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REVIEW ARTICLE

Effect of COVID-19 on Biodiesel Industry: A Case Study in Indonesia and Malaysia

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ABSTRACT – Indonesia and Malaysia are currently holding prominent roles in the global palm oil market. Both countries are the top two palm oil producers in the world and have ambitious targets to increase the palm oil-based biodiesel mandate. In Indonesia, the current programme of blending 20 per cent palm oil into 80 per cent diesel (B20) increases to B30 in 2020. Likewise, Malaysia plans to increase its biodiesel mandate from B10 to B20 in 2020. However, the outbreak of COVID-19 has infected millions and brought the global economy to a near-deadlock. The effect is particularly severe in the fuel industry owing to movement restrictions and the historic drop in oil prices. Evaluating the impact of the COVID-19 on the biodiesel industry is crucial for policymakers but challenging as the pandemic has evolved with intense speed. This article aims to discuss the impact of COVID-19 on the Indonesian and Malaysian biodiesel industry. In addition to that, a number of possible solutions to overcome the challenges were addressed and proposed. Despite severely affected by COVID-19, both Indonesia and Malaysia can use this momentum to improve and strengthen their biodiesel sector. Given its fiscal deficit, Indonesia should postpone its biodiesel blending mandate as the subsidy to support the programme can worsen the country's financial stability. In Malaysia, where labour shortage is prevalent, modernising plantations with automated equipment, for instance, could potentially remove the dirty and dangerous stereotypes associated with plantation works, thus attracting more locals to work in the palm oil plantation and solving the labour shortage. This paper also briefly addresses the adoption of Industry 4.0 and Circular Economy for the palm oil biodiesel industry.

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INTRODUCTION

The use of fossil fuels in the transport sector generates the second-largest source of greenhouse gas emissions (GHG) [1]. For this reason, the search for clean and renewable substitutes for fossil fuels has currently become a pivotal issue for the automotive industry [2]. Biofuels in the forms of alcohol [3, 4] and biodiesel [5] have been growing in popularity as alternative and renewable energy supplies. Biodiesel, in particular, is proving to be a promising renewable alternative for conventional petrol diesel owing to its clean-burning and domestically produced characteristics. Between 2000 and 2005, biodiesel production increased by 295% globally, as reported by the International Energy Agency (IEA). The increasing trend is projected to continue, and it is estimated that biofuels will contribute about 7% to road transport in 2030 [6].

Despite its obvious advantages as a clean and renewable fuel, biodiesel shows some drawbacks. Its relatively higher viscosities compared to petrol diesel by a factor of about 11–17 means will cause a number of problems in fuel pumping, combustion and atomisation [7]. The coking of fuel injectors is also another common problem [8]. Moreover, in an unmodified diesel engine, excessive engine wear may occur with the use of biodiesel [9]. Therefore, it is important to improve the physico-chemical properties of biodiesel so that it is compatible with diesel engines [10]. Note that minor modifications may be required to ensure the compatibility of biodiesel with current diesel engines.

Indonesia and Malaysia, the top two palm oil producers in the world, have emerged as two prominent global leaders in the production of biodiesel. The biodiesel market in both countries was expecting major momentum in 2020. Early in January, Indonesia raised the biodiesel mandate from 20 to 30 per cent (B30), which was predicted to benefit the palm oil industry and potentially increase domestic biodiesel consumption by 45% [11]. Likewise, Malaysia aims to increase its biodiesel mandate to B20 for the transportation sector and B10 for the industrial sector starting in 2020 [12]. Figure 1 illustrates the locations of palm oil mills and processing facilities in Peninsular Malaysia. However, the recent outbreak of COVID-19 is changing the direction of the biodiesel mandate in both countries.

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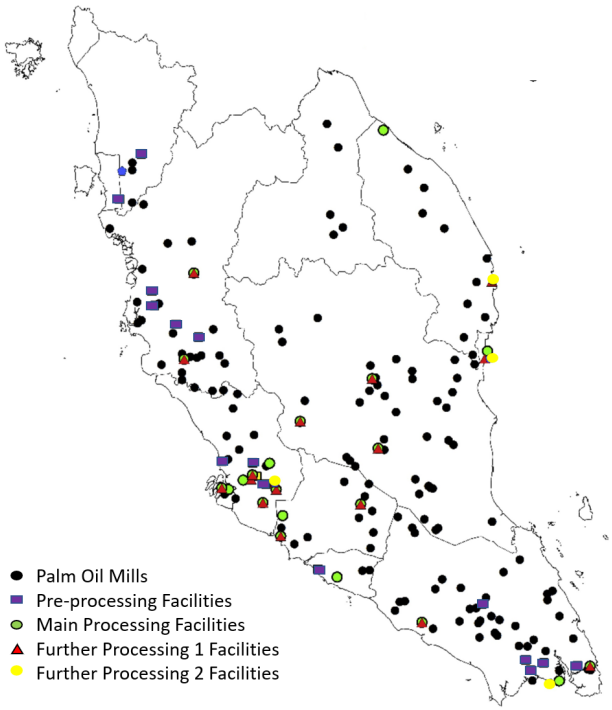

Figure 1. Location of palm oil mills and processing facilities in the Malaysian Peninsular. Adapted from Rubinsin et al. [13].

