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A REVIEW ON BIODIESEL AND ITS PRODUCTION TECHNOLOGIES

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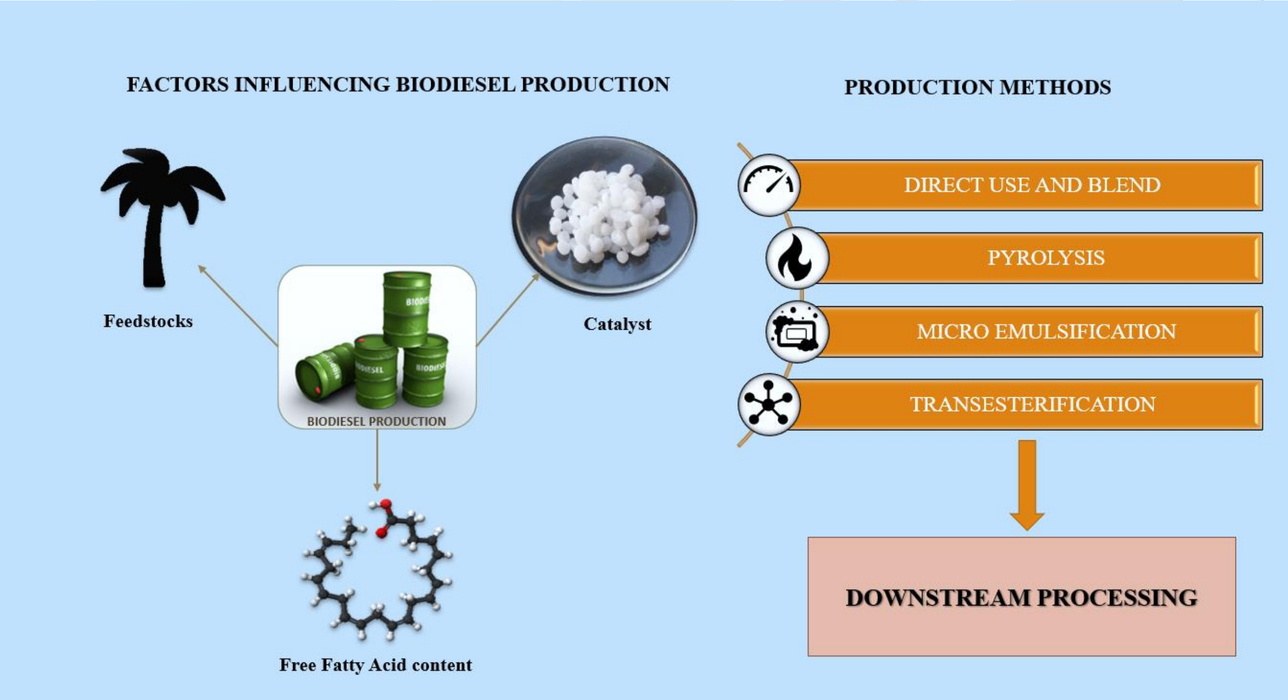
GRAPHICAL ABSTRACT



HIGHLIGHTS

- Biodiesel is a renewable, clean-burning, and potential substitute for conventional diesel fuels.
- The cost of Biodiesel could be reduced if not for their feedstock cost, accounting for 75% of the total production cost.
- Biodiesel properties depend on the type of feedstock used, the catalyst used, and the amount of free fatty acid present.
- Biodiesel production methods also impact the final Biodiesel properties.

ABSTRACT

Biodiesel is a fuel that has multiple advantages over regular conventional diesel. It is made from renewable materials, emits fewer pollutants into the atmosphere, and is biodegradable which makes it less toxic and its overall production can be redistributed which increases its potential to develop rural economies. The production technologies of Biodiesel in industries are changing in a broader range at a faster pace today. While the effects of fossil fuels are simultaneously being drastic due to the associated hazards, researchers across the globe are striving hard to find solutions to counter the effects. This is when Biodiesel steps in gaining global popularity concerning a biomass-based fuel which appeared as a timely solution. Many options for processing are available for the production technologies of Biodiesel, which is due to the varieties of raw materials and processing technology options that are available for Biodiesel production. Quality of feedstock, its source, its type, and catalyst used to impact the choice of a particular technology. The steps involved during postproduction such as separation of the product, its purification along with the recovery of the alcohol and catalyst also impact methods for processing. While all these factors are considered, the cost of feedstock seems to be a more prominent factor influencing production, since the capital costs only account for 7-8% of the total costs. Hence the use of cheap feedstock is of importance in Biodiesel production technologies. Even after being consigned to the shadows for so many years, biodiesel has effectively remained an energy source.

Keywords: Biodiesel, feedstock quality, catalyst, conventional, biodegradable

1. Introduction

Over the last few years, consumption of energy has grown drastically due to development in lifestyles and population growth. Fossil fuels although contributing to 80% of world energy requirement, also contribute to the increase in energy demand, as they are limited, non-renewable, and environmentally hazardous (Daming Huang et al., 2012; Ivana B et al., 2012). Fossil fuels are the primary source of greenhouse gases whose devastating effects on environmental pollution, ozone destruction, and human health are not hidden. To meet these issues, sources of alternative energy which are sustainable, feasible in terms of cost, as well as ecologically friendly are sought. Biodiesel has a lot of promise as a substitute fuel. It is a non-toxic, biodegradable fuel that helps to reduce carbon dioxide emissions by photosynthesis recycling. This reduces the greenhouse gas emissions caused by biodiesel combustion (Ivana et al., 2012; Talavari et al., 2021). Biodiesel may be obtained by a chemical process, which involves blending fat or oil with an alcohol such as ethanol or methanol. In the commercial manufacture of biodiesel, methanol has been the most often utilized alcohol (Elkady et al., 2015).

One of the significant issues with biodiesel is the high production cost, which can be mitigated by converting waste from biofuel production into useful coproducts (Wahlen *et al.*, 2012). According to reports, the raw material costs around 80% to 85% of the overall biodiesel production cost. As a result, numerous studies are being conducted in order to identify an appropriate raw material for the production of biodiesel.

2. Feedstocks used for production

Biodiesel production is highly reliant on feedstocks, which are various kinds of raw materials used in industrial processes. The selection of feedstock is the most crucial phase in the biodiesel production process. It is well known that each form of feedstock has a different fatty acid composition, which determines the biodiesel properties and, in turn, influences biodiesel quality (Pikula *et al.*, 2020). It is defined as a long-chain fatty acid ester that is made using biological and renewable raw materials such as animal fat, vegetable oil, used cooking oil, or algae (El-gharbawy *et al.*, 2021). Currently, biodiesel is produced from superior quality vegetable oils i.e., soybean oil and rapeseed oil using alkaline and methanol catalyst. It is inconvenient to use high-quality edible oils since the final production cost is determined by the type and price of feedstock used. Currently, feedstock accounts for at least 80% of biodiesel production costs (El-gharbawy *et al.*, 2021; Canakci *et al.*, 2008). Haas *et al*., (2006) conducted a study to look into the relationship between biodiesel production costs and feedstock costs. According to the findings, there is a linear association between the two, with a shift in commodity cost of US $0.020/l for every change in oil cost of US $0.022/kg. This implies that the mass input and mass production of feedstock and biodiesel are roughly equal (Canakci *et.al.*, 2008). For example, biodiesel made from virgin vegetable oil was found to be more expensive than biodiesel made from fossil fuels. The high cost of raw materials was the reason for the difference in the cost.

