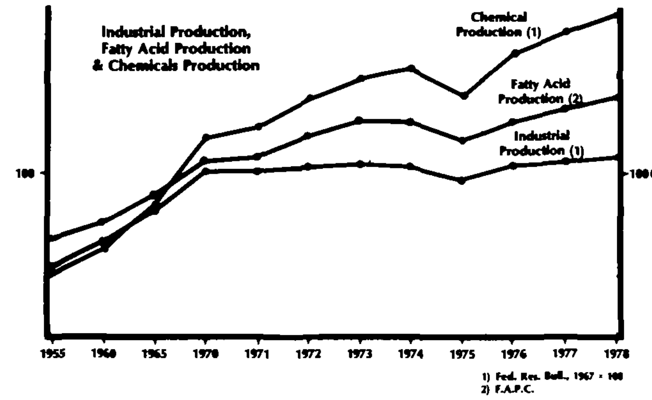

FIG. 1. Parallel of fatty acid production to U.S. industrial production.

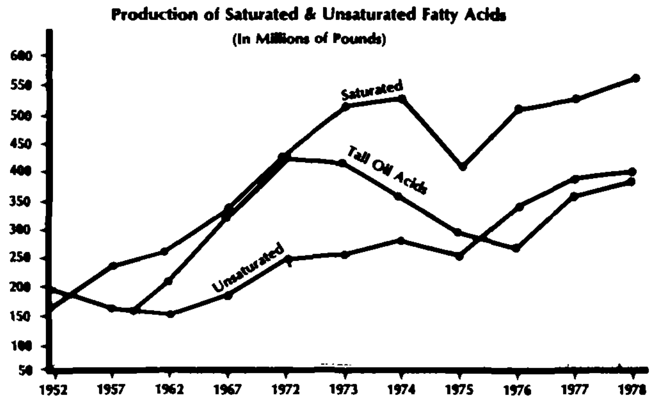

FIG. 2. Fatty acid production of 1978.

the U.S. for imports of acids and derivatives are today, to say the least, convoluted and conflicting.

The company that produces *only* fatty acids and fatty acid derivatives is the exception today, rather than the rule. For the most part they are divisions or subsidiaries of larger corporations. Perhaps part of this is due to the scope of applications of the acids themselves and the even wider scope of derivative applications. It has been estimated (4) that no one field of use represents more than 20% of the total one billion pounds consumed in 1978. It should be pointed out that the figures shown for production are fatty acids produced for merchant sale or captive use, and do not reflect acids produced as part of a continuous soapmaking process. This diversity of markets can have its own problems. The costs of keeping abreast of uses, technology, and marketing in all the possible fields of application are high for the dollar volume involved. Developmental and technical departments, operating independently of sales staffs, offer new fatty chemicals for experimental use with the objective of breaking into new markets.

Fatty acids in today's markets find their way into thousands of uses and probably most of these uses are via derivatives. The diversity of end use applications is partially explained by the relatively low cost of commercial fatty acids, their physiological compatability with animals and humans, availability of raw materials and the highly functional surface activity of the derivatives. For example, grease is merely petroleum oil until 1% to 5% of fatty acid soap is added; rubber compounds do not vulcanize properly until about 1% of stearic acid is added; 0.15% of a fatty acid-derived emulsifer in bread minimizes variations in texture and volume and provides antistaling properties. Nitrogen derivatives of fatty acids are even more dramatic in their surface active properties—0.25% of a fatty acid amine provides corrosion resistance in secondary oil recovery and only parts per million of a fatty acid quaternary maintain control of sulfate-reducing bacteria in the same process. A very small amount of fatty acid amine will function as an additive in automobile gasoline, and an equally small quantity of a fatty acid quaternary will soften and render static free 80 pounds of dry laundry.

Expansion of the fatty acid derivative market has over the years tended to change the nature of the fatty acid industry from fat splitters to chemical compounders. It has been estimated, in one study, that there are 26 or 27 sharply defined end uses for fatty acids and seven main classes of derivatives. In 1952 when the FAPC started collecting its data on production and disposition of fatty acids, 14% of annual production was used captively by the reporting companies. In 1978, 30% of production was reported as being used captively to make derivatives. Or, more specifically, in 1952 the captive use was 51 million pounds, in 1978, 290 million pounds.

