Technological Development and New Growth Areas of the Oil Palm Industry

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ABSTRACT

Technological development has transformed the Malaysian palm oil industry into a strategic and well planned industry that responds to global challenges. In particular, genetic knowledge since as early as 1912 first led the phenomenal growth of the industry through the planting of tenera *instead of* dura *palms. This was complemented by the government allocating land to the poor and landless to plant more oil palm, in great part causing the area to increase from 54 000 ha in 1960 to 1.02 million hectares in 1980 and 2.03 million hectares in 1990. By 2006, there were 4.16 million hectares of oil palm, constituting nearly two-thirds of the national agricultural area* (Table 1). *Malaysia continues to be the world's largest palm oil producer with a production of 15.90 million tonnes in 2006.*

The success of the crop is largely market driven with good long-term price prospects for palm oil making oil palm more attractive than most other crops. Palm oil contributes more than one-third of the national agricultural GDP, generating RM 31.81 billion in export earnings in 2006, making it one of the pillars of Malaysia's economy. At present, the industry employs more than 1.5 million people in the core and related sectors. This paper provides an overview of the technological developments which have propelled the industry into a strategic and important sector and which will shape the future of the oil palm agro industry.

ADVANCES IN PLANTING MATERIALS

The continued expansion in oil palm cultivation in Malaysia has been accompanied by continuing introduction of ever better planting materials. At present, there are 18 certified seed producing centres that conform to stringent technological standards with 12 of them solely producing seeds. In 1995, 56 million seeds were produced, increasing to 81 million in 2005. The demand for seeds has grown in tandem with the increase in area under new planting and replanting. Despite the availability of better planting materials, the Malaysian national yield has stagnated at below 20 t FFB /ha/yr for the last 20 years (*Figure 1* and *Table 2*). The current yield represents a gap of about 60% as the present planting materials have the potential of producing 8.8 t/ha/yr of palm oil (Jalani *et al.*, 2002). As indicated in *Table 3*, the low Malaysian fresh fruit bunch (FFB) yield is mainly dragged down by public agencies. Up to 35% or even higher yield can be expected with

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TABLE 1. OIL PALM PLANTED AREA: 1960-2006 (ha)

Year	P. Malaysia	Sabah	Sarawak	Total
1960	na	na	na	54 000
1975	568 561	59 139	14 091	641 791
1980	906 590	93 967	22 749	1 023 306
1985	1 292 399	161 500	28 500	1 482 399
1990	1 698 498	276 171	54 795	2 029 464
1995	1 903 171	518 133	118 783	2 540 087
2000	2 045 500	1 000 777	330 387	3 376 664
2001	2 096 856	1 027 328	374 828	3 499 012
2002	2 187 010	1 068 973	414 260	3 670 243
2003	2 202 166	1 135 100	464 774	3 802 040
2004	2 201 606	1 165 412	508 309	3 875 327
2005	2 298 608	1 209 368	543 398	4 051 374
2006	2 334 247	1 239 497	591 471	4 165 215

Sources: Department of Statistics, Malaysia: 1960 – 1985; MPOB: 1985 – 2006.

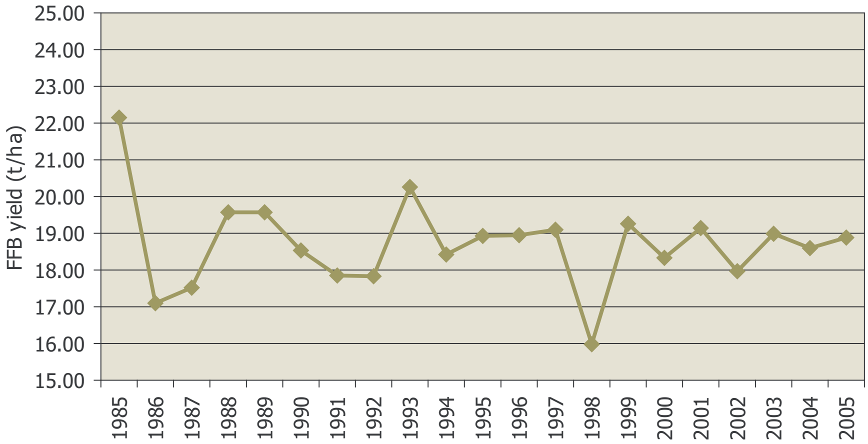

Figure 1. Fresh fruit bunch (FFB) yield (t/ha/yr) 1985-2005.

