Fats and Oils as Feedstocks for Oleochemicals

K.F. GANDER, Unilever Forschungsgesellschaft mbH, Behringstrasse 154, 2000 Hamburg 50, West Germany

ABSTRACT

The approximate quantity of 3 million tons estimated to be required at present for the production of oleochemicals is to be covered from a total production of more than 60 million tons of vegetable and animal fats. While the quantity of oleochemicals produced has nearly doubled in recent years, vegetable oil production alone has increased from 25 to 40 million tons in the same period. More than half the feedstocks required for oleochemicals are acid oils and other fats and oils which are unsuitable for human food. The demand for fats and oils for oleochemicals will certainly grow for price and technological reasons, but only the use of large quantities of oils and fats for diesel engines could shift this balance drastically and endanger the world supply of edible fats. A bottleneck may arise in the supply of fatty acids of medium chain length, although the use of coconut and palm kernel oil by the food industry in the highly developed countries has been on the decline. The green revolution goes on and the fat supply grows faster than the population. In addition, new approaches to plant breeding and agriculture, and biochemical processes as well, might help circumvent any conceivable shortage in the supply of oils and fats in general, and in the supply of special fatty acids in particular.

Fats and oils are renewable resources. This is one of the reasons why they deserve worldwide attention. The great achievements of agriculture and plant cultivation in most of the supply countries have made it possible to meet the demand; actually, the production of edible oil increased faster than the population growth. Particularly in some of the developing countries, the consumption of edible fats has therefore increased with the improved standard of living. Nevertheless, as is shown in Figure 1, the total production of ca. 60 million tons of vegetable and animal fat is small when compared with the mineral oil production of more than 3,000 million tons per year, and still smaller if compared with other renewable commodities like wheat, rice and potatoes.

As a consequence of the continuous increase in production, world market prices for these important raw materials could be kept almost stable over the past decades with only some ups and downs (Fig. 2). It is clearly seen that this trend must have made fats and oils attractive compared to the increasingly expensive mineral oil and gas as raw materials for petrochemicals, especially after taking into consideration the much higher energy costs for chemicals from the latter resources.

Figure 3 shows the world production of fats and oils. Whereas the production of animal fats remained nearly constant over the past 20 years, world production of vegetable oils has been increasing at the enormous rate of 3-5% per year and supply is predicted to be plentiful in the foreseeable future.

Only one-third of the total fat production is put on the world market; the greater part is consumed in producing countries. Approximately 75% of world exports of oils and fats originate from the USA and Canada and from three relatively developed countries, namely, Brazil, Argentina and Malaysia. Over the last two decades the supply of vegetable oils has become more and more dominated by four oils: soybean oil (mainly from the USA), rapeseed oil (from Canada and Europe), sunflower oil (from the USA and Argentina), and palm oil (predominantly from Malaysia).

The cultivation of soybeans and rapeseed will find still more new areas in many parts of the world, especially as

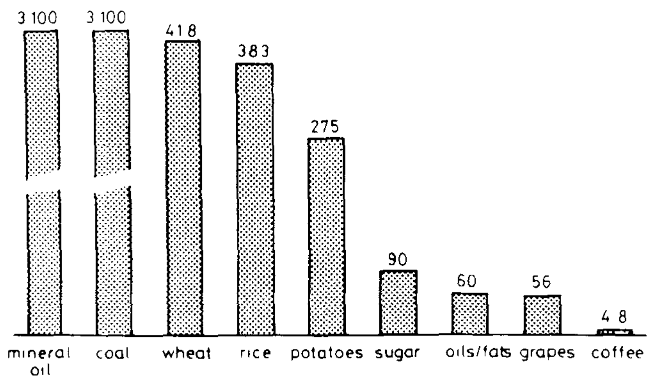

FIG. 1. Yearly production of some important raw materials (million tons).