What in essence is an old industry continues to grow and serve many valuable and diverse speciality end uses today. New uses continue to be found. Raw materials are replenishable and probably will be expanded; they are often byproducts and often interchangeable. The industry has grown and should in future continue to grow and find new outlets.

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Vegetable Oil Raw Materials

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ABSTRACT

Vegetable oils that are important to the chemical industry include both edible and industrial oils, which contribute 24% and 13.5%, respectively, compared to 55% for tallow, to the preparation of surfactants, coatings, plasticizers, and other products based on fats and oils. Not only the oils themselves but also the fatty acids recovered from soapstock represent a several billion pound resource. Coconut oil is imported to the extent of 700-1,000 million pounds per year. Its uses are divided about equally between edible and industrial applications. Safflower oil has a

TABLE I

Relative Contributions of Fats and Oils to Edible and Industrial Uses[a]

Fat or Oil	Edible uses		Industrial uses	
	Amount, million lb	Percent of total	Amount, million lb	Percent of total
Food vegetable oils	9630	90.3	761	24.0
Animal fats	1015	9.5	1850[b]	58.4
Industrial oils	---	---	429[c]	13.5
Marine animal oils	---	---	57	1.8
Other	17	0.2	71	2.3
Total	10,662	100.0	3168	100.0

[a]Calculated from the data given in Ref. 2.

[b]Exclusive of the 1407 million pounds of inedible tallow going into feed.

[c]Exclusive of the 1134 million pounds of tall oil produced in 1977.

TABLE II

Fats and Oils: Per Capita Use in Products for Civilian Consumption, United States, 1935-1977 (1)

Period	Average consumption (lb per capita)		Ratio, food:nonfood uses
	All industrial products	All food products	
1935-39	22.2	45.4	2.05
1950-59	24.0	44.9	1.87
1960-69	25.8	48.0	1.86
1970-74	25.1	53.4	2.13
1975	23.5	53.4	2.27
1976	26.5	56.1	2.12
1977	25.9	54.4	2.10

relatively small production, but 15-25% of the oil goes into industrial products. Soybean oil, the major edible oil of the world, is produced in the United States at the rate of 11,000 million pounds per year with more than 500 million pounds going into industrial uses, representing 5% of the total production. Castor oil is imported to the extent of about 100 million pounds per year. Linseed oil production has declined drastically over the last 25 years but still amounts to about 100 million pounds per year. Oiticica and tung oils are imported in lesser amounts than castor and linseed oils. New crops that have industrial potential, as well as the traditional vegetable oil crops, include seed oils from crambe, *Limnanthes, Lesquerella, Dimorphotheca, Vernonia,* and *Cuphea* plants. Crambe oil contains up to 65% erucic acid. Oil from *Limnanthes* contains more than 95% of fatty acids above C_{18}. *Lesquerella* oil contains hydroxy unsaturated acids resembling ricinoleic acid from castor oil. *Dimorphotheca* oil contains a conjugated dienol system. *Vernonia* oils contain as much as 80% epoxy acids. The *Cuphea* oils contain a number of short chain fatty acids. Of these, crambe, *Limnanthes,* and *Vernonia* are probably the most developed agronomically. Competition between vegetable oils and petrochemicals for the traditional fats and oil markets has been marked over the past 25 years, but prices for petrochemicals have accelerated at a greater rate than those for vegetable oils; and, it is now appropriate to reexamine the old as well as the new markets for fatty acids.

