Oil Palm Empty Fruit Bunches (OPEFB): Existing Utilization and Current Trends Bio Refinery in Indonesia

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Abstract. In a future carbon-constrained global economy, the use of fossil fuels will be restricted. Biomass resources will be increased demand for renewable products. Oil Palm Empty Fruit Bunches (OPEFB) can be used as lignocellulose feedstock. The production of biofuels from lignocellulose feedstock can be achieved through biochemical or thermo-chemical routes. OPEFB contain chemical blocks of cellulose, hemicellulose and lignocellulose. Due to these substances, OPEFB can be converted into bio-products and chemical. Special attention to biorefinery approach that is present at relatively high potential in bio-products such as polymers, nutraceuticals, chemical building blocks, biofuels, and bioenergy. Different utilization types were considered and reviewed, and the most common and efficient process were discussed. In general, there is no single product which could be considered a solution to the utilization of managing OPEFB – in this review a number of product are more economic, effective and environmentally friendly.

1 Introduction

Oil Palm Empty Fruit Bunches (OPEFB) are the solid residue from fresh fruit bunch (FFB) of oil palm tree that are mainly cultivated in several countries, including Indonesia, Malaysia, Thailand and other. The OPEFB contain chemical blocks of cellulose, hemicellulose and lignocellulose, while its present utilization as a biofuels, fertilizer, and compost production [1] [2], however its utilization can lead to emission resulting in organ damages and impact on the environmental systems.
Besides, OPEFB been reported to possess many distinct advantages, some of them are: pulp [3], feedstuff [4], carbon briquette [5], activated carbon [6], and fillers [7]. The OPEFB are also used as foods [8], oleo chemicals [9], and soap [10].

Indonesia is one of the largest palm oil producing countries in the world. Crude palm oil (CPO) is a mainstay industry for Indonesia's national income and foreign exchange, which can be seen from the export value of CPO commodities. In 2014, total CPO exports reached US $ 17.46 billion with volume reaching 22.89 million tons. The growth of oil palm plantation area in Indonesia has also continued to increase, by 2014 the area of oil palm plantation 10.75 million hectares with an estimated increase of 11.67 million hectares in 2016 with production 33.50 million tons CPO [11].

The development of biofuel industry in Indonesia represents the emerging phase, because of the impetus of government commitment to reduce greenhouse gas emission regulations which are decanted in President Decree No. 61 the year 2011. Indonesia has committed to reducing greenhouse gasses by 26% below 2005 levels, equivalent to 767 million tons of greenhouse gasses on their own. National Energy Policy set to blending bioethanol in premium 10% and 20% in 2020 and 2050 respectively [12]. Accumulation biomass from agroindustry in large quantity causes big problem. Biomass processing can help reducing agricultural waste also can added high value of this feedstock [13].

The characteristics of OPEFB is that it act as a renewable energy sources and environmentally friendly. OPEFB may be converted to useful compounds, some of them are: Micro fibrillated cellulose [14], bio vanillin [15], Sugar [16], Ethanol[4], p-hydroxybenzoate [17], Lignin-containing cellulosic Nano fibril [18].

Since OPEFB is a cellulose chain, it can be used as a particle board [1], furniture [10], and fibre boards [19].
Recently, many biorefinery approach have been reported [20], [10]. In order to understand OPEFB and its existing utilization and current trends biorefinery in Indonesia, this paper will provide the complete review of information on Utilization of OPEFB; its current trends biorefinery; production of bio-products such as polymers, nutraceuticals, chemical building blocks, biofuels, and bioenergy.

2 Oil Palm Empty Fruit Bunches (OPEFB)

The availability of OPEFB will continue to increase along with the increase in the production of fresh fruit bunches of palm oil in Indonesia. OPEFB has enormous potential to be developed into high value-added products. Chemically the OPEFB contains lignin> 20%, hemicellulose> 25% and lignocellulose> 35%. All three

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components can be converted into various chemicals, materials and valuable products.

