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Second Generation Biodiesel: Potential Alternative to-Edible Oil-Derived Biodiesel

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Abstract

The extensive use of fossil fuels is depleting its reserve and produces harmful emission causing environmental issues. Hence, considerable attention has been given to alternative sources such as biodiesel. Currently, biodiesel is mainly produced from conventionally grown edible oil plants thus leading to a competition of usage of food versus fuel. The increasing criticism of the sustainability of first generation biodiesels (those derived from edible oils) has raised attention to the use of so-called second and third generation biodiesels. The second generation biodiesel includes non-edible vegetable oils, waste cooking oils as well as animal fats. These are considered as promising substitute for traditional edible food crops as they neither compete with food crops nor lead to land-clearing. This study introduces second generation biodiesel to be used as biodiesel feedstocks. Several aspects of these feedstocks are reviewed and discussed in this paper. These aspects include different sources of biodiesel feedstocks, biodiesel conversion technology and performance and emission characteristics of second generation biodiesel.

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Keywords: Second generation biodiesel; biodiesel feedstocks; conversion technology; performance and emission characteristics

1. Introduction

During the past few decades worldwide use of petroleum has rapidly increased due to the growth of human population and industrialization, which has resulted in depletion of fossil fuel reserves leading to an increased petroleum prices. The scarcity of petroleum fuel reserves has made renewable energy an attractive alternative source of energy for the future. Furthermore, conventional fossil fuels

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contribute to global warming via increased greenhouse gas (GHG) emissions. As a consequence, a move is being made towards alternative, renewable, sustainable, efficient and cost effective energy sources with lesser emissions [1]. Biodiesel is attracting much attention worldwide as a blending component or a direct replacement for diesel fuel in vehicle engines [2]. Biodiesel is considered as one of the promising alternative resources for diesel engine, especially from non-edible oil feedstock as well as its potential to be a part of a sustainable energy mix in the future. The advantages of non-edible oils as a diesel fuel are liquid nature portability, ready availability, renewability, higher heat content, higher flash point, higher cetane number, lower sulphur and aromatic content as well as biodegradability [3]. The second generation biodiesel produced from non-edible feedstock as well as biomass can overcome the socio-economic disadvantages of current biodiesel technology and be able to address many of the challenges of climate change and the energy crisis. This paper focuses on prospects, importance, feedstocks, conversion process as well as performance and emission characteristics of second generation biodiesel.

2. Importance of Second Generation Biodiesel

The use of edible vegetable oils, such as those from soybeans, palm oil, sunflower, safflower, rapeseed, coconut and peanut termed as the first generation feedstocks have been of serious concern recently; because of food versus fuel debate which might cause starvation especially in the developing countries and other environmental social problems caused by the use of more arable land [4] and displacement of rural populations from their marginal holdings. On the other hand, the use of non-edible vegetable oils is of significance due to great necessity for edible oil as food. The oils produced from these resources are unsuitable for human consumption due to the presence of toxic compounds in the oils [4]. Besides these, the reasons for biodiesel production from non-edible oils include: (i) non-edible oil plants can be easily cultivated in lands unsuitable for food crops at a much lower cost than those of the edible oil crops [5]; and (ii) growth of these plants reduce CO_2 concentrations in the atmosphere [4]. The wide range of available feedstocks in the case of non-edible oils represents one of the most significant factors for biodiesel production. Furthermore, the use of cost-effective non-edible oils can be a way to improve the economy of biodiesel production and its commercial production at an industrial scale. However, due to the problems associated with food versus fuel, environmental and economic issues related to edible oils, the non-edible oil feedstocks are gaining popularity for biodiesel production.

3. Biodiesel Feedstock

Selecting the appropriate feedstock is a vital issue to ensure low production cost of biodiesel. As much as possible the biodiesel feedstock should fulfil two requirements for production of biodiesel which are low production costs and large scale production [6]. In general, biodiesel feedstock can be categorised into four groups: (i) edible vegetable oil: soybean, palm oil, sunflower, safflower, rapeseed, coconut and peanut; (ii) non-edible vegetable oil: jatropha, karanja, mahua, linseed, cottonseed, neem, camelina and beauty leaf tree/polanga; (iii) waste or recycled oil: cooking oil, frying oil, vegetable oil soapstocks and pomace oil; and (iv) animal fats: beef tallow, pork lard, yellow grease, chicken fat and by-products from fish oil. [7, 8]. Among those, non-edible vegetable oils, waste or recycled oil as well as animal fats are regarded as the second generation biodiesel feedstocks. The algae have been considered as third generation biofuel and an emerging non-edible oil of growing interest because of their high oil content and rapid biomass production [9].

4. Biodiesel Production

Transesterification is regarded as one of the best techniques to convert oil into biodiesel, as it has the most promising solution to the high viscosity problem among other approaches due to its low cost and simplicity [10]. Furthermore, this technique has been identified as a widely available technique for industrialized biodiesel production due to its high conversion efficiency and low cost [11].

