: [13]

was in accordance with SNI. The last step is compilation. After analysis and evaluation, conclusions can be drawn from the results of the data that have been discussed.

4 | FINDINGS AND DISCUSSION

4.1 | Factors Affecting The Production of Biodiesel

Various processes in the manufacture of biodiesel can be carried out by three processes, namely (i) Micro Emulsion Process; (ii) Pyrolysis Process; and (iii) Transesterification Process.

1. Micro Emulsion Process. Microemulsion means an action to reduce the viscosity of vegetable oil. The process is carried out using an oil dissolution process with methanol. However, the research results show that the methanol used as an emulsifier is relatively large; as a result, it can increase volatility and make its flash point low[11].

2. Pyrolysis Process. Pyrolysis is a process of decomposition of vegetable oil using heat, or it can also be by using a catalyst to break the chain in hydrocarbons. Catalytically breaking the botanical oil chain is carried out using a catalyst, including SiO2 or Al2O3, at a temperature of 450OC. Then the products are separated to make biodiesel and biogasoline. The advantages of biodiesel products derived from this process are their compatibility with diesel from refined petroleum, while the drawbacks of this process must be the absence of oxygen. Therefore the fuel should not be oxygenated, and the tools used in this method are expensive[11].

3. Transesterification Process. The transesterification process is the process of a chemical reaction between alcohol which reacts with triglyceride compounds from oil, the alcohol used in this process is methanol. It uses the help of a homogeneous base catalyst (NaOH). The transesterification reaction using a base catalyst is faster and is also often used commercially than an acid catalyst. The previous research showed that the main factors influencing transesterification were the alcohol-to-oil molar ratio, the amount and type of catalyst, reaction time, reaction temperature, stirring rate, free fatty acids, and moisture[12].

TABLE 3 Process Selection (Zhang, 2003).

Comparison	Biodiesel Production Methods		
	Microemulsion	**Pyrolysis**	**Transesterification**
Raw material	Soybean oil and methanol	Vegetable oil and petroleum	Vegetable oil and methanol
Operating Conditions	Room temperature 30°C Reaction time 1 hour	The temperature at 500°C, Atmospheric pressure 1 atm Reaction time 30 minute	Temperature 60°C, Atmospheric pressure 1 atm Reaction time 2 hours
Conversion	70-80%	50% charcoal, 30% syngas, 20% crude oil	95.0 - 99.5%
Catalyst	Tween 80, oleique plurol, Cremophor RH40, labrasol	Catalyst: SiO_2, Al_2O_3	Catalyst: H_2SO_4, KOH/NaOH
Product	Carnauba-Wax microemulsion, lubricating oil, biodiesel. cleaning fluid, antiseptic formula,	Gasoline, biodiesel	Metil ester / Biodiesel

Biodiesel characterization through the National Standardization Agency already set SNI for biodiesel products. Some of the parameters are listed in Table 2 . It shows several test parameters and requirements in accordance with SNI standards.

Based on the above aspects stated in Table 3 , the transesterification process was chosen in the manufacture of biodiesel with the consideration that the conversion produced is higher, the catalyst used is easy to obtain and relatively inexpensive, and the production process is not too complex. Table 4 indicates the research regarding biodiesel production.

TABLE 4 The types of biodiesel production methods.

#	Process Method	Ingredients	Variable	Purification	Conclusion
1	Esterification Transesterification (Kementerian ESDM Indonesia[14])	• Coconut oil • methanol • Silica Alumina	• Operating temperature • Solvent-Reactant Flow Rate	• Washed with water	The esterification-transesterification process using methanol obtain-ned, among others, the best flow rate and temperature in the extraction process was 50 milliliters/ minute and 60°C, yielding 38.36% for the transesterification process at 60°C with a yield of 94.94%.
2	Esterification-Transesterification (Nugraha and Taharuddin[15])	• CPO Off Grade • Methanol • Sulfuric acid • KOH	• CPO variations: Sulfuric acid • CPO variations: Methanol	• Added hydrochloric acid • Washed with water • In the oven	The more the number of catalysts in the esterification step, the free fatty acid content will decrease. Yield increases with the addition of methanol and KOH
3	Fast Single-Phase Process (Arita et al.[16] S. Arita, 2008)	• CPO • Methanol and Tertrahydrofuran (1:2) • Sulfuric acid • NaOH	• CPO variations: Methanol • NaOH variations: oil	• Added N-Hexane • Washed • Aquadest • In the Oven	Transesterification using the addition of co-solvent compounds gives the amount of biodiesel content to be greater than the conventional method, as much as 5%. The highest yield is 98.42%.

