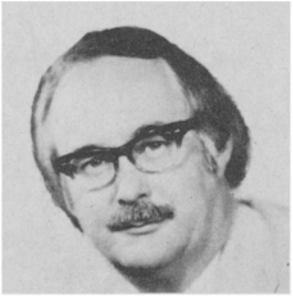

Sunflower Oil

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ABSTRACT

The paper describes sunflower oil, its fatty acid composition, analytical characteristics, uses, applications in products, and advantages and problems associated with its use. Specific processing conditions, including flow diagrams, to produce satisfactory finished products are discussed. The presentation emphasizes developments since 1976, anticipated changes in technology and a forecast of changes that may lie ahead.

Sunflower oil, often referred to as sunflower seed oil or sun oil, is obtained from the seed of the plant *Helianthus annus* which is native to North America. Grown by the native American Indians as food before the year 1600 and by the colonists in North America in 1615, the seed was introduced into Spain before the middle of the 17th century. Peter the Great brought the sunflower to Russia, and the following century, the manufacture of sunflower oil began not only in Russia but in other countries of Eastern Europe. The USSR continues to be the world's largest producer. However, since the introduction to the USA in 1967 of the Russian developed high-oil varieties, the USA has become the world's largest exporter of sunflower seed and, in the year 1980/81, became the largest sun oil exporter. The high-oil seed sunflower contains, on the average, 40% oil and 23% hulls. The low-oil seed, which had been grown in the USA prior to 1967 and is still used for confectionery, nut and birdseed markets, contains 30% oil and 43% hulls. The world production of sunflower oil for the 1981/82 year is estimated at 5.13 million metric tons and forecast for 1982/83 at 5.745 million metric tons (1), making sunflower oil production the third largest of any edible vegetable oil throughout the world. Only in the last few years has sunflower oil fallen behind palm oil. Sunflower oil is currently the fourth largest edible oil commodity traded on the world market, following palm oil, soybean oil and coconut oil.

A simplified flow chart of sunflower seed and oil milling processing is shown in Figure 1.

The paper by Muller (2) discusses the sunflower seed crushing plant. However, a brief look at sunflower seed processing here is important to a better understanding of crude oil quality. Dehulling is a widely discussed process and is done in most processing plants in Eastern Europe and South Africa. However, not all plants in the USA, West Germany and France dehull. This is due to a lack of demand for the hulls and the availability of suitable high-speed equipment that will remove the hulls from the seed kernels without significant loss of kernels in the hulls. The amount of hull per weight of seed varies; in newer hybrids, the hull percentage is decreased but the wax content is increased substantially, with the hulls being more difficult to separate and appreciable quantities of oil being lost with the hulls.

Both expeller pressed and extracted sunflower oil contain a relatively high percentage of wax. The literature shows a range of values: earlier reports of wax content of nondehulled oil from seed with 35% hulls, having 0.65% wax, with 32.5% hulls, waxes of 1.45% and with hulls at 28%, was as high as 2.33%, while the wax content of dehulled oil ranged from 0.17% to 0.47% (3). These levels appear high but comparatively are correct. Recent work shows the wax concentration from high-oil hybrid seed for nondehulled oil to be .03% to .05% with dehulled oil from 0.008% to 0.015% (4). About 85% of the wax in crude sunflower oil comes from the hull, the rest from the seed and pericarp. The hull contains 2-3% fat, of which up to 60% is wax. Theoretically, with 100% extraction, wax in oil could be as high as 1.25%. During storage of crude sunflower oil, especially in cool and wintery temperatures, a settling of the wax and sludge occurs and wax contents of the crude oil can and will vary accordingly. Analytical procedures available to date are questionable as to their accuracy and reproducibility.

