MOSTA
Malaysian Oil Scientists' & Technologists' Association

International Scientific Advisory Panel (ISAP)

ARTICLE #004

QUICK FACT SHEET ON PALM OIL (PO)

By

Academician Emeritus Professor Dato' Dr V.G. Kumar Das

QUICK FACT SHEET ON PALM OIL (PO)

By

V.G. Kumar Das

A. GENERAL

- Many claims are made about Palm Oil and deforestation, but a report by FAO brings clarity to this:
  Livestock industry accounts for 71% of global agricultural land use (3.9 billion ha). Of this 3.4 billion ha are for grazing, while 471 million ha are for producing animal feed. **Area occupied by oil palm in the world is only 15.6 million ha, or 0.3% of all agricultural land use.**
- Cultivated land area for oil palm: Indonesia: 6.0 million ha; Malaysia: 4.5 million ha.
- **Oil palm plantations are also effective carbon sinks that are efficient at absorbing carbon dioxide!**
- **Malaysia is the world's second largest producer, and a major exporter of PO. The country produces almost 20 Mt of PO per year, valued at approximately RM 72 billion. Sime Darby (~0.53m ha) and FELDA (~0.73m ha) are today the world's largest plantation companies (based on planted area).**
- **Oil palm, scientifically known as *Elaeis guineensis* jaq, is a unique crop as its fruit produces two distinct types of oils; crude palm oil from the mesocarp of the fruit and crude palm kernel oil from the kernel. Both of these oils, which are mainly made up of triglycerides, are chemically and physically different from each other with palm oil high in palmitic acid (C16 fatty acid) and palm kernel oil high in lauric and myristic acids (C12 and C14 fatty acids, respectively).**
- Palm clones planted in Malaysia & Indonesia: *Tenera* variety (a hybrid between the *dura* and *pisifera*);
  - Has the highest oil yield per ha: 4-5 tonnes of crude palm oil (CPO)/ha/yr and about 1 tonne of palm kernels.
  - Requires the lowest fertiliser inputs (~1MT of fertiliser per planted ha).
  - Productive cycle of ~25 years (peak production from 7 to 18 years).
  - Average cost of production in Malaysia (plantations): RM 1,220/ha (MPOB estimate)
- **Palm oil has become the most consumed vegetable oil in the world (35% as of 2016). Current worldwide production is estimated at 63 Mt crude palm oil (CPO) per year, or 36% of the total world vegetable production (USDA, 2014).**
- Wilmar International Limited, founded in 1991 and headquartered in Singapore, is today Asia's leading agribusiness group. It engages in oil palm cultivation and milling, and is one of the largest oil palm plantation owners in Indonesia and Malaysia (~240, 000 ha).
- In recent decades, the oil palm industry has witnessed a major breakthrough in oil palm research with the success of oil palm genome sequencing. The access to genome information has opened a new door for the crop improvement towards higher yield and

quality. The production of transgenic oil palm has been reported and this achievement has further created an opportunity towards genome editing technologies for application in breeding, and the realisation of designer oil compositions.

- "***By Jan 1, 2020, 100% of Malaysian PO supply will be certified under the Malaysian Sustainable Palm Oil (MSPO) certification programme, launched in 2015****. MSPO addresses the environmental, social and economic aspects of palm oil production, from the field to the final product.*
  The MSPO standard covers 7 areas: management commitment and responsibility; transparency; compliance with legal requirements; social responsibility; safety and employment conditions; environment, natural resources, biodiversity and ecosystem services; best practices; and development of new plantings." [Ref: 1]

- **Along with sustainability criteria, there is a growing consumer demand also for traceability criteria. This is a new challenge for palm oil which needs to be met, assisted by sophisticated imaging technology platforms and robust certification schemes**. A laudable initiative in this direction is Sime Darby's OPEN PALM TRACEABILITY DASHBOARD that provides critical information on the traceability of its supply chain to its key clients.

