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REVIEW

Utilization of palm oil waste as bioenergy

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Abstract. Palm oil is one of the most widely produced plantation commodities in the world. World demand for palm oil is also increasing due to the increasing demand for products that use palm oil. This increase ultimately results in the development of the palm oil processing industry which causes the increasing volume of waste produced. Palm oil waste can be utilized and treated as bioenergy so as to add economic value to the waste. The purpose of this paper is to determine the benefits of palm oil waste as bioenergy. The results show that palm oil waste such as shells, empty fruit bunches of palm, fibers, leaves, midribs and Palm Oil Mill Effluent (POME) have several potential contents to be utilized as bioenergy such as biogas, biodiesel, biobriquette, electricity generator, and activated charcoal. Apart from that as bioenergy, palm oil waste can be used as an antioxidant, animal feed, fertilizer and concrete additives.

Keywords: Palm tree; Palm oil; solid waste; bioenergy

1. Introduction

Indonesia is one of the world's palm oil producing countries and has successfully served the domestic and world markets with palm oil products and its derivatives. Indonesia's oil palm plantations in 2013 was 10.47 million hectares and in 2015 it increased to 11.26 million, then decreased to 11.20 million hectares in 2016 (BPS, 2017). In 2013-2015, the area of oil palm in Indonesia increased, despite experiencing a decline in 2016. At present, despite the declining area, the demand and production of palm oil has skyrocketed (Figure 1) due to increased awareness of the benefits of palm oil, especially palm oil. Statistics Indonesia reported that until 2016 palm oil production increased by 17.77 million tons to 31.49 million tons or there was an increase of 77.18% (BPS, 2017). This shows that the palm oil industry will continue to grow.

Increased production of palm oil causes an increase in the volume of palm oil waste. Some of palm oil byproduct are oil palm empty fruit bunches (OPEFB), palm kernel shells, midribs, stems, fibers and Palm Oil Mill Effluent (POME) (Hambali & Rivai, 2017). POME comes from the processing of palm oil which is one of big wastes (Nasution, 2004). Palm oil waste should be managed to reduce its negative impact to the environment because oil palm production in 2020

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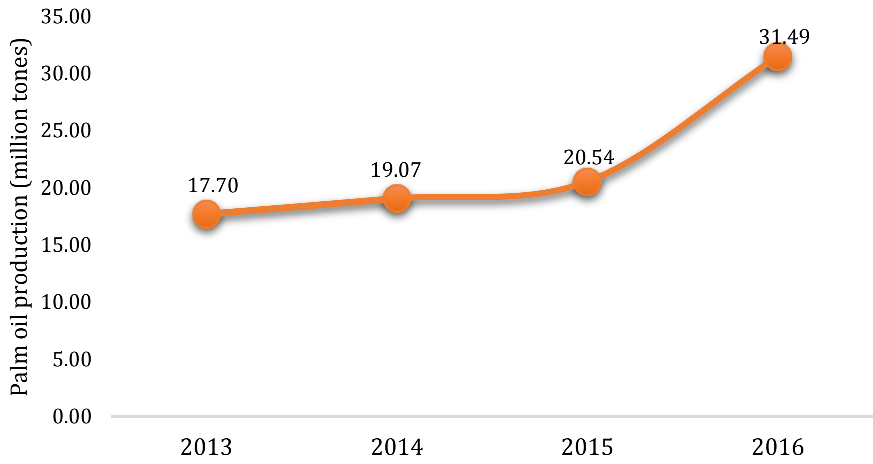

Figure 1. Development of palm oil production (million tons)(BPS, 2017)

to 2030 continues to increase. Hambali and Rivai (2017) reported, in 2020 there will be production of 37,816,105 tons of OPEFB, 21,560,251 tons of mesocarp fiber, 10,389,975 tons of palm kernel shells, 91,224,865 tons of palm oil mill waste, 128,914,621 tons of leaves, and 59,722,455 tons of trunk. While in 2030, the total production will be 53,904,512 tons of OPEFB, 30,732,801 tons of mesocarp fiber, 14,810,264 tons of oil palm shells, 130,035,387 tons of palm oil mill effluent, 128,914,621 tons of leaves, and 59,722,455 tons of stems. Increased production in 2020 and 2030 is caused by a moratorium on the expansion of land use for oil palm plantations. Therefore, the management and utilization of waste needs to be done to create a sustainable industry, where the utilization of palm oil waste is mentioned in the Indonesian Sustainable Palm Oil (ISPO)(Fuadah and Ernah, 2018).

