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Biodiesel as an Alternate Energy Resource: A Study

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***Abstract* - As the world has been lately relied upon non-renewable fossil fuels for its daily energy requirements. Their depletion rate has been increased alarmingly, so there is a need to find an alternative energy source which can prove as a good alternative. From the many available sources, biodiesel has emerged as one of the best sources available. The reasons being included properties like it is highly biodegradable, non-toxic and has almost zero emissions. Distinct edible and non-edible oils such as coconut oil, castor oil, mahua, rice bran oil, apricot, jatropha, curcas, karanja and cotton seed oil, eucalyptus oil can be utilized to produce biodiesel. It has a potential to replace existing fuels, like diesel and petrol in many applications. This paper includes a detailed review on different aspects related to biodiesel. This includes properties, merits, demerits, extraction, and production techniques of biodiesel. In addition, future scopes of the biodiesel are also discussed in this paper.**
***Keywords*: Biofuel; Biodiesel Feedstock; Properties; Merits and Demerits; Renewable Energy**

I. INTRODUCTION

Biodiesel is a clean, sustainable, renewable and biodegradable energy source has received viable interest principally in recent years. The increasing requirement for rapid diminishing supply of distinct fossil fuels (natural gas, coal and crude oil), global warming, clean energy sources etc. are principle key factors prominent for people to investigate for renewable sources of energy. Although, the fossil fuel shares eighty percent of the world's energy requirements.

However, there are still many industries that use diesel operated machine. In transportation sector, many vehicles (buses, car, truck etc.) consume large amount of gasoline and diesel fuel. Overall, the human life is strongly depending upon fossil fuel. But on the other side the availability of fossil fuel is limited. Thus, it becomes a serious challenge in coming future. Therefore, researcher needs to search an eco-friendly alternate energy sources that fulfill the current energy requirements [1].

Presently, many countries (USA, Brazil, Germany, Australia, Italy, etc. are using biofuels [2]. As we know, the fossil fuels are the essential source of the world's total energy consumption. Despite of the fact that these fuels are adding enormously to meet the world's total energy demand, their use gave rise to many problems. To counter pollution emissions [3], biodiesel emerges as the best alternative as it is highly bio-degradable, non -toxic and has almost zero emission Biodiesel produced from distinct feed stocks namely, plant oils (palm, soybean, peanut, cottonseed, sunflower, and coconut, rapeseed/canola, etc), waste oils (fried oil)and animal fats because of eco-friendly and providing less gas emission content.

In addition the biodiesel has same physicochemical characteristics to that of diesel produced which is obtained from crude oil and can be utilized, directly or as a blend with petro diesel to run the existing compression ignition engines without modifications [4-8].

A. Sources of biodiesel

The distinct sources of biodiesel can be classified into main 4 categories as indicated in Figure 1.

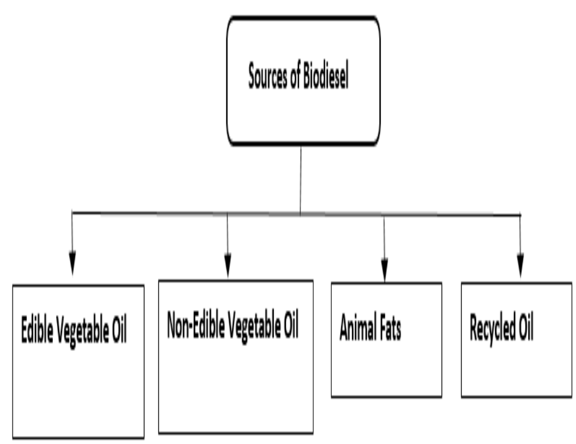

Fig.1 Distinct sources of biodiesel [9]

While evaluating the sources and feedstocks, one must remember the main requirements. However, the percentage of oil content present in distinct feedstock is summarized in Table 1.

