American-Eurasian J. Agric. & Environ. Sci., 5 (6): 767-776, 2009
ISSN 1818-6769

Oil Palm: The Rich Mine for Pharma, Food, Feed and Fuel Industries

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Abstract: The rapid increase of palm oil (PO) production in the last 20 years has made it the most important oil in the world. By year 2007, the annual global production of PO reached 40 million metric tons. Currently, Malaysia accounts for almost 50% of world palm oil production. As most of natural oils, PO has only a limited application in their original form, as a consequence of its complex chemical composition. PO contains free fatty acids, sterols, tocopherols, hydrocarbons, pigments, vitamins and many other components. Therefore, PO has wide applications for the production of high value products for pharmaceutical, food and chemical industries. Moreover, based on its lower price compared to other plant oils, PO is considered as one of the main raw materials for biodiesel production. These all together makes PO the most widely fractionated oil. The Palm Oil Production Chain (POPC) is integrated process with several segments started from good cultivation practice to obtain fruit of high oil content through well integrated refinery process for maximal separation and utilization of each oil fraction and ended by the better use of different processes by-products. Beside PO, the byproducts obtained from oil palm residues after oil extractions, which are about 5 times in weight more than crude oil, are very rich carbohydrate source for many agricultural and industrial applications. In the present work, this integrated approach in oil palm industries will be represented in more details as complete R&D platform for agro-based industries.

Key words: Oil palm, Integrated process, Oil fractionation

INTRODUCTION

The rapid expansion in world production of palm oil over the last three decades has attracted the attention of oils and fats industry. Many are interested to know how palm oil has been able to compete successfully to gain continuous increased share of the international oils and fats markets. The oil palm (*Elaeis geuineensis)* is mature single stemmed tropical tree and belongs to palm family (*Arecaceae*). This palm tree is characterized by its pinnate large leaves up to 5 meter long. The fruit is the most economically important part of this plant and composed of fleshy outer layer and single seed. Both of these parts characterized by their high oil content and therefore used for palm oil production. In spite of the oil palm is not Malaysian natural flora and originally obtained from West Africa. Nowadays, Malaysia and Indonesia are account for 90% of palm oil world export trade. Based on the fast progress in plantation, palm oil accounts of 25.5% of the global fats and oils production in volume of 37 million metric tons by end of 2006 [1]. The viability of palm oil for export is determined by the ability of the oil palm to be grown successfully in the country concerned. High yield of the palm throughout the year is essential to achieve good sustainability for the export market. A well-managed plantation should aim to achieve an average yield up to 25 tons of fresh fruit bunches per hectare and oil extraction yield of 20-25%. This means that a hectare of mature oil palms should yield between 4 to 6 tons of Crude Palm Oil (CPO) in addition to 0.5 tons or more from palm kernel when it crushed [2]. However, no other oil producing crop has a productivity that comes close to that of palm oil. Thus, palm oil production in Malaysia for export purpose is found to be highly viable and oil palm has become a favorite cash crop to replace other traditional economic crops such as rubber. For long time,

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the main palm oil export was in its crude form. Nowadays, wide range of semi processed, processed and fully fractionated oil are the main forms of palm oil for export. These include the different fractions of processed palm oil known as palm olein (liquid) and palm stearin (solid) and many fractionated fine products. In parallel, similar trend has been seen in the export of palm kernel. Palm kernel is a co-product to palm oil produced at a ratio of 10-13 tons of palm kernel oil for every 100 tons of palm oil. With the increasing exports of refined form products, many developing countries which did not have refining capacities, were able to import processed palm oil for direct consumption with minimal or no further refining. This helped to expand the market for palm oil in the developing countries. Moreover, the recent applications of palm oil in energy and biodiesel industries increased the PO market size as well [3-5].

Integrated Approach for Cultivation and Processing: In fact, good quality palm oils are made in the farm during plantation and not in the factory. This started by good cultivation practice of oil palm. The quality of the crude oil, which is also affected by fruit quality, ripeness and storage, have to be also considered that it affect the refining process thereafter. Thus, good cultivation practice is important segment of palm oil production chain. In the integrated system, all parties involved with palm oil, from growers to final product manufacturers should work closely to ensure the sustainable of the production chain with minimal negative impact on the environment.

