EFFECT OF SUNFLOWER HYBRID OR VARIETY AND PLANTING LOCATION ON OIL CONTENT AND FATTY ACID COMPOSITION

By

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Abstract

Total oil and fatty acid compositions were determined on the oil of sunflower seed from the 1976 and 1977 U.S. National Sunflower Performance Trials. In 1976, total oil content ranged from 33.2-54.2% and averaged 46.8% for all locations. Oleic acid content ranged from 15.1-59.3% and averaged 34.3% for all locations, whereas linoleic acid content ranged from 31.8-74.0% and averaged 55.7%. Plamitic and stearic acids averaged 5.3% and 3.8%, respectively. In 1977, total oil content ranged from 33.2-53.9%, averaging 46.3%. Oleic acid content ranged from 13.7-59.2% and averaged 31.1% for all locations, whereas linoleic acid content ranged from 32.4-75.9% and averaged 59.5%. Palmitic and stearic acids averaged 5.4% and 3.9%, respectively. Analysis of variance showed a highly significant difference in oil content between hybrids and varieties in 1976 and 1977. For both years, temperature and/or latitude had a highly significant effect on fatty acid composition. Oleic acid was positively correlated with minimum temperature ($r = 0.87$), whereas palmitic ($r = -0.71$), stearic ($r = -0.57$) and linoleic acids ($r = -0.83$) were negatively correlated with minimum temperature. A linear regression model of linoleic acid content versus average minimum temperature during seed development showed a straight line fit of the data, with $R^2 = 0.69$.

Introduction

In 1977, a record 2.3 million acres of sunflowers were produced in the United States, and a long-term expansion potential of 7 million acres has been forecasted (3). Only about 10% of the oilseed-type sunflowers are used in domestic markets, the remainder being exported (2). Since sunflower oil is such a nutritious vegetable oil, the potential for expanding domestic markets in the U.S. is great. Test marketing of sunflower oil products is being tested by Lever Brothers (Promise margarine), Hunt-Wesson (Sunlite salad oil) and Proctor & Gamble (Puritan vegetable oil). These and other new products will mean greater demand for sunflower oil.

The fatty acid composition of sunflower oil is known to vary, depending upon the temperature during seed development (1, 6, 7). Linoleic acid content of oil from commercial varieties has been found to range from 31.4% for plantings in Texas (7) to 75.5% for plantings in Canada (6). Putt et al (5) reported inbred lines with linoleic acid content as high as 81.8%. Therefore, differences

in fatty acid composition make usage of sunflower oil in a wide range of food applications possible and desirable.

We report here data on the effect of planting location (latitude) and temperature on the total oil content of fatty acid composition of commercial sunflower hybrid and open pollinated varieties grown at different locations in 1976 and 1977.

Materials and Methods

Sunflower seed samples were obtained from the 1976 and 1977 U.S. National Sunflower Performance Trials. These trials were a cooperative effort of commercial seed companies, the National Cottonseed Products Association (NCPA) and the Sunflower Association of America, with Mr. Dalton E. Gandy, formerly of NCPA, as project coordinator.

In 1976, seed of 10 sunflower hybrids and of Sputnik 71 and Peredovik 66 varieties were obtained from 24 locations in the U.S. and one location each in Canada and Mexico. In 1977, seed of 12 hybrids and of Sputnik 71 and Peredovik 66 varieties were obtained from 36 locations in the U.S. and one location each in Canada and Mexico. The experimental design of the plantings was usually a randomized complete block design with four replications. Row width varied from 30 to 40 in. and row length from about 20 ro 40 ft. Seed were usually hand harvested from 0 to 4 weeks after they had reached physiological maturity (the point at which oil filling and seed weight are maximum) depending on weather and availability of equipment.

Foreign material was removed from seed by hand picking and sieving prior to analysis. Total oil content was determined in duplicate on three composite samples of 12 to 14 grams each of dry seed (130°C for 1 hour) by the Newport MK III wide-line nuclear magnetic resonance analyzer. Fatty acid composition was determined on two composite samples in duplicate by gas-liquid chromatography (6). Moisture content was determined by A.O.C.S. Method Ai 2-75 (4). Mean daily maximum and minimum temperatures at each planting location were obtained for the period of full bloom until seed harvest.

