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Oil Palm Empty Fruit Bunches (OPEFB) – Alternative Fibre Source for Papermaking

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Abstract

Elaeis guineensis (oil palm) is one of the most economical perennial oil crops for its valuable oil-producing fruits in tropical regions such as West Africa and South-East Asia. During oil extraction process, these fruits are usually stripped from the fruit bunches leaving behind empty bunches to be discarded as residues. Thus, empty fruit bunches (EFB) of *Elaeis guineensis* are usually considered as waste in the oil palm industry. The abundance of oil palm empty fruit bunches (OPEFB) has created enormous environmental issue, ranging from fouling, attraction of pests, greenhouse gas emissions to soil acidification, thus posing very serious threats to humans and the environment. Globally, in 2014 alone, over 22.4 million tons of EFB were estimated to have been produced. Therefore, exploring eco-friendly disposal methods and productive utilisation of oil palm EFB as alternative fibrous material for papermaking becomes imperative in converting waste to wealth, and initiating environmental wellness. *Elaeis guineensis* empty fruit bunch (EFB) fibre on the average measures 0.99 μm in length, while the fibre diameter and cell wall thickness are 19.1 μm and 3.38 μm respectively. Fibres of EFB are of ligno-cellulosic materials, consisting on the average of an estimated cellulosic content of 30–50%, 15–35% of hemicelluloses and the lignin constituting about 20–30% of extractive-free fibre. The rich cellulose base of EFB fibre makes *Elaeis guineensis* a good potential resource for papermaking furnish moreso that the pulp and paper industry is often referred to as the cellulose industry. Every 5 tons of EFB gives 1 ton of pulp for papermaking. This book chapter will therefore attempt to examine the fibre morphological characteristics of oil palm empty fruit bunch, the chemical properties of EFB fibre, papermaking potentials of empty fruit bunches and ultimately their impact on the environment.

Keywords: Empty fruit bunch (EFB), Oil palm, *Elaeis guineensis*, Fibre morphology, Chemical characterisation, Papermaking potentials, Environmental impact

1. Introduction

Oil palm, *Elaeis guineensis*, is cultivated on a vast scale as a source of oil in West and Central Africa, where it originated, and in Malaysia, Indonesia and Thailand, where it predominates and thrives luxuriantly, and has become well-established over years [1]. The explosive expansion of oil palm plantation in these regions and countries has generated enormous amount of vegetable waste, creating problems in re-planting operations and tremendous environmental concern. Thus, oil palm biomass refers to agricultural by-products generated from oil palm

industries during re-planting, pruning and milling activities, which in most cases is left to decompose in the fields [2]. In essence, fibres of empty fruit bunches are either by-products of the process of extracting palm oil from the palm fruits, cultivation activities or remains of the trees at the end of their useful life [3]. The wastes are usually disposed indiscriminately or used by the locals as cooking fuel, both of which are not environmentally friendly. During oil extraction process, the fruit bunches are left empty as residues after fruit extraction. The presence of these empty fruit bunches (EFB) at mill's gate is unavoidable, but the great headache these biomass residues cause mill management cannot be ignored in waste management and disposal strategies [4].

Millions of tons of oil palm empty fruit bunches on the average are generated annually in different countries across the globe. In Malaysia, for instance, over 5.2 million tons of EFB were generated in 2002 [5]. Thus, oil palm industry is the largest contributor of biomass in Malaysia. These biomass residues are continually generated in large quantities annually with only a small fraction being converted into value-added products while a large percentage are left underutilised [2]. Globally, in 2014, 22.4 million tons of EFB were estimated to have been produced [6], as waste from crude oil palm (COP) processing, the amount of which is abundantly high [7].

The abundance of oil palm empty fruit bunches (OPEFB) has created enormous environmental issue such as fouling and attraction of pests, thereby posing very serious threats to humans and environment. In the context of the afore-mentioned challenges, examining oil palm EFB as an alternative fibrous material to other known pulpable resources such as wood, bamboos, bagasse, straws and grasses, strikes an important concordant note in converting waste to wealth and enhancing environmental wellness.

In countries like Malaysia and Indonesia, oil palm is one of the non-woody plants that have shown great potential as papermaking raw materials. Therefore, this book chapter will attempt to examine the fibre morphological characteristics of OPEFB, the chemical nature of oil palm fibre, the papermaking potentials of empty fruit bunches (EFB) and ultimately their impact on the environment.

2. Fibre morphology and chemical characterisation of OPEFB

Empty fruit bunches are products from the oil palm processing industry. They have great potency as basic raw materials for fermentation because of their cellulose and hemicelluloses contents. The fibres of *Elaeis guineensis* empty fruit bunch (EFB) are of ligno-cellulosic materials, consisting on the average of an estimated cellulosic content of 30–50%, while the hemicelluloses and lignin constitute 15–35% and 20–30% respectively [8]. The OPEFB fibres, which are normally used as mulch for the palm oil mill, have been found to be a rich source of lignocellulosic material, especially cellulose, which can be 33.70–35.11% in composition for a press-shredded fibre [9]. According to reference [10], oil palm fibre exhibits the following percentage chemical composition as presented in **Table 1**.

