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A Mini Review of Palm Based Fertiliser Production in Malaysia

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Malaysia is the second largest exporter of palm oil products (crude palm oil, etc.) after Indonesia. Along with oil palm processing, abundance of lignocellulosic palm biomass is produced annually. Currently, more than 85 % of the total biomass in Malaysia is derived from the oil palm industry. Inefficient management and disposal of such biomass might threaten the environment. On the contrary, wise utilisation of the biomass by applying 'waste-to-wealth' concept can strengthen the economy and sustainable development in agriculture sector. This paper reviews the progress, potential and technologies used to convert palm biomass into fertiliser in Malaysia. In overall, palm biomass exhibits great potential to be converted into fertiliser to substitute portion of the country's fertiliser import fraction for efficient utilisation.

1. Introduction

The increasing global demand for edible oil, biodiesel and oleochemicals derived from palm oil has encouraged the public and private sectors in Malaysia to get actively involved in oil palm industry. The total planted area of oil palm has increased from 1.5 Mha in 1985 to 5.74 Mha in 2016 (MPOB, 2017a). Malaysia, as the second largest exporter of palm oil products in the world after Indonesia, produces 17.32 Mt of crude palm oil (CPO) in 2016 (MPOB, 2017a). The total Malaysian export for palm oil achieved 16.05 Mt in 2016, which was approximately 44 % of total world exports (MPOC, 2017). This accounted for about 8 % of total Malaysian Gross Domestic Product (MPOC, 2016).

Despite the significant value of economic income brought from producing CPO, palm fresh fruit bunch (FFB) which CPO is extracted contains only 22 % of oil (20 % CPO and 2 % palm kernel oil), while the remaining 78 % remains to be palm biomass (MPOB, 2017b). Palm biomass, which was also known as palm wastes, consists of empty fruit bunches (EFB), mesocarp fibre (MF), palm shell (PS), and palm oil mill effluent (POME) are simultaneously generated along with the processing of FFB in a palm oil mill. In addition to these biomasses from the mill, palm biomass such as pruned fronds and harvested trunks is produced in palm plantation. This constituted approximately 85.5 % of biomass in Malaysia with an average of 53 dry Mt/y (Tang et al., 2016). The rapid expansion of palm industry and huge volume of CPO production have resulted in massive amount of lignocellulosic palm biomass being generated which raises disposal issue. As such, green solutions are sought to clear the biomass, at the same time, creating new business opportunities by converting the waste into wealth. For instant, palm biomass has been utilised in the generation of electricity and production of various types of value-added products such as pellets, bio-briquettes, bio-char, plywood and others (Lam et al., 2012). Recently, the conversion of palm biomass to fertilisers has been paid attention by both public and private sectors as the tremendous expansion of agriculture sector in Malaysia has led to the growing demand for input fertilisers. In 2014, the total imported value of fertiliser exceeded 1,470 M USD (Knoema, 2016).

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2. National policies to develop palm based fertiliser

Realising the massive need of fertiliser, local source of fertiliser is sought as one solution to increase the product supply security and reduce national import. Palm biomass appears to be one promising raw material for fertiliser production as a win-win strategy for sustainable development. Previously, palm biomass was disposed through open burning or incineration or disposed in waste ponds (Saleh and Omar, 2001). This had contributed to the global climate change due to the emission of greenhouse gases (Zafar, 2015). The uncontrolled incineration of palm biomass is banned by the government under Environment Quality Act 1974 (Chiew and Shimada, 2013). Since then, researchers and palm biomass generators took initiative to look into the potential of palm biomass for efficient utilisation such as fertiliser production.

In 1998, Malaysia's government established a policy - The Third National Agricultural Policy or NAP3 for the strategic directions for agricultural and forestry development to year 2010 (FAO, 2004). This policy aims for high productivity, at the same time, promotes conservation and sustainable utilisation of natural resources. According to Ministry of Agriculture (1998), the government motivates and promotes the development, expansion and modernisation of the input industries under this policy by providing incentives to the potential companies to ensure that the agriculture sector in Malaysia is competitive with other countries to face the upcoming challenges, while fertiliser is one of the crucial inputs for the cultivation of crops. In addition, organic farming industry is also promoted and this has led to the production of organic fertilisers (Ministry of Agriculture, 1998).

