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Future Direction of Microalgae Biodiesel in Indonesia

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ABSTRACT

Microalgae has a greater potential to be used as biodiesel feedstock compared to vegetable oils. Biodiesel derived from microalgae produce more quantity of oil, consume less space, and could be grown on unsuited land for agriculture. Sunlight is essential to produce microalgae biodiesel. Microalgae production is largely dependent on light levels that are affected by day-to-day and seasonal variations. Indonesia, with its tropical climate and abundant sunlight throughout the year is very suitable for microalgae life. Yet, the development of microalgae biodiesel in Indonesia has not reached significant milestones. This review article aims to discuss future direction of algae biodiesel in Indonesia. A number of microalgae strain found in Indonesia is highlighted. Several challenges in the study of microalgae is also presented. Lastly, this article points out to the need of research on the direct application of microalgae in internal combustion engines.

Keywords:
Microalgae; biodiesel; Indonesia; strain; engine

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1. Introduction

Expanding urbanization, better living standards and increasing population have been known as the reasons in global energy consumption. Environment concerns alongside with anxiety over the decreasing fossil fuels has destined biodiesel to be used as a substantial alternative fuel to the future energy demands. Non-edible vegetable oils are gaining popularity as promising substitutions for conventional edible food crops. With the enormous demand for edible oil as food source, the deploying of non-edible plant oils (second generation biofuel) plays an important role to solve the food vs fuel dilema [1].

Despite its potential, second generation biofuels have not yet been produced commercially on a large scale due to lack of low-cost feedstock supply as well as technological innovation and infrastructure requirements. This challenge has led to the development of third generation biofuel from microalgae. The notion of deploying algae to produce fuel is not new, yet it has not been received much attention as sustainable energy resources until recently. Although there has been a

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growing number of concerns about its sustainability, algae are predicted to play an important role in the coming future.

Lipids in microalgae can be converted into biodiesel. Oil from algae is converted into biodiesel via a transesterification [2]. It is a process of exchanging an ester compound of the alkoxy group by another alcohol, being the reaction of a fat or oil with an alcohol to form esters and glycerol. The extracted oil is then combined with both alcohol and an acid to produce the fatty acyd methylesters which produce biodiesel. Large number of algae are enormously rich in oil to be converted to biodiesel. Several microalgae contain more than 80% of oil compared to dry weight of algae biomass. Also, it can be grown on non-arable land. Therefore, algae has the potential to be the alternative energy sources for the world energy demands.

With its strategic location on equator where intense sunlight available throughout most of the year, Indonesia is the perfect place to grow microalgae. The country has approximately 27.700 ha for microalgae to be grown with annual potential production reaching 462.400 tons [3]. Despite its potential, the development of microalgae has not attracted much interests in the country. Few review papers have been published regarding this issue, but they tend to focus on the cultivation method and strain development. The effect of microalgae properties on real engine needs further discussion. This review article aims to address two major issues in the development of microalgae biodiesel in Indonesia; (1) the recent progress of promising strain development and (2) the effect of microalgae properties on engine’s performance, combustion and emissions characteristics.

2. Benefits of Microalgae for Biodiesel Production

Microalgae are karyotic photosynthetic microorganisms that can be cultivated quickly. Due to their cellular structure, microalgae can live in severe environment. Not only do they live in aquatic, but also in terrestrial conditions. Over 50,000 species exist in earth ecosystem, yet only 60% of them have been researched [4]. It can be used for renewable fuels such as biodiesel, methane, hydrogen, ethanol, etc. Biodiesel made from algae has no sulphur content thus it can decrease the emissions level of Sulphur Oxides (SOx), a major cause of acid rain.

Numerous studies have highlighted various advantages of using microalgae biodiesel. Compared to other alternative sources, microalgae do not require intensive care to be produced. They can grow easily by merely using water that is unsuitable for human consumption. Using microalgae can also reduce the competition with agricultural crops for arable soil. This is due to their higher growth rates and productivity using far less land area compared to agricultural crops. Rapeseed or soybean, for instance, need land area up to 132 times more than microalgae for an oil content of 30% (w/w) [4].