Good Cultivation Practice: Palm oil is now considered as one of the major sources of sustainable and renewable raw material for the world's food, oleo chemical and bio fuel industries. Involvement in cultivation or downstream activities has uplifted the quality of life of people, a key plank of the sustainability platform. Advancement in the technology of oil palm cultivation is directed at increasing yield and reducing costs. Improved knowledge of soil and water management has enabled the palm to sustain a consistent pattern of high yield. To attain the maximal PO production, different factors should be considered. These include: use of plant variety of high productivity, site selection with optimal environmental conditions, improvement of soil fertility, an integrated control system for pest and pathogen control, improve harvesting and post harvesting processes [6,7]. The ideal environmental requirements for maximal oil yield are: annual rainfall of 2000-2500 mm, relative humidity above 85%, low vapor pressure deficit, moderate temperatures with low wind speed, adequate sunshine hours and solar radiation of 16-17 MJ/m^2 per day [8]. Yield is also being improved through better-quality seeds developed via intensive breeding programs [9,10]. High yields, harvesting efficiency and the right harvesting standards are important in maximizing the product value. For producing the optimum amount of high quality product, free fatty acid (FFA) content must be kept at acceptable levels. The fruit harvest at the right stage of maturity is also important to recover maximum oil with good quality. Oil formation in the fruits hastens during the final weeks of ripening and over ripening enhances fatty acids formation. The fruits should be processed immediately after harvest as the fatty acid formation is accelerated by the activity of lipase enzyme [11,12]. Moreover, all potential contamination sources in the product stream should be covered by strict quality control. In order to obtain good quality palm oil, it is essential that the damage to the fruit is minimal and therefore the handling of fresh bunches from the field to the sterilizers must be carried out with the utmost care. As part of integrated system, wastes like palm oil empty fruit bunches (EFB), beside some other mill factory wastes are returned to the land as fertilizer. This will minimize the use of inorganic fertilizers in plantations which are not environmentally friendly. Moreover, the reuse of palm oil mills wastes is important in the waste management system of oil factories as well.

Post Harvest Processes and Biomass Separation: Crude Palm Oil (CPO) could be primary extracted from the mesocarp of the oil palm fruit by either standard wet process or dry process. In the wet process, steam and water are employed to inactivate lipase enzyme in palm fruits and to extract the oil. The products obtained by this process are crude palm oil and palm kernel oil. In the dry process, dry heat is used for lipase inactivation and the whole palm fruit is fed to a screw press. The product in this case is in form of mixture of crude palm oil and kernel oil. However, the superiority we process is based on the following advantages:

- Moist heat promotes high efficient inactivation of lipases and prevents hydrolysis and auto-oxidation.
- For large scale installation, the moist heat weakens the fruit stem and facilitate the removal of fruit from bunches
- Moist heat promotes the protein oxidation process and this help to extract the oil during pressing.

- Moist heat treatment weakens the pulp structure and thus helps to disrupt the oil containing cells in the mesocarp and facilitate the oil release.
- Steam acts chemically to break down gums and resins and thus prevent oil foaming during frying.
- Moist heat hydrolyzed starches present in the fruit and can removed successfully through this way.

However, Figure 1 summarizes the different steps of PO processing and the possible utilizations of different fractions in the whole PO production chain.

Fractionation Process: Fractionation is a physical method using the crystallization properties of triglycerides to separate a mixture into a low melting liquid fraction and a high melting liquid fraction. Fractionation is thus a process producing at least two fractions, unlike other fat modification processes such as inter-esterification and hydrogenation. The main purpose of these processes is to change the physicochemical properties of the oil or fat by reducing the degree of unsaturation of the acyl groups through redistributing the fatty acids chains using different selective crystallization and filtration methods [13,14].

