Techno-Economic Aspects of Palm Oil and Palm Kernel Oil in Oleochemicals

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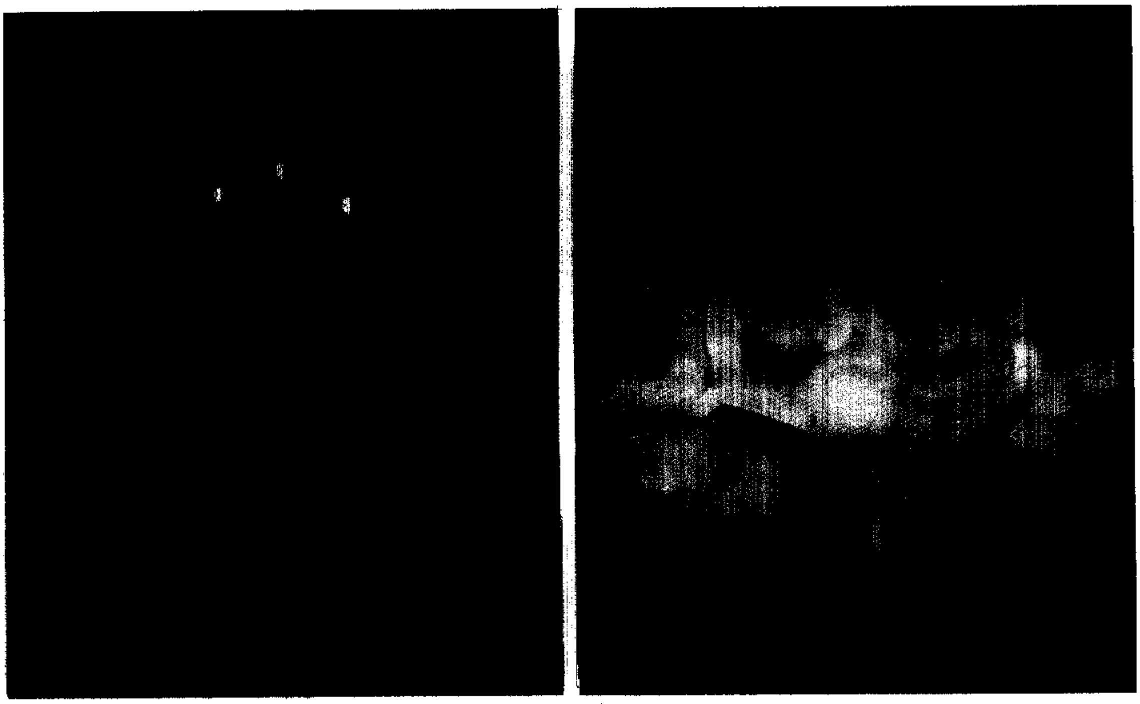


Candles and Soaps from Palm- and Palm Kernel-based Oleochemicals

It is said that the first oleochemical produced by man was soap, made accidentally by nomads when they happened to spill some stale fat (with high FFA) on hot wood ashes (potash) and then found it had useful cleaning properties. Those nomads could never have imagined that one product of that type would take up 11 million tonnes of oils and fats annually and would be used to make everything from ladies' face cream to steel plate.

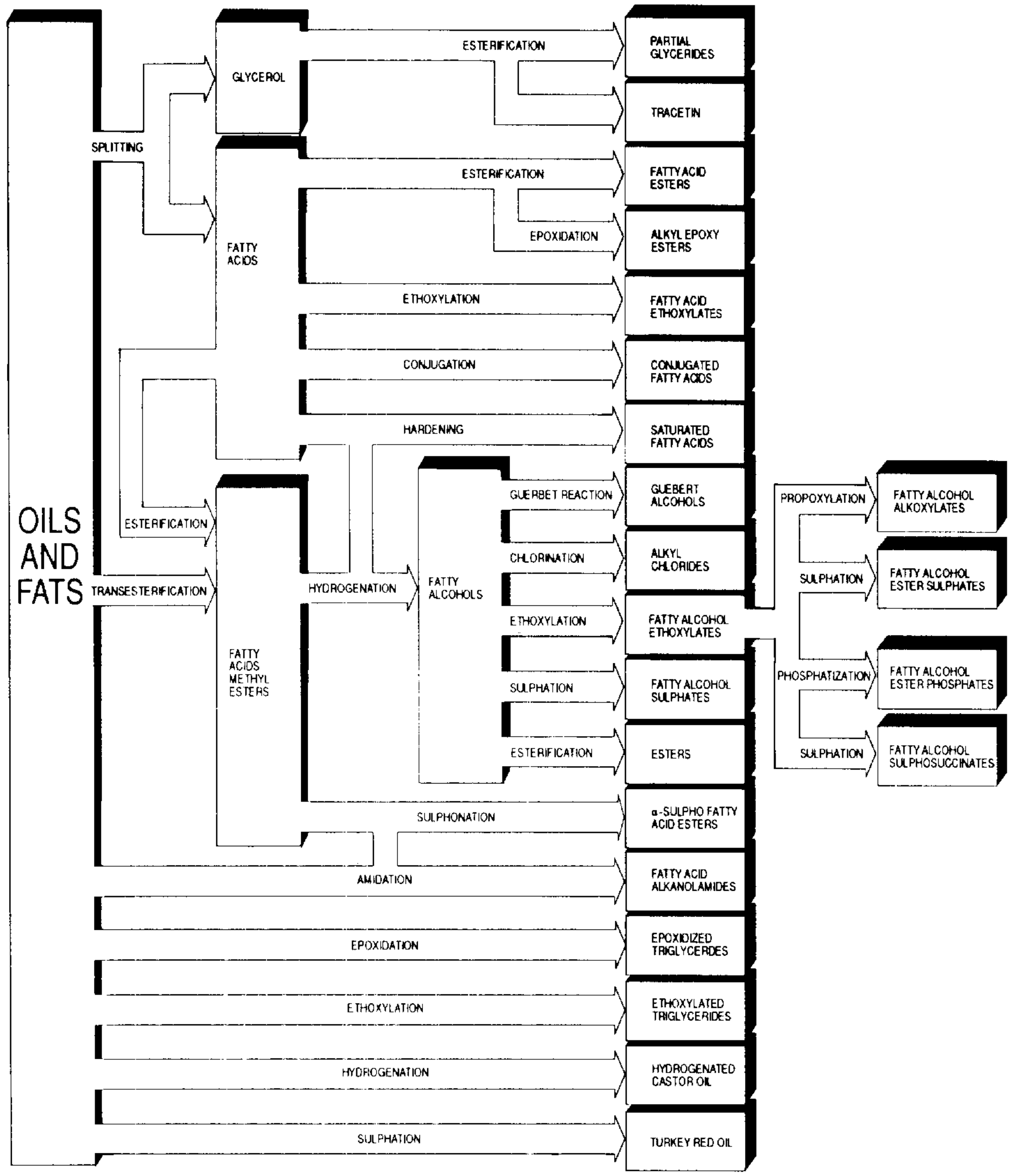
The uses to which oils and fats are put by the industries of mankind fit neatly into three broad classes: human foods, animal feeds and oleochemicals (including soap and paint). Of course by far the biggest application, and the one using the highest grades of oils, is for human foods, but the subject of oleochemicals is interesting not only because they account for a substantial share (*ca* 15%) of the world market for oils and fats, but also because of the huge variety and complexity of the products which can be made from a handful of basic oleochemicals.

