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Development of Biofuels as an Alternative Source to Petroleum: A Review

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Authors' contributions

This work was carried out in collaboration between both authors. Author RM designed the study, wrote the protocol and wrote the first draft of the manuscript. Author AME managed the literature searches. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Biofuel is a type of renewable energy created from living materials, compared to fossil fuels like coal, oil, and natural gas, which are formed through slow natural processes. Biofuels can be liquid, gaseous, or solid. In place of petroleum and other fossil fuels, biofuel is frequently promoted as a convenient and environmentally friendly option. Since there is already a substantial infrastructure in place to facilitate their use, particularly in transportation, liquid biofuels are particularly alluring. Ethanol, a liquid biofuel that is most frequently used, is made by fermenting starch or sugar. The second most common liquid biofuel is biodiesel, which is mostly produced from oily plants (like palm or soybean oil) and to a lesser extent from other oily sources. Biodiesel is used in diesel engines and is usually blended with petroleum diesel fuel in varying quantities. Some algae species have up to 40% lipids by weight, which can be used to make biodiesel or synthetic petroleum. The four basic forms of biofuels were discussed in this review along with their benefits and drawbacks, aside from their economic and environmental concerns.

Keywords: Biofuels; biomass; biodiesel; ethanol; feedstock; sustainability; biofuel generations.

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1. INTRODUCTION

Fossil fuel combustion results in the release of greenhouse gases (GHGs), which contribute to global warming and have detrimental effects on the ecosystem [1]. The need for more energy and the depletion of fossil fuel supplies have forced researchers to look for alternative energy sources made of living things like microbes, plants, and animals [2]. In order to reduce greenhouse gas emissions and stop global warming, biofuel has become a powerful source of energy [3]. There are four generations of biofuels: first, second, third, and fourth. Each generation of biofuel aims to meet the world's energy needs while reducing environmental effects. The liquid or gaseous fuels that are produced from biomass sources are called biofuels, which are an alternative to fossil fuels. The fermentation of biological feed-stocks that contain fermentable sugars, lipids, or carbohydrates yields biofuels. This is accomplished by transforming the biomass in the feed-stocks into various energy sources, including heat, electricity, biogas, and liquid fuels [4]. The use of biofuels is optional; they can be combined with other fossil fuels. The first generation of biofuels includes bioethanol and biodiesel, which are made from seed oils and starches, respectively. Vegetable oils have high viscosity, high density, and a number of other issues that make them potentially dangerous for use directly in diesel engines. In order to replace petroleum-based diesel, it is necessary to convert these sources into biodiesel through a process called bio-trans-esterification [5,6]. Cellulosic raw materials for the second generation of biofuels were grown on land that couldn't be used for food production. The third and fourth biofuel generations, on the other hand, are categorized as being made from algal biomass and, respectively, specially engineered plants and microorganisms [7–12]. This review article discusses the various generations of biofuels and how non-edible and vegetable oils can be converted to biodiesel through the bio-transesterification process, as well as how sugars can be converted to bioethanol either by enhancing the medium and substrates needed for ethanol production or by genetically altering yeast cells.

2. TYPES OF BIOFUELS

By using clean energy technology like biofuels, we can avoid the drawbacks of fossil fuels. Biofuels come in a variety of forms and are applied to meet a range of energy needs. The four most prevalent biofuel generation types are listed below (Table 1).

First generation: The first generation of biofuels includes bioethanol and biodiesel produced from starch, sugars, and seed oils, besides biogas, which is created by anaerobic bacteria fermenting organic waste [13]. Rural communities can best meet their energy needs by using biogas, which is recognised as a low carbon fuel source. In this regard, due to their high viscosity, high density, and several other issues associated with them, the direct use of vegetable oils may prove dangerous for diesel engines. In order to replace petroleum-based diesel, these sources must be transformed into biodiesel through a process called trans-esterification. Biodiesel is the second most prevalent liquid biofuel, and it's manufactured mostly from oily plants (palm or soybean oil) and to a lesser extent from other oily sources [14]. The first generation of biofuels is distinct from the second in that the majority of the biofuels currently in use come from plant crops, as opposed to other sources. First generation biofuels' primary disadvantage is that their biomass, which is used as a food source, is also a source of energy [15]. Ethanol is generally produced on a large scale by the fermentation process of six-carbon atom sugars, such as glucose, using the genetically modified yeast strain *Saccharomyces cerevisiae* [16,17]. Other different feedstocks such as sugarcane, corn, barley, sugarbeets, and potato wastes, are also used. Biodiesel is another biofuel produced on an industrial scale. Its production differs from ethanol's one in that after extracting the oils, there is a need methanol to convert the long chain fatty acids to glycerol by a transesterification process.