TABLE 3. FRESH FRUIT BUNCHES (FFB) YIELD BY AGENCIES (t/ha) 1995 AND 2005

Category	1995	2005
Private estates	20.13	20.30
Public agencies:		
1. FELDA	17.88	16.11
2. FELCRA	16.72	16.73
3. RISDA	16.67	12.09
4. State schemes/govt agencies	17.18	16.57
National average	18.93	18.88

Source: MPOB (various issues).

TABLE 2. PALM OIL YIELD BY COUNTRY (t/ha/yr)

	1995	2005
Malaysia	3.60	4.20
Indonesia	3.58	3.54
Nigeria	1.80	2.16
Colombia	3.31	3.88
Papua New Guinea	4.02	4.09
World	3.20	3.60

Source: Oil World (various issues).

the planting of clones. There are currently campaigns going on to increase the FFB yield and improve the oil extraction rate (OER) with a long-term goal of 35:25 (FFB yield of 35 t/ha/yr and 25% OER). This will be achieved through systematic replanting with good quality planting materials, especially by the public agencies.

BIOTECHNOLOGY

One important strategy to improve yields is to plant clones which produce more uniform and higher yield than the seedlings now planted from conventional breeding. MPOB has identified highly productive ortets (mother palms) for clonal propagation (*Table 4*) and developed protocols for liquid culture, which is more

TABLE 4. CLONAL PERFORMANCE (MPOB trials)

No.	Clone	Oil to bunch (%)	Oil yield (t/ha/yr)
1.	P164	30.6	8.71
2.	P162	29.31	7.80
3.	P135	28.39	7.56
4.	P194	29.09	7.75
5.	P149	30.8	7.25
6.	P200	29.1	7.74
7.	P203	30.8	8.01

efficient with minimal clonal abnormalities produced. MPOB has also developed molecular markers for detecting tissue culture abnormality and a tracking system for quality control and identification of clones. It is now working on a bioreactor for mass tissue culture.

MPOB ventured into biotechnology to give the oil palm industry a competitive edge. Today, MPOB has the most comprehensive biotechnology programme on oil palm in the world. Besides tissue culture, MPOB has also ventured into genetic engineering. However, no genetically modified oil palm has yet been produced commercially and Malaysian palm oil is still GMO-free. MPOB has developed tools and techniques for genetic engineering of oil palm. The tools and techniques include identification of enzymes in the pathway, isolation of relevant genes, isolation of promoters to ensure that the manipulated gene is targeted to the mesocarp and not other parts of the palm and the development of techniques for introducing the manipulated gene into the oil palm. MPOB is the first and only organization in the world to have high oleate and high stearate transgenic oil palm plantlets in the nursery (under strictly controlled conditions). In the area of genomics, MPOB has developed and presented to the industry for adoption, techniques on DNA fingerprinting and chromosome painting.

As far as biotechnology for oil palm is concerned, the short- to medium-term potential lies in effective propagation of high performance clones through tissue culture. In the long-run, genetically engineered oil palm with identified traits such as high oleic acid disease resistance and other selected characteristics will be desirable, especially when GMOs have become more acceptable to all.

OPTIMIZING LAND USE

Commercial oil palm planting is mainly monoculture with little livestock and crop integration (LCI) for fear of damaging the palms and causing a loss in yield. Yet, technological advances have shown that integrated farming is possible with livestock rearing and inter-cropping. There are already successful LCI programmes in various plantations in Malaysia. While oil palm remains the anchor crop, LCI will allow the industry to diversify and optimize its land use.

LCI requires the oil palm to be planted at wider spacing, as for example, in double avenues, which have been shown to have no adverse effects on yield. In-between, cash crops can be planted, even when the palms are at matured stage, and/or livestock reared (Yusof and Suboh, 1998), generating extra income throughout the life of the palms. Crops such as hill paddy, sweet corn, yam, yellow sugar cane, pineapple, melon, banana and even soyabean have been shown to produce reasonable returns to investment. Under-grazing mature oil palm with cattle has also been shown by MPOB to be economically and technically viable prompting 78 estates to venture into cattle rearing (Rosli, 1998). Apart from the extra revenue from selling the cattle, weeding cost can be reduced by grazing.

