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Review of Ecological Impacts and Future Developments of Biodiesel

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ABSTRAK

Biodiesel telah menjadi semakin populer sebagai pengganti yang layak untuk sumber energi yang tidak terbarukan, yang menjadi semakin langka. Biodiesel diproduksi dari berbagai jenis minyak nabati maupun minyak hewani. Studi ini bertujuan untuk mengevaluasi situasi biodiesel saat ini, prospeknya untuk masa depan, dan kemungkinan kekhawatiran ekologis atau mekanis. Penelitian ini menggunakan data sekunder dan ulasan literatur. Hasil penelitian ini menunjukkan bahwa biodiesel memiliki potensi untuk menggantikan bahan bakar fosil sebagai sumber energi utama, mengurangi emisi gas rumah kaca dalam proses ini. Namun, ada kelemahan untuk biodiesel, termasuk penggunaan lahan yang berpotensi menyebabkan kerusakan pada ekosistem dan konsumsi pasokan dasar yang dapat mempengaruhi ketersediaan makanan. Selain itu, korosi dan peningkatan oksidasi yang disebabkan oleh biodiesel telah diamati untuk menurunkan efisiensi mesin. Untuk mengatasi masalah ini, upaya dilakukan untuk menciptakan biodiesel yang lebih efektif dan ramah lingkungan. Menggunakan sumber daya mentah yang tidak bersaing dengan ketersediaan makanan, menggunakan teknologi mutakhir untuk meningkatkan kualitas biodiesel, dan menggunakan tanah yang tidak membahayakan lingkungan adalah beberapa kemajuan dalam pembuatan biodiesel. Kesimpulan penelitian ini menunjukkan potensi biodiesel untuk berkembang menjadi sumber bahan bakar terbarukan di masa depan, tetapi potensi ini perlu disertai dengan pengembangan teknologi yang lebih efisien dan ramah lingkungan.

Kata kunci: *Biodiesel, Bahan bakar baru terbarukan, Emisi gas rumah kaca.*

ABSTRACT

Biodiesel has become increasingly popular as a decent substitute for non-renewable energy sources, which are becoming increasingly rare. Biodiesel is produced from various types of vegetable and animal oils. The study aims to evaluate the current biodiesel situation, its prospects for the future, and possible ecological or mechanical concerns. This research uses secondary data and literature reviews. The findings of this research indicate that biodiesel can displace fossil fuels as the main source of energy, reducing greenhouse gas emissions in this process. However, there are weaknesses for biodiesel, including land use that can potentially cause damage to ecosystems and consumption of basic supplies that can affect food availability. In addition, corrosion and increased oxidation caused by biodiesel have been observed to decrease engine efficiency. To address this problem, efforts are made to create more efficient and environmentally friendly biodiesel. Using raw resources that do not compete with food availability, using cutting-edge technologies to improve the quality of biodiesel, and using soil that does not harm the environment are some of the advancements in biodiesel manufacturing. The research findings show the potential of biodiesel to develop into renewable fuels in the future, but this potential needs to be accompanied by the development of more efficient and environmentally friendly technologies.

Keywords: *Biodiesel, Renewable fuel, Greenhouse gas emissions.*

1. INTRODUCTION

Biofuels, which are renewable fuels, are produced from organic materials known as biomass, including plants, crops, and forestry wastes. These biofuels have the potential to replace fossil fuels, reduce greenhouse gas emissions, and support the transition to a low-carbon economy [1]. Government programs supporting low-carbon fuels, increased concerns about climate change, and rising demand for renewable energy have all helped biofuels advance in recent years [2]. There are two generations of biofuels: first-generation biofuels, such as those made from food crops like corn and sugarcane, and second-generation biofuels, which are derived from non-food sources like agricultural waste, algae, and cellulose [3]. Recently, research and development efforts have been focused on second-generation biofuels due to their potential to be more environmentally friendly than first-generation biofuels [4]. For example, second-generation biofuels can be produced without posing a threat to food security and can significantly reduce greenhouse gas emissions. Detailed information about various types of biofuels, their sources, and their conversion pathways can be seen in Figure 1.