TABLE I DISTINCT FEEDSTOCK MATERIALS ALONG WITH OIL CONTENT [10]

Feedstocks	Oil composition
Rapeseed	38 to 46%
Peanut	45 to 55%
Palm	30 to 40%
Karanja	27 to 39%
Caster	53%
Cotton seed	18 to 25%
Soybean	15 to 20%
Sunflower	25 to 35%
Corn	48%
Coconut	63 to 65%
Olive oil	45 to 70%
Rubber seed	40 to 50%

B. Edible oils

Edible oil is one of the important and 1st feedstocks utilized to make a biodiesel. Hence itis called1st generation sources of biodiesel. The major example of edible oil is the soybean oil, sunflower, peanut, coconut, palm oil, mustard oil, olive oil, etc. The greater than ninety five percent of the biodiesel is produced using edible oils. The requirements of biodiesel are increasing continuously as the population increasing day by day. Also, the cost of vegetable oils have been increasing drastically [11,12]So, one must look for other feedstocks to serve the future. India imporedible oil from Ukraine (13%), Indonesia (36), Argebtina (17%) and Malaysia (23%) of total imports. The example of edible vegetable oil feedstock is depicted in Figure 2

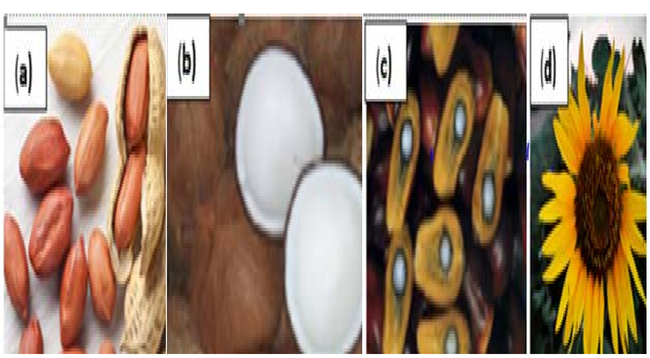

Fig.2 Some edible vegetable oil feedstock (a) Peanut (b) Coconut (c) Palmoil (d) Sunflower

TABLE II THE CURRENT FEEDSTOCKS OF THE COUNTRIES AS OF 2020 [13,16]

Country	Feedstock
UK	Rapeseed
Japan	Waste cooking oil
China	Jatropha
Italy	Rapeseed
France	Sunflower and Rapeseed
Germany	Rapeseed
Brazil	Soybean
Malaysia	Palm oil
United states	Soybean
Indonesia	Palm oil
Spain	Linseed oil
Mexico	Animal fat and waste oil

C. Non-Edible Oils

It is a 2nd generation feedstock used to make a biodiesel. This category of feedstocks is very helpful in the production of sustainable biodiesel. The common examples of non-edible oilseed crops are Calophylluminophyllum, Azadirachtaindica (neem), jatrophacurcas (Ratan jute), Madhucaindica (Mahua), Heveabrasiliensis etc. For many demands the jatropha curcas (non -edible oil) is considered as best among all the oils [17,22]. The example of some non-edible feedstock is illustrated in Figure 3.

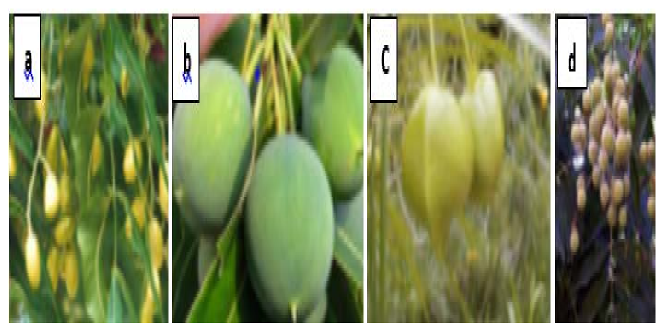

Fig. 3Common used Non edible vegetable oil feedstock
(a) Azadirachtaindica (b) Inophyllum (c) Thevatiaperuviana
(d) Sapindusmukorossi [23]

But now a day, microalgae are appearing as the 3rd generation- feedstock. The main characteristics of microalgae arethe high oil content, high growth rate than another feedstock. Hence it can be considered as more efficiently as compared to conventional crops. In addition, it does not require more land space, oil yield twenty-five times more than palm and two fifty time in case of soybean oil. Hence, it can be said that it can be game changer in the way of biodiesel production i.e., food vs oil crisis in future [23].