Some of these products and the routes of their manufacture are shown in *Figure 1,* although it must be noted that the term 'oleochemical' is usually restricted to fatty acids, methyl esters, fatty alcohols, fatty amines and glycerol.

OLEOCHEMICALS AND PETROCHEMICALS

Desert nomads notwithstanding, the founder of oleochemistry was the French scientist Chevreul, who discovered that oils and fats were in fact compounds of a homologous series of fatty acids and glycerol. Many oleochemicals and down-stream products (such as fatty alcohols, detergents, *etc.*) can be made either from oils and fats or petroleum and so we have two widely used and commercially viable routes for their manufacture: the oleochemical (or natural) route and the petrochemical (or synthetic) route, each one predominating in different countries according to local conditions and availability of raw materials. It was only to be expected, for example, that the USA which in earlier times had ample supplies of cheap petroleum, would go mostly for the synthetic route, while Europe, until recently without any petroleum, and South-East Asia with abundant oils and fats, would go for the natural route.

Petrochemicals had the advantage of



Source: Henkel KGaA, Dusseldorf

Figure 1. Oleochemical Raw Materials and their Derivatives

historically lower raw material cost, but their processing is more complicated and they are fundamentally less easily biodegradable, a very important consideration these days and becoming more so all the time. In a recent survey of attitudes, 20% of West German consumers, 13% of US consumers and 4% of Japanese said they would buy environmentally-friendly products even if they were 50% more expensive than other products (*Financial Times* 1990). Also the word 'synthetic' conjures up further unfavourable images in the minds of consumers and, of course, petrochemicals are based on a diminishing resource, the price of which has only one way to go when supplies begin to dwindle. For all these reasons the natural route is currently much in favour and this trend can only accelerate in the years to come.

The most basic class of oleochemicals, and the one which accounts for by far the largest volume of production is fatty acids. Although in theory these can be made from petroleum feed stock, and Germany and Russia are reported to have made them this way during the last world war (Swern 1979), the process is so complicated and the quality so inferior that, in practice now, only the natural route is in use (*Table 1*).

SCALE OF PRODUCTION

The quantities of the 17 major oils and fats produced in the world in any year are known with a good degree of accuracy and detail because oilseeds, oils and fats are very important agricultural commodities, they can be defined unambiguously and statistics on them are recorded by all countries and reported regularly in the trade press. However, the proportions going into human food, animal feed and oleochemicals are far more difficult to ascertain with any degree of certainty and one has to rely mostly on reports from oleochemical manufacturers who monitor market shares and the activities of competitors. One of the best such estimates was probably that of the Henkel Company (Schmid, 1987) for 1985, and our estimates for 1989 have been obtained by extrapolation and other calculations from those figures (*Figure 2*). It can be seen that in 1989 the largest uses were, in descending order, for human foods (approximately 77% of the total), animal feeds (9%), soap (7%), oleochemicals (5%) and paint (2.5%): the last three are often grouped together under the heading 'technical uses'. *Table 2* shows the trend in world production of the basic oleochemicals from 1950 to 1982 according to the Henkel Company, and it is seen that while fatty acids constitute by far the biggest class, the fastest growing ones are methyl esters and the amines.