BIOLOGICAL CONTROL OF PESTS

To maintain productivity, pesticides are used to control pests. However, with increasing environmental concern and adverse effects of pesticides on human health, oil palm estates must adhere to adopting integrated pest management. This includes the use of biological control. The barn owl, *Tyto alba javanica*, for example is being encouraged to control rats (Smal, 1989) and *Metarhizium anisopliae* (a fungus) to control *rhinoceros* beetle, *Oryctes rhinoceros* (Ramle *et al.*, 2006). Against bagworms, MPOB has developed a biopesticide based on *Bacillus thuringiensis* (Bt) (Siti Ramlah *et al.*, 2005a, b). This Bt product is toxic only to the target insects but harmless to humans and non-target insects.

Parasitioids play a role in suppressing the bagworm population (Basri *et al.*, 1995). Several flowering plants common in plantations provide nectar for the parasitoids. Field studies showed that these parasitoids are highly attracted to the plant, *Cassia cobanensis* (Basri *et al.*, 2001). This is particularly so for the parasitoids associated with the bagworm, *Metisa plana*. Planting more *Cassia cobanensis* will encourage more of these natural enemies to control the bagworm (Basri and Norman, 2002). Technological developments in integrated pest management will, in the long-run, contribute towards sustainability of the oil palm industry.

MILLING TECHNOLOGY AND EXTRACTION OF BIOACTIVES FROM POME

Malaysia has the largest palm oil milling industry in the world. Palm oil production has increased from a mere 431 069 t in 1970 to 15.90 million tonnes in 2006, and is forecast to increase further to 16.6 million tonnes in 2010 and 20.5 million tonnes in 2020. The expected increases are envisaged to come from higher productivity through replanting of old palms with higher yielding materials, better plantation management and more efficient processing practices.

Technological development in palm oil milling is important to increase the efficiency of processing, reduce labour requirement and minimize the discharge of pollutants into the environment. In the past, palm oil mills caused severe air and water pollution and emitted stench. Today, all the 397 mills in the country with a combined annual capacity to process 86.24 million tonnes of FFB stringently adhere to the Environmental Quality Act on effluent discharge. The conditions have, in fact, become more stringent over time as better technologies for effluent treatment came about. Most of the mills now participate in the competency scheme of MPOB to produce quality products with better OER. The OER depends much on the quality of FFB. The grading standard developed by MPOB has helped mills improve their OER. There is no compromise now on unripe bunches with the mills refusing to accept them anymore. Many mills are also gearing up for ISO certification and GMP status. With the establishment of the Palm Oil Milling Technology Centre (POMTEC) at MPOB, new technologies are being developed. One of them is continuous sterilization (Sivasothy *et al*., 2005) which is more amenable to automation than the conventional batch processing and allow labour requirement to be reduced.

Research in MPOB has confirmed the presence of potent water-soluble antioxidants, mainly flavonoids and polyphenols, in oil palm mesocarp. During milling, these antioxidants are discarded with the effluent (POME). A simple process for extraction of the phenolics and flavonoids has been developed. Phenolics from oil palm present an exceptional opportunity for the Malaysian oil palm industry to enter the vibrant and rapidly growing, hundred billion ringgit nutraceuticals market. The phenolics and antioxidants extracted from POME have been found to have antioxidant properties and potent protective effects against cancer and atherosclerosis in animal and cell culture systems. Patents have been filed for the process and products, from this palm mill waste.

EXPANDING THE FOOD USES OF PALM OIL

Technological development in food applications has kept pace with the dynamism of the palm oil industry in satisfying consumer demand. Palm oil is now widely used in a wide range of food products. In the 1960s and early 1970s, Malaysia exported palm oil mainly in its crude form. In the mid 1970s, in line with the industrialization policy of the government, the country moved towards greater value addition by producing palm oil products in various fractions and refined forms for specific needs of the market. This entail developing the requisite technologies for refining, bleaching, deodorization, fractionation and related processes. Today, the refining sector in Malaysia has grown to become the biggest palm oil refining industry in the world with 51 refineries in total, able to process 18.50 million tonnes of crude palm oil (CPO) annually.