Theoretically, microalgae convert the energy from the sun into chemical sources of energy to reproduce themselves while completing the whole growth cycle every few days. Even though they need an extra nutrients and enough aeration to accelerate the growth rate, microalgae can develop practically in all places with merely sunlight and several simple nutrients. Most biodiesel feedstocks such as soybean, rapeseed, sunflower and palm oil require some growth characteristics to grow. As a result, they cannot live in a wide range of environmental conditions. While other biodiesel sources may not be possible to be produced in some specific places, microalgae can be adjusted to live practically everywhere. Also, microalgae can grow in photobioreactors on a large scale. Among various photobioreactors designs that have been developed, a tubular photobioreactor appears to be the most promising design for microalgae biodiesel production.

3. Microalgae Biodiesel in Indonesia

Indonesia is a tropical country with abundant sunlight which makes it suitable for the development microalgae. The country has also great microalgae diversity. However, despite its potential, microalgae have not yet gained significant interest in Indonesia. Like other countries, Indonesia still focus on the utilisation of biodiesel from first- and second-generation biodiesel as shown in Table 1. This is because their infrastructure has been established thus massive production can be realised and lower production cost can be achieved. Currently, Indonesia has a B20 mandate for biodiesel with palm oil being the major feedstock, aiming to achieve B30 by 2020. Note that even with the use of current biodiesel from palm oil, new alternative sources are required to diversify the energy sources thus achieving energy security in the country.

Table 1
Potential of biodiesel and its production cost by countries [5-7]

Country	Potential Feedstock	Volume (l)	Production ($/l)
Malaysia	Palm oil, rubber seed	14,540,000,000	$0.53
Indonesia	Palm oil, kapok, jatropha	7,595,000,000	$0.49
Argentina	Soybeans, sunflower	5,255,000,000	$0.62
USA	Soybeans, corn, and waste oil	3,212,000,000	$0.85
Brazil	Soybeans, palm oil, sunflower	2,567,000,000	$0.62
Germany	Rapeseed	2,024,000,000	$0.79
Philippines	Coconut oil	1,234,000,000	$0.53
Spain	Linseed and sunflower	1,073,000,000	$1.71

4. Promising Strains

Since lipid production is influenced by the characteristics of algae strain and the cultivation approach, it is important to isolate microalgae as each strain has different behaviours where suitable cultivation method must be selected accordingly. Figure 1 shows recent development of microalgae strain both conducted by universities and government agencies in Indonesia. Rahman et al. reported in their studies that several microalgae strain from Indonesia such as Synechococcus sp. HS-9, Spirulina platensis, Glagah consortium microalgae, and Nostoc HS-20 have higher fatty acid compared to strains from other countries [8]. In fact, the total saturated fatty acid (SFA) of Spirulina platensis from Lampung is among the highest in the world.

Microalage studies in Indonesia were mainly conducted in Central Java cost. Hadiyanto et al. found that the microalgae identified at Panjang island, Teluk Awur, and Rembang coastal have high oil content ranging between 20% and 30% [9]. This include Nitzschia palea (23%), Chlorella vulgaris (27%) and Euglena gracilis (20%). The marine green algae of Nannochloropsis from Jepara beach also gave the formation of oil content comparable to palm oil [10]. Moreover, a study conducted by Amini and Susilawati found another promising microalgae species known as the Botryococcus braunii [11]. Long chain hydrocarbons, in the form of oil or unbranched triterpenes, from this species is called botryococcene and are very potential to be used as biodiesel. These findings suggest that microalgae, which do not compete with food products, are available in Indonesia with high oil content and can be used as a promising biodiesel feedstock.

Despite its potential, biomass harvesting for microalgae production is still challenging and the extraction of oil from microalgae is still a very expensive process [12]. Therefore, further investigation on the transesterification process and the search for an alternative economic extraction method is required. It is also important to develop the artificial cultivation method so that higher production yields and less environment risk can be achieved. However, its progress may not be significant in the short coming year due to several technical limitation. Therefore, optimizing current natural cultivation through a cost-effective method is considered the best approach today.

