



THE ROLE OF BIODIESEL IN SUPPORTING ENERGY SECURITY: GLOBAL OPPORTUNITIES AND CHALLENGES/ A REVIEW ARTICLE

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Article history:	Abstract:
Received: 20 th August 2024	Background: This study builds upon a range of prior research examining the influence of biofuels on reducing carbon emissions, enhancing energy security, and meeting the increasing demand for sustainable energy resources. Objective: The analysis incorporates environmental and economic data to compare the performance of biodiesel with conventional fossil fuels, focusing on emissions and the degree of dependence on local sources. Results: The findings indicate that biodiesel can lower greenhouse gas emissions by 50% to 70% compared to traditional fossil fuels and contribute to better energy security. However, challenges such as high production costs and competition with food crops persist. Conclusions: Biodiesel is anticipated to play a significant role in promoting environmental sustainability and reducing dependence on fossil fuels to achieve these goals more effectively, advancements in production technologies and policies that support cost reduction and increased efficiency are essential.
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INTRODUCTION

The last years have brought about a revolution in energy driven by the pressing need felt for alternative and sustainable sources of energy within this framework, biodiesel represents one of those innovative responses to make large contributions toward securing better energy at the global level. Biodiesel is a biofuel manufactured from organic materials, vegetable oils, or animal fats and is envisioned as an alternative to fossil fuels in a sustainable manner [1]. During a time when the whole world was struggling with a very critical energy crisis, along with severe climate changes, biodiesel would contribute much to improving energy sustainability and is associated with many opportunities and challenges [2]. Biodiesel is considered one of the most important renewable alternatives to energy in a world that confronts major challenges such as climate change, increased demand for energy, and high oil prices. This biofuel, obtained from plant or animal material, presents several advantages in the field of improvement of energy security; however, it also has some obstacles that should be surmounted [3].

1. The role of biodiesel in confronting climate change: One of the greatest challenges facing the world today is climate change brought about by the emission of greenhouse gases Fossil fuels, including oil and coal, are the primary causes of these gases. On the other hand, biodiesel is helpful in keeping the amount of these gases much lower because it is manufactured from organic materials that do not add to the amount of carbon dioxide accumulating in the atmosphere when used. In fact, according to various studies, it was

shown that biodiesel reduces greenhouse gas emissions from 50% to 70% compared to conventional diesel, hence it is environmentally friendly [4].

2. Challenges associated with high oil prices: This shift in the global market, according to changes in the oil price, has a direct consequence on the energy price. It may affect the economies of countries reliant on energy imports. Biodiesel thus provides a local alternative capable of being produced by renewable agricultural resources, hence reducing the dependence on imported oil. Biodiesel could help improve energy security by minimizing the influence that volatile oil prices have on economic activities [5].

3. High demand for energy: With the rapid population and economic growth in most countries, the demand for energy in the world continues to surge upwards. In meeting this growing demand, biodiesel can certainly play its part. Being a substitute for fossil fuels, it is viable on account of its sustainability, ease of integration with existing energy grids, and reduction in pressure on perhaps limited oil and natural gas resources [6].

4. Improvement in energy security: The heavy consumption of fossil fuel may render a state to an energy crisis because of price fluctuation or supply disruption due to political reasons at some region. By adopting biodiesel, countries can reduce their energy dependence on such regions. Countries that heavily depend upon local sources like agricultural crops can reduce their risks of external fluctuation and improve energy security [7].

5. The challenges biodiesel faces: Despite all the great benefits coming from biodiesel, there is also some obstacles that need to be faced. The highly expensive production in comparison to the fossil fuel, in addition to the environmental impacts caused by some agricultural practices to produce the necessary raw material, represent obstacles that need to be breached. New technologies must be developed which could minimize such obstacles - whether it be by enhancing production efficiency or through the use of less expensive raw materials [8].