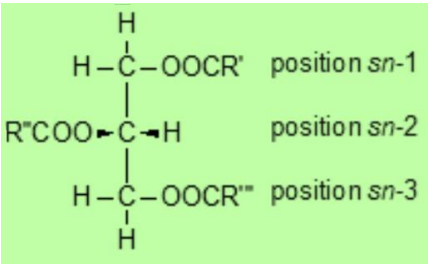
B. PALM OIL COMPOSITION: BASICS

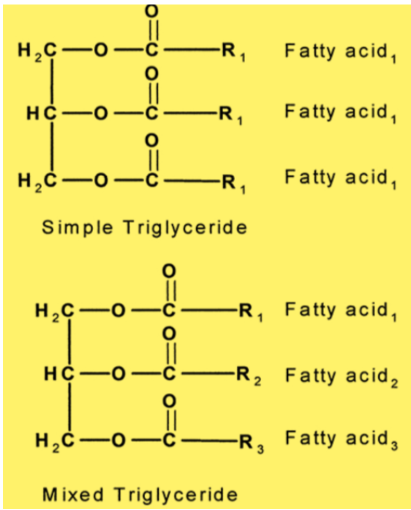
- Vegetable oils and fats are in chemical parlance called **lipids**, and they are essentially fatty acid esters of the glycerol molecule.

  The glycerol molecule, also called propanetriol, is a trihydroxy alcohol.

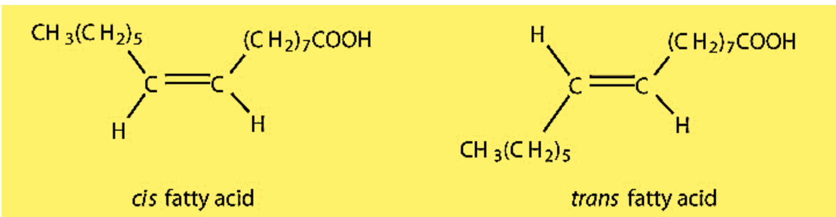
  Fatty acids (RCOOH) are mono-carboxylic acids which consist of hydrocarbon chains with a terminal carboxyl group.

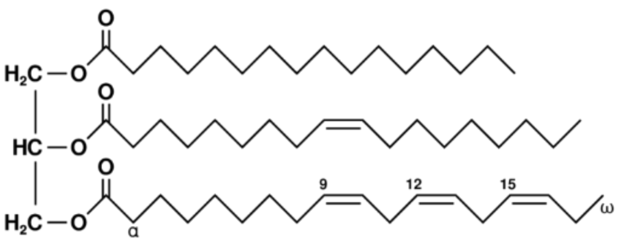
  The interaction between the alcohol hydroxyl (OH) groups and the fatty acid carboxyl (COOH) groups results in 'ester' formation. The triester product is called a triglyceride or triacylglycerol (TAG) if all the three hydroxyl groups of glycerol are esterified, a diglyceride (DAG) if only two hydroxyl groups are esterified, and a monoglyceride (MAG) if only one hydroxyl group is esterified.





- The hydrocarbon chains of fatty acids contain a mix of saturated, monounsaturated, and polyunsaturated fatty acids. The mono- and polyunsaturated fatty acids contain respectively single and double bonds between adjacent carbon atoms. The double bonds normally orient the connected carbon atoms all in the "cis" configuration, rather than in the "trans" configuration.