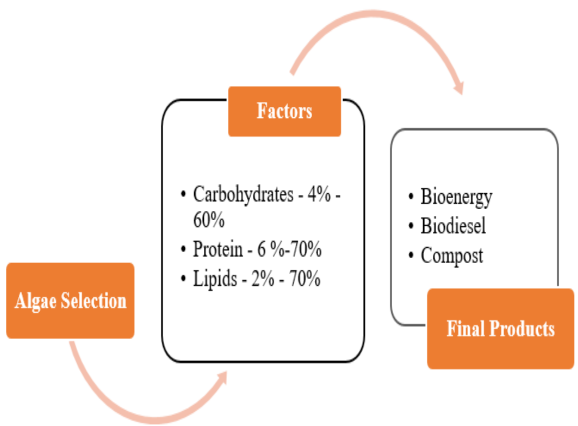

Fig.4 Factors affecting selections of algae [24]

D. Waste oil

From the literature study it is found that the soya bean oil, waste cooking oil, palm oil and jatropha oil the waste cooking oil is very economical raw material to produce biodiesel. In addition, it possesses 10 percent more density than mineral diesel. The CI engine is can be powered by using cooking oil, but it is difficult to collect the used cooking oil [25].

E. Animal Fats

This category of feedstock oil is the animal fats. It comprises beef tallow, pork lard fats and poultry fat. The main demerits of this feedstock are that it does not perform efficiently well in cold climate. In addition, transesterification process is very complicated. So, it is not preferred.

II. OILS EXTRACTION AND BIODIESEL PRODUCTION TECHNIQUES

There are several ways to produce biodiesel from its feedstocks like direct use and blending, thermal cracking, micro emulsion, and transesterification process. But before production, extraction of oils from the sources plays a vital role. There are numerous processes to extract oil. Here in this paper, we will discuss all the processes in brief.

A. Extraction

After having a goodfeedstock, the 2nd step in the process of production of biodiesel is the extraction of oil from the seeds of those plants, either edible or non- edible or it can be the extraction of lipids from the microalgae to produce oil. There are mainly three main methods for the extraction of oil Fig 5.

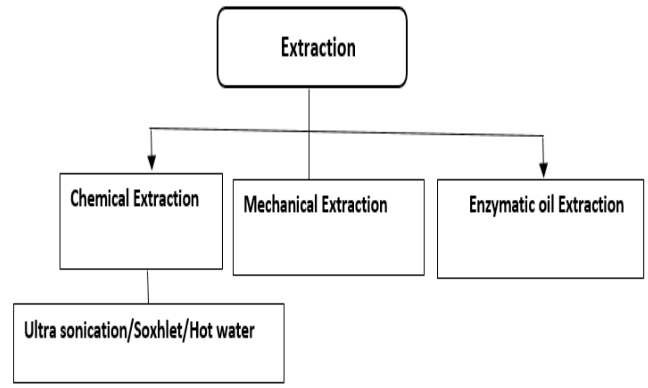

Fig.5 Distinct biodiesel extraction techniques

A. Mechanical Extraction

This technique the oldest technique to extract oil from the seeds as compared to the other ones. In this method we can either us conventional manual ram press or a modern engine driven screw press. Engine driven screw press can extract 60-80% of oil from seed, whereas from manual ram press value is only 60-65%. But the oil extracted from this method should be further passed through filtration and degumming [26].

B. Chemical Extraction or Solvent Extraction

This is primarily done by a leaching process in which one constituent is removed from the solid using a liquid solvent. The rate of extraction is dependent upon many factors like size of particle, temperature, type of solvent chosen and agitation of solvent. There are three methods that are used in this technique [26,27].

1. Soxhlet extraction
2. Ultrasonication extraction
3. Hot Water Extraction

C. Enzymatic Oil Extraction

This method is measured to be one of the others. In this technique several enzymes are used to extract oil. The greatest benefit of this technique is that it's environmentally friendly but even, though it has a lot of advantages, but the main which raised questions on this technique is that it takes much time to extract oil as compared to the others.