Second generation: This category of biofuels is manufactured from various organic feedstocks (biomasses), including woody plants, lingo-cellulosic biomass, agricultural forest residues, municipal solid waste, and waste plant materials. On land that cannot be successfully used for food production, the raw materials for second-generation biofuels should be grown [18,19]. This biomass is processed in a complicated manner that makes use of a number of different technologies [20,21]. The plants used as biomass for second-generation biofuels include those specifically bred for the purpose of producing bioenergy (bioenergy crops), which are grown on small plots of land, as well as non-edible byproducts of conventional crops and forest trees that can be processed efficiently for bioenergy by developing current technologies. Second-generation biofuels use thermochemical and biochemical routes, respectively, to convert lingo-cellulosic biomass into biofuel [22,23,15]. In the thermochemical process, biomass is heated to different degrees with a negligible quantity of an oxidising agent, resulting in its conversion into three fractions: biochar, a liquid termed bio oil or pyrolytic oil, and syngas. Under the influence of a reducing catalyst, methanol can be generated via this process from hydrogen and carbon monoxide [24–27]. The biochemical route begins with the separation of cellulose from lingo-cellulotic biomass and ends with the saccharification of cellulose through an enzymatic fermentation process [28–30]. Genetically engineered yeast strains can ferment hemicellulose, a carbohydrate-based polymer made of C5 and C6 nonosaccharide sugars, as opposed to conventional yeast. In the case of the presence of acetic and formic acids in the fermented biomass, additional operations are needed for detoxification [31]. According to Shabtai and his collaborators, lignin may be transformed into transportation jet fuels and added-value chemicals including phenol, guaiacol, and cathecol [32]. Since the majority of the species generate harmful seeds and are not consumed as food, jatropha is typically approved as a second generation feedstock [33].

Third generation: According to one definition, the third generation of biofuels are those made from algal biomass, which has a far higher quality and growth output than traditional lignocellulosic biomass [34]. The oil produced by algae is simple to convert into diesel fuel, but its stability is lower than that of other biofuels because excessively unsaturated oils are volatile at high temperatures. Lipids extracted from algae such as Chlorella can be transferred to biodiesel through the transesterification process or can be processed by hydrogenolysis to produce kerosene [35]. Although commercial-scale algae production for the purpose of extracting oil for biofuels has not yet been undertaken, feasibility studies were conducted to determine the aforementioned output estimate.

Fourth generation: These biofuels can be cultivated on non-agricultural land or in bodies of water and are made from specifically bred, engineered microbes, plants, or biomasses that will have higher energy outputs, fewer restrictions on cellulose breakdown, or both [36]. The fourth generation of biofuel also emphasises the genetic engineering of microalgae [37]. With the help of cutting-edge technologies, it is intended to generate microalgae that can efficiently absorb huge levels of CO_2, boost the output of biofuel, and adapt to their environment in wastewater [38,39]. Due to the fact that the amount of CO_2 released is less than the amount of CO_2 taken up, genetically modified microalgae are regarded as carbon negative [40,41]. This kind of biofuel is produced by photosynthetic microorganisms to produce photo-biological sun-powered fills, by combining photovoltaics and microbial fuel generation, or by manufacturing cell production lines or manufactured organelles that are specifically designed for the production of desired high-value chemicals and biofuels [42]. Biomass crops are viewed as effective "carbon capturing" devices in the fourth generation because they remove CO_2 from the environment and store it in their branches, trunks, and leaves. Following that, second generation processes are used to transform the carbon-rich biomass into fuel and gases. In addition to being renewable, the producing fuels and gases are also practically carbon-negative. By substituting fossil fuels, the system not only removes and stores CO2 from the atmosphere but also lowers carbon dioxide emissions.