Dehulling is performed in two steps: cracking the seeds into hulls and kernels, and separating the hulls and kernels. Dehulling does have a number of advantages: better quality crude oil with lower wax content; production is increased due to removal of 18-22% of hulls since 1% reduction in hull content translates to a 2.5% increase in plant capacity; hull porosity increases the absorption of oil making it much harder to extract the oil from the hulls, thereby increasing residual hexane content of the meal. According to Leibovitz and Ruckenstein (5), a good dehulling operation produces 8-12% hulls in the kernels and a maximum of 1.5% kernels in the hulls. The meal has 42-43% protein and 13-14% fiber. Dehulling to a lower hull content in the kernels increases losses and is not economical.

Most processing plants extract sunflower oil by prepress followed by hexane extraction. Some older plants may employ mechanical extraction while other mills not having expellers may employ direct solvent extraction. The prepress/solvent extraction is the preferred method for oil yields with meals having low oil contents of 0.5-1.5%. The kernels are first flaked and then pressed or expelled. The pressed material contains 15-20% oil which is then solvent extracted. The expeller and extraction oils are then combined for crude oil. The expeller oil is of higher quality in color and clarity.

Crude sunlfower oil ranges from light to dark amber in color and contains some phosphatides and mucilaginous matter, but less than cottonseed or corn oils. Its free fatty acid content is 0.5% and above (similar to most other seed oils) and is easy to refine (see Table I).

Crude sunflower oil has a distinctive odor, but it is neither unpleasant nor offensive.

Few vegetable oils reflect the influence of climate, temperature, genetic factors and position of seed location in the flower head so significantly in their composition as does sunflower oil. Linoleic and oleic averages of northern sunflower oil grown above 39 degress latitude compared with southern grown sunflower oil vary with linoleic ranging from 68 to 44% and oleic from 19 to 47% (7).

The linoleic/oleic distribution is most affected by growing temperatures: the warmer the climate, the lower the linoleic and the higher the oleic becomes. Varieties of sunflower with high oleic can also be grown in the northern climate, although none are currently being produced. The high linoleic oil predominates. Comparative fatty acid compositions for sunflower oil from various sources are shown in Table II.

