

Biodiesel: A Review on Next Generation Fuels

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ABSTRACT

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The importance of biodiesel production was studied and analyzed based on research papers and theses published by different authors in various e-journals. The hike in fossil fuel prices with increase in usage demands, has forced the research to find new alternatives to petroleum fuels. Despite this, there is a crucial need to protect the environment from harmful effects of fossil fuels. Biodiesel is a renewable alternate fuel substitute that can be obtained by using various chemical methods such as transesterification, acid-catalyzed methanolysis etc. detailed survey of available literature is taken to review the different research achievements on different aqueous as well as land species for producing biodiesel as an alternative fuel for a compression ignition engine, problems associated with their production, such as the oil quality and quantity and also the methodology used for their production. In addition to this, general properties of oils taken from different natural species as well as techniques of biodiesel production and utilization have been collected.

Keywords:

Biodiesel, biofuels, transesterification, alternative fuel.

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1. Introduction

Biodiesel is an alternative source of diesel fuel, which can be made from a wide range renewable bio species such as from crops like sugarcane, crop grains etc. They can be also produced from certain water or aqueous species like water hyacinth, algae (micro and macro). Due to the finite availability of fossil fuels, there is a high concern for energy security as well as need to respond to climatic variations worldwide [1]. These factors have initiated an overall global interest in switching to renewable energy sources [2]. Biofuels have found to be more effective because of the ill-effects of conventional petroleum fuels, their price hike and increased emissions during combustion. Producing biofuels from certain species of crops whether it be land or aqueous, which can be grown locally in some waterbodies or land area, has become a best method to bypass energy crisis. It is expected that, producing biofuels by suitable optimized method can reduce the dependence on fossil fuels, and at the same time decreasing the amount of pollutant emissions considerably.

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2. History

German Engineer Dr. Rudolf Diesel tested vegetable oil in his prototype Diesel engine at the World's Exhibition in Paris in the year 1900. The factors such as production cost and profits, natural availability, low harmful contents like Sulphur, biodegradable and renewable properties makes these biofuel sources more dependable than conventional fuel [3]. Nowadays, crops are processed and used for a variety of purposes, especially for edibles and processed food items. This creates a limitation for using certain species of crops as biofuel sources. Although the worldwide production of biofuels has increased, political and public support has not yet been determined, as it has a significant effect on food security.

3. Importance of Biodiesel

Biodiesel can be also called as green fuel and its works as a good alternative for petroleum diesel. There are many advantageous characteristics of this fuel, such as cleaner burning and good lubricity [4].

Its contribution to greenhouse effect and atmospheric pollution is comparatively less. Also it is biodegradable, so that it won't leave any harmful traces in the environment. They dissipate engine heat better than other fuels. Also its feedstock is renewable.

Table 1
Some general properties of biodiesel [5][6]

Properties	Values
Specific Gravity	0.87 – 0.89
Kinematic viscosity at 40 °C (mm ² /s)	3.65 – 5.6
Cetane number	44.5 – 69.9
Higher heating value (btu/lb)	16,927 - 17,994
Lower heating value (Btu/lb)	15,699 - 16,730
Sulphur wt %	0.00 - 0.00241
Cloud point °C	-11 to 16
Pour point °C	-15 to 13
Flash point °C	120-130

4. Types of Biofuels

The paper has described a simple approach of using CAD/CAM tools in the modelling and virtual manufacturing of a flange tube. Effective utilization of CAD/CAM as automation technology in manufacturing can optimize operations, allow manufacturing flexibility, respond to consumers' requirements and demands, improve product quality, reduce production costs and shorten product development cycle. It can be concluded that CAD/CAM as an automation tool has been applied to modelling and manufacturing of a flange tube virtually without the consumption of materials and power.

A. Biodiesel

As Biodiesel is a non-petroleum derived diesel fuel, it consists of mainly Alkyl esters. Esters can be Methyl or Ethyl. They are produced using transesterification process normally and can be used either as a blend with fossil diesel fuel or it can be used alone too.

Their feedstocks or sources are mainly;

- I. Jatropha[7]
- II. Soy
- III. Mahua
- IV. Mustard
- V. Sunflower
- VI. Palm oil
- VII. Algae (Micro and Macro)

B. Bio-Alcohols

Taking into consideration, some main types of bio-alcohols, Ethanol is the most widely used one because of its favorable physical and chemical properties, when compared to others like methanol, propanol and butanol, in which the later ones have some undesirable properties. Their sources are mainly from microorganisms and enzymes [8].

These are normally produced by fermentation of sugars obtained from sugarcane, corn, etc.[9] Ethanol production is mainly done by enzyme digestion of sugars from stored starches, followed by fermentation, distillation and afterwards drying. A considerable amount of heat energy is required for performing the distillation process.

C. Bio-Ethers

Bio-ethers are also known as fuel ethers or fuel oxygenates, or in other words we can say oxygen based functional groups [10]. These compounds have one oxygen in the middle of the carbon chain. These compounds are normally expensive as they are used as octane enhancers to improve engine performance and at the same time reducing engine wear and toxic emissions.

