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Effect of Heat and Frying on Sunflower Oil Stability

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ABSTRACT

Sunflowers are one of the most important sources of vegetable oils in the world, second only to soybeans. Although in use throughout many parts of the world, sunflower seed are just now beginning to attract attention and use in the United States. Composition of the oil appears to be dependent on area of production. Sunflower oil from seed grown in northern US typically contains 70% linoleic acid. In contrast, oil from seed produced in the South generally contains 40-50% linoleic aicd and is higher in monounsaturated fats. For most of the edible oil market, sunflower oil appears to have an advantage over most other vegetable oils. Lightly hydrogenated sunflower oil was compared with a cottonseed-corn oil mixture for frying potato chips. Organoleptic evaluation indicated that chips did not differ significantly. We also evaluated the useful life of various sunflower seed oils for deep-fat frying. Hydrogenated and unhydrogenated sunflower oils and a commercial shortening were used to deep-fry raw potatoes. A plot of the log of the Active Oxygen Method (AOM) values of the oils versus time gave a straight line, the slope of which reflects the oxidizability of the oil. Data indicated that lightly hydrogenated northern sunflower oil was much less prone to oxidation after abuse than the commercial shortening and was useful for a longer time. The southern oil deteriorated faster than the northern sunflower oil, but the two oils were processed differently. Thus, in recent work, care was taken to process both northern and southern grown sunflower seed under identical conditions. Frying studies indicated that oil from southern grown seed was more stable than that from northern seed as would be expected from their fatty acid composition.

The sunflower, *Helianthus annus*, is a native American wildflower which belongs to the largest family of flowering plants, the Compositae. It has been described by a Russian agronomist as a "heretofore little grown plant that raises its head to follow the sun across the sky" (1). Production of sunflowers, one of the most important sources of vegetable oils in the world, is now second only to soybeans. Sunflowers are widely grown in Argentina, the Soviet Union, and other eastern European countries (Table I) (2). They are still a minor crop in the United States, but production has rapidly increased in the Red River Valley of Minnesota and the Dakotas and considerable interest has been developing in other regions of the US especially in the Cotton Belt.

There are two distinct types of sunflowers: (a) oilseed

TABLE I

1974 World Sunflower Seed Production[a]

Country	Production (In 1,000 metric tons)	Acreage (In 1,000 acres)
USSR	6,358	11,792
Argentina	1,000	2,686
Romania	671	1,493
Turkey	460	1,013
Bulgaria	400	710
Yugoslavia	300	494
United States	291	647
South Africa	253	596
Spain	250	1,070
All others	535	1,627
Total	10,518	22,128

[a]From Reference 2.

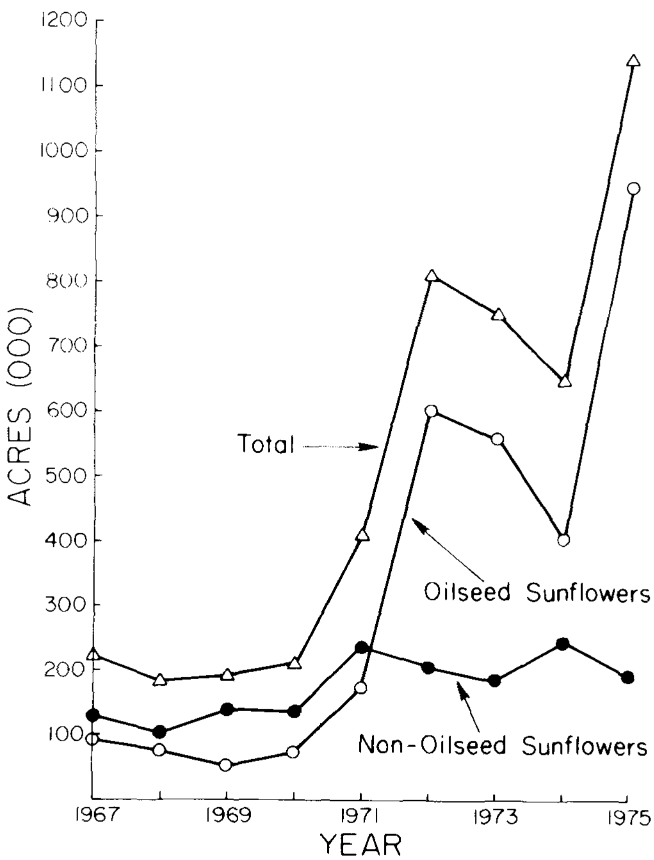

FIG. 1. Harvested US sunflower acreage, 1967 to 1975.

type which is used primarily as a source of vegetable oil and high-protein meal, and (b) non-oilseed type (confectionery), used primarily for human food (as nut meats and whole roasted seed) and for bird feed.

