Compositional Data on Sunflower Seed

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Abstract

Comparative data are provided on the composition of achenes from sunflower varieties Armavirec, Peredovik, VNIIMK 8931, Smena, Krasnodarets, Arrowhead and Mingren. Hand-separated achene components were analyzed. Kernel oil from seed raised in northern United States or southern Canada typically contains about 70% of linoleic acid. In addition to other common acids, traces of C_{17}, C_{20}, C_{22}, C_{24} acids and linolenic acid are present. The amino acid composition of sunflower kernel protein suggests that the meal may be a valuable ingredient of high-quality feed or food materials. The hull is primarily cellulose, lignin and pentosans; hull lipid and protein differ in composition from the corresponding kernel constituents.

Introduction

BETWEEN 1962 and 1967 sunflower seed oil has probably increased in world importance faster than oil from any other source (24). During those years world production of the oil expanded by nearly 60%, the amount produced surpassed peanut, cottonseed and coconut oils to climb from fifth to second place (after soybean oil) among vegetable oils of the world (24), and the growth in exports in that time interval represented almost a doubling of the quantities entering world markets. The increased activity in production and export of sunflower seed and oil has occurred primarily in the Soviet Union.

Sunflowers (*Helianthus annuus*) are native to the United States; the species is adapted in many areas of the country. But the insect pests and diseases that attack the plant are also well entrenched and have spread from wild populations to cultivated fields when attempts were made to establish the crop in various parts of this country. The continued latent interest in sunflower as a possible oilseed crop for the United States has been kindled particularly by the availability of seed from Russian varieties that contain considerably greater percentages of oil than those previously at hand (7,8,20). Until more resistant lines, hybrids, or suitable control measures are developed, however, it has been recommended (20) that major North American sunflower seed production be limited to northern United States and Canada (19) where pests do not now cause serious damage. Such a restriction has been advised particularly because of possible damage by the sunflower moth.

In 1967, there were 236,000 acres planted to sunflower in Minnesota and North Dakota, about three times the 76,000 acres in 1966. The increase is largely due to greater acreage of oilseed types; of the 1967 acreage, 116,000 acres were in oilseed varieties.

In view of the renewed interest in commercialization of sunflower as an oilseed crop for the United States and because of the difficulty in finding sufficiently detailed analytical information in readily available journals, we report here our data on the chemical composition of selected varieties of sunflower seeds and of their components and constituents.

Seed Analyses

Technically, the plant part usually referred to as "seed" is a one-seeded fruit or achene. The achene includes the pericarp (hull) and seed (kernel). The seed has a thin translucent tissue-paperlike covering, which is the seed coat. In separating the achene into component fractions, a portion of the seed coat appears in both hull and kernel fractions.

In Table I are shown analytical data, obtained by procedures in regular use in our Laboratory (4), on the achenes of the various samples and on their hand-separated hull and kernel fractions.

The Arrowhead and Mingren varieties, used for confections and birdseed, have larger achenes, more hull and smaller percentages of oil than the various oilseed varieties of Russian origin. One sample of Mingren was separated into fractions arbitrarily designated as large or small achenes. The small-seeded Mingren achenes contained less hull and more oil

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TABLE I
Data on Sunflower Achenes and Their Components

