An overview of potential production of bio-lubricant in Indonesia

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Abstract. The European Union's embargo on Indonesian crude palm oil (CPO) has resulted in excess of domestic palm oil reserves. The embargo has resulted in a build-up of domestic CPO due to the fact that the majority of Indonesia's CPO production is exported overseas. The CPO price has dropped in recent months as a result of CPO overstock. On the other hand, as a by-product of rice production, Indonesia produces millions of tons of rice bran. The bran is treated more as waste than a resource for raw material to produce valuable products, such as bran oil. The need for lubricants in Indonesia is expected to rise as the number of cars and industries grows. As a result, some lubricant requirements must be met through importation because domestic manufacturing is insufficient. Palm oil and bran oil are both excellent candidates for conversion into biolubricants. This paper looks at the possibility of biolubricant production in Indonesia using alternate raw materials rather than petroleum-based sources. The paper begins by detailing the country's lubricant demand, then moves on to the probable availability of biolubricant raw materials in Indonesia, and finally to the biolubricant process production method.

1. Introduction
Various types of machines are constructed from many components made of metals, some of which move and are in contact with one another through the interface of these components. When the engine is in operation, friction occurs between machine parts that are in contact with each other, causing the surface of the elements becomes worn and hotter if no protection is provided [1,2]. For the engine to operate appropriately, friction, wearing component surface, and excess heat must be controlled by lubrication. Lubrication is a process used to reduce the wear of one or both surfaces of components that move relative to one another in close proximity by placing a lubricant liquid.

The majority of lubricants on the market today are derived from hydrocarbons extracted from the heavy fraction of the crude oil refinery process [3,4]. The depletion of world oil reserves, increased fossil fuel use, rising oil prices, environmental concerns, and more stringent environmental restrictions have generated interest in using plant-based, environmentally friendly, and easily biodegradable products [5]. As a result, alternative technologies based on renewable bio-resources, such as fuels and lubricants, are becoming a hot area for research at present. Even though lubricants are currently made from a small percentage of total oil production, uncontrolled disposal of spent lubricants has had numerous harmful consequences. Millions of tons of lubricating oil have been reported to be spilt...
annually into water bodies such as rivers and seas, contaminating groundwater [6]. It is a significant threat to plants and aquatic life [7,8].

The world’s demand for lubricants increases with an average growth of 2.3% per annum. The global market value of lubricating oil is expected to grow at 5.4 % compound annual growth rate (CAGR) from 2016 to 2024 [9]. China and the United States led the global lubricant consumption in volume, accounting for more than one-third of global demand. The same pattern is also observed in the market for lubricating oil in Indonesia. Such increase has been triggered mainly by the growing number of vehicles at a rate of 5% per year. At present, the country requires more than one million kiloliter of lubricant per year; and the domestic production volume cannot meet the demand due to a lack of raw material supply. Consequently, the shortage of lubricating oil has to be fulfilled from import. In addition, it is predicted that approximately 40% of used lubricants will end up in the environment as non-biodegradable waste.

It is vital to develop and produce bio-lubricants based on sustainable, easily biodegradable, and renewable raw materials to address the challenges described above. Indonesia has a plentiful supply of raw materials for manufacturing lubricants. As the largest producer, palm oil has the potential to be converted into bio-lubricant since the synthesis of palm oil into bio-lubricant is similar to that of petroleum-based lubricants [10]. The majority of domestic palm oil products are exported as Crude Palm Oil (CPO). However, due to the European Union's palm oil embargo and the COVID-19 pandemic scenario, CPO exports have been limited, forcing CPO production to be used domestically. Even though CPO has been transformed into various goods in the country for a long time, the amount used is minimal compared to CPO production. As a result, converting some CPO into bio-lubricant will not affect the CPO trading system.

While other oils, such as castor and soybean oil, have potential, they are not readily available in significant quantities, making them unlikely to be sustainable. Among many other possible vegetable oils, rice bran oil is a suitable choice as a base stock for industrial lubricants. Indonesia does not manufacture rice bran oil, but it does have a lot of bran, which can be used to make rice bran oil. Only a small amount of rice bran is used for animal feed or a combination of natural fertilizers; the rest is thrown away or burned [11]. With a large amount of bran available, rice bran oil has a high potential for production, which is backed up by technology for improving oil recovery from the bran [12]. Since rice bran oil is not commonly used as an edible oil in Indonesia, converting rice bran oil into bio-lubricants does not interfere with the edible oil trade. This paper examines the potential of Indonesian raw material resources for bio-lubricants production and environmentally friendly bio-lubricant manufacturing technology.