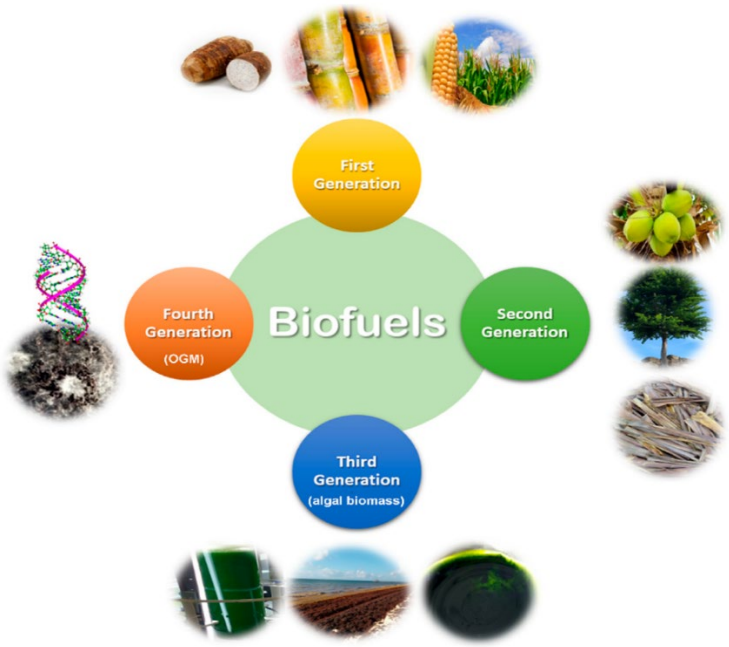

Figure 1. An overview of feedstocks and production processes for different biofuels [5]

Despite the potential benefits of biofuels, there are also concerns about their environmental impact, particularly regarding land use change and the potential for negative impacts on biodiversity. These concerns have led to ongoing debates about the sustainability of biofuels and the need for careful planning and regulation to ensure that their development is carried out responsibly [6]. Overall, biofuels have the potential to play an important role in the transition toward a low-carbon economy, but their development will need to be guided by careful planning and regulation to ensure that they are sustainable and environmentally responsible [7]. With ongoing research and development efforts aimed at enhancing their production, effectiveness, and environmental sustainability as of 2023, the development of biofuels has continued [8].

Second-generation biofuels, which are made from non-food sources such as agricultural waste and algae, have received particular attention in recent years [9]. These fuels offer several advantages over first-generation biofuels, including reduced competition with food production and lower greenhouse gas emissions [10]. Research has also focused on the development of third-generation biofuels, which are made

from microorganisms and offer even greater potential for sustainability and efficiency [11]. The use of biofuels has also continued to grow, with increasing adoption in transportation, aviation, and other sectors [12]. In addition to their potential as a renewable energy source, biofuels also offer opportunities for local economic development and rural job creation [6]. However, there are ongoing concerns about the environmental impact of biofuels, particularly about land use change, water use, and biodiversity. These concerns have led to efforts to develop and implement sustainability criteria and certification schemes for biofuels to ensure that their development is carried out responsibly.

2. METHOD

The method used in this review involves gathering information and discussing topics such as biodiesel utilization, biodiesel production, the effects of biodiesel, and updates on biodiesel developments, and the future of biodiesel.

2.1 Biodiesel Utilization

Due to its clean burning characteristics, biodiesel is a domestic product that provides renewable energy resources. It is gaining popularity in both the energy production and sustainability management sectors and can lead to improved air quality and energy security. Emissions of pollution based on carbon can be curtailed by incorporating biodiesel into petroleum, which will boost the oxygen levels in fuel resources that emit carbon, and By lowering environmental toxins, enhancing combustion plays a crucial role in promoting green technology, stimulating alternative energy sources, and fostering sustainable growth. Table 1 provides a list of the several uses for biodiesel.