D. Biodiesel Production Techniques

After the extraction of oils there are several methods to overcome some problems like high viscosity, low volatility, and polyunsaturated characteristics of vegetable oil. The classified of biodiesel production methods are illustrated in Figure 6.

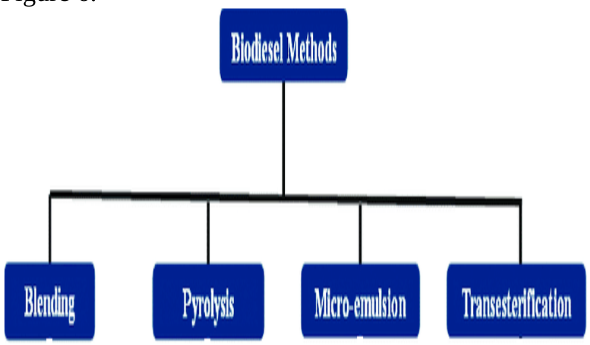

Fig. 6 Biodiesel production methods

E. Direct Use Oils and Blending

The direct applications of vegetable oils in diesel engines help to create several difficulties. The extensive research was made during the past few years [25], only in spite of being experimented with for almost a hundred years. Although some engines can run on vegetable oils, but the problems arise after longer usage periods. These problems include [28].

1. Thickening of lubricating oil owing to contamination of vegetable oils
2. Fuel atomization did not exist properly because of excess coking as well as trumpet formation.
3. Improved carbon deposits
4. Oil ring sticking

Vegetable oil gives similar energy consumption to the diesel. A ratio ranging from 1:10 to 2:10 for short term applications has been found successful.

F. Thermal Cracking or Pyrolysis

The conversion of one substance to another substance by the application of heat, heating with the help of a catalyst or heating in the absence of oxygen or air and cleavage of chemical bonds to yield small molecules. Several researchers' research on this topic and it has been concluded that thermal decomposition of triglycerides produces aromatics, alkenes, alkadienes, alkanes, and carboxylic acids in distinct proportions. The major properties of this process include is an environmentally friendly, effective, and simple. But it is a costly technique to produce biodiesel mainly for developing countries. In addition, this process requires a separate distillation equipment for separation of the distinct types of fraction [29].

G. Micro Emulsion

It is a colloidal equilibrium dispersion of optically isotropic fluid microstructures having dimensions 1 to 150 NM formed spontaneously from two normally immiscible liquids and one or more ionic or non-ionic. The major problem solved by micro emulsion such as high viscosity by adding solvents, improve spray properties, reduction in viscosity and increment it cetane number [29].

H. Transesterification

Transesterification method is a cost effective, simple, and feasible method. In this method the distinct categories of oils, ethanol, or methanol to produce glycerine and esters [32,35]. During the transesterification of distinct types of oils, triglycerides react with an alcohol (methanol or ethanol) in the presence of a catalyst to form esters and glycerine [36]. Catalysts play major role as alcohol is barely soluble in fat or oil. Therefore, the catalysts are utilized to enhance the rate & yield of the reaction.

It is observed that acid catalysts are most effective in converting FAA to biodiesel. The classification of transesterification method and reactions are illustrated in Figure 7(a,b)respectively [37].

