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The potential of the Malaysian oil palm biomass as a renewable energy source

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ABSTRACT

The scarcity of conventional energy such as fossil fuels (which will lead to eventual depletion) and the ever-increasing demand for new energy sources have resulted in the world moving into an era of renewable energy (RE) and energy efficiency. The Malaysian oil palm industry has been one of the largest contributor of lignocellulosic biomass, with more than 90% of the country's total biomass deriving from 5.4 million ha of oil palms. Recent concerns on accelerating replanting activity, improving oil extraction rate, expanding mill capacity, etc. are expected to further increase the total oil palm biomass availability in Malaysia. This situation has presented a huge opportunity for the utilization of oil palm biomass in various applications including RE. This paper characterizes the various forms of oil palm biomass for their important fuel and other physicochemical properties, and assesses this resource data in totality – concerning energy potential, the related biomass conversion technologies and possible combustion-related problems. Overall, oil palm biomass possesses huge potential as one of the largest alternative energy sources for commercial exploitation.

1. Introduction

Oil palm, commercially named as *Elaeis quineensis* Jacq., is one of the main agricultural crops in Malaysia which thrives in a hot tropical climate. It produces a variety of biomass forms which in one way or another can be used in internal combustion engines, combined heat and power (CHP), cogeneration, tri-generation system, etc. as fuel [1,2] via different energy conversion processes i.e. thermal [3] or thermochemical [4,5] and biological [1] or their different combinations. The main harvested biomass is the fresh fruit bunches (FFB) which are the desired economic portions of the palm's total biomass, yielding the main export commodities. The main traded commodities are crude palm oil (CPO), crude palm kernel oil (CPKO) and palm kernel cake (PKC). An interesting fact is that the oil only contributes about 10% of the total dry matter of the palms; the remaining 90% being oil palm biomass [1] which can be potentially used in multiple applications.

The oil palm industry has been conveniently quoted the main sector generating abundant biomass as renewable sources; these include empty fruit bunches (EFB), mesocarp fibre (MF), palm shell (PS), oil palm fronds (OPF) and oil palm trunks (OPT). Of the 95.38 Mt (million tonnes) of FFB processed in 2014 and based on the standard biomass to FFB extraction rate (Table 1) [6–10], the estimated oil palm biomass (dwb) generated along its supply chain comprised 21.03 Mt of pruned OPF (50% removal from the plantation), 7.34 Mt of EFB, 4.46 Mt of PS and 7.72 Mt of MF, in all totaling 40.55 Mt (dwb).

In addition, the oil palm replanted area was estimated at 96,584 ha [11]. Thus, the estimated amounts of other biomass forms were 3.60 Mt of OPT (based on 74.48 t ha^{-1} of dry OPT [6], Table 1) and about 699 kt of OPF (based on 14.47 t ha^{-1} of dry OPF [6], Table 1) and that at least 50% of the plantation wastes to be retained in the fields for long term soil management and the other 50% would be removed, totaling 4.30 Mt of oil palm biomass last year from replanting activities alone. This implied that a total of 44.85 Mt (dwb) of oil palm biomass was available from replanting, pruning and milling activities, while the often untapped palm roots can be an additional biomass source. Nevertheless, although it is a good fertilizer source [12], the increasing growing incidence of *Ganoderma* affecting the palm roots has raised major concerns on its disposal. Although burning was the most effective to control the disease, it has been banned in Malaysia and currently total clearing of old stands is essential to completely remove the disease before it spreads to other palms. More eco-friendly means through

Abbreviations: RE, renewable energy; CHP, combined heat and power; FFB, fresh fruit bunches; CPO, crude palm oil; PKC, palm kernel cake; CPKO, crude palm kernel oil; EFB, empty fruit bunches; MF, mesocarp fibre; PS, palm shell; OPF, oil palm fronds; OPT, oil palm trunks; POME, palm oil mill effluent; NPK, nitrogen, phosphorus and potassium; CV, calorific value.

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Table 1
Oil palm biomass availability based on standard biomass to fresh fruit bunches (FFB) extraction rate [6–10].

Type of oil palm biomass	Availability
Empty fruit bunches (EFB)	EFB (wet basis) = 22% of FFB EFB (dry weight) = 35% of EFB (wet basis)
Palm shell (PS)	PS (wet basis) = 5.5% of FFB PS (dry weight) = 85% of PS (wet basis)
Mesocarp fibres (MF)	MF (wet basis) = 13.5% of FFB MF (dry weight) = 60% of MF (wet basis)
Palm oil mill effluent (POME)	POME (wet basis) = 67% of FFB or 0.65 m^3 t^{-1} FFB [15]
Oil palm trunks (OPT)	OPT (replanting, dry weight) = 74.48 t ha^{-1}, an average of 142 OPT is available from a ha of oil palm, and only 50% can be removed from the plantation
Oil palm fronds (OPF)	OPF (pruned, dry weight) = 10.40 t ha^{-1}, 75% of oil palm trees aged 7 years are due for pruning, and only 50% can be removed from the plantation OPF (replanting, dry weight) = 14.47 t ha^{-1}, and only 50% can be removed from the plantation

accelerating biodegradation of the biomass mulch on plantation floor is being researched [13,14].

