Properties and Utilization of Palm Kernel Oil

Pantzaris, T P* and Mohd Jaaffar Ahmad*

INTRODUCTION

In the world of oils and fats, the lauric oils are the aristocrats. There are very few of them, they move in their own higher price plateau and they do not mix comfortably with the common oils and fats.

Among the 17 major oils and fats in world trade, there are only two lauric oils, coconut oil (CNO) and palm kernel oil (PKO) (Oil World Annual, 2000) and they are called lauric because lauric acid is the major fatty acid in their composition at about 50%, while no other major oil contains more than about 1% (butter fat contains 3%). This paper is intended to give a brief outline of the properties, uses and some economic aspects of PKO.

The Origin of Palm Kernel Oil (PKO)

PKO is very similar to CNO in fatty acid composition and properties. The two trees also look rather similar, both are called palms but they belong to different species. The coconut palm is *Cocos nucifera,* while the oil palm which gives both palm oil (PO) and PKO is *Elaeis guineensis* (Hartley, 1988). This tree is generally believed to have originated in the jungle forests of East Africa and there is some evidence that PO was used in Egypt at the time of the Pharaohs, some 5000 years ago (Cottrell, 1991), but now its cultivation is confined mostly to Southeast Asia.

The variety cultivated in nearly all the world's plantations is the hybrid *Tenera* - the cross between *Dura* and *Pisifera*, which gives the highest yield of oil per hectare of any crop. The great economic efficiency of the oil palm is easily seen from the following simple calculation. Soyabean cultivation in the USA for example, gives a yield of about 2.5 t of beans per hectare (1 ha = 2.47 ac), which translates into about 0.5 t of oil and 2 t of meal. Taking the monetary value of the meal at about half that of the oil, the total income to the farmer is equivalent to 1.5 t of oil. In Southeast Asia, oil palms yield about 4 t of PO, plus 0.5 t of PKO, plus 0.5 t of palm kernel meal, with income equivalent to more than 4.5 t of oil. Roughly for every 8 t of CPO produced at the mill, about 1 t of PKO is produced.

The palm fruit looks like a plum. The outer fleshy mesocarp gives the PO, while the kernel, which is inside a hard shell, gives the PKO and it is rather strange that the two oils from the same fruit are entirely different in fatty acid composition and properties. Unfortunately, the two oils had often been confused by nutritionists in earlier days. In PO, most of the fatty acids are C16 and higher, while in PKO, they are C14 and lower. PO has iodine value (IV) 50 minimum, while PKO has 21 maximum (Codex Alimentarius Commission, 1999). Semi-solid in temperate climates, PKO can be fractionated into solid and liquid fractions known as stearin and olein respectively. These are then physically refined, bleached and deodorized or chemically neutralized, bleached and deodorized to give the RBD and NBD grades used in the food industry. The fractionation can be done either before or after the refining, according to circumstances.

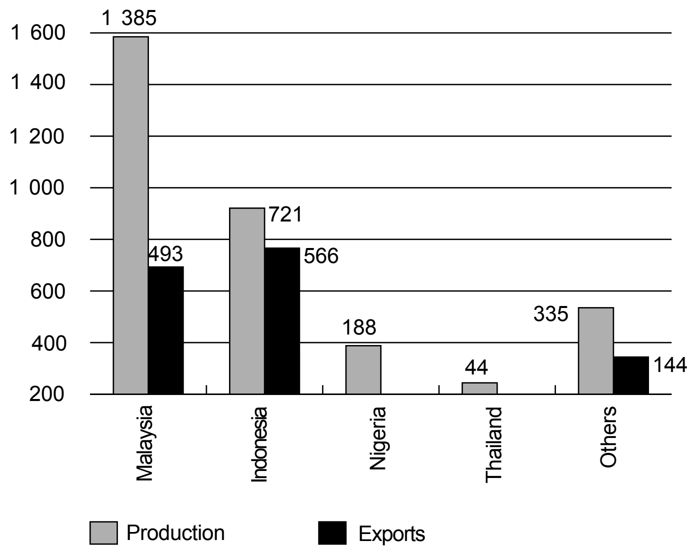
PRODUCTION AND EXPORTS

The oil palm only grows well in tropical climates and so all the palm kernel producing countries are in Southeast Asia, Sub-Saharan Africa and South America (Oil World Annual, 2000).