A comparative broad varied value of the percentage chemical distribution of OPEFB fibres as reported by reference [11] is presented in **Table 2**.

As indicated in **Table 2**, cellulose is the main component in oil palm fibre, with the lignin content also relatively high. Hemicelluloses are of moderate quantity, and contain xylan as the main component. Extractives are of relative proportion, and can be found in traces and in considerable amount. According to reference [12], OPEFB has 50.9% cellulose, 29.6% hemicelluloses, 17.84% lignin, 3.4% ash and 3.21% extractives. Oil palm (OP) fibre contains comparatively high ash content, ranging from 1.6–6.69% [13]. This characteristic might contribute to an abnormal

Parameter	Mean value (%)
Holocellulose	59.6
Lignin	28.5
Ash	5.6
Protein	3.6
Lipid	1.0
Others	0.8

Source: Kobi and Isluzaki (2014).

Table 1.
Chemical composition of oil palm fibre.

Cellulose	Hemicelluloses	Lignin	References
42.85	11.70	24.01	Rahman <i>et al.</i> , 2008
37.28	14.62	31.68	Sudiayani <i>et al.</i> , 2013
33.25	23.24	25.83	Mullati <i>et al.</i> , 2011
43–43.47	22.93–23.67	21–22.10	Mardawati <i>et al.</i> , 2014

Source: Kresnowati *et al.*, 2015.

Table 2.
Chemical composition of OPEFB fibre (dry basis).

Parameter	Mean value
Length-weighted fibre length (µm)	0.99
Fibre diameter (µm)	19.1
Cell wall thickness (µm)	3.38
Fibre coarseness (mg/m)	0.107
Fines (< 0.2 mm, %)	27.6
Rigidity index (T/D) ³ x 10 ⁻⁴	55.43
Lignin (%)	17.6
Holocellulose (%)	86.3
1% NaOH solubility (%)	29.9
Hot water solubility (%)	9.3
Alcohol-benzene solubility (%)	2.83

Source: Law and Jiang, 2001.

Table 3.
Physical and chemical characterisation of OPEFB fibre.

mechanical wear of processing equipment. Thus, the potential build-up of silica in the black liquor recovery system might also be a source of concern in pulping oil palm material [14].

OP fibre is an important lignocellulosic raw material for the preparation of cost-effective and eco-friendly composite materials. One morphological peculiarity of oil palm fibres is that they have a much thicker cell wall when compared with those of wood, yielding substantially a high rigidity index. An electronic microscopic view of fibre cell wall layer reveals that oil palm fibres have structure similar

to those of wood cell wall, with lignin distributed highest in the middle lamella in comparison to that of other cells [15]. Fibrous strands of oil palm EFB have unique structure characterised by several large vessel elements in the core region surrounded by vascular fibres [1].

According to reference [16], the average indices of the physical and chemical characterisation of OPEFB fibre can be presented as shown in **Table 3**.

3. Papermaking potential of OPEFB fibre

The utilisation of empty fruit bunches (EFB) of *E. guineensis* is more than an act of environmental friendliness. It is a means to create job and wealth. In order to transform the massive biomass waste generated during oil palm processing into a resource with industrial utility, a viable and sustainable area of utilisation is desirable. The pulp and paper industry becomes the inevitable destination, presenting itself as a veritable option for productive utilisation.

Moreover, substituting the lignocellulosic material of the fast diminishing wood resource with biomass of non-wood plant of various diversity, takes the burden off the forest, while at the same time, supporting natural biodiversity. Thus, using EFB of oil palm for papermaking ameliorates waste management challenges associated with its disposal. In the words of reference [17], every 5 tons of EFB gives 1 ton of pulp for papermaking. Therefore, the oil palm industry is now at the stage of seeking more value-added products, not only from oil and kernel, but also from its biomass. EFB of oil palm is now regarded as a potential feedstock to produce a variety of renewable and valuable biofuel and bio-based chemicals that can be derived from sugar, cellulose and lignocellulose, using furfural [18]. Hence, there is increasing ample opportunity to convert the available lignocellulosic biomass residues into pulp and paper, paperboard, medium density fibreboard (MDF) and other composites [19].

The global production of pulp and paper is expected to increase by 77% from 1995 to 2020 due to the increasing world population, in addition to improved literacy and quality of life worldwide [4]. Consequently, the high growth of paper consumption makes it more demanding to diversify the sources of papermaking fibres which are very much dependent on the forest for their supply. The continued high growth in paper consumption will surely lead to increased demand for papermaking fibres, creating additional pressure on the world dwindling forest resources. Therefore, exploring alternative fibre sources becomes imperative. Oil palm is one of the non-wood plants that show great potential as papermaking raw material.