According to a market study by Frost and Sullivan in January 1987 oleochemical sales in the EEC were expected to increase by 2.5% annually through 1990, or in constant-dollar terms from $1.53 billion in 1985 to $1.75 billion in 1990. This is a much faster rate than for the overall disappearance of oils and fats in the EEC which is only expected to rise by 1.9% p.a in that period (Oil World).

FATS USED BY OLEOCHEMICAL INDUSTRY

In 1989 world disappearance of the 17 major oils and fats was 78.1 million tonnes: some 74% was of vegetable origin (including 5.3% laurics) and 26% was from animal sources (including marine). The growth rate over the previous 10 years averaged 3.7 per annum. These are the raw materials with the use potential in the oleochemical industry.

There are more than 1000 different fatty acids known in nature (including those with unusual chain lengths or branched chains and multi-unsaturated, hydroxy-, epoxy-, keto-, acetylenic and cyclic fatty acids and so on), but the main ones needed by the oleochemical industry are as follows:-

i) Medium-chain fatty acids, C10 and C12, from coconut and palm kernel oils. This group probably accounts for 10% of the total.

ii) Long-chain fatty acids C16 and above, from tallow, palm oil, fish oil and tall oil. This is by far the largest group, probably 85% of the total.

iii) Unsaturated fatty acids from soyabean, linseed, castor and tung oils, accounting for about 5% of the total.

A feature of the edible uses of oils and fats is the high degree of interchangeability which has been achieved. The food chemists have been remarkably successful in modifying oils and fats by a few simple processes such as hydrogenation, fractionation, interesterification and blending to

TABLE 1. WORLD SHARE (%) OF OLEOCHEMICALS AND PETROCHEMICALS (1983)

	Oleochemicals	Petrochemicals
Fatty acids (C7, 10)	100	-
Fatty alcohols (C7,10)	44	56
Fatty amines	90	10
Glycerol	74	26

Source: Schmid (1987).

TABLE 2. WORLD PRODUCTION OF BASIC OLEOCHEMICALS ('000 Tonnes)

	1950	1960	1970	1982	Growth %p.a.1970-1982
Fatty acids	550	1100	1400	1600	1.1
Fatty acids methyl esters	70	100	180	390	6.7
Fatty alcohols	75	125	425	680	4.0
Fatty amines	-	-	145	300	6.2
Glycerol	200	290	360	420	1.3
TOTAL	895	1615	2510	3390	2.5

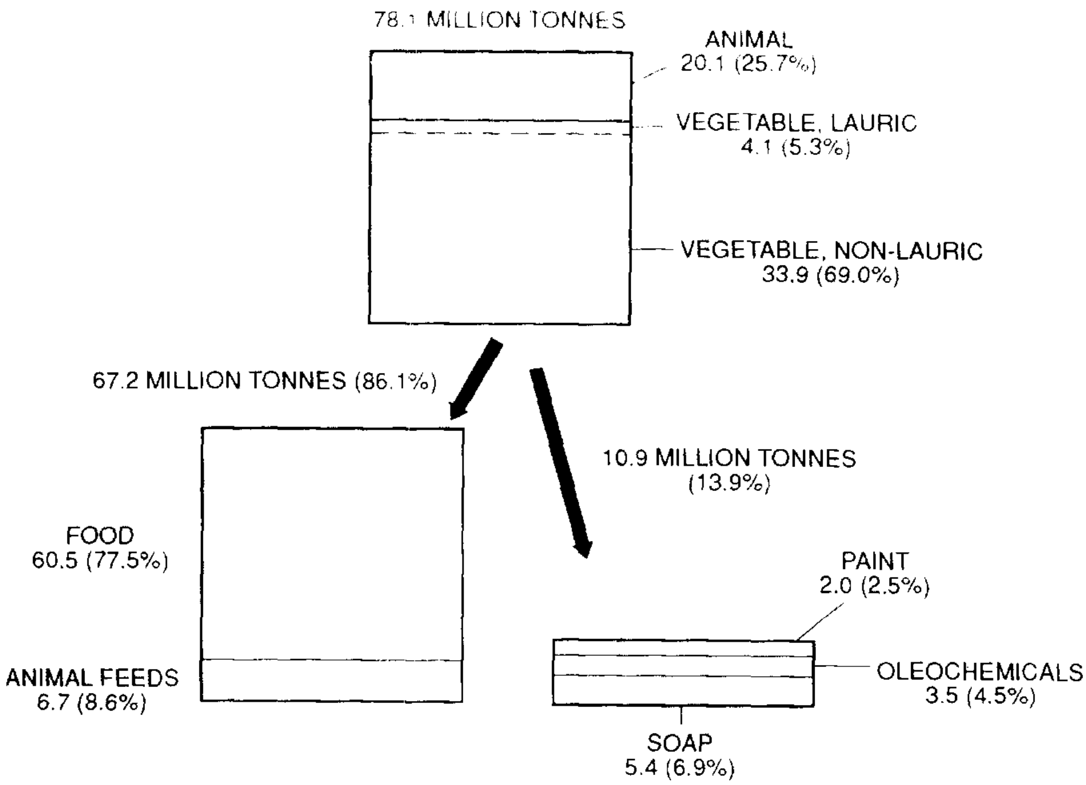
Source : Richtler and Knaut (1983).

