BIOCHIMICAL CHARACTERISTICS OF THE PRESENT SUNFLOWER VARIETIES AND HYBRIDS

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Sunflower breding for high oil content changed not only the ratio between oil and protein in the seeds, but also the chemical composition of the gel and oil part of the seed as a whole. The reduction of husk content was accompanied by a substantial change in their chemical composition. This had an evident influence on the physical and biological characteristics of the seeds and more particularly on the hydrophile and hygroscopic properties and enzyme activity.

Table 1, elaborated according to N. F. Dubleanskaia's data, shows that the content of compounds entering the gel composition changes alongside the change in oil and protein amount in kernels i.e.

Table 1

Chemical composition of kernels and achene coat in sunflower varieties with high and low oil content

Chemical composition	VNIIMK 8931	Kruglik A-41
Oil in absolutely dry achene, %	49.0	35.1
Kernel composition (% as compared to absolutely dry substance)		
lipids (oil)	64.4	57.8
protein	19.8	25.2
extractive nitrogen-free substances	7.4	9.2
ashes	3.4	3.6
cellulose	5.0	4.1
Husk composition (% as compared to absolutely dry substance)		
lipids	2.96	0.99
protein	4.19	1.88
extractive nitrogen-free substances	36.9	30.8
ashes	2.59	1.37
cellulose	53.3	65.9

extractive nitrogen-free substances, cellulose, substances rich in ashes. The content of cellulose increased, while that of extractive nitrogen-free substances and ashes decreased.

The husks of the actual sunflower varieties with high oil content are much richer in extractive nitrogen-free substances, lipids and substances containing nitrogen and ashes, but they contain however less cellulose as compared to the varieties with lower oil content formerly grown in the Soviet Union.

The oil content of the cultivated sunflower varieties reaches 63% and even more, and the total oil and protein content represents 80—83% (table 2).

Table 2

Oil and protein content (% as compared to absolutely dry substance) in kernels of sunflower cultivated varieties (Krasnodar, 1971)

Sunflower varieties	Oil	Protein (N × 6.25)	Total oil and protein
Peredovik	60.9	20.6	81.5
VNIIMK 8931	61.8	18.9	80.7
Luch	60.9	19.6	80.5
Smena	60.4	20.1	80.5
Armavirski 3497	61.7	19.8	81.5
Maiak	63.2	18.8	82.0
VNIIMK 6540	62.6	19.2	81.8
VNIIMK 1646	63.2	18.1	81.3
VNIIMK 8883	61.2	21.2	82.4
Armaviretz	60.2	22.3	82.5
Saliut	61.7	20.0	81.7
Enisey	58.1	22.1	80.2

Together with the growth of oil content in the seeds up to the existent limit, the ratio between oleic and biologically active linoleic acid also changed. As a final result it was found that the oil of sunflower high oil varieties obtained at VNIIMK (V. S. Pustovoit) contains twice more linoleic acid than oleic acid (an average of 60 and 30% respectively) (table 3). In low oil varieties cultivated under the same conditions as high oil varieties the content of each of these acids averages 45%. In high oil varieties, a tendency towards the increase of all saturated fatty acids may be noticed.

In oil composition of sunflower varieties with high oil content, except the four basic fatty acids: palmitic, stearic, oleic and linoleic, there is also as a rule the palmitoleic acid (from traces to 1%) and sometimes the linolenic acid (from traces to 2%). The arahidic, behenic, lignoceric and other acids are found only in insignificant amounts.

G. V. Pustovoit (1968) showed that the interspecific hybrids, obtained in order to develop immune sunflower varieties, have a great range of variation in oleic and linoleic acid content but as concerns their

Table 3

Fatty acid composition of the oil of cultivated sunflower varieties (average for 1969—1971, Krasnodar

Sunflower varieties	Oil % in totally dry achene	Fatty acid content in % of the total					
		Palmitic $C_{16}:0$	Palmitoleic $C_{16}:1$	Stearic $C_{18}:0$	Oleic $C_{18}:1$	Linoleic $C_{18}:2$	Linolenic $C_{18}:3$
Peredovik .	50.8	5.7	0 3	3 8	33.6	56.6	traces
Luch	50.4	5.8	0.2	4.0	33.5	56.5	traces
Armavirski 3497	50.7	5.9	0.3	4.0	35.0	54.7	0.1
VNIIMK 6540	52.7	6.2	0.1	5.1	28.0	60.6	traces
Sputnik	53.1	5.1	0.2	4.2	36.4	54.0	0.1
Smena	50.3	5.9	0.2	3.7	34.7	55.5	0.1
Saliut	47.4	6.1	0.3	4.1	34.8	54.8	0.1
VNIIMK 8883	48.4	5.7	0.1	3.8	35.6	54.8	traces
VNIIMK 8931	50.4	5.8	0.3	4.0	34.5	55.4	traces

*) Average for 1969, 1971 and 1972

fatty acid composition, they are, in most of cases, closer to sunflower varieties than to the wild parent (table 4).