Oil palm empty fruit bunches can be pulped by semi-chemical mechanical process. Clean pulp obtained by this process is suitable for making unbleached brown paper and moulded products. EFB of oil palm is also very adaptable to chemical pulping such as soda and kraft processes [20]. Soda EFB is claimed to be very suitable for manufacturing printing and writing papers, corrugated cartons, and other paper-based products [21].

Pulp produced from EFB responds favourably to mechanical treatment as reported by reference [22] in their work on the effect of beating time on fibre morphology and drainage time on soda pulp derived from oil palm empty fruit bunches. The beaten fibres were modified to become more shortened, swollen, flexible and collapsible into a smoother sheet with better formation and improved paper quality. The thick cell wall of oil palm fibres is likely to contribute to the production of sheet of high bulk and lower inter-fibre bonding potential in comparison with wood counterparts [23].

However, the paper quality obtained from EFB pulp is comparable to that of hardwood kraft pulp. And with total chlorine bleaching (TCF), pulps can be modified to make them much more conformable and suitable for papermaking.

According to reference [24], paper made from empty bunch pulps has good web characteristics and good printing properties. Consequently, empty fruit bunch of oil palm can serve as a sustainable alternative source of pulp and papermaking fibre.

4. Environmental impact of OPEFB

Oil palm biomass can generally be classified into oil palm fronds (OPF) and oil palm trunks (OPT), oil palm empty fruit bunches (OPEFB), palm kernel shells (PKS), mesocarp fibre (MF), and palm oil mill effluent (POME). In total, 44.85 MT of oil palm biomass is generated annually during the fresh fruit bunch processing, oil palm tree planting and pruning activities [12]. Enormous waste is often generated in the oil palm processing industry in form of empty fruit bunches after fruits extraction for palm oil and palm kernel production. These biomass residues are usually discarded indiscriminately to the detriment of environmental beauty. Where they are gathered away from the immediate vicinity of processing activities, this massive waste is often dumped around the periphery of factory or mill site to form heaps of unhygienic decaying biomass [25].

Proper management of this waste and its disposal is an ardent task and consequently create environmental hazards. These heaps of discarded empty fruit bunches become attractive sources for insects and pests, and a breeding ground for various infectious diseases [26]. The emission of foul-smelling odour at millsite is a constant reminder of the lurking health hazards with the potential for epidemic explosion within the environs of the oil palm processing factory.

Disposal of this massive solid waste causes pollution to the environment. Hence, success in converting this waste material into benefitting products would reduce cost of waste disposed and contribute towards cleaner environment [27]. As reported by reference [28], the use of biomass from the residues of African oil palm would reduce emissions from CO₂ from 17.4 Tg p/year to 12.6 Tg p/year and from 3.0 PJ oil p/year to 23.0 PJ of oil p/year, corresponding to 72% and 67% of reduction respectively [28]. Nonetheless, some productive utilisation of these waste materials is not without its attendant effects on the environment. For instance, utilisation of EFB by fast pyrolysis has the potential environmental impact of SO₂ as the causes of acidification and C₂H₄ as the causes of photochemical oxidation process. Greenhouse emissions of CO₂ and CH₄ resulting from the burning of EFB, especially at landsite, are the major causes of Ozone layer depletion and the attendant accentuation of global warming [29].

Life cycle assessment (LCA) of the utilisation of EFB through recycling technologies for fuel, fibre and fertiliser products reveals that methane recovery and compositing are more environmentally friendly than other technologies as measured by reduction of greenhouse gas emissions. On the other hand, pulp and paper, and medium density fibreboard (MDF) production are favourable technologies for land use impacts. However, both recycling technologies for EFB utilisation require intense primary energy, high chemical uses and considerable emission from their waste treatment systems [30].

5. Conclusion

Empty fruit bunches of *Elaeis guineensis* are generated in enormous quantity as waste materials globally in oil palm processing industry. Fibres of *Elaeis guineensis* empty fruit bunch (EFB) are lignocellulosic materials, majorly consisting of an estimated cellulosic content of 30–50%, 15–35% of hemicelluloses and about

20–30% of lignin, based on extractive-free fibre. The rich cellulose base of EFB fibre makes *Elaeis guineensis* a good potential resource for papermaking furnish. In addition, the pulp and paper industry is often referred to as the cellulose industry. Notwithstanding these positive attributes, the abundance of empty fruit bunches as oil palm biomass residues poses serious challenges to humans and is of great consequence to the environment. Consequently, productive uses are needed for oil palm EFB, and research has shown that they can be utilised as an alternative, suitable and sustainable source of papermaking fibre.

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Conflict of interest

I declare that there is no conflict of interest in the concept, execution and outcome of the research work done towards the making of this book chapter.

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