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REGIONAL RENEWABLE ENERGY (A SHARMA, SECTION EDITOR)

Role of Biodiesel in Indian Renewable Energy

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Abstract The world is confronted with the twin crises of fossil fuel reduction and environmental degradation. The random extraction and consumption of fossil fuels have led to a reduction in petroleum reserves. Alternative fuels, energy conservation and management, energy efficiency, and environmental protection have become important in recent years. Biodiesel is a one of an alternative, which is being used in large quantities in transport, agriculture, industrial, commercial, and domestic sectors. Biodiesel obtained from vegetable oils has been considered a promising option. In the present study, a detailed comparison has been made of the various processes of manufacture of biodiesel with latest feedstocks. The recent market of biodiesel with respect to Indian economy has also been presented in the present work.

Keywords Renewable energy sources · Bio-energy · Vegetable oils · Biodiesel · Sustainable · Fuel economy

Introduction

The world has been confronted with an energy crisis due to the reduction of finite resources of fossil fuel. The petroleum-based fuels are continuously used which is now recognized as unsustainable because of depleting supplies and huge use of these fuels to pollute the environment. India meets early 75–80% of its total petroleum requirements through imports. The hydrocarbons sector plays an essential role in the economic growth of the country. With the increase in the share of hydrocarbons in the energy supply/use, this share of imported energy is expected to exceed 90% by 2030 [1]. Another effect of global warming includes a potential increase in sea level and following submerging of lowlands, deltas, and islands, as well as changing of nature. It has been believed that climate change is currently the most urgent global environmental problem [2]. So, the global warming has been caused by widely used of fossil fuels; therefore, fossil fuels as a source of energy should be replaced with renewable, clean energy sources to reduce carbon dioxide and greenhouse gas emissions [three new]. Renewable energy sources (RES) will play an important role in the world's future. RES supply 14% of the total world energy requirement [4]. RES includes biomass, hydropower, geothermal, solar, wind, biodiesel, and marine energies. The renewables the primary, domestic, and clean or inexhaustible energy resources [5]. For increasing demand of diesel, biodiesel is one of an alternative fuel produced from renewable resources means natural sources. Long years ago, Rudolf Diesel examined peanut oil as fuel for his engine for the first time on August 10, 1893 [6]. During the 1930s and 1940s, vegetable oils were used as diesel fuels, usually only in an emergency. Vegetable oils hold promise as alternative fuels for diesel engines [7].

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International Review

Dincer [8] stated that achieving solutions to environmental problems that is faced now days requires long-term potential actions for sustainable development. In this regard, renewable

energy resources appear to be one of the most efficient and effective solutions. Ahmad et al. [3] and Mata et al. [9] investigated that out of three generations of biodiesel feedstocks like food crops, non-food crops, and microalgae-derived biodiesel, microalgae is the only source that can be sustainably developed in the future. Microalgae can be converted directly into energy, such as biodiesel, and therefore appear to be a promising source of renewable energy. They presented a comparison between the use of microalgae and palm oil as biodiesel feedstocks. They also depicted the inefficiency and unsustainability of the use of food crops as a biodiesel source having increased interest in the development of microalgae species to be used as a renewable energy source. Demirbas [10] suggested biodiesel be the best candidate for diesel fuels in diesel engines. The biggest advantage that biodiesel has over gasoline and petroleum diesel is its environmental friendliness. Biodiesel burns similar to petroleum diesel as it concerns regulated pollutants. They investigated that biodiesel probably has better efficiency than gasoline. According to their study, biodiesel is mainly being produced from soybean, rapeseed, and palm oils. The major economic factor to consider for input costs of biodiesel production is the feedstock, which is about 80% of the total operating cost. The high price of biodiesel is in large part due to the high price of the feedstock. Economic benefits of a biodiesel industry would include value added to the feedstock, an increased number of rural manufacturing jobs, an increased income taxes, and investments in plant and equipment. Gerpen [11] described that biodiesel is an alternative diesel fuel that is produced from vegetable oils and animal fats. It consists of the monoalkyl esters formed by a catalyzed reaction of the triglycerides in the oil or fat with a simple monohydric alcohol. The reaction conditions generally involve a trade-off between reaction time and temperature as reaction completeness is the most critical fuel quality parameter. The main constraint in the manufacturing process originates from contaminants in the feedstock, such as water and free fatty acids, or impurities in the final product, such as methanol, free glycerol, and soap. He reviewed that new processes have been developed to produce biodiesel from high free fatty acid feedstocks, such as recycled restaurant grease, animal fats, and soapstock. Marchetti et al. [12] described various possible ways of biodiesel manufacture. They noted that biodiesel production is a very modern and technological area for researchers due to the relevance that it is winning everyday because of the increase in the petroleum price and the environmental advantages. They reviewed alternative technological methods that could be used to produce this fuel. Different studies have been carried out using different oils as raw material, different alcohol (methanol, ethanol, butanol), as well as different catalysts, homogeneous ones such as sodium hydroxide, potassium hydroxide, sulfuric acid, and supercritical fluids, and heterogeneous ones such as lipases. Atabani et al. [13] reviewed on biodiesel as an alternative energy resource and its characteristics. They studied on various aspects like biodiesel feedstocks, extraction and production methods, properties and qualities of biodiesel, problems and potential solutions of using vegetable oil, advantages and disadvantages of biodiesel, the economical viability, and finally the future of biodiesel. Based on their review, it is revealed that the search for beneficial biodiesel sources should focus on feedstocks that do not compete with food crops, do not lead to land-clearing and provide greenhouse gas reductions. These feedstocks include non-edible oils such as *Jatropha curcas* and *Calophyllum inophyllum*, and more recently microalgae and genetically engineered plants such as poplar and switchgrass have emerged to be very promising feedstocks for biodiesel production. Their study showed that feedstock alone represents more than 75% of the overall biodiesel production cost. Biodiesel is currently not economically feasible, and more research and technological development are needed. Thus, supporting policies are important to promote biodiesel research and make their prices competitive with other conventional sources of energy. Accordingly, with reference to world energy scenario [14], some 85–90% of world primary energy consumption will continue (until 2030) to be based on fossil fuels. At the same time rising petroleum prices, increasing the threat to the environment from exhaust emissions and global warming have generated intense international interest in developing alternative non-petroleum fuels for engines. The use of vegetable oil in internal combustion engines is not a recent innovation. Nowadays, it is known that oil is a finite resource and that its price tends to increase exponentially, as its reserves are fast depleting [14]. Biodiesel is a clean burning fuel that is renewable and biodegradable. Biodiesel is being extracted from Mahua oil [15], rubber seed oil [16], *Pongamia pinnata* oil [17], palm oil [18], *Jatropha curcas* [19, 20], duck tallow [21], and castor seed oil [22].