Harvested sunflower acreage in the US from 1967 to 1975 is shown in Figure 1 (3,4). Commercial nonoilseed sunflower production began about 1952, and birds consumed over 80% of the crop. Production for human food, started in the 1960s in the Red River Valley, was stimulated by the introduction of dehulled sunflower seed as a nutmeat in the confection trade. There was a small but gradual increase in nonoil sunflowers until 1971, when production began leveling off.

In 1967, high-oil sunflowers were grown commercially for the first time in the US, and production has steadily increased with oilseed production surpassing nonoil in 1972. There has been a five-fold increase in oilseed acreage in the last 4 years.

During 1967-1972, average price received by farmers in U.S. for sunflower seed ranged from 3.9 to 5.6 cents per pound. In 1973 and 1974, prices increased even more for sunflower than for most other crops, reaching a high of about 22 cents per pound for oil and 17 cents per pound for nonoil varieties. These extremely high prices have triggered a great deal of grower interest inthe crop and probably will result in increased acreage in the immediate future (3).

Sunflower oil, a nutritious, high quality cooking and salad oil, is the most valuable component of sunflower seed. The popularity of the oil is due to its attractive color and pleasant flavor. In Europe, it has been used extensively in shortening and margarine (5). The fatty acid composition of sunflower oil makes it desirable for use as an edible oil. Table II shows that the oil of seed grown in the northern US and Canada contains ca. 70% linoleic acid (iodine value of 130-138) and has a high ratio of polyunsaturated to saturated fatty acids (6,7). In contrast, sunflower oil from seed produced in the South generally contains 40 to 50% linoleic acid (Table III) (iodine value of 105 and 120) and would be an ideal edible oil from flavor and stability aspects (8,10). The degree of unsaturation depends upon climatic conditions during the growing season (flowering to maturity) (8,10), although some scientists believe that oil quality may be under genetic control (6).

Sunflower oil is finding acceptance as a cooking fat for potato chip frying. Evans and Shaw (11), in a 20 hr potato chip frying test, compared northern-produced sunflower oil with a mixture of 70% cottonseed and 30% corn oil, which is a standard oil for frying potato chips. Potato chips fried in sunflower oil and stored at room temperature generally received the higher flavor scores of each evaluation by the taste panel.

The fatty acid composition of sunflower oil suggests that the stability of the oil could be improved by reduction of its iodine value, so we tested partially hydrogenated sunflower oil for potato chip frying (12). A northern sunflower oil was partially hydrogenated to lower the linoleic acid content from 69% to 37% and the iodine value (IV) from 137 to 108. This hydrogenated sunflower oil was compared with a standard 70% cottonseed-30% corn oil mixture for frying potato chips. Potatoes were fried in the oils at 360 F for a total of 23 hr. The free fatty acids increased in both oils, and the IV decreased but leveled off at 23 hr in the sunflower oil. The viscosity plateaued after 16 hr for the lightly hydrogenated sunflower oil and after 23 hr for the cottonseed-corn oil mixture. Except for the initial 2 hr of heating, peroxide value was lower for sunflower oil than for the cottonseed-corn oil throughout the 23 hr of use.

Potato chips were sampled after the frying oils had been used for 2, 12, and 23 hrs, and were stored in the dark at room temperature for 10 wk. Chips fried in each oil were organoleptically evaluated at 2-wk intervals. Flavor did not differ significantly between the chips fried in fresh oil or in oil heated about 20 hr or among the chips stored up to 10 wk. No preferences were shown for chips fried in either oil.