The main products of the refining industry include refined, bleached and deodorized palm oil (RBDPO), RBD palm olein, RBD palm stearin and palm mid fractions. These are mainly used for cooking or frying, shortenings, margarines, vanaspati (vegetable ghee) and confectionary fats. Palm oil is now widely consumed and represents one-quarter of the edible oils and fats consumed in the world. The major users are China, European Union, Pakistan, Egypt and India.

Palm oil is popularly used in both solid fat products as well as in liquid form as cooking oil, especially for industrial frying. It offers several technical advantages, such as resistance to oxidation, conferring a longer shelf-life to the products. Palm oil is ideally suited for shortenings and margarines as it has 20% – 22% solid fat content at 20°C, which helps in the formulation of fat products requiring a variable range in consistency. It tends to crystallize in beta-prime form with small crystals, a property desirable for many applications, in particular, table and industrial margarines. Palm oil also has other functional attributes that make it a valuable ingredient in food formulations. In many applications, palm oil can be combined with harder fractions such as palm stearin to produce products of the required consistency without hydrogenation. Common products made from palm oil and palm kernel oil, wholly or in blends with other oils, include frying and cooking oils, shortenings, vanaspati, margarines and spreads, confectionary and non-dairy products.

Besides the above traditional products, the changing trends in lifestyles and demands for novel consumer products based on convenience and health considerations have led to the development of new food products from palm oil and its fractions. MPOB has done its share of work in formulating new products to meet the demand. The new applications for palm oil in foods include being a specialty animal fats replacer (SAFaR™) for beef and chicken fat in sausages and burger patties. Exciting products from new processes such as red palm oil or red palm olein which contain high levels of carotenes have been introduced as healthy cooking and salad oils. Palm oil has also been blended with soft oils to produce a final product (Smart Balance™) with a 1:1:1 ratio of saturates, monounsaturates and polyunsaturates which satisfies the American Heart Association's Step 1 Dietary recommendation for a healthy diet. Some other food products from R&D still undergoing commercialization include palm-based low saturated oil with cold stability, palm-based mozzarella cheese and sprayable palm-based cooking oil.

FUNCTIONAL FOOD COMPONENTS: NEW GROWTH AREAS

Palm oil is an important source of natural minor components like phytonutrients such as carotenoids, tocotrienols, tocopherols, sterols and squalene. However, much of them are destroyed or discarded in conventional refining. Special processing conditions can be used to produce red palm oil with the carotenes retained. CPO contains 500-700 ppm carotenes, which are pro-vitamin A, and 600-1000 ppm tocopherols and tocotrienols (vitamin E). The carotenes may be extracted after transesterification of the oil into methyl esters (for biodiesel), while the tocotrienols and tocopherols gravitate as palm fatty acid distillate, a by-product of the physical refining process, and can be extracted by esterification, molecular distillation and ion exchange. Extraction of phytonutrients, including sterols and squalene, has been done using supercritical fluid/supercritical fluid chromatography.

These phytonutrients can be used as nutraceuticals, pharmaceuticals and food supplements. At present, only palm-based carotenes and vitamin E are commercially produced in Malaysia. The promise of these and other palm-based minor components in the health-related industries presents opportunities for the palm oil industry to add value to them.

OLEOCHEMICALS

Palm oil and palm kernel oil are used to produce oleochemicals. The Malaysian oleochemicals industry began in 1980 with a mere 10 000 t a year capacity, and has since grown to produce about two million tonnes a year, or 20% of the world production. This industry in Malaysia generated more than USD 1.3 billion in 2005 through the exports of mainly basic oleochemicals, *viz*., fatty acids, fatty esters, fatty alcohols, fatty amines, and glycerin and soap noodles. These basic oleochemicals are usually synthesized into derivatives which are then used to produce the end-products. Oleochemicals compete with petrochemicals in various applications. The advantages of oleochemicals over petrochemicals are their biodegradability and renewablility, which contribute towards environmental sustainability. With growing environmental sensitivity and with it, the increasing demand for eco-friendly products, palm-based products are beginning to gain greater popularity, especially with the recent sharp volatility in petroleum prices.