The development of a highly prospective palm oil market in the global market has problems mainly from other vegetable oil producing countries. The black campaign on environmental, sustainability and health issues poses the greatest obstacle to the export of world oil and vegetable oil markets. In addition, the weak development of downstream industries in the country caused Indonesia's competitiveness and added value to be low in obtaining optimal benefits from the global palm oil market. Another major problem is the low productivity compared to its potential. The problem demands a huge research role in supporting strategic palm oil commodities into a formidable industry. Aspect of OPEFB utilization as one of palm oil industry waste is needed to increase productivity, added value, efficiency, and environmentally friendly.

As mentioned earlier, it is widely believed that lignocellulose is the major component that is responsible for the difficulty of OPEFB utilization. However, when decomposed in delignification using microbe, lignocellulose becomes toxic and causes mortality of microbe in the bioprocessing. Apart from lignocellulose, cellulose and hemicellulose is also available in OPEFB [21]. Figure 1 depicts the method pre-treatment and structure of OPEFB.

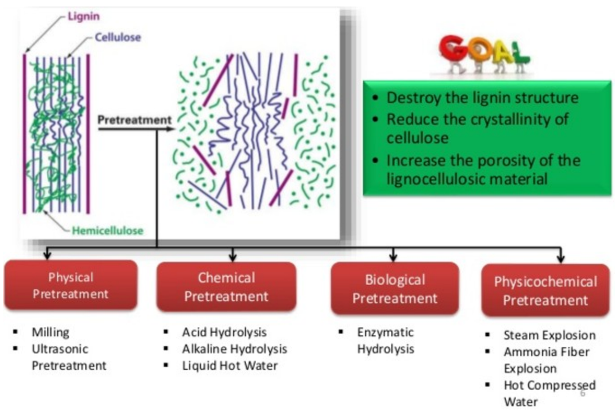

Fig. 1. Chemical blocks and structure of OPEFB [22].

2.1. Existing Utilization of OPEFB

OPEFB were extensively largely dumped and traditionally been burnt in incinerator of palm oil mill and ash recycled into the plantation as fertilizer. Utilization of soil improver and co-composting has been widely applied in Indonesia. However, due to the environmental pollution, the incineration of OPEFB has been avoided. In order to protect the environment and to ensure the sustainability of the oil palm industry, the OPEFB must be fully converted.

The building block of native OPEFB fibre is made up from a complex matrix of three main polymers which are cellulose, hemicellulose and lignocellulosic. The lignocellulosic material from OPEFB has been considered as a very good source of fermentable sugar for conversion into value added products. Cellulose and hemicellulose can be hydrolysed chemically by acid or enzymatically into glucose and a variety of pentose and hexose sugars, which can then be fermented to produce bioethanol.

Biorefinery approach that is present at relatively high potential in bio-products such as polymers, nutraceuticals, chemical building blocks, biofuels, and bioenergy are under development. The possible cause for the late biorefinery approach because the price of bio product is still not economical due to the high cost of production. Figure 2 represent conversion route of OPEFB via biological and thermo-chemical routes.

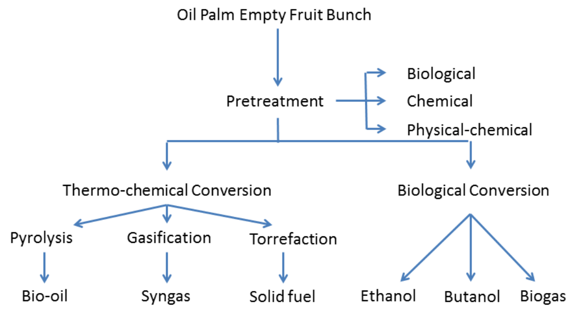

Fig.2. Biofuel production from OPEFB [23].

2.2 Biorefinery Approach

The development of the national palm oil industry in addition to positively impacting the economic sector also has considerable challenges with environmental issues, especially related to greenhouse gas emissions due to the impact of oil palm industry activity. An increased awareness of the importance of environmental protection, and the possible impacts associated with the product. In terms of production has increased interest in the development of methods to overcome these impacts. One of the techniques developed is an environmentally friendly biorefinery.

In the biorefinery, through different processes (physical, chemical and/or biological), OPEFB is transformed into a wide range of products with high added value. The whole process includes turning carbohydrates, lignin and other products into fuels, high value-added chemicals and other materials, with an approach to the prospect of not generating waste and with processes that ideally involve minimal energy and environmental impact.