In general, fractionation is based on the difference of melting points of triacylglycerides (TAGs). The complex mixture of TAGs in palm oil, their polymorphism and the influence of the conditions under which crystallization occur were covered in many industrial Know-How and patents for better separation and extension of TAGs applications [15-19].

There are three principal techniques applied to crystallize fractions of palm oil which are: dry fractionation, solvent fractionation and detergent fractionation. The dry fractionation is the simplest and most economical separation technique. Detergent fractionation is a modification of the dry method in which an aqueous detergent solution is utilized to separate the solid and liquid phase. However, the main differences between the different crystallization techniques are the cooling time.

Crystallization: The crystallization process of fats can be divided into three basic steps as follows: super cooling of the melt, formation of crystal nuclei and crystal growth. Crystallization of the oil under controlled cooling followed by separation yield low-melting liquid phase (olein) and high yield-melting solid phase (stearin).

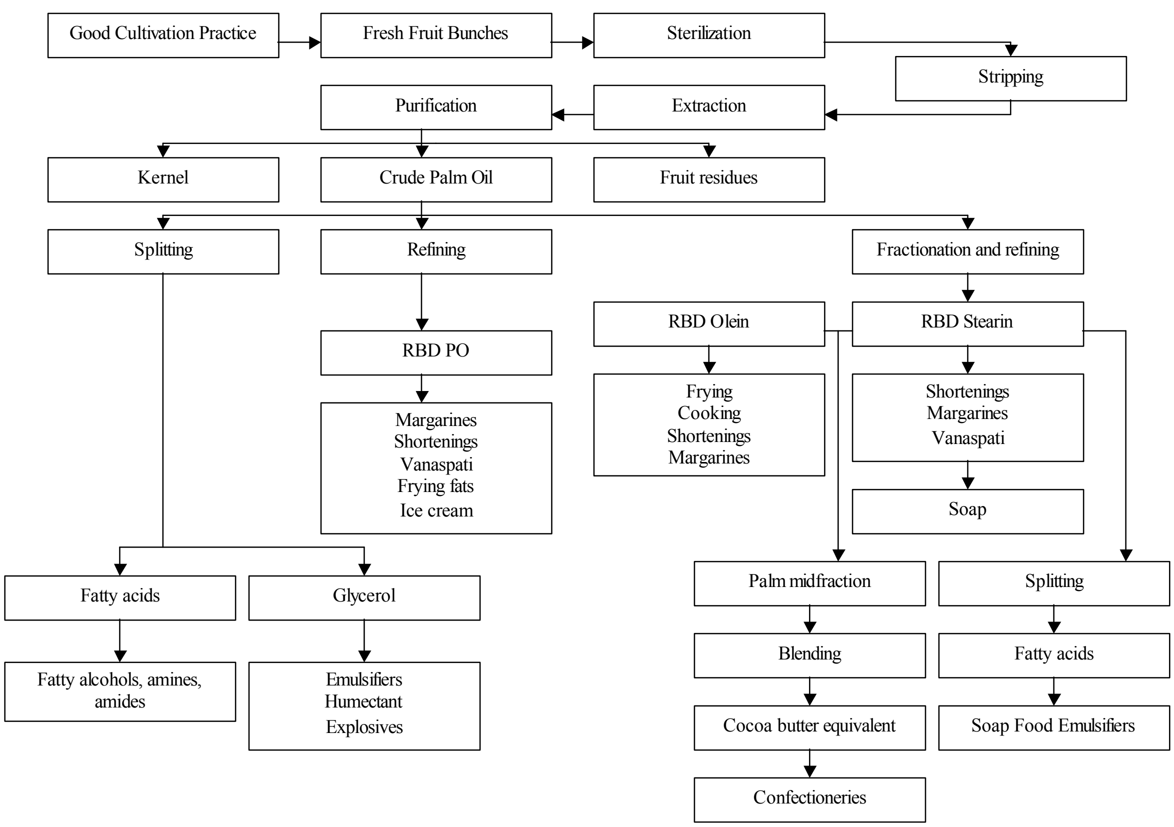

Fig. 1: Palm oil utilization chart

Normally, prior to crystallization, the oil is fully melted in order to destroy the crystals present in the oil phase. Then the oil is cooled in a controlled manner according to a given cooling profile that functions of the feedstock and of the required fractions. Nucleation occurs when the temperature of the melt is much lower than the thermodynamic equilibrium temperature, when the melt becomes super-cooled. Once the nuclei are formed, the crystal grows very fast. The crystal formation rate is proportional to super-cooling and inversely proportional to viscosity. Factors affecting the crystallization process are oil composition, polymorphism and cooling condition [20]. In general, palm oil contains about 4-8% diglycerides, which can form a eutectic mixture with the triglycerides resulting in lower solid content. These all together can slow the rate of crystallization.

On the other hand, the monoglycerides content of palm oil is less than 1% in and has insignificant effect on the crystallization. Palm oil triglycerides are polymorphic and thus can crystallize in several forms. The polymorphic are designated as α, β' and β in the order of increasing stability and melting points.

Different thermal conditions are needed to induce crystallization of the different polymorphic forms. Upon cooling, palm oil initially crystallizes in the form, which gradually transforms in the order of α >β'>β form. To have good separation, it is desirable to have β' form because this type of crystals agglomerate in large, firm clusters resulting in good subsequent filtration. Cooling rate affects the nucleation and crystal growth of the oil. As the oil is cooled, it becomes supersaturated. When the temperature is sufficiently low (between 32 and 36°C), saturated triglycerides will crystallize and these crystals will act as nuclei for further crystallization of the lower melting glycerides, resulting in formation of larger clusters of crystals. Slow cooling rate and proper stirring speed is essential for the formation of the desired crystal form.