Because the expense of biodiesel is a key barrier to its marketing, a variety of other low-cost feedstocks have been considered. Less expensive feedstocks such as animal fats, cooking oils, soap stocks, non-edible oil, and greases are potential alternatives to make profitable biodiesel (Canakci *et.al.*, 2008; Gnanprakasam *et.al.*, 2013).

2.1.Plant-based feedstocks

Major sources of feedstocks are obtained from vegetable oils produced from various plant sources. Depending on the type of oil obtained, they are grouped into two categories

2.1.1.Edible Source

Edible oil is made from various vegetable which is commonly used by humans as a source of food. It's noteworthy because of its nutritive value and related health benefits. Biodiesel generation with edible oil reduces the need for additional chemical processing. However, due to high demand and insufficient availability of capital, it faces an economic disadvantage (El-gharbawy *et al.*, 2021). The following are the most popular edible oil feedstocks used in biodiesel production.

Soybean oil

Soybean oil is produced in 222 million tonnes everywhere in the world, mostly in the US, Brazil, and East Asia. Because of its health benefits, it is regarded as a significant edible oil. The USA is the leading producer of soybean and is a possible feedstock for the processing of biodiesel, according to studies. It is estimated that 1.3 litres of soybean oil are needed to produce one litre of biodiesel (El-gharbawy *et al.*, 2021).

Cashew oil

Anacardium occidentale L, most commonly known as cashew, is a member of the Anacardiaceous family whose origin is from the tropics. It's well-known for its therapeutic and dietary benefits. The fruit appears as a grey-coloured pseudo-fruit consisting of two varieties of oil, one of which is brownish-black in colour, corrosive and vicious. This is used to keep insects at bay. The other is light amber and contains a lot of fatty acids. It has begun to be seen as a possible biodiesel feedstock (Lafont *et al.*, 2015).

Rapeseed oil

Rapeseed, also known as canola, is a yellow flower widely grown in Europe and Canada. Rapeseed oil is a high-productivity oil that produces 1 litre of biodiesel per 1.1 litres of rapeseed oil (El-gharbawy *et al.*, 2021).

Palm oil

Palm oil is an essential edible oil since 75% to 90% of it is used in the food industry, with the rest going to industrial uses. Palm oil has high biodiesel productivity, with 1.25 litres of palm oil-producing per litre of biodiesel. Seeds of the palm tree are a source of palm oil and have an oil quantity of 20–21 percent by weight. *Cocos nucifera* is a palm tree that belongs to the Aceraceae family most commonly known as coconut. Before transesterification, palm oil must be treated to extract solid particles, water, colour, and odour, post-treatment, the palm oil-free fatty acid content is reduced to 0.1 percent (El-gharbawy *et al.*, 2021; Lafont *et al.*, 2015).

It's estimated that edible oils are used in 95 percent of biodiesel production. Owing to the food vs. fuel problem, this is seen as undesirable. The use of such natural resources has resulted in high food prices and deforestation problems, raising global environmental and energy concerns. As a result, scientists focused their efforts on non-edible oils. They are inexpensive, have a high triglyceride content, and solve the problems associated with edible oils. To reduce overall biodiesel prices, using inexpensive non-edible or edible feedstocks such as waste cooking oils, jatropha curcas, and camelina sativa oils can be an appealing choice (El-gharbawy *et al.*, 2021; Gude *et al.*, 2013).

2.1.2. Non-Edible Source

Non-edible oil is inedible to humans because it is unhealthy and unsanitary; it is mostly utilized in industry-based applications such as biofuel, soap, detergent, and the painting industry. Animal fats, castor, jatropha, jojoba, and used frying oils being the most commonly used non-edible source of oil feedstocks for the production of biodiesel. High content of Free fatty acid (FFA's) in non-edible oil tends to react with the base catalyst, forming soaps and emulsions, which reduce the overall biodiesel yield as well as inhibit the base transesterification. As a result, before the transesterification reaction, the concentration of FFA's should be reduced (El-gharbawy *et al.*, 2021). Some examples are Karanja, Jatropha tree, Tobacco seed, Rubber seed tree, castor bean tree, etc (Gnanprakasam *et al.*, 2013).

Castor oil plant

The castor oil vine, Ricinus communis, belongs to the Euphorbiaceae family of plants. Originated from Africa, the Castor oil plant is a small woody tree that grows to around 6 metres in height. This plant produces castor oil which is a clear or pale-yellowish in colour liquid with a peculiar flavour and aroma. With a density of 961 kg/m^3, its boiling point is 313°C. Castor oil's viscosity is seven times greater compared to that of other vegetable oils. Biodiesel obtained from castor oil has much lesser cloud point and pour point, making it an excellent choice for winter use. However, the viscosity of castor oil biodiesel does not meet international biodiesel fuel requirements. However, compared to Jatropha curcas and Pongamia pinnata, Ricinus communis has a far shorter growing season and farmers with much more experience and knowledge of its cultivation (Ivana *et al.*, 2012; El-gharbawy *et al.*, 2021).

Jatropha

Jatropha plant seeds are used to extract the oil. Jatropha is a favourable biodiesel resource in Egypt, particularly because it is the most prominent biodiesel resource in Asia and Africa. It is grown in high-temperature conditions using sewage water. Because its seeds contain oil in the region of 30-35 weight percent, which may be converted to biodiesel, jatropha oil has a high biodiesel output. Jatropha oil is utilized in sectors such as soap, cosmetics, and lubricants (El-gharbawy *et al.*, 2021).

Mahua

Mahua, mostly named as the butternut tree, is a massive tree whose span of height is 10–15 metres. It is a member of the Sapotaceae family. Every year, 20 to 40kg of seeds are produced per tree. The oil content of Madhuca indica seeds is 35% and the protein content is 16%. The oil of Mahua has more amount of FFAs, ranging up to 20%. A method for obtaining biodiesel from Mahua is urgently needed (Ivana *et al.*, 2012).

Pongamia pinnata

Pongamia pinnata commonly referred to as Karanja is a perennial tree that grows to be around the size of a medium-sized shrub native to Southeast Asia and Australia's littoral regions. It's a 12–15m tall hardy tree with a hemispheric crown of dense green leaves. Oilseed yield per tree ranges from 8 to 24kg. The amount of oil in Pongamia pinnata seeds has a range of 30% to 40%. Since its oil is less harmful and less expensive than the oil of Jatropha curcas, it has been the major focus for the study of biodiesel production (Ivana *et al.*, 2012). Pongamia can become a promising source for biodiesel in the future, particularly in hot and dry climates, due to its favourable economic and environmental characteristics (Ziolkowska *et al*., 2014).

2.1.3. Waste cooking oil

Used cooking oil has several advantages that make it a promising biodiesel substitute. When compared to other oils, it is distinguished by its ease of collection from restaurants and homes, renewability, low cost, and availability. Furthermore, it reduces the need for land to be used for biodiesel-producing crops. Free fatty acids (FFAs) are prominently found in used cooking oil. FFAs are unfavourable substances since they obstruct the overall yield of biodiesel along with the transesterification reaction, hence they are required to be reduced and treated to a manageable level. In the United Kingdom, used cooking oil is used to make 89 percent of biodiesel (Ivana *et al.*, 2012).

