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Overview of Manufacture of Fish Waste-Derived Biodiesel

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Abstract: ***Energy security is crucial to the global economy as fossil fuel supplies are fast running out. and it is consequently becoming more important to develop alternate sources of energy. An alternative fuel must be inexpensive, ecologically fair, and technically practicable. Biodiesel has become a valuable alternative fuel due to its renewable source and its non-toxic and biodegradable properties. Fish wastes are a fine choice to be the feedstock as raw material to convert to biodiesel because of their high lipid content and low microbial presence. The economic potential of producing biodiesel from fish oil generated from leftover fish parts was extensively examined in this review paper.This comprehensive study has gone through a thorough literature review of the necessary components and an extensive exploration of extracting fish oil from its waste, characterizingas well as several transesterification processes for converting it into biodiesel. Therefore, this type of biodiesel can address energy related issues in the next generations.***

Keywords: Alternative fuel; Biodiesel; Feed stocks; Fish oil;Transesterification.

1. Introduction

With population growth and increasing industrialization, the demand for petroleum products is rapidly uphill. This rising consumption of petroleum is having countless detrimental effects on human life and geopolitical dynamics worldwide (Basha *et al*., 2009). Unless we act now, the world will soon find itself on the brink of an energy crisis. In addition, using fossil fuels causes environmental pollution. Therefore, the global oil industry has been forced to stop being so dependent on fossil fuels and to start focusing on other sources as a result of the diminishing supply of fossil fuels and their negative effects on the environment (Samat*et al*., 2018).

Developing renewable energy sources is necessary in order to tackle the current issues. The alternative fuel should be economically viable, environmentally safe, and technologically feasible in order to work effectively (Aktas*et al.*, 2020; Behcet,2011). Biodiesel is considered one of the most viable energy alternatives to diesel fuel. It has numerous advantages that make it a great choice for many applications. such as its excellent biodegradability (Crutzen*etal*.,2008; Saifuddin & Boyce, 2017). And also,it derived from renewable energy sources (Aktas *et al.*, 2020). Additionally, owing of its higher flash point and lower pollutant levels, biodiesel has a low emission profile and is environmentally safe. It does not warn of threats to our fragile planet (Saifuddin& Boyce, 2017; Behcet, 2011). Not only that, but localized production of this type of energy will reduce the need for imported fuels and can be beneficial for our economy. Natural resources are key when it comes to creating this energy, making it a great option (Samat*et al*., 2018; Ushakov *et al*., 2013).

There have been numerous attempts to investigate prospective feedstocks with significant oil/lipid content that could also result in the economically viable manufacture of biodiesel. Organic wastes (including vegetable, animal, and fish wastes (Lebedevas*et al.*, 2006; Preto *et al*., 2008; Son*etal*.,2010), microalgae (Benemann, 2013), seaweeds, and plants (Kywe&Oo, 2009) are among them. Plant and vegetable resources are not the most feasible option when it comes to producing biofuel. This is because oil can be extracted from an edible source, thus leading to wastage of food. In such a scenario, investing in dedicated planting and cultivation assets would be impractical. Consequently, researchers have been looking into other sources of oil, such as fish oil derived from the by-products of fish (Makoure*et al*.,2020; Yari*et al*., 2019).

A billion tons of fish are consumed annually owing to the great nutritive value it provides- mainly for its high EPA (Eicosapentaenoic Acid) and DHA (Docosahexaenoic Acid) omega-3 fatty acid content (Sharma *et al*., 2014). Inedible parts of a fish such as the head, internal organs, dorsal fins, tail, skin and liver can contain high levels of lipids. These waste non-edible components are disposed of without any attempt to recover value goods, either by dumping them on land or disposing into the water and cause environment pollution (Yuvaraj*et al*., 2016). To overcome this issue, make fish waste economically viable and sustainable for the manufacture of biodiesel (Wisniewski *et al.*, 2010).