OPPORTUNITIES OFFERED BY BIODIESEL

Biodiesel presents various opportunities for enhancing energy security both at the domestic and international levels through several key advantages. This is because biodiesel is among those promising solutions to support global energy security, in particular, in view of the challenges which the energy world is still facing. It is a biofuel produced from nature and renewable resources such as vegetable oils, animal fats, and agricultural waste, hence offering a sustainable and eco-friendly option to traditionally used fossil fuels. With the backdrop of global climatic change and increased greenhouse gas emissions, governments and companies are increasingly under pressure to seek cleaner and less destructive sources of energy. Here comes the role of biodiesel, as its usage emits less carbon dioxide and other pollutants in the atmosphere. The point in its favor helps it stand on higher ground concerning environmental policies to curb climate change, hence it also supports sustainability[9], on the other hand, biodiesel offers huge opportunities to reduce dependence on oil imports-a significant factor for a number of countries relying heavily on imported energy. Locally produced fuel contributes to greater energy independence and reduces exposure to geopolitical fluctuations affecting global oil markets. Independence that will contribute to improving the economic situation in accordance with the consequences of the global crisis: a rise in oil prices, disruption in supply chains. Moreover, it figures prominently in support for local economies by opening wide the door to new job opportunities in agriculture, production, and distribution [10]. Growing crops for biodiesel production, such as rapeseed, corn, and soybeans, increases agricultural activities and infrastructural development in rural areas, further promoting sustainable development and helping to improve the quality of life in these communities, there is some concern with regard to biodiesel production in the way of what advanced technology is needed to increase efficiency in production and cut costs, balancing the use of crops to produce fuel versus food. With developments in technology and the increasing interest taken in sustainability, in the future, biodiesel is expected to contribute more toward solving energy problems and represents an opportunity to provide a more flexible and sustainable energy system that enhances the ability of countries to confront energy and environmental crises while reducing dependence on fossil fuels in a sustainable manner [11].

Biodiesel-related issues:

Despite all the benefits biodiesel provides as an environmentally friendly alternative fuel, a set of challenges exists impeding its wide applicability on a global scale. The economic, environmental, and technical issues originating in its development are the major hindrances to developing it as a primary energy option. Some of the major ones among them are explained below according [12].

High cost: Production of biodiesel requires huge investment in the infrastructural and technological equipment required for extraction and processing of the fuel. The costs range from the purchase of equipment to the conversion technology and even the costs related to the waste treatment. The production

cost of biodiesel is normally higher than that of the fossil fuels. This is the reason why its investment is not significant, particularly for the small companies and governments that have less resources. Although large-scale processing and enhancement of technology can reduce the prices of biodiesel, huge initial costs provide a big hindrance to getting started.

Agricultural land competition: Agricultural land used to grow crops suitable for biodiesel, such as soybeans or palm oil, may replace areas used to grow staple food crops. The replacement brings about a question of food security in nations that have suffered from the lack of local food production. Demand for biofuel crops increases food prices, hence affecting the low-income community.

Environmental Impact: With regards to the consideration of how much greener biodiesel is, taking into consideration the fact that its production through crop cultivation has resulted in environmental destruction in cases where the practice is not sustainable. Such problems include soil degradation as a result of overuse of land for intensive agriculture and loss of biodiversity due to the reduction in forests and natural pastures as a result of conversion to agricultural land. It also consumes vast amounts of water, pesticides, and fertilizers in agriculture that might cause water pollution and degradation of local environments.

Technological bottlenecks: Most of the technologies for biodiesel production have to be further developed in order to reach higher efficiency and low costs. A variety of such processes require advanced technology for the conversion of feedstock into vegetable oil or organic waste into quality fuel. These are some of the major technological constraints that make it difficult to produce biodiesel on a large scale with qualities competitive enough to match fossil fuels.

In all, there is a great need for technological advancement, sound government policy of support, and encouragement for research and development in the areas of sustainable and ecologically safe production of biodiesel if these challenges are to be overcome, in view of huge benefits accompanying the use of biodiesel as part of sustainable energy strategy [13].