Results and Discussion

Total oil content and fatty acid composition of the 1976 sunflower plantings are shown in Table 1. Total oil content of the hybrids (varieties) at the 26 locations ranged from 33.2-54.2% and averaged 46.8% for all locations. Oleic acid content ranged from 15.1-59.3%, averaging 34.3% for all locations, whereas linoleic acid content ranged from 31.8-74.0% and averaged 55.7%. Palmitic and stearic acids averaged 5.3% and 3.8%, respectively.

Table 2 shows the total oil content and fatty acid composition of the 1977 sunflower plantings. Total oil content of the hybrids (varieties) at the 38 locations ranged from 33.2-53.9% averaging 46.3%. Oleic acid content ranged from 13.7-59.2% and averaged 31.1% for all locations, whereas linoleic acid content ranged from 32.4-75.9% and averaged 59.5%. Palmitic and stearic acids averaged 5.4% and 3.9% respectively.

TABLE 1. Average total oil and fatty acid composition of sunflower hybrids (varieties) grown at 26 locations in 1976.

Hybrid (Variety)		Total Oil, % DB[a]		Fatty Acid Composition (Area %)							
				Palmitic (16:0)		Stearic (18:0)		Oleic (18:1)		Linoleic (18:2)	
		Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
Cargill	204	45.9	36.7-52.6	5.5	4.4-6.3	3.5	1.9-5.1	33.4	15.8-51.9	56.7	39.1-73.0
DO	410	47.1	41.6-52.7	5.1	4.3-6.4	4.2	2.7-5.8	34.3	17.4-55.7	55.3	35.4-71.9
Sun Gro	372	47.4	36.1-52.8	5.4	4.4-6.1	4.0	2.4-5.1	34.0	17.5-50.4	55.2	41.9-71.7
Sun Gro	380	48.1	42.4-53.8	5.3	4.5-6.0	3.7	2.3-4.8	33.5	16.2-53.5	57.6	37.7-74.0
Hybrid	891	48.2	40.6-53.1	5.3	4.6-6.0	3.7	2.4-5.3	32.7	17.2-52.5	57.4	39.7-71.0
Hybrid	8944	46.1	39.3-50.4	5.4	4.3-6.1	3.5	2.2-5.3	35.2	17.3-54.7	54.9	36.4-70.6
Sunbred	212	46.9	38.2-53.2	5.1	4.4-6.1	3.7	2.5-4.8	35.7	18.3-59.3	54.5	31.8-71.7
Sunbred	223	45.9	40.4-51.4	5.3	4.6-6.2	3.9	2.7-5.2	36.1	16.5-54.6	53.6	36.7-72.3
Sun Hi	301	47.3	39.8-53.0	5.2	4.5-6.2	3.7	2.6-4.9	32.8	17.1-56.7	57.3	34.9-73.2
Sun Hi	304	45.2	33.2-51.8	5.5	4.7-6.3	3.4	2.0-4.9	33.3	15.1-50.6	56.9	40.2-73.1
Sputnik	71	48.2	39.5-54.2	5.2	4.4-6.4	3.9	2.3-5.4	35.1	17.0-54.8	54.8	36.6-73.0
Peredovik	66	45.8	36.1-51.9	5.0	4.1-5.9	3.9	2.7-5.3	35.9	18.4-59.0	54.1	32.5-72.8
Overall Average		46.8	-	5.3	-	3.8	-	34.3	-	55.7	-

[a] Dry weight basis.

TABLE 2. Average total oil and fatty acid composition of sunflower hybrids (varieties) grown at 38 locations in 1977.