Figure 1 shows the production and exports of the top four producing countries and as it may be seen, the largest producer by far is Malaysia, which currently accounts for more than 50% of world production, while two countries, Malaysia and Indonesia together, account for about 80% of production and 88% of exports. No other country produces more than 7% or exports more than 3% of the world total.

Many people in commerce will remember that until the mid 1970s, Nigeria was the world's largest producer of palm kernels while Europe did most of the

* Malaysian Palm Oil Board (Europe)
Brickendonbury, Hertford, SG13 8NL, UK.



Notes: world total production = 2.67 million tonnes.
world total exports = 1.20 million tonnes
Source: Oil World Statistics Update (9.2.2001).

Figure 1. PKO: major producing and exporting countries, 2000 ('000 t).

crushing and was therefore, effectively the world's largest PKO producer. But now all the crushing is done in the producing countries and Europe does no palm kernel crushing at all.

In 1977/78, Malaysia overtook both Nigeria and Europe to become world's biggest producer of palm kernels and of PKO. However, in the last few years, her oleochemical industry has been absorbing very large and increasing quantities of the oil and her lead in exports has been reduced. In fact, Indonesia's exports were higher than Malaysia's in 2000.

With PKO and CNO having very similar properties and competing with each other in the world's markets, their relative production volumes and growth rates are important. The trade publication, *Oil World* gives some interesting statistics on PKO from the earliest days of its production. In 1970 for example, world PKO production was only about 380 000 t or less than 20% of CNO, which stood at 2.0 million tonnes. But since then, PKO being a co-product of PO has been growing at a much faster rate (6.7% annually against 1.6%), and in 2000, it reached 2.7 million tonnes or 81% of CNO. By the year 2015, the forecast is that PKO will overtake CNO with 4.6 million tonnes against 4.4 million tonnes (Oil World 2020, 1999).

COMPOSITION AND PROPERTIES

The major fatty acids in PKO are C12 (lauric acid) about 48%, C14 (myristic acid) about 16% and C18:1 (oleic acid) about 15% (Codex Alimentarius Commission, 1999). No other fatty acid is present at more than 10% and it is this heavy preponderance of lauric acid, which gives PKO and CNO, their sharp melting properties, meaning hardness at room temperature combined with a low melting point (Pantzaris, 2000). This is the outstanding property of lauric oils, which determines their use in the edible field and justifies their usually higher price compared with most other oils. Because of their low unsaturation, the lauric oils are also very stable to oxidation. *Table 1* shows the fatty acid composition of PKO, its similarity to CNO and their differences from PO, the co-product of PKO and typical non-lauric fat.

Even after full hydrogenation, the melting point of PKO does not rise much above mouth temperature and fractionation gives a stearin which is even sharper melting. Sharp melting fats leave a clean, cool, non-greasy sensation on the palate, impossible to match by any of the common non-lauric oils. Cocoa butter and palm mid fraction (PMF) come to mind, but they are much more expensive and PMF is a manufactured (fractionated) speciality fat and not a major oil in world terms.

TABLE 1. FATTY ACID COMPOSITION OF PALM KERNEL, COCONUT AND PO MEAN VALUES (%)

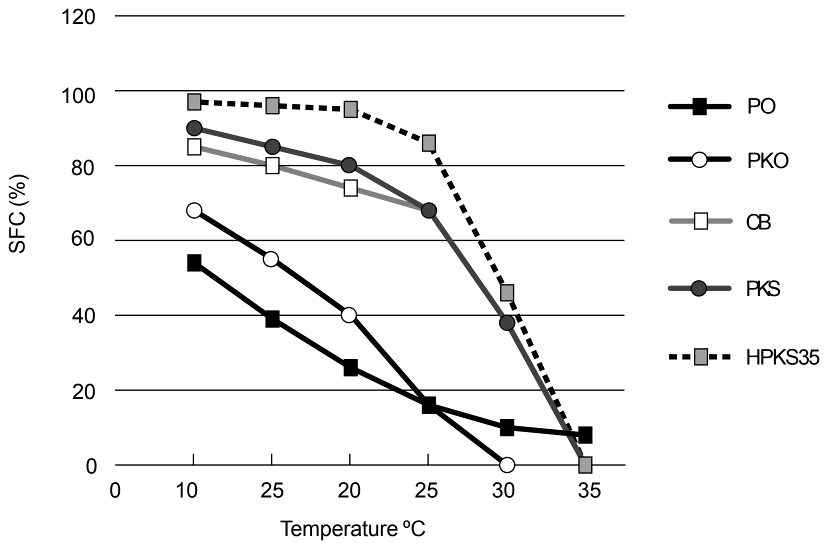
Fatty acids	PKO[1]	CNO[2]	PO[3]
C6	0.3	0.4	-
C8	4.2	7.3	-
C10	3.7	6.6	-
C12	48.7	47.8	0.2
C14	15.6	18.1	1.1
C16	7.5	8.9	44.1
C18	1.8	2.7	4.4
C18:1	14.8	6.4	39.0
C18:2	2.6	1.6	10.6
Others	0.1	0.1	0.75[4]