Table 1. Differences between non-edible and edible oil (Ivana *et al.*, 2012)

Factors	**Edible oil**	**Non edible oil**
The source	Vegetable sources	Vegetable oils, petroleum oils
Composition	Consist of nutritional elements	They are not healthy and do not have nutritive value
Oil extraction	Chemical treatment is not necessary for oil extraction	Various chemical treatments are required to extract oil.
Use	Humans consume it as food	Mainly used to produce detergents, soaps and biofuels
Price	High	low
Example	Soybean, cashew, rapeseed, palm	Jatropha, jojoba, waste cooking oil

2.2. Microorganism based feedstock

Concerns about the limited supply of land for an expanding human population, along with environmental, social, and climatic problems related to the usage of food crops and crops for feed as an energy source have sparked curiosity in using microorganisms to produce biodiesel. In the field of biodiesel processing, microorganisms such as yeasts, bacteria, cyanobacteria, and microalgae can also be used. The best candidates for this function are cyanobacteria and microalgae (Pikula *et al.*, 2020; Busic *et al.*, 2018; Wang *et al.*, 2012). Microorganisms, which are normally single-celled organisms, can not only provide substrates for biodiesel syntheses such as fatty acids and alcohols, but they can also act as a catalyst during the process (Lin *et al.*, 2012).

In their cellular compartments, microorganisms are well known to create oil naturally (Patel et al., 2020). Microbial lipids or single-cell lipids are generated by microorganisms and are regarded as the most effective feedstock for biodiesel production because of their similarity to vegetable oils. These microbial lipids serve as a non-edible raw material for the production of biodiesel (Busic *et al.*, 2018; Patel *et al.*, 2020). Oils produced from microorganisms are advantageous compared to plants or vegetable oils, including higher efficiency, faster genetic modifications for particular products, upstream and downstream processing, and the ability to grow in a regulated environment without being affected by the weather (Patel *et al.*, 2020).

2.2.1. Oleaginous Microorganisms

Oleaginous microorganism's lipid amounting to more than 20% on the basis of cell dry weight. Some organisms can synthesis lipids to an extent of 70% w/w dry weight basis of the cell, which is influenced by culture conditions. Most of the lipids produced by oleaginous microorganisms have unbranched carbon chains with a length of 4 to 28. It may be unsaturated or saturated fatty acids, based on the content of the hydro carbonated chain, or monounsaturated or polyunsaturated fatty acids which depends on the number of double bonds. Oleaginous microorganism's fatty acid profiles might be utilised to make biodiesel or nutraceuticals (Patel *et al.*, 2020). The benefits of oleaginous microorganisms include high growth rates and lipid yields. The lipids from oleaginous microorganisms could be used to make biodiesel, with the following steps: oleaginous microorganism cultivation, harvesting, drying, and extraction of lipid from oleaginous microorganisms, along with the synthesis of biodiesel through lipid transesterification. However, not all of them can be used to make biodiesel. Subramaniam et al. describe the major oleaginous microorganisms used in microbial oil production. Many oleaginous microorganisms (moulds, bacteria, and yeasts) utilize sugary or starchy organic substrates or lignocellulosic materials to produce lipids. This is also known as Second generation microbial oil production (Busic *et al.*, 2018; Wang et al., 2012). Oleaginous microalgae are the third generation of microbial oil producers because they are autotrophic bacteria that can create lipids directly from CO_2 (Busic *et al.*, 2018).

2.2.2. Microalgae

Microalgae are the earliest type of microorganisms on the planet. They can be found in all environments and exist in a variety of conditions (Matuszewska *et al.*, 2016). Microalgae as a feedstock could help meet rising global demand for biodiesel while posing fewer environmental and food security risks than traditional edible or non-edible oil feedstocks (Tabatabaei *et al.*, 2015). They are unicellular plants in their most basic form. They lack leaves, branches, and roots that are fully developed. These organisms have a very basic cell structure, which makes it relatively easy for them to adapt to new environments. Microalgae can conduct photosynthesis because they have chlorophyll built into their cells. However, certain plants are heterotrophic, requiring additional organic carbon and energy sources to thrive. Also, there are Mixotrophic microalgae that can switch from autotrophic to heterotrophic nutrition depending on the environment. It also has a lot of biodiversity; over 100 000 species of these organisms are known to exist. Their pigment type, life cycle, and cellular structure vary from those of other organisms (Patel *et al.*, 2020; Matuszewska *et al.*, 2016). Microalgae are utilized to get various other kinds of biofuels. Microalgae uses both biochemical or thermochemical routes which are suitable for the conversion of microalgae to useful energy. Biodiesel can be obtained from extracted microalgae oil, biohydrogen in the dark fermentation stage, anaerobic digestion of microalgal biomass to produce biomethane or bioethanol by fermentation of ethanol. The most important step in algae biomass conversion, regardless of the method, is to select the suitable feedstock for the production. Microalgae are commonly grown in specialized systems such as open ponds and various types of photobioreactors. Species collection, cultivation, processing, biomass concentration, and algae pre-treatment before conversion are the key steps in the microalgae conversion method (Matuszewska *et al.*, 2016).

3. Composition/properties of Biodiesel

Biodiesel fuel characteristics are affected by the fatty acid chain and alcohol moiety, both of which are components of fatty esters, and altering either will resulting in fuel properties changes. The fatty ester profile has a significant influence on biodiesel characteristics (Hoekman *et al.*, 2012).

It is made up of Fatty Acid Methyl Esters (FAME), which are usually obtained from animal fats and vegetable sources that underwent transesterification. When comparing the fatty acid profiles of common feedstocks, there is a lot of variation in composition. Coconut, palm, and tallow, for example, are high in saturated fatty acids, while rice, safflower, rapeseed, soy, and sunflower are high in unsaturated fatty acids. In contrast, little is known about the Fatty Acid content of algal lipids which could be used as biodiesel raw materials. Although, few algal groups have significantly elevated levels of Poly-Unsaturated Fatty Acids (PUFA) than standard vegetable oils (Hoekman *et al.*, 2012).

Quality standards for biodiesel production, marketing, and storage are being established and applied worldwide in order to ensure the final quality of the product and customer trust (Masjuki *et al.*, 2013). Viscosity, Density, iodine value, cetane number, acid value, pour and cloud stage, range of distillation, ash content, flash point, sulphur content, copper corrosion, carbon residue, and greater heating value are all physical and fuel properties of biodiesel (HHV) (Ivana *et al.*, 2012).

