The Future of Palm Oil in Oleochemicals

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INTRODUCTION

Historically the chemical industry has used coal, minerals, and more recently, petroleum as its basic raw materials. Whilst the use of oils and fats as chemical raw materials has hitherto been minimal as compared with petroleum feedstocks, oils and fats, which are of vegetable, marine and animal origin are renewable, whereas coal, minerals and petroleum are being depleted, and are limited in their availability.

By 2000, the world production of palm oil is expected to exceed 22 million tonnes or 21% of the total production of oils and fats. About 80% of the world's production of palm oil will come from ASEAN, a region which holds tremendous potential for growth for oleochemicals.

Though relatively new to the industrial scene, palm and palm kernel oils are being increasingly used, not only for edible purposes, but also for the production of oleochemicals.

Tallow and coconut oil have long been the traditional raw materials for the world's annual requirement of oleochemicals estimated at 4.5 million tonnes. But palm and palm kernel oils are now being used as replacements for tallow and coconut oil respectively.

This paper discusses the position of palm and palm kernel oils in relation to other oils and fats, and in particular their use as economical raw materials for the production of oleochemicals.

The paper also discusses the world demand for 'green' products; the role of Malaysia as an important raw material base; ASEAN as a growing oleochemical centre; and applications for oleochemicals with reference to the use of palm and palm kernel oils in particular.

WHAT ARE OLEOCHEMICALS ?

The word 'oleochemicals' denotes chemicals derived from natural oils and fats as opposed to chemicals derived from petro-

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chemical feedstocks such as ethylene, propylene and paraffins.

Oleochemicals can be divided into two groups of products, *i.e.* basic oleochemicals and oleochemical derivatives.

Basic oleochemicals are produced by splitting and processing oils and fats, and include fatty acids, methyl esters, fatty alcohols, fatty amines and glycerine. Products derived from these oleochemicals (oleochemical derivatives) include soaps, fatty amides, quaternary ammonium compounds, amine oxides, fatty alcohol ethoxylates, *etc.*

THE DEVELOPMENT OF THE OLEOCHEMICAL INDUSTRY

Oleochemicals can be traced back more than 2000 years, to the time when the Celtic and Germanic tribes used a concoction of grease and wood ash to stiffen their long beards and hair.

The Phoenicians made crude soap by heating goat fat with ashes from their cooking fires. However, soap making as an industry emerged in the late 18th century, and was based on the research of Scheele and Chevreul, the founders of oleochemistry. They identified the structure of fats as glycerine esterified with a variety of fatty acids. Chevreul isolated stearic acid and oleic acid, while E.Frémy discovered palmitic acid.

The splitting of fats under atmospheric pressure in the presence of catalysts was discovered by Twitchell (1862-1929). Splitting under pressure in autoclaves was started around 1905-1910.

Gay-Lussac obtained a patent in 1825 for the separation of fatty acids by distillation, and in 1870 the first patent was issued in the United States for the recovery of glycerol by distillation. In 1882, Armandy produced glycerol by vacuum distillation.

Hydrogenation of liquid fats was discovered in 1901 by W Normann, who hardened whale oils by treating them with hydrogen in the presence of a nickel catalyst.

In 1903, L Bouveault and C Blanc discovered the catalytic conversion of fatty acid esters into fatty alcohols. The industrial manufacture of fatty alcohols via the high pressure hydrogenation route was started by W Schrauth and H Bertsch, both working for Henkel, in 1931

Fatty nitrogen compounds such as fatty amines and their derivatives were introduced in 1940.

RAW MATERIALS FOR SURFACTANTS

The main raw materials from which the organic component of surfactant chemicals is obtained are:-

- Petroleum hydrocarbons.
- Oils and fats from natural sources.
- By products and co-products of the pulp and paper industry.

Petroleum Hydrocarbons

Petroleum hydrocarbons provide both linear and cyclic chemical intermediates to the manufacturers of surfactants. These key intermediates, such as ethylene and propylene oxides, alpha olefins, benzyl halides and surfactant alcohols are derived from petrochemical raw materials – ethylene, propylene, benzene and normal paraffins. They are then used in the manufacture of alkylamines, amine alkoxylates and benzyl quaternaries.