Hybrid (Variety)		Total oil, % DB[a]		Fatty Acid Composition (Area %)							
				Palmitic (16:0)		Stearic (18:0)		Oleic (18:1)		Linoleic (18:2)	
		Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
Cal/West	894	46.0	35.7-51.5	5.8	4.5-6.8	3.7	1.9-6.1	29.7	14.8-52.7	60.6	38.1-74.3
Cal/West	903	45.3	37.0-51.6	5.2	4.1-6.5	4.2	2.4-6.1	30.6	14.5-51.2	59.6	39.8-74.1
Cargill	204	45.2	35.3-51.5	5.6	4.5-7.0	3.5	1.9-5.7	29.5	14.6-50.4	60.9	40.2-75.9
Sun Gro	372A	47.5	37.0-53.0	5.3	4.1-6.7	4.1	2.0-6.2	42.7	13.8-59.2	57.5	32.6-75.2
Sun Gro	380	48.3	36.9-53.0	5.2	4.3-6.4	3.9	1.8-5.7	30.2	13.8-50.0	60.2	41.1-75.8
Hybrid	8943	46.7	39.2-51.1	5.2	4.3-6.6	4.5	2.2-6.3	32.5	14.5-59.2	57.6	32.4-74.0
Sunbred	254	45.6	35.4-51.7	5.5	4.6-6.9	3.6	1.7-5.0	30.1	14.2-49.7	60.5	42.4-75.8
Sunbred	223	45.3	37.6-50.6	5.5	4.7-6.7	4.0	1.9-5.6	31.9	15.5-55.2	58.2	35.2-74.3
Sun Hi	301A	48.3	38.0-53.8	5.2	4.2-6.5	3.8	1.5-6.2	30.2	14.8-48.2	60.4	43.6-75.2
Sun Hi	304	45.6	36.4-52.1	5.6	4.7-7.1	3.6	1.4-5.2	29.5	13.7-50.3	60.8	41.4-74.7
Big Top+		45.1	37.6-51.0	5.4	4.5-6.9	3.9	1.7-5.5	29.8	15.9-48.5	60.3	42.9-73.7
Sigco	894	44.7	33.2-51.5	5.5	4.7-7.0	3.5	1.6-5.5	29.9	14.2-50.0	60.5	41.4-75.3
Sputnik	71	48.8	38.8-53.9	4.9	4.1-6.3	4.1	2.0-6.2	37.5	15.0-55.9	57.8	37.4-74.9
Peredovik	66	45.8	37.9-51.9	5.2	4.5-6.8	4.3	1.6-6.2	31.8	15.5-51.0	58.1	40.6-73.5
Overall Average		46.3	-	5.4	-	3.9	-	31.1	-	59.5	-

[a] Dry weight basis.

Analysis of variance showed a highly significant difference in oil content between hybrids in 1976 and 1977 (P .0001). Duncan's Multiple Range Test of oil content, seed and oil yields of the hybrids (varieties) are given in Tables 3 and 4. The same or similar varieties tended to give consistently high or low total oil contents in both years. Sputnik, an open pollinated variety, had the highest oil content in both years but did not produce the highest oil yield because of low seed yield, particularly in 1977 (Tables 3 and 4). The oil yield data show that the hybrids (varieties) with the highest oil content will not necessarily give the highest oil yield.

Location affected oil content of hybrids highly significantly (P .0001), as would be expected because of different environmental and agronomic conditions.

Temperature and/or latitude had no significant effect on total oil. Nevertheless, sunflowers grown at the cooler locations and latitudes above 39° had a slightly higher oil content than those grown at the warmer locations below 39° latitude (Table 5). As expected, latitude was significantly correlated with average daily temperature ($r = -0.84$) for the planting locations. Canvin (1) reported higher oil contents of rape and flax seed at the lowest temperature and a continual decrease was observed with increase in temperature. Oil contents of sunflower, safflower, and castor bean were not affected by temperature. A comprehensive evaluation of the total oil contents at selected locations in our study support Canvin's data on sunflower oil. For example, sunflowers grown at six locations in southeastern U.S. with an average temperature of 26.6°C during seed development had an average oil content of 48.7% compared to 48.5% oil content for plantings at six locations in the Red River Valley of Minnesota and the Dakotas with an average temperature of 17°C.