The pandemic of COVID-19 has devastated numerous industries, and biodiesel is no exception. A number of emerging and developing countries such as Indonesia and Malaysia were already experiencing weaker economic growth before the pandemic; now, COVID-19 makes these countries confront the challenges even tougher. Before the outbreak of COVID-19, the biodiesel industry in Indonesia and Malaysia are predicted to experience significant growth in 2020. Apart from government support, a growing concern to replace non-renewable fossil fuels with renewable and clean alternatives were anticipated to increase the consumption of palm oil-based biodiesel in both countries. However, elevated demand has not been seen due to the COVID-19 pandemic. Also, the drop in global oil prices contributed to worsening the situation.

The price of biodiesel is significantly influenced by the volatility of crude oil prices. A three-year pact between Organisation of the Petroleum Exporting Countries (OPEC) and Russia finished in resentment on 6th Mar 2020 in Vienna following a refusal by Moscow to cut oil production to cope with COVID-19 [14]. This has triggered Saudi Arabia to increase its oil production to an unprecedented level, causing the most extreme one-day market crash in 30 years when Brent Crude fell to $25.70/barrel from $34 on 23rd Mar 2020 [15]. Although oil prices have been relatively stable as the number of deaths from COVID-19 has reduced, the breakdown of the pact has resulted in an oversupplied market, thus potentially creating the most serious oil price crises in history.

Palm oil has two essential roles in the Indonesian and Malaysian economy. Firstly, it is a vital export commodity providing substantial export income and employment opportunities [16]. Secondly, it is the main source of cooking oil, which both countries consider as a vital commodity. The biodiesel industry provides substantial socio-economic benefits. However, the global biodiesel market has not improved considerably in recent years [7]. Numerous measures have been taken to enhance many aspects of biodiesel production. To achieve a sustainable biodiesel industry and long-term energy security, governments in many countries have invested generously to support their biodiesel industry.

Despite their prominent roles as the first and second-largest palm oil biodiesel producing countries in the world, Indonesia and Malaysia do not contribute significantly to published patents related to biodiesel production. It is China, as shown in Figure 2, that contributes the most to the number of published patents, followed by the World Intellectual Property (WIP) Organisation and the USA with totals of 647, 343 and 266 patents, respectively [7]. These three categories account for approximately 75% of the total patents. This finding implies a convincing prospect for the development of the biodiesel industry in China, but at the same time indicating a lack of research and development for biodiesel production in Indonesia and Malaysia despite their roles as the global leading palm oil producers.

It is important to remember that for sustainable development, research and development alone is not enough. Support and well-established policy from the government is crucially important. Government policies will be critical in the subsidisation programme, tax relief and financial assistance [17]. When the crude oil price plummets, for instance, higher biodiesel price will be unable to compete with petrol diesel fuel, thus resulting in a significant drop in its demand. As a result, numerous biodiesel plantations should either be closed or forced to slash their production. This situation has occurred several times in the past, and such a situation can happen again in the future. With the outbreak of COVID-19, policymakers need to address such a problem cautiously.

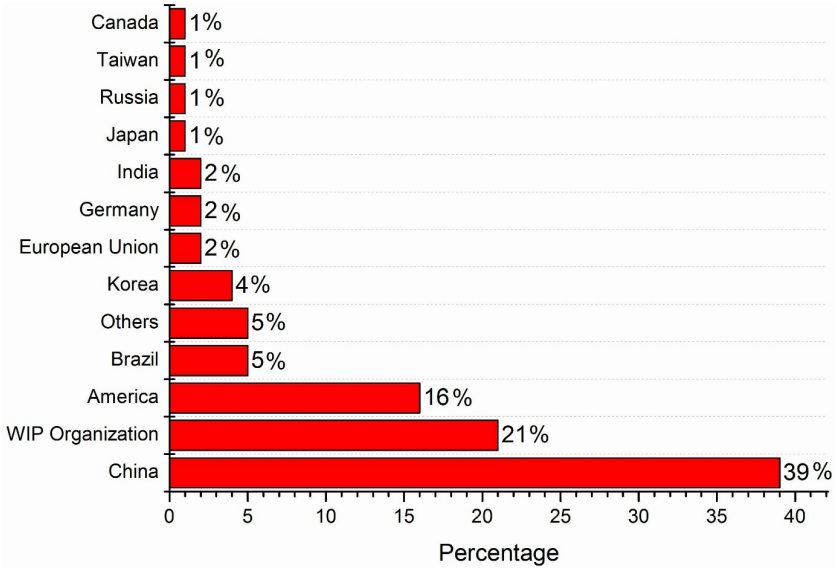

Figure 2. Patent on biodiesel production from 1999 to 2018. Reproduced from Mahlia et al. [7].

