VARIABILITY OF LINOLEIC ACID CONTENT IN SUNFLOWER OIL, DEPENDING ON GENOTYPE AND ENVIRONMENT

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INTRODUCTION

The last ten-fifteen year outlook calls for a continuous sunflower development all over the world, for widely different purposes. This imposes, along with other research, the progress of oil quality study. Oil quality is generally defined by its fatty acid composition, and particularly by the linoleic acid proportion.

At present, linoleic acid is unanimously recognised as an essential fatty acid for the human organism and precursor of the PGE_1 and PGE_2 prostaglandines, which have a leading part in prevention and cessation of the aterogenesis process (Juillet, 1972 ; Boldingh, 1975).

In temperate zones, sunflower oil has been considered of the first price among the other vegetable oils, especially due to its high linoleic acid content (over 60%). However unsaturated fatty acid composition of sunflower oil proved to be greatly influenced by the environmental conditions, particularly by temperature and humidity (Campos, 1972 ; McWilliams et al., 1976 ; Vereschiagyn, 1976). Other results established that the genotype effect on oil composition is much exceeded by the environment effect (Putt et al., 1969 ; Schuster et al., 1972 ; Filipescu, 1975 ; Dompert et al., 1975 ; Ermakov and Iarosch 1976 ; Marquard et al., 1977). However some genotypes have a more constant high linoleic acid content and they could be of interest for warm and arid areas, where conditions are less favourable for linoleic acid accumulation.

One of the research topics of the European Research Network on Sunflower, sponsored by F.A.O., is centred upon the variability of fatty acids and tocopherols in sunflower oil. This investigation was started in 1976 using the seed samples taken from the international trials with sunflower cultivars organized by the Network in different European countries.

This paper represents a preliminary study based on 1976 experiments, being intended to characterize the fatty acid composition of different sunflower genotypes and its variability due to the environmental changes.

MATERIALS AND METHODS

Sunflower cultivars and locations are presented in Table 1.

Oil was prepared by extraction from dehulled kernels with petroleum ether, followed by filtration through Na SO_4 sicc. and evaporation of the solvent at 40°C under low pressure.

Fatty acid composition was determined by gas-liquid chromotography of methyl esters, prepared in the presence of H Cl O_4 (Mavrikos and Eliopoulos, 1973). A Carlo Erba Mod. 2304 instrument was used, equipped with flamme ionization detector, 2.1 × 5.0 mm stainless steel column packed with 15% DEGS on Chromosorb W-AW 100—120 mesh. and carrier gas nitrogen. The injector, column and detector temperatures were 225, 190 and 225°C respectively. The percentage of each component was calculated using the ratio of each area to the sum of the areas under all of the component peaks. Peak areas were determined by multiplying the height by width at half height. Iodine value was calculated from the unsaturated fatty acid composition of the oil samples.

Analysis of variance and regression coefficients (b_x, y) were calculated by standard methods (Eberhart and Russel, 1966).

Table 1

Sunflower hybrids and varieties studied in F.A.O. co-operative trials in 1976 [1]

Trial No. 1 Half-late hybrids and varieties	Trial No. 2 Early and half-early hybrids and varieties
Countries and locations	
France (Montpellier) ; Hungary (Szeged) ; Israel (Bet Dagan) ; Italy (Pisa) ; Romania (Fundulea) ; Spain (Córdoba).	France (Montpellier) ; Hungary (Iregszemcse) ; Israel (Bet Dagan) ; Italy (Pisa) ; Poland (Poznań) ; Romania (Fundulea) ; Spain (Córdoba) ; Sweden (Uppsala).