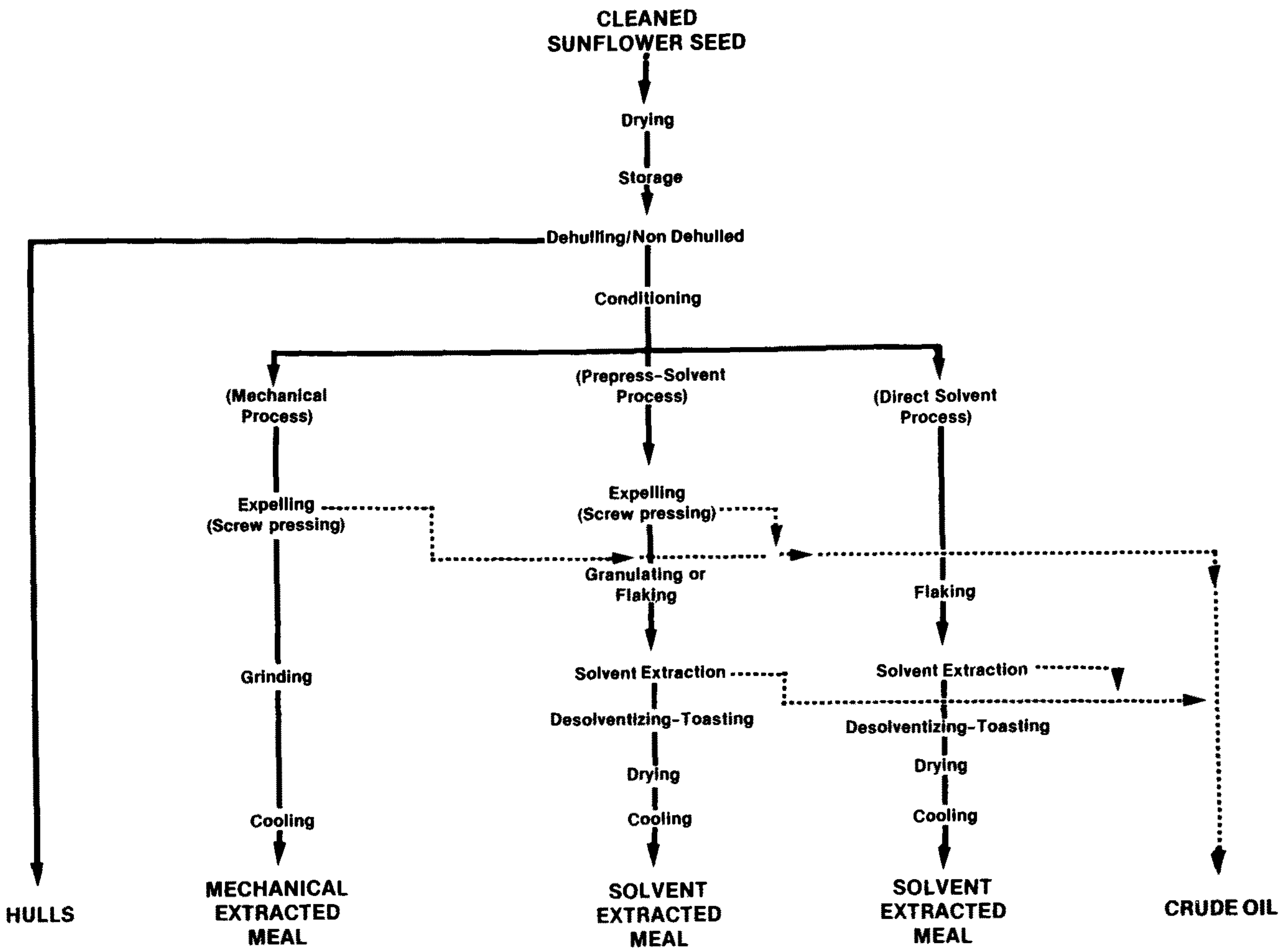

FIG. 1. Generalized flowchart of sunflower seed oil milling process.

TABLE I

Analytical Characteristics and General Standards Recommended by Codex Alimentarius Commission (6)

Iodine value	110-143
Refractive index @ 40 C	1.467-1.469
Saponification value	188-194
Unsaponifiable matter (mgKoH/g)	1.5% maximum
Specific gravity, 20/20 C	0.918-0.923
Density @ 60 C	0.897
Titer	16-20 C

US crude sunflower oil for international trading is governed by rules of the American Fats and Oils Association, Rule 14 (10), and shall be pure and produced only from sunflower seed of fair average quality (see Table III).

Sunflower oil contains the highest level of α-tocopherols, the most active form of vitamin E, as shown in Table IV.

Sunflower lecithin is not generally separated due to the refining processes in use. The phospholipid content varies from 0.5 to 1.0%, and about half is extracted with the oil. The composition of major phospholipids are 52% phosphotidylcholine (lecithin), 19.7% phosphatidylethanolamine

TABLE II

Fatty Acid Compositions

Fatty acid		Northern 1980 Avg prod	Northern 1981 Avg prod	Southern 1978 (8)	Northern 1978 (8)	Canada 1981 Avg prod	Argentina 1981 Avg prod	Russia 1968 (9)
Palmitic	16:0	6.28	6.24	5.1	5.8	6.3	5.7	6.0
Stearic	18:0	4.24	4.14	3.9	3.9	4.2	3.0	5.6
Oleic	18:1	18.40	19.76	26.0	26.0	18.3	24.0	17.8
Linoleic	18:2	70.4	69.5	64.4	64.4	69.0	66.0	68.7
Linolenic	18:3			0.5	0.5	0.4	T	0.2

TABLE III

Rule 14 of the American Fats and Oils Association

		Typical production
Flash point (AOCS Method Cc 9b-55)	250 F minimum	–
Halphen test	Negative	–
Saponification value	188-194	–
Unsaponifiable	1.3% maximum	–
Free fatty acid (as oleic)	2.0% maximum	1.11
Moisture and volatile (AOCS Method Ca 2d-25)	0.5% maximum	0.28
Insoluble impurities (AOCS Method Ca 3-46)	0.3% maximum	0.17
Color (in 5¼ in. cell or tube), as determined under AOCS Method Cc 13b-45, bleached (AOCS Method Cc 8g-52), after refining (AOCS Method Ca 9a-52)	2.5 red maximum	–
Linolenic acid	1.0% maximum	0.096