To understand the pandemonium effect on the biofuel industry, we summarise the effect of COVID-19 on the biodiesel sector, focusing on Indonesia and Malaysia, which are the two largest palm oil-producing countries in the world. The first part discusses the pandemic effect on the Indonesian biodiesel industry, whereas the second part discusses that of Malaysia. The following section explains the future impact of COVID-19, revealing the vulnerability of the biodiesel industry in Indonesia and Malaysia. The adoption of Industry 4.0 and the Circular Economy for the palm oil biodiesel industry is also addressed briefly in this paper.

CHALLENGES WITH INDONESIAN AND MALAYSIAN PALM OIL-BIODIESEL INDUSTRY

Biodiesels are typically produced from bioenergy resources such as animal fats or vegetable oils. The enormous advantages of biodiesel do not only convince the government in many countries to consider it as a potential energy alternative but also persuade the government to implement new policies to support biodiesel production [18]. In the USA, rapeseed and soybeans have been established to be promising feedstocks for biodiesel, while in Asia, such as in Indonesia and Malaysia, palm oil plays a comparable role. As the top two prominent producers in the world, both countries have been developing palm oil as a potential biodiesel feedstock for years.

One of the most vulnerable points of biodiesel in Indonesia and Malaysia is its competition with the food industry, as palm oil is also used as the raw material for cooking oil and other processed industries. The price is also very susceptible to fluctuation. Brazil, which has made the use of ethanol biofuel mandatory for decades, has faced a similar dilemma. Over time, this dilemma was resolved, and ethanol remains mandatory in Brazil. However, global pressure against crop-based biofuels continues to be echoed. *Jatropha curcas*, a shrub with high oil content, has been extensively investigated as a non-edible source to produce biodiesel. It contributes to the biodiesel feedstocks in Indonesia and Malaysia. However, the contribution is not as significant as palm oil since *Jatropha* oil has not yet reached commercial levels; thus palm oil will remain the primary feedstock for biodiesel production in Indonesia and Malaysia.

In terms of land utilisation, although Indonesia and Malaysia have similar rates of rising productivity and revenue in the biodiesel sector, both neighbouring countries have experienced opposite directions of land use [19]. Indonesia has been in support of expansion, while Malaysia has put more emphasis on intensification. In Malaysia, palm oil is predominantly planted in designated land as the government aims to retain its landmass for at least 50% under forest cover. Indonesia, on the other hand, has no such assurance, resulting in the expansion that favours the market establishment and production targets. Despite their different trajectories, both intensification and expansion have led to a number of social conflicts. Conflict can arise over land rights between communities and palm oil companies. The land rights of local people are often not documented and therefore not acknowledged by the government. The government can then hand over their land to the business owner without their consent. As a result, the indigenous people have been relocated out of their traditional agricultural land. Also, as most palm oil industry depends on foreign labour, the number of undocumented and overstaying workers may increase especially when the border is closed due to pandemic.

Numerous technologies have been investigated in the last decade to reduce the environmental risks from the palm oil biodiesel industry, as addressed by Abdul-Hamid et al. [20]. Traditional ponding system has been the preferred technique to treat palm oil mill effluent [21], but this method has some limitations, such as higher greenhouse gas (GHG) emissions. One of the solutions is proposed by Jamaludin et al. [22] to use recycling water to reduce GHG emissions. Foong et al. [23] also reported that optimising the operation in palm oil palm operation using an input-output model was found to significantly enhance the sustainability and reduce the plantation area by nearly a quarter with a substantial decrease in

GHG emissions. It is important to remember that despite recent technical advances in biodiesel production, the application of the above approaches requires an efficient technology.

IMPACT OF COVID-19 ON THE INDONESIAN BIODIESEL INDUSTRY

Indonesia is now the largest palm oil producer in the world, exceeding Malaysia in 2008 [24]. Most of the biodiesels in Indonesia produced from crude palm oil (CPO). CPO is an essential commodity for Indonesia. It is a major resource to meet the government's biodiesel blending target [25]. While palm oil exports are vital for Indonesia economy, the biggest domestic use of CPO after food is for biodiesel production. Khatiwada et al. [26] reported that the increasing demand for biodiesel in Indonesia could still be met without expanding palm oil plantations. By utilising 63% of the planted area as in 2014 and assuming the country maintains the same average yield, Indonesia can still supply its domestic CPO demand until 2025. However, this will be compensated by lower exports, thus potentially reducing the profit from the global palm oil markets. Also, reduced palm oil exports from Indonesia may severely affect food security in many countries that depend on continuous and sizeable supplies of Indonesian palm oil, such as India and China.

