Safflower, Its Development and Utilization

R. H. PURDY, L. O. CUMMINGS, C. E. CLAASSEN, and J. A. KNEELAND,
Pacific Vegetable Oil Corporation, Richmond, California

SAFFLOWER *(carthamus tinctorius)* is among the oldest crops known to man. The species is believed to be indigenous to Southeastern Asia but has long been cultivated in China, the Near East, and Northern Africa. In the middle ages the plant was grown in Europe and was introduced to the New World colonies by the Spanish. During the 19th century safflower was brought into the United States by immigrants primarily from Spain and Portugal. Until recent years the history of safflower has been concerned mostly with the use of its florets, from which an unstable pigment (of no commercial importance) and the rouge dye carthamine were extracted. Carthamine was at one time an important article of commerce, being used as an adulterant of saffron, a cosmetic and textile dye, and even to color broths and ragouts. With the advent of aniline dyes and on account of the impermanent nature of carthamine, the plant was abandoned as an important dye source.

In India, where some half-million acres are grown annually, the cake from the decorticated seed has been considered to be one of that country's most important protein supplements for livestock. Because of the low oil content, as compared to other available oil-stock material and the low-yield methods of crushing, the use of safflower seed has not been important as a source of edible or drying oil.

Safflower as a possible field crop in the United States was not considered until early in this century. Between 1925 and 1940 most western-state agricultural experiment stations tested safflower. In 1940 the Chemurgic Department of the Nebraska Agricultural Experimental Station included safflower in a study of 70 different species of plants which were not commercially grown in that state and considered it promising enough to warrant the establishment of an extensive breeding program. Sporadic attempts were made by at least five companies to establish safflower as a crop in various parts of the Western Great Plains from about 1945 through 1957. None of these attempts were successful. In 1958 Pacific Vegetable Oil Corporation and its affiliated company, Pacific Oilseeds Inc., entered Western Nebraska with a plant located at Sidney. A plant site at Culbertson, Mont., is under construction for processing seed grown in the Northeastern Montana-Northwestern North Dakota area. Plantings for 1959 are expected to exceed 100,000 acres in these two regions.

Safflower is now a well-established and profitable crop in the Sacramento Valley of California. This crop was pioneered by Pacific Vegetable Oil Corporation and Pacific Oilseeds Inc. Commercial production was started in 1950, and the crop has been considered established since 1956. Yearly seed production in California and other states from 1949 to 1959 are shown in Table I.

TABLE I

Production of Safflower Seed, 1949-1959

Year	Seed production, millions of lbs.	
	California	Other states
1949	—	16
1950	14	20
1951	15	5
1952	47	5
1953	52	4
1954	29	0
1955	72	5
1956	142	3
1957	114	13
1958	116	24
1959	180[a]	48[a]

[a] Estimates based on contracted acreage.

Agronomy

Safflower, botanically a member of the composite family, is an erect annual herb which grows 18–40 in. in height. The seed is planted during March or April, and 5–20 days are required for emergence. After four or five weeks, rapid growth occurs, and the plant begins to branch with one to five flower buds forming on each branch. Individual flower buds have 20–100 florets, each of which may bear one seed. The seeds are white, somewhat similar in appearance to those of sunflower, and are about the size of barley seeds. The plant is harvested usually from early August to late September, depending on the area.

Climatically safflower is adapted to the arid and semi-arid regions of the world that have a frost-free growing period of 125–130 days. It takes at least 26 in. of stored moisture in the soil, or the equivalent in irrigation, to produce minimum yields of the crop. Under dry-land farming conditions, yields will range from 350–1,200 lbs. per acre. On irrigated land, yields of 1,000–4,000 lbs. per acre have been obtained. Safflower is somewhat susceptible to rust and root rot; the latter is especially a problem to irrigated plantings. Should disease-resistant varieties be developed that could profitably be grown on irrigated land, a sizeable acreage would be opened up.

Prior to 1942 the best varieties available in the United States averaged 27–28% oil and 45–48% hull. These seed strains were of Indian and European origin. With the introduction of higher oil-bearing seeds of Egyptian and Sudanese types during the early 1940's, cultural experiments were begun to develop better varieties. Most California seed during the 1958 season averaged 34–37% oil. From our own research and the research of others now in progress, it is the consensus that safflower varieties will soon be available that should produce more than 40% oil and less than 30% hulls. At this time it also seems feasible to combine these high-oil varieties with resistance to rust and root rot which will make it possible to grow safflower as an irrigated crop.

Processing

Safflower seed is relatively easy to process with conventional equipment. Early methods of processing utilized the continuous screw press, but prepress-solvent extraction techniques have proved to be superior from both tonnage and quality aspects. The advantages of removing the high fibrous hull prior to crushing are obvious, but practical methods only recently have been proven on a pilot-plant scale.