Fish oil biodiesel shares many of the same physical and chemical characteristics as diesel, it may be blended with diesel oil and utilized in engines (Girish *et al.*, 2017; Rebello *et al.*, 2020; Zhao *et al.*, 2012).

Table 1: The composition and properties of biodiesel and diesel(Adapted from Godiganur *et al*., 2010)

Properties	Diesel	Fish oil biodiesel
Density (kg/m3)	850	880
Specific gravity	0.85	0.88
Kinematic viscosity at 40°c	3.05	4.0
Calorific value (kj/kg)	42,800	42
Flash point °c	56	176
Fire point °c	63	187
Oxygen content(%)	Nil	10.9%

An abundance of studies has been conducted on the applicability of vegetable oils for biodiesel production (Saifuddin *et al*., 2014). the potential of fish waste and fish oil for biodiesel production is yet to be fully explored. the literature available on biofuels from fish oil is limited. To

address this gap in knowledge, this review paper aims to analyses and summaries the existing literature on biofuel production from fish oil and providing general information on the most recent techniques for producing biofuels using fish oil to give a better understanding of its potential for environmental sustainability.

2. Study Methodology

To get the most up-to-date information, a thorough literature search was conducted in multiple databases regarding fishoil biodiesel. The review was mainly concentrated on articles published between 2000 and 2022 to provide the most recent findings. As part of the research, a few seminal publications that are often referenced in academic literature were also taken into consideration.

Literature to support the use of fish waste as a biodiesel rawmaterial

Raw materials are the cornerstone of the biodiesel industry. They provide the foundation for producing biodiesel, and their cost directly affects the price of biodiesel production. Therefore, selecting and processing the right raw material is crucial to keeping costs low while producing high quality biodiesel. According to Balat (2011) a vast majority of biodiesel that is produced in the world is from edible oils. This has been viewed as a highly wasteful approach considering the fact that many parts of the world still face food insecurity. To address this challenge, many have proposed utilizing alternative sources of oil, such as non-edible oils (Gui*et al.*,2008) or waste materials. For instance, biodiesel can be produced through fish waste oil extraction.

Fish processing by products contain fish oil. The amount generally depends upon the fat content of the fish species. Generally, fish contains 2-30% fat. Almost 50% of the body weight generated as waste during the fish processing would be a great potential source for good quality fish oil which can be used for human consumption or production of biodiesel

Fish is a highly nutritious food, due to its low-fat content (2-3%) and high protein levels. In addition, it has minimal amounts of saturated fat and an abundance of essential fatty acids (Ghaly*et al.*,2013). Eating fish is known to be extremely beneficial for human health.

Despite this, research indicates that more than half of the fish caught is not utilized and wasted from the rest of the remains (Varuvel *et al.*, 2012). In the past, discarding fish remnants was viewed as a loss. Fish byproducts now have various applications, such as producing renewable energy through the generation of biodiesel and biogas, as stated by Yahyaee et al. (2011). The fish processing industry's waste can be transformed into a profitable business by serving as a raw material for renewable energy sources. As a result, there is a tendency to create biodiesel from economical non-edible oils like fish oil. These feedstocks have a high triglyceride content, resulting in a significant amount of biodiesel being generated.

Depending on how much the fish has been processed, fish waste may be produced in significant quantities by the fishing and seafood processing industries. In many cases, the waste can make up 20-50% of the total weight of the fish. According to research by Shahidi (2006) and Ghaly et al. (2010), fish viscera can account for between 7.5% to 15% of the total weight of the fish. However, this part of the fish is generally considered useless for commercial purposes.

The constitution of fish viscera can vary according to the species, season, age, gender, food consumption, and environmental factors. Additionally, fish viscera are rich sources of protein, lipids, and various minerals. According to a study by Shirahigue et al. (2016), the viscera of tilapia contain about 14.62% protein, 10.75% fats, 60.44% moisture, and 4.90% minerals.

