VOL. 11, NO. 4, FEBRUARY 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

FEASIBILITY STUDY ON PALM OIL PROCESSING WASTES TOWARDS ACHIEVING ZERO DISCHARGE

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ABSTRACT

To sustain a greener image of the palm oil industry, the producing countries have been placing remarkable efforts to promote palm oil as an environmental friendly product. This paper aims to report a study regarding the wastes generated in local palm oil mills. Study was conducted to seven palm oil mills of different capacity, years of operation commencement, and management background. Attention is given to milling wastes as they represent a wider potential for beneficial reuse and probably leads to monetary returns, large quantity, and more environmental hazardous. Milling wastes included lignocellulosic palm biomasses namely the empty fruit bunches (EFB), oil palm shells (OPS), mesocarp fibres, palm oil mill effluent (POME), and palm oil mill sludge (POMS), as well as the solid wastes generated as a result from further processing of these biomasses into the palm oil fuel ashes (POFA) and palm oil clinkers (POC). An agro-industrial waste profile for palm oil mills was computed based on the thirteen years operation and production data. Management approaches of these palm oil mills on the by-products were also summarised. The information will be attention-grabbing for estimation and later prediction of the oil palm wastes accessibility, hence offer a statistic for future references.

Keywords: environmental management, pollution, solid wastes, wastes and resources, wastes utilization.

INTRODUCTION

As the backbone of Malaysia economy, greening the palm oil industry has become a key step to achieve the goal of developing the nation's economy with environmental considerations. Realizing zero-wastes in the palm oil industry is a driver for improved business performance at the same time gaining environmental benefits. The palm oil industry in Malaysia flourish since the 1970's. Traveling across the nation, oil palm plantations are seen in most rural and sub-urban areas. The nation has approximately 5.3 million oil palm planted area as at December 2014 (MPOB, 2015). We surpassed Nigeria as the world top producer of palm oil in 1974 and became the second largest producer after Indonesia in 2006. In 2014, Malaysia produced some 19.7 million tonnes of crude palm oil (CPO) worth approximately RM 44.3 billion of sales (MPOB, 2015; Sovacool and Drupady, 2011).

Seeing the fascinating monetary returns, another aspect that we should gain an insight is the receiving environment. An oil palm plantation can produce massive amount of total dry matter (TDM). The TDM production rate is about 55 tonnes per hectare annually. In palm oil processing mills, utilization of the TDM for palm oil and palm kernel oil constitutes 5.5 tonnes per hectare annually (10% of the TDM) whilst the remaining 90% large amount of TDM or biomass in the form of lignocellulose are available to be exploited (Chan, 1999; Jalani *et al.*, 1999).
This paper is prepared to document a preliminary survey conducted to the local palm oil mills. The objective is to study the availability of by-products as a result of the milling activites. Their fates of either being disposed-off, used, or sold were also summarized. When sufficient information on these by-products are presented, zero-discharge plans can be anticipated and implemented to achieve zero-wastes in the future.

RESEARCH METHODOLOGY

The study was conducted through information assembly from the visited local palm oil mills. Seven palm oil processing mills with different background has participated. Mills selection were in accordance to the processing capacity, age of mill, management background, and at utmost important for the palm oil millers to voluntarily participate in the study.

Visits to palm oil processing mills were attended by the operators, chemists, or engineers. Detailed explanations were given on the milling procedures, operation of factory, sources of water and wastewater alongside the production, in addition to solid or liquid wastes generation, handling, processing, and disposal systems. Questionnaires were prepared and distributed to the palm oil mill staff. The prepared questionnaire covered all managerial and technical information on palm oil mill's organization and handling of the by-products.

Part A of the survey consists of information on the company profile and economic performances of the palm oil mill. Thirteen years of fresh fruit bunches (FFB) processed data (year 2000 – 2012) were obtained from the millers' records and the remaining were completed through the MPOB's online database (MPOB, n.d.). The FFB data is vital for subsequent estimation of the oil palm by-products generation / availability. All literatures below reported the ratio of various by-products to the FFB processed: Borhan *et al.* (2010); Chan (1999); DOE (1999); MPOB (2009); Ng *et al.* (2011); PORIM (1985); Robani and Chan (2009).