TABLE IV

Tocopherol Contents of Vegetable Oils (11)

Crude oil	α-Tocopherols (mg/100 g oil)	Total Tocopherols
Coconut	.35	
Corn	13.71	116.71
Cottonseed	51.34	105.52
Peanut	14.4	37.88
Rapeseed	25.79	62.75
Safflower	38.25	51.63
Soybean	10.99	110.56
Sunflower	62.26	68.19

(cephalin), 26% phosphatidylinositol, and 2.2% phosphoric acid in the high-oil varieties.

Sunflower oil processing follows the basic steps in vegetable oil production: degumming, bleaching, refining, hydrogenation, deodorizing, and dewaxing.

Degumming is optional for processing plants but where performed is accomplished by the addition of hot water to the crude oil. This is followed by a centrifugation to remove the phosphatides and mucilaginous material. A self-cleaning centrifuge is recommended due to the build-up of impurities and waxes that accumulate. This process would be considered more as a desludging step.

Sunflower oil may be conventionally caustic refined (70-90 C) or physically (steam) refined without difficulty. Further processing such as deodorizing to make cooking oils or hydrogenating and deodorizing for various shortening or margarine stocks can follow. Liquid nonhydrogenated sunflower oils and partially hydrogenated sunflower oils are suitable for commercial frying. Sunflower oil for these purposes does not require dewaxing. Sunflower oil, if not dewaxed, may exhibit a cloudiness and a settling out of the waxes to the bottom when held at varying temperatures. When the oil is held cool, less than 15.6 C, and at refrigerator temperatures, -1-10 C, the waxes will crystallize and either impart a cloudy appearance to the oil or settle out as a crystalline precipitate. When the temperature of the oil is raised to room temperature, the crystallized waxes may redissolve in the oil or the oil may remain cloudy if the wax concentrations are high. For a consumer-grade salad oil and for preparation of mayonnaise and salad dressings, clarity of the oil and removal of the waxes is required.

It has been reported (12) and has been our experience that when conventional methods for dewaxing sunflower oil are employed, filtration becomes slow and difficult. Even with addition of a filter-aid (diatomaceous earth) and precoating the filter, almost immediate blinding by the waxes occurs, reducing the flow rate and necessitating high labor costs from constant scraping and cleaning filter screens.

Sullivan (13), in his review of processing, describes several methods of caustic refining following degumming which included the use of low temperatures 5-10 C for refining sunflower oil. The low temperature partially dewaxes the oil due to the slight polar affinity of the waxes. These are removed in the water phase of the refining operation through centrifugation.

Low temperatures were also used in combination with steam refining. Degummed sunflower oil was cooled to 8 C, a small amount of sodium lauryl sulfate and water were added, the oil held and agitated in a crystallizing tank for 4 hr. Separation by centrifugation of the oil and aqueous phase containing the waxes was followed by phosphoric acid pretreatment, bleaching and final steam refining/deodorizing. Physical refining has advantages over caustic refining in that refining losses are lower, capital investment in equipment is less costly and better quality fatty acids are produced.

Numerous US patents have been issued in the past six years concerning dewaxing oils and particularly sunflower oil. Levine (14) chilled a refined oil and rerefined this cold oil, Young (15) simultaneously refined and dewaxed cooled oil at -9.5-7.2 C, while Gibble (16) used a mixture of surfactants in oils at temperatures of 15.6-32.2 C to dewax oil. Beharry (17) has approached bulk dewaxing by first tempering the crude oil for at least 24 hr for wax nucleation at a temperature from 24 C to 49 C, then cooling to 4.5-21.1 C for at least 5 hr to agglomerate the wax, refining at temperatures of 24-35 C, followed by separation, claiming to remove 60-90% of the waxes.

