CHAPTER

2

SUSTAINABLE BIOFUEL PRODUCTION FROM LIGNOCELLULOSIC BIOMASS

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2.1 LIGNOCELLULOSIC BIOMASS AS A BIOFUEL SOURCE

Biofuel technology has developed through multiple generations and is categorised according to the source of biomass. It is classified into three categories: Edible biomass (first-generation), non-edible biomass (second-generation), algal biomass (third generation), and genetically engineered microbes (fourth generation). First-generation biofuels, including bioethanol and biodiesel, are typically produced from food crops containing sugar and starch, such as wheat, corn, and sugarcane (Lee & Lavoie, 2013). However, first-generation biofuels sparked debate between food and fuel, particularly the ethical concerns of diverting resources from food production to meet energy demands, especially given world hunger and poverty.

To address these issues, second-generation biofuels are produced from inedible lignocellulose residual plants, which contain up to 70% polymerized sugars and are the most prevalent type of biomass on Earth (Liu et al., 2021). Agricultural and forestry residues are lignocellulosic

biomass (LCB), an economically viable feedstock for producing biofuels (Binod et al., 2019). According to Mujtaba et al. (2023), forests generate around 1.3 billion tons of LCB annually, with 606 gigatons of living biomass and 59 gigatons of dead wood worldwide. Hence, utilising these residues as feedstock contributes to waste reduction and sustainable waste management practices. Moreover, LCB is a versatile energy source due to its abundance, can be obtained easily, and is a better substrate for biofuel production.

2.2 OIL PALM BIOMASS

Oil palm (*Elaeis guineensis*), is a plant that primarily produces and consumes oil globally. Pollination to maturity takes 5–6 months for the oil palm fruit, which develops in enormous bunches of 10–20 kg and is about the size of a plum. With the advancement of oil palm farms and palm oil mills year-round, Malaysia is among the world's leading producers and exporters of palm oil. Jafri et al. (2021) reported that oil palm in Malaysia contributes 34.56% of total crops, while rubber, cocoa, rice, and coconut account for 39.67%, 6.75%, 12.68%, and 6.34%, respectively.

Oil palm biomass encompasses the residual materials the oil palm sector generates during activities like replanting, pruning, and processing, as presented in Figure 2.1. The oil palm fronds (OPF) and oil palm trunks (OPT) are formed during replanting and pruning operations, while oil palm shell (OPS), palm kernel shell (PKS), palm oil mill effluent (POME), and empty fruit bunch (EFB) are commonly generated during the milling stage (Derman et al., 2018; Jafri et al., 2021). EFB constitutes about 20–23% of the fresh palm fruit bunches processed in the mill, as 1.07 tons of EFB is produced in every ton of palm oil.

The abundance of palm biomass waste has further motivated its conversion into profit, making it a valuable resource for bioenergy generation. Multiple studies have been conducted to convert this abundantly accessible and environmentally friendly biomass into value-added products like bio-composites, pulp, paper, and biofuels. This is to

mitigate the problems created by incorrect disposal. Moreover, the chemical industry's reliance on petrochemicals, particularly organic compounds from petroleum feedstock, has increased fossil fuel demand (Onoja et al., 2019).

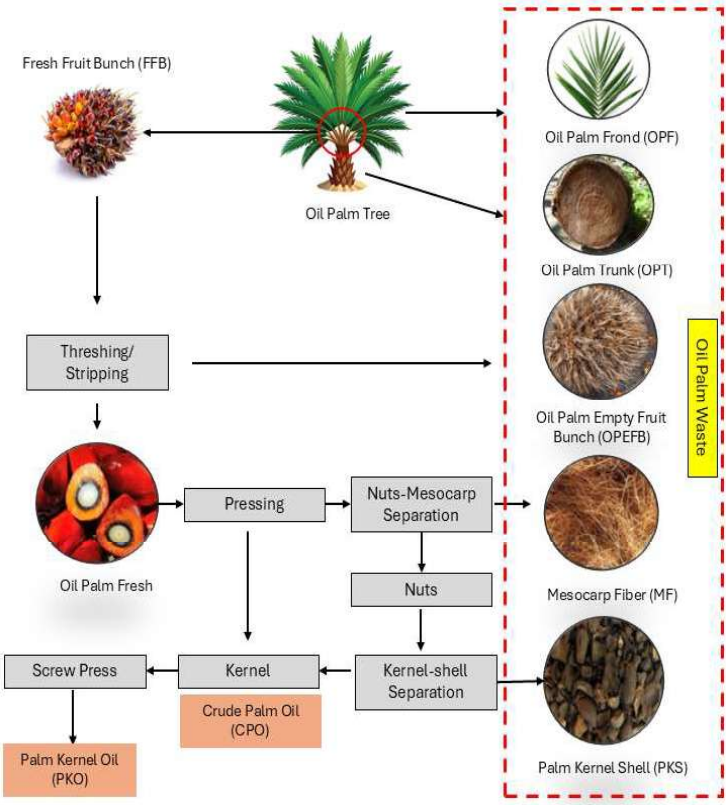

Figure 2.1 Oil palm waste produced from oil palm mill processing

2.3 OIL PALM EMPTY FRUIT BUNCH

Oil palm empty fruit bunches (OPEFB) are one of the waste materials of LCB produced during palm oil processing. Historically, OPEFB was burned at the mills to produce steam, and the resulting ash was utilised as a soil conditioner or fertiliser. Nonetheless, incinerating OPEFB was promptly discontinued due to the substantial quantity of white smoke