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Part B of the survey subsequently highlighted the handling methods of the by-products. Fates of these materials were recorded, which included discarded as landfill material, reused, or sold. Since the monetary values of these by-products varies among the palm oil processing mills, a summary of this information can be a valuable reference to the palm oil industry in general.

RESULTS AND DISCUSSION

Wastes Profile of Palm Oil Mills and Wastes Generation (Availability)

In Malaysia, 439 palm oil processing mills are reported in operation in the year 2014 and there are 244 mills in Peninsular with the Pahang state having the highest number of mills (MPOB, 2015). Most study sites in this survey are located in the Johore state, which has the second highest amount of palm oil processing mills in the Peninsular (64 mills in operation in the year 2011). Although our respondents are merely about 3% from the total mills in the nation, the agro-wastes quantity analysis is anticipated to be adequate to deliver a rudimentary conception and deliver insights on the amount of by-products, or potential renewable resources accessible in the palm oil processing mills. This is due to the amount of by-products available is depending on the amount of FFB processed. By applying the estimation procedure as described earlier in the methodology section, the generation of by-products is predictable. Although there are a number of literatures describing the calculation methods, the ratio of by-products to the FFB are similar among these references. Moreover, since the mills only belongs to several clusters of management background, their handling practice on the by-products are virtually comparable. Table-1 below described the details of the seven (7) palm oil processing mills participated in this study.

Table-1. Basic information of the palm oil mills.

Company	State[a]	District	Region	Capacity (tonnes CPO per year)	Year[b]	Management Background[c]
POPM-1	S	Sepang	Central	41,800	1986	IND
POPM-2	J	Kota Tinggi	Southern	67,640	1996	IND
POPM-3	J	Kulaijaya	Southern	22,800	1968	GOV
POPM-4	J	Kluang	Southern	79,984	2006	PA
POPM-5	J	Kluang	Southern	51,300	2004	GOV
POPM-6	J	Kulaijaya	Southern	42,729	1977	GOV
POPM-7	J	Segamat	Southern	29,260	1986	GOV

a Location of the palm oil mills by state (S: Selangor; J: Johore).

b Year of operation commencement of the palm oil mills.

c Categories of management background (IND: individual millers; PA: public-listed corporation; GOV: government-backed organizations/companies).

In order to address the arousing interest on resources recovery from palm oil processing by-products, the availability is often in concern in order to ensure that the new application / reuse purpose is practical and conceivable. As abundant amount of biomass by-product and solid wastes are generated in this industry, intensive research and exploration on the beneficial reuse are encouraged in all palm oil producing counties. The following discussion entails the by-products available in the palm oil mills which provide an idea on their accessibility for potential applications.

The estimation of palm oil wastes or by-products is based on the amount of FFB processed by each mills. In other words, high FFB processing mills will generate higher amount of by-products which offer better advantage on the availability of these resources to seek for beneficial returns.

A number of studies on the mass flow and mass balance of palm oil processing have provided important information to estimate the availability of several by-products in the palm oil mills. Table-2 presented an estimation of fresh and dry weight of the processing wastes. Fresh weight is an estimation of “as-is” or the fresh sample directly from the FFB processed, with the moisture content and all the fluids included in the weight calculation. Dry weight is considered as a more precise and consistent estimation of organic matter as it represents only the sample weight without any water content. Hence, dry weight is used to eventually estimate the availability of these by-products from the fresh weight derived.

Table-2. An estimation of the availability of the palm oil processing wastes (Borhan *et al.*, 2010; Chan, 1999; DOE, 1999; MPOB, 2009; Ng *et al.*, 2011; PORIM, 1985; Robani and Chan, 2009).