Notes: [1]PORIM Survey 1984, n = 68.
[2]Leatherhead Food RA, Surrey, UK, Survey 1990, n = 35.
[3]PORIM Survey of RBD PO 1989, n = 244.
[4]Others = C18:3 0.37%, C20:0 0.38%.

The best method for assessing the sharpness of melting of a fat is organoleptically by a trained panel or even better by an outstanding individual. But the information so obtained cannot be communicated or stored in quantitative terms and so for that purpose, technologists rely on the solid fat content (SFC) values at various temperatures. *Figure 2* shows the melting behaviour in terms of SFC values of PKO, palm kernel stearin (PKS) and hydrogenated PKS of melting point 35ºC (HPKS 35), together with cocoa butter (CB) and PO for comparison. The data for the graphs are average values calculated by us from Malaysian manufacturers' specifications.

Although only three basic products are made from PKO, *i.e.* PKO itself, palm kernel olein (PKOo) and PKS, there are also their hydrogenated and blended versions which complicate the picture considerably. The simplest way to distinguish between them is from their IV/SMP relationships and an almost complete characterization can be made by examining also their SFC profile and fatty acid composition.

The characteristics of PKO, PKS and PKOo are covered by Malaysian Standards (Department of Standards, 1987;1988a,b) which like all standards, give a range of values for each property. *Table 2* gives the important values from those standards but for the fatty acid composition and SFC, for the sake of clarity, we give the mid range values rounded to the nearest 0.5. One point worth mentioning here is that the Malaysian Standards are set from the results of large detailed surveys carried out by the Palm Oil Research Institute of Malaysia (PORIM), which is now known as Malaysian Palm Oil Board (MPOB) at regular intervals, from samples taken from processing plants and bulking installations throughout Malaysia. They are based therefore on a solid, scientific and verifiable foundation unlike the case with most other oils.



Note: average values from Malaysian Manufacturers' Literature.

Figure 2. SFC of cocoa butter, PKO product and PO.

TABLE 2. MALAYSIAN STANDARDS FOR PKO, PKS AND PKOo

	PKS[1] MS1437:1998	PKO[2] MS 80:1987	PKOo[3] MS1436:1998
Iodine value (Wijs)	5.8 - 8.0	16.2 - 19.2	20.6 - 26.0
SMP point (ºC)	31.3 - 33.1	25.9 - 28.0	21.8 - 26.0
Fatty acid Composition %[4]			
6:0	0	0.5	0.5
8:0	2	4.5	4.5
10:0	3	3.5	4
12:0	56.5	48.5	44.5
14:0	22.5	15.5	14
16:0	8	8	9
18:0	2	2	2.5
18:1	6	15	18
18:2	1	2.5	3
Others	0	0	0
Solid fat content % (NMR)[4] 5ºC	91.5	73	63.5
10ºC	90.5	67.5	55
15ºC	88	55.5	38.5
20ºC	81.5	40	20.5
25ºC	65.5	17	6
30ºC	33	0	0
35ºC	0	-	-

Notes: [1]n = 49, [2]n = 118, [3]n = 52
[4] Values are mean for PKO and mid range for PKS and PKOo.
These values have been rounded to the nearest 0.5. Percentages may not add up due to rounding.

Also many Malaysian Standards give not only the sample ranges but also the mean, standard deviation and sample size and so in this respect also, they are superior to those of most other oils, which only give range limits. It is well known from elementary statistics, that the sample range is a crude and inefficient measure of variability, while with the mean and standard deviation, one can calculate statistical ranges, estimate the probability of any particular deviation and carry out many statistical tests.