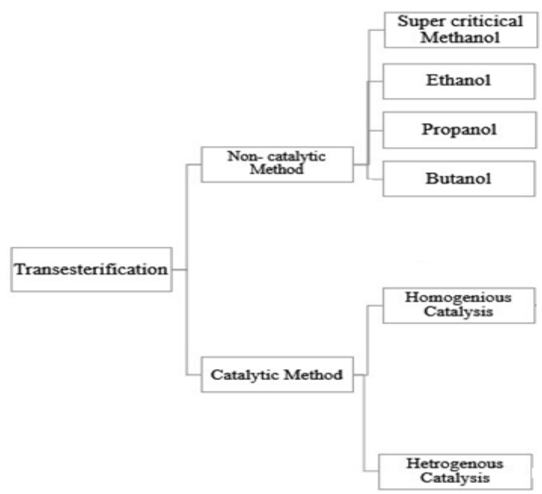

Fig. 7(a).Types of Transesterification techniques

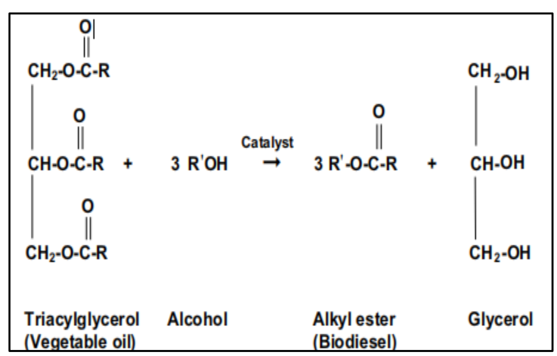

Fig. 7(b). Transesterification reactions

Even though it is considered as the on the best method, but it also has some flaws like in transesterification driven by the catalysts there is highly time consumption, lag of reaction time due to less solubility of alcohols in triglycerides. These problems do not occur in the non-catalytic reaction but that method costs very much due to requirement of high temperature and pressure. However, the consumption of methanol is very high. The common process parameters include reaction temperature, catalyst, application of row oil and blending intensity etc.

III. MOISTURE CONTENT AND FREE FATTY ACIDS

The Free Fatty Acids (FFA) and moisture contents has major effects on the transesterification of glycerides with alcohol using catalyst. The acid content of glycerides should be less than 1 because if there will be the more acid value more alkyl catalyst (NaOH) will be needed to neutralize FFA. In addition, if there will be more moisture content than soap formation will occur and the separation of products will be very hard, which will result in a lower yield of biodiesel [38]. Furthermore, gels and foams formation will make separation of glycerol from biodiesel harder [39]. For instance, the water content in waste cooking oil will accelerate the hydrolysis reaction and simultaneously reduce the amount of ester formation" [40]. The chemical arrangements of most used fatty acids are represented in Table 3**.**

TABLEIII CHEMICAL STRUCTURES OF MOST COMMONLY USED FATTY ACIDS [41,46]

Fatty Acid	Chemical Formula
Caprylic acid	$C_8H_{24}O_2$
Miristic acid	$C_{14}H_{30}O_2$
Capric acid	$C_{10}H_{26}O_2$
Oleic acid	$C_{18}H_{34}O_2$
Palmitic acid	$C_{16}H_{32}O_2$
Lauric acid	$C_{12}H_{28}O_2$
Stearic acid	$C_{18}H_{36}O_2$
Linoleic acid	$C_{18}H_{30}O_2$

The solution to these problems is supercritical methanol method. It has been observed that in supercritical methanol method, water is less effective [47]. The effects of free fatty acids and water on transesterification of beef tallow with methanol were also examined and the reports displayed that the free fatty acid content of beef tallow should remain under 0.5%, w/w and the water content of beef tallow should remain under 0.06% w/w in order to attain the finest results [48].

Therefore, it is advised that water content should not more than0.5% w/w to obtain better results because it is more important variable in the transesterification process than the free fatty acids.

A. Temperature

The reaction temperature plays a significant role towards producing quality results. The temperature in Transesterification reaction depends upon the oil used in it. The reaction temperature is generally kept below the boiling point of the alcohol to avoid evaporation. The transesterification reaction of soybean oil with methanol with molar ratio 6:1 using 1% NaOH as a catalyst was investigated at three different temperatures and the results are shown in Table 4**.**

TABLEIV% AGE YIELD OF SOYBEAN OIL WITH METHANOL AFTER 0.1 HOURS

Temperature	% Yield
60°C	94%
45°C	87%
32°C	64%

After 1 hours of reaction time, the ester formation was almost same for the "60°C" and "45°C" but was slightly lower for the "32°C" [49]. This experiment clearly demonstrates how reaction temperature affects the reaction.