Palm Oil Processing Wastes	Availability
Empty fruit bunches (EFB)	EFB is assumed to be 22% of the FFB; dry weight is 35% of the total weight
Oil palm shell (OPSh)	OPSh is estimated to be 5.5% of the FFB; dry weight is 85% of the total weight
Mesocarp fibres	Mesocarp fibre is estimated to be 13.5% of the FFB; dry weight is 60% of the total weight
Palm oil mill effluent (POME)	When 1 tonne of FFB is processed in the mill, 0.67 tonnes of POME is generated
Palm oil mill sludge (POMS)	POMS is assumed to be 18% of the FFB
Palm oil fuel ash (POFA)	Burning the mesocarp fibres and the OPSh produce 5% of POFA
Palm oil clinker (POC)	Burning the mesocarp fibres and the OPSh produce 15% of POC

The oil palm industry generates a massive amount of wastes such as the lignocellulosic palm biomass and the solid waste. Lignocellulosic palm biomass stated in this paper consists of empty fruit bunches (EFB), oil palm shell (OPSh), mesocarp fibres, palm oil mill effluent (POME) and palm oil mill sludge (POMS) while solid waste are palm oil fuel ash (POFA) and palm oil clinker (POC). The use of palm oil waste is abundant. Chan (1999) summarizes several applications of the EFB and POME which are common and prevalent reuse preferences in the 1990's. Take EFB for an example, it can be utilized for many advantages. It can be used as pulp for paper making, as bunch ash after incineration, as mulch and recycling of nutrient for palms, as an adjunct to improve efficiency in fertilizer uptake, as a fuel after dewatering to 40% moisture and become value-added products like medium density fibre board and wood composite product. POME too can be used as fertilizer, become cellulose and single cell protein from sterilizer condensate and to generate biogas.

In Figure-1, it shows biomass production for 7 companies. Each companies produce different amount of oil palm waste namely the empty fruit bunches (EFP), oil palm shell (OPSh), mesocarp fibres, palm oil mill effluent (POME) and palm oil mill sludge (POMS) while solid waste are palm oil fuel ash (POFA) and palm oil clinker (POC). Each companies has different amount of fresh fruit bunch (FFB) processed each year. The information above is based on the average amount of FFB in 13 years which is from the year 2000 to 2012. Thus the amount of each waste is calculated from the average amount of FFB processed by mills. Note that even the FFB processed data collected was from 13 years of mill operation, the amount of FFB processed monthly throughout all these years do not differ expressively. There are low crop seasons and high crop seasons in a year but generally the differences is found to be less than 10%. Besides, each palm oil processing mill is designed to handle certain loading of FFB to be processed into crude palm oils and other palm products. Unless major upgrading of facility is conducted or else the 13 years FFB processing data do not differ ominously.

EFB is a renewable organic material which is generated during the processing of FFB at palm oil processing mills. It is an important biomass resource which can be converted into energy (Rosnah *et al.*, 2012). EFB is assumed to be 22% of FFB where 35% of that 22% is the dry weight (Chan, 1999). From the bar chart (Figure 1), POPM-2 has the highest EFB which is 31,196.26 tonnes due to the high amount of FFB processed. POPM-4 too produces high amount of EFB. Both companies have bigger capacity to store the CPO. POPM-3 produces the lowest amount of EFB due to the small capacity to store the CPO.

In Figure-1, POME has the highest amount among all wastes. For every tonne of FFB processed in the mill, there are 0.67 tonnes of POME produced (Chan, 1999). That is why POME has the highest amount in every company investigated in this study. The more FFB is used, the higher amount of POME is generated. POME is a wastewater produced from palm oil milling activities which has high polluting properties. It needs proper and effective treatment before it is released into watercourses (Poh *et al.*, 2010). POPM-2 and POPM-3 have a quite high amount of POME while POPM-3 has the least amount of POME produced. POPM-1 and POPM-5 have a similar amount of POME with 158,029.9 and 157,561 tonnes respectively.

The second highest of wastes from oil palm activities of the companies stated above is POMS. Huge amount of sludge, POMS is generated in palm oil processing mills during wastewater treatment or biogas production every year (Tanawut *et al.,* 2011). POMS is assumed to be 18% of FFB (Chan, 1999). Like POME, POPM-2 has the highest amount of POMS; 72,926 tonnes while the lowest amount of POMS is held by POPM-3 with 21,233.49 tonnes.