To increase its palm oil production and domestic consumption, Indonesia endorsed the adoption of biodiesel in 2009. The government subsidies the biodiesel industry to make biodiesel price more competitive compared to petrol diesel fuel. Since 2009, the country has progressively increased the blend ratio. Indonesia began with its B1 blending mandate in 2009. The ratio was then increased to B2.5 between 2010 and 2012. In 2014, 2015 and 2016, the country further raised the percentage to B10, B15 and B20, respectively [27]. The B20 was entirely adopted across the country in 2018 [28]. In 2020 and 2021, Indonesia aims to implement B30 and B40, respectively.

Despite the COVID-19 pandemic, the B30 programme has been decided to continue. The Indonesian government and all stakeholders are determined to continue the mandatory B30 programme even though petroleum prices continue to decline and the COVID-19 will reduce the use of biodiesel in the domestic market. National biodiesel production in the first half of 2020 was 4,876,404 kilolitres [29]. Since the price of petroleum fell, Indonesia's biodiesel exports have dropped equally as demand from the global market has slumped. In addition, numerous trade barriers facing palm oil and its derivatives have also contributed to the decline in biodiesel exports.

Amidst the outbreak of COVID-19, the Indonesian government is targeting the B40 programme to be launched in June 2021 and preparing the implementation of B100. The Research and Development Agency of the Ministry of Energy and Mineral Resources together with several related parties, are conducting trials on the B40 programme. The world's largest palm oil producer will resume the B40 mandate. Endurance test on the engine test bench for 1000 hours was conducted in July 2020. This will be followed by the fuel endurance test this year. The results have not been published. However, if the B40 is successfully implemented, Indonesia is expected to be able to save up to US $ 8 billion in foreign exchange. Furthermore, Indonesian state-owned oil and natural gas corporation, Pertamina has also successfully tested 1,000 barrels of B100 at the existing Dumai Refinery facility [29]. The trial and other preparations are still being examined to produce it commercially. One of the preparations for production is ensuring the supply of catalysts. B100 is made from refined pure palm oil that has been refined so that it is free from dirt, sap, grease, and odours or Refined Bleached and Deodorised Palm Oil (RBDPO). Pertamina is also preparing a B100 processing and production facility at the Plaju Refinery with a target production capacity of around 20 thousand barrels per day in 2023. Production will also be carried out at the Cilacap Refinery, with a capacity of around 6000 barrels per day in 2022.

Despite its ambitious plan, Indonesia should consider its financial capability to support the implementation of the biodiesel mandate. COVID-19, along with lower oil prices, have heightened the necessity for policy backing to maintain the biodiesel sector. This is particularly a critical issue in Indonesia as biodiesel production is economically uncompetitive compared to conventional petrol diesel fuel. According to Presidential Regulation No. 61/2015, a levy on CPO exports can be imposed when the price of crude palm oil surpasses the upper limit [30]. The collected levy funds can later be allocated to subsidise biodiesel prices to become more competitive in the market. Therefore, biodiesel price needs to be adjusted to the price of petrol diesel so that the difference between the two is not increasingly imbalanced. Otherwise, the price gap will increase the subsidy costs taken from the palm oil funds.

Despite the COVID-19 and historic drop in oil prices, the Indonesian government has decided to continue the use of B40 in 2021. The trials for B100 is even being investigated. The government believes that through this mandatory biodiesel programme, domestic palm oil production can be absorbed, and the price can be maintained. If the excess domestic supply is not absorbed through the biodiesel programme, there will be excess stock, which will lead to lower prices. However, it is important to remember that with the declining oil prices, the gap between biodiesel and diesel prices that has to be balanced by the palm oil funds will increase. This burden may eventually deplete the palm oil funds. Saif and Saputra [30] reported that the government should allocate Rp 42.3 trillion to subsidise B30 for this year. Therefore, the Indonesian government should reconsider the ambition of the B40 and B100 mandate. Considering the current enormous fiscal deficit due to Rp 450 trillion allocation for COVID-19, the B40 is no longer feasible to be implemented.

IMPACT OF COVID-19 ON THE MALAYSIAN BIODIESEL INDUSTRY

Biodiesel is one of the products that was encouraged under the Promotion of Investment Act 1986 [31]. Initiated in 1982, the biodiesel programme in Malaysia started at a laboratory scale. Since then, Malaysia has been able to produce high-quality biodiesel to meet the international biodiesel standards, i.e. ASTM D 6571 and EN 14214 [17]. Today,

domestic biodiesel demand is supplied by small and medium palm oil producers. The Malaysian government plans to boost palm oil production and support its use by increasing the blend ratio mandate. The B10 was adopted for the transportation sector in 2018, whereas B7 was implemented for the industrial sector starting from February 2019 [32]. In 2020, Malaysia aimed to further raise its biodiesel mandate to B20 for the transportation sector and B10 for the industrial sector [12]. Approximately 117 million ringgits will be allocated for research and development in the agricultural sector to boost production [33]. Table 1 shows the important events in the Malaysian biodiesel industry and policy. Despite its strong government support, the outbreak of COVID-19 has forced Malaysia to delay the adoption of B20.