TABLE 3. MAJOR FATTY ACIDS IN TALLOW, PALM OIL, COCONUT OIL AND PALM KERNEL OIL (% mass)

Fatty Acid	Tallow	PO	CNO	PKO
C8:0 (Caproic)	-	-	9	3
C10:0 (Caprylic)	-	-	6	4
C12:0 (Capric)	-	-	47	49
C14:0 (Myristic)	3	1	18	16
C16:0 (Palmitic)	25	45	9	8
C18:0 (Stearic)	20	4	3	3
C18:1 (Oleic)	48	40	6	15
C18:2 (Linoleic)	3	10	2	2
C18:3 (Linolenic)	1	-	-	-
	100	100	100	100
Iodine Value	49.1	51.7	8.6	16.4
Saponification Value	196	199	256	244
Glycerine yield (%)	10.7	10.9	14.0	13.3

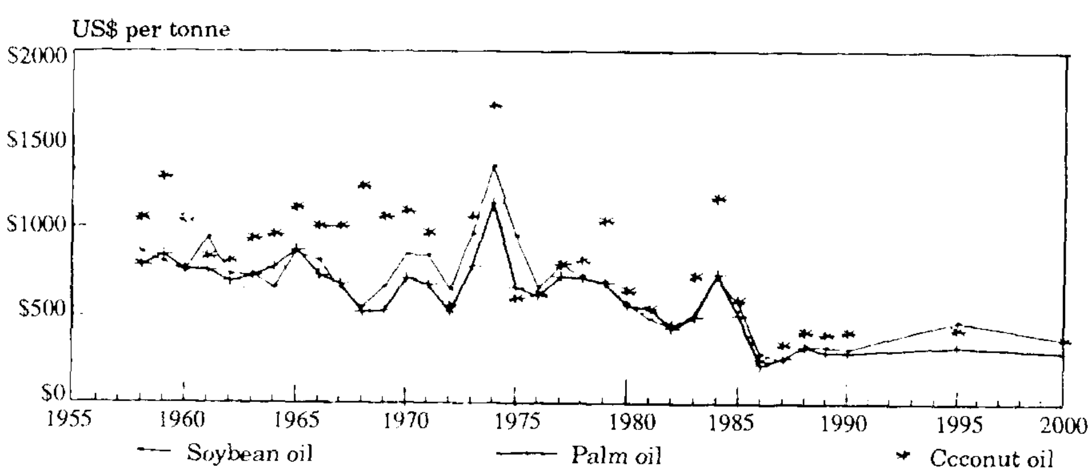
Fatty acid composition normalized. IV, Saponification Value and Glycerine yield calculated from fatty acid composition.

Source : ISEO (Institute of Shortening and Edible Oils) USA, (1988).



Source: Calculations by authors from data of Schmid(1987).

Figure 2. World oil and fat disappearance in 1989(million tonnes).



Source: Bastin(1990).

Figure 3. World Vegetable Oil Prices

make them suitable for different applications. For example, lauric oils can be substituted, for many purposes, by high-*trans* hydrogenated seed oils, and groundnut frying oil by palm oil liquid fractions: even cocoa butter can be replaced by palm mid-fraction blended with other fractions. It is mainly for this reason that the prices of oils and fats tend to move in unison to such a remarkably high degree, although on different planes. Even the prices of lauric oils, which have an entirely different composition and large specialized uses, keep on a parallel course (*Figure 3*).

In the oleochemical field however interchanging acids is impossible, or at best very difficult, because the functional properties of oleochemicals depend on chemical composition, while performance in food uses depends primarily on physical characteristics. The chain length of fatty acids is impossible to change by any commercially viable process and must be present in the oil feedstock.

The major fatty acid required by the oleochemical industry is stearic acid (18.0). The availability of the various fatty acids can be calculated from the supply of the various oils and fats and their composition, and such calculations in 1987 (*Figure 4*) showed that the most abundant saturated fatty acid in nature is palmitic (16:0), representing 10% of the total and twice as plentiful as stearic acid. However oleic, linoleic and linolenic acids together account for over 70%, and all these can be easily converted to stearic acid by simple hydrogenation.

Palmitic acid supplies, however, cannot be similarly increased, because unsaturated C16 acids are only present in nature in very small amounts indeed.

TALLOW AND PALM OIL

Tallow (including grease) is by far the largest source for the production of stearic acid. It should be noted that commercial stearic acid is in fact a mixture of stearic acid as the major component with various amounts of palmitic acid. The predominance of tallow is due to a combination of chemical properties and (especially) economic factors, *e.g.*:

- Its fatty acid composition, with a ratio of C18 to C16 chain lengths equal to 70:30 *(Table 3)* is suitable for a very wide range of down-stream products and soap. (C14 is here counted with C16).

- Its low iodine value (IV) results in modest hydrogenation costs and its low level of polyunsaturated fatty acids confers good resistance to oxidation.

- As a by-product of beef production, tallow has been available in very large quantities and in cheap inedible grades in the major industrially developed countries of the West, where the oleochemical industry started, and so the specifications of many oleochemicals and down-stream products from them were fixed on tallow.

But the position of tallow in the technical field is being increasingly challenged by palm oil (PO), which comes from the highest oil-yielding plant in cultivation, has the lowest cost of production of any oil and has been increasing in availability at a far higher rate. Tallow production, being tied to beef production, has been growing at a diminishing rate for the last 30 years *(Figure 5)* and prospects for the future are very poor indeed. Beef production is restricted more or less to temperate countries with static populations, and research effort has been increasingly directed towards the production of leaner animals and upgrading the tallow by-product to the more expensive edible grades. In the last 30 years or so (from 1985 to 1989) the overall annual growth of tallow production averaged 2.5%, but the rate has been falling continuously. Thus in the first 10 years of that period, growth was 3.9% p.a. , in the next 10 years 2.6% and in the last 10 years only 0.5% per annum.