Separation: The aim of this process is to produce a solid (stearin) and liquid (olein) phase where each have its proper physicochemical characteristics and its particular applications. At the end of the crystallization process, TAGs are distributed as solid in the form of crystals, as liquid and as liquid physically trapped on the surface of the crystals. Based on this, different separation techniques and equipments are used depending on the efficiency of the separation required.

The separation equipments, which have been used for large scale, include: vacuum drum filtration, vacuum belt filtration, decanting, centrifuging, membrane pressing and hydraulic pressing. The additional steps can be applied to effect further improvements in separation efficiency are multi-stage fractionation and counter current crystallization.

The separation efficiency may depend on the mode of crystallization, either stagnant or stirred. Often good results are obtained with "stagnant crystallization rather than with stirred crystallization. The stearin and olein phases may be separated by filtration but for an effective separation of the solid from the liquid phase generally a membrane filter press is used.

Refining Process: Crude palm oil is rich in minor components that impart unique nutritional properties. Palm oil is generally refined by the physical process, which is preferred over the chemical process since high acidity can lead to excessive loss of neutral oil in the soapstock after alkali neutralization. The quality of the crude oil is to be considered as it can greatly affect the efficiency of the refining process and the quality of the end-products. The production of crude oils and fats, by normal operations of rendering, crushing or solvent extraction, results in the incorporation of variable amounts of minor components like free fatty acids (FFA), partial acylglycerols, phosphatides, sterols, tocopherols, tocotrienols, hydrocarbons, pigments, vitamins, sterol glycosides, protein fragments, traces of pesticides, dioxins, heavy metals, etc. To become acceptable for human consumption, most oils are usually undergo different purification steps. Mainly, a light color, a bland taste and a good and oxidative stability are required. To achieve this, the oils are submitted to several treatments. The objective of the refining is to remove the objectionable minor constituents in the oil with the least possible damage to the acylglycerols and minimal loss of the desirable constituents.