Palm oil waste can be produced as bioenergy (Kurnia et al., 2016), fertilizer, animal feed and antioxidants which provides more economic value. This paper provides review of the literatures on utilization of palm oil waste. So, it byproducts reduces environmental burden and will be more sustainable.

2. Theoretical review

Palm oil is an agricultural commodity that has an important role in the growth of the agriculture and plantation sectors (Christian et al., 2018). Along with the many uses of palm oil, the demand for palm oil continues to increase. This is because palm oil is easy to convert to be biodiesel (Kuss et al., 2015). But the increase in palm oil is putting pressure on the environment and ecosystems, giving rise to pros and cons in the global community.

For those who support oil palm, oil palm development is considered to have a positive impact not only on the welfare of the community but also on the country itself. According to Erman (2017) the development of oil palm contributes significantly to state income, empower small farmers, and create employment opportunities in every process of management, such as on plantation land to palm oil processing factories. In developing oil palm, a strategy is needed to support a sustainable palm oil industry. One of the efforts promoted in the sustainability of oil palm is the Roundtable on Sustainable Palm Oil (RSPO) certification. If certification is successful in increasing sustainability, farmers can be prioritized for certification in the perspective of poverty alleviation (Hutabarat et al., 2019). Besides, the research of Napitupulu et al. (2017) shows that oil palm plantation companies tend to make transactions easier for farmer groups that already have RSPO certificates.

On the other hand, the negative issue of oil palm continues to grow. The issue that is often associated with oil palm is the environmental problem. The oil palm industry is known to have adverse impacts on the environment and ecosystems such as habitat loss, biodiversity loss (Freudmann et al., 2015), forest fragmentation (Reza, 2014), and increased greenhouse gas emissions (Inubushi et al., 2003). In addition, POME waste is a toxic compound that causes eutrophication and acidification, pollutes land and aquatic systems and releases greenhouse gases (Khatun et al., 2017). The palm oil industry has also come under pressure from the European Union, which is a resolution to schedule the elimination of the use of palm oil in 2020. The resolution states that oil palm plantations in Indonesia cause deforestation and forest fires. Indonesia as a world palm oil producer is affected by the resolution so that it can cause harm to Indonesia (Bonita, 2018).

3. Methodology

Literature studies are related to theoretical studies which are an important part of research because they are inseparable from scientific literature, books, notes and reports related to research (Nazir, 2013; Sugiyono, 2012). The study is a part of a literature review on the use of palm oil waste. Research methods and instruments regarding the use of palm oil waste are reviewed through articles, organizational websites, published surveys, national statistical documents, official reports, and papers. Papers included were identified from structured keyword searches in the following databases: Elsevier Science Direct, Springerlink, and Google Scholar. Sources are then selected according to the following criteria for scientific research, research articles, nationally recognized media publications and publications published in Indonesian and English. The results were then categorized into several categories of the utilization of palm oil waste as bioenergy.

4. Results

Bioenergy is a renewable energy that can be produced from biomass. Organic matter such as plants and waste materials are included in biomass (Rasool & Hemalatha, 2016). Based on Table 1 it can be seen that palm oil waste can be used as bioenergy such as biogas, biodiesel, activated charcoal, and electricity generator, and other uses.