World production of PO on the other hand, only really started growing about 20 years ago but it has maintained a constant rate of 9.6% p.a. since then. The shapes of the two curves in *Figure 5* make a remarkable contrast. The ratio of PO to tallow production was 0.36 in 1970, 1.0 in 1984 and 1.57 in 1989. The forecast for the year 2000 is that the ratio will rise to 2.26.

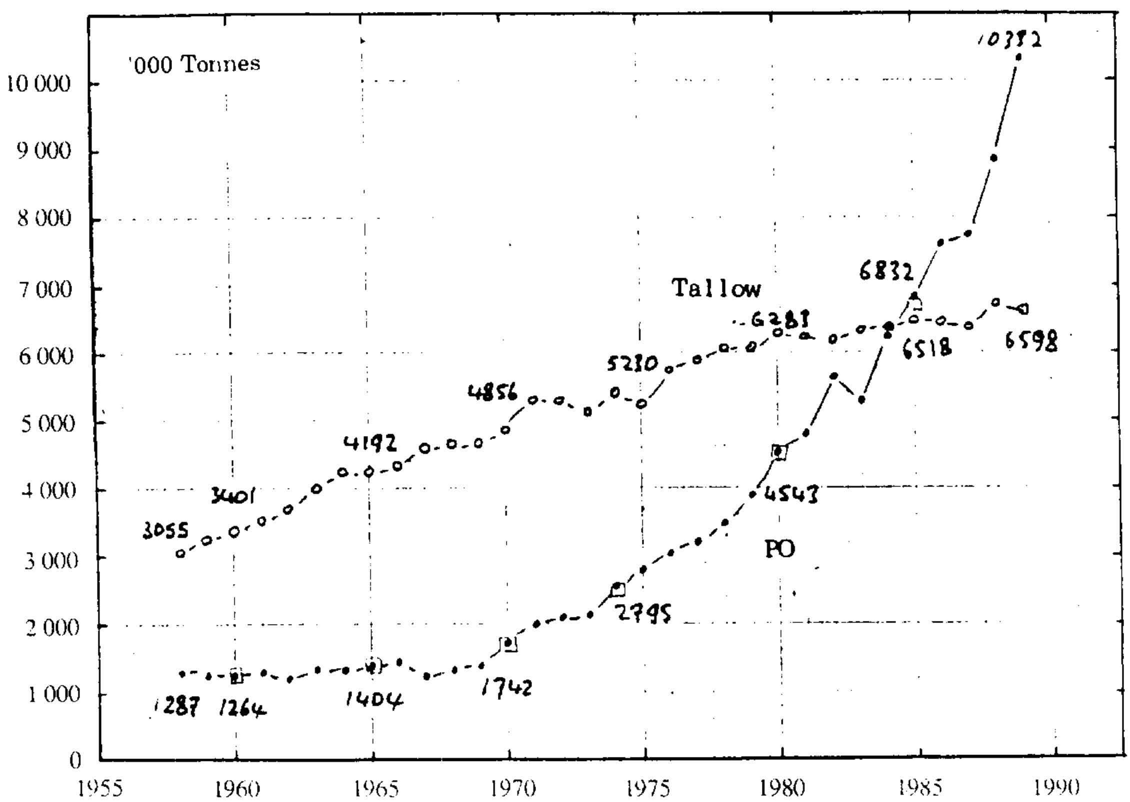
It was to be expected that the great divergence in the growth rates of the two oils would result in changes in their price relationship and indeed that is exactly what happened. From *Figure 6* (top graph) it is seen that from 1975 onwards, successive 5-years average premiums for the PO have been on a falling trend and in 1986, for the first time in its history, the annual price

(75.4 million tonnes=100%)

C12:0 Lauric	5%
C14:0 Myristic	5%
C16:0 Palmitic	10%
C18:1 Stearic	5%
C18:1 Oleic	32%
C18:2 Linoleic	34%
C18:3 Linolenic	6%
Others	3%

Source: Schmid 1987

Figure 4. World Distribution of Major Fatty Acids, in 1987(%)



Source: Oil World 1958-2007
Oil World 1990

Figure 5. World and Tallow Production, 1958 - 1989

went to a discount. And if, as looks increasingly likely, it remains at a discount for this year also (1990), it will be for the fourth year out of the last five. Forecasts to the year 2000 and beyond expect present trends in the production of the two oils to continue and so it seems fairly certain that future PO prices will be increasingly attractive by comparison with tallow (as far as the user is concerned). But successful replacement of tallow in oleochemicals requires appropriate properties as well, and these are examined below:

- PO has a lower C18 to C16 ratio than tallow (55:45 compared with 70:30) but this is no great disadvantage, except that it is non-traditional, and it can even be an advantage technically. Palmitic acid is very similar to stearic acid and it is preferable in certain applications like cosmetics, because of greater softness, and soap, because of greater solubility. The ratio present in PO is a eutectic composition which confers other advantages such as better contraction in candle making.