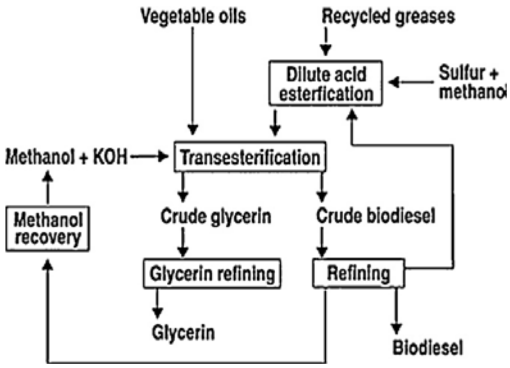

Fig. 1. Basic transesterification protocol [12]

In transesterification process, alcohol is reacted with vegetable oil in the presence of appropriate catalyst. Generally, ethyl or methyl alcohol is used to produce ethyl or methyl esters. When the reaction is completed, two distinct layers of liquids i.e., ethyl or methyl ester and glycerine appear and they separate out as shown in Fig. 1 [12]. The glycerine is refined and disposed of for further use. The crude biodiesel is also refined and alcohol is separated from it which is reused in the cycle [12]. The technology of biodiesel production includes transesterification of oils (triglycerides) with alcohol which gives biodiesel which is chemically-known as fatty acid methyl ester (FAME) as the main product and glycerol as the by-product.

The triglyceride is converted step-wise into diglyceride, monoglyceride, and finally, glycerol, during which one mole of alkyl ester is removed in each step. The main transesterification reaction variables include: methanol/oil molar ratio, catalyst concentration, reaction temperature and reaction time are optimized for high biodiesel conversion and quality. Methanol to oil ratio is varied from 3:1 to 12: 1, while catalyst concentration is varied from 0.25 % to 1.25 %. The reaction upper temperature limit is restricted by the boiling point (65^0C) of methanol and the lower limit is based on room temperature. To obtain pure methyl ester, the product is washed with hot water to separate from soap formed during reaction. The biodiesel sample is to be tested to determine the fuel quality. Fatty acid profile of the feedstock is obtained by Gas Chromatograph (GC). Fuel property test is conducted according to ASTM as well as EN test standards. The important fuel property parameters that are investigated include: cetane number (ASTM D613), kinematic viscosity (ASTM D445), density (ASTM D1298), calorific value (ASTM D240), flash point (ASTM D93), pour point (ASTM D97), cloud point (ASTM D2500), oxidation stability (EN 14112), acid value (ASTM D664), lubricity (ASTM D6079), carbon residue (ASTM D4530), iodine value (EN 14111) and sulphated ash content (ASTM D874).

5. Performance and Emission Characteristics

Engine performance with biodiesel or its blends with diesel fuel varies largely on the combustion air turbulence, air-fuel mixture quality, injector pressure, actual start of combustion and other factors. However, the effect of using blended non-edible biodiesel with petroleum diesel can be evaluated by determining the engine power/torque, brake thermal efficiency, brake specific fuel consumption and emissions generation [13]. The maximum increase in power was observed for 50% jatropha biodiesel and diesel blend at rated speed while the best brake specific energy consumption improvement was observed with 20% of polanga biodiesel [14]. No [3] reported that biodiesel generally causes an increase in NOx emission and a decrease in hydrocarbon (HC), carbon monoxide (CO) and particulate matter (PM) emissions compared to diesel. It was also pointed out that a diesel engine without any modification would run successfully on a blend of 20% vegetable oil and 80% diesel fuel without damage to engine parts. Biodiesel is capable of reducing PM, HCs, CO, sulphates, polycyclic aromatic hydrocarbons, nitrated polycyclic aromatic hydrocarbons, and toxic emissions. As a result, it is considered to be more environmentally favourable than the fossil fuels as they essentially contain no aromatic compounds [15].

Moreover, biodiesel is a sulphur free fuel with significantly higher oxygen content than petroleum diesel, thus rendering it to be more eco-friendly than conventional automotive fuel.

6. Discussion and Further Study

The second generation biodiesels have not yet adequately been explored and evaluated in internal combustion engine. In order to improve the technical and economic feasibility, and improve the conversion technology to achieve a sustainable production at a cheaper cost, it is essential to promote further research. However, a thorough research is still needed to advance the technological breakthroughs in biodiesel use to achieve the cost reductions along with the appropriate engineering technology. In future study, oil extraction as well as biodiesel production will be carried out from Australian Beauty Leaf Tree (BLT) which is native to Australia. The optimizing factors associated with the optimization of oil extraction techniques will be also investigated. Further characterisation of biodiesel properties of BLT will be undertaken.

7. Conclusion

The second generation biodiesels have become the leading raw materials for obtaining biodiesel due to an increase in world's energy demand, competition of edible oil sources for human use and biofuel production as well as environmental pollution. To establish and continue to optimise the procedures for the use of second generation biodiesel, various aspects such as cost effectiveness, necessity of second generation biodiesel, biodiesel conversion technology, improving efficiency of the production process as well as performance and emission characteristics must be scrutinized and studied. The transesterification method is the most suitable method among the several possible methods for biodiesel production.

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