4.1. Utilization of palm oil waste as biogas

Palm oil waste can be managed and converted into energy sources in the form of biogas (Kramanandita et al., 2014). One of the wastes that has potential as biogas is oil palm empty fruit bunches (OPEFB). The use of palm oil waste as biogas is one of the ways to encourage the sustainability of anaerobic digestion systems (Choong et al., 2018). The research by Nieves et al. (2011) shows that OPEFB contains carbohydrates that can be converted into methane by anaerobic digestion processes to become biogas. The same process was done by Chaikitkaew et al. (2015) in oil palm fibers and decanter cake producing 53-65% methane in biogas. Anaerobic

Table 1. Utilization of solid and liquid waste of oil palm

Type of Waste	Utilization	Method	Reference
OPEFB	Active Charcoal	Biochar production through pyrolysis is followed by physical activation	(Wafti et al., 2017)
		Precarbonation is followed by chemical activation using potassium hydroxide (KOH)	(Taer et al., 2016)
	Biogas	• Pretreatment using sodium hydroxide (NaOH) and phosphoric acid (H_3NO_4) • Pretreatment using NaOH	(Nieves et al., 2011);
		Anaerobic fermentation developed using a circulation system	(Purnomo et al. 2018)
	Bioethanol	• OPEFB irradiation uses electron beam • Chemical process (NaOH) • Simultaneous Saccharification Fermentation Process	(Darsono & Sumarti, 2014)
	Fertilizer	• Dry Volvariella volvacea is mixed with soil (dry) • Put into 50 x 60 cm polybags as planting medium for oil palm seeds	(Widiastuti & Panji, 2007)
		Giving Trichokompos of OPEFB with different dosages	(Sianturi et al., 2017);
		Bio-decomposers containing Trichoderma pseudokoningii, T. polysporum, and Phanerochaete chrysosporium	(Santi et al., 2018)
	Biobriquette	Writing / Pyrolysis of rice waste adhesives	(Putra et al., 2016);
		Carbonization process and the addition of crude palm oil (CPO) waste	(Purnama et al., 2012)
OPEFB Ash	Biodiesel	• Atomic Absorption Spectrophotometry (AAS) analysis and carbonate ion levels was tested by alkalinity test • Transesterification test	(Yoeswono et al., 2007)
Palm Shells	Active charcoal	• Carbonization process • Activation of activated charcoal physically and chemically • Characterization with Scanning Electron Microscope	(Rahmawaty, 2016)
	Electric steam power plant	• Preparing the data on palm production, operating data on Steam Power Plants, data on electricity usage • Calculating the potential power generated by palm shells and fibers. • Calculating the potential power to make an Electric Steam Power Plant • Calculating generator costs • Calculating the amount of water needed/Kw	(Erhaneli & Syawal, 2017)

Table 1. cont'd

Type of Waste	Utilization	Method	Reference
		• Thermal energy is transferred into water to produce steam that is collected in the drum from the boiler. • Steam from the boiler drum is directed to the steam turbine. • Conversion of steam energy into mechanical energy • Electric energy conversion	(Harris et al., 2013)
		• Fixed carbon testing • Material is weighed • Heat testing by working procedures according to the bomb calorimeter	(Syafriuddin & Hanesya, 2012)
	Concrete additives	• The shell is washed with detergent • The shell is soaked for 24 hours before it is dried • Oil Palm Shell and mined sand are mixed dry in a 2-minute drum mixer followed by the addition of a binder. • The specimen is printed • Compressive strength test carried out on 100 mm cube specimens according to BS EN 12390-3 (2002) • Water absorption tests are performed on specimen concrete discs with a thickness of 100 mm f 50 mm • Absorption test • Drying shrinkage test according to ASTM C157 • 100 mm cube specimens are soaked in a solution containing about 5% of magnesium sulfate • Rapid chloride penetration test method is carried out according to ASTM C1202	(Islam et al., 2016)
		• Collection of research information in the form of Electric Steam Power Plant equipment specification data, Diesel Power Plants and production costs • Calculation of data to determine the feasibility of Steam Power Plant made from fiber fuels and palm shells	(Napitupulu & Warman, 2015)
	Antioxidant	Antioxidant activity was tested using the DPPH method	(Tsouko et al., 2019)
	Water purifier	• Oil Palm is dried for 3 days • The oil palm activation process is carried out using H_3PO_4 (1 N) overnight at room temperature at 550°C for 2 hours, then wash and dry at 130°C. • Examination of pH, turbidity, chemical oxygen demand (COD), total disolved solids (TDS) and total suspended solids (TSS) of water and greywater samples is determined according to American Public Health Association (APHA) • Turbidity, COD, TSS and TDS analysis • Optimization of operating parameters of new composite adsorbents with the response surface methodology	(Razi et al., 2018)