Biodiesel usage in diesel engines is permitted based on the characteristics included in table 2. Biodiesel can be made from either good grade quality vegetable oils or low-cost, low-grade feedstocks as long as these standard values are followed (Ivana *et al.*, 2012; Canakci *et al.*, 2008). Table 2 indicates the essential biodiesel fuel properties and their standards in the EU and US:

Table 2. Properties of Biodiesel fuel

Property with units	Limits
Kinematic viscosity (at 40°C), mm^2 /s	3.5-5.0
Density (at 15°C), kg/m^3	860-900
Cetane number	51 min
Flash point, °C	120.0 min
Water, mg/kg	500 max
Sulfated ash, Mass (%)	0.02 max
Sulfur, mg/kg	10.0 max
Copper strip corrosion (3 h, at 50°C)	No.1
Carbon residue (10% sample), Mass (%)	0.3 max
Acid number, mg KOH/g	0.5 max
Free glycerol, Mass (%)	0.02 max
Total glycerol, Mass (%)	0.25 max
Phosphorus content, mg/kg	10 max
Iodine number	120 max
Oxidative stability (at 110°C),h	6 min
Monoglyceride content, Mass (%)	0.8 max
Diglyceride content, Mass (%)	0.2 max
Triglyceride content, Mass (%)	0.2 max

3.1. European standards for biodiesel (EN 14214) [Canakci *et al.*, 2008]

Property with units	**Limits**
Kinematic viscosity (at 40°C), mm^2 /s	1.9–6.0
Cetane number	47 min
Flash point (closed cup), °C	130.0 min
Cloud point, °C	Report
Water and sediment, Volume (%)	0.050 max
Sulfated ash, Mass (%)	0.020 max
Sulfur, Mass (%)	0.05 max
Copper strip corrosion	No. 3 max
Carbon residue (100% sample), Mass (%)	0.050 max
Acid number, mg KOH/g	0.80 max
Free glycerol, Mass (%)	0.020 max
Total glycerol, Mass (%)	0.240 max
Phosphorus content, Mass (%)	0.001 max
Distillation temperature (90% recovered), °C	360 max

3.2. American standards for biodiesel (ASTM D-6751) (Canakci *et al.*, 2008)

3.2.1. Viscosity

One of the most crucial features of engine fuel is its viscosity. It is important in the spraying of gasoline, the formulation of mixtures, and the combustion phase. Biodiesel specifications specify viscosity in the context of kinematic viscosity, which is greater compared to that of fossil fuel, and it can become very viscous or even solidify at low temperatures in some situations. The injection spray and volume flow dynamics in the engine can be affected by high viscosity. It can also jeopardize the mechanical stability of the injection pump drive systems at low temperatures. Along with the increasing chain length and saturation, the viscosity level of a fatty ester rises. Only cis double bonds allow viscosity to be reduced, as trans double bonds cause viscosity to be close to that of their saturated counterparts. Soy methyl esters have a kinematic viscosity of 4.0–4.1 mm^2 /s, except for rapeseed (canola) whose kinematic viscosity is 4.4 mm^2 /s for methyl esters (Ivana *et al.*, 2012; Canakci *et al.*, 2008; Knothe *et al.*, 2010).

3.2.2. Density

Another vital characteristic of biodiesel fuel is its density, which is defined as mass per unit volume at a certain temperature. The breakdown of the fuel pumped into the cylinder is affected by the fuel's density. Furthermore, as the fuel density rises, fuel is pumped mass-wise. Compared to diesel fuels, biodiesel fuels are less compressible and denser, regardless of whether they are made from vegetable oils or fats. Density and compressibility, like viscosity, have a major impact on the engine fuel injection system. These criteria possess an influence on the volume of fuel pumped, the injection timing, and the injection spray pattern (Ivana *et al.*, 2012; Canakci *et al.*, 2008).

3.2.3. Flash point

The flashpoint is defined as an indicator of its flammability, making it a critical safety criterion for transportation and storage. The least temperature at which fuel can suddenly burn without the presence of spark or flame is known as its flashpoint. This temperature is linked to its instability, which is a significant fuel characteristic for starting and warming an engine. Misfire and ignition delay are all caused by a fuel's mix of high viscosity and low volatility. Diesel fuels have a flashpoint that is half that of biodiesel fuels, which is a huge safety advantage for biodiesel. Pure biodiesels have a much higher flash point than the recommended caps, but this will drop steadily as the residual alcohol content rises. The flashpoints of non-edible oil's methyl esters are very high, making them less reactive and simpler to ship or treat than diesel fuel (Ivana *et al.*, 2012; Canakci *et al.*, 2008; Knothe *et al.*, 2010).

3.2.4 Cold flow

The characteristics of the individual components have an effect on the properties of the low-temperature of biodiesel. Fatty acid ester's melting point raises along with the length of chain and saturation (even though odd-numbered chains have significantly lower melting points than even-numbered chains). As a result, mixtures like biodiesel have melting ranges, which are mirrored in the biodiesel standards requirements. The pour and cloud points of a fuel decide its cold-flow consistency.

When a liquid is cooled, the cloud point is defined as the particular temperature at which a cloud of wax crystals is formed. Since the crystals can clog the fuel pipes, they can create complications during service.

The pour point is the least temperature at which gasoline continues to flow and be injected. The cloud and pour points of all biodiesel fuels, regardless of their source, are higher than those of diesel fuel, and this weak cold flow property is regarded as the most important barrier to widespread biodiesel use.

Biodiesel's cold-flow characteristics are heavily influenced by its fatty acid composition. Biodiesel fuel's freezing point raises with a rise in carbon atoms present in the chain and tends to fall with the number of double bonds present. Biodiesel made from feedstocks rich in saturated fatty acids should have higher pour and cloud points. Despite the fact that these low-temperature characteristics are the most prominent characteristics that determine the appropriateness of biodiesel fuels that are put into use, due to considerable seasonal and regional temperature fluctuations, neither the US nor European biodiesel specifications contain solid criteria for them (Canakci *et al.*, 2008; Hoekman *et al.*, 2012; Masjuki *et al.*, 2013; Knothe *et al.*, 2010).

3.2.5. Oxidative stability

The oxidation stability of biodiesel is another significant factor to consider. This property indicates how resistant the fuel is to oxidation during long-term storage. The copper strip has the greatest catalysing effect on oxidation, so it determines oxidation equilibrium. At normal temperatures, hydroperoxides are the initial products of oxidation. As the oxidation progresses, the peroxides can break, forming short-chain acids, aldehydes, and ketones, which emit foul odours.

It is one of the essential fuel characteristics for biodiesel in-use efficiency. Gasoline that is unstable causes gum formation, silt, increase in viscosity and various other deposits Because of gum forming, oxidation gradually deteriorates the fuel properties. Although this gum does not entirely burn, resulting in particles of carbon in the combustion chamber and thickening of the lubrication fluid. Furthermore, as biodiesel oxidizes, its viscosity increases and its cetane number rises. As a result, oxidized biodiesel burns faster than unoxidized biodiesel, increasing NO_x emissions. The oxidation reaction of biodiesel fuel is influenced by its chemical composition.

Feedstocks that consist of a high level of polyunsaturated fatty acids are more susceptible to oxidation compared to feedstocks whose unsaturated fatty acid levels are high. This phenomenon is due to double bonds present in the chain Biodiesel are more prone to oxidative oxidation than diesel obtained from fossil fuels. This is due to the chemical composition of biodiesel. Such a phenomenon is true for fuels consisting of elevated proportions of unsaturated esters as the methylene group is susceptible to radical assault. Hence, as a result, it is critical to preserve oxidative stability (Canakci *et al.*, 2008; Hoekman *et al.*, 2012; Masjuki *et al.*, 2013; Knothe *et al.*, 2010).