Sample	Variety										
	Armavirec	Armavirec	Peredovik	Peredovik	VNIIMK 8931	Smena	Krasnodarets[a]	Arrowhead	Mingren	Mingren, large-seeded	Mingren, small-seeded
Achene											
Wt/1000, g[b]	59	84	86	78	62	65	87	91	102	180	77
Hull, %	28	26	26	24	27	22	23	44	44	52	43
Moisture, %	6.0	6.5	6.7	5.9	6.5	6.5	5.0	7.2	6.8	7.1	8.2
Oil, % DB	48.0	44.4	45.6	51.4	45.8	39.7	43.3	29.8	31.2	21.0	30.7
Protein, N × 6.25, % DB	16.9	21.1	19.8	15.8	16.0	23.8	22.2	18.1	15.9	19.0	17.2
HBr equiv.[c] in oil, % 0 C	0.6	0.6	0.6	0.6	0.6	0.8	0.6	0.5	0.6	0.6	0.5
55 C	0.6	1.2	1.2	0.8	1.0	1.2	1.4	1.2	1.0	2.3	0.8
Hull											
Moisture, %	6.6	8.8	8.0	7.1	7.1	7.4	7.4	9.3	6.9	6.4	7.7
Oil, % DB	1.7	1.7	0.6	0.7	1.7	2.2	2.5	0.9	0.4	0.5	1.3
Protein, N × 6.25, % DB	3.8	4.5	3.9	3.6	4.3	6.1	5.7	2.5	1.7	4.1	2.9
Kernel											
Wt/1000, g	42	62	64	59	45	51	67	51	57	86	44
Moisture, %	7.8	4.8	7.4	3.6	8.2	8.8	3.7	9.8	5.8	5.7	4.4
Oil, % DB	64.7	57.5	59.8	62.9	61.8	52.7	53.0	54.5	54.4	46.7	53.0
Protein, N × 6.25, % DB	21.2	25.8	25.2	19.0	21.4	29.4	28.8	30.8	26.6	36.4	26.6
HBr equiv.[c] in oil, % 0 C	0.2	1.0	0.1	1.3	0.2	0.2	0.5	0.1	0.4	0.8	0.6
55 C	0.3	1.0	0.3	1.3	0.3	0.4	0.9	0.4	1.0	2.8	0.8

[a] Except for the variety Krasnodarets, seeds were produced in northern United States or in Canada and, insofar as can be ascertained, are from the 1966 crop year. The duplicate samples each of Armavirec and Peredovik varieties are from different commercial sources. The Krasnodarets seed was produced in the USSR.
[b] Calculated from weights of kernel and hull, to avoid inclusion of empty or wormy achenes.
[c] Calculated as epoxyoleic acid.

TABLE II
Gas-Liquid Chromatographic Analysis of Methyl Esters (area per cent)

Component	Variety										
	Armavirec	Armavirec	Peredovik	Peredovik	VNIIMK 8931	Smena	Krasnodarets[a]	Arrowhead	Mingren	Mingren, large-seeded	Mingren, small-seeded
14:0	0.2	0.1	Tr	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
16:0	6.0	5.6	5.6	5.8	6.1	5.9	5.7	5.4	5.5	5.0	6.1
16:1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
17:0	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	0.1	Tr
17:1	...	...	Tr	....	...	Tr	Tr	...	Tr	0.1	Tr
18:0	5.6	6.2	6.5	5.2	4.4	5.5	4.8	4.9	4.7	5.6	4.6
18:1	17.8	19.2	19.1	15.9	17.0	16.8	41.4	21.4	19.5	19.7	20.5
18:2	68.7	67.2	67.0	71.5	71.1	69.9	46.4	66.8	68.6	67.9	67.3
18:3	0.2	0.1	0.1	0.2	0.1	0.2	Tr	0.2	0.1	Tr	0.1
20:0	0.3	0.3	0.4	0.2	0.2	0.3	0.2	0.3	0.3	0.4	0.2
20:1	0.1	0.1	0.1	0.1	Tr	0.1	0.1	0.1	0.1	0.1	0.1
22:0	0.8	1.0	0.9	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.8
24:0	0.1	0.1	0.1	0.1	Tr	0.2	0.2	0.1	0.2	0.1	0.1
IV[b]	135.0	133.4	132.9	138.2	138.1	136.2	116.4	134.8	135.8	134.7	134.6
IV[c]	133.9	131.8	131.8	136.0	136.5	135.0	114.6	132.1	135.0	133.0	132.3

[a] In addition to components shown, this sample contained a trace of 15:0.
[b] Iodine value of esters calculated from GLC analysis.
[c] Iodine value observed experimentally.