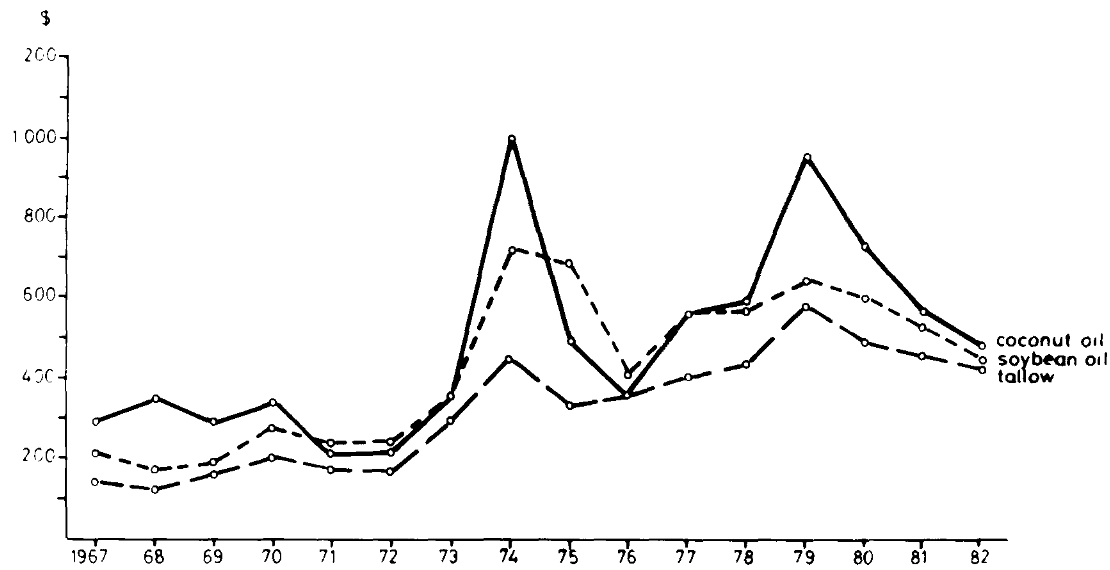

FIG. 2. Trend of prices of important oils and fats.

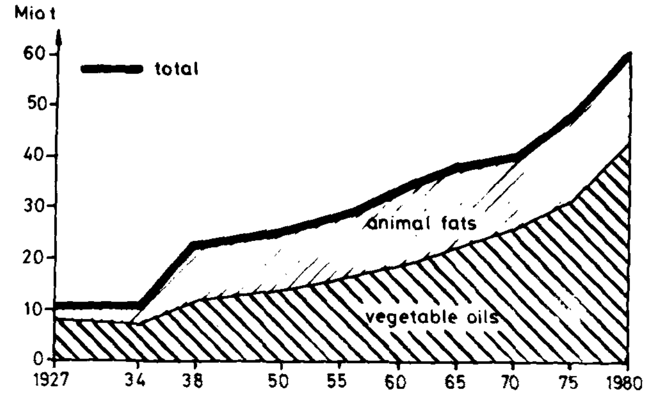

FIG. 3. World production of oils and fats.

TABLE I

Oils and Fats: World Production

Commodity	1955	1965	1975	Sept. 1982
	(million tons)			
Edible vegetable oils (except palm oils)	9.5	16.3	23.9	34.0
Palm oils	3.7	4.0	6.5	10.0
Industrial oils	1.2	1.6	1.3	1.3
Animal fats	9.3	12.0	13.6	14.6
Marine oils	0.9	1.1	1.2	1.2
World total	24.6	35.0	46.5	61.1

Source: USDA–FAS.

TABLE II

Consumption of Crude Vegetable and Marine Oils[a]

	Season 1970/71	Season 1980/81
	–(million tons)–	
World consumption	26.3	40.5
of which		
– for edible purposes	22.6	35.2
– for additives in animal feed	0.3	0.8
– for soap-making	2.4	2.6
– for oleochemicals or other industrial uses	1.0	1.9

Source: Unilever.
[a]Olive oil excluded.

the meal of both seeds is rich in protein and is gaining importance as animal feed due to an increasing meat consumption and milk production. Palm oil production continues to improve in Malaysia and will become more and more interesting to the African countries. Other oils and fats will also increase if prices remain attractive in the long run.