Table 1. cont'd

Type of waste	Utilization	Method	Reference
Oil Palm Fiber	Electric steam power plant	• Prepare palm oil production data, electric steam power plant operation data, electricity usage data • Calculate the potential power generated by palm shells and fibers. • Calculate the potential power to make a electric steam power plant • Calculate generator costs • Calculate the amount of water needed/Kw	(Erhaneli & Syawal, 2017)
		• Thermal energy is transferred into the water in the boiler pipe to produce steam that is collected in the drum from the boiler. • Steam from the boiler drum is directed to the steam turbine. • Conversion of steam energy into mechanical energy • Conversion of mechanical energy into electrical energy	(Harris et al., 2013)
		• Prepare and collect research information in the form of electric steam power plant and diesel power plant equipment specification data and production costs • Data calculation is performed to determine the feasibility of electric steam power plant made from fiber fuel and palm shells	(Napitupulu & Warman, 2015)
	Antioxidant	Antioxidant activity is tested using the DPPH method	(Tsouko et al., 2019)
	Biogas	Oil palm fibers are evaluated for methane production by solid state anaerobic digestion	(Chaikitkaew et al., 2015)
	Active charcoal	UV-Vis Spectrophotometry analysis method with research variables in the form of variations in the pH of the solution, contact time, weight of the adsorbent and temperature carried out to obtain the optimum conditions of the adsorption process.	(Puspita et al., 2017)
	Bioethanol	• Analysis of glucose content using Luff-Schoorl Method (SNI 01-2891-1992) • Scanning Electron Microscope (SEM), to determine the structure and morphology of the sample t. • X-Ray Diffraction (XRD) to find out the crystal structure • Analysis of bioethanol content, using Gas Chromathography.	(Ni'mah et al., 2015)

Table 1. cont'd

Type of waste	Utilization	Method	Reference
Oli palm shell	Biobriquette	• The shells are then dried naturally for 5 days • Inner oil palm shells • In the dry state, the shells are crushed into powder • The powder is mixed with 2.5% and 5% amylum adhesive, then put in a container and pressed with compressive pressure of 3 tons, 5 tons and 7 tons. • Briquettes that have been pressed are naturally dried	(Purwanto, 2010)
Palm kernel	Goat feed	Treatment additional feed consists of good quality supplementary feed and supplementary feed based on palm kernel and palm sludge.	(Batubara et al., 2005)
	Antioxidant	Antioxidant activity is tested using the DPPH method	(Tsouko et al., 2019)
Palm oil leaves	Cattle feed	The midrib is processed into small pieces and then put into a chopper machine so that it is smooth. Then, the feed is given to cattle	(Nurhayu et al., 2013);
		Fermentation of Trichoderma sp.	(Rizali et al., 2018)
Palm oil midrib	Active charcoal	• Burn oil palm usicng furnace to create charcoal • Hilangkan water content by using electric oven • Measure the weight of charcoal • Measure the acid and base of charcoal using pH meter • Charcoal is sifted using sieve • Charcoal is saved in desiccator • Water content test using NaOH, NaCl dan HCl • Ash content test using NaOH, NaCl dan HCl • Organoleptic test using NaOH, NaCl dan HCl	(Resya et al., 2017)
	Cattle feed	The midrib is processed into small pieces and then put into a chopper machine so that it is smooth. Furthermore, feed is given to cattle	(Nurhayu et al., 2013) ;
		Fermentation of *Trichoderma sp*.	(Rizali et al., 2018)
	Biobriquette	• Raw materials are chopped according to the desired size • The chopped material is dried with a vacuum machine • The process of pressing briquettes is using with a press machine • Testing the biobriquette energy level	(Papilo, 2012);