2. Domestic demand for lubricant

Lubricant demand is predicted to expand at a consistent pace of 2.0-3.0% per year annually. Even though the expansion rate is constant, the volume of lubricants necessary to keep up with it will continue to rise. As illustrated in Figure 1 [13], the globe is expected to require 40.0 million metric tons or more of lubricants by 2022. The rise in lubricant volume required corresponds to the rising demand for engine oil in industry and new automobiles. Figure 1 shows that the industrial sector has continued to dominate engine oil use during the last ten years, followed by commercial and consumer automotive. When comparing the use of engine oil by country, there are discrepancies since in some countries, such as the United States, personal vehicles govern the usage of engine oil.

Figure 2 depicts a regional comparison of global lubricant consumption in 2016 (a) and projections for 2021 (b) [14]. Data collected in 2016 showed that lubricant demand climbed in Asia and South America (South America), fell in North America (North America) and Europe, and remained constant in Africa/Middle East (AME), according to a report published by Kline & Company. It is apparent that the Asia-Pacific region will continue to dominate global lubricant demand in 2021. This is understandable given that the Asia Pacific region accounts for over 60% of the worldwide population. Furthermore, as the number of motor vehicles and industrialization in the Asia Pacific region grows,
so does the use of lubricants. The demand for lubricants in Central and South America and the Middle East, and Africa is predicted to rise as the number of manufacturing units, motor vehicle production, and ownership rates rise.

Figure 1. Global lubricants market volume by products [13].

Figure 2. Global lubricant demand by region in 2016 (a) and projected in 2021 (b) [14].

Given Indonesia's lubrication requirements, the domestic lubricant consumption pattern differs from that of the rest of the world. Automobiles are the most common users of lubricants in the country. Such difference is understandable given the dramatic increase in the number of automobiles on the road, as illustrated in Table 1 [15]. Table 1 shows that the number of carriages of various sorts increased by roughly 6% annually between 2017 and 2019. Motorcycles and personal automobiles account for the majority of vehicle growth. Vehicles account for up to 86% of home lubricant demand. Domestic lubricant output is estimated to be around 900 thousand kiloliters (kL) per year, with annual demand of 1.15 million kL. This means that imports will be required for more than 250 thousand litres of lubricant. It is apparent that the country's market possibilities and lubricant production remain untapped. Given Indonesia's vast natural raw material resources, it is important that bio-lubricant production be encouraged in order to reduce imports and ensure lubricant availability in the country.
3. Feedstocks for bio-lubricant production

Bio-lubricants are lubricants made from natural raw resources, including vegetable and animal oils, that are renewable, non-toxic to humans and other living things, and environmentally benign. Plant seeds, such as edible or non-edible vegetable oils, can be utilized to make bio-lubricants. Vegetable oils produced from castor, rice bran, rapeseed, jatropha, palm, sunflower, coconut, soybean, olive, and canola are potential raw materials that can be utilized as bio-lubricants [16–18]. Among the raw materials described above, palm oil and rice bran oil are the most promising raw material sources for the production of bio-lubricant, as these two commodities are sustainably produced in considerable amounts in the country. Although Indonesia does not produce rice bran oil, it does generate a significant amount of rice bran that can be processed into the oil. Although coconut, sunflower, and soybean plants grow well in Indonesia, the oil generated from their fruits or seeds is only enough to cover for domestic edible oil demand; therefore, they cannot be converted into bio-lubricants.

Indonesia has been the world's top producer and exporter of palm oil over the previous decade. The country produced 48.7 million tons of palm oil in 2018, of which 40.6 million tons of crude palm oil (CPO) and 8.1 million tons of palm kernel oil (KPO). In the form of CPO, palm oil is primarily turned into cooking oil and biodiesel [19]. Domestic cooking oil and biodiesel manufacturing required 3.4 and 4.7 million tons of CPO, respectively, in 2018. Compared to domestic CPO production, which is fairly significant, CPO utilization is considered very low. However, as seen by the export volume of palm oil, which reached 29.1 million tons in 2017, excess CPO output is absorbed worldwide. Indonesian palm oil is heavily imported by Asian countries such as India, China, Pakistan, the European Union, and the United States of America [20].

A new issue with CPO exports has arisen due to the European Union's rejection of CPO from Indonesia. The EU implemented a policy that identifies oil palm as the sole crop with a high risk of indirect land-use change (ILUC) and is also connected with significant greenhouse gas emissions as the reason to prohibit CPO from producing countries. Because only around 20% of palm oil production is used domestically and the rest is exported, the embargo significantly impacted the palm oil industry. As a result, converting palm oil into bio-lubricant is a fantastic way to boost the use of palm oil in the country. The process for converting palm oil into bio-lubricant has been extensively researched and found to be effective [21–23]. In addition to being the largest palm oil producer, Indonesia is also one of the world's most important rice producers. According to statistics, Indonesia's paddy fields covered 8.19 million hectares in 2016. Annually, 75.39 million tons of dried paddy are produced in this large region. Each rice milling operation produced rice (67-60%), husks (18-20%), and rice bran (8-10%). On this basis, Indonesia produces approximately 6-7.5 million tons of rice bran every year. In addition to the millions of rice yields in Indonesia, bran waste is also plentiful [11].

