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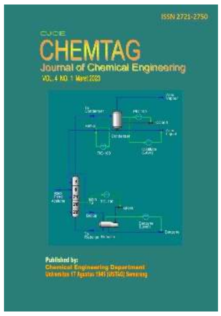


# BIODIESEL PRODUCTION: POTENTIAL AND FUTURE TRENDS – A REVIEW

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***Abstract***

*Biodiesel is a potential renewable energy that can reduce greenhouse gas (GHG) emissions and increase energy security. Biodiesel has been shown to have lower carbon emissions compared to petroleum diesel, and it can reduce GHG by as much as 86%. Governments around the world have set targets for renewable energy, with a specific focus on the use of biofuels like biodiesel. Biodiesel can be derived from various feedstocks such as animal lipids, vegetable oils, and waste oils. It can be made through the transesterification of triglyceride with ethanol or methanol. This reaction requires strong base catalysts, such as sodium hydroxide or potassium hydroxide, in order to produce methyl esters. The potential of biodiesel has led to advancements in its production, such as the use of enzymatic transesterification, novel feedstocks, and the optimization of production parameters. Additionally, various companies have ventured into biodiesel production with a range of business models and approaches.*

***Keywords:*** *biodiesel, process, productivity, renewable energy*

***Abstrak***

*Biodiesel merupakan potensi energi terbarukan yang dapat mengurangi emisi gas rumah kaca (GRK) dan meningkatkan ketahanan energi. Biodiesel telah terbukti memiliki emisi karbon yang lebih rendah dibandingkan dengan diesel minyak bumi, dan dapat mengurangi gas rumah kaca sebanyak 86%. Pemerintah di seluruh dunia telah menetapkan target untuk energi terbarukan, dengan fokus khusus pada penggunaan biofuel seperti biodiesel. Biodiesel dapat diperoleh dari berbagai bahan baku seperti lemak hewani, minyak nabati, dan minyak sisa. Biodiesel dapat dibuat melalui transesterifikasi trigliserida dengan etanol atau metanol. Reaksi ini membutuhkan katalis basa kuat, seperti natrium hidroksida atau kalium hidroksida, untuk menghasilkan metil ester. Potensi biodiesel telah menyebabkan kemajuan dalam produksinya, seperti penggunaan transesterifikasi enzimatik, bahan baku baru, dan optimalisasi parameter produksi. Selain itu, berbagai perusahaan telah memfokuskan produksi biodiesel dengan berbagai model dan pendekatan bisnis.*

*Kata Kunci:* *biodiesel, proses, produktivitas, energi terbarukan*

## 1. Background

Biodiesel production is an important field of research and development in chemical engineering scope, with significant potential for reducing greenhouse gas (GHG) emissions and promoting sustainable energy production. In recent years, there have been numerous advancements in biodiesel production processes and technologies, including the use of enzymatic transesterification, the development of novel feedstocks, and the optimization of production parameters for improved efficiency and yield.

One area of research in biodiesel production is the use of enzymatic transesterification, which has several advantages over traditional base-catalyzed processes, including higher yields and fewer waste products. Taher et al. [1] have investigated a novel enzymatic reaction for biodiesel production using a combination of lipase enzymes and an ionic liquid solvent system, which has demonstrated improved yields and efficiency compared to traditional base-catalyzed methods.

Another research area in biodiesel production is the development of novel feedstocks, including crude palm oil (CPO), palm fatty acid distillate (PFAD), Nyamplung seed oil, castor/jatropha oil, algae and waste cooking oil (WCO). Due to its high lipid content and potential for large-scale production, algae have drawn an abundance of interest as a promising feedstock for biodiesel synthesis. Santana and his friends [2] have developed a new methods for biodiesel production from algae using supercritical carbon dioxide, which has demonstrated improved yields and reduced energy consumption. Another interesting feedstock is WCO, as it is inexpensive and easily accessible. A novel technique for producing biodiesel from WCO that combines ultrasound-assisted transesterification with heterogeneous catalysts has demonstrated improved yields and reduced waste production [3].

In addition to these technological advancements, there are also numerous companies involved in biodiesel production, with various business models and approaches. One example is Renewable Energy Group (REG), a leading producer of biodiesel in North America, which has a vertically integrated business model that includes feedstock procurement, production, and distribution [4]. Another example is Neste, a Finnish renewable energy company that produces renewable diesel and biodiesel from various feedstocks, including waste and residues [5].

Overall, the biodiesel industry is a dynamic and rapidly evolving field with significant potential for growth and innovation. From an engineering perspective, there are numerous challenges and opportunities related to biodiesel production, including developing novel processes, the optimization of production parameters, and the use of non-traditional feedstocks. Through a detailed analysis of the companies involved in biodiesel production, as well as technical advances and research developments in the field, communities, governments and investors can gain a better grasp of the potential and processes of this important industry.

## 2. Biodiesel as Promising Renewable Energy

Biodiesel is a potential renewable energy that can significantly reduce GHG emissions besides improving energy security. Biodiesel is a type of biofuel produced from a number of feedstocks, such as animal lipids, vegetable oils, and waste oils. As a result, biodiesel makes it possible to reduce dependence on foreign oil and promote rural development by creating new markets for agricultural products [6]. Biodiesel has a lower carbon footprint than petroleum diesel, with estimates indicating that it can reduce GHG emissions by as much as 86% [7]. Furthermore, biodiesel has been demonstrated to have engine performance and fuel economy comparable to petroleum diesel, making it an appropriate substitute fuel source [8].