INTRODUCTION

Total domestic fats and oils (including butter fat) disposition amounted to 17.3 billion pounds in 1977; ca. 5.6 billion pounds went into nonfood products (1). The major nonfood uses included:

	Million pounds
Soap	931
Drying oil products	543
Other	4136

Oils and fats going into nonfood products originate from a variety of sources and include (Table I) (2): food vegetable oils, industrial vegetable oils, land animal fats, and marine animal oils. The most important source of industrial products is the animal fats, which contribute 58% of the total. Surprisingly, food vegetable oils contributed more than industrial oils to industrial products in 1977 (24% vs. 13.5%). A previous estimate for 1974 had indicated food oil contribution of 20% and industrial oil contribution of 23% (3). The differences reflect both an increase in absolute amounts of food oils used for industrial products and a decrease in industrial oils. It is fortunate that the edible oil industry has large reserves that can be drawn upon in relatively stable markets and prices. Also fortunate is the large scale in which refining of edible oils is carried out to produce millions of pounds of byproduct fatty acids.

The ratio of fats and oils consumed in food products as opposed to those consumed in all inedible products (including feed additives) has remained close to a value of 2:1 with minor fluctuations for a period of more than 40 years (Table II) (1).

Out of the 174 billion pounds of synthetic organic chemicals produced in the United States in 1977 (4), only a small portion (1.8%) were based on vegetable oils. The potential for providing a much greater portion exists and must be exploited in our research for alternative resources and materials.

The current situation with regard to both commercial and potential seed oil crops is reviewed in the following

TABLE III

Prices (5) and Characteristic Acid of Vegetable Oils and Their Fatty Acids

Vegetable oil or fatty acid	Price, dollars/lb	Characteristic acid (wt %)
Castor oil, raw	0.3775	Ricinoleic (89)
Dehydrated, bodied	0.59-0.62	
Hydrogenated	0.57	
Sulfonated, 50%	0.47-0.48	
Acids, dehydrated	0.87-0.90	
Coconut oil, crude	0.4750-0.4875	Lauric (44)
Acids distilled	0.52-0.57	
Corn oil, crude	0.36	Linoleic (57)
Soapstock acids, 95%	0.15	
Acids	0.40	
Cottonseed oil, crude	0.34	Linoleic (50)
Soapstock acids, 95%	0.1775	
Acids, distilled	0.32	
Linseed oil, raw	0.24	Linolenic (57)
Acids	0.39-0.57	
Oiticica oil	0.56	4-Oxo-9,11,13-octadecatrienoic acid (78)
Palm oil	0.33	Palmitic (42)
Acids, distilled	0.35	
Safflower oil, non-break	0.41-0.42	Linoleic (73)
Soybean oil, crude	0.2679	Linoleic (51)
Soapstock acids, 95%	0.15-0.16	
Acids, single distilled	0.42-0.43	
Sunflower oil	---	Linoleic (64)
Tung oil	0.68-0.70	α-Eleostearic (80)

TABLE IV

Uses for Castor Oil and Its Derivatives (6)

Treatment	Application
None	Lubricants
	Polyurethane encapsulating resins
Sulfation	Surfactant
Dehydration	Paints and varnishes
Pyrolysis	Undecylenic acid (fungicide, nylon-11)
Alkali fusion	Sebacic acid (plasticizers, polyesters, polyamides)
Hydrogenation	Lithium hydroxystearate (greases)

paragraphs. Speculations on their future uses are also reviewed.

COMMERCIAL OILS IN NONFOOD USES

Introduction

Commercially available vegetable and palm oils used at least to some extent in industrial products include castor, coconut, corn, cottonseed, linseed, oiticica, palm, safflower, soybean, and tung oils. Coconut and soybean oils are the most important in nonfood uses with annual consumption at about 500 million pounds apiece. Prices for these oils vary considerably but remain at about the same position relative to each other (Table III) (5). The compositions also are considerably different for the various oils and are direct indicators for many of the nonfood uses for the oils.

Castor Oil

Grown to some extent in the southern states in years past, this industrial oil is now almost exclusively imported–95 million pounds in 1976 and 109 million pounds in 1977 (2). Castor oil contains up to 90% ricinoleic acid, 12-hydroxy-9-octadecenoic acid, and, because of the variety in its reaction, its derivatives have found numerous uses (Table IV) (6). Castor oil is the source of undecylenic and sebacic acids, nylon 11, and the grease thickener lithium 12-hydroxystearate and other products (6).