The price and availability of petroleum, and thus of the hydrocarbon intermediates, is basically determined by the demand for, and supply of, energy. Around 95% of crude oil goes into energy applications, 4% into petrochemicals, and the balance is used for lubricants (Rapheal, 1986).

The specific products where petroleum feedstocks compete with natural oils and fats as raw materials are glycerine, detergent-range alcohols, short chain linear fatty acids and fatty amines. However, about two-thirds of the world production of these chemicals comes from natural oils and fats (Haupt *et al,* 1984).

Natural versus Synthetic Raw Materials

The main advantages that natural raw materials have over synthetic are:-

•Natural raw materials are interchangeable. There is a wide selection of natural raw materials from which one can choose on the basis of price and availability. No parallel exists in the petrochemical industry.

• Natural raw materials are replenishable since they can be grown. Thus their availability is guaranteed. Synthetic raw materials are obtained from petroleum sources which are being depleted and are not replenishable.

• Some natural raw materials are by-products, *e.g.* natural glycerine, which adds a credit to the price of the basic raw material such as fatty acid or methyl ester. In consequence, natural glycerine is sold at a discount to synthetic glycerine and natural fatty acids are priced lower than synthetic fatty acids.

Natural Oils and Fats

The oils and fats used as feedstocks for oleochemicals are derived from vegetable, animal and marine sources. *Table1* shows the historical growth in world production of natural oils and fats. World production of vegetable oils and fats in 1989 was 49.4 million tonnes, which represented an almost fourfold increase from 1950. By contrast, world production of animal oils and fats increased by a factor of only two during the same period.

The principal oils and fats which are important to the oleochemical industry are tallow, palm, soyabean, coconut and palm kernel oils. *Table 2* shows the historical growth in world production of these oils and fats. Tallow and coconut oils have been the predominant raw materials for oleochemicals, tallow as a major source of C16-C18 fatty acids and coconut oil for C12-C14 fatty acids.

World production of palm oil in 1989 was 10.3 million tonnes, which represents an almost eleven-fold increase since 1950: during the same period, the production of tallow increased by a factor of only three and that of soyabean oil by a factor of seven, while the increase in world production of palm kernel oil was double that of coconut oil.

The growing importance of palm and palm kernel oils in the world's oils and fats scene is indicated in the projected increase in their production up to the year 2000.

PALM AND PALM KERNEL OILS AS RAW MATERIALS

The oil palm is one of the world's most economical oil crops. A tonne of palm fruit, known as fresh fruit bunches (FFB), can yield 200 kg of crude palm oil and 40 kg of palm kernels, which in turn yield about 50 % or 20 kg of palm kernel oil. A hectare of land can yield 20-24 tonnes/year of FFB. Thus a hectare yields four to five tonnes of palm oil and 400 - 500 kg of palm kernel oil annually.

Prior to 1980, palm and palm kernel oils were mainly used, after refining and fractionation, for edible purposes. Since the development of the Malaysian oleochemical industry in the early eighties, there has been an increasing use of these oils as raw materials for oleochemical production.

In 1989, Malaysia was responsible for almost 60% of the world production of palm and palm kernel oils *(Table 3)*, while ASEAN (the Association of South-East Asian Nations) produced 75% of the world output of palm and lauric oils (palm kernel and coconut oils) *(Table 4)*. So, it is not surprising that ASEAN is becoming a major producer of oleochemicals.

The similarity in composition of tallow and palm oil and of coconut oil and palm kernel oil is well known. Initially, there were doubts that palm and palm kernel oils could be used to produce acceptable oleochemicals. However, extensive research carried out by the oleochemical producers, has shown that there are few, if any, applications, for which palm-derived oleochemicals cannot be used.