- **Palm oil has a balanced composition of saturated and unsaturated fatty acids: Saturated palmitic acid (C16:0; 44%), Monounsaturated (ω-9) oleic acid (C18:1; 40%), Polyunsaturated fatty acids [mostly the (ω-6) linoleic acid – C18:2; 10%].**
- **The natural disposition of the fatty acids on the glycerol backbone in palm oil is that the mid-point of the backbone (i.e. at stereospecific number 2: sn-2) is occupied mainly by the mono-unsaturated oleic acid (65%), and partly by the polyunsaturated acid (linoleic- 22%), but only to the extent of 13% by the unsaturated palmitic and stearic acids.**
- **When fractionated, PO yields a liquid fraction called palm olein and a solid fraction called palm stearin. Basically, there are two major grades of palm olein: standard olein and super olein (iodine value greater than 60).** Palm stearin is used in blends with other vegetable oils to obtain suitable functional products such as margarine fats, shortenings, vanaspati, etc. It is a useful natural hard stock for making trans-free fats. Besides edible usage, palm stearin also possesses suitable properties for making soaps and formulating animal feeds.
- **Standard palm olein has about 66% oleic (O), 30% linoleic (L), and just 4% saturated acids at the sn-2 position; the saturated acids - dominantly palmitic (P) - essentially occupy the sn-1 and sn-3 positions.**
- In palm olein (iodine value 60-64), the major triglycerides are POO (30.6%), POP (19.0%), PLO (13.6%), PLP (9.8%), and near-equal amounts (3-4%) of SOO, POS and PLL.
  POP and POO are also the major TGAs present in palm stearin, along with a significant amount of PPP.
- Palm olein confers health benefits akin to the so-called healthy olive oil (contains predominantly triolein, OOO, followed, in order of incidence, by POO, OOL and POL) – meaning no significant difference between them on human patients tested for BMI, serum total cholesterol LDL-cholesterol, HDL-cholesterol, fasting glucose, or insulin concentrations.
- It is to be noted that the predominant saturated fatty acid in most diets is palmitic (C16:0); it is cholesterol raising when compared with *cis*-mono-unsaturated fatty acid such as oleic acid (C18:1), which is considered neutral with respect to serum cholesterol levels.
  Stearic acid (C18:0) does not seem to raise serum LDL concentrations – this may be the result of its rapid conversion to oleic acid in the body.
- **Recent large scale cohort and randomized controlled trials (RCTs) on human subjects [Ref: 2-6] have revealed that the high health risk associated with consumption of saturated fat with regard to cardiovascular events and type-2 diabetes has been grossly overstated.**
  While saturated fats raise LDL in the blood stream in the short-term, a number of long-term observational studies have found no link between saturated fat consumption and LDL levels. It is also important to note that saturated fats can also raise "good cholesterol" HDL levels.

  Other salient points to note in this regard are the following:
  - The mechanisms whereby saturated fatty acids raise LDL cholesterol levels are not known, although available data suggest that they suppress the expression of LDL receptors.
  - LDL has two main sub-types**: small, dense LDLs** and **large, fluffy LDLs**; only the former can penetrate arterial walls easily, which drives heart disease; the small LDLs are also more susceptible to becoming oxidized, which is a crucial step in the heart disease process.

- Eating saturated fat changes the LDL particles from Small, dense to Large LDLs, that is, to the benign sub-type, even though the saturated fat can mildly raise LDL.
- **More than the LDL concentration and their particle size, there is now mounting evidence it is the <u>number of LDL particles</u> (LDL-p) floating in the blood stream that really matters: low-carb diets, which tend to be high in saturated fat, can lower LDL-p, while low-fat diets can have an adverse effect and raise LDL-p!!**

- **There is wide consensus among nutritional experts of the urgent need to undertake RCTs that compare effects of saturated fats derived from different food sources (plant, animal and dairy) on cardiovascular diseases and mortality across populations from different geographical regions.**

- In the interim, based on prevalent data from RCTs to which moderate to high quality evidence could be ascribed, WHO has recommended reduced intake of saturated fatty acids (SFA) in adults and children whose SFA intake is greater than 10% of total daily energy intake. {Energy content of foods: Macronutrient such as fat: 9 kcal/g; carbohydrates (including total sugars and dietary fibre): 4 kcal/g; protein: 4 kcal/g; alcohol: 7 kcal/g}

