Relationship between Fatty Acid Profile and Vitamin E Content in Maize Hybrids (*Zea mays* L.)

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The balance between the vitamin E (tocochromanols) and polyunsaturated fatty acid (PUFA) contents mainly determines the susceptibility to lipid peroxidation and the storage stability of corn oil. In 1997, field experiments were conducted at two different locations to evaluate a collection of 30 corn hybrids for fatty acid profiles and tocochromanol contents. Hybrids differed significantly ($p < 0.01$) for major fatty acids, as well as for tocochromanol contents and composition. The major fatty acids were palmitic, oleic, and linoleic acids, whose contents were in the ranges 9.2−12.1%, 19.5−30.5%, and 53.0−65.3%, respectively. The tocopherol contents ranged as follows: α-tocopherol, 67−276 mg (kg of oil)$^{-1}$; β-tocopherol, 0−20 mg (kg of oil)$^{-1}$; γ-tocopherol, 583−1048 mg (kg of oil)$^{-1}$; δ-tocopherol, 12−71 mg (kg of oil)$^{-1}$; total tocopherol, 767−1344 mg (kg of oil)$^{-1}$. γ-Tocopherol was the predominant derivative among all tocopherols. The tocotrienol contents were in the ranges 46−89, 53−164, and 99−230 mg (kg of oil)$^{-1}$ for α-, γ-, and total tocotrienol contents, respectively. The tocotrienol profile was not characterized by the predominance of any tocotrienol homologue. α-Tocopherol was positively correlated with PUFA ($r = 0.41$**) and with the vitamin E equivalent (vit E equiv) ($r = 0.84$**), and it was not correlated with γ-tocopherol. γ-Tocopherol was highly correlated with total tocopherol and tocochromanol contents ($r = 0.93$** and $r = 0.90$**, respectively), indicating that the contribution of this vitamer to the total tocochromanol content is the most important among all tocochromanols. The high positive correlation found between the vit E/PUFA ratio and the vit E equiv, as well as the absence of correlation between this ratio and PUFA indicates that a higher vit E/PUFA ratio can be easier achieved be increasing the vitamin E content than by modifying fatty acid profile in corn oil.

Keywords: *Fatty acid composition; oil quality; PUFA; tocopherol; tocotrienol; vitamin E; Zea mays*

INTRODUCTION

In addition to the fatty acid composition, the vitamin E (tocochromanol) content and the balance between vitamin E and polyunsaturated fatty acid (PUFA) levels are quality traits to be considered in vegetable oils, as they possess great significance as essential dietary components and also strongly affect storage stability. Vitamin E is the most powerful fat-soluble antioxidant, being indispensable for the protection of PUFA against oxidative deterioration in both plants and animals. Animal experiments have shown that an increase in the degree of dietary fatty acid unsaturation increases the peroxidability of lipids and reduces the time required to develop symptoms of vitamin E deficiency (*1*). In general, an intake of 0.6 mg of α-tocopherol equivalent (1 IU) per gram of PUFA is seen as adequate for human adults (*2*), whereas in growing swine, 2.5 IU of vitamin E/g of PUFA was enough to prevent the development of vitamin E and selenium deficiency syndrome (*3*).

The term "tocochromanol" refers to two kinds of compounds: tocopherols and tocotrienols, both showing vitamin E activity. Whereas tocopherols are mainly present in seeds of common oil crops (oilseed rape, sunflower, etc.) and in green parts of higher plants, tocotrienols are mostly found in cereal kernels (wheat, corn, etc.) and in certain tropical fruits (oil palm, coconut, etc.). All tocochromanols have quite similar chemical structures, consisting of a chroman-6-ol head and a carbon side chain of three isoprenoid units. Tocopherols and tocotrienols can be distinguished from each other by the degree of saturation of this side chain, which is saturated in the tocopherols and unsaturated in the tocotrienols. They exist as a family of four derivatives each (α, β, γ, and δ), which differ in the number and position of methyl substitutions in the chromanol ring. Tocopherols are well recognized as antioxidants in vegetable oils, and their presence increases the stability of lipids against autoxidation (*4*). Tocotrienols exhibit biological and antioxidative properties as well, but they also appear to have unique functional properties. Tocotrienols have been shown to lower a number of lipid-related risk factors related to cardiovascular diseases including cholesterol, LDL cholesterol, apolipoprotein B, and lipoprotein a (*5*).