Technological development can be expected to move the present production of basic oleochemicals to higher value derivatives and even some end-products. Higher value derivatives are used in various industries such as textile, cosmetics, pharmaceuticals and plastic. Although fatty alcohols find limited use, their derivatives - fatty sulphates, fatty alcohol ethoxylates and fatty alcohol ether sulphates - are extensively used in the production of washing and cleaning products. Fatty amines are mainly used in the detergent industry as softening agents, in the mining industry as anti-caking agent, as biocides and in road building and other applications. Substitution of the non-renewable and synthetic petrochemical products by these 'green' oleochemicals is expected to increase, especially in Europe and the Americas.

Technology will also play an important role in expanding the use of oleochemical end-products hitherto produced from petrochemicals. End-products from oleochemicals include soaps, surfactants, polyols and polyurethanes, cosmetics and personal care products. In particular, it is expected that production of alpha sulphonated methyl ester for detergents will increase. This will be aided by palm-based oleochemicals being cheaper than their petroleum-based counterparts, and increased availability of methyl ester feedstock from higher production of winter biodiesel from palm oil.

Another product that is expected to feature prominently is palm-based polyol and the end-product, polyurethane. MPOB has, jointly with another party, patented a process to convert palm oil into polyol. The polyol can then be used to produce polyurethane by reacting with isocyanates using water as blowing agent. The world production of polyurethane in 2005 was about 13.7 million tonnes of which 4.9 million tonnes were flexible polyurethane. This volume of production would require about 3 million tonnes of polyol. There is therefore much potential in this area for substitution of petroleum-based polyol with palm-based polyol.

POTENTIAL OF BIOMASS

The oil palm industry in Malaysia produces about 100 million tonnes of biomass (wet weight) as empty fruit bunches, fronds and trunks. This rich resource has yet to be fully exploited. Technological development in the utilization of oil palm biomass will become important in the future as the potential is enormous. Oil palm is a *dual purpose forest* – besides producing oil, it is a prolific source of biomass and fibre which are available throughout the year. These can be used as raw materials to replace wood in value-added intermediate and finished products. Oil palm biomass is the answer to the growing concern over forest conservation. Technologies for the production of products such as pulp and paper, medium density fibreboard, moulded particleboard, oil palm plywood and other products are already available.

At MPOB, the Biomass Technology Centre has made good progress and launched a range of products. However, commercialization is still in its infancy. Some industry players can already produce good quality fibre strands from empty fruit bunches for use in mattresses, seats and insulation. The fibre can also be woven into mats for mulching and erosion control. These mats have been tested in China to alleviate the effects of sandstorms, combat desertification and for slope erosion control.

Another application of oil palm biomass is the production of plywood. Some 70 000 ha of oil palm are expected to be replanted annually, yielding 9 million trunks which can be converted into 1.6 million cubic metres of plywood. Production of pulp and paper from oil palm biomass will soon start with the setting up of a full scale commercial plant in Sabah.

Oil palm biomass is also a potential raw material for the chemical and biochemical industries. The cellulose component can be hydrolysed to yield glucose from which ethanol, citric acid, butanol and single-cell protein can be obtained through chemical and microbiological transformation. Hemicelluloses in the biomass can yield pentoses, especially xylose, which can be hydrolysed to produce xylitol, furfural, furan, resins and furfuryl alcohol. The lignin in oil palm biomass is a potential source of phenolic resins.

ENERGY

Besides the above uses, the biomass and oil can be used to produce energy. The biomass generated in palm oil mills, such as empty fruit bunches, fibre and shell, can be used to produce electricity. They are already used to produce steam, heat and electricity to the mills, and it is just a small step to send the power to the national grid. All palm oil mills are self sufficient in energy. Although the individual mill generates only about 1–2 MW electricity, their sheer numbers and the large volume of biomass available will make them inconsequential generating force for the country.

