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Original Article

A Review Article of Biodiesel Production

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ABSTRACT

Biodiesel is a sustainable fuel derived from grease, vegetable oils, or animal fats through processes such as transesterification or esterification. In transesterification, triglycerides are converted into fatty acid alkyl esters with the help of alcohol and a catalyst, resulting in glycerol as a byproduct. With the reduction of petroleum supplies and environmental concerns related to diesel emissions, biodiesel has emerged as a renewable and biodegradable alternative. The predominant method for producing biodiesel involves alkali-catalyzed transesterification using methanol, requiring careful moisture control and free fatty acid levels to avoid soap formation. This article explores different sources of biodiesel, including edible and non-edible oils, the potential of algae-based biodiesel, various catalysts utilized in production, and recent developments in the field.

Keywords: Biodiesel, biofuel, Microemulsion, Pyrolysis, Fenton reaction, Transesterification

INTRODUCTION

Biodiesel is a liquid biofuel created through the chemical reaction of vegetable oils or animal fats with alcohol, making it suitable for use in diesel engines, either on its own or blended with traditional diesel fuel.

HISTORY:

Rudolph Diesel first explored the use of biodiesel in 1890, employing pure vegetable oils in diesel engines for agricultural purposes where petroleum diesel was unavailable. The modern biodiesel we know today evolved from research in Belgium in the 1930s, which converted vegetable oils into fatty acid methyl esters (FAME) through a process called transesterification. This method produces fatty acid alkyl esters, offering a lower-viscosity alternative to traditional diesel fuel. As concerns about environmental sustainability and energy independence have grown, biodiesel has gained traction. Its popularity surged in the U.S. after the September 11, 2001, attacks, which led to rising oil prices. Today, biodiesel is utilized worldwide, addressing global warming challenges. Its future depends on the capacity to produce renewable feedstocks, like vegetable oils and fats, to maintain competitive pricing with petroleum fuels.

The benefits of using biodiesel as an alternative to conventional diesel include:

1. It is a renewable resource derived from vegetable oils or animal fats.
2. It has a lower toxicity compared to traditional diesel fuel.
3. Biodiesel decomposes more quickly than diesel, reducing the environmental effects of spills.
4. Its use results in decreased emissions of harmful substances, such as carbon monoxide, particulate matter, polycyclic aromatic hydrocarbons, and aldehydes.
5. It lowers health risks through reduced emissions of carcinogenic compounds.
6. Biodiesel does not produce sulfur dioxide (SO2) emissions.
7. It has a higher flash point, with a minimum of 100°C.

(Review: Oils, Fats, and Alcohols Used in Biodiesel Production *Vinod Kumar Ashramiya, et.al International Journal of Advance Research in Science & Engineering. Volume no.07, Special Issue no.02, April 2018.)

Disadvantages of the use of biodiesel

Biodiesel has several disadvantages as a diesel fuel alternative:

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1. It generally leads to higher fuel consumption because of its lower calorific value.
2. There is a slight increase in nitrous oxide (NOx) emissions compared to conventional diesel.
3. Its higher freezing point can pose challenges in colder climates.
4. Biodiesel is less stable, making it unsuitable for long-term storage (over six months).
5. It can degrade certain materials, such as plastic and rubber gaskets; using Teflon components is advisable.
6. Additionally, biodiesel may dissolve deposits in storage tanks and fuel lines, which can cause problems in the engine. Therefore, it's recommended to clean tanks before filling with biodiesel.
7. Many of these issues can be minimized when biodiesel is blended with regular diesel fuel.

Raw Materials for Biodiesel Production

Biodiesel is produced from vegetable oils, animal fats, and short-chain alcohols. The most common oils used globally include rapeseed, soybean, palm, and sunflower, along with alternatives like peanut and recycled vegetable oils. Methanol is the primary alcohol employed, though ethanol can also be used. To address cost concerns influenced by oil prices, non-edible vegetable oils are increasingly being studied, as they do not compete with food supplies. Trials in various countries have explored the use of non-edible oils such as castor, tung, and jatropha. Animal fats are another option, especially in livestock-rich regions, although they require processing to handle their solid state. Microalgae are a promising future source due to their high oil yields, but only certain species are suitable for biodiesel. Regardless of the raw materials used, the final biodiesel must comply with international standards. Several synthesis techniques are available for production.

Typical Oil Crops Useful for Biodiesel Production

This section highlights key oil crops that are beneficial for biodiesel production.

Rapeseed and Canola

Rapeseed thrives in low-fertility, high-sulfur soils, yielding 40% to 50% oil and suitable for winter cover cropping and rotation. It is a critical feedstock for biodiesel in the EU, though its use is limited by competition with wheat and lower yields. Rapeseed flour is nutritious and serves as a protein source in cattle feed. Canola, a genetically modified version of rapeseed, has reduced erucic acid levels, making it safer for consumption. It is valued for its quality and is considered one of the best cooking oils for cholesterol management.

Soybean

Soybean, a legume from East Asia, shows height variation based on environmental conditions. Major producers include the United States, Brazil, and Argentina. Biodiesel from soybeans yields glycerin and valuable by-products, including soybean meal and high-protein flour. With yields of 2,000 to 4,000 kg per hectare, soybean seeds contain about 18% oil.