Fig. 1. Researches on microalgae strain by Indonesian universities and government agencies [8]

5. Applications on Internal Combustion Engines

Regarding the use of microalgae as biodiesel in diesel engine, there are two major concerns; (1) the microalgae biodiesel properties and (2) its effect on engine's performance, combustion and emission characteristics. In terms of its properties, two main standards of biodiesel are ASTM D6751 (American) and EN 14214 (European). Any biodiesel to be used in diesel engine should meet these standards. However, the Indonesian government has also set its own national standard known as SNI 04-7182-2006. The requirements for biodiesel quality in Indonesia have been standardized in SNI-04-7182-2006, introduced by the National Standardization Agency (BSN) on February 22, 2006 [13]. However, the SNI standard is less strict compared to the American and European standards. Take the viscosity of Indonesian Palm Oil for example, it is 3.825-4.655 cps at 40°C which is slightly higher than ASTM limit, but within the SNI standard [14].

Some aspects of biodiesel properties should be taken into consideration. Flash point is a substantial safety measure of fuels flammability. Biodiesel, including algae biodiesel, have higher flash point compared to conventional diesel fuel, being two-times more. However, adding residual alcohol can decrease the flash point of biodiesel rapidly. Viscosity is another issue. It affects volume flow and injection spray characteristics of an engine. Biodiesel kinematic viscosity is higher than that of conventional diesel fuels. Consequently, biodiesel at low temperature can be very viscous or even solidified, compromising the mechanical integrity of the injection pump drive system. Besides the flash point and viscosity, cetane number is also an important point to consider. Cetane number defines the fuel tendency to combust under certain pressure and temperature condition. Very few studies can be found investigating the Indonesian microalgae biodiesel properties. Likewise, its application in real engines is difficult to find. No studies are found comprehensively examining the effect of Indonesian microalgae on engine's performance, combustion and emission characteristics.

6. Points to Consider

As a nation with massive available land, abundant supply of water and high average sunlight, Indonesia has a great potential to lead the development of microalgae in the world. However, most of studies were conducted on Java islands, particularly in Central Java. Given the massive area of Indonesia and lack of energy supply outside Java, the development of microalgae needs to be investigated thoroughly throughout the country. Moreover, since biodiesel can be used to generate electricity besides its application in automotive sector, the development of microalgae biodiesel can help the country to fulfil its energy consumption in several isolated islands or regions.

Note that producing biofuels from microalgae has several challenges. Its development is still in preliminary stages and mass commercial production are still in progress, hindered by some challenges. One major drawback is the low biomass concentration in the microalgal culture caused by the limit of light penetration, but this is not an issue in Indonesia. It is the small size of algal cells that make the production of algal biomasses relatively expensive in Indonesia. Furthermore, their higher capital cost and intensive care compared to a conventional agricultural farm is another negative point discouraging the commercial implementation of microalgae biofuel plan.

Fertilizers is another important issue to be considered for microalgae commercial production. For large-scale production, it requires large quantities of fertilizers. Even though microalgae can produce 10-20 times more biodiesel than rapeseed, nitrogen fertilizers are needed 55-111 times more than the requirement for rapeseed: 8-16 tons per hectare annually [15]. This such massive quantities of nitrogen and phosphorus could harm the environment. To solve such problem, the use of phosphate fertilizers in an open pond culture using seawater with commercial nitrate can be used to reduce lipids production cost. Note that this approach will determine the strain requirement thus suitable strain should be selected for such environments.

7. Conclusions

The instability of oil prices and the need to lower harmful emissions have attracted global interest to produce biodiesel derived from microalgae. Given the wide variety of microalgae available throughout Indonesia, it is important to carefully select and develop high-yielding strain. Several factors should be taken cautiously prior to the mass production of microalgae biodiesel in Indonesia. This include the selection of cultivation method, the development of suitable media and the consideration of environmental variable of microalgae development. If these fundamental aspects have been established, the advancement in genetic engineering of Indonesian microalgae can be proceeded further.

Another important issue is the direct application of microalgae biodiesel in the existing modern internal combustion engines. No studies can be found examining comprehensively the effect of Indonesian microalgae biodiesel on engine's performance, combustion and emission characteristics. Therefore, it is difficult to measure the feasibility of microalgae biodiesel if it has not been tested on real engines. Huge research gaps are found in this area.

With its massive potential and natural abundance, Indonesia can be the leading nation in microalgae research. Further studies should focus on how to cultivate microalgae with suitable technology through a cost-effective method. Since microalgae has numerous applications ranging from pharmacy, automotive to cosmetics, thus more interdisciplinary collaborations need to be established between research groups throughout the country, from biotechnology departments, chemical engineering to automotive research groups. Also, partnerships between universities, industry and government agency should also be established.

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