To process satisfactorily sunflower oil for salad oil, the cold refining concepts mentioned have been employed in a somewhat similar manner (Fig. 2). Crude sunflower oil from extraction or storage at 21-60 C is cooled through two heat exchangers to a temperature of 7.2 C, although temperatures of 1.7-12.8 C sometimes occur. The plate-type

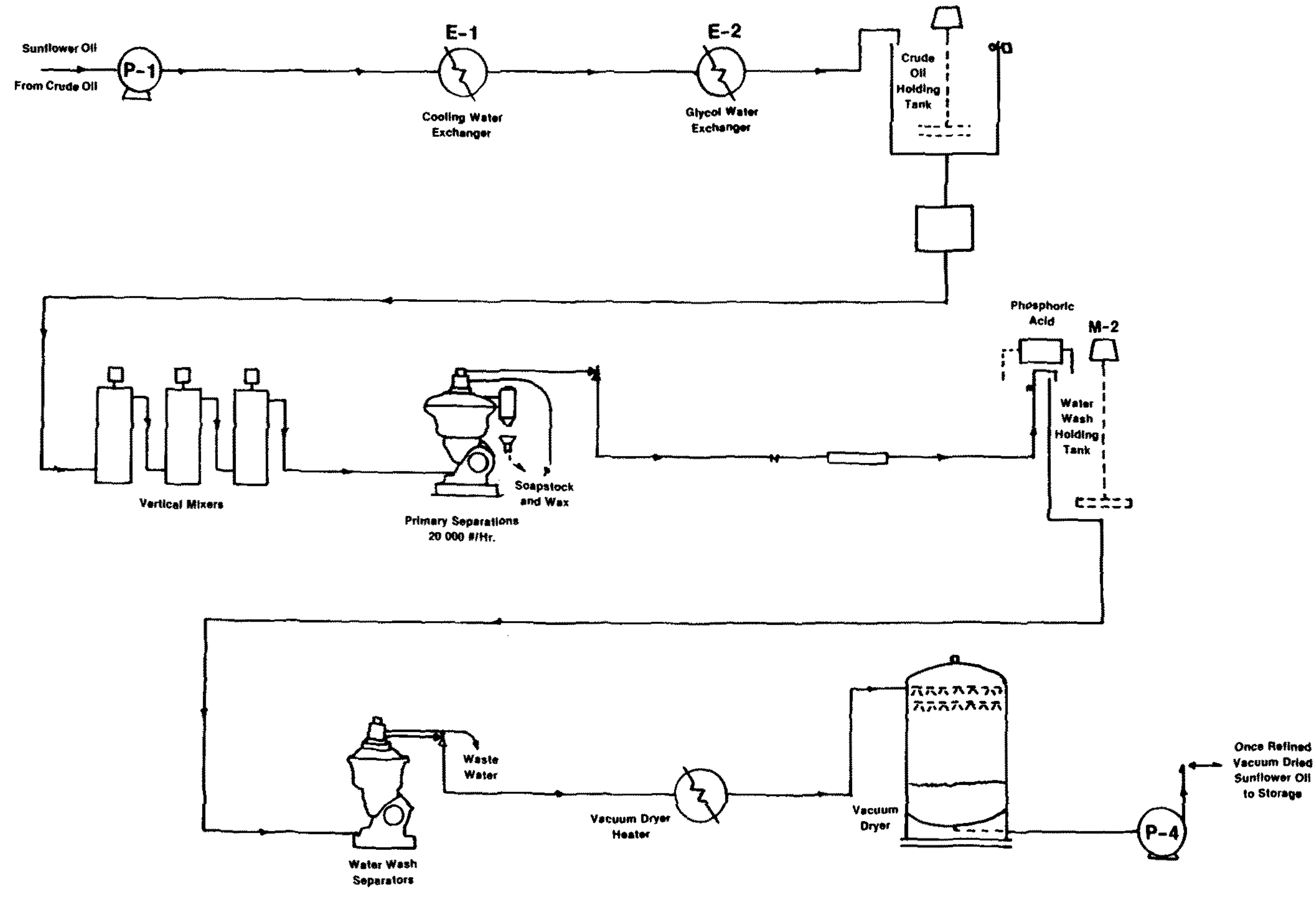

FIG. 2. Sunflower oil refining.