Exp. no.	Cultivar	Genotype *	Origin	Exp. no.	Cultivar	Genotype *	Origin
1	Peredovik	OPV	U.S.S.R.		Issanka	OPV	France
3	Helios 322	SH	Bulgaria		Wielkopolski	OPV	Poland
4	Yu NS-65	SH	Yugoslavia		Helios 14	SH	Bulgaria
5	H-223	SH	Spain		Yu NS-1	SH	Yugoslavia
6	H-465	SH	Spain		H-23	SH	Spain
7	H-489	SH	Spain		Fransol	SH	France
8	Airelle	SH	France		Romsun 18	SH	Romania
9	Relax	SH	France		Romsun 20	SH	Romania
10	Remil	SH	France		Romsun 301	SH	Romania
11	Romsun 52	SH	Romania				
12	Romsun 53	SH	Romania				
13	Romsun 59	SH	Romania				
14	Sorem 80	SH	Romania				
15	Sorem 82	SH	Romania				
16	Sorem HT-64	TH	Romania				

[1] Seed samples supplied by : G. Piquemal (France), E. Kurnik and J. Frank (Hungary) Y. Shchori (Israel), G. Vicentini (Italy), D. Dominguez Giménez (Spain), L. Rune (Sweden)

* OPV = open pollinated variety
SH = single hybrid
TH = three-way hybrid

RESULTS AND DISCUSSION

1. LINOLEIC ACID CONTENT AND IODINE VALUE

The analysis of variance (Table 2) clearly shows that the environmental influences have contributed much more than cultivars to the variability of linoleic acid content and iodine value, both in Trial No. 1 and Trial No. 2.

Table 3 presents the linoleic acid content in the oil of half-late cultivars tested in six locations. The differences between genotypes are significant in the same locality (6—13% linoleic acid), but they are considerably surpassed by the environmental factors (13—27% linoleic acid). The genotype differences are smaller in areas with favourable climatic conditions for linoleic acid accumulation and larger in less favourable areas, for instance in Israel. The highest mean values of the linoleic acid were obtained with Romsun 53, Sorem 80 and Sorem 82 (65.6%, 63.8% and 63.7%), and the lowest with Remil (57.5%).

The lower F values of the interaction cultivar × location indicate that, in general, the

Table 2

Analysis of variance for linoleic acid content and iodine value of sunflower cultivars experimented in F.A.O. international trials in 1976

Trial No. 1 Source of variation	df	F	Trial No. 2 Source of variation	df	F
Linoleic acid content					
Cultivar (C)	14	217.2**	Cultivar (C)	8	43.6**
Locality (L)	5	6449.3**	Locality (L)	7	3736.1**
C × L	70	55.4**	C × L	56	23.7**
Error	168		Error	128	
Iodine value					
Cultivar (C)	14	25.8**	Cultivar (C)	8	26.0**
Locality (L)	5	828.0**	Locality (L)	7	1900.2**
C × L	70	5.0**	C × L	56	10.9**
Error	168		Error	128	

** significant at probability 0.01

Table 3

Linoleic acid content (%) in sunflower oil from half-late cultivars (mean of three replications, 1976)

Exp. No.	Cultivar	Hungary	Romania	France	Italy	Spain	Israel	Mean	$b_{x,y}$	s^2_b
1	Peredovik	71.1	71.8	62.5	60.7	60.7	51.7	63.1	0.96	9.4
3	Helios 322	68.6	67.2	59.3	57.3	57.3	45.8	59.2	0.87	11.3
4	Yu NS-65	68.6	68.3	60.8	56.3	58.3	55.0	61.2	1.16	5.8
5	H-223	69.9	70.6	64.1	60.8	58.8	54.2	63.1	1.12	6.9
6	H-465	70.3	70.9	61.9	59.7	56.7	50.7	61.7	0.92	10.3
7	H-489	70.2	69.9	63.1	60.2	57.5	53.3	62.4	1.06	7.6
8	Airelle	70.3	68.5	61.3	55.9	58.5	48.3	60.5	0.87	11.2
9	Relax	70.2	69.3	63.8	63.2	57.5	51.0	62.5	0.97	8.8
10	Remil	66.0	64.7	60.7	53.3	57.7	42.7	57.5	0.80	12.4
11	Romsun 52	69.2	71.3	61.6	60.9	53.6	44.7	60.2	0.75	16.1
12	Romsun 53	70.4	72.9	66.3	61.6	62.6	59.8	65.6	1.34	4.5
13	Romsun 59	71.7	72.8	64.8	61.4	56.5	51.4	63.1	0.85	11.8
14	Sorem 80	69.5	71.2	64.1	61.6	60.3	55.7	63.8	1.15	6.1
15	Sorem 82	71.7	73.8	67.5	61.9	60.8	46.6	63.7	0.72	16.2
16	Sorem HT-64	68.1	69.0	64.4	56.6	60.8	55.5	62.4	1.19	5.5
	Mean	69.7	70.1	63.1	59.4	58.5	51.1	62.0		
	LSD 5%	0.8	0.7	1.1	1.6	0.1	1.2	0.8		