In the palm oil milling process (Fig. 1), the main by-products generated are EFB, MF and PS. All palm oil mills in Malaysia (∼443 mills in 2014) use mainly MF and PS as boiler fuel in CHP system to produce steam which generates electricity for the milling process [15,16] and also for other uses within the mill complex [17]. EFB have also been utilized to a certain extent [15]. Other energy systems researched worldwide on a variety of biomass resources, if applicable, pose oil palm biomass great potential for electrical and thermal power generations. Among these are cogeneration or biomass-fuelled power plants configured with a different device e.g. combined cycle [18] or heat exchanger via externally-fired gas turbines [19], tri-generation system [20,21], a distributed energy generation system combining several bioenergy sources within the vicinity of the demanded community [22], electrochemical energy storage device – biomass-based supercapacitor [23], etc.; all attempted within the context of cost-effective and sustainable reuse of biomass along its supply chain [24,25]. These systems may in future solve the oil palm biomass disposal problem in palm oil mills as currently the combustion of fibre and shell in boilers has been made intentionally low in efficiency; more of a disposal means, rather than for the optimal utilization of the biomass to produce energy [15,26].

Another valuable biomass source, *viz.* palm oil mill effluent (POME), is generated annually during the milling process amounting to approximately 64 Mt or 62 Mm^3 in 2014. POME via conventional treatment method i.e. anaerobic digestion produces a large quantity of biogas that is emitted freely to the atmosphere. As biogas contains ∼65% methane [27] which is ∼25 times more potent than carbon dioxide [28], it is currently being captured and utilized

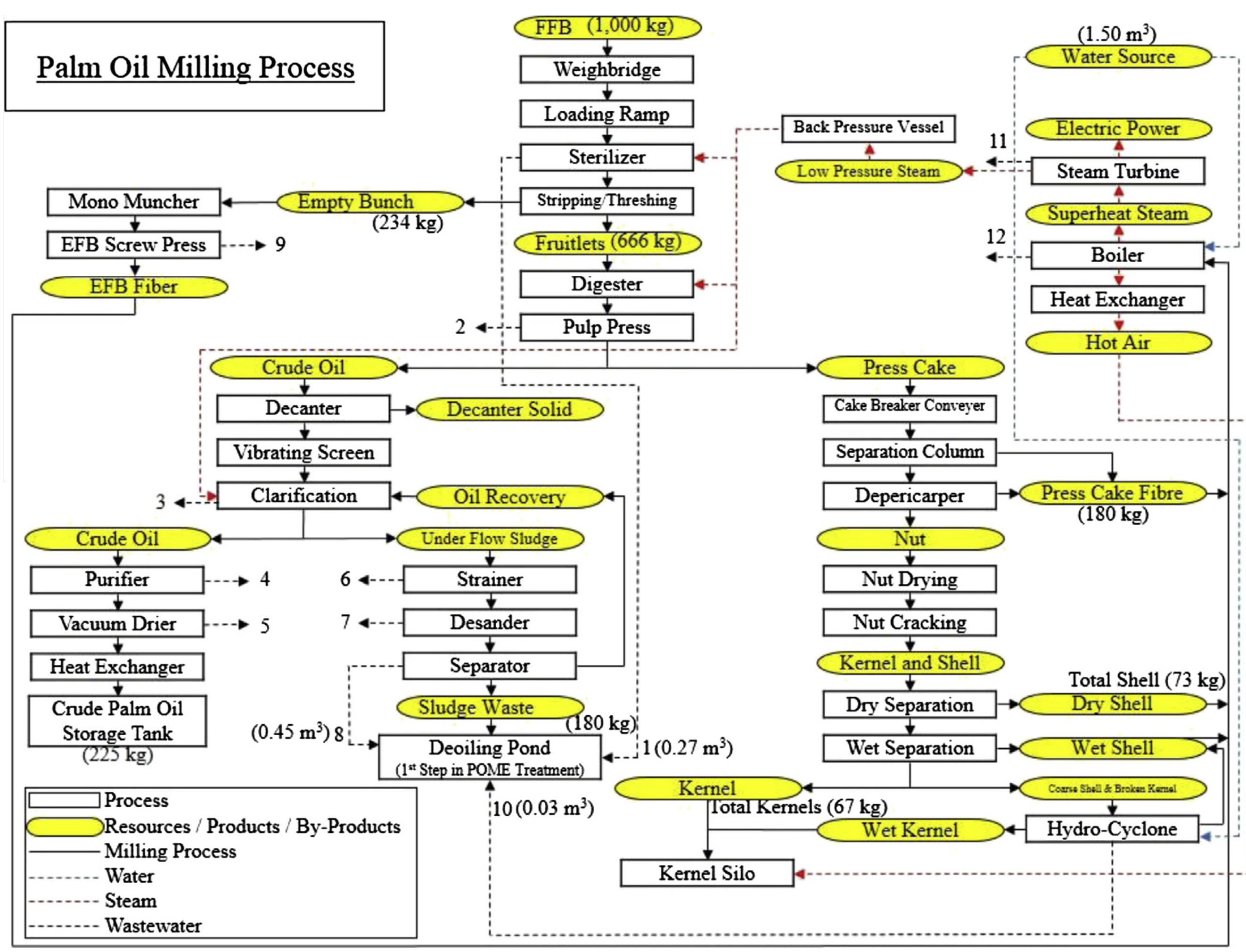

Fig. 1. A typical palm oil milling processes illustrating the efforts in maximizing recovery and utilization of palm oil milling by-products in the production system (the mass balance computed based on [7,10,15]). FFB = fresh fruit bunches. EFB = empty fruit bunches. POME = palm oil mill effluent.

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