heat exchanger should have sufficient surface area to allow for a build-up of waxes and higher melting triglycerides without a resulting loss of heat transfer. Should this occur, warm oil is used to melt the waxes and either returns to the crude source or goes to the surge tank and is chilled further. The chilled crude oil is pumped into a surge tank having glycol water cooling coils, and is held under mild agitation for a minimum period of one hour. The oil leaving the surge tank is injected with 0.3-0.5% excess 18 degree baume caustic cooled to 15.5 C before entering 3 DeLaval vertical contact mixers. The oil flow is split, 20,000 p/hr each to two DeLaval SRPX 3-phase separator units. A self-cleaning system is necessary, due to build-up of filterable impurities and waxes which are automatically ejected. A nonself-cleaning system such as an SRG will plug quickly. The chilled wax comes out with the aqueous soapstock. Water along with ca. 10 ppm phosphoric acid is intimately mixed with the oil, having soap contents of 250-350 ppm and FFA .01%, at either cool or at water wash temperatures of 82.5-94 C to remove remaining soap and insolubles. These are separated from the oil in two DeLaval B-214 water wash separators. The oil, having zero soap, is vacuum-dried, and pumped to storage or further dewaxing. This cold refining process normally reduces contents of 500-1000 ppm to 100 ppm or less. At times, wax contents of 40 ppm have been achieved. The phosphatides will be removed during cold refining if the oil has not been degummed previously.

Bleaching of sunflower oil follows normal bleaching conditions of 90-110 C with amounts of bleaching clay from 0.15 to 3%. Additional color removal occurs in "heat bleaching" during hydrogenation and deodorization. Eliminating clay bleaching, using only heat bleaching during deodorization has been investigated by Ostic-Matijasevic (18) and satisfactory finished product resulted in addition to economic considerations, higher tocopherol content, better stability and lower conjugated diene content.

Although dewaxing during the refining process eliminates most waxes, in practice an additional dewaxing step is still recommended to prevent clouding under cold test or in normal distribution and consumer conditions (see Fig. 3). Refined, partially dewaxed sunflower oil from storage is chilled through heat exchangers to 7.2 C into a series of 2 or 3 crystallization tanks. The chilled oil is held for 24 hr under slow agitation to allow for formation of wax crystals. The pressure leaf filter is charged from the precoat tank having diatomaceous earth added to good cold test oil, the quantity depending on filter surface area. A body feed of 0.15% diatomaceous earth is added. The diatomaceous earth keeps the filter media porous and allows for good throughput with the filter needing cleaning only once every 24 hr. Oil having a cold test of 24 hr plus is produced.

Hydrogenation of sunflower oil follows those conditions established for soybean and other similar oils and can be controlled by refractive index, melting point and solid fat index. Hydrogenated sunflower oil base stocks can be produced and formulated into consumer shortenings, industrial shortenings for baking and frying as well as for margarine stocks. Selection of sunflower oil for these products would