Table 1. Important events in Malaysian biodiesel industry and policy [12, 32-34].

Year	Progress
1982	Research at laboratory scale on biodiesel was initiated
1983	Palm Diesel Steering Committee was formed
1984	First biodiesel plant was built
1984-1985	Biodiesel was investigated in taxis
1985	First biodiesel plant was established
1986-1989	Trials phase I started —31 commercial vehicles and stationary engines
1990	Trials phase II started — test by Mercedes Benz in Germany
1990-1994	Trials phase III started —commercial buses
2001	The use of biodiesel in power plant and research on low-pour-point was initiated
2002	The trial of B2, B5, B10 using liquid palm oil was started
2004	The trial of B5 using refined, bleached and deodorised (RBD) palm oil was started
2005	National Biofuel Policy began to be drafted
2006	National Biofuel Policy was launched
	First commercialised biodiesel plant started to run
	Envo Diesel was launched
	92 biodiesel licences were approved
2007	A number of biodiesel projects were cancelled due to higher CPO price
2008	Malaysian Biofuel Industry Act 2007 was implemented
	Envo Diesel was replaced with B5
2009	The adoption of B5 for government vehicles was initiated
2010	The B5 mandate was postponed to June 2011
2011	The B5 programme began in Putrajaya, Selangor, Kuala Lumpur, Negeri Sembilan and Melaka for transportation and other subsidised sectors
2013	B5 began in Johor for transportation and other subsidised sectors
2013	B5 began in Penang, Kedah, Perak and Perlis for transportation sector
2014	B5 began in Pahang, Kelantan and Terengganu for transportation sector
2014	B7 began in whole peninsular Malaysia for the transportation sector
2015	B7 began in nationwide including Sarawak, Sabah and Labuan for the transportation sector
2018	B10 began in nationwide (by phases) for the transportation sector
2019	B7 began in nationwide (by phases) for industry
2020	Target to use B20 for the transportation sector
2020	Target to use B10 for the industrial sector

Unlike Indonesia, which has no labour problems, Malaysia faces a serious shortage due to COVID-19. New employees have been limited as Malaysia enacted movement control orders or partial lockdown to prohibit mass movements and crowds throughout the country. Furthermore, this problem is compounded by the termination of foreign workers recruitment until December 2020. Migrant workers from Indonesia and Bangladesh contribute to about 84% of the workforce in the Malaysian palm industry [35]. Foreign workers who returned to their home countries cannot re-enter Malaysia because of travel restriction. As a result, the labour shortage has resulted in 25% of palm yield loss as the country closes its borderlines and prohibits foreign workers from entering [36]. However, even before the pandemic, there was approximately a 36,000 shortage in personnel that resulted in a 10-25% production loss [35].

The effect of the labour shortage on the Malaysian biodiesel plantations is particularly noticeable in the peak cycle season between September and December, in which the palm trees produce the most fruits. One reason for the labour shortage in Malaysia is partly triggered by the poor image of working in palm oil plantation considered by locals as dirty and risky jobs [36]. Companies are now luring potential workers with free housing and other enticing facilities as the peak production period approaches. Lack of manpower in the biodiesel industry will not only delay the harvest season but will also increase the production cost, giving an advantage to its biggest competitor, Indonesia.

Compared to $400-$450/tonne in Indonesia, the average production cost of palm oil in Malaysian is already higher at approximately $406-$480/tonne [37]. If labour shortfall in the world's second-largest palm oil producer cannot be immediately solved, a significant increase in the production cost will become inevitable. One solution the country can do is by adopting advanced and automated mechanisation to reduce dependence on labour, which represents approximately 30 per cent of the total production costs. This includes the use of light machines to remove harvested crops and to apply

fertiliser. Also, the utilisation of remote sensing and artificial intelligence can assist the industry in achieving precision farming.

Plantation companies have been trying to lure the locals to work in the plantation. Over the last decade, palm oil producers in Malaysia have reduced their dependence on migrant workers by approximately 30% [38]. The industry has successfully increased the area of a single worker can manage. Through substantial investments and modernisation, a worker can manage nine hectares from seven hectares, signifying a decrease of 30%. The industry still aims to achieve a 40% reduction using a worker to manage 10 hectares. To attract more Malaysian to work in the plantation industry, Malaysian Palm Oil Board (MPOB) plans to offer higher salaries stimulus through the Malaysian Palm Oil Training Centre (Plasma). Initiated in 2006, Plasma was founded to develop local citizens to work in the plantation industry by providing training such as Farm Mechanisation Operators Course [39].