- Palm oil has high **carotene** content - 15x higher than carrots – 300-400 mg/kg oil; PO is naturally reddish in colour because of its alpha- and beta- carotene and lycopene content. However, crude red palm oil that has been refined, bleached and deodorized, a common commodity called RBD palm oil, does not contain carotenoids.
- Polymeric membranes have been successfully exploited for the effective recovery of carotenoids from crude palm oil.
- PO is known to be one of the most abundant natural sources of the fat soluble **vitamin E**, with composition of approximately 30% **tocopherols** and 70% **tocotrienols**; total content 500-600 mg/kg CPO. An average of 50 to 65% of the vitamin E content remains after refining.
- There are 4 forms of tocopherols and 4 forms of tocotrienols that make up Vitamin E, which is noted for its powerful antioxidant properties. While tocopherols have been more extensively studied, recent medical evidence shows tocotrienols have greater benefits when it comes to preventing brain cell death, particularly after stroke injury.
- **The unsaturated bonds in vegetable oils can easily be broken down by oxygen. This produces compounds that make the oil rancid. Rancidity produces off-flavours in foods. In the food industry, hydrogen is added to oils (in a process called hydrogenation) to make them more solid, or 'spreadable'.**
- Hydrogenated vegetable oils are not as likely to break down and will produce a product with a longer shelf life. Completely hydrogenated fat is solid at room temperature. Moderately hydrogenated fats are liquid at room temperature and contain more saturated fatty acids than the original oil.
- **Hydrogenation will convert "*cis*" double bonds to "*trans*" double bonds, producing trans fatty acids due to the heat used in hydrogenation**. Hydrogenated vegetable oil that is solid at room temperature can contain 15-25 percent *trans* fatty acids. Partially hydrogenated oils are lower in *trans* fatty acids. Margarines are often mixtures of both hydrogenated fats and un-hydrogenated vegetable oils.

- **Trans fatty acids (TFAs) can raise LDL cholesterol (the 'bad cholesterol") levels. At relatively high intakes they can also lower HDL (the "good cholesterol") levels. In addition, they produce inflammation in the body**. Indeed, noting that industrially-produced TFAs are the predominant source of dietary TFAs, the WHO has recommended that the daily intake of TFA in adults and children should be less than 1% of the total daily energy intake.

  [*It has been shown that TFAs increase the risk of atherosclerosis and coronary heart disease due to their in vivo effects in two ways. They effect the levels of prostacyclin and thromboxane, which increases the risk of thrombosis, and they increase sphingomyelin production by the body, which then causes calcium influx into the arterial cells to increase, leading to atherosclerosis*.]

- Naturally occurring TFAs are found in some animal products including butter, cheese and meat. The major one is called vaccenic acid (octadec-11-enoic acid). Butter contains about 4-11% *trans* fatty acids. Pomegranates are low in fat, but 70% of it is a *tran*s fatty acid called punicic acid (conjugated linolenic acid).

- **The U.S. Food and Drug Administration (FDA) has already moved to ban the use of partially hydrogenated oils, the main dietary source of <u>artificial</u> *trans* fats, after determining they are not safe to use in food.** The move by FDA likely means an increased amount of palm oil (a *trans* fat-free vegetable oil) in the diet of Americans and an opportunity for companies to source only palm oil that is deforestation and peat-free.

<u>Note on the digestion and absorption of fats [Ref: 7]</u>

*The major site of fat digestion in the digestive tract is the small intestine which receives pancreatic secretions and bile which aid its function through the hepatopancreatic duct. When consumed as a dietary fat, the TAG of palm oil gets hydrolysed by the enzyme **pancreatic lipase** to release fatty acids (predominantly from the sn-1 and sn-3 positions) and monoglycerides (dominantly 2-MAG). The enzyme, being water-soluble, only works on the surface of the hydrophobic fat globules. The digestion is aided by emulsification of the fat globules, that is, the breaking up of fat globules into small **emulsion droplets**. This occurs in the duodenum of the small intestine by the emulsifying action of bile salts. The motility in the small intestine further breaks up the emulsion droplets into smaller emulsion droplets which are prevented from coalescing by the bile salts and phospholipids present in the bile. **The emulsion droplets are where digestion really occurs**. Another factor that helps is colipase which helps to bind the pancreatic lipase at the surface of the emulsion droplet.*