EI-Rahman et al. conducted a study to compare the amount of oil extracted from the viscera of two different species of fish, mackerel and tilapia, using a modified wet rendering extraction method. They used 400 grams of each species' viscera and found that tilapia produced a higher oil yield of almost 20%, while mackerel produced only a 7% increase in oil yield. Therefore, it can be concluded that the oil yield varies between different fish species and making fish oil from the viscera can be effective with tilapia.

Narayan, 2020. suggests that fish waste can be a promising alternative energy source as biofuel and animal feed. Fish wastes have high lipid content and low microbiological content. One liter of fish oil and 10 milliliters of fish oil produced from one kilogram of fish waste can generate 0.9 liters of biodiesel. Fish oil is a great option for producing biodiesel feedstock due to its high lipid content.

The lower value comestible fish wastes, similar as the heads, tails, fins, and organs, were collected as fish waste and used to make biodiesel, according to Girish et al. (2017). Over the course of 85 experiment attempts, 560.1 ml of fat were recovered from the fish waste.

In a study by Rebello et al. 4 kilograms of sardine fish were raised with 12 liters of water in a steelvessel at 97°C. in oil production. The mixture was then filtered using a muslin cloth following this procedure. The riddled oil was slightly yellow in color while the crude oil was brownish-yellow in color. 100 ml of oil was obtained (86 g).

The manufacture of biodiesel from the viscera of Nile tilapia was researched by Motaet al. (2019).The internal organs can yield between 40-50% of the oil, and the suggested oil extraction device can yield up to 201.08 kg of oil in an 8-hour shift.

Kusmiyati (2015). demonstrated that fish waste, such as fish liver, internal fish organs, fish meat, or fish, can be used to make fish oil. Fish oil produced from fish waste has the potential to be used in Indonesia as a biofuel. (Astawan, 2004).According to Saifuddin, et al. (2014). fish wastes are a good source of fatty acids and can be used as a starting point for the transesterification reaction that creates biodiesel. The findings revealed that all of the triglycerides were successfully converted to methyl esters by the seven peaks, which are fatty acid methyl esters.

Sharma et al. (2014) showed that biodiesel of a high-quality could be produced using oil that had been derived from residual fish parts. To be more precise, a single-step transesterification process using waste fish oil, methanol and sodium methoxide (CH3ONa) as a homogeneous catalyst resulted in biodiesel with a fatty acid methyl ester (FAME) concentration of greater than 98% when conducted at moderate operating conditions.As Andersen and Weinbach (2010) reported, their findings were in line with the notion that the production of biodiesel from triglycerides acquired from poultry and fisheries would have a major impact on the global biodiesel industry.

Investigating Techniques to Obtain Fish Oil from Fish Leftovers

Research conducted by EI- Rahman et al. (2018) has highlighted wet rendering extraction as a popular method used to extract fish oil from fish viscera, as it does not require harsh chemicals, preserves the natural form of the fish waste components, is cost-effective, and has no adverse environmental effects (Oliveira *et al.*, 2013). Other methods such as enzymatic hydrolysis, autolysis, dry rendering, solvent extraction and supercritical fluid extraction are also available to extract fish oil (Ghaly*et al*., 2013; Jayasinghe *et al*., 2013; Suseno *et al*., 2015).

1) Wet rendering extraction method:

Wet rendering extraction method according to *EI*- Rahman et al. (2018).400 grams of either mackerel or tilapia viscera were utilized in this technique. The extraction procedure was carriedby using a hot plate stirrer, the sample was heated to 80 °C for 20 min to break up the fat cells. The oil was separated from other solids and wastewater by centrifuging at 1500 rpm for 5 minutes. The crude oil and wastewater were separated using a funnel. Washing the oil involves adding water at 90°C in a 1:1 ratio to the oil. Then centrifugation for 10 minutes at 3000 rpm. Afterwards, the water and purified fish oil were separated using the separating funnel.