- The cost of hydrogenation of PO is similar to that of tallow, because of similar IV and its resistance to oxidation is even better because its content of natural antioxidants. Resistance to oxidation is extremely important in all applications, but most of all perhaps in the case of toilet and other expensive soaps, because it helps to preserve the perfume which often costs more than all the other ingredients in the formulation put together.

- Palm oil gives on average about 1.6% more glycerine than tallow in relative terms. Glycerine yield is directly proportional to the saponification value of the oil and most reference tables give saponification values for tallow in about the range 190-200 and for PO in the range 196-205 (Cocks and Van Rede, 1966): our calculations in *Table 3* give 196 and 199 respectively.

- The difference in glycerine yield is rather small in the case of crude palm oil (CPO), but it can become appreciable in the case of processed PO (PPO) because of differences in moisture and FFA content.

Normally for fatty acid and other oleochemical production the lowest grades of crude oils are adequate, but the price of Malaysian PPO is often quite close to that of CPO (*e.g.* within US$10 per tonne cif Rotterdam) (Oil World, 1989) and so it merits serious consideration even for oleochemicals. Technical tallow is normally sold with a moisture specification of 1% maximum, against a maximum of 0.1% for PPO. The difference of 0.9% will be reflected in exactly the same difference in the relative glycerine yield, and will of course be additional to the effect due to saponification value.

- Technical tallow is also usually offered with FFA max 5% (some greases can have FFA up to 50%), against 0.25% for some PPO grades and 0.1% for RBD PO.

Since FFA gives no glycerine, the lower FFA of PO will result in higher glycerine yield, but the exact amount can only be founded by experiment because the presence of partial glycerides complicates the picture.

Naturally the techno-economic advantages of PO became evident in Malaysia much earlier than in the rest of the world, enhanced as they were by the availability of local supplies of technical grades of PO at lower prices. This has led to the establishment of a large oleochemical industry but it seems inevitable that, in the years to come, the oleochemical industry in the rest of the world will also be relying increasingly on PO products for its raw material.

COCONUT OIL AND PALM KERNEL OIL

A comparison of coconut oil (CNO) and palm kernel oil (PKO) for oleochemical use is in many ways much simpler than that between tallow and PO, because the two oils are so similar. They are the only two members of the select lauric group, which amounts to only about 5% of the total world supply of oils and fats, and so their prices usually move on a higher plane, though parallel with that of the other vegetable oils. There are of course some other lauric oils known in the world, *e.g.* babassu, tucum, murumuru, *etc.*, but the quantities of these are very small and they are of only local significance.

From *Table 3* it is seen that in respect of fatty acid composition the only appreciable difference between CNO and PKO is that the former contains more caprylic and capric acids (C8:0 and C10:0) and less oleic acid. It is sometimes said, even by people who know better, that CNO is more valuable for oleochemical use because it con-