Malaysia can use this momentum to revitalise its palm oil plantations by replacing manual with automated processes. Under the 11th Malaysian plan, the Palm Oil Mechanisation Incentive Scheme states that companies are entitled to a discount of up to 20% for procuring advanced machines to be utilised in plantations [16]. Collaborating with Orion Biosains, MPOB has created a selection technology to sieve through certain palm seeds. Such technology is able to detect and separate the high-yield palm (the tenera palm seeds) to achieve maximum production yield owing to its capability to produce a 30% higher extraction rate. In order to take full advantage of tenera palms, producers use selective breeding methods to produce more oils from thin-shell palm fruit. Currently, around 90% of the oil palms in Malaysia are produced from the ultra high-yielding tenera palm trees [39]. Previously, MPOB has also successfully decoded the oil palm genome sequence, which resulted in the finding of high-yielding palms, which are now utilised in commercial plantations.

THE ADOPTION OF INDUSTRY 4.0 AND CIRCULAR ECONOMY IN MALAYSIAN AND INDONESIA BIODIESEL INDUSTRY

Recently, the adoption of the Fourth Industrial Revolution of Industry 4.0 digital technologies involving sensing, computing and communicating systems has also attracted considerable attention in numerous industry and the biodiesel sector is no exception. Industry 4.0 adopts advanced smart technology where machine-to-machine communication and the Internet of Things are integrated to increase automation, enhanced communication and self-supervising with the ability to analyse and identify problems without human intervention. Industry 4.0 can improve process systems of palm oil production, cut production waste and supervise operational processes [20]. A number of studies have revealed that Industry 4.0 does not only reduce waste consumption and improve resource utilisation, but it also enhances real-time information, supply chain transparency and flexibility, thus facilitating palm oil producers to optimise their economic benefits [40, 41].

In addition to Industry 4.0, Circular Economy (CE) can enhance the resources and energy circularity inside biodiesel production systems so that natural resources waste could be prevented. It is known that the growing palm oil industry generates a massive volume of wastes such as palm fronds, empty fruit bunches (EFB), mesocarp fibres, and palm oil mill effluent (POME) [13]. This could result in severe environmental damage, and sustainable practice is therefore required. In the past few years, CE has received increasing attention to addressing the current production and consumption model [40, 42]. By encouraging the implementation of closed-loop production models inside a system, CE intends to improve the efficiency of resource usage, thus achieving an enhanced balance between economy, environment and society [40]. However, the implementation of CE is often opposed by many companies due to the high initial investment [43]. Lack of information regarding return on investments also contributes to why many companies are reluctant to adopt CE. [44]. This finding implies that the promising of CE approaches has not yet convinced companies to invest as the economic benefits in terms of profitability and market position sustainability are not clear. Therefore, it is important for the government to increase investment and development so that technological innovations in CE can be developed and improved [45].

It is also interesting to see the integration of Industry 4.0 and Circular Economy to improve sustainability in the supply chain since, in practice, both I4.0 and CE have a common effect. Abdul-Hamid et al. [20] investigated the challenges of Industry 4.0 in the Circular Economy for the palm oil industry. This study offers theoretical and managerial insights by identifying the criteria that challenge the adoption of I4.0 in CE. Eighteen critical challenges of Industry 4.0 in Circular Economy were identified, as shown in Figure 3. The three most significant challenges are lack of automation system virtualisation, the unclear economic benefit of digital investment and lack of process design. Palm oil practitioners should focus on such three challenges. Lack of automation virtualisation, in particular, is the greatest challenge that needs the most attention. The paucity of standards makes it more challenging for palm oil companies to apply Industry 4.0 in CE [46]. Moreover, higher dependability of connectivity between machines and the integrity of maintenance data results in more virtualisation difficulties [47]. Therefore, it is crucial to develop a well-organised automation virtualisation system by maximising the real-time visibility of biodiesel operational processes.

FUTURE IMPACT OF COVID-19 ON INDONESIAN AND MALAYSIAN BIODIESEL

COVID-19 emerged when renewable energy policies were in an increasing momentum [48]. In the USA, despite its controversy, a proposed ‘Green New Deal’ received considerable attention in the 2019–20 presidential elections. In the EU, a new policy targeting carbon neutrality, the European Green Deal is projected to be implemented in 2020. In China,

decarbonisation actions are being considered for the forthcoming 14th five-year plan 2021–2025. In Indonesia, the biodiesel programme of B40 will be fully implemented in January 2021. The biodiesel programme is crucial for the country to slash oil imports and reduce carbon dioxide emissions. Similarly, Malaysia plans to implement the use of B20 by mid-June 2021 fully. However, the outbreak of COVID-19 along with low crude prices, could force many countries to reconsider their energy policies.