These trends are shown in Table I: the very steep rise in vegetable oil production and the slightly rising tendency of animal fats. Marine oils are stagnant, as are oils for industrial use. The latter fact deserves a few comments.

Over many decades there was great disparity between the prices of raw materials for petrochemicals and oleochemicals. Only in the last few years has a dramatic shift occurred. Crude mineral oil is sold for DM 0.50/kg and soybean oil sometimes is now on the market for DM 1.00/kg. Should the gap decline further, there would be considerable potential for an increased demand of vegetable oil for industrial use, considering the much lower costs for conversion into oleochemicals. There are even some investigations in the United States to use bean oil as carrier for pesticides in agriculture and for dust control in grain storage.

These developments would not necessarily mean a dramatic change in the world supply of edible oils and fats, particularly if the oleochemical industry responds with flexibility to the supply situation. Only a large-scale use of fats and oils for diesel engines could shift this balance to the extreme. From the quality point of view, there is available a sufficient variety of oils and fats that differ in their fatty acid compositions. The fatty acids vary in chain length and degree of saturation/unsaturation and thus comply with the many needs.

In addition, there exist considerable resources that are yet difficult to quantify, e.g., new crops of plants with seed fats not yet exploited; application of tissue cultures and genetic engineering to produce higher yields, and perhaps tailor-made vegetable fats. Finally, one could even imagine a large-scale fat production by microorganisms.

THE PROPORTION OF FATS AND OILS IN INDUSTRIAL USES

The data available on worldwide use of oils and fats by the oleochemical industry are certainly inadequate. However, for most of the countries there are reliable figures concerning the split between food and industrial uses of crude vegetable and marine oils. Moreover, we know the approximate turnover of the most important oleochemical producers, so that the two accounts can be combined. The result is shown in Table II. These estimates suggest that oleochemicals, together with other similar industrial uses, accounted for 5% of the world consumption of these crude oils, or for only 3.5% if other fats like butter, lard and olive oil are included in the estimates.

But tallows and greases have not been considered (see later in Table III), as the split in the use of these fats has even greater fluctuations. Another one million tons of oils used exclusively for technical purposes, e.g., tung oil and castor oil, are not included in this account.

The acid oils arising when crude oil is refined for food purposes are included in the estimates for animal feed, soap-making and oleochemicals. Quantities and percentages of free fatty acids (FFA) vary considerably among the different raw materials, as, e.g., palm oil, palm kernel oil and coconut oil, have generally 3-6% FFA, compared with only 1-2% FFA in the majority of seed oils. A rough estimate could start from an average of 2% acid oils, which means that ca. 0.7 million tons are available for the production of oleochemicals and soaps. About 0.2 million tons of this may be counted among the particularly important acid oils from coconut and palm kernel oil. Furthermore, this proportion of acid oil should decline on account of the fact that more and more crude products are freshly processed in the countries of origin.

It is also striking in Table II that the increase of 0.9 million tons of oleochemicals from these resources over 10 years is small in absolute terms, compared with the growth of feed uses of ca. 12 million tons in the same period. There is obviously much scope for further development of oleochemicals.

OIL AND FATS AVAILABLE PRIMARILY FOR TECHNICAL USES

Oils and fats available primarily or exclusively for technical uses due to their special composition are listed in Table III. Reliable figures on today's production of high-erucic rapeseed oil for technical and other uses are lacking and, therefore, are not included in this table, but India, China

TABLE III

World Consumption of Oils and Fats for Primarily Technical Uses[a]

	1971	1981
	–(million tons)–	
Linseed oil	1.23	0.64
Castor oil	0.35	0.35
Tung oil	0.14	0.09
Olive residue	0.13	–
Tallows and greases	4.67	6.04
Total	6.52	7.12

Source: USDA-FAS.
[a]High-erucic rapeseed oil excluded.

and the Comecon still produce this type of rapeseed primarily as an edible oil. There should be sufficient commercial interest to export some high-erucic oil as a raw material for oleochemicals.