genotypes respond in the same manner to the alteration of the environmental conditions. This supposition was confirmed by the analysis of regression from the mean of each cultivar in a given location (Eberhart and Russel, 1966 ; Fick and Zimmer, 1976). The regression coefficients for 11 genotypes varied from 0.85 to 1.19 (Table 3). Lower values (0.72—0.80) were obtained with Remil, Romsun 52 and Sorem 82, which indicates that these hybrids give a poor response in areas with less favourable conditions for linoleic acid accumulation, as for insance in Spain and Israel. The highest regression coefficient was noticed to Romsun 53, which has given the highest mean of linoleic acid content even under less favourable environmental conditions.

The variation curve of iodine value, which is in a close and positive correlation with linoleic acid content, reveals the amplitude of differences among genotypes and locations (Figure 1). In comparison with the general mean of the experiment (iodine velue 131), the iodine values are superior with 8—9 units in Romania and Hungary, they are situated near the general mean in France, Italy and Spain, and below this mean, with 17 units, in Israel.

The results presented in table 4 show that the differences among early and half-early cultivars are significant but much more reduced than those existing between half-late cultivars. It is evident that climatic conditions of Sweden are extremely favourable for linoleic acid accumulation, blurring even the differences among genotypes, all cultivars reaching linoleic acid values between 76 and 78%. On the contrary, in Israel such differences are very

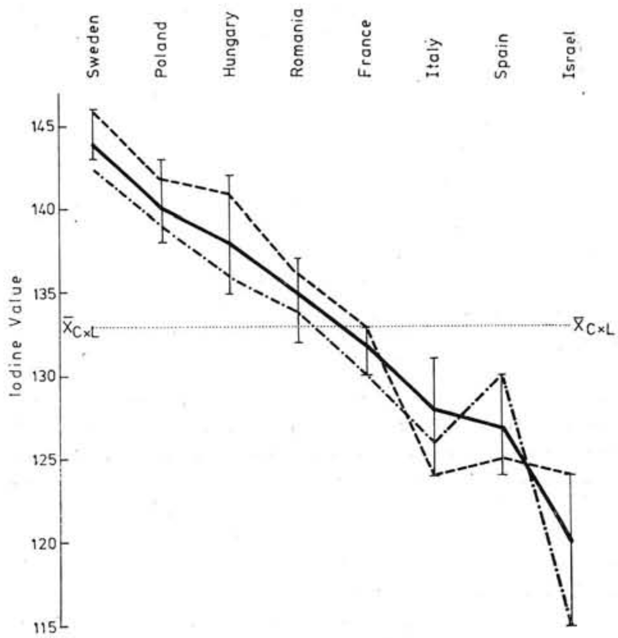

Fig. 1 — Variability of iodine value of 15 half-late sunflower cultivars grown in six localities. $X_{C\times L}$, general mean of trial; — locality mean ; — Remil ; — Romsun 53 ; LSD 5% = 1.5

well expressed, varying from 43.6% (Romsun 20) to 53.7% (Romsun 301). In almost all areas excepting Italy and Spain, Romsun 20 and Romsun 301 achieve the lowest and respectively the highest linoleic acid content, suggesting that linoleic acid accumulation is controlled genetically and is not only the results of an interaction between the vegetative period and temperature of a given area. Similar results were obtained by Putt and Craig (1969),