After cleaning, the seed is ground, cooked at about 240 lbs. of steam pressure, and conditioned. Properly treated material handles easily in the screw press, but 140° F. cooling oil, circulating over the horizontal barrel, is required. The resultant press cake containing 12–14% oil is broken up and extracted with hexane. The cake is relatively easy to extract with no fines problem. After desolventization and drying, using conventional equipment, the extracted cake is ground. As an alternate to decortication the fibrous hull portion can be removed after oil extraction by screening, yielding a higher protein, lower-fiber meal, and by-product hulls.

Refining of prepress oil is conducted by employing methods similar to those used for degummed soya oil. The extract obtained from the prepress cake is somewhat higher in free fatty acid content and contains an average of about 2% gums. Refining of solvent oil however yields a product similar in quality to refined prepress oil. Normal bleaching techniques, using activated clays and carbon, result in colors less than 4 Gardner.

Safflower Oil

Composition. Safflower oil is unique in its simplicity of composition, containing only linoleic, oleic, and saturated fatty acids. Linoleic acid contents have been reported from as low as 56.7% to as high as 80.0% with saturated acids ranging from 5.0% to 13.4% (1). A study by Milner *et al.* (2) of eight varieties grown in Montana showed an average linoleic acid content of 74.5% with linolenic acid contents of less than 0.1%. Saturated fatty acid contents of these varieties ranged from 5.0 to 6.7%. Four seed varieties were represented in an examination of 25 1957 California-area composite samples by our laboratory. An average linoleic acid content of 74.8% was found with an apparent absence of linolenic acid. Scholfield and Dutton (3) reported 73.2% and 75.7% linoleic acid and 0.1 and 0.3% linolenic acid in two varieties of 1956 seed grown in California. Although linolenic acid has been found by several investigators in amounts greater than those reported above, their evidence has been questioned (4).

The glyceride structure of safflower oil has been determined by a number of workers but with conflicting results. Barker and Hilditch (5), using crystallization techniques, found 31% trilinolein, 36.9% oleo-dilinolein, and 29.7% saturated dilinolein, suggesting an even-distribution system. Scholfield and Dutton (3) however in their examination of two safflower seed oils, using countercurrent distribution, concluded that the fatty acid distribution closely approximated a random pattern.

A typical safflower oil produced from California-grown seed would have the following composition and characteristics:

Specific gravity 25°/25° C.	0.925
Refractive index D/25° C.	1.4742
% Free fatty acids (prepress oil)	0.5
Saponification value	189.0
Viscosity (Gardner-Holt)	A-
% Unsaponifiable matter	0.5
Iodine value, Wijs	145.4
% Saturated acids	8.3
% Oleic acid	13.8
% Linoleic acid	73.5

Application in Protective Coatings. The application of safflower oil in protective coatings is based to a great extent on its low percentage of saturates, high linoleic acid content, and virtual absence of linolenic acid. This ideal fatty acid combination is responsible for good drying qualities, a lack of after-yellowing on exposure, and uniformity of polymer structure. Excellent color and heat-bleachability characteristics enable safflower to be used wherever light-colored end-products are required.

Protective coatings incorporating safflower oil exhibit the following properties: good initial dry and excellent through-dry, good gloss and gloss retention, excellent initial color with minimum after-yellowing, low tendency to wrinkle, good outside durability, and uniform polymers giving good film flexibility.

Catalytic isomerization yields a product with approximately 22% dienoic conjugation and a viscosity of 1½ to 2 poises. In addition to retaining many of the desirable characteristics of the unconjugated form, its speed of polymerization, rate of dry, and flexibility approximate those of dehydrated castor oil.

The initial rate of drying of safflower oil is somewhat slower than that of linseed oil, but through-dry is attained more rapidly. Table II shows a comparison of the two oils when used in a typical oil-based outside house paint. The formulations are based on U. S. Government Specifications TTP-102 (leaded) and TTP-103 (lead-free).

TABLE II

Comparison of Set and Through-Dry Times of Safflower- and Linseed-Based Outside House Paints [a]

Oil	Formula	Driers	Set Time	Through-Dry
			hours	*hours*
Safflower	TTP-102	Pb, Mn	12	27
Linseed	TTP-102	Pb, Mn	11	32
Safflower	TTP-103	Zr, Mn	23	32
Linseed	TTP-103	Zr, Mn	18	33½
Safflower	TTP-103	Pb, Mn	10	24
Linseed	TTP-103	Pb, Mn	8	27

[a] 9-mil wet films on glass.