Table 1. Uses of biodiesel

Uses	Interpretation	Description	References
Car	Truck, Hybrid vehicle	Biodiesel can be used for driving cars and farm machinery and to serve as fuel for vehicles used in mining and building. Hybrid electric cars also utilize biodiesel.	13 14
Agricultural adjuvants	• Pesticides carrier • Fertilizer • Biodegradable	Due to their biodegradable and non-toxic characteristics, agricultural sprays can utilize them as a medium for transporting pesticides and fertilizers.	15
Boiler fuel	Alternative for boiler use.	Biodiesel can serve as a preferable substitute for natural gas, as its cost rises. Minor adjustments may be necessary for boilers to use it.	16
Producing electric power	• Auxiliary power • Engine degradation reducer	In the event of a power shortage, biodiesel-powered generators can serve as backup power sources. Furthermore, these generators have improved lubrication properties that may help reduce engine wear and tear.	17

2.2 Biodiesel Production

Biodiesel is a renewable fuel that is generated from biologically sourced lipid feedstocks, including utilized derivatives such as discarded cooking oils, animal fats, and vegetable oils [18]. There are three ways to turn fats and oils into biodiesel. One of these methods is base-catalytic transesterification [19], acid-catalytic esterification [20], simultaneous esterification, and transesterification [21]. Most of the

biodiesel available today is manufactured using a method called base-catalyzed transesterification [22]. This approach is preferred because it is cost-effective, requires relatively low temperatures and pressures, and typically results in a production yield of more than 98% [23]. The transesterification process involves the combination of a glycerine molecule with long chains of fatty acids to create a triglyceride [24]. As a result of this substance's reaction with alcohol, which is catalyzed by a potent alkaline base like sodium hydroxide, There is the production of biodiesel, mono-alkyl ester, and crude glycerine [25]. Usually, ethanol or methanol is the main alcohol used in this procedure, and nowadays, biodiesel is more often produced using a potassium hydroxide catalyst because it has a very high reaction conversion. Figure 2 visualizes actual global biodiesel production and projects it for the future.

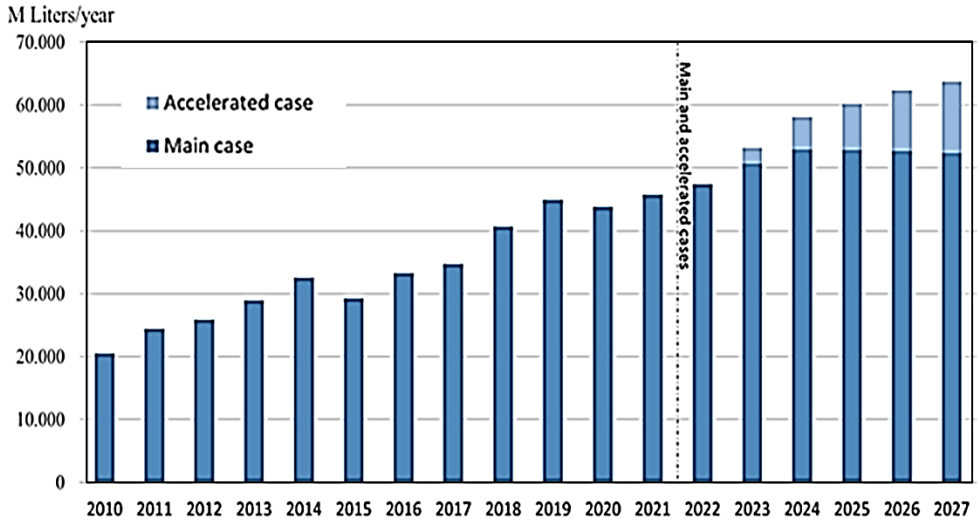

Figure 2. Visualize actual and projected biodiesel production globally from 2010 to 2027 [26]