Table 1. Types of biofuels generations: Their bio-masses sources and products

Biofuels ‘generation	Source	Product
First generation	Starch, Sugars, Seed oils	Bioethanol, Biodiesel, Biogas
Second generation	Ligno-cellulosic Biomass or woody crops, Jatropha, Waste plant materials	Bio oil, or pyolytic oil, Syngas, Biochar
Third generation	Classical lignocellulosic biomass	Biodiesel, Unsaturated oils
Fourth generation	Specially designed engineered microorganisms and plants, Genetically modified microalgae	Carbon-negative fuels, Biohydrogen, Biomethane

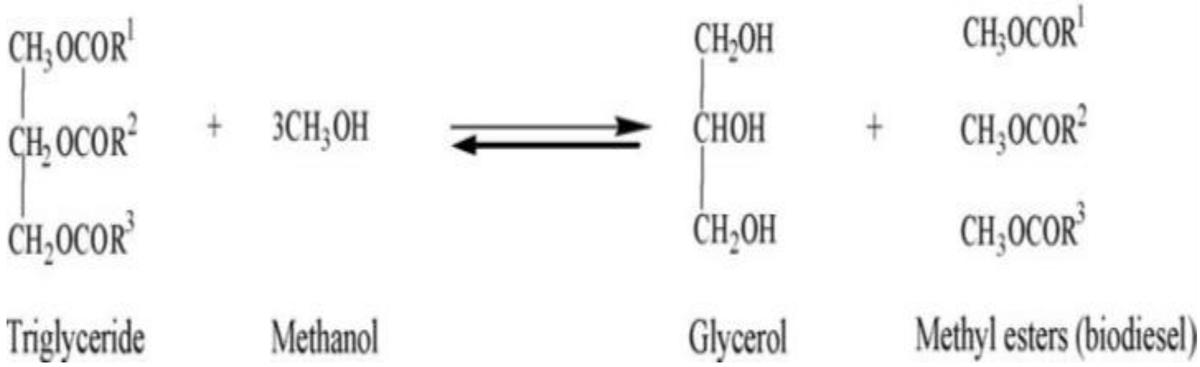

Fig. 1. Transesterification in biofuel production

Transesterification: When a triglyceride and an alcohol molecule mix, glycerol and alkyl esters are produced as byproducts. This process is known as transesterification. Catalyst impact, which aids in accelerating the reaction, causes this process to progress. A high yield of methyl esters can be produced through transesterification by carefully regulating the different factors that govern the process [43,44]. These variables include the catalyst dosage, the proportion of alcohol to oil, the reaction temperature, and the reaction period. There are two methods that have been suggested for trans-esterifying vegetable oils to produce biodiesel. Enzymatic transesterification is carried out in a non-aqueous environment in the first method, which uses lipase as the catalyst. The second method is chemical, including the use of methanol or ethanol to treat extracted oil in the presence of a potent acid or base [45].

2.1 Advantages and Disadvantages of Biofuels

The price of biofuels has been dropping, and they will likely be far less expensive than gasoline and other fossil fuels soon. Biofuels can be created from a wide range of materials, including crop waste, manure, and other by-products, as opposed to oil, which is a limited resource and derived from certain materials. As a result, recycling is a useful procedure. Furthermore, the production of fossil fuels takes a very long period, whereas the production of biofuels may be done much more quickly as new crops are raised and waste materials are collected [46]. Domestic biofuel production can reduce the country's dependency on foreign resources. By lowering their reliance on foreign sources, the nations will thus ensure the security of their energy supply and protection from international influences [47]. The development of biofuels would increase the need for enough biofuel crops, boosting the economy of the agriculture sector. Biofuels are a better option for protecting atmospheric health and lowering air pollution because they emit fewer pollutants and produce significantly less carbon dioxide when burned [48]. Biofuels can be produced in any country without interfering with the energy sources of other countries, unlike fossil fuels, which are only found in a small number of countries. A nation can simply set its own product prices if it can create its own biofuel, unrestricted by regional or worldwide restrictions. Due to their similarity to fossil fuels, biofuels can be used to assist break the monopoly that they produce [49]. For instance, biogas can be used in the same ways as natural gas. People will therefore have the choice to switch to biogas when natural gas prices rise [50]. When fossil fuel prices rise, drivers can switch to ethanol or butanol, which are better substitutes. Despite the many positive aspects of biofuels, there are still many negative aspects to these fuel sources. Because they produce less energy than traditional fuels, biofuels must be used more frequently to provide the same quantity of energy. Food costs and food shortages may be impacted by the usage of cropland for the production of fuel crops [48]. By requiring more area and water for crop irrigation, bio crops can raise production costs. The correct watering of biofuel crops and the generation of gasoline, which may put a burden on local and regional water supplies, also require a sizeable amount of water. The low diversity biofuel sources, such as corn, sugarcane, soybeans, and oil palms, which are conventional agricultural crops, are mostly to blame for some of the drawbacks of biofuels (Table 2).