Coconut Oil

The Philippine drought resulted in low output for 1977-78 and in higher prices–43¢/lb. -during the first 4 months of the 1978-79 season, up 70% from the previous season. However, imports will still be ca. 90% of the previous season, when 1.0 billion pounds were imported. In 1977, more coconut oil was consumed in inedible than in edible products (Table V) (2). Coconut fatty acids, containing 48% of lauric acid and lesser amounts of shorter chain acids, now appear to be losing out to linear alcohols prepared by the ethylene telomerization route as a source for C-12 sulfated-alcohol surfactants. However, continuation of this trend will depend upon the price of coconut oil increasing at a greater rate than ethylene, a situation that does not seem probable in view of the recent price increases in petroleum.

Refining losses and foots, a source for the short chain fatty acids, amount to about 45 million pounds per year (7). Coconut fatty acids are priced at 0.50-0.60¢/lb. (5).

Corn Oil

Corn oil is in itself not important to nonfood uses, but foots and loss amount to 30 million pounds and provide a source of linoleic acid.

Cottonseed Oil

Prospective cotton acreage at 14.0 million acres is up

TABLE V

Coconut Oil Uses (2)

Use	Amount, million lb	
Edible, total		383
Inedible, total		495
Soap	197	
Paint	5	
Fatty acids	116	
Other	177	

from the 13.4 million last year. Reduced cotton production in 1978 and relatively favorable prices to growers are main reasons for expansion (8).

Cottonseed oil supplies are at 1.4 billion pounds, ca. 10% lower than the 1977-78 season. Domestic use may continue at about the 0.7 billion pound rate of the 1977-78 season, but soybean and sunflower oils will provide stiff competition. Preference for cottonseed oil in Western Europe, South America, and Egypt should keep exports strong, albeit at a lower level, compared to the 0.7 billion pounds exported in 1977-78 (8).

Cottonseed oil prices (crude, Valley) are strong, averaging 29¢ per pound for the first few months this season compared to 21¢ the year before (8).

Only 10 million pounds of cottonseed oil were consumed in nonfood uses in 1977, but foots and losses provide about 100 million pounds of cottonseed fatty acids (7).

Linseed Oil

This industrial vegetable oil had markets of more than 800 million pounds in 1941 and 1942, but this value has steadily declined ever since to ca. 225 million pounds in 1977-78 and 1978-79 (Fig. 1) (7,9). The major use of linseed oil is in paints and varnishes, and this market volume has declined from a volume of more than 650 million pounds in 1941 and 1942 to its present value of 225 million pounds. During the period of about 1940 to 1953, 80 to 100 million pounds were also consumed in linoleum and oilcloth production; however, this use has essentially disappeared. The disappearance of linoleum markets and the reduced consumption of linseed oil in paints can be ascribed to the development of low cost petrochemicals for these applications. The behavior of linseed markets in the last three years suggests that perhaps the decline has bottomed out.

Linseed oil prices (raw, Minneapolis) are averaging 24¢ per pound, about the same as the previous year (Fig. 1). The OPEC crisis in 1973 gave rise to an average price of almost 50¢ per pound, but prices have declined steadily since then.

Oiticica Oil

This quick-drying oil, used in paints and varnishes, is imported to the extent of only several million pounds annually.

Palm Oil

West Malaysian palm oil production is expected to rise 0.3 million tons over 1977-78's 1.6 million tons. This increase may result in lower prices, compared to the 31¢/lb. for the October-January level, and in increased imports, which amounted to 362 million pounds in 1977-78 (8). Imports in the United States reached a maximum of 962 million pounds in 1975 and have since declined. The major part of the imported palm oil goes into shortening.

Palm oil is a good source for palmitic acid, which results from physical refining of the oil to make edible products.