2) Microwave-assisted extraction method

According to Rahimi et al. (2017). Distilled water and a 3:2 (v/v) hexane/isopropanol mixture were used as extraction solvents during the microwave-assisted extraction process. In 42 ml of the extraction solvent, 2 g of fish waste and 1 g of sodium sulphate were combined. The mixture was then heated using an 800 Watt microwave. When using water as a solvent, the sample was exposed to radiation at this power for 2, 3, 5, 7, and 10 minutes. When using an organic solvent, the sample was exposed to radiation for 1 to 4 minutes. Filter paper was used to separate the mixture. The filtrate mixture was separated by adding 5 ml of hexane. Removed the top layer and dried it. Weight of lipids was calculated.

3) Pressure cooker. Conventional method

A set-up for an experiment utilizing a pressure cooker. Conventional approach, as per Narayan (2020). A pressure cooker's internal pressure is used in this old approach to pressurize fish wastes and extract the oil from them. This method is typically less expensive, easier, and slower. With this strategy in the end, approximately 1L of fish oil was extracted using this method, after an initial test extraction of about 10ml of fish oil. The steps of this methods were , first cleaning the fish waste, water was added to a level where the fish waste sank in it. Putting pressure on it for roughly 15 minutes. Can create a layer of water and oil combination. A separating funnel can be used to divide mixtures

4) Wet pressing method

According toRebello et al. (2020). it forces out the water and solids produced during steaming, wet pressing yields more fish oil than dry pressing. The oil rises to the top and the sludge sinks to the bottom when press liquor is stored in a tank. However, this process is time-consuming and increases the amount of impurities in the oil. Centrifugation speeds up the process and produces cleaner fish oil.The steps of this methods were ,the fish are cleaned thoroughly . Then heated to about 95 degrees Celsius in order to extract the water and oil from the protein. Water, oil, dissolved protein, vitamins, and nutrients are all present in the liquid extraction. By using a centrifuge, which separates materials with different densities, the oil is divided from other liquids. After a brief period of cooling, the oil is then filtered through muslin fabric.

5) Method for removing oil from fish viscera according to Motaa, et al. (2019).

700 g of fish waste were added to a heated system (60 °C) and stirred continuously for 20 minutes. A sieve-based filtration device was used to collect solid waste. The system was allowed to settle so that the sludge could be decanted. After adding 2 g of heated water (60 °C), the degumming procedure was carried out with constant stirring for 20 min. The oil was left to settle. Bile acids, phosphorus compounds, and solid particulates that were in suspension of polar compounds were decanted. To get rid of any extra free fatty acids as well as other impurities like proteins, oxidized acids, and pigments, the residue was neutralized. This process took place for 15 minutes with constant churning. The material was then washed with distilled water heated to 80 °C (5% of the oil mass), while being continuously stirred for 10 minutes. The oil was dehumidified (100 °C) under continuous stirring for 30 minutes as the last stage.

6) Bligh & Dyer method

According to Norziahet al. (2009).Compared to the other procedures, the method yielded the most fish oil that could be recovered from fish wastes. Chloroform and methanol are combined with a polar solvent in this method to extract the oil from fish by-products. According to Bligh and Dyer, polar solvents may enter cells and remove lipid from their membranes as well as from muscle fibers, including phospholipids (1959). The steps were waste samples weighing 50 g each were collected and thawed. An electronic shaker was used to completely combine the sample with the solvent mixture for 15 minutes. After being homogenized, the mixture was filtered using Whatman No. 2 filter paper. The filtrate was collected. To achieve a high hydrocarbon recovery, the tissue residue was re-extracted using the same volume of chloroform. In order to separate the filtrate solutions, they were mixed and poured into a separatory funnel. The lower organic layer containing the lipids was collect. The lipid-containing lower organic layer

was recovered. To completely eliminate all of the methanol and chloroform, the solvent was evaporated off at 25 ^{o}C in a rotary vacuum evaporator. The lipid-containing lower organic layer was recovered. To completely eliminate all of the methanol and chloroform, the solvent was evaporated off at 25 ^{o}Cin a rotary vacuum evaporator.