TABLE 1. WORLD PRODUCTION OF NATURAL OILS AND FATS
(Million Tonnes)

Year	Vegetable Oils and Fats	Animal Oils and Fats (including marine oils)	Total
1950	13.9	9.3	23.2
1960	18.6	13.6	32.2
1970	26.2	13.9	40.1
1980	43.2	17.3	60.5
1985	49.4	18.8	68.2
1989	57.4	19.9	77.3
1990*	59.2	20.0	79.2
2000*	85.3	21.7	107.0

*Forecast
Source: 1950 to 1990- *Oil World*
2000 - Estimated

TABLE 2. WORLD PRODUCTION OF OILS AND FATS SUITABLE AS RAW MATERIALS FOR OLEOCHEMICALS
(Million Tonnes)

Oils and Fats	1950	1960	1970	1980	1989	1990*	1995*	2000*
Soya Bean	2.1	4.0	6.1	12.2	15.0*	16.1	18.2	21.0
Tallow	2.2	3.6	4.4	6.0	6.6	6.6	7.1	7.0
Coconut	1.9	2.1	2.2	3.3	2.8	3.1	3.8	4.2
Palm	0.9	1.1	1.7	5.0	10.3	10.8	17.8	22.0
Palm Kernel	0.4	0.4	0.4	0.7	1.3	1.4	2.3	2.8
Others	16.1	20.9	25.3	29.6	41.3	41.2	35.2	50.0
TOTAL:	23.6	32.1	40.1	56.8	77.3	79.2	84.4	107.0

*Forecast
Source: 1950 to 1995 - *Oil World*
2000 - Estimated

TABLE 3. COMBINED PALM OIL AND PALM KERNEL OIL PRODUCTION : MALAYSIA VS WORLD (Million Tonnes)

Year	Malaysia	World	Malaysia/World %
1980	2.81	5.59	50.26
1985	4.66	7.87	59.21
1989	6.79	11.60	58.53
1990*	6.91	12.16	56.82

*Forecast

TABLE 4. COMBINED PALM OIL AND LAURIC OIL PRODUCTION : ASEAN VS WORLD (Million Tonnes)

Year	Asean	World	Asean/World %
1983	6.38	8.79	72.58
1985	7.94	10.50	75.61
1989	10.83	14.40	75.20
1990*	11.64	15.30	76.07

*Forecast
Source: *Oil World*

Palm Oil versus Tallow

Tallow is a major source for C16 and C18 fatty acids. Palm oil contains about 44% of the C16 and 55% C18 acids, and so can be used to replace tallow as a raw material. Palm oil has additional advantages:-

- While world production of tallow is not increasing, the planted acreage of oil palm ensures increasing availability to the year 2000 and beyond.

- To produce food grade oleochemicals in the United States, Europe and Japan, special and more expensive grades of tallow are required. Palm oil being of vegetable origin is a food grade raw material and can be used without further processing. Thus, manufacturers are looking to palm oil as an essential component in their long-term raw material strategy.

Palm Oil versus Seed Oils

Seed oils such as those from soyabean, cottonseed, rapeseed and corn are also sources of C16 and C18 fatty acids. Compared with these oils, palm oil has the following advantages:-

- Palm oil is derived from a perennial crop, so that a reliable supply is available throughout the year, whereas seed oils come from seasonal crops.

- The unit production cost of palm oil in ASEAN is much lower than that of seed oils in the West (Tan, 1989).

The abundant supplies of palm oil and the cost differentials between palm oil and seed oils make a cheaper raw material available to ASEAN oleochemical producers; these factors also make it more attractive for Western producers to import partly finished raw materials derived from palm oil for further processing in their home-based plants.

The Lauric Factor

Of the estimated 3.4 million tonnes of lauric oils produced in 1983, about 70% was used for food and 30% for oleochemical production, especially for soap, fatty acids and fatty alcohols (Diecklemann *et al.*, 1988). Coconut has been the major source of lauric oils hitherto. There are currently two other sources – palm kernel and cuphea. Cuphea oil, derived from a Mexican annual plant, *Cuphea*, is considered a serious contender to coconut oil. It yields the same specific fatty acids as coconut oil but with a much higher percentage of lauric acid. However, large-scale commercial production is not foreseen in the near future.

Palm kernel oil is to a large degree interchangeable with coconut oil due to its similar fatty acid composition. Its availability is closely linked to the production of palm oil and is the reason for the establishment of a number of oleochemical plants in Malaysia and Indonesia using palm kernel oil as feedstock.