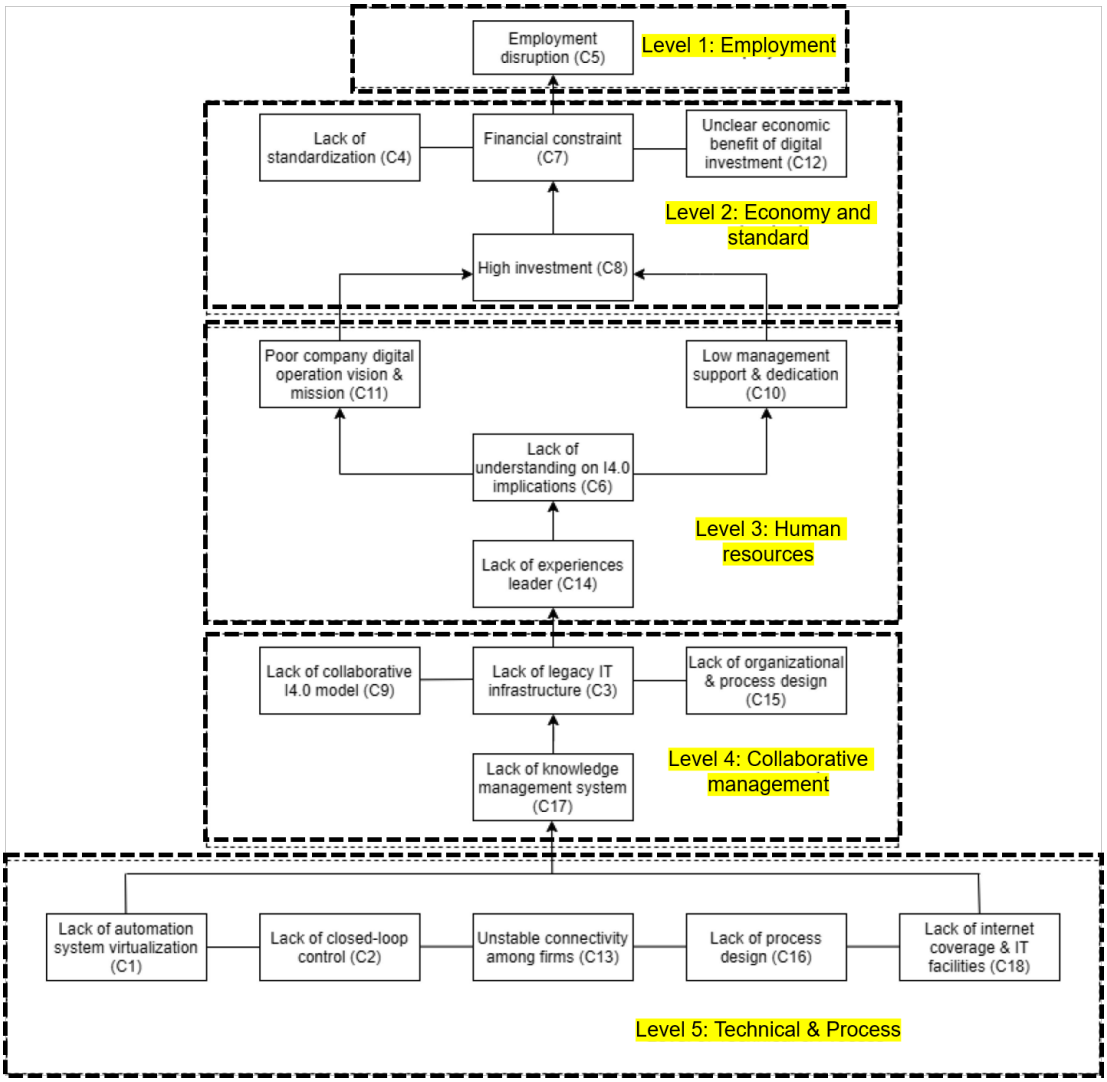

Figure 3. Challenges of Industry 4.0 in the Circular Economy for palm oil industry. Adapted from Abdul-Hamid et al. [20].

The economic downturn due to COVID-19 is projected to affect the biodiesel industry in Indonesia and Malaysia until later this year and even into 2021. However, the rise of e-commerce sectors has the potential to maintain the biodiesel market share owing to a greater increase in the number of deliveries by diesel vehicles. There was a less steep drop in diesel consumption owing to stable commercial activity fuelled with diesel lorries in Indonesia as higher volumes of online sales were reported [49]. According to the Indonesian Ministry of Communication and Informatics, the number of online shop transactions in the country increased by 400 per cent, and it is predicted to continue in the new normal [50]. However, further studies need to be conducted to determine how much the e-commerce sectors can contribute to the market share of biodiesel during the coronavirus pandemic.