7) Soxhlet extractormethod

Fish oil extraction by usingSoxhlet extractor according to Samatet al.(2018) and Yahyaeeet al. (2011).The already-fine fish refuse was put into a cotton cloth. The sample's weight (50 g) was measured before it was inserted into the soxhlet's interior tube. It was attached to a 150 ml flask with a round bottom that is the right size and holds n-hexane. A 60 ^{o}C heat source was used for three hours. The solvent-fish oil extraction combination was cooled for a short period of time at room temperature. To extract crude fish oil, the resulting mixture was separated using a rotary evaporator. The water bath's temperature was fix at 35 ^{0}C. The rotary bottle was filled with 200 ml of the prepared mixture of extracted fish oil and n-hexane for each run, which lasted 15 minutes. The rotary bottle contained the raw fish oil that was obtained.

Features of processed fish oil

Fish oil characterization is crucial for figuring out the potential applications for the extracted oil and whether additional processing is required before processing it into biodiesel. Viscosity, water content, free fatty acids and acid number of refined fish oil should be evaluated. Moisture content was determined using aTitro Line Karl Fischer Trace (SCHOTT,D-55122 Mainz, Germany) according to ASTMD6304 (West Conshohocken, 2009).

To determine kinematic viscosity, need to measure the time (t) required for a liquid to move from point A to point B on the viscometer. Calculate the kinematic viscosity (v) using the following formula [19]: v = c. Determined using T. ASTM D445, Standard Test Method for Kinematic Viscosity of Clear and Opaque Liquids (and Calculation of Dynamic Viscosity). Centistokes (cSt) or mm2/s are used to measure kinematic viscosity (West Conshohocken, 2006). It was performed using a viscosity bath (Tamson Instruments, TV4000, Germany). EI Rahman et al., 2018).

Highly viscous fish oils can interfere with their use in diesel engines and cause problems such as: high carbon deposits, engine liner wear, injector failure, gumming, lubricant thickening and highhaze. Point and Pour Point (Murugesan *et al*., 2009). To avoid these problems, the oil must be chemically modified into a derivative with properties close to those of conventional diesel.

After determining the TAN in the samples using the Test Procedure for Acid Number of Petroleum Products by Potentiometric Titration, the free fatty acids values were computed using the mathematical formulae provided in the American Oil Chemists' Society (AOCS) Method Ca 5a- 40. The year 2019 (West Conshohocken)

Fish oil must have a low value of free fatty acids (less than 5%) in order to be used in the synthesis of biodiesel. Higher levels of free fatty acids (FFAs) could make soap formation (EI- Rahman et al.) The main obstacle to the biodiesel industry is the soap formation reaction since it reduces biodiesel yields, raises product viscosities, creates emulsions, and makes it harder to separate glycerol from biodiesel (Ramadhas*et al*.,2005). Therefore, feedstock should be subjected to treatment processes.

Acid esterification is the most widely used treatment method to reduce FFAs in industrial applications. Acid is used as a catalyst in the reaction of alcohol and FFAs to create biodiesel and water, lowering the FFA level. This treatment method is employed when the raw materials FFA content exceeds 1 weight percent ((Elgharbawy *et al*., 2021; Knothe *et al*., 2005).

Methodology to produce biodiesel from fish oil

Transesterification is the process of replacing an organic group (alkyl) from alcohol with an organic group from a triglyceride, either with or without the aid of a catalyst, such as an enzyme, an acid, or a base. Triglycerides (fats) found in oils are utilized as feedstocks in the transesterification process to create viable biodiesel.(Elgharbawy*et al.*,2021)

Types of transesterification

There are different types of transesterification reactions: those involving catalytic(acid, base) enzymes, and non-catalyzed supercritical methanol. (Elgharbawy *et al.*, 2021; Likozar & Levec, 2014)

Base catalyst transesterification according to Elgharbawy *et al*., 2021

A glyceride interacts with a basic aliphatic alcohol (usually methanol or ethanol) in the base transesterification process to produce fatty acid alkyl esters (biodiesel) and glycerol (Rashid, *et al.*,2008).