than the large-seeded fraction, but the proportions of these components were still markedly different from those of the newer oilseed types. Differences among the oil and protein values of the oilseed varieties are not significant since variability among the samples of a variety was frequently as great as between varieties. The small sampling does not allow one to distinguish varietal differences precisely. Also, agronomic and environmental factors were not necessarily constant in production of the samples analyzed. For both achenes and kernels of the oilseed varieties a qualitatively inverse relationship exists between oil and protein contents. Percentage of oil is greatest in kernels of the newest varieties—Armavirec, Peredovik, and VNIIMK 8931. No relationship is apparent between size of achene or kernel and oil content. The fibrous hulls have only small amounts of oil and protein. Both achene and kernel oils apparently contain traces of substances that react with hydrogen bromide (7), a response that may be due to the presence of oxygenated fatty acids (12). The crude protein contents shown in Table I are calculated by use of the conventional factor of 6.25 times the nitrogen percentage, but one literature report (21) suggests that a factor as low as 5.4 may be more appropriate.

Fatty Acid Composition of Kernel Oils

Qualitative GLC analysis of the kernel oil glycerides carried out in a manner generally like that of Litchfield et al. (10) revealed a similarity among the samples, each having a major peak at C_{54}, a lesser one at C_{52}, and quite minor peaks at C_{50}, C_{56}, C_{58} and C_{60}.

The oils were converted to methyl esters by the BF_3-methanol procedure of Metcalfe et al. (11) and the esters analyzed by GLC on an F&M Model 402 chromatograph equipped with flame ionization detectors held at 250 C. A 12 ft × ¼ in. polar column packed with 5% LAC-2-R 446 and a 4 ft × ¼ in. nonpolar column of Apiezon L were used at 200 C; both liquid phases were on Chromosorb W (acid-washed and silanized). To assure quantitation of minor components, a sample size of 0.1 μl was used with an attenuation of 400X. Under these conditions, peaks for major components ran off-scale (20 times full chart range) on the 1-mv recorder but were well within the linear range of the digital integrator employed. Iodine values of the methyl ester mixtures were computer-calculated from the composition found, for comparison with experimentally determined values.

Data on the methyl esters are shown in Table II. The linoleic acid percentages are consistent with those reported by Kinman and Earle (7). From the lower values for the Krasnodarets variety, we presume that it came from an area in Russia where higher temperatures prevailed during seed development (7) than in the northern United States and Canadian growing regions where the other samples originated. Fatty acid composition is not apparently influenced significantly by variety. Noteworthy is the consistent presence of small amounts of C_{17}, C_{20}, C_{22} and C_{24} acids. The chromatograms show a definite C_{18} peak which has the proper retention time for methyl linolenate and is presumably that compound.

Composition of Hull Constituents

A large proportion of the sunflower achene is

TABLE III
Analytical Data on Sunflower Seed Hulls (in percentages)[a]

Variety	Alcohol-benzene solubles[b]	Benzene-soluble "waxes"[c]	Ash	Silica[d]	Lignin[e]	Pentosans[f]	Cellulose[g]	
							Crude	Alpha
Armavirec	3.8	3.0	3.3	0.2	29.6	26.5	30.3	28.8
Armavirec	3.4	2.3	2.9	0.2	28.0	28.7	30.3	29.0
Peredovik	2.2	1.4	3.2	0.2	28.6	26.8	31.3	29.6
Peredovik	3.0	1.4	3.2	0.1	26.6	26.6	32.0	30.2
VNIIMK 8931	2.9	1.3	3.6	0.3	26.3	27.0	30.1	28.8
Smena	4.2	2.6	3.7	0.2	25.6	25.4	31.1	29.4
Krasnodarets	4.6	3.6	2.8	0.2	27.2	26.8	31.4	29.8
Arrowhead	2.3	1.7	2.4	0.1	28.3	28.6	31.4	30.0
Mingren	1.7	0.8	1.8	0.2	25.1	31.0	33.4	32.4