Sunflower oil produced in the southern part of the US, which has a lower content of linoleic acid, higher oleic and lower iodine value, should have better keeping qualities and stability characteristics than northern oils with higher linoleic acid content. We investigated this relationship by comparing the effects of deep-fat frying conditions on stability and on other chemical characteristics of sunflower oil produced in Alabama and Minnesota with cottonseed oil (13). The vegetable oils used were refined and deodorized and contained no added antioxidants. Their composition and properties are shown in Table IV.

Each vegetable oil was heated at 182 C in a household deep-fat fryer. The oils were heated for 8 hr each day, sampled, and allowed to cool to room temperature overnight. This heating and cooling cycle was repeated until the oils had been heated for a total of 120 hr. As expected, the free fatty acids, color, and viscosity of all the oils increased

TABLE II

Fatty Acid Composition of Oil from Sunflower Seed Grown at Different Locations

Planting location	Variety	Fatty acid compositionœof oil (area, %) Palmitic	Stearic	Oleic	Linoleic	Linolenic	Other fatty acids
Canada[a]	'Peredovik'	6.1	3.7	16.4	73.7	–	–
Canada[a]	'Armavirec'	6.0	4.3	18.1	71.6	–	–
Minnesota[b]	'Peredovik'	5.6	6.5	19.1	67.0	0.1	1.7
Minnesota[b]	'Mingren'	5.5	4.7	19.5	68.6	0.1	1.8
Davis, CA[c]	'Peredovik'	7.0	4.5	25.0	61.9	<0.1	1.5
Five Points, CA[c]	'Peredovik'	6.5	3.9	36.7	51.5	<0.1	1.3

[a]From Reference 6.
[b]From Reference 7.
[c]Robertson, J.A., USDA, ARS, R.B. Russell Agricultural Research Center, Athens, GA, unpublished data.

TABLE III

Average Fatty Acid Composition of Sunflower Varieties Grown in the South

		Fatty acid composition of oil (area, %)					
		Saturates		Oleic		Linoleic	
Planting location	Number of varieties	Range	Average	Range	Average	Range	Average
College Station, TX[a]	8	8.7–9.9	9.2	37.2–59.0	49.2	31.6–52.5	41.3
Experiment, GA[b]	21	7.3–11.3	9.1	29.3–60.0	44.6	29.9–61.8	45.9
Cotton belt[c]	12	9.3–11.8	10.9	38.3–58.8	49.4	31.4–49.7	39.6
Cotton belt[c]	7	10.2–12.3	11.5	37.3–55.7	46.6	33.8–50.5	41.6

[a]From Reference 8.
[b]From Reference 9.
[c]From Reference 10.

TABLE IV

Composition and Properties of Vegetable Oils[a]

Composition and property	Alabama sunflower oil	Minnesota sunflower oil	Cottonseed oil
Iodine value	120	131	107
Peroxide value (meq/kg)	0.21	0.41	0.60
Free fatty acids, % as oleic	0.04	0.03	0.45
Color	1 Yellow, 0.1 red	2 Yellow, 0.3 red	6 Yellow, 0.9 red
Stability, 8 hr AOM[b]	18.9	37.2	35.9
Fatty acid content, %[c]			
16:0	6.5	6.5	21.5
18:0	5.0	4.3	3.2
18:1	37.2	22.5	23.2
18:2	50.5	66.4	49.8

[a]From Reference 13.
[b]Increase in peroxide value in active oxygen method at 8 hr (AOCS Method Cd 12-57).
[c]Corrected data, calculated by use of response factors determined with standard methyl ester mixtures (Hormel GLC No. 13).

and the IV and linoleic acid content of the oils decreased; the change was least in the cottonseed oil. In each oil, free fatty acid concentration increased only slightly. The IV of the northern oil decreased 28.8% (from 132 go 94) while the IV of the southern oil decreased 21.7% (from 120 to 94). These decreases indicated a substantial reduction in unsaturation which was substantiated by the decreased linoleic acid content (48-50%) of both sunflower oils.

The color and viscosity of both sunflower oils increased gradually during the first 48 hr of heating, then rapidly during the heating from 48 to 120 hr. The viscosity for the Alabama oil appeared to be following the Minnesota oil to a higher viscosity, and at the end of the heating the Minnesota oil was more viscous than the Alabama (southern) oil. Since Rock and Roth (14) showed a direct relation between viscosity and the amount of non-urea-adducting fatty acids, this increase in viscosity of the sunflower oils is probably due to polymerization.