Table 4

Linoleic acid content (%) in sunflower oil from early and half-early cultivars (mean of three replications, 1976)

Exp. No.	Cultivar	Sweden	Poland	Hungary	Romania	France	Italy	Spain	Israel	Mean	$b_{x,y}$	s_b^2
1	Issanka	76.8	72.0	70.4	61.1	63.0	57.7	56.9	45.6	62.9	0.89	12.4
2	Wielkopolski	75.6	71.5	69.4	65.0	64.2	58.4	60.3	47.5	64.0	1.02	9.6
3	Helios	76.3	75.0	73.9	67.6	62.6	59.5	60.0	51.7	65.8	1.01	9.8
4	Yu NS-1	76.0	73.3	71.6	68.5	63.2	62.1	55.8	46.0	64.6	0.88	12.5
5	H-23	75.7	73.9	72.2	68.1	63.8	62.0	58.7	47.8	65.3	0.96	10.7
6	Fransol	75.5	72.1	69.8	66.7	60.6	58.4	59.0	52.9	64.4	1.18	7.2
7	Romsun 18	76.4	71.0	68.3	62.6	60.9	58.7	57.9	50.4	63.3	1.08	8.6
8	Romsun 20	75.5	71.6	67.4	65.3	60.6	56.3	62.2	43.6	62.8	0.88	12.2
9	Romsun 301	77.9	75.4	73.1	67.0	64.3	54.6	56.2	53.7	65.3	0.89	11.7
	Mean	76.2	72.9	70.7	65.8	62.6	58.6	58.5	48.8	64.3		
	LSD 5%	0.4	0.5	0.3	1.2	0.9	2.0	1.8	2.2	1.0		

Kinman (1972), Filipescu et al. (1977), although Robertson et al. (1971) consider the environmental conditions as the determinant factors for sunflower oil composition.

The highest mean values, over 65%, were obtained with Helios 14, H-23, Romsun 18 and Romsun 301. The environment seems to exert a greater influence on early and half-early cultivars than on half-late ones. In table 4, the differences in genotype performances vary from 22.6% (Fransol) to 31.9% (Romsun 20), while in table 3 such differences are situated between 13 and 27%. The low value of the interaction cultivar × location as well as the values of the regression coefficients close to the unit (0.88—1.18) show that the genotypes respond in a similar manner to the environmental changes, their order remaining almost the same in each location.

The variation curve of the iodine value presented in figure 2 has almost the same aspect as in figure 1. It is evident that a decrease of the iodine value takes place along with the decrease of latitude. Sweden, Poland and Hungary are always placed over the general mean, Romania and France are near this mean and Italy, Spain and particularly Israel are situated below the general mean.

It is known that the accumulation of linoleic acid in sunflower seeds is influenced by daily temperatures occuring during blooming-maturity period (Kinman, 1972). Moreover, it seems that its synthesis takes place mainly during the night (Popov, 1973), being in close correlation with the minimum night temperature (McWilliams et al., 1976). It is not yet clear wheter temperature acts directly on the activity of enzymes involved in desaturation reaction or indirectly, by regulating the partial pressure of the molecular oxygen in cell sap (Dompert and Beringer, 1970). Such considerations could certainly explain the differences concerning linoleic acid acumulation in various sunflower growing areas.