#	Process Method	Ingredients	Variable	Purification	Conclusion
4	Ultrasonic Wave Assist (Putri et al.[3])	• Coconut oil • Methanol • NaOH	• Feed Initial Temperature • Variation of CPO: Methanol • Variations of NaOH: Oil	• Washed with water • In the oven	Using the help of an ultrasonic wave can increase the conversion. conversion resulting from ultrasonic waves is 85.66%, and conventional is 20.15%
5	Methanolysis (Transesterification) (Rachmaniah et al.[17])	• Coconut oil • Methanol $CaCO_3$	• Variation of oil: Methanol • Variation of $CaCO_3$: oil	• Washed with water • In the oven	Using a $CaCO_3$ catalyst that has been ignited, the biodiesel yield is 75.02%.
6	Transesterification Using Microwaves (Padil et al.[18])	• Coconut oil • Methanol • KOH	• Coconut oil (mole) • Catalyst concentration • Reaction time • Power variation	• Washed using aquadest at 40°C	The best results were obtained at 0.20% KOH and a reaction time of 150 seconds and 400 watts of power in the microwave, with the yield of biodiesel products formed being 93.22%.
7	Live Transesterification (Hidayanti et al.[19])	• CPO • Methanol 99% • NaOH	• CPO feed mole ratio: Metanol • Catalyst weight	• The washing process is carried out with aqua dest • Dried in the oven with a temperature of 80°C	The bigger the mole ratio of methanol: to oil, the higher the yield. The heavier the catalyst, the higher the yield of biodiesel produced. The purity of the methyl ester in bio-diesel is 54.75%.
8	Static Mixer (Ristianingsih et al.[20])	• Palm oil (RBDPO) • Methanol • KOH	• Combination of KOH Catalyst Concentration • Quantity Variation • Static Mixer Module (Static Mixer)	• Washing With Aquadest • After washing, evaporation is carried out at T=65°C	The catalyst can be replaced by using 0.9 modules (static mixer) of 58.1 centimeters

#	Process Method	Ingredients	Variable	Purification	Conclusion
9	Transesterification (Sari et al.[21])	• Used cooking oil • Methanol • Activated Natural Zeolite (H-Zeolite)	• Reaction Time • Zeolite	• Separation on the Separating Funnel	The best-operating conditions were obtained when the reaction time was 5 hours with a zeolite concentration of 1% and biodiesel yield of 12%.
10	Transesterification (Kusyanto and Hasmara[22])	• Palm oil • Methanol • Rice Husk Ash with calcined KOH	• Catalyst Mass	• Washing With Water • Heating at 100°C	Rice husk ash can be used as a heterogeneous catalyst with 1.9 N KOH, and the highest yield is 67%.
11.	Catalytic Cracking Process (Hazzamy et al.[23])	• Cooking oil • Fly Ash	• Operating Condition Temperature • Fly Ash Weight Percentage		The catalytic cracking process of used cooking oil produced the highest yield of 31.72%, with a 9% weight of fly ash and a reaction temperature of 420°C.
12.	Catalytic Cracking Process (Buchori et al.[24])	• Used cooking oil • Zeolite Activation • Using H_2SO_4 solution	• Concentration of H_2SO_4 • Natural Zeolite Catalyst Size		The best results were obtained under the operating conditions of a natural zeolite catalyst with a size of 0.125 mm, which was activated with sulfuric acid with a concentration of 4N.
13.	Transesterification Process (Kartika Sari Dwi Udyani; Matrika[25])	• Castor Oil • Methanol • NaOH	• Zeolite-Biodiesel Mass Ratio	• Using Zeolite Adsorbent Activated By Sulfuric Acid	The higher the ratio of zeolite-biodiesel, the lower the acid number and density of the purified biodiesel. The biodiesel content was 44.66% before purification and 55.78%. after purification
14.	Dry Washing Process (Suriaini et al.[26])	• Cooking Oil • 96 • NaOH	• Variation of Bentonite Adsorbent Mass	• With the addition of activated bentonite, then stirred and then filtered	The best results are with 3% bentonite adsorbent mass with a biodiesel yield of 91.73%