3.2.5. Cetane number

A fuel's cetane number (CN) explains its tendency to burn under specific pressure and temperature conditions. It is the primary measure of fuel ignition efficiency and is the inverse of a gasoline's octane number. Polyunsaturated fatty acids are highly susceptible to oxidation compared to saturated fatty acids due to double bonds present in the chains. Because of their chemical makeup, biodiesel fuels are more prone to oxidative oxidation than fossil diesel fuels. This is especially true for fuels with a high percentage of di- and higher unsaturated esters because the methylene groups next to the double bonds are very susceptible to radical assault. As a result, it's critical to keep oxidative stability. The higher the cetane number, the faster the engine starts and the smoother the combustion. Low cetane numbers, on the other hand, result in poor combustion and higher hydrocarbon and particulate emissions in the exhaust gas. The cetane number will also affect how quickly a cold engine starts and how much white smoke and noise it emits. An elevated cetane value is equally as bothersome as a low cetane number. Since biodiesel has a greater cetane number than ethanol, it has a shorter ignition delay. Biodiesel fuels generated from long carbon chain feedstocks, such as waste greases and fats, possess greater cetane values compared to biodiesel made from oil obtained from vegetable sources. However, this difference has little bearing on the combustion process. The CN has minimum values of 47 (ASTM D6751) and 51 (ASTM D6751) in biodiesel standards (Canakci *et al.*, 2008; Hoekman *et al.*, 2012; Masjuki *et al.*, 2013; Knothe *et al.*, 2010).

3.2.6. Lubricity

Lubricity is known as the decrease of friction between solid surfaces in relative motion. Low–sulphur petrol diesel has proven to be inefficient, due to which the low lubricity must be restored by adding or blending with another lubricant-rich fuel. At a blended rate of around 2% and above, biodiesel that has naturally high lubricity restores lubricity to such low-lubricity diesel fuels. Although lubricity is not listed in biodiesel guidelines, it is one of biodiesel's main technological advantages (Hoekman *et al.*, 2012; Knothe *et al.*, 2010).

3.2.7. Total Glycerol

The amounts of free and bound glycerol found in the form of monoglycerides, diglycerides, and triglycerides make up total glycerol. Its concentration is determined by the manufacturing phase. Fuels that do not satisfy these requirements are vulnerable to coking, which can lead to deposits forming on valves, pistons, and injector nozzles (Masjuki *et al.*, 2013).

3.2.8. Phosphorus

Phosphorus of FAME comes from the feedstock's phospholipids (vegetable and animal matter) and used cooking oil. Phosphorus has a significant negative effect on exhaust pollution catalytic systems' long-term efficiency (Masjuki *et al.*, 2013).

4. Methods for production

Biodiesel production primarily involves four basic methods which are 1. Direct use and blending, 2. Thermal cracking (pyrolysis), 3. Micro emulsification, 4. Transesterification. Transesterification is the most preferred method for the production of biodiesel so far.

4.1. Direct use and blending:

Animal fat or vegetable oil should be utilised as a form of fuel indirect injection engines since it has a high heating value and can offer enough energy. However, because of its unfavourable characteristics, it cannot be employed in the DI engine without modification. To avoid any problems, alternative fuel sources are blended with existing fossil fuels. This form of mixing improves fuel efficiency while still lowering fossil fuel consumption, making it the most practical way to use renewable fuels like biofuels. Different ratios of oil and diesel can be used, such as 10:1, 10:2, 10:3, and so on (Rajalingam *et al.*, 2016).

In a study of biodiesel processing techniques, Ma *et al.*, (1999) found that the viscosity proportion of 50:50 (rapeseed oil and diesel) and 70:30 (whole rapeseed oil and diesel) mix were considerably greater than diesel. According to them, a 70:30 blend of rapeseed oil and diesel fuel-powered a single-cylinder diesel engine for 850 hours. Excessive wear, as well as impacts on the lubricating fluid and power production, were not observed (Shemelis *et al.*, 2017).

4.1.1.Thermal cracking:

Thermal cracking, also known as pyrolysis, is a method of cnverting a hydrocarbon's complex structure into its simplest structure, either with or without the use of a catalyst. Oil density and viscosity will be reduced as a result of this operation. These two properties have an effect on engine atomization by using vegetable oil as an alternative fuel (Rajalingam *et al.*, 2016; Shemelis *et al.*, 2017).

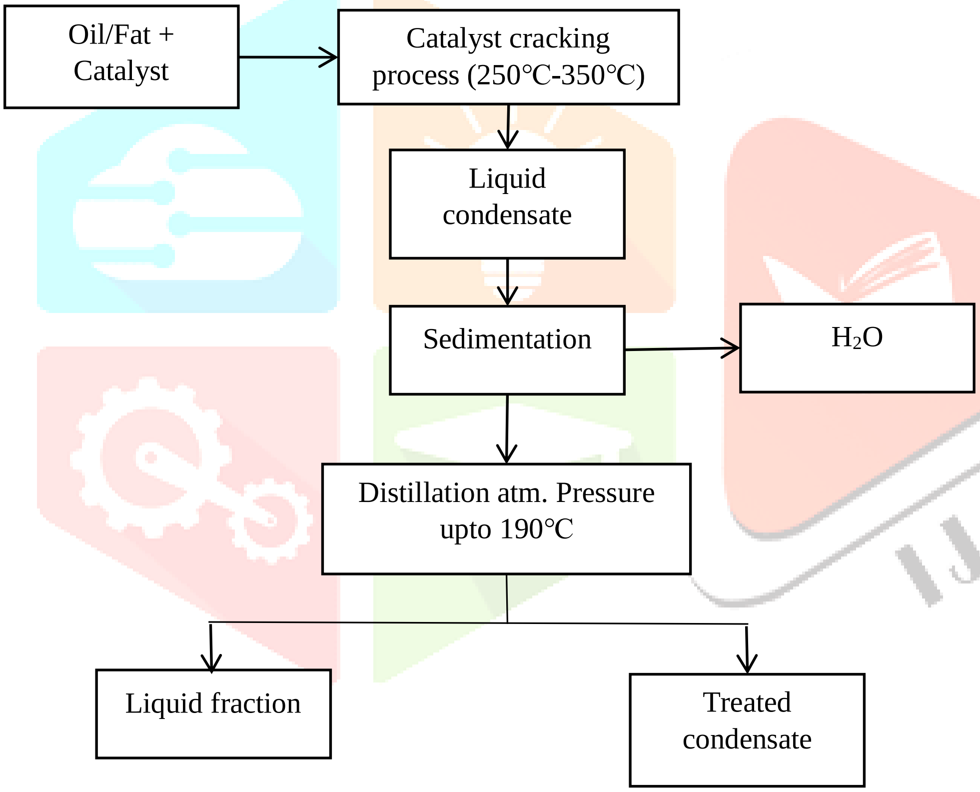


Fig1. Thermal cracking process (Rajalingam et al., 2016**)**

Pyrolysis takes place at temperatures between 400 ^{0}C and 600^{0}C. Based on the rate of pyrolysis, the process produces bio-oil, char and gases. It can be divided into three subclasses based on the operating conditions: traditional pyrolysis, quick pyrolysis, and flash pyrolysis (Shemelis *et al.*, 2017).