Increasing global biodiesel production can help reduce air pressure caused by exhaust emissions from fossil fuel vehicles which have a direct effect and contribute greatly to reducing contamination of air pollution and saving the environment [27]. Because it can lower carbon emissions and sulphur emissions from vehicle exhaust gases, the production of biodiesel will ultimately indirectly encourage the use of green fuels as an alternative to fossil fuels, which has a significant impact on lowering air pollution [28]. To begin the process, a catalyst and alcohol combination, Typically, a standard mixer or agitator is utilized to produce potassium or sodium hydroxide [29]. After that, the mixture is put into a covered reaction vessel, and added oil or fat [30]. The process is carried out in an atmosphere that completely prevents alcohol from evaporating. The process can be sped up by keeping the temperature of the blend slightly higher than the boiling point of alcohol, which is usually around 78 degrees Celsius. At room temperature, the reaction should be allowed to proceed for between one and eight hours. More alcohol is required to ensure that the vegetable oil or fat is completely converted into esters. More alcohol is required to ensure that the vegetable oil or fat is completely converted into esters [31]. The original fat or oil's moisture and fatty acid concentration must be carefully monitored since too much of either can trigger the formation of soap reactions and the isolation of by-products, which may cause problems with the generation of biodiesel [32]. Figure 3 demonstrates the related phases that are part of the production process.

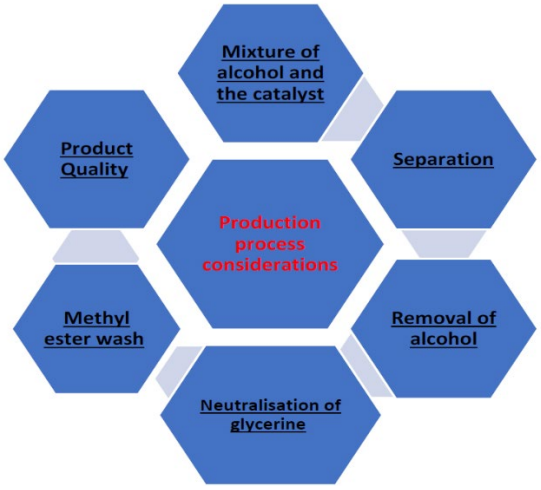

Figure 3. Biodiesel production process circle [33].

2.3. Effect of Biodiesel

A vast body of literature exists regarding the analysis of performance differences that arise when employing varying varieties of biofuel, and in certain instances, even with identical oil types. It is common knowledge that fuels that exhibit high viscosity can lead to numerous severe complications concerning engine operation and performance. Motor load, producer, acceleration, feedstock uniformity, environmental factors, and injection mode are the main factors that affect engine performance testing (direct or indirect). The temperature of the biofuel is also a crucial factor in evaluating engine performance [34]. Nwafor examined the impact of altering the temperature of the vegetable oil fuel inlet on the diesel engine operation, observing that the engine's performance improved when the temperature exceeded 55°C. This is attributed to the correlation between temperature and fluidity [35]. Biodiesel continues to provide an important decrease in emission levels of greenhouse gases, from 10% to 20%. Nevertheless, various studies suggest that due to the higher viscosity of biofuels, there is a decline in power output of approximately 2-18%. This viscosity hinders the injection process, resulting in poor atomization, incomplete combustion, and un-burnt biofuel, which ultimately leads to power loss. Additionally, biofuels have a lower calorific value, leading to a slightly reduced energy output compared to fossil diesel. Nonetheless, using biofuels has many benefits, one of which is a significant decrease in greenhouse gas emissions.

The fuel usage for brakes is approximately 4-8% higher for biodiesel and all blends than for fossil diesel [36]. The reduced calorie content and higher density of vegetable oils may be to blame for the increased specific fuel usage. Pure biodiesel and all mixes thermal efficiency changes depending on the load and speed of the engine [37]. Diesel fuel, however, virtually always falls within this variety. Vegetable oils have a BTE *(brake thermal efficiency)* that is between 3% and 10% higher or lower than fossil diesel. This could be due to the mixes' increased viscosity and vegetable oils' decreased volatility [38]. According to a study, if combustion is started early, Vegetable oil's slow combustion can be compensated for. Therefore, advancing the injection timing is adequate to provide greater brake thermal efficiency.