Base-catalyzed transesterification is the most widely used and lucrative method among different transesterification processes because it is the cheapest, easiest, and fastest process and has the fewest processing steps (Varanda*et al*., 2011). Only a few of the numerous factors that have a significant impact on the output and quality of biodiesel are the quantity, kind, and purity of the feedstock. Other important factors include the temperature, pressure, mixing rate, water content, FFA content, and purity of the feedstock.

In transesterification, sodium hydroxide and potassium hydroxide (KOH) are the two most often utilized catalysts (NaOH). The favored one is KOH since it reduces the propensity for soap production. It is simpler to extract crude glycerol from the biodiesel produced when KOH is employed as a catalyst than when NaOH is. KOH is distinguished by inexpensive cost, high output, and maintaining a mild condition. At suitable pressures, temperatures, and times, base transesterification can yield 98%(Leung&Guo.2006). It is constrained by the existence of water and FFAs in the feedstock, as well as by solid contaminants like sand, dust, and solid particles, and by the purity of the reactants; as a result, treating the feedstock before the reaction is necessary (Timothy *et al.*,2009).

It is better to employ base transesterification with feedstocks that have FFA content less than 1 weight percent. FFAs and water present the most challenging hurdles to base

transesterification because they react with the catalyst to produce soap. While triglycerides in water hydrolyze to form monoglycerides or diglycerides and FFAs. Additionally, raising the reaction's FFA levels surroundings and causing the reaction to break down, the breakdown of triglycerides also results in the production of additional soaps (Lotero, e*t al.*, 2005).

The temperature of the reaction has a significant impact on base catalyst transesterification. The pace of reaction also accelerates with rising temperature, which improves the production of biodiesel. According to Ferrari et al. (2011) an excessive temperature increases speeds up the saponification reaction, which becomes substantial as the reaction time increases According to Li, et al. (2013) Between 40 °C and 60 °C is the optimal reaction temperature range. Because doing so will result in methanol evaporating and stop the production of biodiesel, the reaction temperature shouldn't be greater than the boiling point of methanol.

KOH was shown to be the best catalyst in the transesterification reaction by Atadashiet al. (2012) because it produced the maximum yield of biodiesel in the shortest amount of time. Investigation into KOH and NaOH activity during transesterification led to the discovery that KOH action outperformed NaOH activity. In addition, the reaction speed increased when KOH was used, and soap formation decreased.

According to Kawentar & Budiman (2013) insufficient methanol led to an incomplete transesterification reaction and a decreased production yield. As a result, it took a lot of alcohol to fuel the reaction and produce the products. They also stated that the most widely used industrial biodiesel processes employed a methanol to oil ratio of 6:1, although the minimum methanol to oil ratio needed to complete the reaction according to stoichiometric ratio was 3:1.

Two hours is the recommended reaction time for the transesterification process; further reaction time has no effect on yield. Reaction time is immediately inversely correlated with the transformation of FFAs. According to Huber et al. (2006) excessive reaction time drives the backward reaction, lowers the lastyield, and results in soap production. KOH was used as a catalyst by Komintarachat & Chuepen (2010) to produce biodiesel with an 88% yield under the following conditions: 15:1 methanol to oil ratio, 5% KOH, 70 °C, 120 min.

KOH was used as a catalyst by Zayed and Jehad (Al-Hamamre & Yamin, 2014) to generate biodiesel with a 98% yield under the following conditions: 9.5:1 methanol to oil ratio; 1% KOH; 50 °C; and 20 min. The resulting biodiesel had a viscosity of 5.8 Cst and a density of 0.877 g/cm2. KOH was used as a catalyst by Komintarachat & Chuepeng, (2010) to get an 88% yield under the following reaction conditions: 15:1 methanol to oil ratio, 5% KOH, 70 °C temperature, and 120 min.