Innovations and Future Trends:

Over the years, several innovations and future trends have been pursued in biodiesel production to overcome certain obstacles in the way of its wide usage. The innovations being made are in enhancing production efficiency, cost reduction, and shifting to new and more sustainable sources of raw materials [14]. Various developments other improved technologies for biodiesel production include enzymatic catalytic technologies, which are promising innovations to further improve biodiesel production efficiency. This involves the use of enzymes as catalysts instead of traditional chemical catalysts in the production process and, while doing so, helps decrease the cost of production while raising higher levels of quality with reduced impacts on the environment, these technologies make processes of conversion more efficient and reduce the usage of harmful chemicals and utilizing wastes and non-conventional resources such as organic wastes in the form of used cooking oils and animal fats have gained much interest as a biodiesel feedstock source, these feedstock represent a very green environmental solution to handle organic wastes and minimize pressure on food crops [15]. There are also attempts to produce biodiesel using microalgae, which is capable of growing in waters that do not lend themselves to agricultural uses, this makes the use of this species an excellent option for biodiesel production without the interference of agricultural land destined for food [16].

The integration of biodiesel with other renewable energies solar and wind-includes how best efficiency can be achieved to produce biodiesel with very minimal emissions, this makes it possible to reduce energy consumption during the actual production process, increasing sustainability and reducing dependence on traditional sources of fossil fuel and biotechnology and genetic engineering application helps develop crop varieties with high oil content and enhances production efficiency [17]. For example, genetically modified types of algae have been developed for more oil production to provide higher amounts of biodiesel with fewer environmental impacts. This would lead to broader usage of biodiesel as a more feasible option for alternative fuels. With continuous research and technology improvement, it's hoped that biodiesel would contribute more toward securing sustainable supplies of global energy while mitigating the impacts of climate change and fossil fuel dependencies [18].

The Role of Biodiesel in Supporting Energy Security: Global Opportunities and Challenges and connect It to a Sustainable Environment:

Biodiesel plays an important role in propagating the concept of the sustainable environment because it has a source of clean and renewable energy. The sustainable environment indeed relies on the use of renewable resources while preserving the environment with reduced pollution; here comes the role of biodiesel, which is produced from natural sources like vegetable oils or animal fats. Biodiesel is a sort of fuel that releases a very insignificant amount of greenhouse gas compared to fossil fuels, such as gasoline and diesel commonly derived from petroleum. In fact, based on researches, biodiesel is capable of providing carbon dioxide emissions reduction in rates falling within the range between 50% up to 70%, hence helping reduce the

impact of global warming [19]. Biodiesel, by the very fact, offers more energy security to countries through being able to be produced domestically from local agricultural resources; this reduces the need for imported oil from the world market, lessening bounces in prices and affecting the economies of countries. This shall allow many countries to increase their energy independence and avoid such crises brought about by supply disruption or geopolitical turbulence [20].

About biodiesel production, from an environmental point of view, enables the development of rural communities and the activation of agricultural activities, opening up jobs and developing the area with farmers who grow crops like corn and soybeans needed for biofuel. However, this field comes with several challenges, the use of land meant for agriculture to produce energy crops instead of food may affect food security in some countries. In addition, some unsustainable agricultural practices that are being used to produce the primary crops may be harmful to the environment; this calls for the need to apply sustainable agricultural techniques [21], other challenges that the biodiesel industry has to put up with are technical and financial difficulties: high production cost compared to conventional fossil fuel and the need for the development of more efficient and less costly technologies. This is mitigated by current innovations, including the use of enzymes as catalysts in the production process, the exploitation of unconventional sources like used cooking oils or animal fats, and even the use of algae grown in waters that may not be usable for agricultural purposes, further alleviating stress from agricultural resources allocated for food [22], with supportive government policies and the realization of advanced technologies, the efficiency-cost relationship will improve further in biodiesel production and hence be a more feasible fuel alternative in the near future. It is expected that, in the future, biodiesel will increasingly contribute to cleaner and sustainable energy supplies, thus alleviating the dependence on fossil fuel and, in this way, contribute to mitigating climate change and foster sustainable development through protection of the environment for future generations [23].