[a] All data on dry basis.
[b] EtOH-benzene (1:2, v/v), 16 hr extraction at reflux.
[c] Alcohol-benzene soluble components dissolved in warm benzene. Percentage based on original, moisture-free material.
[d] By hydrofluoric acid treatment of acidified (H_2SO_4) ash and ignition at 600 F.
[e] Procedure of the Northern Laboratory. Two-hour digestion with 80% H_2SO_4 at 5 C.
[f] Bromate-bromide procedure, TAPPI T223 ts – 63 (23).
[g] Ash- and pentosan-free basis. Pentosan content of crude cellulose, 34–39%; of α-cellulose, 8–16%. Crude by monoethanolamine procedure (16). Alpha by TAPPI T203 (23) as originally written, but with 1 g of crude, and quantities of reagents adjusted accordingly. Dilution was with an equal volume of water and immediate filtration of the α-cellulose.

hull; even the newer oilseed varieties are about one fourth hull. Knowledge of the amounts, types and characteristics of constituents present is therefore desirable to serve as a guide in exploring potential uses for this large volume by-product of processing sunflower as an oilseed. The chemical composition of the hulls (Table III) indicates that about 85% of the sample may be accounted for by the lignin, pentosan and cellulosic constituents common to other fibrous and related lignocellulosic materials. For comparison oat hulls, wheat straw, sugarcane bagasse and corncobs typically have the following approximate percentages of those constituents, as found in our laboratories. Generally the sunflower hulls contain more lignin and lesser amounts of pentosans and

Material	Average percentages (and range)		
	Lignin	Pentosans	α-Cellulose
Oat hulls	17	39	36
Wheat straw	18 (15–21)	30 (27–32)	33 (29–37)
Sugarcane bagasse	19 (16–22)	30 (27–32)	33 (30–37)
Corncobs	14 (8–17)	41 (31–45)	32 (22–39)
Sunflower hulls (Table III)	27 (25–30)	27 (25–31)	30 (29–32)

cellulose than other common agricultural residue materials. The hulls might serve as a raw material for furfural production, but anticipated furfural yield should be less because of the smaller quantity of pentosans present. Chemical composition of hulls from the different varieties is similar. Potential uses for hulls may be like those for corncobs (3).

Since sunflower hulls are fibrous in nature, microscopic measurements of fiber dimensions were made after digestion of the hulls in acidic chlorite to free cells by removal of lignin and related cementing substances (17). Apparent under the microscope were elongated cells, accompanied by a considerable quantity of small, irregularly shaped debris. Some of the long cells were cigar-shaped, had pointed ends, and resembled plant stem fibers. Other of the elongated cells were rectangular or appeared to have one pointed and one squared end. The scope of our work did not include characterization of the cell types involved; cells more than 0.1 mm long were measured to determine their possible value as a fibrous raw material (Table IV). Fiber length is somewhat greater for the Arrowhead and Mingren varieties, which have higher hull content, than for the oilseed varieties. There was no significant difference among samples in the latter group. Length-to-width ratio of fibrous elements is about 12:1 for the oilseed varieties. This ratio is considerably below the values for most papermaking fibers (18). This low length-width ratio, considered together with relative shortness of the fibers, suggests that as a primary raw material they would not contribute to favorable properties in derived pulps. Small amounts of hull fibers might be used as a filler in blends with other longer fibered pulps. Compared to most plant stem and stalk fibers, the hull fibers are broad and have large lumens.

In contrast to the kernel oil, GLC of the hull oils suggested the presence of many components in addition to the usual triglycerides. A complex chromatogram was observed with several distinct peaks, collectively representing 15–20% of the total and emerging between injection and the time that a C_{30} triglyceride would appear. A second series of peaks that represented another 8–10% of the hull oil eluted in the C_{42} to C_{48} region (considered as triglyceride retention values). The normal triglyceride peaks accounted for 70–75% of the oil. Methyl esters from hull oil (Armavirec) had the following composition: $C_{12:0}$ 0.3%; $C_{14:0}$ 0.6%; $C_{14:1}$ 0.1%; $C_{15:0}$ 0.2%; $C_{15:1}$ 0.1%; $C_{16:0}$ 8.1%; $C_{16:1}$ 0.8%; $C_{17:0}$ 0.1%; $C_{17:1}$ 0.3%; $C_{18:0}$ 5.1%; $C_{18:1}$ 17.5%; $C_{18:2}$ 59.7%; $C_{18:3}$ 0.3%; $C_{20:0}$ 2.3%; $C_{20:1}$ 0.5%; $C_{22:0}$ 2.4%; $C_{24:0}$ 1.1%; conj. $C_{18:3}$—from dehydration of dienol(s) (12)—0.2%; and vernolate 0.1%. Comparison of these data with results in the kernel oil (Table II) reveals a larger quantity of other than C_{18} acids in hull oil than in kernel oil. Since definite C_{60} and C_{62} peaks in the GLC curve of the hull oil are consistent with the results from methyl esters, a larger quantity of C_{22} and C_{24} acids is indicated. Although we have not further investigated the constituents of hull lipids, they seem to merit study since incomplete removal of hulls in commercial decortication operations undoubtedly cause some hull oil to be mixed with the kernel oil.