For 1976 and 1977, temperature and/or latitude affected fatty acid composition highly significantly. Correlations between latitude as well as temperature (average, maximum and minimum temperatures from flowering to harvesting) and fatty acid composition for the combined years of 1976 and 1977 were determined. The correlations were best for minimum temperature. Oleic acid was positively correlated with minimum temperature ($r = 0.87$), whereas palmitic ($r = -0.71$), stearic ($r = -0.57$) and linoleic acids ($4 = -0.83$) were negatively correlated with minimum temperature. A linear regression model of linoleic acid content versus average minimum temperature during seed development showed a straight line fit of the data, with $R^2 = 0.69$. Figure 1 is a plot of the actual data for both 1976 and 1977. Thus, if the average minimum temperature for the period from flowering to harvest at any given location is known, the linoleic acid content of sunflower seed could be predicted by the formula:

Percent Linoleic acid = 89.094 - 1.951 (average minimum temperature). Therefore for 1°C each increase in average minimum temperature, linoleic acid would decrease by 1.95%.

Linoleic acid content correlated well with latitude ($r = 0.78$) and average temperature ($r = -0.80$). The relationship between linoleic acid content and latitude is illustrated in Table 5. Both in 1976 and 1977, sunflowers that were planted by June 1st at 39° latitude or above generally had linoleic acid contents above 60%, with the exception of locations near Davis, CA and Cortez, Colorado. Plantings below 39° had linoleic acid contents below 60%. This observation could have important implications on the use of sunflower oil. Sun-

TABLE 3. Effect of hybrid (variety) on oil content and yield of sunflowers grown at 26 locations in 1976.

Hybrid (Variety)	Total oil % dry basis	Seed yield[1] kg/ha	Oil yield kg/ha
Sun Hi 304	45.15 a[2]	2155	973
Peredovik 66	45.79 a	1967	901
Sunbred 223	45.86 a	1961	899
Cargill 204	45.94 a	2066	949
Hybrid 8944	46.07 ab	2113	973
Sunbred 212	46.88 bc	2173	1019
DO 410	47.10 c	2024	953
Sun Hi 301	47.26 cd	2118	1001
Sun Gro 372	47.38 cde	1984	940
Sun Gro 380	48.05 de	2109	1013
Hybrid 891	48.18 de	2176	1050
Sputnik 71	48.24 e	2072	999

[1] Average of 36 locations.

[2] Duncan's Multiple Range Test (5% level) - means of oil contents followed by a common letter are not significantly different.

TABLE 4. Effect of hybrid (variety) on oil content and yield of sunflowers grown at 38 locations in 1977.

Hybrid (Variety)	Total oil % dry basis	Seed yield[1] kg/ha	Oil yield kg/ha
Sigco 894	44.71 a[2]	2103	940
Big Top+	45.08 ab	2241	1010
Cargil 204	45.18 abc	2120	958
Cal/West 903	45.25 abc	2136	967
Sunbred 223	45.29 abc	1880	853
Sun Hi 304	45.55 bc	2023	921
Sunbred 254	45.56 bc	2137	974
Peredovik 66	45.83 bc	1929	884
Cal/West 894	45.96 c	2184	1004
Hybrid 8943	46.73 d	2093	978
Sun Gro 372A	47.53 e	2000	951
Sun Hi 301A	48.26 ef	2115	1021
Sun Gro 380	48.28 ef	2080	1004
Sputnik 77	48.78 f	1910	932

[1] Average of 40 locations.

[2] Duncan's Multiple Range Test (5% level) - means of oil contents followed by a common letter are not significantly different.

TABLE 5. Effect of latitude and temperature on sunflowerseed oil content and fatty acid composition

	1977					1976				
Latitude	No. of Locations	Average Temp. °C	Average Oleic Acid, %	Average Linoleic Acid, %	Average Oil, % dry basis	No. of Locations	Average Temp. °C	Average Oleic Acid, %	Average Linoleic Acid, %	Average Oil, % dry basis
26°-38.5°	20	26.2	40.3	50.7	45.9	15	25.1	42.3	47.9	46.2
39°-49°	15	18.2	19.8	69.4	46.6	7	20.0	21.7	67.7	48.3