A few of the most recent studies that focus on technologies of biodiesel production include the following discussing ways to enhance production from algae: In 2023, a study was presented with modified algae for biodiesel production. The properties of algae were enhanced in this regard to endure harsh environmental conditions and enhance oil production from them. They are rich in lipids and therefore more suitable in producing biofuel with efficiency [24].

A study on the effects of spent vegetable oils: Spent vegetable oils, such as those from used cooking oil, have been researched in 2023 to understand their effects on biodiesel production. In fact, it demonstrated that the spent oils, due to the impurities that may be contained therein, do demand special treatment in order to improve the quality of the produced fuel [25].

Study on molecular biology to improve the production of biodiesel : In the same year, the use of molecular biology techniques to improve the production of marine algae biofuel was discussed. Genetic modifications have been made to empower the capability of algae to produce more significant amounts of oils that could easily be transformed into biodiesel. Zhang et al., 2023 Improving Efficiency by the Use of Agricultural Waste** : A study conducted in the year 2023 on how the production techniques can be improved by making use of agricultural wastes such as rice straw and palm oil that are not fit for human consumption. The study indicated how conversion efficiency to biodiesel may be improved by using superior processing techniques, such as chemical catalysis. [25].

Study of Agricultural Waste Utilization for Biodiesel Production, 2023: Study on the use of agricultural crop residues, such as rice straw and cottonseed cake, in the production of biodiesel. Results showed that agricultural waste can be a potential source for producing bio-fuel, as oil conversion efficiency was improved by applying advanced chemical reaction methods. Jayasree et al., 2023 Marine Algae in Biodiesel Production** 2023: The above study concluded that marine algae are greatly potential to produce oils which can be converted into biodiesel. Genetic engineering was done on different species of algae to enhance oil production, and the study shows promise in a very good increase in total productivity when compared with conventional ones [26].

Bacteria in the Conversion of Oils into Biodiesel, 2023: Bacteria that were involved in the fermentation process for converting vegetable oils into biodiesel were immensely effective. The work showed that through genetic modification, bacteria have the ability to improve the biological processes involved in the production of biodiesel from oils to achieve high efficiency in production [28]. Study on oil utilization for biodiesel production increasing spent oils use, such as used cooking oil reprocessing into biodiesel production useful for taking waste away and increasing environmental sustainability, was investigated. These were the processes for improvement through the use of modern techniques in order to take away impurities and enhance the purity of the fuel at the end [27]

These studies confirm the trend within the development and use of natural, renewable resources with a view to improving biodiesel production and thereby offering a sustainable solution to environmental queries.

CONCLUSION:

- 1- Biodiesel, is an important step toward achieving sustainable and environmentally viable energy sources in the face of the challenges from climate change, rising oil prices, and increasing demand for energy. Key findings include:
- 2- Biodiesel plays a pertinent role in reducing greenhouse gas emissions. According to studies, biodiesel ensures the reduction of these gases by 50%-70% compared to conventional fuels and is therefore an environmentally friendly alternative.
- 3- Local production of biodiesel adds to the reduction of reliance on oil imports, hence bolstering energy security and contributing to protecting the economy from fluctuations in global prices and disruptions to supply that may be related to geopolitical factors.
- 4- The constantly growing population, along with economic development, increases energy needs, especially considering biodiesel as a complement to this growing demand.
- 5- Biodiesel production is faced with obstacles like high costs related to production and processing equipment. Environmental impacts of some agricultural practices, including soil degradation, and pesticide and fertilizers may have negative environmental effects.
- 6- Productive crops that are intended for biodiesel can affect food crop cultivation, and hence put questions on food security, especially in resource-limited countries.
- 7- Improvement in production technologies includes the use of techniques such as enzyme catalysis, exploitation of cooking wastes, and non-traditional oils such as algae cultivation. The big focus there is to develop crops that resist unfriendly conditions so that the crop increases in productivity and decreases in costs.
- 8- In general, biodiesel is a promising opportunity that might help support environmental sustainability and reduce dependence on fossil fuels despite the challenges with technological development and governmental support, such obstacles can be overcome, promoting the use of biodiesel in renewable energy strategies.

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