From *Table 2,* it may also be noted that the C12 content is highest in the stearin and lowest in the olein. The level of this fatty acid is therefore an important index of fractionation efficiency and of the quality of the product. The differences in their melting profiles are obvious. In practice, two qualities of PKS are made: one with IV 6-8 and SMP about 31ºC-33ºC and the other hydrogenated to IV below 2 and SMP about 34ºC-36ºC. Proprietary brands may be based on blends of the two and may also contain emulsifiers for enhanced performance in particular applications, such as bloom resistance or viscosity reduction in coatings.

Hydrogenated PKOo can be made to resemble the SFC profile of PKO and hydrogenated PKO, but the SFC curve will not be quite as steep, the C12 content will be somewhat lower and the mouthfeel will be a little inferior. But in practice, only some very keen tasters can tell the difference. It is worth noting that with PKO (contrary to the case with PO), the most valuable product is the stearin and the least valuable one is the olein.

By blending the basic PKO products (oil, olein and stearin) in different proportions, hydrogenating to different melting points, and/or interesterifying, a large number of graduated speciality products can be made for the same end-uses but offering different performance/cost combinations. These are the differences which distinguish the branded products of different manufacturers.

A note on health aspects may be appropriate here. PKO is about 82% saturated which is much more than the major liquid oils such as soyabean, which is only 16% saturated or sunflower oil, 12%, saturated (Codex Alimentarius Commission, 1999). Nutritionally, this may be thought of as a great disadvantage, but such simplistic comparisons are misleading. Lauric oils are only used in foods where a sharp melting hard fat is needed and when liquid oils are hydrogenated to a similar consistency, they form not only more saturates but also *trans* fatty acids which some recent studies have shown may be even more objectionable in regard to blood cholesterol profiles than the saturated ones (Bayers, 1997; Pietinen *et al.*, 1998). Another important consideration is that because of their higher price and special properties, the lauric oils are only used where clearly necessary and so only reach a very low level in our diet. In West Europe, for example, in 2000, annual per capita disappearance (use for all purposes including oleochemicals, soap and waste) for both lauric oils combined, was 3.2 kg against 44 kg for the non-laurics (Oil World Annual, 2000), and so the amount used for edible purposes is probably below 2.5 kg.

Malaysian PKO bought from origin is usually traded according to the Malaysian Edible Oils Manufacturers' Association (MEOMA, 2001) or FOSFA specifications (FOSFA, 1994). The same bodies also set the trading specifications for the other major products derived from palm kernels, such as palm kernel meal, PKS, PKOo and palm kernel fatty acids. The MEOMA specifications for PKO products are shown in *Table 3* and it is worth noting that the upper limit for IV is much lower than that in Codex, thus ensuring better quality.

USES OF PALM KERNEL OIL (PKO)

Because of their similarity in composition and properties, PKO has similar uses to CNO in both the edible and non-edible fields, but there are some small differences which are worth noting.

PKO is more unsaturated and so can be hydrogenated to a wider range of products for the food industry, while CNO has a somewhat greater content of the

TABLE 3. MEOMA SPECIFICATIONS FOR EXPORT MARKET

	Crude PKO	Crude PKOo	Crude PKS
FFA (as lauric acid)	5% max	5% max	5% max
M&I	0.5% max	0.5% max	0.5% max
Iodine value (Wijs)	19 max*	21 min*	8 max*
	RBD PKO	**RBD PKOo**	**RBD PKS**
FFA (as lauric acid)	0.1% max	0.1% max	0.1% max
M&I	0.1% max	0.1% max	0.1% max
Iodine value (Wijs)	19 max*	21 max	8 max
Colour (51/4" Lovibond cell) Red	1.5 max	1.5 max	1.5 max

Note:*at the time of shipment.
Source: MEOMA Handbook 2000-2001.

more valuable shorter-chain fatty acids which make it usually a little more attractive to the oleochemical industry.

PKO and its hydrogenated and fractionated products are widely used either alone or in blends with other oils for the manufacture of cocoa butter substitutes and other confectionery fats, biscuit doughs and filling creams, cake icings, ice cream, imitation whipping cream, sharp-melting creaming and table margarines and many other food products.

SPECIALITY FATS - COCOA BUTTER SUBSTITUTES (CBS)

Speciality fats are used extensively in the food industry for applications where specific physical and chemical properties are important. For this reason, the requirements placed on these fats are different from those placed on general purpose oils. Most confectionery products for example, have a high fat content and as a result, their melting behaviour in the mouth is critical.