The widest use of safflower oil in protective coatings today is in the manufacturing of alkyds, where it is considered to be one of the most desirable oils available. Thurmond *et al.* (6) in comparing safflower alkyds with those made from soya and linseed oils concluded that colors were comparable to soya, gave air-drys faster than soya but slower than linseed, and alcoholized faster than either soya or linseed. Good gloss, color, and through-dry are attained with both phthalic anhydride and isophthalic alkyds. In isophthalic alkyd-oil house paints its unique characteristics contribute an ideal rate of dry and a low tendency to wrinkle. The excellent compatibility of safflower alkyds in odorless solvents, combined with their lack of yellowing, indicates widespread use of these products in interior odorless finishes.

Glycerol or pentaerythritol rosin esters with or without maleic, phenolic, or modified phenolics make excellent varnishes with unbodied or conjugated safflower oil; the outstanding properties contributed by the oil portion are good color and flexibility. Copolymers with styrene or vinyl toluene exhibit very light colors, good drys, and excellent gloss. Adducts produced from maleic anhydride and fumaric acid also yield light-colored products with superior drying properties.

Edible Oil. The ability of certain unsaturated vegetable oils to lower human serum cholesterol levels, first demonstrated by Kinsell *et al.* (7), has led to increased interest in an edible grade of safflower oil. Although the mechanisms involved in this phenomenon are unknown, it is hypothesized that a high ratio of either the so-called essential fatty acids or *cis-cis* methylene-interrupted polyunsaturated acids to saturated acids in the dietary fat is involved. Hansen and Weise (8) have recently recommended dietary requirements of essential fatty acids to be 3-4% of the total caloric intake for infants. Safflower oil on the basis of its low percentage of saturates and high linoleic acid content shows promise as an ingredient in food products designed for the prevention of certain diseases associated with hypercholesterolemia and essential-fatty-acid deficiencies.

Beal *et al.* (9), using pilot-plant apparatus, produced deodorized oil with good flavor scores. After four-day storage at 60° C. the flavors were still rated acceptable, leading to the conclusion that safflower oil is suitable for use as a salad oil. In our laboratory, investigations are under way to determine means of improving the keeping quality of deodorized oil. The weight-increase method as described by Olcott (9), using 1-g. oil samples in 20-ml. beakers at 60° C., and shelf-life tests at normal storage temperatures are used for evaluating oxidative deterioration and flavor stability. Induction periods at 60° C. of unstabilized deodorized production batches range from 7 to 10 days as compared to cotton oil at 8 to 14 days. Oils stabilized immediately after deodorizing with propyl gallate and citric acid give 60°C. induction periods of 13 to 18 days and flavor scores comparable to freshly produced cotton oil when evaluated after five months under normal temperature conditions.

Solvent-extracted crude safflower oil appears to have much greater resistance to oxidative deterioration than prepress crude oil. However this resistance is largely removed by aqueous refining. Both alkali refining and treatment with acidic degumming reagents produce similar effects. Addition of mixed tocopherols at 0.05, 0.10, or 0.20% levels to either prepress or aqueous-refined solvent-extracted crude oil offers relatively little protection. The addition of crude solvent-extracted oil or its aqueous degumming residue to prepress oil remarkably improves the oxidative stability. There is reason to believe that certain phosphatides are involved, probably as synergists for the minor amounts of natural tocopherols present in the crude oil.

Butylated hydroxy anisole and butylated hydroxy toluene, either by themselves (with citric acid as a synergist) or in combination, offer relatively little protection to the deodorized oil. Propyl gallate and citric acid in amounts allowable by the Food and Drug Administration are quite effective, doubling the induction period at 60°C.

Safflower oil is now being used as an ingredient in pharmaceutical oral emulsions and is being considered for use in intravenous fat emulsions. Baked goods, "unsaturated" margarine, and various other prepared food products are now on the market on a limited scale. The primary use for the deodorized grade is as a salad and cooking oil.

Methyl Esters. Because of the relatively small amount of soapstock produced, safflower fatty acids are not available. The methyl ester is easily produced from the triglyceride by using alkali-catalyzed methanolysis procedures. Close to theoretical yields of a very light viscosity noncorrosive product is obtained with a relatively anhydrous, 70-75% glycerol by-product. Bleaching with activated clays yield colors of less than 2 Gardner. The methyl ester can be used as a replacement for safflower fatty acids in many chemical reactions involving the carboxyl group.

Both the fatty acid and methyl ester of safflower oil are excellent starting materials for producing linoleate concentrates. Our laboratory has produced on a pilot scale, by using urea-adduct techniques, an ester containing more than 90% linoleate and less than 1% saturates. Beal *et al.* (11) fractionated safflower oil fatty acids by using pilot-plant liquid-liquid extraction apparatus. Furfural was employed as the selective solvent and hexane as a secondary solvent. Under optimum conditions a 95% concentrate of linoleic acid was obtained.