The southern oil appeared to be slightly more stable than the northern, but the difference is not as great as would be expected from the fatty acid composition of the oils. Thus, in view of the interest in the southern oil by large processors, we explored the stability of the two oils further.

We compared the effect of deep-fat frying of potatoes on the oxidative stability of northern and southern sunflower oils and of a commercial vegetable shortening. Hydrogenated and unhydrogenated sunflower oils and the commercial shortening were used to deep-fry 8 lb of raw potatoes daily for six 8-hr days, in a 4-qt household deep-fat frying at 180 C. The sunflower oils contained 0.076% Tenox 6 antioxidant and 2ppm Dow Corning Antifoam A. The commercial shortening was used as received. Make-up oil was added at the beginning of each day's run. Oils were sampled and Active Oxygen Method (AOM) values were determined daily. The composition and properties of each oil to be evaluated are shown in Table V (15).

The northern sunflower oils from a prepress solvent ex-

TABLE V

Composition and Properties of Oils Evaluated[a]

Chemical characteristics	Commercial shortening	Hydrogenated northern sunflower oil	Southern sunflower oil	Northern sunflower oil
Iodine value	55.2	109.4	121.0	134.9
Peroxide value (meq/kg)	1.0	3.5	1.4	3.2
Free fatty acids, % as oleic	.06	.09	.04	.08
Viscosity (centistokes 70 C)	17.0	15.8	14.2	13.8
Active oxygen method[c] (hr)	50.5	29.2	26.0	13.2
Fatty acid composition %				
14:0	2.6	–	–	–
16:0	25.0	7.2	5.7	6.0
18:0	19.3	5.1	4.1	4.1
18:1	39.7	47.9	37.1	19.1
18:2	7.3	37.0	52.2	69.5
18:3	0.5	0.9[b]	–	0.6[b]
20:0	–		0.2	
22:0	–	0.4	0.6	0.5

[a]From Reference 15.

[b]These sunflower oils were contaminated slightly with soybean oil and the percentages of 18:3 and 20:0 have been combined.

[c]AOCS Method Cd 12-57.

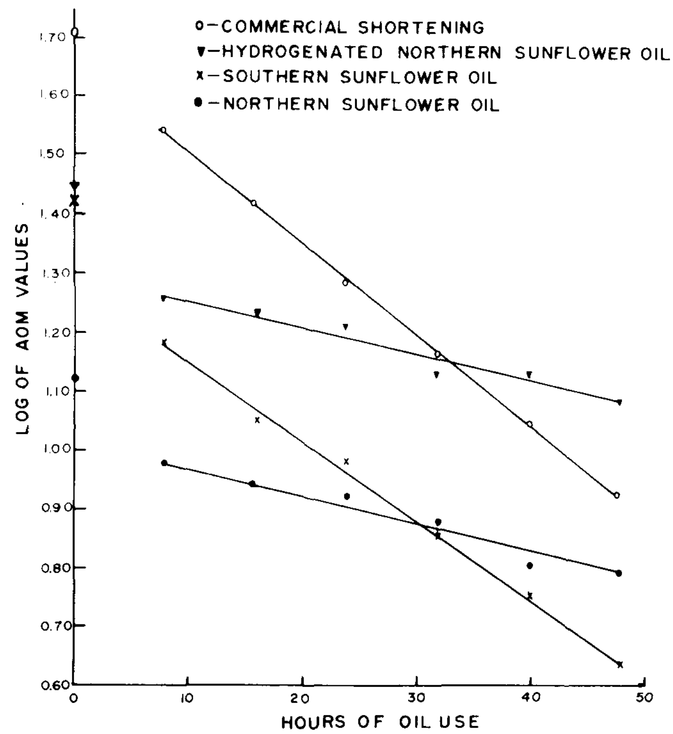

FIG. 2. Change in active oxygen method values with oil use. o = commercial shortening, △ = hydrogenated Northern sunflower oil, X = Southern sunflower oil. o = Northern sunflower oil. (From reference 15).

traction process were commercially prepared and contained a trace of soybean oil which is responsible for the small amount of linolenic acid shown in this table. The southern sunflower oil which was from a commercial expeller extraction process was pilot plant refined and deodorized. The commercial shortening was obtained from a local fastfood establishment.