One of the most important classes of speciality fats is that of cocoa butter substitutes (CBS) for which the standard of comparison is cocoa butter (Pantzaris, 2000). They can be divided into two basic types, lauric and non-lauric. These fats must have not only a very steep SFC profile but must also melt in the appropriate temperature range. For this property, the non-lauric type rely on a high content of *trans* fatty acids, while the lauric type rely on a high content of lauric acid - here we exclude the cocoa butter equivalents (CBE) which form another class with somewhat different uses. The physical properties of PKS resemble particularly closely those of cocoa butter and it is generally acknowledged that the best type of CBS as opposed to CBE, are made from this fat. Substantial quantities of PKO are therefore fractionated in Europe, USA and Malaysia for this purpose.

Coconut stearin on the other hand, while having exceptionally sharp melting properties and mouth feel, has a lower melting point, is obtained at lower yield and is more costly to produce. Its uses therefore, are restricted to a small number of luxury products.

Hydrogenated PKS of SMP about 35ºC has even higher SFC at 20ºC than cocoa butter, it gives higher contraction on cooling and tolerates better the softening effect of full cream milk powder. These properties make it especially suitable for hollow moulded chocolate confectionery such as Easter eggs, moulded bars and the finest biscuit creams.

Hydrogenated PKO products with and without interesterification, of SMP 30ºC - 38ºC (according to climate) are used for their lower cost, but their SFC profile is flatter and they are of lower quality than PKS. Nevertheless, most substitute chocolates for biscuit coating and cakes are made from these fats. Even lower cost coating fats and filling creams are made from hydrogenated PKOo. The SFC profiles of some confectionery fats are shown in *Figure 2.*

FILLING CREAMS

These products are essentially made of sugar, milk powder and fat, with a fat content of about 24%-28%. The finest creams for biscuits, wafer fillings and cakes are made from PKO or CNO stearins but these fats are only used in luxury brands. In the vast majority of cases, filling creams are made from PKO, PKOo and their hydrogenated versions. Important considerations here are adhesion to the biscuit shells and rate of setting. Lauric fats, because of their shorter chain length, set faster than non-lauric ones and so the freshly made cream biscuits in a factory, for example, can be transported on conveyors, handled and packed without coming apart or sheering off-centre.

Toffees and Caramels

These two products are very similar to each other and essentially consist of boiled sugar and glucose, but usually some fat is also incorporated in their formulations in order to adjust their texture, hardness, chewiness and richness of taste. A further advantage of fat incorporation is that it delays sugar inversion during storage and reduces stickiness on wrapping materials (Pantzaris, 2000).

The fats used are usually based on hydrogenated PKO (HPKO) or hydrogenated PKOo (HPKOo), because of their sharp melting properties and long shelf-life. Incorporating some PKS in them gives even better eating quality.

Ice-Cream

PKO and CNO are the best fats for non-dairy ice cream because of their combination of high SFC at about 0ºC, low melting point and perfectly bland taste (Pantzaris, 2000). Surprisingly, ice cream is particularly sensitive to any flavour notes from the fat.

Similarly, CNO and PKOo are used to make the chocolate for dipping ice cream. This chocolate is made by diluting standard chocolate with extra fat. The product must have low viscosity and yet set quickly so that the ice cream does not melt too much and drip into it. The operation is quite finely balanced.

Imitation Whipping Creams

This product is very critical in its fat requirement because it must whip quickly to a high volume and hold that volume for many hours with as little shrinkage and seepage as possible. Pure HPKO, PKS and their blends are the standard fats used.

see p.19

from p.15

Non-dairy Creamers (coffee whiteners)

These powder products have a very large surface area in relation to their mass and yet are required to have long shelf-lives. Hydrogenated PKO and CNO are the most suitable fats because when reduced to an IV below about 2, they have extremely high oxidative stability and yet reasonably low melting point. Most of the leading international brands of non-dairy creamers are made with HPKO.

Filled Milk

This is a widely used product in which the milkfat has been replaced by vegetable fat. In many respects, it is similar to non-dairy creamers, but with a lower fat content. CNO has been the traditional fat in this application, because of its high stability, low melting point and bland taste but increasingly now, it is being replaced by PKO or hydrogenated PKOo, when there is a price advantage. Hydrogenated PO is also used for lower cost.