D. Bio-fuels from algae (3rd generation biofuels)

Algae are one of a kind species from which we can produce biodiesel in high quantities while providing low input simultaneously. It produces more than 30 times energy per acre compared to that of land crops. So as the fossil fuels prices are higher nowadays, algae farming can become significant breakthrough for biodiesel production [11].

Algae such as *Botryococcus braunii* and *Chlorella vulgaris* are easier to cultivate, but still extraction of biofuel from these species is a bit more difficult [10]. There are many approaches done for extraction, of which some are better than others. Microalgae can be grown almost everywhere whether it be any season, it can be grown in any time of the year and from certain species of it, biofuel can be reaped daily.

E. Fourth generation biofuels

A company named Synthetic Genomics [12] owned by Craig Venter is currently making use of genetic engineering in production of large scale biofuel. They are currently making use of genetically modified microorganisms to produce fuel directly from carbon dioxide on an industrial scale.

Also, another 4th generation biofuels are derived from genetically modified crops in which they consume more carbon dioxide from atmosphere than they release during combustion which makes it a carbon negative fuel.

5. Production Methods and Processes

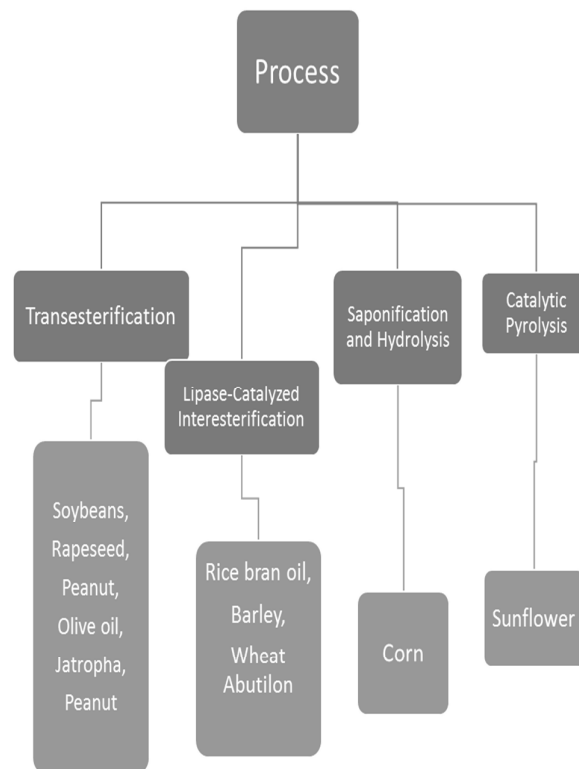


Fig. 1. Biofuel production methods for different sources [13][14][15][16][17][18][19][20]

6. Methods of Production: Biodiesel

A. Transesterification: catalytic process (Acid & Base)

Transesterification is the widely used process. Viscosity is an important property to be taken care of in case of fluid fuels. Comparing both conventional petroleum fuels and biofuels, oils which are derived from crops tend to have higher viscosity than the former. Therefore, it must be reduced to consider its use in diesel engines.

The oil is extracted from the plant species with help of alcohols such as ethanol or methanol. This reaction is to be carried out in the presence of a suitable catalyst so as to vary the rate of reaction process accordingly[24]. The end products will be mainly alkyl esters and glycerol. Glycerol content is later separated and the alkyl ester so obtained is nothing other than biodiesel [25].