4.1.2. Microemulsion:

Microemulsions are liquid isotropic mixtures of water, surfactant, and oil that are thermodynamically safe. This step will overcome the viscosity problem as well as certain other oil atomization properties. Alcohol is commonly used to improve the oil's volatile properties, which lowers smoke. The cetane number improver would be alkyl nitrate. As pumped into the engine by the nozzle, the microemulsion process is often used to obtain a strong spry property. Incomplete combustion, carbon deposit, and nozzle loss can occur if micro emulsified fuel is used in a diesel engine (Rajalingam *et al.*, 2016; Shemelis *et al.*, 2017).

4.1.3. Transesterification:

The transesterification process produces biodiesel (mono alkali ester) and glycerol by reacting triglycerides in the vegetable with alcohol. In this step, the utilization of catalysts helps to increase the rate of reaction and improve the overall efficiency of the end product. The quantity of free fatty acid present in the feedstock oil estimates the amount and form of catalyst used. The increased volume of free fatty acid is detrimental to biodiesel processing, resulting in soap formation and lower biodiesel yield quality (Shemelis *et al.*, 2017). Transesterification, unlike the other processes, results in little to no carbon accumulation, and the substance has properties similar to petroleum diesel. There are two types of transesterifications: catalytic and non-catalytic. The category of catalysts used in catalytic transesterification is classified. Reactions under supercritical conditions are used in non-catalytic transesterification. Biodiesel is often generated using a combination of methods in operation (Sander *et al.*, 2010).

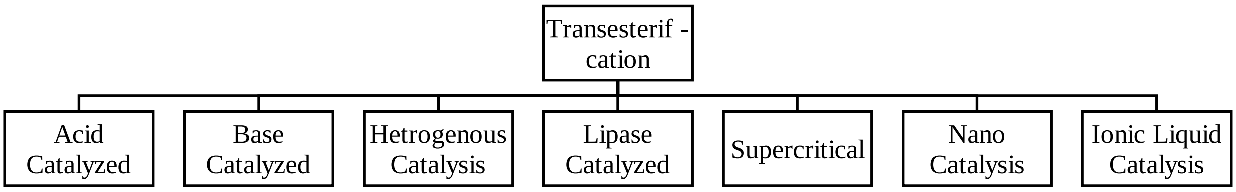


Fig 2. Representation of types of transesterifications (Shemelis *et al.*, 2017)

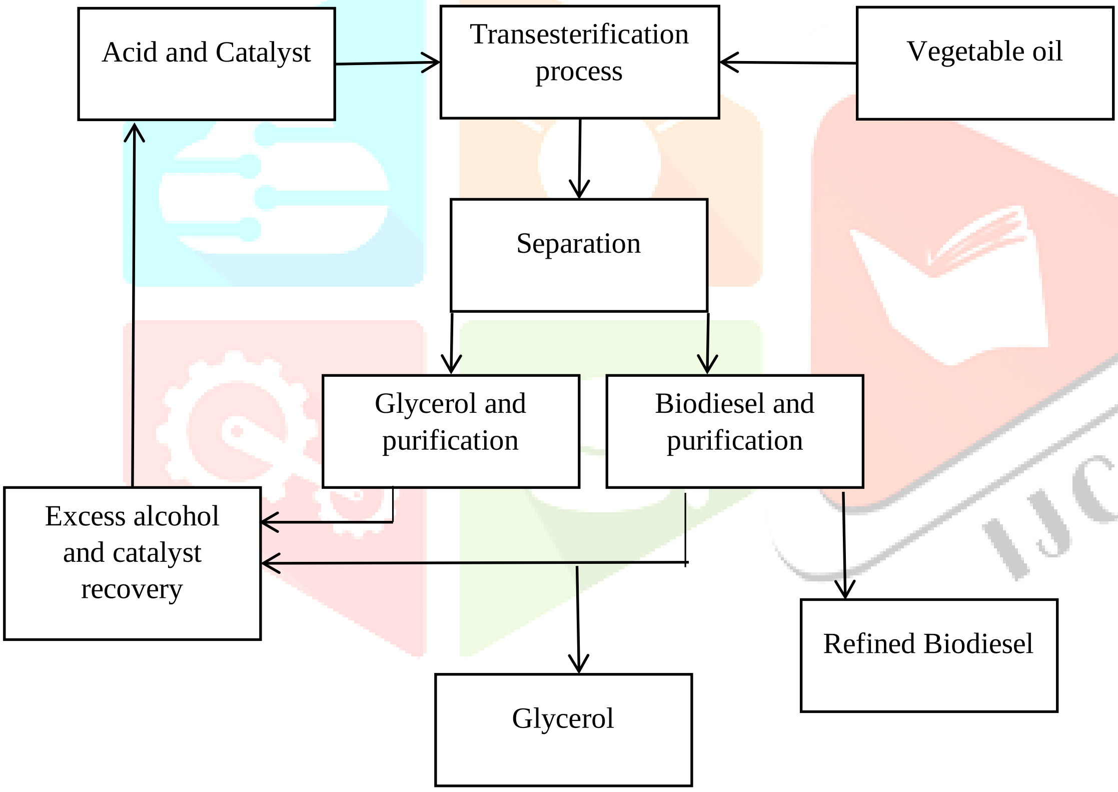


Fig 3. Transesterification process (Rajalingam *et al.*, 2016)

5. Downstream processing

Microorganisms with more than two-hundredths of super-molecule contents such as oleaginous microorganisms are helpful for oil extraction and ensuant biodiesel production. The algae's ability to supply a high quantity of lipids makes Protoctista feedstocks a good resource for biodiesel production. However, the lack of an extreme process that combines the numerous stages connected to the collection, extraction, and biomass to biodiesel conversion is the major cause for the increased expense of Protoctista biofuels. The downstream process might be the serial technique that includes Protoctista lipid production, harvest, oil extraction, and conversion to advanced biofuels. The extraction of supermolecules follows the collection and drying of microalgal biomass. The energy used to extract supermolecules from dried microalgal biomass makes up a small part of the overall energy life cycle of microalgal biofuels (Sander *et al.*, 2010). Various cell rupturing methods, such as autoclave, ultrasonic, mixing, and bead edge, is often used to extract oil from dry biomass (Kim *et al.*, 2013). The most common approach for extracting supermolecules from microalgal biomass is chemical solvent extraction. This is frequently due to a chemical solvent with high property and solubility toward supermolecules, and as a consequence, even the most intrepid are frequently extracted by diffusion over a microalgal semipermeable membrane.

Treatments involving enzymes, acids, organic solvents, and alkalis are often used for the biological or chemical breakdown of the semipermeable membrane (Ranjan et al., 2010). Physical ways, like cooling and diffusion shock, are additionally used for the oil extraction method. It's not advised to extract oil from microalgal biomass in mechanical ways because of the character of the thick microalgal semipermeable membrane (Lam et.al., 2012). The drawbacks of chemical-based solvents are that they primarily possess high toxicity towards humans and the surrounding environment.