Although corn (*Zea mays* L.) is principally cultivated for carbohydrate production, in the past several years, it has gained great significance as a source of vegetable oil for the food industry. Corn kernel oil is mainly used for salad and cooking oil and for the production of table

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Table 1. Mean Squares of the Analysis of Variance for Fatty Acids[a] from the Kernel Oil of Maize Hybrids[b,c]

		mean squares							
source	df	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1
environment (E)	1	0.2817	0.0020	0.0199	1.7164	1.3067	0.1853	0.0358	0.0199
hybrid (H)	29	3.9264**	0.0006	0.1101**	40.0835**	56.9778**	0.3211**	0.0173*	0.0178
E × H	29	0.3963	0.0006	0.0247**	6.3005	6.0337	0.0524	0.0101	0.0120
error	119[d]	0.4759	0.0007	0.0127	5.8250	5.9043	0.099	0.0107	0.0179

[a] Percentage of total fatty acids. [b] Abbreviations: C16:0, palmitic acid; C16:1, palmitoleic acid, C18:0; stearic acid, C18:1, oleic acid; C18:2, linoleic acid; C18:3, linolenic acid; C20:0, arachidic acid; C20:1, eicosenoic acid. [c] The symbols * and ** indicate significance at the 0.05 and 0.01 probability levels, respectively. [d] df reduced because of one missing value.

margarine. Its fatty acid composition comprises 40−68% of linoleic acid, 20−32% of oleic acid, and 8−14% saturated fatty acids, mainly palmitic acid (*6*). Corn oil contains high amounts of tocochromanols, mainly α- and γ-tocopherol and α- and γ-tocotrienol. Grams et al. (*7*) reported tocopherol concentrations in kernels ranging from 14.7 μg/g of dry matter of α- and 38.6 μg/g of dry matter of γ-tocopherol in a short-season corn hybrid to 25.4 and 70.0 μg/g of dry matter of α- and γ-tocopherol, respectively, in a high-oil hybrid. Galliher et al. (*8*) reported a sizable genetic variability of tocopherol contents in corn embryos, with α-tocopherol ranging from 0.0 to 138.2 μg/g of embryo and γ-tocopherol from 0.0 to 409.3 μg/g of embryo. By studying different vegetable oils including corn oil, Kamal-Eldin and Andersson (*9*) found a positive correlation between PUFA and tocopherols. That investigation provided general information about the relationship between the two lipid components but without inferences at the species level, as the data were statistically analyzed collectively. The present investigation was undertaken to elucidate whether a relationship exists between fatty acids, particularly PUFA, and tocochromanol contents, as well as to report the variation for these quality traits in the kernel oils of a collection of maize hybrids.

MATERIALS AND METHODS

Plant Material. In 1997, 30 maize hybrids (*Zea mays* L.) were evaluated in a field experiment at the German locations of Calhorn (black sand soil) and Katzenberg (sandy loam soil), situated in north and east Germany, respectively. The genetic material is a collection of the most widespread hybrids used in European countries, particularly in Germany. The hybrids were arranged in a randomized complete block with three plots as replications. Each plot consisted of four rows, 5 m long each, with a row spacing of 75 cm and a plant density of 90 000/ha. The two center rows were dedicated for harvest. Fertilization and weed control were applied according to standard commercial practices but avoiding sulfonyl urease herbicides. Each plot was harvested at commercial maturity by combine. Harvested grains of each plot were bulked, and samples were taken for analyses of grain compounds.

Reagents. Isooctane and methyl *tert*-butyl ether were of high-performance liquid chromatography (HPLC) grade (Merck, Darmstadt, Germany). Petroleum ether (40 °C) was of analytical grade (>98%) (Merck, Darmstadt, Germany). Methanol, $NaHSO_4$, and sodium methylate and were also of analytical grade (Fluka, Neu-Ulm, Germany).

Oil Extraction. Two grams of ground maize grains (particle size 0.25 mm) were placed into a 50-mL flask with 20 mL of petroleum ether and extracted for 20 h at room temperature. The flasks were shaken by hand five times during the 20-h extraction time. The organic solvent layer was filtered through a 0.45-μm lipophilic filter. The samples were extracted twice. The combined filtrates were evaporated under reduced pressure at room temperature, and the remaining oil was used for chemical analyses.