#	Process Method	Ingredients	Variable	Purification	Conclusion
15.	Esterification-Transesterification (Resti and Zibbeni[27])	• Nyamplung Seeds • Degumming with the addition of 0.5% weight of H_3PO_4	• Washing Method	• Stir Washing, Using Aquadest Then Process • Drying In Oven At T = 110°C. • Bubble Washing Using Aquadest Connected To An Aerator Pump As A Bubble Producer. Then Drying In The Oven At A Temperature Of 110°C. • Dry Washing Using Magnesium Silicate With Stirring. Then Separate Between Biodiesel And Adsorbent Using A Vacuum Pump Filter.	Biodiesel content obtained: 1. For stir washing 85.47% 2. For bubble washing 85.67% 3. For dry-washing 89.93%
16.	Esterification-Transesterification (Arifin et al.[28])	• Cooking Oil • Methanol • Esterification • Snail Shell as Heterogeneous Catalyst	• Amount of Catalyst • Adsorbent (magnesium silicate)	• Using Magnesium Silicate Takes Water's Role in Absorption Of Impurities In Biodiesel.	The best results were obtained with a yield of 63% with a catalyst concentration of 6%, and a magnesium silicate of 1%.
17.	Esterification (Widayat and Suherman[29])	• The ratio	• The ratio of free fatty acid volume and temperature • Volume ratio of the volumetry acids and catalyst	• Done in a coolant triple-neck bottle • Performed with methanol and an acid catalyst (i.e., 1M sulfuric acid). Free fatty acids were analyzed every 5 minutes.	The rubber seed oil content obtained is 50.5%. Composition of free fatty acids, including 14.34% linoleic acid. The highest conversion to diesel oil is obtained at 59.91% and the lowest at 48.24%. Variable raThe variable volume of free fatty acid to the volume of catalyst is stronger than changing temperature.
18.	Transesterification (Istadi et al.[30])	• K_2O/CaO-ZnO • Soybean oil • Methanol	• Weight of catalyst 6 wt. • Oil to methanol mole ratio 1:15 • Temperature 60°C	• Co-precipitation method of calcium and zinc nitrate with potassium nitrate impregnation	As a result, the catalyst showed high catalytic activity (80% yield of fatty acid methyl ester (FAME) after three use cycles) and could be reused after regeneration. The catalyst also showed acceptable stability of the catalytic activity, even after three cycles of use.

#	Process Method	Ingredients	Variable	Purification	Conclusion
19.	Central Composite Design (CCD) Method (Widayat et al.[31])	• Coconut oil • Palm oil • Methanol	• The ratio of methanol to total vegetable oil • reaction concentration temperature.	• Using ultrasonic 6000 as the reactor where the transesterification reaction occurs. • Experiments were carried out in ultrasonic cleaners and batch systems.	Optimum conditions of volume ratio of palm and coconut oil 4:1, catalyst concentration of KOH,0.3%, and the mole ratio of methanol to oil 7:1. The biodiesel yield was determined under these conditions and obtained at 81.105%.

TABLE 5 The types of pre-treatment methods for producing biodiesel.

Treatment	Advantages	References
Esterification Process	This method is more suitable to apply to oils or fats with high FFA and low-quality ingredients.	Nugraha and Taharuddin[15]
Degumming + Esterification Process	This method minimizes impurities and purifies the oil before the esterification process is carried out so that when the esterification is faster.	Resti and Zibbeni[27]
Neutralization	The neutralization method uses NaOH solution to minimize the need for methanol for esterification.	Hidayanti et al.[19]
Micro-Filtration	Microfiltration minimizes suspended solids and organic compounds, including protein, carbohydrates, and free fatty acids	Buchori et al.[24]
Adsorption	Reducing FFA levels and minimizing sulfuric acid catalysts that can interfere with the transesterification process	Adaileh and Alqdah[5]

TABLE 6 The types of biodiesel production process methods.