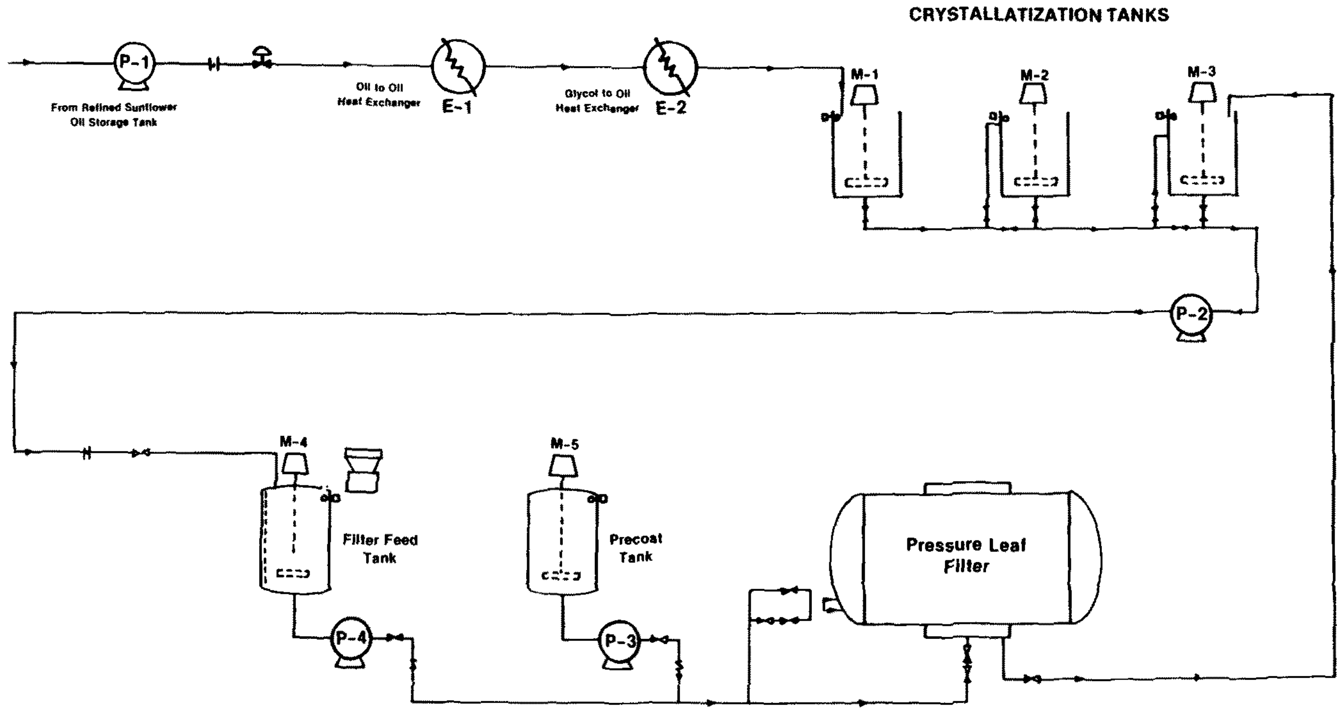

FIG. 3. Sunflower dewaxing.

be decided, on the availability and economics at the time. Compositional and functional characteristics of sunflower oil are limited only to the extent of the oil's β-crystal forming habits and its low palmitic acid (19). Suitable β′ tending oils then should be blended at levels to provide the desired physical and performance characteristics.

Deodorization follows common practices as for other vegetable oils.

The principal uses for sunflower oil are as a salad and cooking oil where its high concentration of linoleic acid and pleasing flavor and odor contribute to make sun oil highly acceptable for food use.

Sunflower oil is the oil of choice in most producing countries, however, in the USA, sunflower oil was not nationally distributed until 1978. Sunflower oil sales grew to almost 12% of the US salad and cooking oils' billion plus pound market. However, it has dropped to ca. 8% this current year. The high percentage of linoleic acid present in much of the sunflower oil used, exceeds that of other vegetable oils except safflower. Linoleic acid, an essential fatty acid, must be supplied by the diet. Infants' requirement for essential fatty acids have been demonstrated clearly. For much of the general population, 3% of calories as linoleic acid is considered to be a satisfactory minimum intake. Diet modifications have been recommended which include increasing the proportion of polyunsaturated to saturated fat (P/S ratio) in the diet (20).

Many consumer foods, especially margarines, have altered their components to include higher levels of polyunsaturated fats and in many parts of the world this has been contributed by liquid sunflower oil. Margarine formulations include 50-75% liquid sunflower oil along with a suitable hardstock generally a soybean/cottonseed blend. By corandomizing, a soft tub product from 100% liquid sunflower oil can be produced (21). Margarine made from 100% sunflower oil, liquid and hardstock, are being produced in both print (stick) and tub type, but interesterification is required to prevent a sandy physical characteristic. Sunflower oil gives margarines excellent flavor characteristics and polyunsaturate levels. The desirable high linoleic values of liquid sunflower oil for salad oils and margarines are, of course, sacrificed once sunflower oil is hydrogenated.