B. Catalyst

The final yield of biodiesel is also affected by the type and amount of catalyst used for the reaction. Catalysts can be classified as alkali, acid, or enzyme. Catalysts are important in this reaction because alcohol is not much more soluble in oil or fat. So, to increase the solubility of alcohol and thus the rate and yield of the reaction catalysts are used.

Catalyst used are mostly strong base, mainly sodium and potassium hydroxide (NaOH and KOH) {and some other examples are $NaOCH_{3,}$ $KOCH_{3,}$ NaMeO, K_2CO_3} Even though their yield is better but Sodium and Potassium meth oxides are the best but they are not commonly used because of their cost. Basic catalysts are much effective than acid ones to increase the rate of reaction for converting triglycerides to biodiesel. Many researchers have found that the yield with base catalyst is 4000 times faster than the yield with acid catalyst of the same amount [50]. But it has been seen that acid catalysts are pretty much effective in converting free fatty acids to biodiesel. Therefore, free fatty acids are pre-treated with acid catalysts to reduce them to esters than they are further followed by an alkali-catalysed step to convert the triglycerides.

Generally, as the amount of catalyst increases the yield of fatty acid alkyl esters also increases as the availability of active sites increases by adding of larger amounts of catalyst in the transesterification process. This might sound great, but if we increase the amount of catalyst then automatically price of production will also increase. So, like the ratio of oil to alcohol, the optimization process is essential to determine the favourable amount of catalyst required in the transesterification process [51].

C. Effect of Molar Ratio

Alcohol to Triglyceride molar ratio is an important factor for the yield of biodiesel. Generally, there are 3 moles of methanol are required to react with triglycerides or vegetable oils. As the reaction is reversible, so it requires higher amounts of alcohol to shift the equilibrium to the right side. Stoichiometric factors are always important in a chemical reaction. In an experiment, it was observed that an acid catalysed reaction needed a 30:1 ratio of BUOH to soybean oil, while an alkali-catalysed reaction required only a 6:1 ratio to achieve the same ester yield for a given reaction time [52].A similar experiment was carried out for detection of the effect of volumetric ratio of Methanol and Ethanol to Oil. The results showed the maximum biodiesel yield of 99.5% at 1:6 oil/methanol. Whereas in case of methanol, the biodiesel yield increases with the raise of Methanol molar ratio [53].

D. Reaction Time

Reaction time always plays a vital role in the chemical reactions. Many researchers have experimented with different feedstocks to know the reaction time. With the feedstocks like peanut, cottonseed, sunflower and soybean oils transesterification reaction was performed under the condition of methanol to oil, molar ratio of 6:1, 0.5% sodium methoxide used as catalyst and 60°C temperature. Approximately 80% of the yield was after 1 min then about after an hour yield became almost constant to 93-94%. Then the experiment was conducted with beef tallow in this to starting was slow due to the mixing processes occurs, then again, the reaction was at its peak and then became constant. So, after these experiments, it has been concluded that for the starting one minute the reaction is slow but after that around one to five minutes reaction rate increase drastically and after about 90 minute rate become constant [49].

E. Mixing Intensity

Mixing is an important role in the rate of the transesterification reaction. Many researchers have that the slower rate of the reaction is only because the less intensity of mixing of alcohol and triglycerides. As oils and alcohols are almost immiscible so it is necessary to take some steps to mix them properly. The very effective way to increase the solubility is using a right amount and quality of catalysts. The reaction will only proceed if both feed stocks will be in contact with each other. Many researchers claim that the reactants initially form a two-phase system during the transesterification process.

So as the phase separation halts, results in insignificant mixing. "The effect of mixing on the kinetics of the transesterification process forms the basis for process scale-up and design" [54]. So, the intensity of mixing must be increased to get the better and uniform quality of final product i.e. biodiesel.