Table 4

Fatty acid composition of the oil of interspecific F_{11} hybrids (H. tuberosus x H. annuus — VNIIMK 8931 variety) and of their initial forms

Entry number	Fatty acids, % of the total						
	Palmitic $C_{16}:0$	Palmitoleic $C_{16}:1$	Stearic $C_{18}:0$	Oleic $C_{18}:1$	Linoleic $C_{18}:2$	Linolenic $C_{18}:3$	Arahidic $C_{20}:0$
175	6.1	0.6	3.8	38.1	46.8	1.6	1.7
822	7.5	1.0	4.0	30.2	43.5	10.6	1.4
765	6.4	0.1	2.8	28.3	62.2	0	0
772	7.8	0.3	2.6	25.2	64.2	0	0
694	5.2	0.4	4.6	46.2	43.5	0	
746	6.0	0.3	5.1	46.3	42.3	0	0
VNIIMK 8931	6 6	traces	3.7	35.4	54.4	0	0
H. tuberosus	5.3	traces	2.9	12.9	78.9	0	0

The result of investigations carried out during the last years showed that the external factors, the cultural practices and most particularly the soil climatic conditions, strongly affect the fatty acid composition of the oil. The fatty acid composition of sunflower oil obviously varies according to the meteorological conditions of the cropping year.

More substantial differences concerning fatty acid composition are observed when comparing the various geographic zones of the Soviet Union.

The oil acid number varies also evidently according to plant cropping conditions. But there is no substantial difference concerning oil acid number between the actual varieties if they are cultivated under the same conditions. The acid number is usually lower than the unit, however, under unafavourable conditions of the year (high moisture before or during harvesting), this index increases evidently up to two or more units. The specific causes changing the oil acid number of sunflower seeds are presently under study.

The nutritive seed and oil value and oil resistance to oxidation depends not only on the fatty acid composition but also on the existence of the natural oxidation inhibitors and of the prooxidants, which form the so-called oil accompanying substances.

We studied the main oil accompanying substances : phosphatides, sterols, tocopherols, pigments (table 5). The concentration of these substances in oil depends both on the extraction method and on their quantitative content in seeds.

Table 5

Oil content and its accompanying substances in sunflower kernels (% dry matter). Krasnodar, 1970

Variety	Oil	Tocopherols (mg % in oil	Carotenoids (mg %)	Sterols	Phospholipids	Phospholipid forms (% of the total)			
						Lecithins	Cephalins	Inositol-phosphatides	Phosphatide acids
VNIIMK 8931	62.2	69.8	0.16	0.30	0.82	55.4	18.2	24.0	2.2
Peredovik	63.0	67.2	0.13	0.28	0.75	64.2	19.5	15.2	1.2
Armavirski 3497	63.4	68.4	0.11	0.30	0.86	58.8	19.6	20.6	1.1
Saliut	61.8	62.8	0.15	0.26	0.72	56.1	17.0	22.4	4.5
Enisey	58.8	60.0	0.12	0.23	0.74	61.0	13.1	21.4	4.4

In sunflower seeds the phosphatides and carotenoids are located mainly in the gelly part of the seed, while the sterols and tocopherols in the oily part.

Carotenoid content in the seeds ranges between quite large limits from varietal stand point, but their variation does not exihibit any regularity either in dependence of oil content or of growth period. It was established that the carotenoids from sunflower seeds contain xantophyll and carotene. Chlorophyll is absent from the mature seeds. Sterol and phospholipid content varies much less in dependence of variety. Our experiments concerning the qualitative composition of sterols revealed that they mainly represents β-sitosterols followed by stigmasterols and kamlesterols (in nearly equal amounts), the cholesterol existing only in small amounts (4 to 8% of the total amount). The sterols are present in sunflower seeds primarily in unesterified form (approximately 80% of the total). Lecithins are the main component of phospholipids in sunflower seeds being the most desired in edible oils. The phosphatide acid content is very reduced — not more than 5% of the total phospholipids.

In sunflower seeds, the tocopherols are generally represented by α-tocopherols (80—90% of the total) while the rest is formed by β—, γ and δ-tocopherols. Tocopherol content in the oil of different sunflower varieties is relatively high — up to 70 mg/%, their content being highly affected by the cropping conditions.

The determination of the water-soluble vitamins in sunflower seeds showed the presence of nicotinic acid, thiamine, biotine and riboflavine (table 6). Concerning their content in nicotinic acid and biotine, sunflower seeds are similar to peanut seeds (127 and 140 mkg/g nicotinic acid 1.45 and 1.1 mkg/g biotine). We wish to emphasize that sunflower seeds contain more nicotinic acid than soybeans (21.4 mkg/g) and cotton (16 mkg/g). Acoording to their thiamine content, sunflower seeds (22.5 mkg/g) are close to soybeans (21.4 mkg/g) and exceed peanuts (10 mkg/g) and cotton seeds (16 mkg/g). Therefore, by their water-soluble vitamin content sunflower seeds are not inferior to other oil crops, and they are superior in what concerns nicotinic acid content. Sunflower seeds with a high oil content store more nicotinic acid as compared to low oil content varieties.