Biofuels, such as vegetable oil or biodiesel, have been shown to reduce exhaust emissions compared to traditional fossil fuels [39]. Biofuels have several environmental advantages over conventional fossil fuels. Biofuels can reduce particulate matter (PM) emissions from engines, which can be harmful to human health. Biodiesel, for example, can reduce PM emissions by up to 50% compared to diesel [40]. In addition, biofuels have lower sulfur content than fossil fuels, which can reduce sulfur dioxide (SO_2) emissions [41].

Biodiesel has almost no sulfur content. In addition, biofuels can have a lower carbon footprint, which can reduce greenhouse gas emissions. Biodiesel can reduce greenhouse gas emissions by up to 80% compared to diesel because sustainable raw materials are used to make it [42]. However, the use of biofuels can increase emissions of nitrogen oxides (NOx) which are harmful to health. The new engine specifically designed to use biodiesel is proven to reduce NOx emissions. In conclusion, the use of biofuels can provide major environmental benefits, especially in reducing harmful emissions. Overall, biofuel can have a positive impact on exhaust emissions, particularly when compared to traditional fossil fuels [43].

2.4 Updates on Biodiesel Developments

A substitute fuel that is thought to be less harmful to the environment than fossil fuels is biodiesel [44]. Biodiesel is produced from vegetable raw materials or animal fats through a transesterification or esterification process [45]. Biodiesel has several advantages, including being more environmentally friendly, can improve air quality, and can reduce dependence on fossil fuels. Along with technological developments and awareness of the importance of protecting the environment, the biodiesel industry continues to experience growth [46]. The biodiesel industry continues to innovate to increase production efficiency, develop more productive alternative raw materials, and collaborate with other industries to develop technologies and products that are more environmentally friendly [47]. This chapter will discuss the latest updates regarding the development of biodiesel in the current era. Some of the topics that will be discussed include increasing production efficiency, raw material innovation, and collaboration between industries, the potential for increased utilization, and the application of green diesel technology.

Utilizing modern technologies like automation and machine learning can also help increase the effectiveness of production. The use of sustainable energy sources and emission control systems can make biodiesel production more efficient while adopting best practices like routine maintenance and monitoring of production parameters [48]. The biodiesel industry can become more competitive and sustainable by increasing productivity, lowering costs, and minimizing environmental impact through improved production efficiency.

Biodiesel raw material innovation is an effort to reduce dependence on limited and expensive raw materials such as soybean oil and palm oil [49]. This innovation involves the development of non-edible raw materials, alternative sources of raw materials, and the use of organic waste as raw materials for biodiesel [50]. The development of non-edible raw materials such as jatropha, and microalgae is one of the efforts to reduce dependence on raw materials that compete with food production. Non-edible raw materials have a higher oil content and can grow on marginal land, so the development of non-edible raw materials can reduce pressure on agricultural land and maintain a balance between food and non-food production [51].

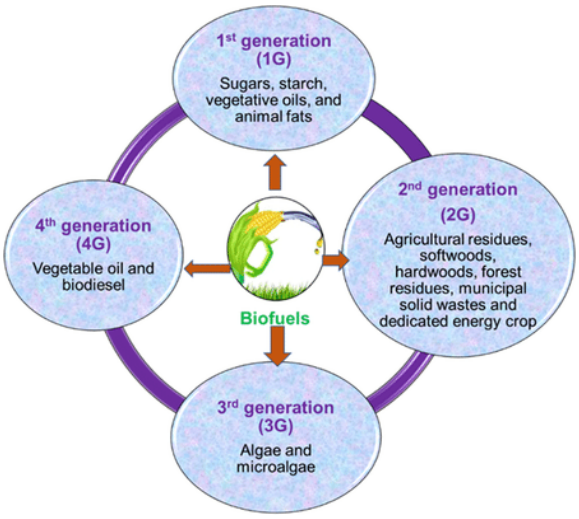

Figure 4. Innovation of Raw Materials Biodiesel [52]