THE EXPANDING OLEOCHEMICAL INDUSTRY

Table 5 shows the world production of basic oleochemicals in 1985 and the projected demand in 1990, 1995 and 2000. The 1985 and 1990 figures were obtained from industry sources while those for 1995 and 2000 are the authors' estimates.

Fatty acids

Fatty acids are obtained by the hydrolytic splitting of natural oils and fats, and subsequently refined by distillation, hydrogenation and fractionation.

For the period 1985 - 1990, production grew at an average annual rate of 1.3 per cent. For the periods, 1990 - 1995 and 1995 - 2000, the average annual growth rates are forecast at 2.4% and 1.8% respectively. Europe and the Americas are expected to register negative growth, however. This is because many producers of fatty acids are subsidiaries of multi-national firms which will meet their internal needs before selling the excess on a commercial basis. Therefore, smaller quantities of fatty acids will appear on the market (Bruce *et al.*, 1989).

The Pacific Rim (Japan, Korea, Taiwan, ASEAN and Australasia) will register significant growth because of the considerable capacity being added by basic oleochemical producers, especially in ASEAN where producers are moving 'downstream' to produce higher value added products. End uses for fatty acids encompass a broad range of products, from detergents, fabric softeners and personal care products to food, ink, textiles, asphalt, and adhesives.

Methyl Esters

Methyl esters are employed mainly as intermediates for fatty alcohol production and are thus used captively. Methyl esters can also be transformed into alkanolamides and sulpho-fatty methyl esters. They are also used for toilet soap production and have been proposed as a substitute for diesel oil. Their direct uses, as in case of fatty acids, are limited, and the demand for them will react to the demand for fatty alcohols.

The annual growth rates are estimated at 2.5% for 1985 - 1990; 4.2% for 1990 - 1995 and 2.9% for 1995 - 2000. The larger rate of increase for 1990 - 1995 is due to the substantial increase in fatty alcohol capacity coming on stream in ASEAN, production being by the methyl ester route.

Detergent Alcohols

Detergent alcohols are produced from natural oils and fats and from synthetic feedstocks.

Fatty alcohols serve principally as intermediates for derivatives used as detergents and cosmetics, and in personal care products. With the widespread belief that natural is better than synthetic, natural-based materials are preferred, particularly in the production of personal care products.

While growth in the West is expected to

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TABLE 5. WORLD OLEOCHEMICAL PRODUCTION/DEMAND
(Thousand Tonnes)

	Region	1985	1990	1995[a]	2000[a]
Fatty Acids[b]	Western Europe	850	900	800	780
	Americas	550	580	500	490
	Pacific Rim	600	625	1033	1223
	Others	-	25	50	100
	World	2000	2130	2383	2593
Methyl Esters	Western Europe	200	225	255	225
	Americas	150	99	99	99
	Pacific Rim	50	126	160	200
	Others	-	-	60	100
	World	400	450	544	624
Fatty Alcohols	Western Europe	240	265	265	265
	Americas	390	440	440	440
	Pacific Rim	130	120	403	810
	Others	-	30	60	100
	World	760	855	1168	1575
Fatty Amines	Western Europe	125	140	140	140
	Americas	150	175	175	175
	Pacific Rim	50	41	92	142
	Others	25	69	80	80
	World	350	425	487	526
Glycerol	Western Europe	200	218	218	218
	Americas	140	144	144	144
	Pacific Rim	190	46	160	258
	Others	-	149	160	160
	World	530	557	682	780
OLEOCHEMICALS	TOTAL WORLD	4040	4417	5264	6098

[a]Forecast
[b]Excluding TOFA & Synthetic FA
Source: Henkel, Montreux 1986 (1985 & 1990)

be stagnant over the next decade, major growth will occur in the Pacific Rim, especially in ASEAN, where new capacity based on palm, palm kernel and coconut oils continues to come on stream.

The growing population in the Pacific Rim will enjoy improving nutrition. The expanding economy will be able to absorb more consumer products, including detergents.

Average annual growth rates are estimated at 7.3% for 1990-1995 and 7.0% for 1995 - 2000.

Fatty Amines

Fatty amines, which are made primarily from fatty acids through nitriles, are extensively used as intermediates for derivatives such as quaternary ammonium compounds and amine oxides.