2.3 Production of bio-products

The production of biofuels from lignocellulose feedstock can be achieved through biochemical or thermo-chemical routes. Majority of OPEFB bio-products were via the thermo-chemical route, in some minor cases via. OPEFB contain chemical blocks of cellulose, hemicellulose and lignocellulose. Due to these substances, OPEFB can be converted into bio-products and chemical. Special attention to biorefinery approach that is present at relatively high potential in bio-products such as polymers, nutraceuticals, chemical building blocks, biofuels, and bioenergy. The most significant biorefinery with highly prospective involves the bioenergy and polymers.

Approach production of bioethanol using methods that have been done on similar lignocellulosic biomass is very relevant to do, such as: from coconut fibre using alkaline pre-treatment and acid hydrolysis method [44], rice straw biomass by direct saccharification and fermentation [45], microwave-NaOH pre-treatment and hydrolysis enzyme using Trichoderma reesei - Aspergillus niger [46], chemical pre-treatment for cocoa pod [47].

OPEFB as waste from palm-oil processing are abundantly potential offering ligno-cellulosic fibre stuffs, which have not been utilized effectively hence suggesting their potential use in those paperboard industries. Center for Forest Products Research Development Center Bogor using semi-chemical hot soda process in the semi-pilot scale closed (pressurized) digester for manufacturing fancy paperboard from the mixture of OPEFB [24] [25]. The manufacture of composite boards from OPEFB to produce environmentally friendly furniture products [26], material for pulp and paper manufacture [27]. Research by creating composite from OPEFB to be particle board have fulfilled standard of SNI 03-2105-1996 [28]. Cellulose is a natural polymer having good mechanical properties and is widely used as a polymer matrix. Compared with synthesis polymers, the use of cellulose as a polymer gets a lot of attention because it does not contain health hazardous materials, is biodegradable and does not cause environmental emissions. One product that can be developed from empty palm bunch cellulose is cellulose ester as a bioplastic raw material.

OPEFB used to increase the quality of briquettes from cassava skin waste [29]. The pyrolysis method was used to convert the palm empty fruit bunch from biomass to bio-oil. Slow pyrolysis at a temperature of 450-600 ^oC which is fed by nitrogen gas. In the bio-oil product identified the presence of ethanol, benzene, toluene and xylene [30]. Pre-treatment on OPEFB with NAOH and used for fibre concrete [31] [32]. The spent alkaline (black liquor, BL) that obtained from the pilot plant scale pre-treatment of OPEFB is used as a solvent in next OPEFB pre-treatment [33].

OPEFB production potential as a source of bioethanol in Indonesia is huge, but it needs more complicated and longer process technology than the production of starch and sugar base bioethanol [34]. Pre-treatment at 220 ^oC in 30 minutes and saccharification using accretion of cellulase & BG optimash and fermentation with Saccharomyces cerevisiae IR-2 was 0.12 ml / g bioethanol [35]. Relatively low biofuels cause carbon burning that can damage the environment, but the production process can have a major impact on environmental destruction because it raises 10 times more carbon burning than fossil energy production [36].

Processing OPEFB into compost [37] [38]. Treatment OPEFB compost 50 g and coco peat 50 g produce in the growth palm oil seedlings better than the other treatments on medium subsoil ultisol in pre nursery [39]. The compost fertilizer product that has been obtained already fulfill the standard of fertilizer cultivation issued by SNI and fertilizer quality standard issued by PT. PUSRI. The C / N standard can be achieved at 3 months composting age for 25 grams of mushroom addition, whereas without the addition of mushroom fungus, the condition is only reached at 4 months composting age [40]. Composition of OPEFB compost + sub soil + sand 3:1:1 + 4 g urea/pot is the best composition as a substitution of top soil [41]. The quality of the compost produced in laboratory-scale inoculum testing in principle meets the standard, SNI 19-7030-2004 [42].

Utilizing the isolated lignin from OPEFB as a sodium lignosulfonate surfactant. Highest purity analysis results 78%. While the lowest purity value of 66% [42]. Conversion OPEFB into base catalyst has been reported [43].