Table 1. cont'd

Type of waste	Utilization	Method	Reference
		• Palm midribs are cut into small pieces with a size of 10 cm, then chopped and dried for 3 days. • Carbonization process is done in a crushing furnace for 2 hours • Charcoal is crushed and then sieved after it is mixed with liquid waste adhesives resulting from the processing of oil palm mills and stirred • The process of pressing uses a press machine with a compressive power of 15 kg/cm^2, 30 kg/cm^2, 45 kg/cm^2 • Drying and testing of briquettes	(Sitanggang & Romy, 2015)
Solid sludge	Fertilizer	• Ultisol soil sampling is taken randomly • Initial analysis was carried out by measuring the initial conditions of Ultisol soil sample • Sludge analysis is done by measuring nutrient content • Application of treatment into a polybag as much as 10 kg equivalent to oven dry soil and sludge according to the dose	(Pandapotan & Marbun, 2017)
Palm oil liquid waste	Biogas	• Anaerobic digestion used is manure for biogas production using POME at unregulated pH and temperature • Two identical bioreactors were used in this study; i.e. R1 and R2 which are given manure without and with POME as an inoculum, • Both bioreactors are permitted for five days to run in batch mode followed by semi-continuous operation on the HRT for 20 days	(Saidu et al., 2013)
	Briquette Adhesive	Charcoal production/ Pyrolysis is done then the charcoal is mixed with rice waste adhesives	(Putra et al., 2016)
	Biodiesel	• Data to meet the needs of the life cycle assessment (LCA) of biodiesel production with 1 (one) ton biodiesel unit. • Data on the quantity and quality of palm oil mill wastewater. • Analysis of water samples: temperature, COD and biochemical oxygen demand (BOD) • POME quality and quantity data obtained from the functional unit (FU) scale • Carbon emission factor data • Data on the accumulated amount of carbon emissions can be stored through the application of liquid waste management from biodiesel production	(Santoso et al., 2017)

Table 1. cont'd

Type of Waste	Utilization	Method	Reference
	Fertilizer	• Anaerobic biogas production and green house gasses emissions from POME are evaluated using a 5 m3 wet anaerobic digester • After the stabilization period, the digester is operated with a hydraulic retention time of 30 days (POME loading rate of 150 l / day). • COD analysis of reactor inlets and outlets was analyzed using the closed reflux method (Hach DRB 200) followed by spectrophotometry	(Hasanudin et al., 2015);
		• POME used is POME originating from PT. Bumi Sawindo Permai • Analysis of planting media which is in the form of soil originating from coal • Pome application in the nursery. Selected seedlings are 3 cm tall seedlings, in the same poly bag planted with Legume Cover Crop of Callopogonium mucunoides	(Maharani et al., 2017);
		Hybrid corn plants as treatments were fertilized using urea fertilizer of 0, 1, 2 and 3 grams per polybag during planting and oil palm liquid waste with four different BOD5 concentrations of 1000, 3000, 5000, and 7000 mg/l with a dose of 375 ml per unit experiment, which is done for 8 times so that it is equivalent to 3 liters of liquid waste taken from the palm oil Primary Anaerobic Pool given every week until the eighth week after planting in each trial unit	(Wahyudi et al., 2011);
		• Prepared 2 levels of treatment namely palm oil solid waste and palm oil liquid waste with difference in each treatment • Prepare planting media and seeds • The application of Palm Oil liquid waste is done one week after planting 1 time per week in the afternoon	(Hr & Nururrahmah, 2016)
	Improve water quality	• POME treatment system based on membrane technology • pilot plant for POME treatment based on membrane separation technology • Supernatants for raw POME are transferred to chemical processing tanks for coagulation, flocculation and sedimentation processes • Pre-treated POME is then pumped to the ceramic UF membrane • The permeate UF is inserted into the RO membrane module • Analysis for turbidity, COD and BOD	(Ahmad et al., 2003)