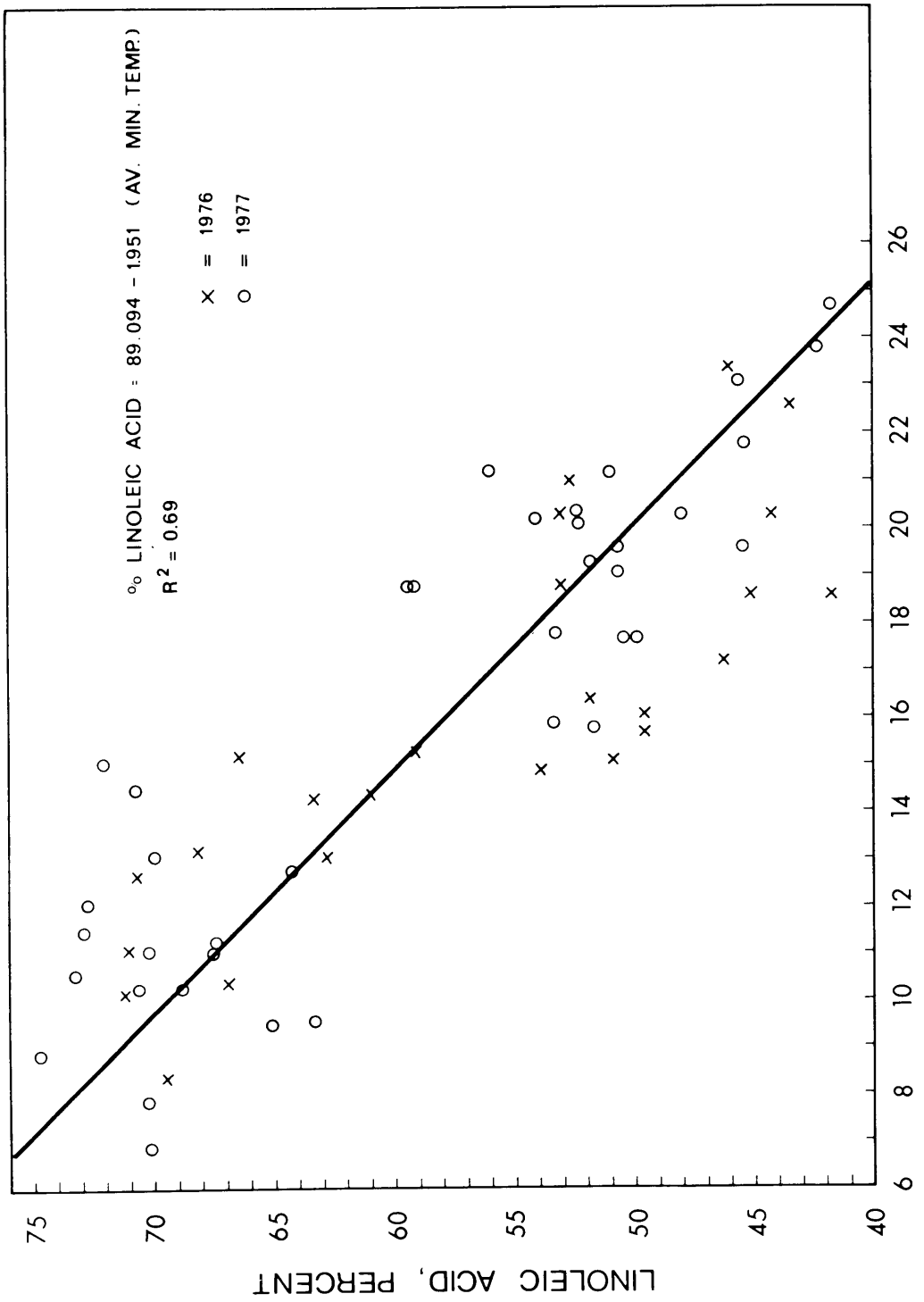

FIGURE 1. Relationship between linoleic acid content and average minimum daily temperature during seed maturation, 1976-1977.

flower oil for products requiring high polyunsaturated oil, such as margarine and salad dressings, might be obtained from planting locations above 39° latitude; whereas, sunflower oil used in snack food frying might be obtained from plantings located below 39°. However, as we indicated, there are exceptions to this observation. For example, late plantings of sunflowers in South Texas have been found to have as high a linoleic acid content as 75%.

In the present study, the exact time of seed physiological maturity for some of the locations wasn't known, and the date of actual harvest was used to determine the average temperature data. Controlled studies in which the seed are harvested at the same physiological maturity would probably show that linoleic and oleic acids are better correlated with temperature and/or latitude than we have shown, and would allow an even better prediction of fatty acid composition on the basis of planting location.

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