Then, the National Agro-Food Policy (2011-2020) was introduced by the government in 2011 after NAP3 to support the development of palm based fertiliser. The companies which take initiative to practise sustainability in agriculture sector by converting agriculture wastes into value-added products such as fertiliser, animal feed and biogas will be given incentives such as Depreciation Accelerated Capital Allowance to procure machineries required for the manufacturing process (FAMA, 2017). In addition, Malaysia Investment Development Authority (MIDA, 2017) claimed that company which produces promoted product (e.g. palm based fertiliser) or engages in such activities are eligible for Pioneer Status (PS). Under PS, company enjoys 30 -1 00 % income tax exemption for 5 y period. Investment Tax Allowance (ITA) is an alternative to PS which company may be granted for an allowance of 60 % on their qualifying capital expenditure incurred within 5 y from the date the first qualifying capital expenditure is incurred (MIDA, 2017). After the 5 y of first PS or ITA incentives, Malaysia offers an extension of another 5 y of PS and ITA incentives for company that reinvest in resource-based industries (MIDA, 2009).

On the other hand, National Biomass Strategy 2020 was introduced in Malaysia in 2011 to direct the country in the development the biomass industries and high-value opportunities by utilising palm biomass (AIM, 2013). The strategy outlines the action plan and opportunities in the biomass value chain that could contribute additional 30×10^9 MYR to the gross national income and 12 % reduction in carbon emissions besides generating up to 66,000 high-value jobs and bringing in 25×10^9 MYR in investments (AIM, 2016).

3. Palm based fertiliser in Malaysia

The demand for fertiliser is increasing correspondingly to the expansion of the area of palm plantation. Fertiliser is one of the contributing factors to the productivity of the palm plantation. Based on a research in Pamol Estate, Kluang, Malaysia, the fertiliser with balanced nutrition could increase the yield of FFB by 29 % (Goh et al., 2017). In the current practice, the main types of fertiliser used by the farming sector in Malaysia are mineral, organic and fortified fertilisers. According to Sabri (2009), the mineral fertilisers account for more than 90 % of the fertilisers used in the agriculture activities in Malaysia. The main fertilisers include urea, ammonium sulphate, kieserite, phosphate rocks, super phosphates, ammonium phosphates, potassium chloride, potassium nitrate, sulphate of potash, NPK compounds, NPK and NK blended and mixtures fertilisers (Sabri, 2009). Palm based fertiliser which is of lignocellulosic based is categorised as organic fertilizer. Due to the low nutritional value of organic fertiliser, fortified organic fertiliser is another category of fertiliser which the nutritional value of organic fertiliser is enhanced through fortification using inorganic matter such as nitrogen, potassium and etc.

3.1 Organic fertilisers

Since 1998, Malaysia has been promoting organic agriculture to ensure the sustainability of the agriculture sector besides seeing it as a niche market opportunity for fruits and vegetables (Sabri, 2009). The usage of organic fertilisers can effectively reduce the reliance on mineral fertilisers as well as moving towards a more natural and healthier methods of food production (FAO, 2004). The palm ash collected from the boiler generating electricity and steam for palm oil extraction can be utilised for fertiliser production. The ash has low level of toxicity and high amount of potassium (Kong et al., 2014). The ash (~ 6.5 %wt. of EFB) which is generated from EFB incineration contains about 30 - 40 % K_2O and thus, it can become a source of potassium, which has been found to be able to increase the yield of oil palm grown on acidic coastal soil (Singh et al., 2010). EFB which is composted into fertiliser has an average macro and secondary nutrient contents noted as Nitrogen (N): 0.8 %, Phosphate (P): 0.1 %, Potassium (K) 2.5 % and Magnesium (Mg) 0.2 % on a dry weight basis (Gurmit et al., 1981). The organic fertilisers made of EFB can effectively improve the soil structure from improved soil aeration, increased water holding capacity and increased soil pH besides releasing nutrients slowly to the soil via micro-organisms activity and thus recycling the plant nutrients (Abdullah and Sulaiman, 2013). Other palm biomass such as oil MF, DC and POME are also raw material sources for organic fertiliser production.