The commercial crude palm oil, obtained directly from fresh fruit bunches, contains small but variable amount of undesirable components and impurities. These include some mesocarp fibers, water, insoluble free fatty acids, phospholipids, trace metals, oxidation products and odoriferous substances. Thus, palm oil is normally refined to a bland, stable product before it is used for direct consumption or for formulation of edible product. Crude oils are refined to remove all impurities such as undesirable odor, flavor and color, but at the same time retaining the beneficial components such as vitamins, pro-vitamins and antioxidants. Refining can be operated according to two main methods namely: physical refining and chemical refining. These two methods are different

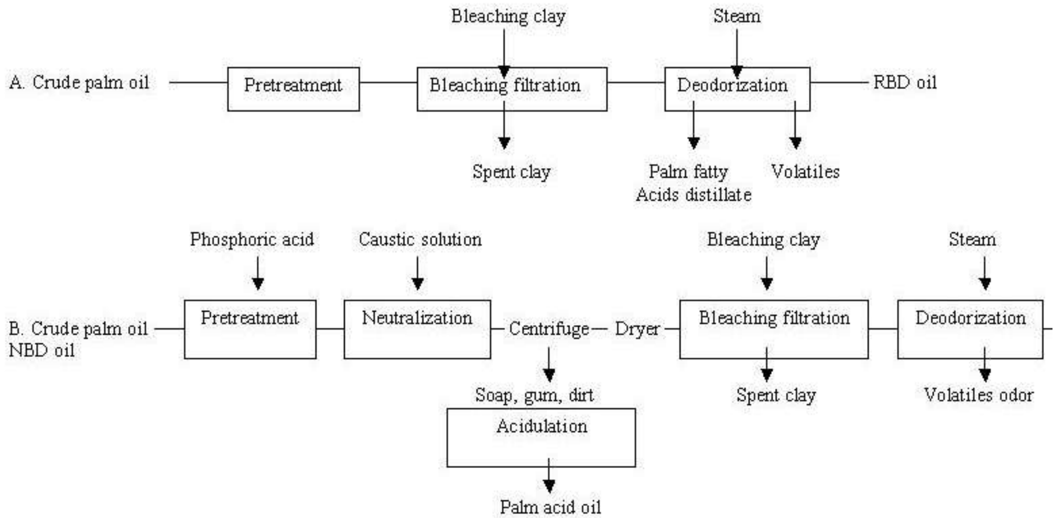

Fig. 2: Simplified flow diagrams of physical refining (A) and chemical refining (B) of crude palm oil

basically in the manner in which the free fatty acids are removed. Both processes are able to produce refined, bleached and deodorized (RBD) palm oil of desirable quality and stability suitable for edible purposes. Figure 2 shows simplified flow diagram to compare between the physical and the chemical refining processes.

Physical Refining Practices: Pretreatment refers to the initial degumming of crude palm oil with concentrated phosphoric acid and the subsequent adsorptive cleansing with bleaching clay. Crude palm oil is dosed with phosphoric acid (80-85% concentration) at a rate of 0.05-0.2% (of the feed oil), heated to 90-110°C and given a residence time of 15-30 min before passing to the bleacher where bleaching earth is added as a slurry. The bleaching earth concentration is ranged between 0.8 and 2% depending on the quality of crude oil. The purpose of the phosphoric acid is to precipitate the nonhydratable phosphatides while the function of the earth is fourhold:

- To adsorb the undesirable impurities such as trace metal, moisture, insolubles and part of the carotenoids and other pigments.
- To reduce the oxidation products.
- To adsorb the phospholipids precipitated by the phosphoric acid.
- To remove any access phosphoric acid present in the oil after degumming.

The final residual color of the pretreated oil is not important at this step as the role of the bleaching earth is not so much of color removal but more critically in its ability to act as an adsorptive cleansing agent [21]. Complete removal of residual phosphoric acid in the bleaching stage is also critical as any “slip through” can result in the rapid rise of free fatty acid content and color of the final RBD oil. As a further assurance, a suitable quantity of calcium carbonate is often added after dosing of the bleaching earth to the degummed oil, to help neutralize the residual phosphoric acid.