Oil Palm

The oil palm grows 20 to 25 meters high, with a life cycle of around 25 years, reaching peak production in eight years. It yields both palm oil from the pulp and palm kernel oil from the nut. The extracted palm kernel cake is used as livestock feed. Indonesia and Malaysia are the leading producers, and the demand for palm oil has steadily increased for cooking and food production. Pure palm oil is semi-solid at room temperature and is often mixed with other oils.

Peanut

Peanut quality is impacted by weather during harvest and is primarily used for human consumption, including peanut butter and confectionery. Lower-quality peanuts are processed for oil, which is commonly used in cooking and sweets. The leftover flour from oil extraction is protein-rich and serves as livestock feed.

Jojoba

Jojoba plants can endure drought but need irrigation for viable yields. They thrive in warm climates but require cold for flower maturation and low rainfall during harvest. It takes about ten years for jojoba to reach peak productivity, with its oil primarily used in cosmetics, making the market competitive.

Jatropha

Jatropha is suited for arid climates, particularly the variety Jatropha curcas, which requires little water and maintenance. Its oil yield can vary from 28–32% with pressing to 52% through solvent extraction. However, the seeds are toxic, rendering the oil non-consumable.

Avocado

The avocado tree grows 5 to 15 meters tall, producing fruit that weighs between 120 grams and 2.5 kilograms. The harvesting period can range from 5 to 15 months, with fruits maturing after being picked. The oil extracted from both the flesh and pit is rich in essential fatty acids.

Biodiesel Production Methods

1. Dilution Process

The dilution process makes vegetable and waste oils thinner by mixing them with diesel fuel. This reduces oil thickness, making it easier to use as fuel. The mixtures are labeled B20, B30, B40, B50, and B80, indicating the percentage of oil in each. Common oils used include peanut, rapeseed, and sunflower oils.

2. Microemulsion Creation Method

Microemulsions use short-chain alcohols like methanol or ethanol to reduce oil thickness. These mixtures contain tiny droplets of oil, but they have lower energy content than regular diesel due to the alcohol.

3. Pyrolysis Method

Pyrolysis involves breaking down oils using heat and nitrogen or air. This method can produce cheaper fuel from low-quality materials, such as used cooking oils. The oils are heated in a closed container, breaking them down into biodiesel similar to regular diesel. This process can produce solid or liquid fuels depending on the reaction conditions. (A Review Of The Biodiesel Sources And Production Methods Ezgi Sühel AKTAŞ1, Özlem DEMİR et.al. International Journal of Energy and Smart Grid Vol 5, Number 1, 2020 ISSN: 2548-0332 e-ISSN 2636-7904.)

4.Transesterification

Transesterification is the primary method for making biodiesel by swapping alkoxide groups between esters, and it is simple and effective.

Biodiesel is made from vegetable oils through a process called transesterification, where the oils react with an alcohol, such as ethanol or methanol. This reaction produces fatty acid esters (biodiesel) and glycerine. It typically requires a catalyst, which can be either basic (like sodium or potassium hydroxide), acidic, or enzymatic. Transesterification converts triglycerides from oils into mono-alkyl esters, the main component of biodiesel. This process also produces by-products like di- and monoglycerides and free fatty acids. Common feedstocks include rapeseed, sunflower, soybean, and used frying oils, with methanol as the alcohol and sodium or potassium hydroxide as the catalyst. Animal fats can also be utilized. Achieving over 99% purity in the refining stage is essential for optimal engine performance. The process can also generate diglycerides, monoglycerides, free fatty acids, and excess reactants. Common sources of oils include rapeseed, sunflower, soybeans, and used cooking oils. Animal fats can also be used, making biodiesel a flexible and sustainable alternative to traditional diesel fuel.

5. Fenton Reactions

Grčić et al. and Sabaikai et al. (2014) conducted 180-minute pre-tests using Fe^{2+} concentrations of 20 to 50 mg/L and H_2O_2 from 100 to 1000 mg/L. The optimal settings were $[Fe^{2+}]$ = 20 mg/L and $[H_2O_2]$ = 1000 mg/L, which were used in subsequent experiments. These were performed in sealed glass containers covered with aluminum foil. A 100 mL sample from biodiesel wastewater was treated with $FeSO_4 \cdot 7H_2O$ to achieve 20 mg/L of iron ions, and H_2O_2 maintained at 1000 mg/L was added every 1000 minutes. The procedure lasted 300 minutes, with TOC monitored every 30 minutes.

6. Solar Photo-Fenton

Experiments utilized solar radiation instead of a mercury lamp to study the photo-Fenton reaction. A 500 mL biodiesel wastewater sample was placed in a 29.6 cm x 17.8 cm x 5 cm glass receiver. After adding 20 mg/L of Fe2+, 1.25 mL of 1000 mg/L H2O2 was added every hour during the 480-minute exposure to natural sunlight outdoors in May 2016 in Midwestern

Brazil. TOC content was measured at each hourly interval.

CONCLUSION

The literature reveals that while fossil fuels significantly impact the environment and are decreasing in availability, there is a growing focus on alternative energy sources. Biodiesel, produced from vegetable and animal fats, is a sustainable option that is non-toxic, biodegradable, and environmentally safe.Through the transesterification process, vegetable oils are converted into biodiesel, enhancing their fuel properties. Despite its advantages—including a high cetane number and efficient combustion—research on wastewater treatment resulting from biodiesel production is limited. Although methods like Fenton's advanced oxidation process show promise, further studies are needed to develop effective wastewater management strategies in this context.

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