digestion process is also carried out on palm oil mill effluent wastes producing 41% methane in biogas (Saidu et al., 2013). While Purnomo et al. (2018) convert OPEFB to produce biogas with high productivity by using the fermentation process. Part of the oil palm fiber has the potential to be used as a substitute for fuel with a total carbon produced 36.89 - 61.67 wt% and 37.63 - 59.11 wt% (Abdullah et al., 2016).

4.2. Utilization of palm oil waste as biodesel

Palm oil is a potential plant to be used as biodiesel. According to Srivastava & Prasad (2000) biodiesel can be derived from vegetable oils, such as palm oil, which has the potential to be used as fuel. OPEFB waste that goes through the boiler combustion process in the factory will produce OPEFB ash. Based on research by Yoeswono et al. (2007), biodiesel can be derived from vegetable oils, such as palm oil, which has the potential to be used as fuel. OPEFB waste that goes through the boiler combustion process in the factory will produce OPEFB ash, based on research of (Santoso et al., 2017). While Smart et al., (2015) stated that with the transesterification process, used palm oil can be processed into biodiesel.

4.3. Utilization of palm oil waste as bioethanol

One alternative energy source is bioethanol. Bioethanol can be produced from palm oil waste such as fiber and OPEFB. Ni'mah et al., (2015) reported that palm oil waste through acid pretreatment, acid hydrolysis and Saccharomyces cerevisiae fermentation produced the highest levels of bioethanol at 2.858%. OPEFB waste has a high lignocellulosic content which can be degraded into a simpler form, namely glucose as raw material for bioethanol. According to Syafwina et al., (2002) Some of the content of OPEFB include 41.3% - 46.5% cellulose, 25.3% - 33.8% hemicellulose, and 27.6% - 32.5% lignin. Based on Darsono & Sumarti (2014), the use of OPEFB fibers with NaOH treatment and the electron beam irradiation method produces a maximum ethanol content of 6.55 g / L.

4.4. Utilization of palm oil waste as biobriquette

Biobriquette is a type of bioenergy that can be produced from waste. The management of waste into briobriquette can increase the productivity and economic value of the waste itself. According to Vachlepi & Suwardin (2013), Biobriquette has a greater heating value. The heating value generated from biobriquette is influenced by the adhesive used because it affects the results of biobriquette (Gandhi, 2010).

Several studies show that palm oil waste is one of the wastes that support the making of biobriquette. Papilo (2012) reported that oil palm midribs can be used as biobriquettes with the resulting heating value of 3,477.67 kCal with 66.3% ash content and 4.20% ash content. In oil palm midribs with 50% adhesive of palm oil liquid waste can produce a heating value of 27789.74 J/g with a moisture content of 6.23% and ash content of 22.92% (Sitanggang & Romy, 2015). Purnama et al. (2012) OPEFB which is used as a biobriquette with 30% adhesive of palm oil liquid waste produces a caloric value of 5629.08 cal/g with a moisture content of 7.16% and ash content of 12.53%. Whereas OPEFB with 60% rice waste adhesive produces a greater heating value of 5914.81 cal/g with a water content of 11.50% and ash content of 12.36% (Putra et al., 2016). The shell of oil palm only produces a heating value of 4,548.53 - 4,587.96 cal/g with a moisture content of 6.19 - 6.45% and ash content of 6.59 - 8.73% (Purwanto, 2010).