Bleaching is carried out under a vacuum of 20-25 mmHg and at a temperature of 95-110°C with retention time of 30-45 min. The slurry containing the oil and earth is then filtered to recover clear, light orange color pretreated oil. Usually a small amount of diatomaceous earth is used to pre-coat the filter leaves to improve the filtration process. As a quality precaution, the filtered oil is polished through another security filter bag in series, to trap any earth particles that escape through the first filter. This is essential as the presence of spent earth particles in the pretreated oil reduces the oxidative stability of the final RBD oil. The spent earth from the filter normally contains about 20-40% oil and this is the major source of oil loss in the refining process.

The pretreatment process can be carried out in batch, semi-continuous, or continuous mode and the filters used are either plate and frame vertical filter or horizontal pressure filters with vertical stainless steel filter screens.

The pretreated oil is then undergo through deacidification and deodorization processes. The pretreated oil is first deaerated followed by heating up to high temperature between 240 and 270°C in an external heat exchanger before pumping into the deodorizer, which is kept under a vacuum of 2-5 mmHg. Traditionally thermal fluids are commonly used as the heating medium. However, to eliminate the risk of possible contamination of refined oil with thermal fluid, superheated high-pressure steam is now commonly being used. High temperatures (above 270°C) should be avoided to minimize loss of neutral oil, tocophrols/tocotrienols and also the possibilities of isomerization and undesirable thermochemical reactions. Under such conditions and with the help of stripping steam, the free fatty acids, which were still present in the pretreated oil, are distilled together with the more volatile odoriferous and oxidation products such as aldehydes and ketones. At the same time, the residual carotenoids present are also thermally decomposed and the end result is the production of a light-colored, RBD palm oil. To maximize the recovery of thermal energy, hot deodorized oil is heat exchanged against incoming pretreated oil to be cooled down to a temperature of 120-150°C. However, further cooling down to 55-65°C prior to storage is necessary before storage. Physical refining has become the major processing method because of its cost effectiveness, efficiency and simple effluent treatment.

Chemical Refining Practices: Chemical refining involves three stages which are gum conditioning-neutralization, bleaching-filtration and deodorization. During the first stage of gum conditioning and neutralization, the crude oil is heated to a temperature of 80-90°C. phosphoric acid of 80-85°C concentration is then dosed in at concentration of 0.05-0.2% (of the feed oil). This serves to precipitate the phospholipids. After this, the degummed oil is further treated with 4 N caustic soda solution with a calculated excess (based on free fatty acid content of the crude oil) of about 20%. The reaction between caustic soda and the free fatty acids in the degummed oil results in the formation of sodium soap, which is readily removed by a centrifugal separator. The lighter phase discharged consists mainly of neutralized oil containing 500-1000 mg/kg of soap and moisture while the heavy phase is mainly soap, insoluble impurities, gums, phosphatides, excess alkali and a small quantity of oil loss through emulsification. As an excess of alkali is used, it is unavoidable that a slight loss of neutral oil through saponification also occurs. The neutralized palm oil (NPO) is then washed with 10-20% hot water to remove the soap traces. After the second stage of centrifugal separation, the washed oil is then dried under vacuum to reduce the water content below 0.05%.

The neutralized palm oil is treated with bleaching earth in a similar manner as that described in physical refining. However, in this case, the earth also removes traces of soap that are present.

The neutralized and bleached oil is then channeled to the deodorizer in a similar manner to that in the in the physical refinery. The oil is subjected to distillation at a temperature of 240-260°C and a vacuum of 2-5 mmHg with direct steam injection. Under such conditions, residual free fatty acids volatile oxidation products and odoriferous materials are removed together with thermal decomposition of carotenoids. The final product, called neutralized, bleached and deodorized (NBD) palm oil is then cooled down to 60°C and passed through polishing filter bags before pumping to the storage tanks.

The Important Oil Fractions and Applications: Palm oil is used in both edible and non-edible applications. However, ninety percent of palm oil and its products are used for edible purposes. Currently, palm oil is widely used in food preparation and manufacturing worldwide. The remaining 10% of palm oil and its products are used for nonedible applications, mainly in the soap and in oleochemical industries.