Determination of Fatty Acid Composition. The fatty acid composition of seed oils was determined by gas−liquid chromatography (GLC) of fatty acid methyl esters after Thies (*10*). About 20 μL of extracted oil were transmethylated for 20 min at 20 °C with 1 mL of a 0.5 M solution of sodium methylate in methanol. Then, 0.5 mL of isooctane and 0.2 mL of 5% (wt/v) of $NaHSO_4$ in water were added in that order. The samples were centrifuged, and 2.5 μL of the upper phase was injected into the gas chromatograph at a split ratio of 1:70. Analyses were performed on a Perkin-Elmer gas chromatograph model 8600 (Perkin-Elmer Corporation, Norwalk, CT) equipped with a fused silica capillary column FFAP, 25 m × 0.25 mm × 0.25 μm film thickness (Macherey & Nagel GmbH and Co KG, Düren, Germany). Separation was done isothermically, with oven, detector, and injector temperatures of 200, 250, and 250 °C, respectively. The carrier gas was hydrogen, at a pressure of 100 kPa. PUFA contents were expressed as the sum of the contents of linoleic and linolenic acids per kilogram of oil [g of PUFA (kg of oil)$^{-1}$].

Tocopherol and Tocotrienol Analysis. Tocopherols and tocotrienols were determined according to Thies (*11*) with slight modifications. About 20 mg of extracted oil was dissolved in 2 mL of isooctane and then centrifuged at 4600*g* for 5 min. Then, 5 μL of the upper layer was directly injected into the HPLC. The HPLC system consisted of a fluorescence detector (Ex at 295 nm and Em at 330 nm) and a C-18 diol column (250 × 3 mm, 5 μm particle size). A solvent mix of isooctane and methyl *tert*-butyl ether (94:6 v/v) was used as the eluent at a flow rate of 0.7 mL/min. Identification and quantification of tocopherols and tocotrienols were done using calibration curves of standards from Merck (Darmstadt, Germany). The total tocopherol and tocotrienol contents were expressed in mg (kg of oil)$^{-1}$. For calculating the vitamin E equivalent (1 IU = 0.6 mg of α-tocopherol) of corn oil, individual tocopherol and tocotrienol contents were converted by using correction factors according to their relative biological activities (*4*): α-tocopherol, 1.0; β-tocopherol, 0.5; γ-tocopherol, 0.25; δ-tocopherol, 0.01; α-tocotrienol, 0.3; and γ-tocotrienol, 0.02.

RESULTS AND DISCUSSION

Hybrids differed significantly ($p < 0.01$) for all fatty acids, except for palmitoleic and arachidic acids, which were minor components of corn oil (mean sum of both fatty acids for all hybrids <0.40%) (Table 1). Environment did not significantly affect the fatty acid composition. Hybrid−environment interactions were significant only for stearic acid. The results indicate that variation for fatty acid composition was principally due to genetic differences among the hybrids. Highly significant differences ($p < 0.01$) were detected among the hybrids for individual and total tocochromanol contents (Table 2). Environmental effects were not significant for the analyzed characters, except for α-tocopherol contents ($p < 0.01$). α-Tocopherol was higher in Calhorn [mean of all hybrids = 156 mg (kg of oil)$^{-1}$] than in Katzenberg [mean of all hybrids = 146 mg (kg of oil)$^{-1}$]. Interactions between environment and hybrids were not significant.

The major fatty acids were palmitic, oleic, and linoleic acids, which were present in the ranges 9.2−12.1%,

Table 2. Mean Squares of the Analysis of Variance for Total and Individual Tocopherol and Tocotrienol Contents[a] in Maize Hybrids[b,c]

		mean squares							
source	df	α-T	β-T	γ-T	δ-T	total-T	α-T3	γ-T3	total-T3
environment (E)	1	4310.41**	9.95	1562.29	199.95	8872.51	64.86	111.10	6.18
hybrid (H)	29	14703.89**	165.16**	80893.68**	1064.61**	113963.69**	861.46**	3168.89**	4127.53**
E × H	29	633.32	16.99	9159.63	55.96	10109.62	68.41	78.23	131.80
error	119[d]	473.99	22.38	6750.40	53.11	7817.05	52.27	150.94	284.73

[a] Contents measured in milligrams per kilogram of kernel oil. [b] Abbreviations: α-T, α-tocopherol; β-T, β-tocopherol; γ-T, γ-tocopherol; δ-T, δ-tocopherol; total-T, total tocopherol; α-T3, α-tocotrienol; γ-T3, γ-tocotrienol; total-T3, total tocotrienol. [c] The symbol ** indicates significance at the 0.01 probability level. [d] df reduced because of one missing value.