Utilized cooking oil, crude palm oil, and jatropha oil are examples of alternate sources of raw materials that can be utilized to make biodiesel [53]. Utilizing alternative raw material sources can reduce biodiesel production costs and utilize waste from the food and palm oil industries. The utilization of organic waste as source material is an additional field of innovation for biodiesel raw materials. Organic wastes such as banana peel waste, tofu waste, and coconut trash can be utilized as source materials for biodiesel through the processes of fermentation and transesterification [54]. Utilization of organic waste as raw material for biodiesel can reduce the organic waste produced and increase the efficiency of biodiesel production [55]. In addition to the development of new raw materials, biodiesel feedstock innovation also involves improving the quality of existing raw materials, such as using palm oil that has been processed with more environmentally friendly technologies or increasing the content of unsaturated fatty acids in soybean oil [56]. With the innovation of biodiesel raw materials, it is expected to increase the availability of environmentally friendly biodiesel raw materials, reduce pressure on raw materials that compete with food production, and increase the efficiency of biodiesel production.

Collaboration between industries is an effort to optimize biodiesel production. Several parties are involved in this collaboration, starting with those who produce raw materials and biodiesel and moving on to related parties like researchers and regulators. One form of collaboration between industries that can be carried out in collaboration in the supply of raw materials. Producers of raw materials can cooperate with producers of biodiesel in providing raw materials of high quality that are available continuously. This can increase the efficiency of biodiesel production and ensure adequate availability of raw materials. Collaboration can also be carried out in the development of biodiesel production technology. Biodiesel researchers and producers can work together in developing biodiesel production technologies that are more environmentally friendly, efficient, and cost-effective. Biodiesel producers can cooperate with vehicle manufacturers or vehicle users to expand the biodiesel market. This can increase sales of biodiesel and increase public awareness of the benefits of biodiesel as an environmentally friendly alternative fuel.

The potential for increasing and utilizing biodiesel is enormous and is still growing along with increasing public awareness of the importance of protecting the environment and conserving natural resources. One potential increase in biodiesel is by using different feedstocks such as algae, seaweed, and lignocellulosic [57]. As a result, biodiesel won't be solely dependent on major raw materials like palm oil and soybeans, which are becoming increasingly scarce. Additionally, use as a vehicle fuel represents a

few of the potential applications for biodiesel. By using biodiesel in transportation, other pollutants and greenhouse gas emissions from motorized vehicles can be reduced [58]. In addition, biodiesel can also be a more environmentally friendly alternative to increasingly scarce and expensive fossil fuels.

In terms of biodiesel production, technological innovations are also being developed to increase the efficiency and quality of biodiesel production. One of them is the use of enzyme technology to accelerate the transesterification reaction process [59]. A type of biodiesel made from alternative raw materials to traditional biodiesel, particularly using vegetable oil or animal fat as a raw material, It is referred to as green diesel or renewable diesel [60]. Green diesel is produced through a hydrocracking or hydrotreating process, where the raw material is treated with hydrogen at a certain pressure and temperature [61]. This process produces a product that is very similar to conventional diesel which is commonly used for motor vehicles. Green diesel has advantages compared to conventional biodiesel, namely having better quality, and not being affected by extreme temperatures [62].

The application of green diesel worldwide continues to increase. One country that has implemented green diesel is the United States, where biofuel producers such as the Renewable Energy Group and Diamond Green Diesel have produced green diesel on a large scale [63]. In addition, countries such as Norway and Finland have also introduced green diesel into their fuel markets. The application of green diesel throughout the world is also supported by increasingly stringent regulations regarding greenhouse gas emissions and air pollution from motorized vehicles [64].