Commercially, sun oil is used for frying snack foods, such as potato chips and corn chips. The high oleic sunflower oil, with a lower percentage of polyunsaturated fatty acids has a higher initial active oxygen method (AOM) value and overall stability than the high linoleic sun oils (7). Both oils, with and without suitable antioxidants, are being successfully used in the production of snack foods. Although sunflower oil is susceptible to oxidation during storage and use, protection through the use of antioxidants showed tertiary butylhydroquinone to provide more protection from oxidative changes than butylated hydroxyanisole and butylated hydroxytoluene (22). Partially hydrogenating sunflower oil improves the flavor and oxidative stability of the oil and foods fried in it. Partially hydrogenated sunflower oil liquid shortenings stabilized with antifoam agents such as methyl polysilicone and antioxidants performed equally to partially hydrogenated soybean oil liquid shortenings.

The quality of crude sunflower oil will improve as high-speed efficient dehulling equipment is more readily available. Markets for the hulls either in animal feed, furfural production, or as an energy source, will encourage more dehulling. Hulls are frequently being burned as fuel to generate steam and electricity.

Improved analytical methodology is needed to determine more rapidly and accurately the quantity of waxes present in crude oils as well as in refined oils. Companies involved in production of dewaxed oils have developed internal tests and standards. However, these are not generally available.

Published analytical methods include a gravimetric method including extraction in special equipment (23), gas liquid chromatographic separation of unsaponifiables (4), measurement of chilled waxes with a sophisticated apparatus too complex for routine control use (24), purification by alumina column chromatography (25), and the measurement of waxes by a turbidimetric technique (26) although the latter cannot be applied to crude oils.

The future of sunflower oil seems to be assured when one looks at production of sunflower seed. In the past 5 years, the USA has become the second largest seed producer; China almost tripled production to become the fourth largest producer; and a number of other countries had significant increases (1). France and Hungary have increased production; while Brazil's production is small, increases have been a result of double cropping with soybeans and corn. This is also occurring in the USA following early wheat harvests in the south and appears to provide growers with a sufficient yield with limited production costs and a reasonable return. Although weather and pest and disease infestation cause year to year fluctuation in growing countries, breeding research is continuing to develop hybrids with stronger stalks and disease and pest resistance, along with higher oil content and easier hull removal. Improved farming practices and the use of weed and pest control chemicals are being used to improve yields.

Research is in progress in the use of sunflower oil as a viable renewable alternative to petroleum-based fuels such as diesel. Major farm implement companies are testing and modifying diesel-burning engines to make them more compatible with vegetable oils as fuel. Recently our company sponsored a sunflower oil fueled 1981 Volkswagen Rabbit Diesel in a Future Fuels Challenge rally. The car traveling in excess of 6,000 miles achieved an average of over 50 miles per gallon on sunflower oil fuel. The sunflower oil was refined and dewaxed using the cold refining processes described. Some modifications to the vehicle were done and are relatively simple and straightforward. They consist of an added fuel booster pump to transfer sunflower oil to the temperature controlled fuel preheater. From the fuel preheater, the 46 C sunflower oil passes through a large capacity fuel filter, then on to the stock fuel injector system. A BAE turbocharger was installed to increase power and decrease fuel consumption by increasing engine efficiency. To facilitate starting, an electric engine preheater was installed.

Some anticipated minor difficulties such as fuel viscosity, harder to start when cold, potential carbon build up on injector nozzles and combustion chamber and filter clogging, were not a problem. The car exhaust, though, did smell like fried chicken as it was driven down the road. The car exhibited excellent driving characteristics and the power and fuel economy are within a small percentage of what they are when regular diesel fuel is used. Continued work suggests blends of sunflower oil and diesel to have the most potential for long-term usage.

When one considers the needs for both food oils and fuel, the potential for sunflower oil is like the morning sunrise—brighter and higher.

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