4.5. Putilization of palm oil waste as electricity generator fuel

Electricity generation is an indispensable need for the community. At present, palm oil waste has the potential to be used as fuel for electricity generation. Safrizal (2014) reported that biomass power plants from palm oil waste in Riau Province were able to meet the electricity needs until 2020. Erhaneli & Syawal (2017) utilizing oil palm shells and fibers as fuel for steam power plants has the potential power generated from palm shells of 21,397,565 MW/year and the potential power generated from oil palm fibers by 49,214.4 MW/year. This power can meet the electricity needs of the community of 3,135.91 MW/year in Bungo Regency. Bangka Belitung steam power plant utilizes oil palm shells and fibers (Harris et al., 2013). Similar research was also carried out by Syarifuddin & Hanesya (2014) which shows that oil palm fibers and shells are very effective as fuel for steam power plant, due to low cost, low environmental impact and abundant availability of oil palm. Utilization of palm oil waste for steam power plant using palm shell and palm fiber waste is also carried out by Napitupulu & Warman (2015) stated that steam power plant which is fueled by fiber produces a heating value of 2,770,544 kcal/Kg = 3,222 kWh, while that fueled by the shell produces a calorific value of 3,881.15 kcal/Kg = 4,513 kWh.

4.6. Utilization of Palm Oil Waste as active charcoal

Active charcoal is carbon which has an absorption ability to anions, cations, and molecules in the form of organic and inorganic compounds, both in the form of solution and gas (Lempang, 2014). Activated charcoal has several contents including 7.36% water content, 2.77% ash content, 8.21% volatile Matter, 19.80% absorption of Iodine (Kurniati, 2008). This active charcoal can be produced from the types of waste produced by palm oil and used for various activities.

One of the benefits of active charcoal from palm oil waste is water purification. Active charcoal has the potential to be used as a pollutant absorbent and to remove chromium in contaminated wastewater (Kurniawan & Babel, 2003). According to Nik et al. (2006) Active charcoal is very good for removing toxic elements in water because it has a good absorption capacity for cadmium, chromium and lead. Active charcoal can also be used as an asorbent hexavalent chromium (Cr (VI)) from wastewater (Gueye et al., 2014). The research result of Taer et al., (2016) also showed that active charcoal from OPEFB has an effective ability to absorb heavy metal iron (Fe) in water. In addition to OPEFB, palm kernel shells have the potential to be active carbon. Oil palm empty fruit bunches (OPEFB) processed into activated charcoal are used as absorbents in POME processing with an optimal activation temperature of 800°C (Wafti et al., 2017). Razi et al. (2018) reported that activated carbon derived from palm kernel shells is more than 50% efficient in removing COD on the surface of polluted water. The part of palm shell is also reported by Rahmawaty (2016) can be made into effective active charcoal as an alternative to blue methylene adsorbent in water. Ahmad et al. (2003) added that POME which is processed using a membrane technology system can improve water quality by showing a reduction in turbidity, COD and BOD up to 100%, 98.8% and 99.4% respectively.

The midribs of oil palm can also be used as active charcoal but there are still many shortcomings when compared to the shell. Resya et al. (2017) reported that active charcoal produced from oil palm midribs is also still classified as liquid phase activated carbon made from raw materials which have small densities and weak structures, which are easily destroyed.

Activated charcoal can be produced from oil palm fibers. Oil palm fibers are able to adsorb Reactive Red and Direct Green synthetic dyes in plastic waste (Puspita et al., 2017).

4.7. Other utilization of palm oil waste

Aside from being used as bioenergy, palm oil waste can be processed and used also as fertilizer, livestock feed, biochemistry and concrete additives because it has ingredients that can support the utilization (Table 1).

a. Utilization of palm oil waste as fertilizer

Palm oil waste has the potential to be used as fertilizer because it has ingredients that support plant growth. Oil palm empty fruit bunches (OPEFB) are lignocellulosic biomass that has great potential to be used as fertilizer. Ariana and Candra (2017) isolated 430 microbes in OPEFB waste, after selecting the 12 best isolates that had the highest index, then there were five isolates of fungi that had the best lignocellulolytic activity that could help the process of biodegradation of OPEFB.