Acid catalyst transesterification (Elgharbawy *et al.*, 2021)
During the acid transesterification procedure, a glyceride and an alcohol join with the help of a homogeneous acid catalyst, such as sulfuric or hydrochloric acid, to create fatty acid alkyl esters (biodiesel) and glycerol (Likozar&Levec, 2014). Acid transesterification is neither common nor favored in commercial or industrial plants because it is slower than base transesterification and needs more catalyst weight and high temperatures (Lam *et al*., 2010).

Acids like hydrochloric acid (HCl) and sulfuric acid (H2SO4) induce metal corrosion, which damages metallic equipment and encourages the production of metal oxides. As a result, using acid catalyst necessitates additional purifying and neutralization steps (de Araújo *et al.*,2013). Water greatly affects acid transesterification because it dilutes the acid catalyst concentration, which lowers biodiesel yield (Atadashi *et al.*, 2011). Because of its sluggishness, need for a lot of catalyst, and high temperatures, acid transesterification is not used in commercial or industrial operations (Likozar & Levec, 2014). The conversion can be completed at temperatures exceeding 100 °C with catalyst concentrations ranging from 1% to 5%.

Water has a significant impact on acid transesterification because it hydrolyzes triglycerides into diglycerides and FFA, which reduce biodiesel yield (Araújo *et al*., 2013). Due to its immunity to free fatty acids, this transesterification has the advantage of being able to occur at free fatty acid contents greater than 1% (Atadashi *et al*., 2011).

Sulfuric acid was shown to be the most effective and efficient catalyst when Michael *et al*. (Goff et al.,2004) tested the acid transesterification of oil using sulfuric, hydrochloric, formic, acetic, and nitric acids at various loading rates. According to the findings, using 0.5 weight percent H2SO4 catalyst and a 9:1 methanol to oil ratio, 99% of the triglycerides in oil could be converted in 8 hours at a reaction temperature of 100 °C. The optimal conditions for the oil acid transesterification, according to Freedman et al.'s research, were 30:1 methanol to oil ratio, 1 weight percent sulfuric acid, 65 °C, and 69 hours of reaction time. 90% of the biodiesel was produced.

Heterogeneous catalyst transesterification (Elgharbawy*et al.*, 2021)
A glyceride and an alcohol interact during the heterogeneous transesterification reaction, producing fatty acid alkyl esters (biodiesel) and glycerol in the process. The typical heterogeneous catalysts used in transesterification reactions include the oxides of bases supported on a wide surface area, such as calcium oxide (CaO), magnesium oxide (MgO), and titanium dioxide (TiO2). Because of its high activity, long lifetime, ability to achieve both mild and severe conditions, and lack of reaction consumption, calcium oxide is the preferred heterogeneous catalyst (Ferreira*et al.*,2012; Math*et al*., 2010).

Heterogeneous catalyst transesterification is more affordable than acid transesterification because the catalyst can be reused, the reaction takes place faster, no unwanted side reactions like saponification or hydrolysis occur, and washing with distilled water is not required (Singh & Fernando, 2007). According to Guo et al. (2010) findings a heterogonous catalyst was capable of producing a 95%

output under the following circumstances: a methanol to oil ratio of 7.5, 3% sodium silicate as a catalyst at a temperature of 60 °C, 60 minutes, and a 250-rpm mixing rate.

The co-solvent addition required to facilitate mass transfer between reactants is a drawback of heterogeneous catalyst (Encinar*et al.*, 2016). The absence of side reactions like the saponification reaction, a quick reaction time, and the elimination of soap generation are all benefits of heterogeneous catalysts. Moreover, heterogeneous transesterification takes place at low temperatures, low pressures, and low mixing rates (Singh & Fernando, 2007).

Many heterogeneous catalysts for the transesterification process were studied. Due to its weak solubility in methanol, they discovered that calcium oxide had an incredibly basic strength and minimal environmental consequences. Among the group II oxides, magnesium oxide exhibited the lowest basic strength and methanol solubility. Because of their high acidity qualities, transition metal oxides including zirconium, titanium, and zinc have received a lot of attention for use in the synthesis of biodiesel. When utilized to catalyze esterification and transesterification at the same time, these catalysts demonstrated good catalytic activity and good stability. They had not, however, been utilized in the industrial manufacturing process, mostly due to the high cost of the catalyst and the difficulties of filtering the tiny catalyst particles.