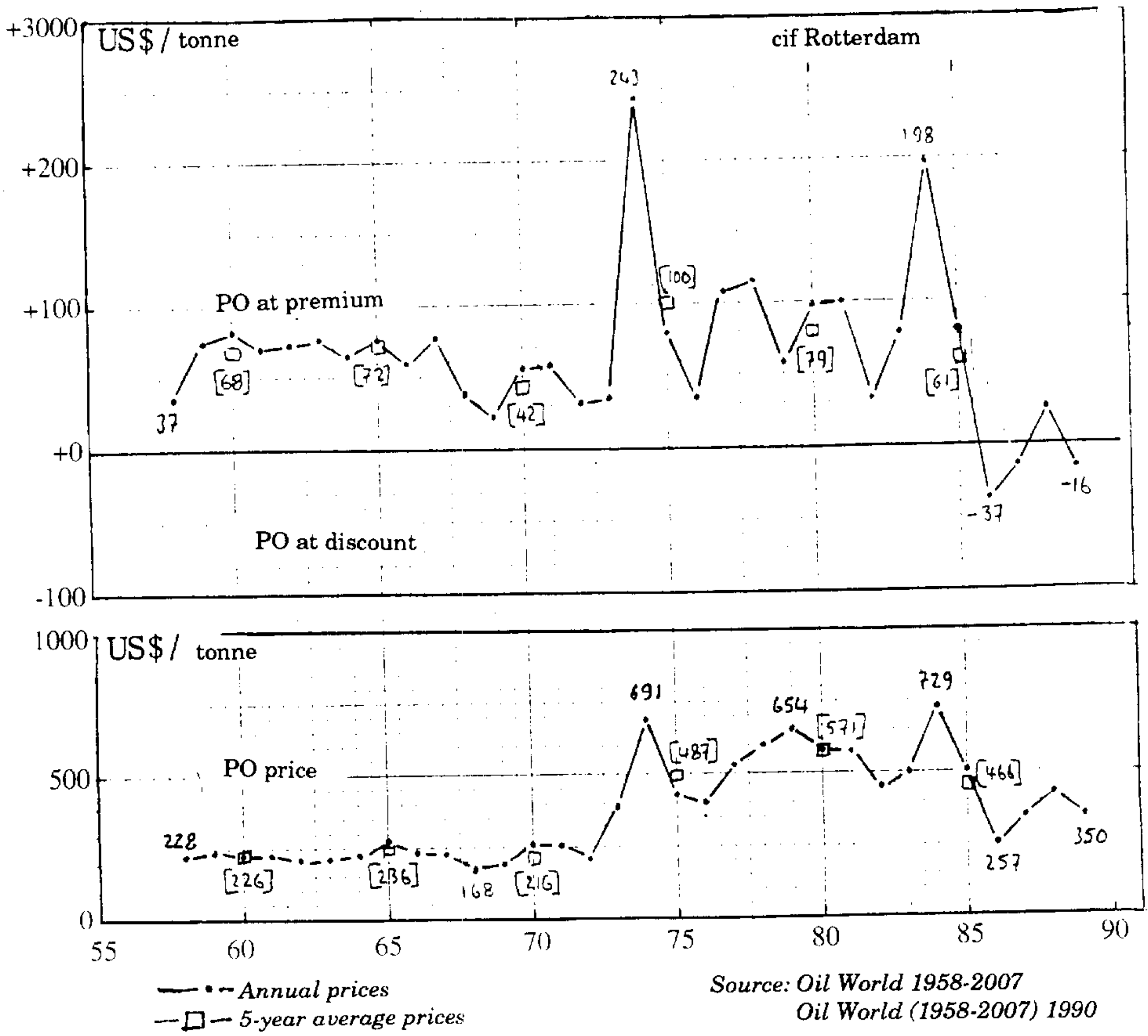


Figure 6. Price of Palm Oil(lower graph) and Premium / Discount to tallow(upper graph)

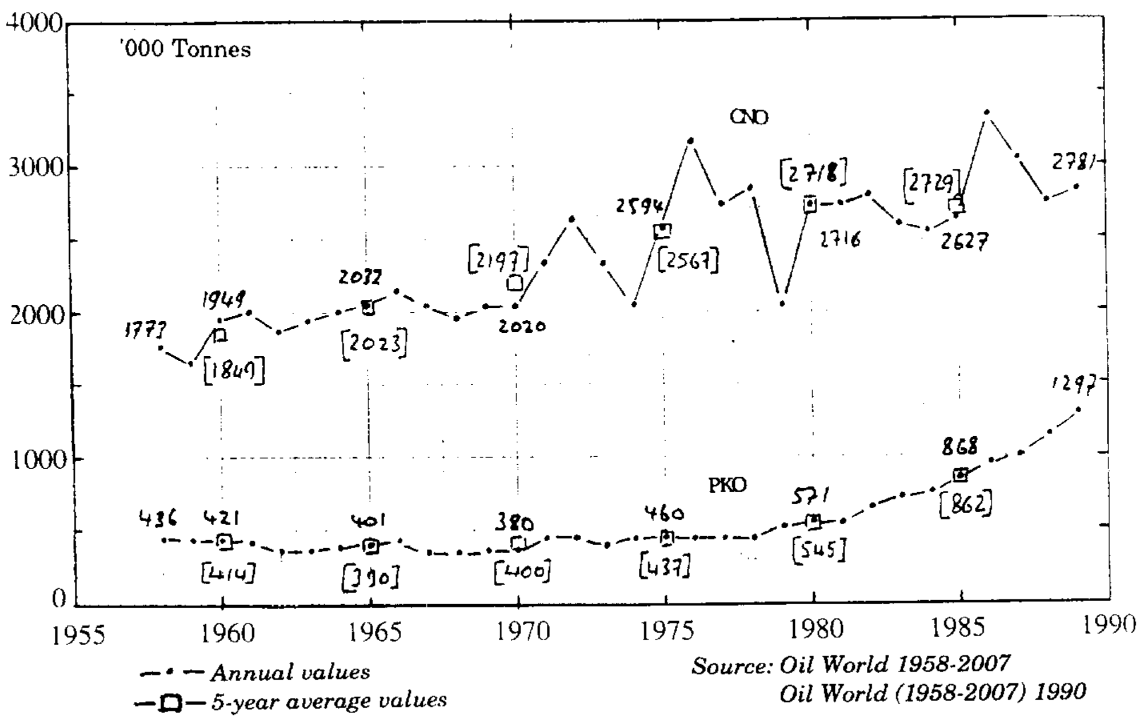


Figure 7. World CNO Production, 1958 - 1989

tains higher amounts of lauric acid (C12:0) and yields about 10% more glycerine. In fact the first of these statements is wrong and the second very exaggerated. Most authoritative tables of the fatty acid composition of oils give mean lauric acid values for PKO which are up to 2% higher than those for CNO. For example:

USDA (1979)	+2.3%
Food RA (1986)	Equal
ISEO (1988)	+2%
Average	1.43%

It is only when the shorter-chain fatty acids C8 and C10 are counted together with lauric acid that CNO appears superior. As for glycerine yield, this can easily be calculated from the fatty acid composition or the saponification value, and the results we have obtained are 13.9% for CNO and 13.3% for PKO, a difference in favour of CNO of only 5.3% (relative).

As regards general soap-making properties, we have it on the authority of some of the largest soap makers in the EEC that the two oils are to all intents and purposes indistinguishable, and they choose between them entirely on price considerations.

CNO is of course produced in much larger quantities *(Figure 7)*. As far back as 1958 world annual production was nearly 2 million tonnes (6.5% of all oils and fats). By comparison, PKO production was very small, only 0.4 million tonnes, and even in 1989 it had not reached the level of CNO thirty years earlier. Nevertheless in relative terms PKO has been gaining on CNO very fast. Significant growth in world PKO production only really began in the late 70s because until then increasing crops in Malaysia were being offset by diminishing crops from Nigeria and other African sources. In the period 1958-78 PKO only grew at the rate of 0.04% p.a., but from 1978 the rate jumped to 9.9% p.a. and has held that level to the present.