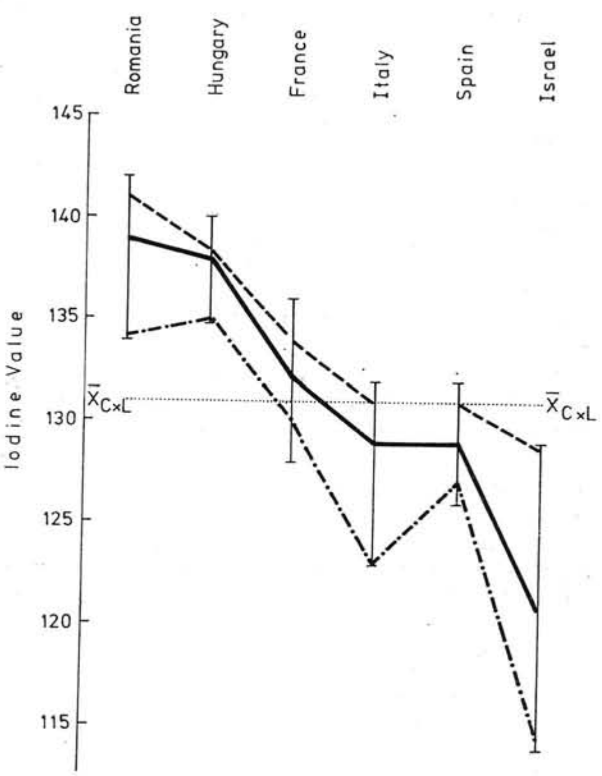

Fig. 2 — Variability of iodine value of 9 early and half-early sunflower cultivars krown in 8 localities. $X_{C \times L}$ general mean of trial ; — locality mean ; — Romsun 20 ; — Romsun 301 ; LSD 5% = 1.1.

2. LINOLEIC/OLEIC RATIO

Data presented in table 5 and table 6 point out that linoleic/oleic ratio decreases substantially in accordance with latitudine, from 4 (Hungary, Romania), to 1 (Israel) in the case of half-late cultivars and from 6 (Sweden) to 1 (Israel) in early and half-early sunflowers.

Table 5

Linoleic/oleic ratio in sunflower oil from half-late cultivars (mean of three replications, 1976)

Exp. No.	Cultivar	Hungary	Romania	France	Italy	Spain	Israel	Mean
1	Peredovik	3.8	3.9	2.3	2.1	2.2	1.3	2.6
3	Helios 322	3.3	3.0	2.0	1.8	1.9	1.1	2.2
4	Yu NS-65	3.3	3.2	2.2	1.7	2.0	1.6	2.3
5	H-223	3.6	3.6	2.5	2.1	2.0	1.5	2.5
6	H-465	3.6	3.6	2.2	2.0	1.7	1.3	2.4
7	H-489	3.6	3.4	2.4	2.0	1.9	1.5	2.5
8	Airelle	3.6	3.3	2.2	1.6	2.0	1.2	2.3
9	Relax	3.6	3.3	2.5	2.4	1.8	1.3	2.5
10	Remil	2.8	2.5	2.1	1.5	1.9	0.9	1.9
11	Romsun 52	3.3	3.7	2.2	2.1	1.5	1.0	2.3
12	Romsun 53	3.8	4.2	2.9	2.2	2.4	2.1	2.9
13	Romsun 59	4.0	4.0	2.6	2.2	1.7	1.3	2.6
14	Sorem 80	3.6	3.7	2.6	2.2	2.1	1.7	2.6
15	Sorem 82	4.0	4.4	3.0	2.2.	2.1	1.1	2.8
16	Sorem HT-64	3.2	3.2	2.6	1.7	2.2	1.7	2.4
	Mean	3.5	3.5	2.4	2.0	2.0	1.4	2.5

Table 6

Linoleic/oleic ratio in sunflower oil from early and half-early cultivars (mean of three replications, 1976)

Exp. No.	Cultivar	Sweden	Poland	Hungary	Romania	France	Italy	Spain	Israel	Mean
1	Issanka	5.9	4.1	3.8	2.0	2.3	1.8	1.8	1.0	2.8
2	Wielkopolski	5.2	4.1	3.6	2.5	2.6	1.9	2.2	1.1	2.9
3	Helios 14	5.5	5.1	4.7	3.0	2.3	2.0	2.1	1.4	3.3
4	Yu NS-1	5.0	4.8	4.1	3.2	2.4	2.3	1.7	1.0	3.1
5	H-23	5.4	4.8	4.2	3.0	2.5	2.3	2.0	1.1	3.2
6	Fransol	5.3	4.4	3.6	2.9	2.1	1.9	2.0	1.4	2.9
7	Romsun 18	5.6	4.0	3.3	2.2	2.1	1.9	1.9	1.3	2.8
8	Romsun 20	5.3	4.2	3.2	2.6	2.1	1.7	2.4	0.9	2.8
9	Romsun 301	6.1	5.5	4.5	3.0	2.6	1.6	1.8	1.5	3.3
	Mean	5.5	4.6	3.9	2.7	2.3	1.9	2.0	1.2	3.0