The used of palm oil in food dates back 5000 years. For edible and non edible uses, palm oil is normally refined. However, even today, unrefined palm oil is still used for cooking in certain African villages as the same way as it used to be since the ancient time. Nowadays, the refined palm oil has many applications in food industries as margarine, deep frying fat and specialty fats.

The newer applications of palm oil in foods include its use in emulsion-based, powdered and convenience food products [22]. Butterfat has been traditionally used in ice cream, but palm oil and palm kernel oil are now used commercially to replace it. Similarly, palm oil can also replace butterfat in the manufacture of milk, to give a product known as “filled milk”. Palm oil is used because it is more economic than other oils and is easily available. In addition, it is more stable to oxidation than butterfat. Filled-milk powder made from skimmed-milk powder.

Another use of palm oil product is in infant food formula [23]. The low-melting olein has been found to be very suitable for use in infant food formula when blended with other vegetable oils [24]. Low-melting olein contains 10-15% palmitic acid in the 2-position of the glycerol chain. This contributes to the high digestability of the product. Apart from the products mentioned, there are many other foods that contain palm oil and palm kernel oil products. These include: cake and desert mixes, “rending” or curry mixes, sardines, baked beans, breakfast cereals, shrimp-paste powder, bouillon, peanut butter and beverages. Palm oil products have also been used as spray oil in biscuits.

An important future application of palm oil in food is the use of refined red palm oil in cooking. Refined red palm oil is highly nutritious oil rich in vitamin E and β-carotene. The deep red color of the oil blends well with ingredients such as chili and curry, making the dishes more attractive and appealing. Beside these, palm oil is widely used in food industries, PO are also used as feed additives for different mammals and aquaculture [25-27].

The use of refined red palm oil is a possible alternative means of combating vitamin A deficiency, which is prevalent in many countries [28]. Another promising application of palm oil in food is the use of RBD palm olein as salad oil. Beside these all applications in food industries, many important oil fractions such as natural carotenes, vitamin E, sterols, squalines, co-enzymes and phenolic compounds are used for many pharmaceutical applications [29,30]. Carotenes, especially in β form have antioxidant activity and inhibitory effect on colon cancer cells [31]. Lycopene is an effective singlet oxygen quencher [32]. Vitamin E has wide range of applications as antioxidant, anticancer and have hypercholesterolemic effects [33,34]. Squalene act as natural protective agent against some types of cancer [35, 36]. Co-enzyme Q_{10} has protective effect against artherosclerosis and heart disease [37]. These all beside the Phenolic compounds in palm oil are potent antioxidant with many functional roles in human body [30]. The non edible application of palm oil include the production of soap, diesel substitute, epoxidized palm oil, polyols, polyurethanes, polyacrylates and raw materials for oleochemicals such as oleochemicals or derivatives based on C12-C14 and C16-C18 chain lengths with wide variety of uses. These beside many industrial applications of PO derived fatty acids in the production of rubber, glycerol, soap, candles and cosmetics.

Solid Wastes of Oil Palm Industry (From By-Products to Value Products): Palm oil industry generates massive amount of solid wastes in form of lignocellulosic residue. These come from empty fruit bunches (EFB), palm press fiber (PPF), palm kernel cake (PKC), palm kernel shell (PKS), sludge cake or decanter cake and palm oil mill effluent (POME). Based on the percentage of fresh fruit bunch (FFB), the expected wastes are 20-28% EFB, 11-12% PPF and 5-8% PKS. These beside the high biomass residues of oil palm during replantation which account for 75 ton/ha [38]. Traditionally, the palm oil trunk was used as good material for furniture industry. Sawing and drying of palm wood are difficult because of density variation inside trunk and resulted in dimensional instability of the finished product and thus limited its application. Fronds are used in plantation and left to rot in between the raws for many purposes such as: soil conservation, increase the soil fertility, increase water retention in the soil, erosion control and to provide a source of nutrient to the growing oil palm trees [5].