*Following digestion, the poorly water soluble MAGs and fatty acids associate with bile acids and phospholipids to form **micelles** which are a couple of hundred fold smaller in size than emulsion droplets. **Micelles transport the MAGs and fatty acids to the surface (brush border membrane) of the enterocyte** (intestinal absorptive cell) where they are absorbed. Micelles constantly break and re-form; it is the non-polar free MAGs and fatty acids in solution, and not the micelles, that diffuse across the plasma membrane of the enterocyte. Once inside the enterocyte, MAGs and fatty acids are re-synthesised into TAG. The TAG is packaged, along with other lipids such as cholesterol and fat-soluble vitamins, into **chylomicrons** which are lipoproteins designed for the transport of lipids in the circulation.*

Chylomicrons flow into circulation via lymphatic vessels, which drain into the general circulation at the large veins in the chest. ***Chylomicrons thus deliver absorbed TAG to the body's cells.*** *An enzyme called lipoprotein lipase, found in capillary endothelial cells, is involved in the hydrolysis of the TAG into MAGs and fatty acids, which then readily diffuse into the cells.*

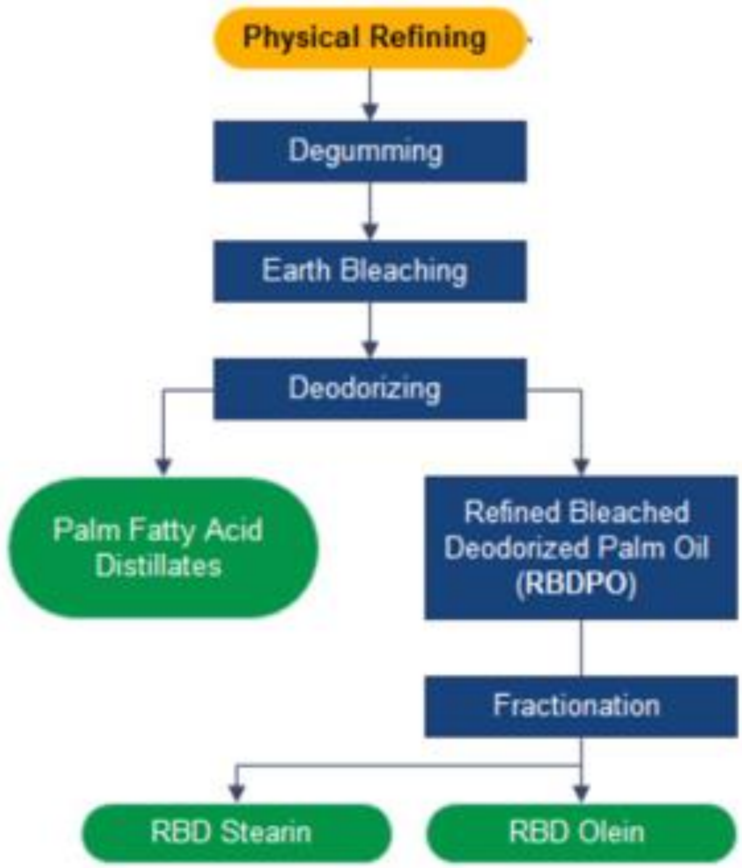
C. PHYSICAL REFINING OF CRUDE PALM OIL

Three key steps: Degumming, Bleaching, Deodorizing

- In degumming, the gum and fatty acid in crude palm oil and crude palm kernel oil are separated together with other impurities such as trace minerals, copper and iron by the application of phosphoric acid. Gums or phosphatides are responsible for high refining losses due to their emulsifying properties and they decompose, darkening the oil due to their thermal instability.

- In bleaching, the oil is mixed with bleaching earth (bentonite –calcium montmorillonite) in a vacuum environment (50 to 125 mm Hg) at room to remove impurities and colour pigments in the palm oil.
- In deodorizing, the odour and taste of the oil are removed when the oil is steamed at high temperatures of between 240°C to 260°C and then cooled to room temperature.