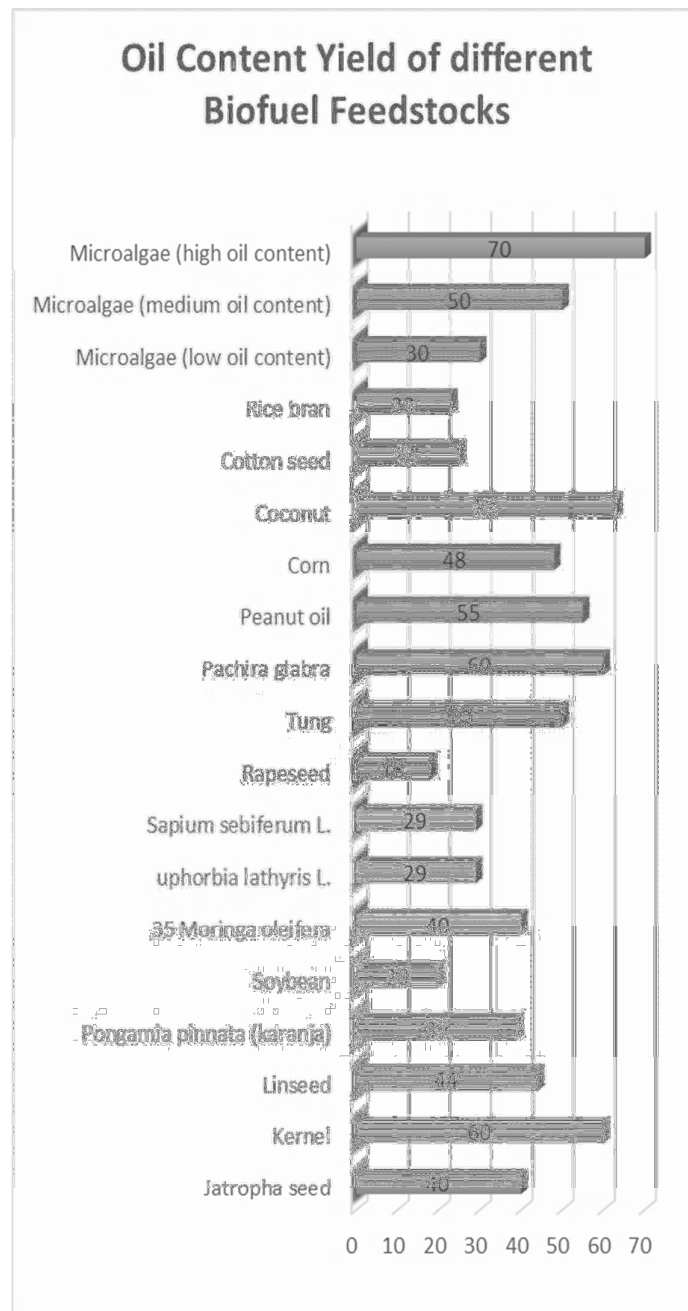


Fig. 2. Oil content and yield for different feedstocks (Estimation)
[4][21][22][16][23]

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Glycerol content is separated initially prior to neutralization and washing process. After a neutralization reaction, soap and water are normally formed as resultant by-products. To remove the residual catalysts and soap which are formed afterwards, acids are introduced to the solution.

Table 2

Transesterification by Acid and Base Catalyst[4][26][27][13]

Catalyst Used	Types	Problems
Acid catalyzed transesterification	Conc. sulfuric acid, Hydrochloric acid	Reaction rate is normally less in this case. Glycerol separation depends on alcohol concentration.
Base catalyzed transesterification[4]	Potassium Hydroxide, Methoxide & Sodium Hydroxide, Methoxide	Potassium methoxide has high heat of reaction with methanol, sodium methoxide is preferred[13]. The reaction proceeds slowly with high molecular weight alcohols.

B. Non-catalytic Transesterification

This mode of transesterification doesn't use any catalyst, which is an advantage compared to catalyzed transesterification process. There are basically two types of non-catalytic transesterification process which are explained below:

C. BIOX process

This process was developed by Professor David Boocock from the University of Toronto. BIOX process makes use of a chemical which helps to increase the speed of reaction [28]. This non-catalytic process can be used to extract biodiesel from grain-based species as well as wasted cooking oil and animal fats. This process makes use of certain solvents or chemicals for the progress of reaction. Tetrahydrofuran is used here to dissolve methanol and also to accelerate the reaction process. The advantage is residual catalysts are absent in the end reaction by-product phase. In addition to that, this co-solvent has high boiling point almost near to that of methanol.

D. Supercritical process:

This process is an alternative for other non-catalyzed transesterification processes. In this method they use certain supercritical alcohols (mostly methanol) at high pressures and temperatures. As these compounds are at supercritical state, they will be at single phase which makes further makes the reaction spontaneous as well as rapid [29].

7. Present Status of Biofuels

Lot of research is done on finding more appropriate crop sources and to enhance the oil yield for biodiesel production. Compared to all other feedstocks, results show that microalgae have shown bright output[30][31]. Microalgae usually grow in the aquatic environment as it provides necessary water, carbon dioxide and nutrients. When comparing with present day feedstocks, microalgae have simple structures and can be grown very abundantly throughout the year[4][32]. Microalgae have rich oil content about 25% to 45% more than others. Also, they have a potential to reduce the carbon-dioxide content from the atmosphere by absorbing it during photosynthesis[33][11]. It is preferred as the best source in production of biodiesel as it can easily synthesize lipids that can be converted into biodiesel.

There are also many other advantages such as, carbon neutrality, non-toxicity, biodegradability and sulfur-less [4].

Certain species can be cultivated daily. The oil extracts of algae can be processed into ethanol and can be used as livestock feed. The carbon emissions can be reduced depending on where it's grown.

A. Best and Feasible Production Methods

Certain transesterification processes have appeared to be best production methods, when considering factors like oil yield or quantity. Processes such as enzymatic esterification, which uses lipases has shown high output in terms of quantity extracted. However, these lipases are generally highly expensive compounds which makes the process cost effective. Taking case of catalytic transesterification reactions, some limitations still exist. There are issues like removal of catalysts and further purifications etc. Therefore, non-catalytic reactions such as BIOX and supercritical process has shown a bright evidence in feasibly producing biodiesel and becomes the best method for biofuel production.

8. Conclusion

From all the researches and reviews done, it is evident that the biodiesel can be incorporated as new evergreen solution for automotive and industrial sector. As discussed above, benefits of bringing biodiesel as a commercial product reaps more benefits than considering its limitations. Recent studies also show that certain marine species such as micro-algae proves to be a more dependable future source of biodiesel, as it yields better quantity and quality of biofuel compared to other feedstocks. Their impacts on environment is also found to be negligible.

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