Margarines

Special margarines which whip easily to produce light filling creams for use in layer cakes and other bakery products rely on high levels of lauric fat to confer good eating and handling properties.

Other general purpose and table margarines often contain PKO or hydrogenated PKO to give them quick melting properties or compensate for the use of other higher melting fats or for the absence of *trans* fats which are also sharp melting.

A recent study of table margarines in Spain has found that those based on higher levels of lauric and palm fats had much lower *trans* fatty acid and higher polyunsaturated content than the other margarines made from blends of partially hydrogenated and non-hydrogenated seed oils (Alonso *et al.,* 2000).

Medium Chain Triglycerides (MCT)

This is an important speciality product made from lauric oils or rather from the fatty acids of these oils. They are usually referred to as MCT and are based on C8 - C10 chain lengths. Their shorter chains and full saturation give them very low viscosity and high oxidative stability. But their main use is in hospitals, *etc.,* for cases where the patients cannot metabolize conventional fats in the usual way. MCT are metabolized by a different pathway. A certain amount of fat is essential in human diets to carry the fat soluble vitamins and synthesize the prostaglandins, *etc.,* and MCT meet the first of these functions at least.

CNO contains much more MCT than PKO. The usual method of manufacture is to start with the lauric acid oils or the distilled C8 and C10 saturated fatty acids and esterify with glycerol. The MCT content can then be further concentrated by further processing.

NON-FOOD USES

Most of the PKO from world production is of course used for food, but the non-food uses are very substantial and becoming of increasing importance because, on the whole, these products are further downstream and offer greater added value to the manufacturers and greater opportunities for local employment in the producing countries. Also, their world markets are easier to penetrate since they do not depend on national tastes and subjective preferences.

Suppositories

This is another important pharmaceutical use of PKO products. Suppositories are designed to supply various medicines through the rectum, where supplying by mouth or by injection is for some reason, less acceptable.

The most appropriate fats are hard, sharp melting ones, SMP 35ºC-37ºC and cocoa butter has been the traditional one. However, CBS, like HPKS or HPKO, offer advantages in ease of production, less discolouration over time, have no need for tempering, their consistency is more easily adjusted and also have lower cost. Cocoa butter does not offer any extra advantages and where it is still used, it is because of tradition, or the difficulty and expense of obtaining licence for a new product.

However, the main non-food uses of lauric oils are in soap and certain oleochemicals, such as: fatty acids, methyl esters and fatty alcohols. Strictly speaking, soap itself is also an oleochemical and the oldest one, but it is usually classed separately since it has an entirely different appearance, uses and market.

Soap

Many different oils can be used for soap making but a proportion of lauric oil is indispensable. Good soap must contain at least 15% lauric oil for quick lathering. Soap in West Europe and USA typically contains 20%-25% PKO or CNO, while soap made for use in sea water is based on virtually 100% lauric oil. Lauric oils confer hardness, combined with good solubility (which in other fats are inversely correlated), quick lathering and a feel of quality to the soap. Also their higher resistance to oxidation helps delay rancidity and deterioration of the perfume, which is a very major consideration in toilet soap.

CNO, being older, has been the traditional fat for this application, but now PKO is used interchangeably with CNO according to price and in fact with some subtle advantages. *Table 4* gives a brief summary of the soap making properties of some fats and of course, these properties follow from their fatty acid composition. Palmitic (16:0) and stearic (18:0) acids confer hardness, lower solubility and slower though more persistent lather. The saturated shorter chain C12 and lower fatty acids confer hardness with greater solubility and quicker, though less persistent lather. However, the very short-chain fatty acids C10 and below can also be irritating to sensitive skins and so their level must be kept very low. This is the advantage of PKO over CNO, which was referred to earlier. Super-fatting the soap will also reduce any tendency to skin irritation.

Myristic acid (C14:0) is usually considered the ideal soap making fatty acid in its combination of properties, but it is not very plentiful in nature. Nevertheless, PKO and CNO contain more of it than any other of the major oils and fats and it may be worth noting that a blend of 50/50 C12/C16 fatty acids has an average molecular weight equal to C14.

Of particular interest to commercial soap makers is PKOo which has very similar fatty acid composition to PKO and yet always sells at a discount to it. MPOB experiments as well as industrial experience have now confirmed that it can replace PKO without any noticeable difference.

Malaysia has a soap making capacity of about 230 000 t annually which is exported mainly in the form of *noodles*. This product offers some very useful advantages to soap producers especially those contemplating expanding their present plants or entering production for the first time with limited capital availability.