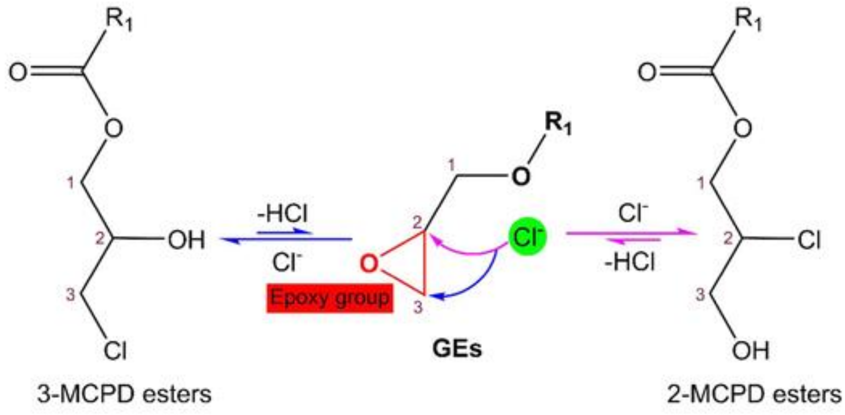
- **Glycidyl fatty acid esters** (GEs), one of the main contaminants in processed oils, are mainly formed during the deodorization step in the refining process of edible oils due to the high temperature, and therefore occur in almost all refined edible oils. GEs, among them the chloropropane diols, 2-MCPD and **3-MCPD**, are potential carcinogens, due to the fact that they readily hydrolyse in the gastrointestinal tract into the free form glycidol, which has been identified as "a possible human carcinogen" [Ref: 8].



- Relatively higher levels of 3-MCPD esters have been reported in palm oil (~2.9 ppm). Their removal from the final refined oil is dependent upon the efficiency of the deodorization process. DAGs and MAGs were found to increase the potential of palm oil to form 3-MCPD and glycidyl esters.

- In the oil deodorization step, apart from deodorization temperature and time, the stripping steam rate can also influence the formation of GEs - a water flow rate higher than 2.0 mL/min lowers the GE content despite the high temperature because of the increased mass of distillation vapor from oil to cooler which may contain MAGs, DAGs and even GEs.

- Based on results from refining studies (32 pilot plant trials, 200 kg batch) conducted at MPOB, the possible factors that contribute to the formation of 3-MCPD esters besides the deodorisation temperature are as follows: acidity (dosage of phosphoric acid); type of bleaching earth (natural versus acid activated); and chloride levels.
  Measures to minimize 3-MCPD and glycidyl esters have been prescribed by MPOB to mills, including particularly identification and elimination of sources of chloride ion contamination [Ref: 9].



- The best quality red palm oil is processed using molecular distillation processes; the levels of 3-MCPD and glycidyl esters are almost non-existent in such products. The molecular distillation process is carried out at a very low pressure so that the distance between hot and condensing surface is less than the mean free path of the molecules.

References

[1] Global Oils & Fats Business Magazine, vol. 14 (4), 2017, editorial pages 6- 7.
[2] L. Hooper *et al*: Cochrane Database Systematic Review, 2015
[3] R.J.de Souze *et al*: British Medical Journal. 2015
[4] P.W. Siri-Trino *et al*: Amer. Journal of Clinical Nutrition, 2010
[5] R. Chowdhury *et al*: Annals of Internal Medicine Journal, 2014
[6] U. Schwab *et al*: Food & Nutrition Research, 2014
[7] *https://courses.washington.edu/conj/bess/fats/fats.html]*
[8] IARC: Some industrial chemicals. IARC monographs on the evaluation of carcinogenic risks to humans Vol. 77 2000, p. 469-486. WHO Press, Lyon
[9*] http://www.mpob.gov.my/images/stories/pdf/2014/2014_3mcpd.pdf*