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**PROCEEDINGS**

**Designing circular economy through bioconversion of solid decanter palm oil waste**

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**ABSTRACT**

Palm oil waste treatment is widely researched. However, effective, and efficient waste treatment related to sustainability and environmental issues is still being encouraged. In the past decades, the circular economy framework is progressively used to address environmental and economic growth issues synchronously. This paper investigates the potential of bioconversion of solid decanter palm oil waste in developing a circular economy. This study also proposes Black Soldier Fly Larvae (BSFL) farm to treat solid decanter palm oil waste.

Oil palm fruit was extracted from palm oil to produce vegetable oil and other derivatives. Palm oil has unique fatty acids and is difficult to replace with other products. On the other hand, palm oil is cheaper and more productive than other vegetable oil such as soybean or sunflower. In a hectare, palm oil can produce 4 tons of crude oil yearly, higher than soybean oil 0.38 tons, sunflower 0.48 tons, and rapeseed 0.67 tons [1]. Companies buy palm oil and its sustainability certification to offset or excuse their usage of uncertified, potentially unsustainable palm oil. Such certification's success depends on peer and market pressure and managerial motivation. The Roundtable on Sustainable Palm Oil (RSPO) and Indonesian Sustainable Palm Oil (ISPO) are the two primary certifications for managing palm oil in Indonesia [2]. The three critical parts of RSPO certification are process requirements, standards, and accreditation. The palm oil firm may certify its output by asking Certification Bodies to undertake a production audit. The advantages of getting RSPO certification include ensuring that palm oil production complies with sustainable environmental practices standards and, more crucially, that marketplaces exist where purchasers are committed to paying a premium price [3].

Moreover, it is crucial for small farmers because they are beneficiaries and at risk (both environmental and social impacts) [4]. One of the efforts to obtain ISPO and RSPO certification is managing palm oil waste into high-value products. The palm oil mill produced solid waste per tonne of fresh fruit brunches, such as 22.5% of OPEFBs [5]; [6]; 13.5% of palm fibres [7], 6.7% of palm shell [8]; 5.4% of palm kernels [8]; and 4% of the solid decanter [9]. The solid decanter is POMs solid waste after decanting the palm oil effluent [10]. It was produced after the oil mesh was pumped into the centrifugal decanter to separate solid and liquid. Based on Hassan and Abd-Aziz [11], solid decanter contains amino acids, protein, and fibre. Kachanasuta and Pisutpaisal [7] showed that solid decanter contains high biodegradable organic content, nutrient-rich composition, and lignocellulose including 21.61% of cellulose, 3.94% of hemicellulose, and 30.66% of lignin [12]. Previously, the solid decanter had been used as animal feed [7], absorbent [13], and fertilizer [10]. However, using solid decanter as the feed of BSFL can produce biomass as the feedstock of biodiesel production.

Black soldier fly larva (BSFL) or Hermetica illucens L (Diptera: Stratiomyidae) is an insect that decomposes large amounts of organic waste and produces biomass. Lim et al. [9] used a solid decanter to feed BSFL for biomass production and converted it to biodiesel. Using cellulose enzyme as a solid decanter pretreatment effectively breaks cellulose into glucose. The results showed that BSFL growth at solid decanter pretreated by 1.0 wt% of cellulose for 72 hours had a maximum growth at 6.56±2.69 mg/larvae. The highest protein yield and lipid yield from BSFL were attained at 1.63 ± 0.11 mg/larva (22.4 wt%) and 5.12 ± 1.01 mg/larva (69.9 wt%), respectively.

This paper reviewed one alternative is treating solid decanter waste with Black Soldier Fly Larvae/BSFL (Hermetia illucens). The solid decanter waste treatment process with BSFL produces high-value biomass in fat and protein. This review introduces the method of treating solid decanter with BSFL and how to improve the efficacy of its bioconversion. This review also discusses the role of high-value products from BSFL, such as biomass and biodiesel.

This study reviews the past research, news on the biodiesel development and the recent development of biodiesel program. Furthermore, in-depth interview with the national experts and the key stakeholders in the biodiesel development are conducted. Spesifically, this study reviewed the potential of biodiesel production based on the BSFL biomass, and this study also shows a simple technology to reduce the palm oil waste through providing energy resource alternative.

BSF biomass is a potential source of renewable energy raw materials due to its high lipid content. Biodiesel production using BSF is said to be more effective than crops such as palm oil or sugarcane, which are currently used as a source of biodiesel because BSF requires less land for production with a short life cycle. The fat content of BSF as the basis for biodiesel reaches 44.9%±1.5% higher than palm oil (0.1%), and saturated fat reaches 67% higher than palm oil 37% [15]. This shows that the quality of BSF biodiesel yields may be better and more than the biodiesel production from palm oil.

The production of biodiesel from fat needs efficient transesterification to obtain high-quality biodiesel. The optimum conditions for the transesterification suggested by Li et al. (2011) required two-step esterifications. First, an acid catalyst is used to reduce the amount of acid in BSF lipids, and then an alkaline catalyst is used to increase the conversion to biodiesel. Esterification conditions that need to be considered are extraction time, molar ratio and transesterification temperature. The results of Li et al. (2011) showed that esterification for 1 hour increased the conversion rate to 90% compared to 73% when carried out for 30 minutes, as well as increasing the temperature from 55°C to 85°C, the conversion rate was 73% to 92%, and the 8:1 molar ratio supported the optimum conversion of 90 %. The quality of BSF lipid conversion biodiesel is equivalent to that of biodiesel quality standards [17]. The lauric acid, palmitic acid, and myristic acid content of BSF biodiesel is comparable to that of conventional biodiesel [16,18]. In addition, the physicochemical properties such as density, and viscosity were similar [16,18] and also consistent with the European standard EN 14214 [19] and Indonesia standart SNI 7182:2015, as shown in Table 2. On the other hand, BSF biodiesel have oxidation stability and sensitivity to air exposure were comparable to conventional biodiesel [20]. Therefore, BSFL-biodiesel was potential source of renewable energy.

This study takes a palm oil plantation province in Indonesia as a case study. The province is located in the southern part of Sumatera, in Indonesia. This study proposes estimating potency of BSF biodiesel production in bulk using the data of Indonesia statistics. The BSF biodiesel production calculated with equation in [9] is identified as 71.21 kL/year in average, which equal to IDR 1.068.120.404/year as total average potential income

From the analysis, the BSFL that using solid decanter palm oil waste as a substrate will produce high-value biomass in protein (approx. 55%) and fat (approx. 12%). Furthermore, this biomass can be transformed into animal feed and the residues from this process will be used as the fertilizer that can be applied back to the palm oil plantations. Based on our results, this design will improve palm oil employee revenue and reduce the solid decanter palm oil waste simultaneously. We also discuss how this design can be implemented: (1) full support from the top management of the palm oil company; (2) technology introduction to the employee smoothly such as the BSFL rearing system, harvesting, and product downstream development; (3) government support; and (4) employee/society goodwill.

**KEYWORDS**

Circular economy, solid decanter palm oil waste, black soldier fly larvae, bioconversion

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**Conflicts of Interest:**

The authors declare that they have no conflicts of interest to report regarding the present study.

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