Supercritical methanol transesterification (Elgharbawy *et al.*, 2021)
Supercritical methanol transesterification is the process of producing biodiesel from triglycerides using alcohol under extreme pressure and temperature (supercritical circumstances) without the aid of a catalyst. The advantages of this process include the lack of a catalyst, high yield, resistance to high free fatty acid and water contents, the absence of side reactions, a diversity of feedstock sources, fewer transesterification steps, and a biodiesel yield of over 96%(Demirbas, 2009).

Transesterification can be done directly on any feedstock with any specification because supercritical methanol transesterification isinsensitive to FFA and water and that soap production is stopped by the absence of a catalyst (Kiwjaroun *et al.*, 2009; Thaiyasuit, *et al.*, 2012)

The harsh operating conditions of the supercritical methanol transesterification, which can reach temperatures and pressures of up to 350 °C and 20 MPa, constitute a drawback. Moreover, a significant amount of alcohol is required to finish the reaction (Kusdiana&Saka,2001). As a result of its high production costs, this procedure is uncommon.

According to Acquaye, et al. (2012), the supercritical methanol transesterification process worked well when the feedstock contained a lot of water and FFAs. They looked at several molar ratios of rapeseed oil to methanol under reaction settings between 200°C and 500°C. The greatest biodiesel production of 95% was attained with a 350°C reaction temperature and a 42:1 molar ratio of rapeseed oil to methanol.

Methanol and ethanol were employed in the supercritical transesterification by Karki et al. (2017) The studies used oil to alcohol molar ratios of 1:6, 1:12 and 1:18 for both alcohols, reaction times of 0 to 60 minutes, and temperatures of 250, 270, and 290 °C. The conversion improved as the reaction temperature and duration were raised. In a reaction time of 60 minutes, the conversion was over 96% at 290 °C, and the oil.

Enzymatic transesterification (Elgharbawy *et al.*, 2021)
Triglycerides and FFAs are converted into biodiesel through the process of enzymatic transesterification, which uses lipases enzymes as a catalyst. A clean and environmentally acceptable method of producing biodiesel is the enzymatic method. Triglycerides and FFA can both be turned into biodiesel at the same time (Imahara, *et al.*, 2008; Wei, *et al.*,2013). Enzymatic transesterification is characterized by a low operating temperature (35 to 45 °C), the absence of glycerol production, the removal of side reactions or by-products, insensitivity to the presence of FFAs or water in feedstock, high yield, and the ability to reuse the catalyst (Math, *et al.*, 2010; Murphy *et a*l., 2014].

The disadvantages of enzymatic transesterification include the expensive cost of the catalyst, the slow reaction rate, the reduced activity, and the catalyst's sensitivity to alcohol. Which results in a lower yield of biodiesel (Bajaj*et al.*,2010; Komintarachat&Chuepeng,2010.Regrettably, scholarly publications and the media continue to have these issue.

3. Conclusion

A betterment of people's standard of life is greatly aided by energy. Fish waste, once regarded as a solid waste, has a number of uses. They have a great potential to produce biodiesel, which is a kind of energy. Due to its renewable status and favorable effects on the environment. Utilizing low-quality feedstocks, such as fish wastes, which do not compete with the food supply is considered to be an effective way to lower the cost of producing biodiesel. Biodiesel manufacturing is a straightforward procedure that does not require a complex technology or permission. Fish wastes could convert in to fish oil. This oil can convert into biodiesel through transesterification process.Acid-catalyzed, alkaline-catalyzed, enzyme-catalyzed, and non-catalyzed supercritical methanol are the four main types of transesterification processes. Among that Base-catalyzed method is great option as the reaction procedure, cost, and yield is good compare with other techniques. Therefore, this most advanced biofuel technologiesmake it the perfect replacement for prolonging the lifespan of diesel.

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The authors declare no competing interests.

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