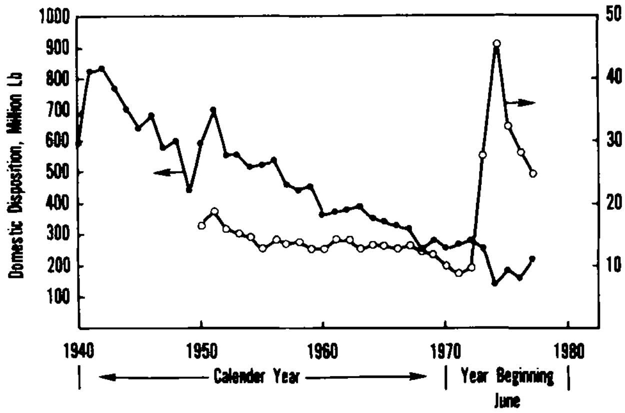

FIG. 1. Linseed oil domestic disposition and price, 1940 to present (7,9).

Only about 13 million pounds of palm oil were used in industrial products in 1977, 26 million pounds in 1976 (2).

Peanut Oil

U.S. peanut oil supplies for 1978-79 total 4.5 billion pounds, ca. 4% above last season. Edible uses will increase 3% to 1.9 billion pounds. Domestic crushing will increase only slightly over last year's 0.5 billion pounds because of strong overseas demand, which amounted to 1.0 billion pounds last year (9). Exports of peanut oil amounted to 1.2 million pounds in 1976 (1).

Only 2.6 million pounds of peanut oil in 1977 and 2.0 million pounds in 1976 went into nonfood uses. Loss and foots amount to only 5-10 million pounds.

Safflower Oil

Production of safflower is limited to the irrigated lands in California and Arizona, and the oil was produced to the extent of 38 million pounds in 1977 and 40 million pounds in 1976 (2). Safflower oil is unusual in that perhaps 15% of its output is consumed in industrial products, particularly alkyd paints, in spite of its standing as a premium edible oil. Its high quality in both edible and inedible uses is the consequence of its high linoleic acid and negligible linolenic acid contents.

Soybean Oil

U.S. soybean supplies for the 1978-79 marketing year total a record 2.0 billion bushels (120 billion pounds) (8). In spite of the high production, demand for both meal and oil has boosted prices to an average of $6.40 per bushel for the first third of the season. For all of 1978-79, exports may total about 760 million bushels (46 billion pounds). Soybean prices may moderate to some extent if U.S. farmers follow through on intentions to plant a record 66 million acres in 1979 and if prospective South American crops are record large.

Soybean crushings for all of 1978-79 are expected to approximate 1.0 billion bushels, compared to the 927 million processed last season. The increase reflects the strong demand for meal in livestock and poultry feeds. Processing margins are also favorable at 44¢/bushel compared to 27¢ a year ago.

Soybean oil supplies in 1978-79 are estimated at 11.5 billion pounds compared with 11.0 billion last season. Domestic use is expected to rise to ca. 8.7 billion pounds, or some 5% above 1977-78. U.S. supplies of competitive cottonseed oil and palm oil are smaller, but there are greater quantities of sunflower seed and corn oils.

The domestic use of soybean oil has shown a strong uptrend for many years and now accounts for more than 60% of all food fats and oils.

TABLE VI

Nonfood Utilization of Soybean Oil, 1976 (10)

Use	Utilization, million lb
Paint and varnish	85
Resin and plastics	83
Other drying oil products	4
Fatty acids	26
Other inedible	32
Foots and loss	278
Total	508

Soybean oil exports are projected at above 1.8 billion pounds, down from the record 2.0 billion pounds shipped in 1977-78. The prospective decline mainly reflects improved oilseed crops in many foreign countries and reduced P.L. 480 (Title I) shipments.

Prices of soybean oil (crude, Decatur) have been relatively stable, averaging 26¢/lb. for the first part of the 1978-79 marketing year compared to 21¢/lb. during October-January, 1977-78. A price rise is not likely this year because of increased competition from other sources of vegetable oils both here and abroad.

Nonfood uses amount to ca. 500 million pounds/year (Table VI) (Fig. 2) (7,9). Soybean oil utilization in paints and varnishes has declined since it reached a maximum of ca. 160 million pounds in 1953 (Fig. 3). The decline has been offset to some extent by an increase in epoxidized soybean oil utilization (Fig. 3) (4) and other uses such as an alternate starting material to tall oil fatty acids for dimer acid manufacture.