Anaerobic digestion of palm oil mill effluent produces biogas. It is estimated that about 20 000 m^3 of biogas can be obtained a day from a 60-t/hr FFB mill working for 20 hr a day. The technology is already available to harness the biogas from effluent ponds for power generation. If the biogas can be used for mill's own needs, the fibre and kernel shell can then be used to generate power for sale or for composite fibreboard production (Ravi, 2006). In the future, the carbon credits earned from the use of biogas and biomass for power generation may contribute further revenue to the country. For example, methane (biogas) will fetch about USD10 a tonne of tradable carbon under the Kyoto Protocol when it comes into effect in 2008.

Apart from solid and gaseous forms of energy, the palm oil industry is also a potential supplier of liquid energy. MPOB has shown that palm oil can be used directly as liquid fuel or used to produce biodiesel. Palm oil can be burnt directly in purpose-built Elsbett engines. During the 2001 plunge in palm oil prices, it was also shown that CPO can be blended with medium fuel oil to fire boilers, the blend tested in the power plant at Prai, Pulau Pinang. A blend of 5% refined, bleached and deodorized palm olein with 95% diesel can be used directly in normal diesel engines without any need for modification. Malaysia is currently preparing the regulatory framework to sell the diesel blend as *Envo diesel*, using an expected 0.5 million tonnes of palm oil annually.

However, the bigger potential is to convert palm oil into methyl esters (palm biodiesel). Road trials with buses have shown that the biodiesel can be a diesel substitute. The palm diesel plant can also extract beta carotenes and vitamin E (if CPO is used as feedstock) to enhance the viability of the biodiesel project. As more palm oil is used for energy, the demand for palm oil will increase. With the option to use palm oil for biofuel, there is now a safety net supporting the palm oil price. The future of the palm oil industry may well hinge on its development as a biofuel. Recognizing this, Malaysia and Indonesia have recently agreed to allocate up to 40% of their CPO production for biodiesel.

Biodiesel initiatives are multiplying throughout the world with increasing concern over energy security and the environment. In Europe, methyl esters from rapeseed oil as diesel fuel have had good acceptance. There are two driving forces for this. Firstly is the need to divert surplus rapeseed oil to fuel to dispose of stocks. Secondly, concern over global warming has stoked up public support for renewable fuels. New legislations and government incentives strongly support the use of biofuels, particularly biodiesel. The EU goal for biodiesel in transport is for it to constitute 2% of the total diesel consumption of about 160 million tonnes in 2005, increasing gradually to 5.75% in 2010. In Malaysia, the potential of palm biodiesel has attracted much investor interest. Some 65 licences have been approved for production with a total capacity of 10 million tonnes a year. One MPOB plant of 60 000 t a year capacity is already in operation, with the facility to produce 30 000 t of winter grade palm biodiesel, and another two similar ones in the offing.

FUTURE SCENARIOS

Palm oil is the most traded vegetable oil in the world. The demand for it will continue to increase with rising consumer income and population growth. The future scenario remains bright. Technology will pave the way for expansion of the palm oil industry by creating new uses for palm oil, developing new products, enhancing product quality, increasing food safety and increasing production efficiency and sustainability. More clones with ever higher yield potential and disease resistance will be planted. Genetically modified oil palm with high oleic oil will be introduced. The use of more environmental-friendly biocides will increase. Palm oil mills will become automated and more efficient. Livestock and other crops will be integrated with oil palm using double avenue planting. More blends of oil and fat products in the style of Smart Balance™ and SAFaR™ will be formulated to meet the varied nutritional demands by consumers. Efficient and cost-effective processes will be developed to extract phyto-nutrients from palm oil. More oleochemicals-based end-products will be commercialized. There will be increased commercialization of certain biomass products such as oil palm plywood. The palm oil industry will become a major source of energy from solid (biomass), liquid (palm oil) and gas (biogas from palm oil mill effluent).

CONCLUSION

Over the last four decades, palm oil has been the driving force in the world of edible oils and fats. Endowed with good technical attributes and economic advantage, it has seen off the keen competition to become the most produced and consumed oil. It beckons users by its price, technical superiority in a multitude of edible and non-edible applications and its assured year-round availability. Continued research and development is crucial for the industry to sustain its competitiveness edge, and, in this regard, technology will pave its way forward in shaping the future of the oil palm industry.

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