Production of soap from oils and fats or even from fatty acids, requires large capital expenditure on heavy plant such as steam boilers boiling kettles, storage tanks for oils and caustic soda, glycerine concentration plant, *etc.* Production of soap from noodles on the other hand, only requires simple mixing with colour and perfume, tableting and wrapping.

TABLE 4. SOAP MAKING PROPERTIES OF DIFFERENT OILS AND FATS*

Fats and oils	Colour of the resulting soap	Consistency of soap	Lathering qualities	Cleansing properties	Action on skin	Application
PKO	Very white	Very hard	Quick but non-lasting	Fair	Biting	Toilet Household Shaving
CNO	Very White	Very hard	Quick but non-lasting	Fair	Biting	Toilet Household Shaving
POs	Pale yellow	Hard	Slow but lasting	Very good	No action	Laundry & household
RBD PO	White	Fairly hard	Slow but lasting	Very good	No action	Toilet & good quality laundry
Tallow	White	Fairly hard	Slow but lasting	Very good	No action	Toilet & good quality laundry
Cottonseed or Groundnut	Buff to white	Medium soft	Quick & medium lasting	Good	No action	Household & laundry
Rosin	Brown	Soft & sticky	Thin & greasy	Medium	No action	Household & toilet

Note: *amended *Table* from Iftikhar, A (1987). *PORIM Technology No. 2*:8 pp.

Besides soap made from oils and fats (triglycerides), another major process uses the fatty acids of the same fats. This route offers the advantages of greater simplicity, lower capital expenditure and better control of the quality of the feedstocks. However, fatty acids are corrosive, more difficult to transport and store in bulk, have a tendency to discolour and they do not yield any glycerine.

Yet another process is one utilizing the methyl esters of the fatty acids, which overcomes most of the problems associated with fatty acids. It has found particular favour in Japan where very white soap is in demand and deserves better attention worldwide.

Ultimately, for soap makers, the choice of process will depend on the scale of operation, availability and quality of raw materials, their relative cost, market for the by-products and capital expenditure envisaged. But in the end, the soap must contain the appropriate level of PKO or CNO fatty acids, whatever the process employed.

Oleochemicals

The modern oleochemical products based on fatty acids and their derivatives are of increasing importance to the oil producing countries because they provide an additional outlet with higher added value. And they are also of increasing importance to the Western countries because they are made from renewable *natural* sources and are more easily biodegradable than those derived from petroleum (Salmiah, 1995). In Malaysia for example, in 2000, about 812 000 t or nearly 60% of her PKO production was used internally, mostly for oleochemicals.

The basic oleochemical products made from lauric fats, are the short and medium chain fatty acids (C8 - C14), their methyl esters and the fatty alcohols which are made by hydrogenation of the esters (Salmiah *et al.,* 1998). PKO and CNO compete directly in this area where they are even more interchangeable than they are in the edible field. In recent years, there has been a tremendous shift in oleochemical production from the West to Southeast Asia and from CNO to PKO. From published statistics, for example, it is evident that since 1990, nearly all the world expansion has been in Southeast Asia which has moved from 12% of the world total to 35% currently (*Table 5*).

In the Philippines, a large oleochemical industry is based on CNO while in Malaysia, there is even greater production based on PKO. In Malaysia, the growth of the oleochemical industry has been spectacular. The first oleochemical plant was built in 1979, producing PK fatty acids and glycerol. Currently, the country has an annual production capacity of 650 000 t of fatty acids, 175 000 t of methyl esters, 175 000 t of fatty alcohols, 120 000 t of glycerine and 230 000 t of soap (Yusof, 1999).

PRICE RELATIONSHIPS

The distinction between pure science and technology is not very clear and has been defined in various ways but the main difference is probably that the latter is concerned with making products that must be sold against competition. Technologists therefore, especially those in research and development, must have some idea of prices and their trends or risk being left groping in the dark. The following points are therefore worth noting.

In view of the similarity of PKO to CNO in respect of composition, properties and uses, one should not be surprised to find similarity in prices and fluctuations in the same direction. Recently, we examined the relationship between their prices over the last 12 years (1989 - 2000) and we found that over that period, PKO was at an average discount of US $9 t^{-1}. The price relationship was linear with a very highly significant correlation coefficient ($r = 0.986$, $p < 0.001$) (*Figure 3*).