Several studies have shown that OPEFB has the potential to be used as fertilizer. Panji and Widiastuti (2007) reported the use of OPEFB from mushroom growing medium remains can be used as a source of organic matter and nutrients. On the research of Sianturi et al., (2017) used trichocompost of OPEFB containing Trichoderma sp on Arabica coffee seedlings and showed an increase in the parameters of seedling height, number of leaves, and root volume, leaf volume and root canopy ratio. Santi et al., (2018) reported OPEFB can be used as BioSilAc through composting by Trichoderma pseudokoningii, T. polysporum, and Phanerochaete chrysosporium during 28 days of incubation. It showed improvement in the quality of organic matter, nutrient content, and availability of Si (Silica) for plants.

Factory production waste is also one that is used to make fertilizer. According to Loekito (2002) palm oil mill effluent contains high nutrients so it is good for plant growth. Research of Pandapotan & Marbun (2017) shows that Sludge can increase nutrient and corn plant growth. Besides that, POME waste has good nutrition to be used as fertilizer (Hasanudin et al., 2015). POME has nutrient sources such as K, Ca, N-total, P2O5-total, K2O, osto-phosphate, Nitrite and MgO needed by plants (Budianta, 2005; Maharani et al., 2017; Lam & Lee, 2011). Fertilizer made from POME is used for the production of corn and the production of animal feed biomass (Wahyudi et al., 2011). In onions, giving POME and sago pulp can provide good growth in plant height and number of tillers (Hr & Nururrahmah, 2016).

b. Utilization of palm oil waste as animal feed

Palm oil produces a lot of solid waste. Palm oil waste can be used as feed both for ruminants and poultry. Nurhayu et al., (2013) reported fermented palm leaves and midribs using Trichoderma sp. able to reduce coarse fiber waste. The fermentation process of Trichoderma sp. is also able to improve the quality of palm oil leaf and midrib waste as it improves the total nutrition and increases protein (Rizali et al., 2018). Oil palm sludge is the result of extortion from oil palm fruit. Oil palm sludge contains nutrients that have the potential to be used for feed such as protein, calcium, phosphorus, amino acids and fat (Sinurat, 2003). Batubara et al. (2005) reported that oil palm sludge and palm kernel can increase the live weight of young male goats by around 54-62 g/goat/day. Supriyati & Haryanto (2011) using palm kernel as additional feed for goats indicates an increase in the live weight in goats. This increased body weight due to nutrient content such as crude protein, crude fat, crude fiber, crude energy, calcium and phosphorus in palm kernel (Alimon, 2004).

c. Utilization of palm oil waste as phytochemicals

Palm oil waste contains phytochemicals such as carotenoids, phenolics, and sterols which can be used as antioxidants. The content certainly provides benefits because it can improve human health. According to Ofori-Boateng & Lee (2013), The phytochemical content in palm oil waste can be beneficial for the nutraceutical industry. Han and May (2012) reported that the extracted OPEFB contains phytonutrients which function as antioxidants because it shows radical antidote activity. The palm kernel, oil palm fibers, extracted palm kernel shells also exhibit antioxidant activity because they contain phenolic compounds (Tsouko et al., 2019).

d. Utilization as concrete resistance

Palm shells and ash from palm oil fuel that comes from the combustion process can be used as an additional material in concrete as a substitute for cement. This is proven by research conducted by Islam et al. (2016). The results of the study show that palm shells can be used as concrete additives even though the absorption capacity is low. However, the addition of ash can increase the absorption of concrete.

5. Conclusion

Based on studies on the use of palm oil waste, it can be seen that palm oil waste can be processed and utilized to be used as bioenergy such as biogas, biodiesel, bioethanol, biobriquette, electricity generation and active charcoal. Aside from being used as bioenergy, palm oil waste can also be used as fertilizer, animal feed, phytochemicals and concrete additives. Utilization of palm oil waste can be used as a strategy in the development of a sustainable palm oil industry and as one of the innovations to increase the productivity of products from palm oil and increase the competitiveness and value added of the palm oil industry waste.

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