POFA and POC are both solid wastes. Both of the amount generated are little compared to the rest of the by-products. POFA is a waste product produced from burning the palm oil husk or fibre and palm kernel as fuel

VOL. 11, NO. 4, FEBRUARY 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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in the boiler where it is obtained in the form of ash (Abdul and Hussin, 2011). As for POC, it is also a by-product produced from the same burning process like POFA. By buring mesocarp fibre and oil palm shell can produce 5% of POFA and 15% of POC (Chan, 1999). From chart (Figure-1), the amount of POFA generated is fewer compared to the POC. Yet, the amount of them combines together is less than each of the lignocellulosic palm biomass's weight.

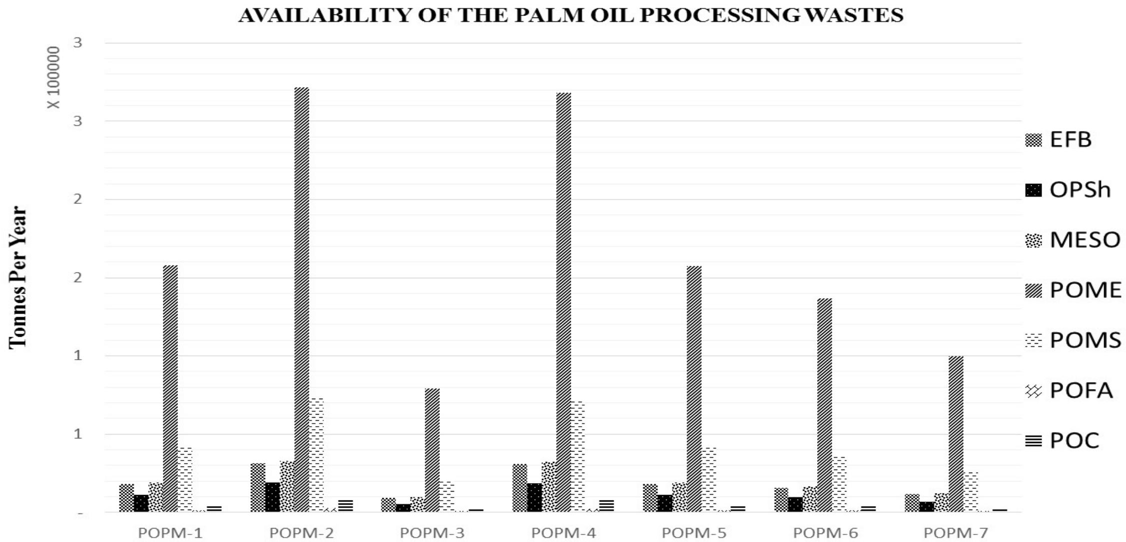

Figure-1. An estimation of the palm oil processing wastes generated per annum in the inspected palm oil mills.

Fates of the Palm Oil Wastes

Although there are 7 types of oil palm by-products discussed in this paper, we intentionally selected three types of wastes which come from both the lignocellulosic palm biomass and solid wastes categories to further highlight their fates in the surveyed local palm oil processing mills. The EFB is very commonly reported in most literatures on their field application and reuse options in the mills. However, the reason for its selection to further discuss in this study is due to the wide range application of this by-product as a renewable resources. Seldom mills reported that the EFB is discarded to the landfills. The extensive application provoke attentiveness in this study as the most plentifully utilized biomass by-product from the palm oil industry.

POC and POFA are solid wastes which receive least attention in current research. Both POC and POFA are produced from burning of lignocellulosic palm biomass to generate steam which is often related to the emission of intermittent dark smoke (carrying remainder of soot and partially carbonised fibrous particulates). Most applications publicised to these two by-products accentuates on civil engineering (construction and transportation) purposes only while the prospective for broader applications is yet to be revealed. In local palm oil processing mills, most millers dispose the by-products to nearby landfill (or more befittingly the dumpsite). The POFA is non-crystalline silicone dioxide – about 57% (in amorphous form) with high specific area and high pozzolanic activity (Karim *et al.*, 2011) while the POC has silicone dioxide content of approximately 82% (Robani and Chan, 2009). Despite thorough characterization on both the materials were reported, less literatures on research and development (R&D) to further investigate their usefulness is available.