Chemical-based solvents such as methanol, ethanol, and combined methanol-chloroform extract microalgal supermolecules, although the extraction potency varies greatly depending on the microalgal strain. A supermolecule isolated from microalgal biomass is prepared for rebirth as biodiesel. Soxhlet extraction is a very simple solid-liquid extraction method. The extracted solvent is gaseous, recondensed, and born into the instruments in the Soxhlet extractor. This due to the fact that the sample used stays in complete contact with the solvent, which is provided in a restricted quantity throughout the process. Also, this method has the potential to extort lipids efficiently. Such benefits make the extraction method a much preferable methodology for the quantification of lipids present in biological samples. However, the high energy utilization and lengthy extraction for the evaporation process are difficult (Kim *et al.*, 2013). As the oil is being extracted, the biodiesel is created through a transesterification reaction in wood spirit employing a heterogeneous catalyst or a homogenized acidic and alkalescent catalyst followed by in-place transesterification. This method is additionally a difficult task because of the issue within the recovery of the merchandise and also the production

The transesterification method is additionally favourable in biodiesel production due to the coinciding dilution of the oil and improvement of its alternative properties as a fuel. It's a chemical action route to get biodiesel, and also the catalyst might be an acid, base, or each in homogenized and heterogeneous forms, and enzymes. The foremost common thanks to manufacturing biodiesel by transesterification are, wherever triglycerides like vegetable oils are reacted with short-chain alcohol like the wood spirit or plant product within the presence of a catalyst (Mollahoseini *et al.*, 2015). For homogenization, alkali catalysts like KOH and NaOH are accustomed to accelerate the reaction. In contrast to homogenised catalysts, heterogeneous catalysts are frequently recycled, regenerated, and reused for further transesterification reaction cycles, increasing cost-effectiveness in biodiesel production.

While harvesting microalgae, the suspension contains a lot of water, therefore it's important to dry the biomass for a longer period time before extracting and trans esterifying it. As a result, broad biomass drying is typically suggested before the in-place transesterification reaction to prevent the possibility of any facet reactions that may affect the subsequent separation procedures. By in place transesterification, the extraction and transesterification occur during a single step, wherever lipid-bearing biomass comes directly in reality with chemical solvents within the presence of a catalyst.

Chemical solvent plays a major important role during this method. They act as a solvent to extract supermolecules from biomass. They additionally behave sort of like a chemical in the transesterification reaction (Lam *et al.*, 2012). This in-place transesterification caters to many benefits over standard biodiesel production methodology like they minimize the solvent separation step, cut back its interval, and consequently cut back the general biodiesel cost (Shuit *et al.*, 2010). Another benefit of generating biodiesel from microalgae using aqueous conversion technology is a hydrothermal physical change, which occurs when freshly obtained wet microalgal biomass is immediately treated without drying. In a hydrothermal physical change, water is heated to subcritical temperatures (200–350°C) under pressure to lower its insulating constant, which aids in the solubilization of less polar molecules (Mollahoseini *et al.*, 2015; Shuit *et al.*, 2010).

6. Applications and benefits

In comparison to the traditional source of fuel, fossil fuels, biodiesel has been described as an efficient and promising source of fuel. It has become more appealing in the current era as a result of the many advantages that come with it.

1. Many experts believe that diesel combustion is the major driver for the effects of global warming while biodiesel is considered to contribute considerably less to global warming compared to fossil fuels (Ilesanmi *et al.*, 2020).
2. As a "clean energy source," biodiesel may be a potential and efficient alternative to conventional fuels. It protects the ecosystem by lowering the levels of CO_2, SO_2, CO, H in the atmosphere (Solomon *et al.*, 2016).
3. Biodiesel is healthier than diesel oil in its levels of sulphur, aromatic content, biodegradability, and flashpoint.
4. Biodiesel production is less time-consuming and complicated than diesel production.
5. Since biodiesel has a Cetane range of over one hundred, it will improve the vehicle's efficiency. It also extends the life of the engine and decreases the maintenance cost as biodiesel lubricating properties are much better than that of fossil diesel (Almeida *et al.*, 2012).
6. Biodiesel has a lot of potential for exciting land rural growth and as a solution to the problem of energy supply (Ramos *et al.*, 2016).
7. Because biodiesel is generated locally, it is less expensive than diesel.

8. It's less virulent, more perishable, and has a better flash purpose, making it safer to treat.
9. Reduces piping pollution, visible smoke, and noxious smells and odours by being non-flammable and non-toxic (Sivasankaran *et al.*, 2020).
10. Greater combustibility.
11. Up to B_{20}, no engine modifications are needed (Masjuki *et al.*, 2013; Gerpen *et al.*, 2005).
12. Biofuels for vehicles are seen as a possible option for reducing carbon emissions because they reduce net emissions significantly (Ramos *et al.*, 2016; Juan *et al.*, 2016;
13. As a result, using biodiesel significantly reduces acid rain, which is a major environmental problem. Furthermore, since oxygen is present in the ester compounds of biodiesel, they facilitate cleaner-burning, resulting in lesser emissions of CO, HC, and particulate matter (Lourinho *et al.*, 2014).
14. Biodiesel is the first alternative fuel to successfully satisfy the criteria of the Clean Air Act's health impact monitoring (Mondal *et al.*, 2017).

7. Conclusions

Biodiesel is a potential and more appealing fuel for diesel engines due to its renewable nature and environmental benefits. The cost of biofuels is greater than that of fossil fuels, which is an important factor to consider. Low-quality raw materials, such as non-edible oils and animal tallow, are regarded as a much better means for lowering biodiesel production expense since they are not in competition with the supply of food and land used for the cultivation of food crops.

References

[1] Almeida, J.R.M., Favaro, L.C.L., Quirino, B.F., 2012. Biodiesel biorefinery: opportunities and challenges for microbial production of fuels and chemicals from glycerol waste. Biotechnol Biofuels. 5, 48.

[2] Busic., Arijana., Kundas, S., Morzak., Galina., Belskaya., Halina., Mardetko., Nenad., Ivancic, S., Mirela., Komes., Drazenka., Novak., Srdan., Santek., Bozidar., 2018. Recent Trends in Biodiesel and Biogas Production. Food Technology and Biotechnology. 56. 10.17113/ftb.56.02.18.5547.

[3] Canakci, M., Sanli, H., 2008. Biodiesel production from various feedstocks and their effects on the fuel properties. Journal of Industrial Microbiology and Biotechnology. 35 (5), 431–441.

[4] Chozhavendhan, S., Vijay Pradhap Singh, M., Fransila, B., Praveen Kumar, R., Karthiga Devi, G., 2020. A review on influencing parameters of biodiesel production and purification processes. Current Research in Green and Sustainable Chemistry. 1-2(1):1-6

[5] Daming, H., Haining, Z., Lin, L., 2012. Biodiesel: An Alternative to Conventional Fuel. Energy Procedia. 16 (C),1874-1885.

[6] Elkady, E.F., Ahmed, Z., Ola, B., 2015. Production of Biodiesel from Waste Vegetable Oil via KM Micromixer. Journal of Chemistry. Article ID 630168, 1-9

[7] El-gharbawy, A., Sadik, W., Sadek, O., Kasaby, M., 2021. A Review on Biodiesel feedstocks and production technologies. Journal of the Chilean Chemical Society. 66(1), 5098-5109

[8] Gerpen, J.V., Knothe, G., 2005. Basics of the Transesterification Reaction.The Biodiesel Hand book, 2nd edition.