Treatment	Advantages	References
Methanol transesterification	Methanol has high reactivity and is relatively inexpensive	Nugraha and Taharuddin[15]
Transesterification of methanol and tetrahydrofuran	Gives higher methyl ester content by 5%	Rachmaniah et al.[17]
Ultrasonic wave-assisted methanol transesterification	Deliver higher conversions	Putri et al.[3]
Transesterification of methanol with NaOH catalyst	NaOH can lower viscosity more than KOH catalyst	Putri et al.[3]
Transesterification of methanol with $CaCO_3$ catalyst	Homogeneous catalysts have the disadvantage of more difficult product separation	Putri et al.[3]
Catalytic Cracking Process	More efficient raw materials	Hazzamy et al.[23]
Methanol Transesterification with Static Stirrer	Minimizes the need for a catalyst	Sari et al.[21]
Methanol transesterification With Microwave (Microwave)	Deliver higher conversions	Hidayanti et al.[19]

Table 5 shows various methods for the preliminary stage in the manufacture of biodiesel, aiming to minimize the levels of FFA in the raw material before the transesterification reaction occurs between the raw material and methanol.

Table 6 shows various methods for the processing stage in the manufacture of biodiesel, aiming to increase the conversion of the transesterification reaction between the raw material and methanol.

TABLE 7 The types of biodiesel purification methods for producing biodiesel.

Treatment	Advantages	References
Washed and then in the oven	The highest yield was 98.42%.	Rachmaniah et al.[17]
Washed then vacuum dryer	Methyl ester conversion reaches more than 97.00%	Hidayanti et al.[19]
Washed then vacuum rotary evaporator	biodiesel yield 87.30%.	Sari et al.[21]
Bleaching earth then filter vacuum pump	More increase conversion	Suriaini et al.[26]
Added zeolite	Easy to get raw materials	Kartika Sari Dwi Udyani; Matrika[25]
Dry Washing	The biodiesel content obtained for dry washing is 89.93%	Resti and Zibbeni[27]
Stir washing	The biodiesel content obtained for stir washing is 85.47%	Resti and Zibbeni[27]
Buble washing	The biodiesel content obtained for bubble washing is 85.67%	Resti and Zibbeni[27]

TABLE 8 The types of transesterification process for producing biodiesel.

Process	Advantages	Weakness
Homogeneous Catalyst	• using an alkaline catalyst so that the reaction time runs faster • The catalyst used is NaOH and KOH. The price is relatively low and easy to obtain[31]	• very complex separation in product purification • its selectivity to the FFA content of the raw material[20]
Heterogeneous Catalysts	• can be separated from the reaction mixture directly, for example, by filtration.	• Related to the surface area of the catalyst available. • there is an open space for the new reactant molecules to attach or absorb, thereby limiting the rate of reaction[20]
Enzyme Catalyst	• The lipase enzyme is an effective catalyst that converts all the FFA content in WCO into fatty acid methyl esters. • when lipase is used to catalyze the transesterification reaction, glycerol can be recovered easily • The yield of biodiesel is higher, and the reaction can be carried out at low temperatures and pressures, which can reduce energy consumption[2]	• expensive lipase cost • lipase inhibition by methanol • glycerol adsorption on lipase • long reaction time[32]

Table 7 shows the various methods of purification steps for the manufacture of biodiesel which aim to remove impurities that are still included in the biodiesel that is formed.

4.2 | Comparison of Transesterification Process

The transesterification process method using a catalyst can be separated into three types: a homogeneous catalyst, heterogeneous catalyst, and enzyme catalyst. The process often applied in the industrial world is transesterification using a homogeneous catalyst (Table 8).

5 | CONCLUSION

Based on this review, it can be concluded that the best preliminary method for making biodiesel is the adsorption method because it reduces the levels of FFA and minimizes sulfuric acid catalyst, which can interfere with the transesterification process. The best biodiesel processing method is the transesterification method with methanol as a solvent and a NaOH catalyst because it can obtain higher biodiesel yields, lower temperatures, does not require a lot of operating equipment, tends to have fewer side products, the time required is relatively short, materials can be recycled. Return is more economical, although it has a weakness in product separation. The best biodiesel purification method is the method of washing and then in the oven because it can provide a higher yield of biodiesel products, namely the yield of 98.42%.

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CREDIT

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