National Review

Khan et al. [6] studied that biodiesel produced from oil crop, waste cooking oil, and animal fats are not able to replace fossil fuel. The viability of the first generation biofuels production is, however, questionable because of the conflict with the food supply. Production of biodiesel using microalgae biomass appears to be a viable alternative. They found that microalgae are photosynthetic microorganisms which convert sunlight, water, and CO_2 to sugars, from which macromolecules, such as lipids and triacylglycerols (TAGs) can be obtained. These TAGs are the promising and sustainable feedstock for biodiesel production. Sahoo and Das [7] reviewed that biodiesel derived from oil crops is a potential renewable and carbon neutral alternative to petroleum fuels. It is produced by transesterification in which, oil or fat is reacted with a

monohydric alcohol in the presence of a catalyst. The process of transesterification is affected by the mode of reaction condition, the molar ratio of alcohol to oil, type of alcohol, type and amount of catalysts, reaction time and temperature, and purity of reactants. In their work, various methods of preparation of biodiesel from non-edible filtered jatropha (*Jatropha curcas*), karanja (*Pongamia pinnata*), and polanga (*Calophyllum inophyllum*) oil have been described. Barnwal and Sharma [23] investigated that biodiesel obtained from vegetable oils has been considered a promising option. They made an attempt to review the work done on biodiesel production and utilization, resources available, processes developed/being developed, performance in existing environmental considerations, the economic aspect, and advantages in and barriers to the use of biodiesel. An assessment of current energy scenario, potential of non-edible oil over edible oils, selected non-edible oil seeds as biodiesel feedstocks, the impact of biofuel on the environment, and future direction was made by Kumar and Sharma [24]. Singh and Singh [25] investigated biodiesel fuel derived from triglycerides (vegetable oil and animal fates) by transesterification with methanol, present the promising alternative substitute to diesel fuels. The main advantages of using biodiesel are its renewability, better quality exhaust gas emission, its biodegradability, and the organic carbon present in it is photosynthetic in origin. It does not contribute to a rise in the level of carbon dioxide in the atmosphere and consequently to the greenhouse effect. Murugesan et al. [26] described various biodiesel production methods among which transesterification using alkali catalyst gives a high level of conversion of triglycerides to their corresponding methyl ester in short reaction time. The process of transesterification is affected by the reaction condition, the molar ratio of alcohol to oil, type of alcohol, type and amount of catalysts, reaction time and temperature, purity of reactants free fatty acids, and water content of oils or fats. Kumar et al. [27] reviewed that jatropha, a non-edible oil seed yielding plant has been identified by the Government of India to produce biodiesel under National Biodiesel Mission. They stated that failure of National Biodiesel Mission Phase-I requires critical analysis of all the possible facts related to its long-term sustainability. In their work, they have identified important sustainability issues related to promotion of jatropha biodiesel in India. These sustainability issues have been regrouped in four major categories: technological, environmental, economic, and social. Karmakar et al. [28] investigated the discrepancies between the expectation and realities regarding Jatropha as a feedstock for production of biodiesel necessitate efforts for diversification of the feedstocks. They suggested that alternative feedstocks like oilseeds like Karanja, Sal, Mahua, Neem, etc. that are widely available and sustainable to the diverse socio-economic and environmental conditions of rural India. They reviewed the morphology of neem tree, various useful uses, physical and chemical characteristics of neem oil, and optimized production process for biodiesel production from neem oil. Sahoo et al. [7, 29] produced non-edible filtered high viscous (72 cSt at 40 °C) and high acid value (44 mg KOH/g) polanga (*Calophyllum inophyllum* L.) oil-based mono esters (biodiesel) by triple stage transesterification process and blended with high speed diesel (HSD) and were tested for their use as a substitute fuel of diesel in a single cylinder diesel engine. Along with they also produced non-edible jatropha (*Jatropha curcas*), karanja (*Pongamia pinnata*), and polanga (*Calophyllum inophyllum*) oil based methyl esters and blended with conventional diesel having sulfur content less than 10 mg/kg. Ten fuel blends (Diesel, B20, B50, and B100) were tested for their use as a substitute fuel for a water-cooled three-cylinder tractor engine. Test data were generated under full/part throttle position for different engine speeds (1200, 1800, and 2200 rev/min). Change in exhaust emissions (Smoke, CO, HC, NOx, and PM) were also analyzed for determining the optimum test fuel at various operating conditions. The maximum increase in power is observed for 50% jatropha biodiesel and diesel blend at rated speed. Subramanian et al. [30] studied the policy and planning issues for utilization of ethanol and biodiesel in automotive diesel engines in Indian context in view of environmental benefits, energy self-sufficiency, and boosting the rural economy as well as measures related to implementation and barriers. They focused on transport and refinery scenario, land availability for production of biodiesel, and potential sources for biodiesel and ethanol. Meher et al. [31] reviewed that biodiesel is gaining more and more importance as an attractive fuel due to the depleting fossil fuel resources. Chemically biodiesel is monoalkyl esters of long-chain fatty acids derived from renewable feedstock like vegetable oils and animal fats. It is produced by transesterification in which, oil or fat is reacted with a monohydric alcohol in the presence of a catalyst. The process of transesterification is affected by the mode of reaction condition, the molar ratio of alcohol to oil, type of alcohol, type and amount of catalysts, reaction time and temperature, and purity of reactants.