The potential of biodiesel as a renewable fuel has been recognized by governments and industry around the world. For instance, the European Union has established a 14% renewable energy target for transportation by 2030, with a particular emphasis on the use of biofuels such as biodiesel [9]. Similarly, the United States has set a target of 36 billion gallons of biofuels by 2022, with biodiesel playing a significant role in achieving this target [10]. In Indonesia, according to the NEP [11], the target for biofuel consumption is 25% of the country's total energy mix in 2025. Meanwhile, the NBP mandates the use of biodiesel blends in transportation fuels, with a target of 30% blended biodiesel (B30) by 2020, which is then increased to B40 in 2030. In addition, the government has also set a bioethanol production target with a target of 3.2 million kilolitres in 2025 [12].

Biodiesel can be synthesized through the transesterification of triglyceride with alcohols such as ethanol and methanol. This reaction requires strong base catalysts like sodium or potassium hydroxide [13]. For feedstocks with high levels of free fatty acids (FFA) (> 2%) such as PFAD, an esterification can be applied with acidic catalysts including hydrochloric and sulfuric acid. In addition, biodiesel production can be conducted by simultaneous esterification-transesterification reaction with the help of $Nb_2O_5$ / $SO_4$ catalyst, sulfonic acid-modified mesostructured or hydroxyapatite catalyst [14]. Furthermore, biodiesel can also be produced through microemulsion and pyrolysis. Table 1 exhibits the triglyceride and FFA content of various potential feedstocks for biodiesel production.

**Table 1.** Triglyceride and FFA content in various feedstock

| Feedstocks | Triglyceride (%) | FFA (%) | References |
|---|---|---|---|
| CPO | 95.62-97.62 | 2 - 4 | [15] |
| PFAD | < 2 | 85 - 93 | [16] |
| Microalgae (Chlorella sp.) | 44.9-45.8 | < 1 | [17] |
| Jatropha seeds | 46.24-58.49 | 4.77 - 4.9 | [18] |
| Nyamplung seeds | 75-77.5 | 6.3-8.51 | [19] |
| WCO | 82 – 85.75 | 14.25 - 18 | [20] |

## 3. Future Trends of Biodiesel Production

Due to its potential as a renewable energy source and as a means of reducing GHG emissions, biodiesel production has attracted significant attention over the past several decades. With technological advancements and increasing demand for renewable energy, the future trends of biodiesel production appear favorable. Employing alternative feedstocks will be a future trend in biodiesel production. While soybean and rapeseed oils are currently the most commonly used feedstocks, there is significant interest in incorporating non-food feedstocks including algae, jatropha, and WCO [21]. These alternative feedstocks provide numerous benefits, including a reduction in competition for food commodities and the utilization of waste.

Another trend is the evolution of more effective and economical production methods. One example is the use of enzymatic transesterification, which has the potential to produce biodiesel at a reduced cost and with greater yields [22]. Additionally, the use of microreactors and continuous-flow systems can reduce production time and increase efficiency [23]. Moreover, combining microwaves and ultrasounds has been found to enhance the efficiency of biodiesel production by reducing reaction time, as reported in recent studies [24]. In one study, waste oils and methanol were used as feedstocks, and a maximum biodiesel conversion efficiency of 98% was attained by combining microwave and ultrasound techniques with 0.75 wt.% sodium hydroxide as a catalyst and a methanol to oil ratio of 6:1 [25]. Eliminating the need for catalysts, saponification reactions, and cleansing water, supercritical alcohol transesterification is yet another promising method for reducing the high cost of biodiesel production [26]. However, this technique requires high temperature and pressure, which increase equipment investment costs and energy consumption [27]. Some researchers [28] have attempted to optimize and improve this method by combining it with other techniques, such as microwaves. While such efforts show promise, more research is needed to bring this technique to the commercial level [29]. Moreover, the biodiesel production process has been simplified by integrating reaction and separation units through the development of a membrane [30]. The incorporation of CaO as a catalyst into polyethersulfone (PES) membranes exhibits encouraging properties. The addition of 20% w/v CaO catalyst particles in the preparation of the membrane resulted in a CaO-PES membrane containing 33.45% w/w active CaO with a more regular particle structure and pores that are selective for biodiesel. However, this research is still in its early stages, and performance evaluations for biodiesel production in one stage simultaneously require further development.

Future trends also include the integration of biodiesel production with other industries, such as agriculture and forestry. Using agroforestry systems, for instance, can provide feedstocks for biodiesel production as well as ecosystem services such as carbon sequestration [31]. This integrated approach can create a more sustainable and diversified economy. Finally, the development of new technologies for biodiesel utilization is another future trend. One example is the utilize of biodiesel as a fuel for solid oxide fuel cells, which has the potential to provide a highly efficient and low-emission power source [32]. Additionally, the use of biodiesel in the aviation industry as a renewable jet fuel is being explored [33].

## 4. Conclusion

Biodiesel is a renewable energy that has potential in reducing GHG emissions and improving energy security. Biodiesel has been shown to have lower carbon emissions compared to petroleum diesel, and it can reduce GHG emissions by as much as 86%. Governments around the world have set targets for renewable energy, with a focus on the use of biofuels like biodiesel. Nowadays, there have been numerous advancements in biodiesel production processes and technologies, including the development of novel feedstocks, the use of enzymatic transesterification, and the optimization of production parameters for improved efficiency and yield. Future trends also include the integration of biodiesel production with other industries, such as agriculture and forestry. Using agroforestry systems, for instance, can provide feedstocks for biodiesel production as well as ecosystem services such as carbon sequestration. This integrated approach can create a more sustainable and diversified economy.

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