Figures 2 (15) is a plot of the log of the AOM values versus the number of hours the oil had been heated and used. The slope of the line reflects the oxidizability of the oil. Initial AOM was 50.5 hr for the commercial shortening and 29.2 hr for the hydrogenated sunflower oil. Those values suggest that the hydrogenated sunflower oil would be less stable toward oxidation than the commercial oil. The data in Figure 2, however, show that stability decreased more slowly in the hydrogenated sunflower oil than in the commercial shortening, so that after 32 hr the lines intersect and the AOM values are then higher for the hydrogenated northern sunflower oil than for the commercial oil. Comparison of the rates of oxidizability shows that the commercial oil deteriorated three times as fast as the hydrogenated sunflower oil. The changes in IV, free fatty acids, and fatty acid composition do not indicate this difference in rates of deterioration. Those observations suggest that oxidative stability cannot be reliably detected by use of those tests. The rate of decrease of the AOM values points out a difference in oxidative stability that would not otherwise be readily apparent.

AOM values have been correlated with the shelf-life of an oil (16). A product such as potatoes, with a low oil content, absorbs oil on cooking and would have a shelf-life proportional to the AOM of the oil used for cooking.

The southern sunflower oil used in this study deteriorated faster than the northern and hydrogenated northern sunflower oils, and at about the same rate as the commercial shortening. Based on fatty acid composition, this rate of deterioration was unexpected. However, differences in the way the oils were processed were probably responsible for the results. The northern sunflower oil was obtained from seed by prepress solvent extraction, whereas the southern oil was obtained by expeller or screw-pressing of the seed. In the latter process, the oil is subjected to high temperatures and pressures which would be detrimental to oil quality. In addition, the oils were not refined and deodorized under similar conditions, thus creating another variable.

In recent work, care was taken to process both northern and southern grown sunflowerseed under identical conditions. After solvent extraction under mild conditions, the oils were pilot-plant refined and deodorized. The oils were then lightly hydrogenated, lowering the IV 4-7 units. The linoleic acid content of the northern oil was reduced from 64.4 to 53.3% and the southern oil from 33.4 to 30.8%. Hydrogenation produced 6.4% *trans* fatty acids in the northern oil and 3.3% *trans* fatty acids inthe southern oil.

Each of the sunflower oils was used to fry one pound of freshly cut potatoes each hour for four 8-hr days at 180 C in a 5-qt household deep-fat fryer.

With both oils hydrogenation increased the overall stabilities without increasing the rate at which the oils lose oxidative stability on heating as measured by the Active Oxygen Method. Although hydrogenation does increase stability, the southern unhydrogenated oil was more stable then the hydrogenated northern sunflower oil. This relation would be expected solely on the basis of the fatty acid composition of the two oils because the southern had higher oleic and lower linoleic acid contents than the hydrogenated northern oil.

Although there was slight polymer formation in the heated oils, generally the hydrogenated oils appeared to have a lower buildup of polymeric materials during heating than the unhydrogenated oils.

In summary, the sunflower industry is in its early growing stages in the United States. We have made great progress in developing foreign markets as well as in stimulating broader domestic usage. Sunflower oil is considered a premium oil on the world market and is widely preferred over soybean oil in many countries. Consequently, over 70% of the 1974 US oil-type sunflower seeds were exported instead of processed for consumption by the American public. The high ratio of polyunsaturated to saturated fatty acids makes sunflower oil a highly desirable commodity for use in such finished products as salad oils, margarine, and mayonnaise. Our studies indicate that southern oil and lightly hydrogenated northern sunflower oil are excellent for frying potato chips and other similiar products in which there is a high turn-over of the oil. Indications are that US manufacturers of some foods would be willing to pay a premium price for sunflower oil. The future of the sunflower crop in the United States probably depends not on seed exports but on the development of domestic markets for sunflower oil (17). Production and utilization research will play a key role in developing sunflower into a premier oilseed crop in the US thus providing the American consumer with an ample supply of a superior vegetable oil.

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