Table 2. Advantages and disadvantages of biofuels

	Advantage	Disadvantage
1	A renewable energy source is biofuels.	Biofuels have a lower energy output than petroleum based fuels.
2	Crop wastes and other byproducts are among the less expensive sources from which biofuels can be made.	Large amounts of carbon dioxide are released when biofuels are burned.
3	In the near future, biofuels may be more or less cheap than fossil fuels, as the prices of fossil fuels rise with time.	great concern about the valuable cropland used for biofuel production.
4	Biofuels are environmentally friendly and their burning causes less pollution.	If crops are cultivated for the purpose of making biofuels, there will be a lack of food for human consumption.
5	The generation of biofuels decreases the nation's reliance on foreign resources.	Wasting a large amount of water for the proper maintenance of biofuel crops.
6	Production of biofuels can significantly contribute to a decrease in greenhouse gas emissions.	Biofuels must be used in vast quantities and are often produced from sources with low biological variety in order to have the same energy levels as petroleum-based fuels.

3. ENVIRONMENTAL AND ECONOMIC CONSIDERATIONS

The energy required to create biofuels must be considered when assessing their economic and financial benefits. Fossil fuels are used in the production of fertilizer, farming machinery, corn transportation, and ethanol refinement during the process of cultivating corn for ethanol. The energy gain from maize ethanol is typically negligible compared to that from sugarcane, cellulosic ethanol, or algal biodiesel, which may be much more apparent [51]. When evaluating the advantages of biofuels, land use is another crucial factor. A debate regarding "food versus fuel" was sparked by the use of popular feedstocks like corn and soybeans as a primary component of first-generation biofuels. By diverting agricultural land and feedstock from the human food chain, biofuel production can change the economics of food availability and price [52]. Furthermore, energy crops developed for biofuel may compete for local environmental characteristics worldwide. One intriguing benefit of biofuels is that, in conjunction with an emerging technology called carbon capture and storage, the process of producing and using biofuels may be able to permanently remove CO2, a greenhouse gas, from the atmosphere [53–55]. Carbon dioxide would be removed from the atmosphere as biofuel crops grew and captured as biofuels are burned to produce electricity in energy facilities. It is possible to store carbon dioxide that has been trapped in the environment in solids like carbonates, deep sea silt, or geologic formations beneath the earth's surface [56–58].

4. CONCLUSION

Fossil fuels are expected to be severely scarce in the near future, which will have serious environmental repercussions. Consequently, it is essential to have a clean, sustainable alternative energy source. Fusion, wind, solar, and tidal energy are among examples. Biofuels are the ideal substitute for petroleum-based fuels due to their excellent combustion profile and environmentally friendly makeup. Moreover, it is possible to obtain the feed-stocks needed to produce biofuels in an efficient manner. Since they may be made from waste materials like used vegetable oils and less expensive sources like non-edible oils like jatropha and neem oils, etc., biofuels have an advantage over petroleum fuels. Parasites and green growth can both be utilized as the basic building blocks for producing biofuels. Because of their superiority over conventional gasoline and diesel due to their renewable nature, biofuels can be employed in place of fossil fuels, which are not renewable. Although there are a number of disadvantages to switching to biofuels instead of gasoline and diesel, overall, they are still preferable to those fuels. Pioneers in the creation of biofuels include Brazil, India, Indonesia, and other countries. Engines benefit from using biofuels because they improve their lubricating properties. Bioethanol and biodiesel are the two main types of biofuels, and they are created by fermentation and transesterification processes, respectively. The productivity of biofuels can be increased and improved by employing various techniques like ultrasound, microwave, and irradiations. By changing the production methods, these two processes can boost the yield of these two items. Additionally, to increase the yield of the biofuel, molecular and genetic engineering techniques can be applied to the raw materials. In principle, biofuels can be a useful approach to lessen our reliance on finite fossil fuels while also being good for the environment. In order to meet the rising global demand brought on by the depletion of the world's oil reserves, the future of biofuels might not be dependent exclusively on one generation but rather on a combination of the four generations.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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