Based on Table-3 above, three types of wastes (the empty fruit bunches, palm oil clinker and palm oil fuel ashes) are identified in this study from the seven palm oil mills. There are many ways to dispose or use the wastes to their advantages. For empty fruit bunch, POPM-3, 4 and 7 return the EFB to the plantation estates for mulching. POPM-1 shredded and sold the waste to other factories as a fuel for RM22/tonnes. POPM-2 processed the EFB to fertilizer and sold it at RM400/tonnes. POPM-5 too uses the EFB to compost plant or return it to plantation estate for mulching. POPM- 2, 3, 4, 5, and 6 dispose POC as landfill material. However, POPM-1 sold POC for road paving in plantation estates or rural area at RM2/tonnes. POPM-6 also sold its POC to other factories. POPM-2, 3, 4 and 7 dispose POFA like POC. Same goes to POPM-1 and 6 which also use the same method to dispose POFA. As for POPM-5, it sends some of its POFA to composting plant and the rest to be disposed as landfill material.

From the scenario above, most of the companies resolve the waste problem by disposing as landfill material especially the POC and POFA. Most of the EFB are used in mulching process in the plantation estate. Yet, the wastes are put to good use. For example, EFB can be processed as fuel and fertilizer and are sold to interested parties like factories. POC and POFA are too can be used in road paving and are sold for more profits.

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Table-3. Management approaches of certain palm oil processing wastes in the inspected palm oil mills.

Palm Oil Mill	Types of Wastes		
	EFB	POC	POFA
POPM-1	shredded and sold to other factories at RM22/tonnes as a fuel after dewatering	sold at RM2/tonnes, for road paving in plantation estates or rural areas	sold at RM2/tonnes, for road paving in plantation estates or rural areas
POPM-2	processed to fertilizer, sold at RM400/tonne	wastes for dispose as landfill material	wastes for dispose as landfill material
POPM-3	return to plantation estates for mulching	wastes for dispose as landfill material	wastes for dispose as landfill material
POPM-4	return to plantation estates for mulching	wastes for dispose as landfill material	wastes for dispose as landfill material
POPM-5	shredded and send to composting plant (40%) or return to plantation estates for mulching (60%)	wastes for dispose as landfill material	send to composting plant (5%) and the remaining as wastes for dispose as landfill material (95%)
POPM-6	some were burned in the incinerator and the remaining were return to plantation estates for mulching	sold to other factories at RM2/tonnes	sold to other factories at RM2/tonnes
POPM-7	return to plantation estates for mulching	wastes for dispose as landfill material	wastes for dispose as landfill material

CONCLUSIONS

The Malaysian palm oil industry as a pillar of the nation's economic advancement have to promote environmental preservation to gear towards better sustainability. The industry in fact have no other options other than promoting green development seeing the influence of the prevailing obstructions on environmental issues which to some degree impede the industry expansion by giving negative publicity. With an estimation of the major palm oil by-products availability, practical options to reuse and recover these by-products can be suggested and made possible. The POME has the highest abundances among the palm oil by-products, followed by the POMS. The solid wastes (POFA and POC) on the other hand were least available. At present, the EFB was seen having better monetory value than the other two solid wastes, but all three materials are potential resources for further explorations through more R&D efforts. In short, the study provided noteworthy information on the palm oil industry waste profile which address its intention as an environmentally sound industry and move towards green marketing for continuous expansion.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support from Ministry of Education and Universiti Teknologi Malaysia (UTM) under the Research University Grant (GUP) – Q.J130000.2509.10H18 and Q.J130000.2522.07H24. The authors also would like to thank Malaysian Palm Oil Board (MPOB) and all palm oil millers for facilitating the study.

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