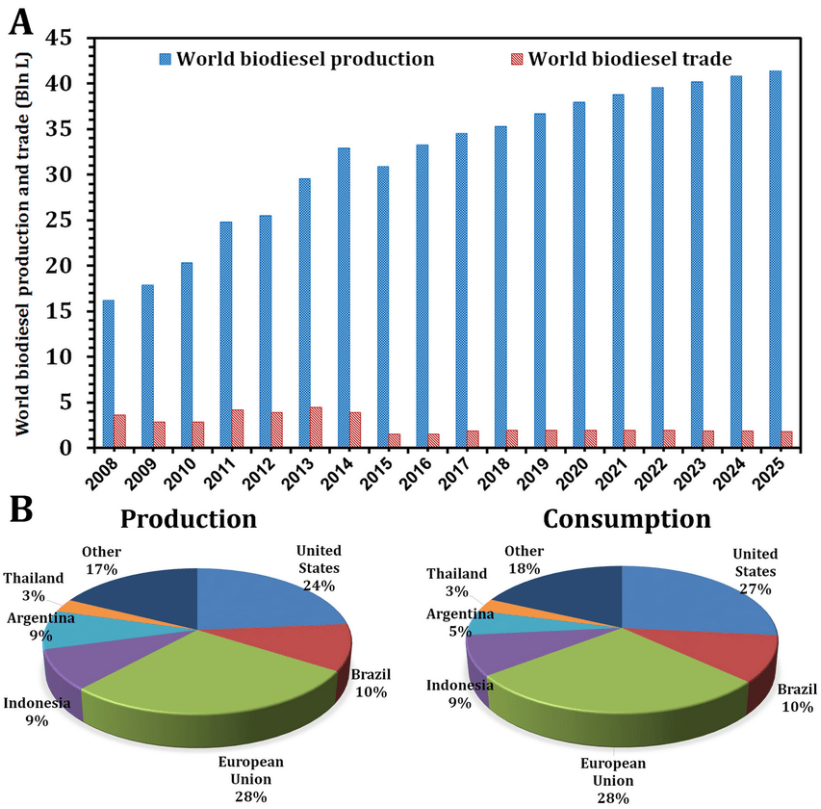

Figure 5. Production and trade of biodiesel in the world [65]

2.5 Biodiesel in the Future

Although biodiesel use is still relatively small, due to its commercial feasibility, it has the potential to play a substantial role in a nation's energy infrastructure. Because plant oil crops absorb the carbon

dioxide released during combustion, it is regarded as a carbon-neutral fuel [66]. Biodiesel has a greater cetane percentage than diesel due to its long fatty acid chains and fewer double bonds [67]. Additionally, it is free of aromatics and contains 10–11% oxygen by weight, thereby decreasing the quantity of carbon dioxide, hydrocarbons, which and other particles released in exhaust gases. The energy content of biodiesel is lower than that of petrol-diesel, hence more biodiesel must be used to provide the same quantity of energy. Studies have investigated the impact of varying concentrations of biodiesel chemicals on human health. According to research, increasing ethanol production by $1 billion, which is the main ingredient in biodiesel, can have an impact on how it is made and increase ozone levels in densely populated areas [68]. To lessen potential health risks, appropriate regulations for the use of biodiesel in vehicles are required. Fuel-related health risks include a higher risk for cardio-respiratory disease, air pollution from vehicle emissions that can have a national impact, and soil and water contamination that primarily affects farmers and local harvesters. Burning these substances can also influence regions and countries. Table 2 gives an example of the biofuel requirements in each nation. The benefits of biodiesel for the environment are extensive. The US government views biodiesel as a carbon-neutral fuel because the plants used to make it, such as soybeans and palm oil trees, absorb CO_2 from the atmosphere. This is so that the CO_2 absorbed by plants can balance out the CO_2 produced during combustion [69]. As a result, the greenhouse effect is diminished and the atmospheric concentration of CO_2 does not rise quickly, delaying the onset of climate change. Additionally, biodiesel degrades quickly, especially in water, according to recent studies [70]. However, the potential impact of pollutants on marine life should not be overlooked. Biodiesel has been regarded as a promising substitute for fossil fuels due to its potential to reduce carbon dioxide emissions and global warming [71].