Amino Acid Composition of Defatted Kernel Meals

Analyses for all amino acids, except cystine and tryptophan (26), were carried out by an automated ion-exchange procedure as previously described (2). Cystine and cysteine were oxidized to cysteic acid (13) and that acid was determined on the long cation-exchange column of an automatic analyzer. Tryptophan was determined on pronase hydrolyzates of meals by the procedure of Spies (22). Replicate samples of five varieties were analyzed to establish limits of precision. Values reported were obtained on 24 hr hydrolyzates, with no correction for small losses of serine and threonine that occur during hydrolysis.

At the 5% probability level, no significant differences in content of the various amino acids were observed that can be related to variety. Therefore, only the means and ranges found for the amino acid composition are reported in Table V. The percentages of some of the amino acids reported earlier (1,25) for unspecified varieties of sunflower were outside the ranges of values given in Table V; yet the amino acid patterns are generally similar. Though the hull protein appears to differ in amino acid composition from the kernel protein (Table V), the low nitrogen content of the hulls suggests little practical importance

TABLE IV

Cell Dimensions in Sunflower Hull Macerates

Variety	Length, mm			Width, μ			Lumen diameter, μ	Cell wall thickness,[b] μ
	Ave.[a]	Min.	Max.	Ave.[a]	Min.	Max.		
Armavirec	0.45	0.15	1.0	30.5	15	60	15.9	5.6
Armavirec	0.39	0.15	0.7	32.3	17	50	19.3	6.2
Peredovik	0.40	0.15	0.8	33.2	16	52	16.9	6.7
Peredovik	0.37	0.15	0.9	32.5	18	50	16.2	6.0
VNIIMK 8931	0.41	0.15	1.0	33.1	12	49	16.7	7.2
Smena	0.37	0.15	0.8	29.5	13	50	16.7	5.8
Krasnodarets	0.37	0.15	0.9	34.6	18	52	20.3	6.2
Arrowhead	0.57	0.25	1.4	29.3	18	52	15.0	7.1
Mingren	0.58	0.15	1.8	26.2	12	43	16.5	6.4

[a] Arithmetic average based on count of approximately 100 cells. All fibrous elements >0.1 mm were counted.
[b] Measurements made only on typical fiber cells having pointed ends since lumen was not always easily apparent in other cell types.

TABLE V
Amino Acid Composition (g/16 g nitrogen) of Defatted Kernel Meals

Amino acid	Mean for seven varieties	Range	Hull from Smena variety
Lysine	3.77	3.4 – 4.2	5.5
Methionine	1.91	1.7 – 2.1	1.6
Cystine	1.82	1.6 – 2.2	....
Phenylalanine	4.70	4.6 – 4.8	4.3
Tyrosine	2.65	2.6 – 2.8	2.3
Tryptophan	1.11	1.0 – 1.2	....
Isoleucine	3.97	3.9 – 4.1	3.7
Leucine	6.13	6.0 – 6.2	6.1
Threonine	3.18	3.0 – 3.4	3.9
Valine	4.76	4.3 – 5.1	4.7
Histidine	2.47	2.4 – 2.6	2.9
Arginine	8.91	8.4 – 9.2	5.7
Glycine	5.05	4.8 – 5.3	6.8
Serine	3.89	3.4 – 4.1	4.7
Alanine	4.07	3.9 – 4.3	4.6
Aspartic acid	8.70	8.4 – 8.9	9.5
Glutamic acid	20.95	19.6 –21.7	13.3
Proline	5.01	4.5 – 5.3	4.5
Ammonia	2.18	1.8 – 2.7	2.4
Nitrogen, as amino acids and ammonia, %	92.4	84.8 –96.1	87.0
R (9)	0.341	0.33– 0.35	....
V(r) · 10^3 (9)	1.49	0.9 – 2.3	....