2.4 Managing OPEFB

The concept of managing OPEFB is attracting increasing attention in all aspects, especially in industrial conversion. An example of managing OPEFB is the environmentally friendly utilization of OPEFB as natural resources, taking place through the recovery of by-products and/or waste generated by utilization or conversion activity. One of the main current challenges of the industrial utilization is the development of products that can fulfill new market requirements with an ecological commitment. Nowadays, Indonesia is awakening and it is convinced of the needs for consuming products that have been produced through environmentally friendly processes.

The biorefinery of OPEFB is becoming increasingly important. This process uses OPEFB of low cost with little commercial significance. Using OPEFB biomass as raw material is intended to take advantage of all the fractions derived from it, obtaining fuels (such as bioethanol or biodiesel) and various chemical products of commercial interest (products for food, pharmacy, polymers etc.), thus producing a maximum plant OPEFB valorization and a minimization of residues.

Many researchers are developing the OPEFB industry to adapt the alternative conversion process to the above-mentioned managing OPEFB concept. Not only the improvement of the conversion involved in the OPEFB industry through new approach process, but also their modification in order to integrate the OPEFB industry into a biorefinery, are being undertaken. Thus, the need for the use of each one of the OPEFB cell components is imperative and under this concept, it can be achieved. On the other hand, the reality is that in Indonesia, residues of OPEFB from palm oil mill have been largely dumped. Considerable efforts are dedicated to searching new biorefinery process and studying their feasibility to be used in OPEFB industry.

2.5 Trends Biorefinery

The presence of biorefinery approach suggests the Presence of a number of product are more economic, effective and environmentally friendly. The production of bio product from OPEFB feedstock can be achieved through biochemical or thermo-chemical routes. Delignification process are very necessary because of the presence of lignocellulose component (i.e., decomposed to lignin and cellulose after process) by the pre-treatment facility. There are no scaling up data to guide the successfully treatment of lignin neutralization or separation. The combination of thermo-chemical and biochemical routes may be required to treat OPEFB more economic and effective. Co-Pyrolysis should be used with caution due to the alternating output of gas and heat during OPEFB pyrolysis [48]. Residues of OPEFB from palm oil mill have been largely dumped. Utilization of soil improver and co-composting has been widely applied in Indonesia. Processing into biogas is under development. While biorefinery becomes a highly prospective product through pyrolysis, bioprocess, and combination.

OPEFB consists of cellulose, hemicellulose and lignocelluloses that have great potential for reuse after being converted to bioethanol and other industrial materials. But the price of bioethanol is still not economical due to the high cost of production. The production of bioethanol through an on-site chemical-enzymatic integration process carried out through a three-way integrated approach is potentially enormous. The first bioethanol unit that processes OPEFB into bioethanol, by hydrolysis with ammonia, alkanol amine, and other auxiliary materials. Followed by the saccharification process using cellulase enzyme obtained on-site from microbes such as *T. viride* and *N. crassa* using OPEFB substrate. The critical points on the production of cellulase enzymes on-site include moisture, substrate size, and nutrients. Both IPAL units that process liquid waste from bioethanol units become biogas. The three generator units that convert biogas into steam and electricity can be used in bioethanol units, IPAL units and palm oil operations. The OPEFB Biorefinery becomes an integrated and commercially potential bioethanol where the biogas / electricity energy generated can be used for other production operations.

The palm oil industry, which converts OEFB into bio-ethanol as a fuel and produces biogas, will save costs in its energy supply and overcome environmental problems. The use of bioethanol and biogas is also very influential on the reduction of greenhouse gas and global warming effects, so it is environmentally friendly[49]. Gaining Added Value and Palm oil revenues will increase with the acquisition of bioethanol and biogas as well as additional revenue derived from CER (Certified Emission Reduction). The utilization of treated clean water and fertilizer from the IPAL unit will lower the operational costs for the palm oil industry.

3 Conclusions

In general, Oil Palm Empty Fruit Bunches (OPEFB) can be converted into bio-products and chemical. To present, no single product which could be considered a solution to the utilization of managing OPEFB. Thus, a number of product are more economic, effective and environmentally friendly.

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