Table 2. Mandates for biofuel in various nations

Country	Current Goal	Future Goals	References
Argentina	B10, E5	Target in 2027 is B10 and increased production	72
Brazil	B2, E22–23	B5 due to 2022	73
USA	One billion gallons of biodiesel, or 0.91% 1.22% of the 2.01 billion gallons of advanced biofuels.	36.5 billion gallons of biofuel by 2022 lignocellulosic biofuels produced 21.9 billion gallons of fuel.	74
EU Stats	almost 5,7% of renewable energy uses for transportation	The target of 11% renewable transportation fuel	75
China	Currently, China is in the E10 stage with a production capacity of 192 kilotons in 2023	China’s biodiesel production to expand by 32% in 2025	76
Japan	N/A	by 2030, implement 11.5% biofuels.	77

According to studies, increasing biodiesel production would result in a significant increase in the amount of isoprene in the air of up to 39%, which would raise ozone levels. An extensive amount of research is being done to evaluate the effects of biodiesel on both human health and the environment. Biodiesel affects the human body in three ways: affecting the body's cells, internal systems, and tissues. However, adverse environmental effects also exist, such as harm to marine life, depletion of the ozone layer, and a rise in hydrocarbons. Processes that produce particles closely related to oxidative stress are released by combustion and non-combustion. Table 3 demonstrates the variables that impact the biodiesel industry. These biodiesel particles cause a variety of reactions, as well as the ejection of inflammatory

mediators and the ensuing stimulation of cell signalling. According to life cycle analyses of biofuels, the lifespan of biodiesel varies depending on storage conditions from five to six months to years. Biodiesel is a good renewable fuel that is better for consumption than conventional diesel fuel.

Table 3. Factors Affecting the Development of Biofuel

Factors	Affecting	References
Increased the solvent ethanol	Increased ozone levels caused by isoprene can cause an increase in lung cancer, asthma attacks, and injuries of up to 39%.	78
Water and Soil Pollution	The impact is limited to farmers and people who harvest locally.	79
Air Pollution	Diseases affecting both the heart and lungs, with effects extending to a larger scale.	80
Burning Effect	The impact on a large scale, both at a national and regional level.	81
Combustion	The initiation of cellular communication and the discharge of substances that promote inflammation.	82

When evaluating the feasibility of biofuels, it is crucial to consider their impact on the environment and other sustainability aspects, such as production costs, competition with fossil fuels, employment, rural development, human health, and food, energy, and water security thorough life cycle analysis is required to prevent burdens from being transferred from one supply chain link to another. However, the findings of sustainability assessments are of little value if they cannot be trusted, and rigorous auditing of biofuel supply chains is necessary to ensure traceability and prevent socio-economic impacts and fraud. Transparency, data accessibility, and data expression should be improved by creating publicly accessible databases on both an international and national scale to raise the validity of life cycle evaluations for policymaking. To avoid exploitation and misinterpretation, the life cycle assessment (LCA) data and models should maintain acceptable levels of transparency and rigor.

3 CONCLUSION

In today's world, it is crucial to adopt sustainable practices for energy use to protect the environment and public health. The negative impacts of human activities on the environment, especially on respiratory health, have become a serious concern. Traditional fuels like coal and petroleum have been linked to several environmental problems, including ozone depletion, respiratory health issues, ecosystem damage, and extreme weather changes. As a result, it is becoming more and more obvious that these resources cannot be sustained. To secure a safer environment for future generations, it is vital to find innovative alternatives. Further research and a deeper understanding of biodiesel fuel sources are required before they can be effectively and affordably utilized as a crucial alternative fuel resource. It is important to consider the difficulties associated with oil production and the potential long-term impacts on the environment and public health. Biodiesel fuel can lead to a substantial decrease in carbon emissions, but it may also increase atmospheric ozone levels. Compared to conventional diesel, biodiesel fuel typically has higher emissions of NOx. Although biodiesel appears to be a promising option as a fuel source in the future, further investigation is necessary to confirm its viability as a sustainable alternative.

To achieve sustainable development and lower greenhouse gas emissions, biodiesel can significantly impact the adoption of innovative and creative energy production methods. It can also improve the production of eco-friendly fuel. However, future research should concentrate on completely describing

the combustion by-products and looking into how they interact with inflammation and poor clearance to understand their detrimental effects on human wellness. Using vegetable and organic components in biodiesel production can increase its profitability and encourage more research into increasing biomass yield per acre, filling the gaps in previous research. Although the link between human health and biodiesel exposure is widely acknowledged, data connecting biodiesel emissions to particular health effects are lacking. As a result, many consider biodiesel to be a more environmentally friendly fuel option compared to other types of diesels.

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