for this difference. The high percentage recovery of nitrogen as amino acids plus ammonia is greater than we found for most seed meals (25,26) and accounts for a large proportion of the kernel nitrogen as known constituents.

Recently Kwolek and VanEtten (9) reported a procedure for comparing various seeds for possible food uses. The amounts and patterns of nutritionally essential amino acids were calculated by using hen's egg as a reference standard. One computed value, R, is a measure of the total quantity of essential amino acids in the protein (hen's egg protein contains 51.3% of essential amino acids). A second constant, V(r), provides information on how the pattern of essential amino acids (i.e., the amounts relative to one another) deviates from that of hen's egg. The value of V(r) is zero for hen's egg. The smaller the value of V(r) for a given material, the more closely the substance agrees with the pattern in hen's egg for essential amino acid composition. Mean values of R and V(r) for the sunflower varieties reported in this paper are given in Table V. The 34.1% of essential amino acids present is below that of animal products, but similar to that found for the protein of most plant seeds (9).

TABLE VI
Amino Acid Composition of Kernel Meals Compared With Estimated Requirements for Humans, Pigs and Chicks

Amino acid	Milligram acid per gram nitrogen required for			Ave. sunflower protein composition
	Humans[a]	Growing pigs[b]	Starting chickens[c]	
Lysine	270	260	344	236
Methionine	109	96	125	120
Cystine	96	95	109	114
Total sulfur-containing amino acids	205	191	234	234
Isoleucine	270	191	234	248
Leucine	306	208	438	383
Phenylalanine	180	122	219	294
Tyrosine	180	52	188	166
Total aromatic amino acids	360	174	407	460
Threonine	180	156	219	199
Tryptophan	65	45	62	69
Valine	270	174	266	298
Histidine	.....	69	125	154
Arginine	.....	69	375	553
Glycine	.....	.....	312	316

[a] Provisional pattern for FAO (5), corrected for lower requirements for sulfur-containing amino acids and tryptophan, as recommended by the FAO (6) in 1965. The lower methionine and cystine values were computed by assuming that they decreased in the same proportion as for the total of sulfur-containing amino acids.
[b] Calculated from data given by the National Research Council based on an 18% protein ration (14).
[c] Calculated from data given by the National Research Council based on a 20% protein ration (15).

The mean V(r) value for the sunflower varieties is close to the mean for the Compositae family, a plant group that has protein more nearly like egg protein than many other families examined (9). The low V(r) value for sunflower seed kernel protein is significantly lower than that for many commonly consumed foods, including cow's milk, wheat, beef and rice. Even though nutritional evaluation based on analysis suggests that sunflower meal contains high quality protein, availability of the amino acids and the possible presence of antinutritional substances that would prevent or interfere with its effective use must be determined by feeding trials.

In Table VI the contents of nutritionally essential amino acids in sunflower meals are compared with the estimated requirements for humans, pigs and chickens. For humans the chemical analyses indicate adequacy of essential amino acids, excepting for lysine and isoleucine. There is a sufficiently large amount of phenylalanine so that, when added to the tyrosine present, it meets the need for total aromatic amino acids. The sunflower meal is deficient only in lysine for growing pigs. For starting chickens, the meal is lacking in lysine, leucine and threonine, and is borderline in the sulfur-containing amino acids, as well as in isoleucine and glycine.

The chemical score for sunflower protein for human nutrition is 89 compared to whole hen's egg as the reference pattern, computed as described by the FAO (6). Lysine is the first limiting amino acid and isoleucine is second.

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