[9] Gnanaprakasam, A., Sivakumar, V.M., Surendhar, A., Thirumarimurugam, M., Kannadasan, T., 2013. Recent Strategy of Biodiesel production from waste cooking oil and process influencing parmaters: A review. Journal of Energy. Article ID 926392, 1-10.

[10] Gude, V.G., Grant, G.E., Patil, P.D., Deng, S., 2013. Biodiesel production from low cost and renewable feedstock. Central European Journal of Engineering. 3 (4), 595-605.

[11] Haas, M.J., Andrew, M., Winnie, Y., Thomas, A.F., 2006. A process model to estimate biodiesel production costs. Bioresource Technology. 97 (4), 671-678.

[12] Hoekman, A.S., Broch., Amber., Robbins., Curtis., Ceniceros., Eric., Natarajan., Mani., 2012. Review of biodiesel composition, properties, and specifications. Renewable and Sustainable Energy Reviews. 16(1), 143-169.

[13] Ilesanmi, D., Emmanuel, B., Tunde, O., Khumbulani, M.,2020. Use of Central Composite Design and Artificial Neural Network for Predicting the Yield of Biodiesel. Procedia CIRP 89, 59-67.

[14] Ivana, B. B.I., Olivera, S. S., Vlada, B. V., 2012. Biodiesel production from non-edible plant oils. Renewable and Sustainable Energy Reviews. 16 (6), 3621-3647.

[15] Jadwiga, R.Z., 2014. Prospective Technologies, Feedstocks and Market Innovations for Ethanol and Biodiesel Production in the US. Biotechnology Reports. 4, 94-98.

[16] Knothe, G., 2010. Biodiesel: Current Trends and Properties. *Top Catal* .**53,** 714–720.

[17] Kim, J., Yoo, G., Lee, H., Lim, J., Kim, K., Kim, C.W., Park, M.S., Yang, J.W., 2013. Methods of downstream processing for the production of biodiesel from microalgae. Biotechnology. Adv. 31, 862–876.

[18] Lafont., Jennifer., Espitia., Amelia., Sodre., Jose., 2015. Potential vegetable sources for biodiesel production: Cashew, coconut and cotton. Materials for Renewable and Sustainable Energy. 4:1 10.1007/s40243-014-0041-6.

[19] Lam, M.K., Lee, K.T., 2012. Microalgae biofuels: a critical review of issues, problems and the way forward. Biotechnology. Adv. 30, 673–690.

[20] Lin., Hui., Wang., Qun., Shen., Qi., Zhan., Jumei., Zhao., Yuhua., 2012. Genetic engineering of microorganisms for biodiesel production. Bioengineered. 4(5):292-304 10.4161/bioe.23114.

[21] Lourinho, G., Brito, P., 2014. Advanced biodiesel production technologies: novel developments. Reviews in Environmental Science and BioTechnology. 14, 287-316.

[22] Ma F, Hanna MA (1999) Biodiesel production: a review. Bioresource Technol 70: 1–15.

[23] Masjuki, H.H., Kalam, M. A., 2013. An Overview of Biofuel as a Renewable Energy Source: Development and Challenges. Procedia Engineering. 56, 39–53.

[24] Matuszewska, A., 2016. Microorganisms as Direct and Indirect Sources of Alternative Fuels. 10.5772/62397.Alternative Fuels, Technical and Environmental conditions.Intech Open Science.

[25] Mondal, M., Goswami, S., Ghosh, A., Oinam, G., Tiwari, O.N., Das, P., Gayen, K., Mandal, M. K., Halder, G.N., 2017. Production of biodiesel from microalgae through biological carbon capture: a review. 3 Biotech. 7(2), 99

[26] Mollahoseini, A., Tabatabaei, M., Najafpour, G.D., 2015. Biofuel production. Adv. Biochem. Eng. Biotechnol. 2, 597–630.

[27] Patel, A., Karageorgou, D., Rova, E., Katapodis, P., Rova, U., Christakopoulos, P., Matsakas, L., 2020. An Overview of Potential Oleaginous Microorganisms and Their Role in Biodiesel and Omega-3 Fatty Acid-Based Industries. Microorganisms. 8(3):434.

[28] Pikula., Konstantin., Zakharenko., Alexander., Stratidakis., Antonios., Razgonova., Mayya., Nosyrev., Alexander., Mezhuev., Yaroslav., Tsatsakis., Aristidis., Golokhvast., Kirill., 2020. The advances and limitations in biodiesel production: feedstocks, oil extraction methods, production, and environmental life cycle assessment. Green Chemistry Letters and Reviews. 13, 11-30.

[29] Rajalingam, A., Jani, S.P., Kumar, A., Khan, M.A., 2016. Production methods of biodiesel. Journal of Chemical and Pharmaceutical Research., 2016, 8(3):170-173.

[30] Ramos., Juan., Valdivia., Miguel.,Garcia Lorente., Francisco., Segura., Ana., 2016. Benefits and perspectives on the use of biofuels. Microbial biotechnology. 9(4): 436–440.

[31] Ranjan, A., Patil, C., Moholkar, V.S., 2010. Mechanistic assessment of microalgal lipid extraction. Ind. Eng. Chem. Res. 49, 2979–2985.

[32] Sander, K., Murthy, G.S., 2010. Life cycle analysis of algae biodiesel. Int. J. Life Cycle Assess. 15, 704–714.

[33] Shemelis, N.G., Jorge, M.M., 2017. Mario Marchetti. Biodiesel production technologies: review[J]. AIMS Energy. 5(3): 425-457.

[34] Shuit, S.H., Lee, K.T., Kamaruddin, A.H., Yusup, S., 2010. Reactive extraction of Jatropha curcas L. seed for production of biodiesel: process optimization study. Environ. Sci. Technol. 44, 4361–4367.

[35] Solomon, G., Adekomaya, O., Nwaokocha, C., 2016. Potential hybrid feedstock for biodiesel production in the tropics. Frontiers in Energy. 10,329-336.

[36] Tabatabaei., Meisam., Karimi., Keikhosro., Sarvari, H., Ilona., Kumar., Rajeev., 2015. Recent trends in biodiesel production. Biofuel Research Journal. 2, 258-267.

[37] Talavari, R., Hosseini, S., Moradi, G.R., 2021. Low-cost biodiesel production using waste oil and catalyst. Waste Manag Res. 39(2), 250-259.

[38] Wahlen., Brad., Morgan., Michael., Mccurdy., Alex.,Willis., Robert., Morgan., Michael., Dye., Daniel., Bugbee., Bruce., Wood., Byard., Seefeldt., Lance., 2012. Biodiesel from Microalgae, Yeast, and Bacteria: Engine Performance and Exhaust Emissions. Energy & Fuels. 27,220–228.

[39] Wang, C., Chen,L., Rakesh, B., Yuanhang, Q.I.N., Renliang, L.V., 2012. Technologies for extracting lipids from oleaginous microorganisms for biodiesel production. Front. Energy 6(3), 266-274.