Present Scenario in Indian Market

India's biodiesel production captured for only 1% of global production in 2012. Currently, first generation feedstocks such as sugarcane, maize, sugarbeet, and cassava are commonly exploited for bio-ethanol along with palm oil, jatropha oil, and other edible oils from various oilseed crops for the production of biodiesel. But since the production of these fuels competes with food crops, questions regarding food security and sustainability issues arise. Thus, there is tremendous potential for second-generation biodiesel in India, especially for cellulosic and agricultural crop residues. Indian Institute of Science, Bengaluru and Tamil Nadu have been carried out

some development works to the production of trans-esterified non-edible oil and its use in biodiesel. To establish the parameters of the production of trans-esterified jatropha vegetable oil and use of biodiesel, Indian Oil Corporation (IOC) has taken up research and development work in its research and development center at Faridabad [32]. Recently, Indian railway set up the four biodiesel plants. Biodiesel producers looking for tie-ups with telecom tower firms. IOC wants 50,000 acres for biodiesel cultivation in UP. Railways develop engines powered by biodiesel. Present estimates indicate India's biodiesel demand at very few billion gallons in 2012 which will grow to 6.8 billion gallons by 2022. According to India's Planning Commission, the demand for diesel in India is five times higher than petrol. But while the ethanol industry is mature, the biodiesel industry is in its infancy. India's ambitious National Biodiesel Mission will aid in the technological research, production and trade of biodiesel in order to meet 20% of the country's diesel requirements by 2012 and drive production levels upwards for the subsequent years.

Conclusions

Currently, India's position in global biodiesel map is not very high up. However, the country has plans to expand the biodiesel sector. In our country, most of the energy demands are met by crude oil import, energy security has become the main importance economic development of the country. Currently, biodiesel has become more attractive as an alternative fuel for diesel engines because of its environmental benefits and it is produced from renewable resources. Among the several methods of production transesterification of natural oils and fats mostly followed. The purpose of the process is to lower the viscosity of the oil or fat. More works are done on edible oils to produce the biodiesel because of easily availability and familiarity. In terms of production cost, there also are two aspects, the transesterification process, and byproduct (glycerol) recovery. A continuous transesterification process is one choice to lower the production cost. The foundations of this process are a shorter reaction time and greater production capacity. The recovery of high-quality glycerol is another way to lower production cost. Due to population growth land is a problem and to overcome this, the high yielding biodiesel plants can be set up in (non-edible producing plants) in marginal and waste land areas. Apart from oils and fats biodiesel feed is mainly jatropha due to its wide adaptability, low fertilizer and irrigation requirement, pest resistance, etc. Among other non-edible oils neem with its multiple valuable uses draws attention as a sustainable biodiesel feedstock. Neem can be used for better pest and nutrient management, reforestation, medicinal purposes, environmental purification, etc. In the initial phase of introduction, biodiesel is likely to be expensive than diesel. The difference between petrodiesel and biodiesel would need to be covered by subsidy/concessions to petroleum sectors.

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Compliance with Ethical Standards

Conflict of Interest Koushik Guha Biswas and Lipika Das declare that they have no conflict of interest.

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