The future growth in the use of these products is expected to be paced by the demand for fabric softeners. Other uses include ore flotation, corrosion inhibition, bitumen emulsifiers, and oil field additives such as demulsifiers and biocides.

The average annual growth rate was 4.3% for 1985 - 1990, and is estimated at 2.9% for 1990 - 1995 and 1.6% for 1995 - 2000. Significant growth is predicted in the Pacific Rim, taking into account the raw material advantage it has over the West.

GLYCERINE

Glycerine is a by-product derived from the splitting of natural oils and fats. It can also be produced synthetically. Since the trend is towards the use of oleochemicals, this will mean an increase in the availability of natural glycerine. The expected growth in the production of fatty acids, methyl esters and fatty alcohols during the next decade will meet the growing world demand for natural glycerine.

Most of the glycerine produced worldwide is utilized by the cosmetic, pharmaceutical, food, tobacco and synthetic resin industries.

The average annual growth rate is estimated at 4.5% for 1990 - 1995 and 2.9% for 1995 - 2000.

ASEAN AS AN OLEOCHEMICAL CENTRE

ASEAN is experiencing a rapid growth in oleochemical production because of locally available low-cost raw materials such as palm, palm kernel and coconut oils. Low labour costs and economic advantages favour the setting-up of manufacturing plants in the region. Technology for the production of oleochemicals has been mainly developed in Europe and North America and has been adopted and sometimes improved upon by local producers. This technology is acquired either on a turn-key basis or by joint ventures with multi-national companies.

Of the fourteen plants operating in ASEAN in 1989, seven were designed to produce fatty acids, five to produce methyl esters and two to produce fatty alcohols. From information obtained from the industry, it is expected that there will be an increase in the number of plants processing basic oleochemicals over the next decade.

In 1989, ASEAN produced 326 100 tonnes of oleochemicals or about 11.5% of the world production. In 1995 and 2000, ASEAN is expected to produce respectively about 25% and 35% of the world demand for these 'green products' *(Table 6)*.

The biggest growth will be in Malaysia, which accounted for about 44% of the total ASEAN production in 1989 and is expected to contribute in excess of 50% during the next decade. The Malaysian Industrial Development Authority (M.I.D.A) has forecast in its Industrial Master Plan, that by 1996, Malaysia will be producing 755,000 tonnes of oleochemicals. The present authors believe that the projection will be exceeded.

The reasons are obvious. Malaysia is in the unique position of having ample low-cost palm and palm kernel oils available, a stable political climate, relatively low labour costs and financial advantages offered by the Malaysian government to the oleochemical industry.

ASEAN countries have learnt that an

TABLE 6. ASEAN OLEOCHEMICAL PRODUCTION CAPACITIES (Thousand Tonnes)

Oleochemicals	1989	1990	1995*	2000*
Fatty Acids	172.0	202.0	609.5	800.0
Methyl Esters	75.1	126.1	130.0	170.0
Fatty Alcohols	47.5	115.0	363.0	770.0
Fatty Esters	-	10.0	50.0	80.0
Fatty Amines	-	5.0	50.0	100.0
Glycerol	31.5	503.0	116.0	214.0
TOTAL:	326.1	508.4	1318.4	2134.0

*Forecast

TABLE 7. AREAS OF APPLICATIONS OF OLEOCHEMICALS

Fatty Acids and Derivatives	Plastics; metal soaps; washing and cleaning agents; soaps; cosmetics; alkyd resins; dyestuffs; textile, leather and paper industries; rubber; lubricants.
Methyl Esters	Cosmetics; washing and cleaning agents.
Glycerol and Derivatives	Cosmetics; toothpastes; pharmaceuticals; foodstuffs; lacquers; plastics; synthetic resins; tobacco; explosives; cellulose processing.
Fatty Alcohols and Derivatives	Washing and cleaning agents; cosmetics; textiles; leather and paper industries; mineral oil additives.
Fatty Amines and Derivatives	Fabric conditioners; mining; road-making; biocides; textile and fibre industries; mineral oil additives.