On the other hand, palm oil mill solid wastes such as PPF and PKS are used as boiler fuel and significant fraction can be recycled inside the palm oil industry. Beside the direct energy generation by means of direction compustion, POME is also used as potential low cost carbon source for biogas production using thermophilic anaerobic microorganisms. It is estimated that for a mill in Malaysia discharging a capacity of 576 m^3 of POME per day, the cost for producing 1 m^3 biogas and 1 KWh electricity are US$ 0.05 and US$ 0.03, respectively [38]. The recent work of [39] showed also the possible production of bio-oil from EFB by means of fast pyrolysis process.

Beside this traditional use of oil palm waste in energy production, different new applications were also developed. Recently, oil palm fibers were used successfully for the production of activated carbon for many environmental and industrial applications[40,41]. Empty Fruit Bunches (EFB) were also used successfully as an alternative raw material to obtain cellulosic pulp [42-44]. More recently, EFB and oil palm derived cellulose were used in polypropylene composite for the production of biodegradable lignocellulosic filler. This form short fiber reinforced polymer composite and used in automotive interior components and geotextile [45].

Based on the high carbon content and high nutritional value based on the trances of vitamins, carotenes, fatty acids and high potassium content of palm oil mill effluent it is successfully used as soil fertilizers [46]. However, based on the high nutritional value of palm oil mill wastes, they are good feed supplements. POME could be used as ruminant feed at 10 to 20% of the diet and its quality could be improved by adding 5 to 6% ammonium hydroxide or urea and fermenting for two to three weeks. In industrial chemicals industries, empty fruit bunch (EFB) and oil palm trunk were also successfully treated by means of acid hydrolysis to produce xylose and glucose, respectively [47,48]. In general, the solid wastes from palm oil mills consist of three major components: cellulose (25 to 50%), hemiceillulose (20 to 35%) and lignin (18-35%). Thus, they can be used as substrate for production of many industrially important enzymes such as cellulases, hemicellulases and lignin peroxidases [49]. Moreover, based on the its high carbon to nitrogen ratio, POME is used as carbon source in culture medium for the production of many microbial metabolites such as: alcohols, organic solvents, [50], organic acids [51] and biopolymer [52, 53]. Pretreated POME (after removal of suspension solids and reducing ash content) were supplemented with ammonium sulphate to obtain the C:N ratio of 20:1 and used thereafter as cultivation medium for penicillin production by *Penicillium chrysogenum* [54].

As shown, many valuable products can be obtained from the leftover wastes in palm oil industry. The process involves many scientific and industrial fields ranging from agriculture, industrial engineering and biotechnology.

Future Prospect of Palm Oil: In the past decade, palm oil has become internationally well known as the most suitable vegetable oil for various food, chemical and pharmaceutical industries. This is brought about by it being versatile oil for the production of various products, with technical and economic advantages over other oils and fats. Its price competitiveness and readily available supply is able to serve the needs of oils and fats consumers worldwide.

Palm oil has the flexibility to be used as it is or in fractionated forms to produce a very wide range of products. Inter-esterification can further significantly modify its properties including crystallization behavior. It has good oxidative stability. It has long been known as a good heavy-duty frying medium because of its relatively low polyunsaturation and the slip melting point, which is low enough to avoid excessive waxiness in most applications.

The utilization of palm oil in products requiring a proportion of solid fats in their formulation would offer technical and economic advantages. Substantial cost savings can be achieved when palm oil is used to replace of other oils and fats in various applications.

Nowadays, there is strong competition between products derived from oleochemicals and those derived from petrochemicals. With the current awareness on environmental issues and preference for environmentally friendly products, the utilization of palm oil/palm oil products for energy production and substituting petrochemicals [1,4,55]. Due to the ready availability of raw materials, technology, capital and market demand, the nonfood applications of palm oil/palm oil products are expected to have a bright future. The future growth in the export trade for palm oil will depend on the continuing acceptance of palm oil products. Price competitiveness, technical and nutritional acceptance will be the key determining factors for continuing improvement in demand for palm oil. There appears to be no drastic change in the cost components in palm oil, in the next decade, especially when compared to other oils. It can thus be assumed that palm oil will continue to be competitively produced to meet the growing world market demand.

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