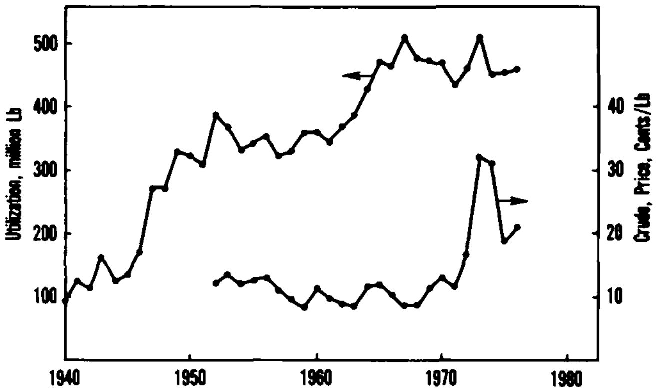

FIG. 2. Soybean oil total nonfood utilization and price, 1940 to present (7,9).

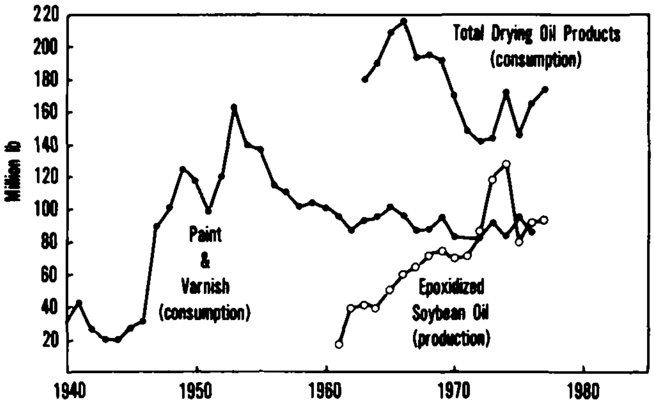

FIG. 3. Soybean oil utilization in paints and varnishes and total drying oil products, and production of epoxidized oil (4).

Sunflower Oil

Total supplies in 1978-79 for this increasingly important crop are estimated to be a record 1.9 million metric tons, ca. 40% higher over the previous year (8). More than 90% is the oilseed variety (40-45% oil content), with the remainder in low-oil content varieties for confectionery and birdseed uses (11). The bulk (two-thirds) of U.S. sunflower seed production is exported, and ca. 1.3 million tons will be exported this season to West Europe, East Europe, Mexico, and Venezuela.

U.S. consumption of sunflower seed oil is expanding sharply this year as food processors use increasing amounts in cooking oil and margarine products. About 4.1 million acres in North Dakota, South Dakota, Minnesota, and Texas will be seeded in 1979, about 48% more than last year, largely at the expense of rye and wheat plantings.

The U.S. crush is estimated at 0.4 million tons for this season, some 75% more than in 1977-78, to produce ca. 155,000 tons of crude oil compared to the 88,000 metric tons produced in 1977-78.

Sunflower oil is too new to have records of possible nonfood uses, but its composition indicates that use in alkyd paints, for example, should introduce no problems.

Tung Oil

This quick-drying oil is still used in paints, varnishes, and enamels to a significant extent. Although tung nuts were once grown in the United States, the trees have been destroyed by frost and hurricane so that present U.S. production is negligible. Tung oil is now imported to the U.S. in the amount of 20-30 million pounds annually, down from a high of 140 million pounds in 1947 (9).

NONFOOD USES FOR VEGETABLE OIL PRODUCTS

Drying Oil Industries

Utilization as drying oils constitutes one of the largest markets for vegetable oils (Table VII) (1); linseed and soybean oils are consumed to the greatest extent in this use. This market has been retained by the vegetable oils in the face of competition from petrochemically derived materials because of their air drying, flexibility, adhesiveness, and other properties that are not easily obtained from petrochemicals. It has been estimated that ca. 40% of the paint binder market has been retained by the vegetable oils (12).