Source: Baumann *et al.*, 1988.

export duty on locally produced raw materials encourages processing and 'adds value' to these materials within the country in which they are produced. Tax holidays, or pioneer status which can last up to ten years, are part of the package of financial incentives which encourage manufacturers to site plants within ASEAN.

Established oleochemical producers from Europe, the United States and Japan have reacted to these incentives. The Philippines oleochemical industry is largely controlled by the Japanese. Unichema, Henkel, KAO, Procter & Gamble and Akzo Chemie all have a share in Malaysian plants.

APPLICATIONS OF OLEOCHEMICALS

Table 7 surveys the industrial applications of oleochemicals. There are many such applications where palm and palm kernel based oleochemicals excel as replacements for those made from tallow and coconut oil. Some of these are as follows:-

Soap

Soap consists of the sodium or potassium salts of a mixture of fatty acids. When selecting a mixture of fatty acids for saponification the necessary ratio of saturated and unsaturated and long and short chain fatty acids should be maintained to give the desired properties of stability, solubility, ease of lathering, and detergency in the finished soap.

Palm and palm kernel acids can be blended in the right proportions to obtain these properties. Research carried out at PORIM shows that palm-based soap has certain advantages, such as better perfume and whiteness retention, compared with tallow-based soap.

Cosmetics and Pharmaceuticals

Traditionally, double-pressed and triple-pressed fatty acids based on tallow have been used in cosmetics and pharmaceuticals for their emulsifying and emollient properties. Palm-based fatty acids can be produced to match the specifications of tallow-based acids and offered as replacements, with the added advantages of having less odour and being *kosher* and *halal* grades, acceptable to the Jewish and Muslim communities respectively.

Textile Lubricants

Dialkyl dimethyl ammonium chloride ($R_2N^+Me_2Cl^-$, where R is a long chain alkyl group) is the cationic surfactant that forms the basic ingredient of home laundry textile softeners. Traditionally, hydrogenated tallow has been the raw material for its manufacture (*i.e.* the source of the alkyl group). It has been effectively replaced with hydrogenated palm fatty acids, the vegetable origin of palm oil making the product more acceptable (de Vries).

Other Applications

Palm-based oleochemicals find extensive use in wide ranging applications such as the manufacture of paint, candles and biocides, in road making, and in the rubber and plastics industries, where they are successfully replacing oleochemicals based on tallow and coconut oil without loss of quality or performance.

CONCLUSION

Technically, almost all the oleochemicals currently produced from tallow and coconut oil can be replaced by oleochemicals based on palm and palm kernel oils. The production of palm based oleochemicals is increasing at a tremendous pace in South-East Asia and in particular, in Malaysia. The majority of these products are penetrating traditional markets in the West for products derived from tallow and coconut oil. Over the past decade, with a high annual rate of increase in production, palm and palm kernel oils have become important as raw materials in the world's oils and fats scene.

With demand for oleochemicals projected to reach 5.3 million tonnes in 1995, it is expected that more than twenty per cent of the world production of oleochemicals will be based on palm and palm kernel oils. Thus, there is no doubt that palm oil will play an increasing role in the growth of the oleochemical industry.

REFERENCES

RAPHAEL, L (1986). Manufacturing Chemist, 53

HAUPT, D E, DRINKARD, G and PIERCE, H F (1984). *J. Am. Oil Chem Soc., 61*, No 2, 280

ONG, A S H, CHEAH, K Y and CHOO, Y M (1989). *Elaeis 1*, No. 1, 33

de VRIES, R J (1984). *J. Am. Oil Chem Soc., 61*, No.2, 404-407

TAN, B (1989). *J. Am. Oil Chem Soc., 6*, No. 6, 770

DIECKELMANN, G and HEINZ, H J (1988). The Basis of Industrial Oleochemistry, 18

BRUCE, F G and LAYMAN, P L (1989). Soaps/Cosmetics/Chemical Specialities, 86

BAUMANN, H, BUHLET, M, FOCHEM, H, HIRSINGER, F, ZOEBELEIN, H, and FALBER, J (1988). Angew. Chem. Int. Ed. Engl. 27, 41

de VRIES, R J. Palm Oil (Gunstone F D (ed.)) published for the Society of Chemical Industry by John Wiley and Sons, 97