Table 6

Vitamin content in sunflower seeds (mkg/g dry substance)

Sunflower variety	Nicotinic acid	Thiamine	Riboflavine	Biotine
		With high oil content:		
Armavirski 3497	148.31	15.96	1.13	1.43
VNIIMK 8931	136.00	24.50	1.67	1.56
Peredovik	126.12	18.27	1.46	—
Smena	125.43	18.29	1.46	1.50
VNIIMK 6540	107.20	21.88	1.40	1.50
Luch	117.60	21.02	1.53	1.53
VNIIMK 8883	100.41	21.69	1.27	1.46
Saliut	144.70	27.60	1.39	1.72
Armaviretz	—	21.88	1.39	1.64
		With low oil content:		
Kruglik A—41	80.12	26.30	14.8	2.07
Saratovski rannii	79.70	29.00	15.5	1.91
Range limits	79.70—148.30	15.96—29.00	1.13—1.67	1.43—2.90

In relation to the actual problem of the vegetable oil improvement, it appeared important to study the causes and the limits of the fatty acid composition variability in sunflower seeds. It was established that the variability range in fatty acid composition of sunflower oil is first of all determined by its hereditary characteristics. However, the growing conditions, as mentioned before, affect to a great extent the oil quality. In sunflower oil the ratio between linoleic and oleic acid content changes quite obviously.

Sunflower with high linoleic acid content (62—68%) and with low (24—26%) and relatively high oleic acid content (42—48%) were identified.

G. V. Pustovoit obtained a wide variation using the interspecific hybridization method which presents a great prospect in breeding for oil content and quality. In the interspecific hybrids, the oleic acid content in oil ranges from 42 to 70%. There is a strong correlation between oleic and linoleic acids (from r = —0.842 to —0.923) and it varies in dependence of the growing conditions while the correlations oil content-oleic acid and oil content-linoleic acid, are reduced. Therefore breeding for oil quality can go independently of breeding for high oil content.

When evaluating the varieties of any oil crop it is necesary to take into account the yield and the quality not only of the oil but of the protein too. The sum of these two substances with high caloric, nutritive and feeding value represents 70% of the sunflower achene weight.

With respect to its oil and protein production per unit area sunflower is the most important oil crop. The oil meal obtained from defatted sunflower seeds contains 60% protein. But the protein amount in the meal is not a sufficient criterium of its nutritive value as the latter depends on the essential amino acid content.

All sunflower high oil varieties are characterized by a substantial protein content, well balanced concerning the essential amino-acid composition. Essential changes occurred in the protein complex of sunflower seeds as a consequence of breeding for high oil content. In seeds of

Table 7

Amino-acid composition in protein of sunflower kernels (in g per 100 g protein) — Krasnodar, 1971

Variety / amino-acids	Peredovik	VNIIMK 8931	Luch	VNIIMK 6540	Smena	VNIIMK 8883	Saliut	Enisey
Lysine	3.5	3.3	2.9	3.1	2.7	3.1	3.5	3.3
Histidine	2.5	2.3	1.9	2.5	1.9	2.3	2.7	2.1
Arginine	7.8	7.8	7.6	7.2	7.6	7.4	9.1	8.0
Aspartic acid	8.0	8.0	8.0	7.7	7.3	6.9	7.6	5.5
Threonine	2.7	2.5	2.7	2.6	2.6	1.9	2.7	2.1
Serine	3.3	3.1	2.8	2.9	3.1	2.4	3.2	2.5
Glutamic acid	20.9	19.3	17.8	18.2	17.5	16.3	19.9	14.6
Glycine	4.7	4.5	4.1	4.2	4.2	3.9	4.3	3.6
Alanine	2.9	2.9	2.9	2.8	2.9	3.0	3.6	2.7
Cysteine	2.3	1.8	2.6	1.9	1.9	2.3	2.4	1.7
Valine	4.1	3.8	4.0	3.6	3.4	4.1	4.1	4.0
Methionine	2.5	2.0	2.5	2.2	2.0	2.4	2.5	2.3
Isoleucine	2.8	2.5	2.8	2.1	2.2	2.6	2.2	2.4
Leucine	5.5	5.1	5.3	5.6	5.6	5.0	6.4	4.5
Tyrosine	2.0	2.0	2.6	2.2	2.2	2.1	2.9	2.0
Phenylalanine	3.6	3.6	3.6	3.6	3.5	3.3	4.1	3.0
Tryptophan	2.0	2.2	2.0	2.0	1.9	2.0	2.2	1.9

high oil sunflower varieties the amount of water-soluble proteins by far exceeds that of proteins soluble in salts, while in low oil sunflower varieties the main protein fraction is represented by salt-soluble proteins.

The proteins of the high oil variety seeds are characterized by a relatively high content of all essential amino-acids, including lysine, tryptophan and methionine (table 7), whose deficit is acutely felt in the protein balance of many countries. During breeding for high oil content, the content of such amino-acids as lysine, glutamic acid and glycine, increased.

At present the V. S. Pustovoit All-Union Scientific Research Institute for Oil Crops widely develops the research programme for creating sunflower varieties with a certain fatty acid composition of the oil, and also makes investigations concerning the posibility of obtaining varieties with a high content of the essential amono-acids, vitamins and other physiologically active substances.