Surfactants

The traditional use of fatty acids in soaps has been continued, and new products such as alcohol sulfates, alkoxylated alcohols, condensation products of diethanolamine, and quaternary salts have been developed so that an estimated 50% of the total market has been retained by vegetable oils and their derivatives (12). The total production of surfactants is on the order of 4.5 billion pounds.

Plasticizers

Plasticizers from vegetable oil sources include various pelargonic, lauric, myristic, palmitic, stearic, oleic, ricinoleic, azelaic, and sebacic esters as well as epoxidized esters, and these contribute ca. 15% to the total market (12). The total plasticizer market is on the order of 1.6 billion pounds.

Miscellaneous

Vegetable oils and their fatty acids have many diverse applications and are essential to lubricants and lubricant additives, greases, cosmetics, pharmaceuticals, and the food industries in addition to the markets already mentioned. A few specific examples can be used to illustrate this diversity. The polyamide nylon 11 is made from the undecenoic acid obtained from castor oil. Erucamide is a good

TABLE VII

Oils Used in the Drying Oil Industries, 1977 (1)

Oil	Amount, million lb
Castor	63
Fish	11
Linseed	156
Soybean	172
Tall oil	85
Tung	19
Other	37
Total	543

antiblock agent for polyolefin films and has been made from rapeseed oil. Food emulsifiers are made from mono- and diglycerides as well as propylene glycol esters. Amines are useful corrosion inhibitors and in ore recovery as well as in the synthesis of quaternary ammonium salts that have surfactant and antimicrobial properties.

POTENTIAL NEW CROPS AND THEIR POSSIBLE USES

The Northern Regional Research Center at Peoria had at one time a screening program for seed oils from all over the world to identify potential domestic sources for imported oils now filling industrial needs (12,13). The most promising seed oils and their characteristic fatty acids are listed in Table VIII (14,15).

Cuphea oils are notable for their high content of short chain fatty acids (16), which are projected to be in short supply as the result of increased use in synthetic ester lubricants (17). The major fatty acids range from C_8 to C_{12} in the various species. Such oils might serve in place of imported coconut oil as a source of 12-carbon compounds in surfactant applications. Agronomic development of *Cuphea* apparently has been successful in Germany, but its development in the United States has not yet been attempted.

Crambe and *Limnanthes* seed oils have high contents of long chain fatty acids and could be grown as replacements for imported, high erucic rapeseed oil.

Crambe is at an awkward stage in its development—between infancy and maturity—in which it is an agronomically developed plant but it is not yet accepted as a commercial crop. *Crambe* oil with its high content of erucic acid has a number of possible uses, with oxidative cleavage to brassylic acid being one of the more interesting possibilities (18,19). Synthesis of polyamides (20,21), copolyamides (22), plasticizers (23), and polyurethane elastomers (24) illustrates the versatility of this 13-carbon dibasic acid.

The *Lesquerella* and *Dimorphotheca* seed oils have hydroxy groups as well as unsaturation. *Lesquerella* oils, being analogous to imported castor oil, could perhaps replace the latter in some of its uses. Lesquerolic acid yields dodecanedioic instead of sebacic acid. *Dimorphotheca* oils have a conjugated dienol system, and after suitable processing, would yield a drying oil comparable to tung oil.

Crepenynic acid, octadec-9-yn-13-enoic acid, is a potential source of cyclic fatty acids (25).

The epoxy oils in the *Vernonia*, *Stokesia*, and *Euphorbia* seed oils are possibly replacements for epoxidized soybean oil. These epoxy oils have the unsaturation as well as the epoxide group and may not be desirable in plasticizer-stabilizer uses, but they may be useful in other applications.

NEW PRODUCTS AND MARKETS

Coatings, surfactants, and plasticizers are the major traditional markets for vegetable oils, and the volume of use in these markets can be expected to be at least maintained but more likely expanded (26).

New derivatives for not only traditional but also nontraditional markets are fair game for fats and oils. Some examples of materials as yet not exploited follow.

Acrylated, epoxidized soybean oil can be polymerized to clear, thermosetting resins or copolymerized with styrene to flexible, tough resins having good abrasion resistance and good tensile and flexural strength (27).