IV. MERITS AND DEMERITS OF BIODIESEL

A. Merits of Biodiesel

1. Biodiesel is highly combustible as it accounts for 10-11% of oxygen constitution in it [55,67]
2. As compared to conventional Diesel fuel, biodiesel emits almost 78% less Carbon Dioxide and other harmful gases
3. Biodiesel is non-toxic, biodegradable and non-flammable.
4. It is the readily available source of renewable energy.
5. If diesel fuel in vehicles get replaced by Biodiesel, will account in reducing the pollution levels by a considerable amount.
6. Unlike petroleum and diesel, biodiesel production requires no expensive methods like drilling, refining, etc. Moreover, each country can produce its own biodiesel and store locally, which cuts the transportation and import/export costs of other fuels like petroleum and diesel [77,78]
7. Biodiesel has a higher flash point, above 100-170°C which is much greater than that of Petrol & Diesel (60-80°C), hence it is much safer for transportation, handling & distribution [79,81]

B. Demerits of Biodiesel

1. Production of energy by burning biodiesel results in an almost % less energy content than petrol or diesel [82,84].
2. As biodiesel is made of biological products, it contains a higher amount of carbon content, so its combustion in engines leads to deposition of carbon and gets contaminated due to incomplete combustion [85].
3. As a huge portion of biodiesel production depends upon edible oil, many claims say that if the scope of biodiesel is in replacement of diesel fuels, edible oils will be exhausted in large portion of the transportation sector, which may cause imbalance in food markets [86].
4. Due to high viscosity and lower volatility than petrol and diesel fuel, the vehicle engine needs higher injector pressure for proper combustion of biodiesel.
5. The use of biodiesel in internal combustion engines may cause many disadvantages for the engine. As

there will be carbon depositions, clogging and contamination.

6. Usage of biodiesel in machinery requires regular maintenance and cleaning.
7. As the process of separation of fatty acids is costly, transesterification process costs more expense.
8. Biodiesel has less oxidation stability, can be oxidized into fatty acids which causes corrosion of fuel tanks.

V. CONCLUSIONS

Energy is a crucial factor for the human development and economic growth. The world has been lately relied upon conventional sources of energy which is raising the concerns regarding the sustainable development and growth. The transportation sector is the 2ndlargest sector responsible for energy consumption after the industrial sector. Almost 30% of the world's total delivered energy is consumed in this sector. Further, due to Covid-19 pandemic in year 2020, the global energy demand felt a large decline. With a halt on imports and exports due to nationwide lockdown, the global coal and oil demand were also declined by 8% and 5% respectively. On the other hand, a growth in the demand of renewable energy sources was seen. Further in the year 2020 we can expect the scenarios quantifying the energy impacts due to widespread global pandemic which will result into a permanent loss in economic activity. According to IEA global energy review report of 2020, the energy demands will contract almost by 6%, which will be the largest in 70 years. With economy crisis around the corner, it may be a good time for the world to look at its current biodiesel sources and exploit it to full usage.

To cheap cost and lower requirements than other fuels, it seems to be a perfect source to shift the focus on. In this paper, the production methods of biodiesel have been discussed in detail, from which, the Transesterification process is most economically viable. Non-Edible feedstocks is a great alternative to shift the focus on. Moreover, the properties of biodiesel like low CO2 emissions is the demand of the future use of energy. With biodiesel in usage, the world can meet sustainable development goals and could improve the conditions of the environment. So,the biodiesel is the call for the foreseeable future, and it can be beneficial both for economy and environment once exploited to its full usage.

VI. FUTURE SCOPE

Biodiesels have a lot of scope in upcoming years. Biodiesel is not a new resource, but its research goes back to 1900's. One of the major challenges faced by biodiesel will be increased costs. As the increase in the global human population, increase in food consumption will be gradual. So, we need to look out for more non-edible biodiesel sources. For instance, one of the most viable sources of biodiesel is vegetable oil, which is already at the hike of price in Asia due to the large population. Its potential solutions are genetically engineered plants and microalgae feedstocks.

With the decrease in non-renewable conventional sources, it is necessary to shift the focus to some promising sources like biodiesel.So, it is expected in upcoming years, biodiesel will gradually make its way to one of the most used energy resources. The change will be slow and gradual with the environment, adjusting accordingly to the new primary energy source.

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