It is assumed that, of the 6 million tons of tallows and greases, only a small portion of high-grade tallow is used for human food, and that the larger portion is used as additive in animal feed. Also for these animal fats we have no reliable figures regarding processing into soap and oleochemicals, particularly as the split of quantities fluctuates considerably from one country to another and from time to time. From the point of view of cost and supply, tallows and greases are important resources of raw materials which will continue to grow with an increased meat production.

In the case of linseed, castor and tung oils, it will be a question of continued steady demand as to whether and to what extent the current low production may be increased. It appears that no great changes have occurred in the past few years.

THE SUPPLY OF FATTY ACIDS OF MEDIUM CHAIN LENGTH

To cover the world's demand in fatty acids, there is no need to split large quantities of oils and fats which are suitable for human food. This has been shown by the figures and production trends as outlined before. There are always some batches on the market which have to be sold for technical uses only, be it for reasons of contamination during transport or for some other hygienic reasons. However, the only significant bottleneck is to be seen in the supply with fatty acids of medium chain length, like lauric or myristic acid, which are distinguished by their specific technical properties. Table IV shows the production of these fats.

An estimate shows that, of the 4.5 million tons of crude vegetable oil used in 1981 for the production of soap, detergents and oleochemicals, at least one-third was needed in the form of these medium-chain fatty acids. It is assumed that the amount of 7.5 million tons of washing powder produced at present contains ca. 0.35 million tons fatty acids of medium chain length; add to this ca. 0.75 million tons for toilet soaps and bars.

The demand for oleochemicals will rise considerably with the anticipated substitution of petro-based surface-active agents in washing powder by substances from renewable resources, e.g., from vegetable oils. Of course, price and demand will take care that other fatty acids too, in one modified form or the other, compete with the fatty acids of medium chain length. Anyhow, currently the demand for these fatty acids (in the order of 1.5-2.0 million tons) is first met by 0.2 million tons of those acid oils; the rest has to come from a total production of 4 million tons of neutral coconut, palm kernel and babassu oil, all of which by tradition are intended primarily for human food.

At present, the production of coconut and palm kernel oil shows an upward trend; however, this is to a smaller extent than other seed oils. Coconut trees are grown to a great extent on the Philippine Islands where new plantations are located on the Southern Islands which are seldom hit by typhoons.

Cultivation of palm trees, mainly in Malaysia, has been improved enormously, and in recent times the percentage of kernels in relation to oil from the fruit has increased.

It is fortunate, from the point of view of the oleochemical industry, that the demand of oils rich in fatty acids of medium chain length for food use in the industrialized countries is declining. For soft margarines, cooking fats and shortenings, which are the favorite products today, coconut and palm kernel oils are not very suitable; they make these products brittle. On the other hand, they play rather an important role as fat constituents in filled milk products.

It remains a challenge to scientific research and to agriculture to further the breeding and cultivation of plants rich in fatty acids of medium chain length, just as it is an economic challenge to the industry to substitute these acids by other fatty acids or use enzymes as specific catalysts to produce them.

To sum up, Table V gives an overall picture, keeping in mind the factor uncertainty as explained before.

If we want to look into the future, the fats and oils must not be seen as an isolated commodity. There are other types of renewable raw materials, and all of them have to be compared with the fossil resources.

Three years ago, the Battelle Institute in Frankfurt undertook a study to look for alternatives for mineral oil and came to the following conclusions:

—as a source of energy, mineral oil cannot be substituted by any type of biomass;
—as a raw material for chemicals, the renewable biomasses have quite different properties and are accordingly of more or less value.