Up to the present time, rice bran has been chiefly used as animal feed or in a mixture of natural fertilizers, with most of it being burned or left. This indicates that rice bran has not been able to provide economic value. However, it can be turned into higher-value goods like rice bran oil, bioethanol, and bio-lubricant. Despite the ban, the most common approach employed by farmers to reduce the volume of rice bran waste is to burn it. This practice, however, has a harmful influence on the environment as well as human health.

**Table 1.** Number of vehicles based on types in Indonesia between 2017 and 2019 [15].

| Vehicle types    | Number of vehicles (unit) |
|------------------|---------------------------|
|                  | 2017                     | 2018                     | 2019                     |
| Motorcycles      | 100,200.245              | 106,657.952              | 112,771.136              |
| Private cars     | 13,968.202               | 14,830.698               | 15,592.419               |
| Passenger cars   | 213.359                  | 222.872                  | 231.569                  |
| Freight cars     | 4,540.902                | 4,797.254                | 5,021.888                |
| Total            | 118,922.708              | 126,508.776              | 133,617.012              |
With the enormous amount of rice bran waste is unutilized, it has a high potential for being transformed into bran oil, which can then be converted into bio-lubricants. However, as palm oil still dominates the edible oil, there has been no attempt to turn the bran into vegetable oil. Research results have shown that extracting bran oil from rice bran yielded 9-15%. The yield of oil extraction can be increased by up to 18% with a bit of effort to provide microbial treatment to the bran [8]. This means that if the majority of the bran can be transformed into vegetable oil, over one million tons of rice bran oil can be produced per year. It is a substantial amount of raw material to turn into bio-lubricant. The Rice bran oil conversion technique has also been thoroughly investigated [24,25].

4. Production process of bio-lubricant

Since it does not meet lubricant criteria, plant or vegetable oil cannot be used directly as a lubricant. Plant oil is susceptible to oxidation due to the presence of a double bond in the carboxylic acid. The double bond must be broken down into a single bond in order to increase the oil stability. As a result, a chemical alteration is required to transform the plant oil into a biolubricant. Various mechanisms, such as esterification, transesterification, hydrogenation, and hydrogenation-esterification reactions, can be used to create this change [5,14]

As indicated in Figure 3, esterification is a process of turning free fatty acids into esters by reacting fatty oils with alcohol. Strong acid solutions can be used as catalysts to speed up the esterification process. A significant excess of methanol reactant must be utilized to accelerate the reaction into a complete conversion at low temperatures (e.g., 120°C). The final liquid ester product must be purified by washing and removing water. Using a combination of correct reaction conditions and water removal processes, the conversion of fatty acids into their esters can be completed in one to several hours.

![Figure 3. Esterification reaction converting carboxylic acid into ester.](Image)

In addition to esterification, one of the most common methods for producing ester-based biolubricants is transesterification. Ester-based biolubricants are made by reacting glyceride-based plant oil source materials with alcohol using a catalyst. Heikal et al. and Sanni et al [17,26] employed two-stage transesterification reactions, as shown in Figure 4, to produce biolubricants. The first stage involves producing biodiesel by reacting palm oil with methanol in the presence of potassium hydroxide as a catalyst. The second stage consists of reacting biodiesel with trimethylolpropane using sodium methoxide as a catalyst to produce trimethylolpropane esters derived from palm oil (biolubricants). Transesterification method has received significant attention among scientists and researchers to develop biolubricants from palm oil, including its by-products. Affah et al. [27] conducted an enzymatic reaction to biolubricant from a by-product of a palm oil mill. Candida antartica lipase was used as a catalyst in a solvent-free system to transesterify palm stearin and methanol. Enzymatic transesterification yielded a high of 95.26% palm stearin methyl ester. For the synthesis of biolubricants, hydrogenation of esters and one-step hydrogenation–esterification methods have been used in addition to esterification and transesterification processes [28–30]
5. Conclusions
At the present time, petroleum-based lubricants are used to meet Indonesia's lubricant demand. Domestic lubricant demand is roughly 1.15 million kL per year, but the production is only around 900 thousand kL. As a result, 250 thousand kL lubricants have to be imported to meet the domestic demand. Given the availability of CPO and rice bran that can be turned into bran oil, the potential source of raw materials for developing biolubricants is enormous. The methods of esterification and transesterification have been widely employed to manufacture biolubricants. To meet domestic lubricant demand, Indonesia must begin utilizing the vast local resources available for bio-lubricant production.

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