Vinyl ethers of unsaturated fatty alcohols form terpolymers with isobutyl vinyl ether and cyclopentadiene that make baked can coatings having excellent flexibility, adhesion, and hardness (28).

Nylon 9, which can best be made from high oleic oils, has strength properties comparable to nylon 6 and nylon 66, but it has improved dimensional stability because of lower moisture absorption (29).

Nylon 1313 has even lower moisture absorption and is also a promising candidate for engineering thermoplastics (30).

Fatty aminimide derivatives have surfactant properties and rearrange to isocyanates upon heating (31).

Epimino- (32) and epithio- (33) derivatives of stearic acid have good potential for lubricant additives.

Of great future significance are the antimicrobial, anticariogenic, and pesticidal activities of fatty acids (34).

More examples can be cited, but to do so would distract attention from the realizations that fats and oils have not been utilized to best effect in the past and that now is the time to examine these renewable resources for optimum benefit.

VEGETABLE OILS VS. PETROCHEMICALS

Inexpensive petrochemicals have become the basis for much of the organic chemical industry, with the result that fats and oils have lost ground in some markets or have remained stationary in others. The fact that they have retained some markets at all can be at least partly attributed to many desirable properties of the long hydrocarbon chain in the fatty acids.

It is fully expected that fats and oils will regain much of their traditional markets in industrial products and will also find several new markets.

Perhaps some basis for making this prediction can be found in several recent news releases. Ashland Chemical Co. has doubled its capacity to 100 million pounds per year for fatty nitrogen derivatives (35). Fatty alcohol expansion in a West German company will be based on vegetable oil and not petrochemical feedstock because of high prices for the latter (36). The Lurgi process will be used involving high pressure and a copper-based catalyst for the direct conversion of fatty acids to alcohols (37). A company in England has developed a process to replace mineral oils with vegetable oils for making urethane foams that do not support combustion and have better insulation properties (38).

In contrast to these developments, however, the industry is turning to petrochemicals to make short chain fatty acids in the C_7 to C_9 range for synthetic ester lubricants, perhaps as the result of insufficient knowledge and development of oils, such as those from the *Cuphea* plants, that produce short chain fatty acids (39, 40).

Vegetable oils cannot replace petrochemicals in their entirety, but they can be expected to supplement other resources such as coal or agricultural biomass. It has been estimated that 600 million acres of soybean plantings would be required to provide sufficient feedstock for the organic chemical industry (3), if a gross presumption is made that soybean oil could meet all types of needs. In the United States, about 360 million acres of land are used as cropland; another 100 million acres are idle or used for pasture; and there are about 600 million acres of grassland pasture (1).

TABLE VIII

Potential New Crops and Their Characteristic Acids

Fatty acid type	Genus of seed oil	Major fatty acid (wt %)
Short chain	*Cuphea hookeriana*	8:0 (65)
	C. painteri	8:0 (73)
	C. ignea	10:0 (87)
	C. carthogenensis	12:0 (57)
Long chain	*Crambe*	22:1, 13-*cis* (65)
	Limnanthes	20:1, 5-*cis* (63)
Hydroxy	*Lesquerella*	20:1, 14-OH (51-72%)
	Dimorphotheca	18:2, 9-OH (65)
Acetylenic	*Crepis*	18:2, 9a (60)
Epoxy	*Vernonia*	18:1, 12,13-epoxy (72)
	Stokesia	18:1, 12,13-epoxy (74)
	Euphorbia	18:1, 12,13-epoxy (60)

More realistic predictions have been made for the soybean oil needed (if the oil could be used across the board) by 1990 at normal growth rates in the traditional markets. An estimated additional 10 million acres in soybean plantings would be needed over the 63 million planted last year (26). If there is accelerated demand as petrochemicals price themselves out of the market, then an additional 25 million acres of soybean plantings would be required.

However, increased participation of fats and oils in the organic chemical industry requires competitive prices compared to petrochemicals. There is evidence that they will indeed become competitive, since prices for many petrochemicals are increasing at greater rates than those for vegetable oils (41).

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