TABLE IV

Production of Oils Rich in Acids of Medium Chain Length

	1955	1965	1975	1982
	--(million tons)--			
Coconut	2.02	2.13	2.89	3.20
Palm kernel	0.38	0.43	0.52	0.83
Babassu	0.05	0.05	0.10	0.14
Total	2.45	2.61	3.51	4.17

Source: USDA-FAS.

TABLE V

Overall Picture of Oils and Fats

Use	(million tons)
Edible and animal feeding	52
Soap	4
Oleochemicals	3
Other industrial uses, e.g., paints, linoleum	2

Table VI shows the evaluation of 5 types of biomass in comparison to mineral oil. From these data it seems to be justified to assume that fats and oils are the best raw material for various chemicals. In other words, the prospects for oleochemicals are obviously very promising.

TABLE VI

Usefulness of Biomasses as Raw Materials for Chemicals

	Mineral oil	Lignin	Cellulose	Starch	Sugars	Fats and oils
Density of energy	+++	++	+	+	+	++
Reactivity	++	+	++	++	++	+++
Production of well defined compounds	++	–	++	++	+++	+++
Multiple application of structural elements	+++	–	–	–	–	++
Vicinity to end-producer	++	–	–	–	–	++
Possibility of homogeneous reactions	+++	–	–	+	++	+++

+++Very useful.
++Useful.
+Applicable.
–Useless.

Oleochemicals: Feedstock or Auxiliary

J.F. HEIDRICH, Henkel KGaA, Postfach 1100, B-4000 Düsseldorf, West Germany

ABSTRACT

Today's oleochemicals are substances which are used not mainly because of their sophisticated chemical structures or their chemical reactivity, but rather because of their adaptability as auxiliaries in a great variety of formulated products. This has determined their success in the marketplace. The conversion to long-chain building blocks for polymers is one possibility to move oleochemicals into a larger scale position as feedstocks. In the near future, this objective cannot be reached because two factors limit their economical chemical derivation; namely, the missing technologies to separate chemical individuals with one or two double bonds in the alkyl chain from the natural mixtures, and to cleave double bonds in a controlled way, without forming larger quantities of byproducts. In any case, before oleochemicals (e.g., fatty acid methyl esters) are used as substitutes for gasoil, as is already tried in certain countries, the chemical potential of oleochemicals should be exploited. That means: "Use it–don't burn it!" Today's chemical processes and uses for oleochemicals are discussed.

OLEOCHEMICALS–FEEDSTOCK FOR THE FUTURE

Key chemicals derived from natural oils and fats are basically different from products obtained by today's petrochemical industry or possibly by the future coal-based chemical industry (Table I).

Primaries or intermediates from crude oil and coal are short-chain building blocks from which chemical compounds of the most varied nature may be synthesized. If the appropriate path of conversion is chosen, e.g., the Mobil process, it will be possible in the future to create products of ethylene chemistry via methanol (1). The American Institute of Chemical Engineers (AICHE) says, "today's feedstock for the chemical industry will undoubtedly remain the feedstocks of the future, but they will have their origins in different raw materials" (2). This can hardly be contradicted.

TABLE I

Key Chemicals from Different Resources

Crude oil	Fats and oils	Coal/methanol
Ethylene	Fatty acids	Ethylene
Propylene	Fatty alcohols	Propylene
Styrene	Glycerol	Formaldehyde
Vinyl chloride	Fatty amines	Acetic acid
Methanol		Ethylene glycol
Formaldehyde		

Even if a report published by the organization for Economic Cooperation and Development (OECD) (3) possibly exaggerates the trend by stating that in 1990 chemicals from coal will total 20 million tons/year and by the year 2000 40 million tons/year, it will be coal which will first supplement crude oil as raw material. The inevitable use of the existing infrastructure for ethylene chemistry will make this necessary.

THE POSITION OF OLEOCHEMICALS

According to a calculation published by the US Department of Agriculture (USDA), only 24% of the heat of combustion of soybean oil is used to produce it (4). This percentage is significantly below the energy necessary to produce diesel oil from coal.