Safflower Meal

Safflower meal in California today is a low-cost source of protein for dairy and beef cattle. The solvent-extracted meal varies from 18-21% protein, 34-37% fiber, 4% ash, and about 1% fat. Most of the fiber is located in the hull and is relatively indigestible. Feeding trials (12) have shown the fiber to be only 22% digestible. Decortication, either prior to or after oil removal, yields a meal of about 40% protein and 14% fiber. This product is best utilized in laying rations because of its lack of methionine and lysine (13). Normal egg production and egg-storage quality were found with a ration incorporating the 40% protein meal (14).

Almost all of the safflower meal produced in this country has been of the 18-21% protein type and has been used primarily as a cattle feed supplement. It has been included in rations at levels of 5-15%, replacing both grain and protein meals such as cotton, copra, and linseed. It has also been used in sheep rations and has been consumed by dairy cows at levels as high as 5 lbs. per head per day. When fed to chickens, turkeys, chinchillas, and rabbits, good results have been obtained. Safflower meal has neither laxative nor constipating effects. As with all new and unfamiliar feed ingredients, it should be introduced gradually into the ration.

Because safflower seed can be grown in relatively dry areas where other oilseeds do not yield as well, it can furnish a low-cost local source of protein supplement.

Summary

Safflower, a relatively insignificant oilseed crop early in this decade, has become a well-established source of oil for the surface-coatings industry and protein for animal feeds. Through extensive breeding programs, higher yielding, higher oil-bearing varieties have been developed. Research in agronomy is now directed toward improving resistance to rust and root rot in order to allow safflower to be grown as an irrigated crop.

The oil's composition, which is largely made up of linoleic acid with a practical absence of linolenic acid, results in very nearly an ideal drying oil. Protective coatings made with safflower oil are characterized by rapid dry, good through-dry, excellent color and color retention, and good exterior durability.

Recent interest in the unsaturated vegetable oils and their relation to the etiology of atherosclerosis has catalyzed the development of an edible grade of the oil. Safflower oil with approximately 75% linoleic acid and less than 10% saturated acids compares quite advantageously with other liquid oils for use as a dietary supplement. With the proper use of antioxidants, good flavor stability and resistance to oxidative deterioration is achieved. This qualifies safflower oil for use as a salad oil and as an ingredient in many food and pharmaceutical products.

Prepress-solvent-extraction operations result in an 18-21% protein meal, which is consumed primarily in dairy cattle feed. Decortication of the seed, now feasible, yields a 40% protein meal suitable for laying-hen rations.

REFERENCES

1. Hilditch, T. P., "The Chemical Constitution of Natural Fats," 3rd ed., p. 187, John Wiley and Sons Inc., New York (1949).
2. Milner, R. T., Hubbard, J. E., and Wiele, Mary B., Oil and Soap, *22*, 304 (1945).
3. Scholfield, C. R., Dutton, H. J., J. Am. Oil Chemists' Soc., *35*, 496 (1958).
4. Winter, G., J. Am. Oil Chemists' Soc., *27*, 82 (1950).
5. Barker, C., and Hilditch, T. P., J. Am. Oil Chemists' Soc., *33*, 6 (1950).
6. Thurmond, C. D., Hempel, A. R., and Marling, P. E., J. Am. Oil Chemists' Soc., *28*, 354 (1951).
7. Kinsell, L. W., Partridge, J., Boling, L., Margen, S., and Michaels, G. D., J. Clin. Endocrinol. and Metab., *12*, 909 (1952).
8. Hansen, A. E., Haggard, M. E., Boelsche, A. N., Adams, D., J. Nutrition, *66*, 555 (1958).
9. Beal, R. E., Moser, H. A., and Brekke, O. L., J. Am. Oil Chemists' Soc., *35*, 97 (1958).
10. Olcott, H. S., and Einset, E., J. Am. Oil Chemists' Soc., *35*, 161, (1958).
11. Beal, R. E., and Brekke, O. L., J. Am. Oil Chemists' Soc., in press.
12. Goss, H., and Otagaki, K. K., Calif. Agr., *8* (5), 15 (1954).
13. Kratzer, F. H., Poultry Sci., *26*, 623 (1947).
14. Grau, C. R., and Zweigart, P. A., Calif. Agr., *7*, (12), 8 (1953).

[Received April 21, 1959]

• *Industry Items*

Engineering Management Inc., 18 S. Northwest Highway, Park Ridge, Ill., announces that it has been retained by Honeymead Products Company, Mankato, Minn., to design and supervise the construction and start-up of a large prepress and extraction installation for processing soybeans and/or flaxseed.

The development of a new titrator, the Stone Automatic Titrator, for the chemical industry has been announced by E. Leitz Inc., New York.