Biological treated POME has been widely used in the oil palm cultivation as a liquid fertiliser and for irrigation purpose (Wu et al., 2009). This is because it contains appreciable amounts of N, P, K, Mg and Calcium (Ca) (Embrandiri et al., 2013). Wu et al. (2009) also claimed that copper, iron and lead were predominant in their organic forms, while zinc was particularly present in its exchangeable form. It is estimated that about 0.5 - 0.75 t of POME will be generated for every t of FFB processed (Madaki and Lau, 2013). For 86 Mt of FFB processed in 2016, it is estimated that 58 Mt of POME was generated. The usage of raw POME on land was initially thought to be impractical. However, Oviasogie and Aghimien (2003) discovered that proper use and safe disposal of POME in the land environment not only conserves the environment, but also improves soil fertility due to its vital nutrient elements for plant growth. Thus, it contributes to a better root health and soil structure as well as higher crops yield (Chan et al., 1981). Table 1 shows the suitable amount of POME to supply the nutrient requirements for each growth stage of oil palm.

Table 1: The application of POME (m^3/acre/y) as fertiliser for palm plantations (Onyia et al., 2001)

Growth Stage of Oil Palm	N	P	K	Mg
Young	25 - 70	27.5 - 32	5.1 - 10	1.2 - 10
Adult	90 - 128	52.5	10 - 18.5	15
Old	162	52	18	20

The fertilising value of POME can be quantified. Wood et al. (1979) estimated that 4.5 ML/ha of POME applied could represent a fertiliser application of about 30 kg ammonium sulphate, 7 kg rock phosphate, 52 kg muriate of potash and 18 kg kieserite per palm tree per y. Table 2 shows the current estimated fertiliser values of POME based on 15 Mt of POME and it is estimated that every 15 Mt of POME represents fertiliser value of 192 × 10^6 MYR.

Table 2: Estimated fertiliser values of POME based on 15 Mt of POME

Fertiliser	× 10^3 t (Wu et al., 2009)	Price[2] (MYR/t)	Fertiliser value (× 10^6 MYR)
Urea[1]	34.5	1450	50.0
Rock phosphate	19.5	400	7.8
Muriate of Potash	68.6	1350	92.6
Kieserite	59.6	700	41.7
Total			192.2

[1] Amount of ammonium sulphate (21 % N) is translated to urea (46 % N) based on N content.

[2] Estimated pricing as of June 2015

3.2 Fortified organic fertilisers

Fortified organic fertilisers are the integration of both organic and inorganic fertilisers to enhance the macro and micronutrients of organic fertiliser so that the nutrient content is suitable and sufficient for crop cultivation. In practice, decanter cake (DC) or palm oil sludge is mixed with inorganic fertilisers which is used to improve soil quality by enhancing the nutrient uptake and retention in the soil (Haron and Mohammed, 2008). DC is a by-product obtained through FFB processing after dehydrating the POME (Seephueak et al., 2011). DC is produced at approximately 3 - 5 %wt. of FFB processed. It is composed of highly biodegradable organic content and nutrient-rich composition such as high fats, high minerals and moderate proteins (Kanchanasuta and Pisutpaisal, 2016). After applying fortified organic fertilisers, growth improvements were observed on the palm seedlings as compared to the control plants (Haron and Mohammed, 2008). Ng (2015) also stated fortified organic fertiliser with combine macronutrients: 10 % N, 10 % P and 10 % K with trace elements, bio-char and organic matter is more cost efficient than the conventional chemical fertilisers.

4. Palm biomass to fertiliser conversion technology in Malaysia

Composting technique is widely used to convert lignocellulosic biomass such as EFB into organic fertiliser. The process is primarily categorised into primary composting, co-composting and vermicomposting, where different technologies are employed in each process.

4.1 Primary Composting

The four types of compost piles that are principally used in the industry include aerated static piles (ASP), open static piles, turned windrows and piles, and in-vessel systems (Hubbe et al., 2010). For static piles, heat is released within the pile during decomposition and the heated air moves upward due to convection while fresh air is drawn in from the sides of the pile to replenish the oxygen supply (Hubbe et al., 2010). ASP is a composting technique used to biodegrade organic material system in the absence of physical manipulation (Gandahi and Hanafi, 2014). The ASP appeared as a static bed that utilises a fan, in which the rate of air supplied is manipulated to maintain the required pile temperature and oxygen supply (Stentiford, 1996) to maintain the moisture and oxygen level for microbial growth. However, ASP can be labour intensive and bio-filters may be required to treat process air and reduce odour.