Even without the outbreak of COVID-19, the Indonesian and Malaysian biodiesel industry has to cope with declines in demand in international markets. Tax concession for palm oil biofuel will be discontinued in France starting in January 2020 [11]. This move has been followed by other EU members as a way to reduce palm oil imports due to stringent sustainability requirements. To compensate for such reduction in demand, Indonesia and Malaysia will rely on markets with weaker standards, such as India and China. To overcome the decline in demand from overseas, Indonesia and Malaysia should establish their sustainable energy policy.

Ideally, as the top two palm oil producer in the world, Indonesia and Malaysia should develop national vehicles that can be run using palm oil-based biodiesel. Malaysia, in particular, has been successful with its two national cars, Proton and Perodua. However, both vehicle manufacturers only produce cars fuelled with gasoline fuel. It would be interesting to see both countries collaborating to develop a national car run on pure or high biodiesel percentage. Brazil has successfully produced flexi-fuel vehicles that can be operated using bioethanol that is abundant in the country [51]. The

success of flexi-fuel vehicles in Brazil could be an inspiration for other countries, especially for those that are blessed with abundant agricultural feedstocks for biofuels production. Policymakers in Indonesia and Malaysia can take valuable lessons from Brazil to develop a dedicated biodiesel engine vehicle, optimising their advantages as the two top palm oil producers in the world.

The main challenge in the introduction of biodiesel dedicated diesel engine in both countries lies in the technical issue. Biodiesel has different physico-chemical properties than conventional petrol diesel fuel. A number of modifications are therefore required so that biodiesel can be directly used in commercialised diesel vehicles. Such technical challenges would undoubtedly increase the price of dedicated biodiesel vehicles as a result of extra funding for research and development [52]. In this case, mass production plays an important role in reducing the selling price. However, it is worth noting that political concerns will sometimes exceed the technical, economic and environmental issues. In the European Union, for instance, policies tend to favour the environmental concerns over economics and engineering issues. Adverse effects such as deforestation and loss of ecosystem will be prevalent if plantations are not operated following the sustainability standards. On the other hand, palm oil producers in Indonesia and Malaysia tend to favour economic aspects. Hence, four aspects i.e. economic, environmental, engineering and political, should be considered altogether if both Indonesia and Malaysia aspire to produce their first dedicated national vehicle that can run using palm oil-based biodiesel.

CONCLUSION

Biodiesel has been shown to be a possible solution to reduce the detrimental environmental effects of global warming. It has been at the forefront as an alternative source of bioenergy to address the depleting and harmful issue of fossil fuels due to its environmentally friendly nature. However, the COVID-19 pandemic has created several challenges for the biodiesel industry. This study has identified several ways in which COVID-19 are affecting the biodiesel sector in Indonesia and Malaysia. The direct effect of COVID-19 is the reduced demand for biodiesel. Partial lockdown procedures imposed in both countries have resulted in lower demand for transport fuels, which biodiesel is normally mixed with. Low oil prices also suggest that biodiesel is less economically attractive, thus struggling to sustain market share. It has also heightened the necessity for policy backing to maintain the biodiesel sector as COVID-19 has caused several delays to scheduled policy. The COVID-19 pandemic is therefore notifying biodiesel's investors, government and policymakers that it can inflict economic damage on an unprecedented magnitude. For Indonesia and Malaysia, the outbreak of COVID-19 has proved that their biodiesel sectors are exceedingly vulnerable.

For Indonesia, it is important to reconsider its biodiesel policy. Indonesia is currently preparing for B40, but the present condition is not conducive to proceed with B40. Following the extraordinary fall in crude oil prices, it is not feasible for Indonesia to continue its B40 programme in 2021. The country is likely to postpone the implementation of B40 and continue with the existing B30 programme. The biodiesel programme, by absorbing extra supplies of palm oil and reducing expensive fuel imports, is one of the major contributors to the Indonesian current account deficit crisis. Indonesia collects levies to support its biodiesel programmes. The collected levies are then disbursed to subsidise biodiesel producers. When the oil prices drop, the price gap between biodiesel and petrol diesel widens. As a result, the government should increase palm oil export levies to subsidise the biodiesel programme.

For Malaysia, it is critical to attracting local workers to support the strong and sustainable growth of its biodiesel sector. In addition, modernising plantation infrastructure is another important step to make the biodiesel sector less reliant on physical labour and more cost-competitive. The implementation of Industry 4.0 for the Malaysian biodiesel industry is also worth investigating. It is the automation applied in industrial practices to replace the conventional approaches. Despite recent progress in biodiesel's research and development, the technology transformations towards Industrial Revolution 4.0 are complex and create numerous challenges as technology innovation requires huge investment for testing and optimisation. Therefore, it is important to remember that the COVID-19 has uncovered the dangers of debt-fuelled biodiesel industry growth. Instead of relying on debt to expand their businesses, palm oil companies should at the same time focus more on maintaining positive cash flows, utilising internal strength and resources and trusting their loyal employees.

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