Such variations have also been communicated by other investigators. Thus, a linoleic/oleic ratio of 3.3 and 1.0 was obtained by Schuster et al. (1972) in West Germany and Mozambique; Ermakov and Iarosch (1976) reported a ratio of 3.5 in Novgorod and Omsk and 1.3 in Tashkent and Kerson; and Marquard et al. (1977) found ratios of 5.3 in Canada, 4.7 in West Germany, 2.8 in Yugoslavia, 1.5 in Iran and 1.0 in Turkey.

It can be concluded that, while in northern areas (Sweden, Poland), sunflower oil is of "high-linoleic" type (75% linoleic and 15% oleic), in southern warm and dry areas (Israel), it is of "intermediate" type (45% linoleic and 45% oleic), similar to sesame oil, with a lower biological value but with a higher temperature oxidative stability.

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VARIABILITÉ DE LA TENEUR EN ACIDE LINOLÉIQUE DANS L'HUILE DE TOURNESOL, EN FONCTION DE GÉNOTYPE ET MILIEU

Résumé

Un nombre de 24 cultivars de tournesol, différents du point de vue de la période végétative, expérimentés en essais comparés en huit pays situés à différentes latitudes, ont été analysés sous l'aspect de la teneur en acides gras non saturés, notamment pour la proportion linoléique/oléique. On a trouvé des différences significatives parmi les genotypes, dans la même localité, mais elles sont considérablement dépassées par les changements causés par les facteurs de milieu. Les différences génotypiques sont plus faible dans les régions favorables pour l'accumulation de l'acide linoléique et plus larges dans les régions moins favorables. Le milieu peut exercer une influence plus forte sur les cultivars précoces et semi-précoces que sur les cultivars semi-tardifs.

La proportion linoléique/oléique décroît significativement en fonction de latitude, de 4 (Hongrie, Roumanie) à 1 (Israël) dans le cas des hybrides précoces et semi-précoces. On peut conclure que, tandis que dans les régions nordiques (Suède, Pologne), l'huile de tournesol est de type „haut linoléique" (75% acide linoléique et 15% acide oléique), dans les régions méridionales (Israël) il est de type „intermédiaire" (45% acide linoléique et 45% acide oléique).

VARIABILIDAD DEL CONTENIDO EN ÁCIDO LINÓLICO DEL ACEITE DE GIRASOL SEGÚN EL GENOTIPO Y EL AMBIENTE

Resúmen

Un set de 24 variedades e híbridos de girasol, que difieren según el período de vegetatión, testados en cultivos comparativos en ocho países situados en varias latitudes, han sido analizados desde el punto de vista del contenido en acídos grasos nosaturados, con interés especial a la relación entre los acídos linólico y oléico. Se han encontrado diferencias significativas entre genotipos en la misma localidad, pero éstas están considerablemente sobrepasadas por los cambios determinados por los factores ambientales. Las diferencias genotípicas resultan menores en las zonas con condiciones climatícas favorables a la acumulación del acído linólico y mayores en las zonas menos favorables. El ambiente puede ejercer una influencia mayor sobre las cultivares precóces y semi-precóces que sobre las semi-tardías.

La relacion linólico/oléico va disminuyendo notablemente según la localidad, desde 4 (Hungría, Rumanía) a 1 (Israel) en el caso de los híbridos precóces y semi-precóces. Se puede concluír que, mientras en las regiones nórdicas (Suecia, Polonia) el aceite del girasol es de tipo linólico (75% ácido linólico y 15% ácido oléico), en las regiones súdicas, cálidas y secas (Israel) es de tipo intermedio (45% ácido linólico y 45% ácido oléico).