In Malaysia, the turned windrows and piles technique is widely used. The composting mixture is blended in an agitated solid bed or long narrow pile by regular turning and agitation with paddles (Basri et al., 2005). This allows oxygen to be introduced within the compost which promotes aerobic microbial activity that speeds up the composting process. Meanwhile, the wastes gas released from microbial activity is vented from the turning process (Gandahi and Hanafi, 2014). The in-vessel system is a cluster of methods which the composting material is confined within a building, container, or vessel (Misra and Roy, 2017). This system employs metal or plastic tanks or concrete bunkers to regulate the flow of air and temperature, while the agitation and bio-filtering are also applied (Gandahi and Hanafi, 2014). It practises the principles of a “bio-reactor”, in which the air circulation is evaluated via buried tubes that allows the injection of fresh air below pressure, with temperature and moisture conditions being measured using probes in the mass to monitor the key parameters.

4.2 Co-composting

Co-composting process is another technique carried out by using EFB and partially treated POME to produce organic fertilisers. The process was first started by pressing and shredding the EFB then send to stacking up pile such as turned windrows system. Then, POME is sprayed onto the compost pile for moisturisation and nutrient enhancement. The compost pile will undergo turning and drying process before being graded as the final products (UNFCCC, 2006).

4.3 Vermicomposting

Organic waste decomposes slowly under normal condition. In order to speed up the decomposition process, vermicomposting technique has been introduced as a cost-effective technique that converts organic material into humus-like product known as vermicast or vermicompost with the aid of earthworms, at a shorter processing time with low phototoxicity, high N content, larger fertiliser value and additional production of earthworms (Lorimor et al., 2001). Vermicomposting allows the physico-chemical and biological reaction to occur simultaneously in the organic matter, causing the vermicast produced to be highly disintegrated (Gandahi and Hanafi, 2014) and plant nutrients in the biomass such as organic carbon, N, P, K, Ca, Mg, Na, Zn, Cu and Fe to be readily absorbed by the plants (Nagavallemma et al., 2004).

Earthworms play an important role in this technique as they are unquenchable feeders on organic wastes, in which the obsessive materials are released in a partially digested form (Gandahi and Hanafi, 2014). They act as natural bioreactors that can control and kill soil pathogens besides converting organic wastes into bio-fertilisers, enzymes, growth hormones and proteinaceous worm biomass (Zulkapri S.Z.B., 2009). For instant, *Lumbricus rubellus* is one of the few species of worms that live in decaying organic waste materials and tolerate temperature ranging from 0 °C to 40 °C at neutral or nearly neutral conditions (Nagavallemma et al., 2004). *Perionyx excavatus* (the Indian or Malaysian blue worm) is another species living in tropical countries in Asia. Gandahi and Hanafi (2014) reported that vermicompost could improve yield of plants such as Black gram (urad), soybean, cucumber, tomato, maize, sorghum, potato and so on. Vermicomposting emerged as an alternative technology to degrade the large amount of palm biomass especially EFB and frond (Gandahi and Hanafi, 2014). The methods of vermicomposting include (i) pits below the ground (1 m deep × 1.5 m wide × varying length); (ii) heaping above the ground, in which the waste materials are spread on a polythene sheet placed in the ground and covered with cattle dung (Nagavallemma et al., 2004); (iii) tanks above the ground, which the earthworms move from one tank to another through the partition wall with small holes, (iii) commercial bio-digester, which this technology is proved to reduce labour cost and save time and water (Nagavallemma et al., 2004); (iv) cement rings, which is commonly used by farmers above the ground (ICRISAT and APRLP, 2003).

5. Conclusions

Malaysia has foreseen the opportunities of converting the palm biomass into valuable added products while extending the product life cycle, at the same time, solving the disposal problems which may lead to environmental degradation. The government has established national policies to ensure the competitiveness and sustainability in the agriculture sector. Fertiliser production seems to be one of the best ways to meet the objectives of the policies as fertiliser is an important input for plantations. This could effectively utilise large amount of palm biomass and improves the crops yield. Furthermore, organic farming is being widely promoted recently and this has also encouraged the usage of the palm biomass such as EFB, fronds and POME for organic fertilisers. Fortified fertilisers that are composed of both inorganic and organic fertilisers are introduced to cover the shortage of organic fertiliser. Different technologies are being utilised to develop palm based fertilisers in three processes, i.e. primary composting, co-composting and vermicomposting. To ensure the sustainability of the industry, environmental studies such as biomass life cycle analysis (Lim and Lam, 2014) are being developed along with the technology advancement. The ongoing research and development with the support from both public and private sectors is believed to exert significant potential to produce palm based fertilisers in Malaysia.

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