The equation linking the two prices was:

PKO = 0.998 CNO - 7.65

About 97% of the price variation of PKO can be explained by that of CNO.

As regards their price trends, both have been rising. That for PKO by US$ 21.5 t^{-1} annually and that for CNO was US$ 20.3 t^{-1} annually, but the difference is not statistically significant.

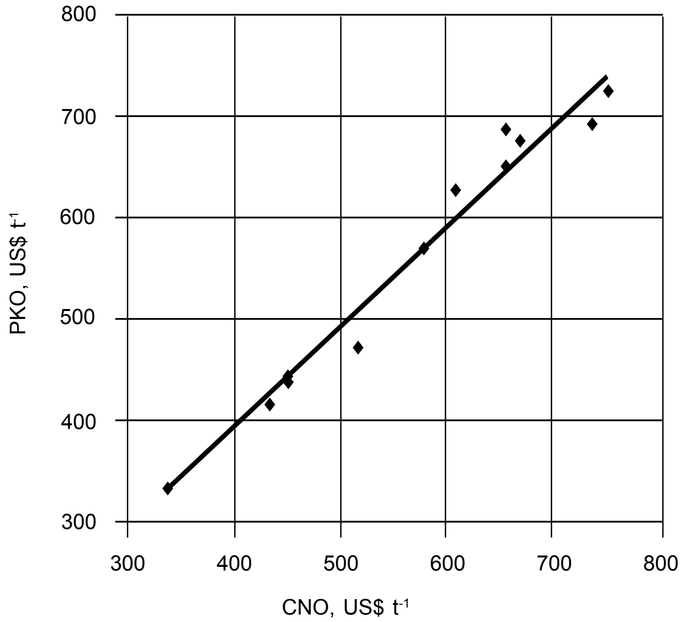
FUTURE DEVELOPMENTS

The MPOB, has been carrying out continuous research to widen the very limited gene pool of the current oil palm planting material,

TABLE 5. PRODUCTION OF BASIC OLEOCHEMICALS IN SOUTHEAST ASIA AND THE WORLD ('000 t)

Country/Region	1990	1995	2000E
Malaysia	262.2	807.0	1 200.0
Philippines	172.5	285.0	480.0
Indonesia	62.7	199.5	400.0
Thailand	11.0	22.0	44.0
Southeast Asia	508.4	1 313.5	2 124.0
Others	3 908.6	3 950.5	3 974.0
World production	4 417.0	5 264.0	6 098.0
Southeast Asia % of world	12%	25%	35%

Source: MPOB.
Note: E = estimated.



Equation: PKO = 0.998, CNO = -7.65
r^2 = 0.973, P< 0.001, (n = 12).

Figure 3. PKO and CNO: relationship between their average annual prices, 1989-2000, cif Rotterdam.

which restricts severely the degree of improvement which can be achieved with them. Germplasm was collected periodically from the regions of Africa where the tree originated, aiming to find suitable genetic material with which to enrich the current breeding population. The first collection was planted in 1976 and after extensive evaluation, two series of elite planting materials were introduced to the industry. These are known as PORIM Series 1 and PORIM Series 2 and offer greater yield of oil and different fatty acid composition (Jalani and Mohd Jaafar, 1999). Another new elite planting material, PORIM Series 3, has now been developed which gives more than 10% kernel content per bunch, compared with 5% from the usual palms (*Table 6*). It is expected that these new palms will put the Malaysian industry in a good position to meet the increasing demand for lauric oils in food, soap and oleochemicals.

PKO world production is currently below that of CNO by about one-third, but being a co-product of PO, its rate of growth is much higher and our forecast is that in the working lifetime of most readers of this paper, it will become the major lauric oil at just about the same time when PO will become the major non-lauric oil.

TABLE 6. RANGE IN THE CHARACTERISTICS OF *Dura* MOTHER PALMS WITH HIGH KERNEL CONTENT

	Range
Fresh fruit bunches (kg palm^{-1} yr^{-1})	162.2 - 197.7
Bunch number (No. palm^{-1} yr^{-1})	8 - 24
Average bunch weight (kg palm^{-1} yr^{-1})	7.4 - 22.8
Kernel to fruit (%)	16.2 - 20.4
Kernel to bunch (%)	10.53 - 13.26
Oil per palm per year (kg)	21.9 - 33.2

Source: MPOB.

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