CNO production on other hand did the opposite. It grew by 2.2% between 1958 and 1978 and then slowed down to barely 1% per annum. A striking feature of the CNO production record has also been its very erratic course, with violent fluctuations from one year to the next year, and with large peaks and troughs following each other every 2 to 3 years. The contrast with the course of PKO is striking,. Unfortunately the Philippines, the major CNO producing country, is plagued with variable climate, droughts, typhoons, *etc*, as well as political turmoil, which are being reflected in her production record. In about 1980/81 the Philippines government announced some rather modest plans to replace the ageing trees with more productive stock. The plans called for replanting about 50 000 hectares per year, but even if this rate had been attained it would have taken 90 years to replace the then existing plantations. But the political upheavals and lack of economic resources stifled the plans and indeed the average age of the coconut trees is now higher than it was when the plan started. The other major CNO producer, Indonesia, is concentrating much more attention on oil palms than on coconut palms, and not very much can be expected from that direction.

The sharp variations in CNO production have naturally been reflected in correspondingly sharp variations in lauric oil prices, for which these oils are in fact notorious (compare *Figures 6* and *8*). Of course, CNO being at least twice as big in volume as PKO, it is the clear price leader and PKO only follows, sometimes above and sometimes below it. *Figure 8* shows the price of PKO since 1958 (bottom graph) and its discount or premium to CNO (top graph); it is seen that the 5-year average price of PKO has been level throughout the period of some 30 years, except for the jump to another plateau in 1973/74 which all oils made. But the plot of difference is more revealing. It clearly shows an upward trend towards a premium for PKO, from 1958 to 1974 and a downward trend, towards a discount for PKO from 1974 to 1989. At present, in 1990 PKO continues to sell at a discount to CNO.

It now seems highly probable that with good discount for PKO against CNO the oleochemical industry will be turning to PKO in a big way.

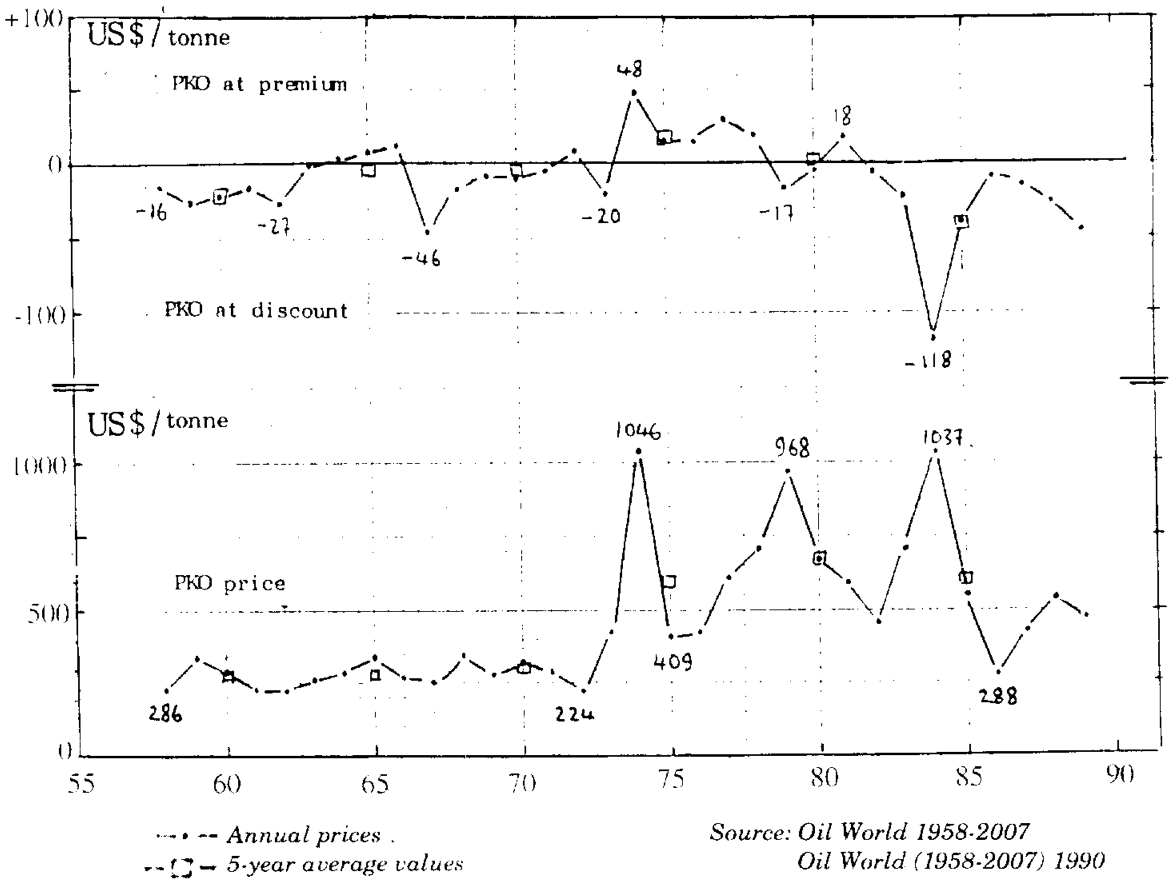


Figure 8. Price of Palm Kernel and Premium / Discount to Coconut Oil, Cif Rotterdam

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