Table 3. Fatty Acid Composition of Kernel Oil in the 30 Studied Maize Hybrids, Averaged over Two Localities

	% of total fatty acids							
hybrid	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1
Achat	9.2	–	1.4	22.1	65.2	1.3	0.3	0.4
Afrika	10.9	–	1.4	25.8	59.6	1.7	0.4	0.4
Algans	10.2	–	1.4	26.0	60.0	1.6	0.3	0.4
Animus	10.7	–	1.4	27.0	58.5	1.6	0.3	0.3
Antares	10.9	trace	1.5	27.8	57.5	1.6	0.3	0.3
Arsenal	10.4	–	1.5	28.5	56.9	1.7	0.4	0.5
Atomic	10.2	–	1.4	25.7	60.4	1.6	0.3	0.3
Bahia	11.7	–	1.4	26.9	57.3	1.9	0.3	0.4
Banguy	11.1	–	1.5	28.1	56.9	1.8	0.3	0.4
Byzance	11.5	–	1.6	29.6	54.9	1.6	0.4	0.4
Damiler	11.6	–	1.5	30.4	53.0	2.1	0.4	0.5
Harpun	10.1	–	1.7	28.4	57.5	1.4	0.4	0.4
Helix	9.3	–	1.5	24.7	62.4	1.2	0.3	0.4
Jericho	10.4	–	1.5	25.0	60.8	1.4	0.3	0.4
Lenz	11.1	–	1.4	25.8	59.1	1.6	0.3	0.4
Major	11.4	–	1.3	19.5	65.3	1.7	0.4	0.3
Manatan	11.1	–	1.5	26.8	58.6	1.2	0.3	0.4
Marignan	12.1	–	1.7	30.5	53.3	1.4	0.4	0.4
Mondeo	9.6	trace	1.3	25.1	60.5	2.0	0.4	0.5
NX 1307	10.4	–	1.3	22.3	63.2	2.0	0.4	0.4
NX 5111	11.2	–	1.1	23.0	62.1	1.8	0.3	0.4
NX 6102	10.5	–	1.2	23.3	62.5	1.7	0.3	0.4
NX 6104	10.9	trace	1.4	26.2	58.9	1.6	0.4	0.3
NX 6107	10.8	–	1.3	23.5	62.1	1.6	0.3	0.4
Oldham	9.7	–	1.5	28.3	57.5	2.1	0.5	0.5
Santiago	9.4	–	1.4	23.3	63.6	1.6	0.3	0.3
Stallion	11.7	–	1.4	28.3	56.0	1.8	0.4	0.4
Symphony	9.7	–	1.3	26.8	59.7	1.7	0.3	0.4
Tuerkis	11.5	–	1.5	24.2	60.4	1.5	0.4	0.4
Unico	11.8	–	1.6	25.0	59.3	1.6	0.4	0.4

19.5−30.5%, and 53.0−65.3%, respectively (Table 3). Within the hybrids, Major was distinguished by the lowest concentration of oleic acid (19.5%) and the highest for linolenic acid (65.3%), whereas Damiler and Marignan showed the highest values for oleic acid (30.4 and 30.5%, respectively) and the lowest for linoleic acid (53.0 and 53.3%, respectively).

A wide range of variation was observed for tocochromanol contents (Table 4). Tocopherol contents ranged as follows: α-tocopherol, 67−276 mg (kg of oil)$^{-1}$; β-tocopherol, 0−20 mg (kg of oil)$^{-1}$; γ-tocopherol, 583−1048 mg (kg of oil)$^{-1}$; δ-tocopherol, 12−71 mg (kg of oil)$^{-1}$; total tocopherol, 767−1344 mg (kg of oil)$^{-1}$. Among all tocopherols, γ-tocopherol was the predominant derivative (mean of all hybrids = 69.5%) for all hybrids. The highest value for total tocopherol content was observed in the hybrid Achat [mean = 1344 mg (kg of oil)$^{-1}$], which also exhibited the highest total tocotrienol contents [mean = 230 mg (kg of oil)$^{-1}$]. Santiago showed the highest α-tocopherol content [mean = 276 mg (kg of oil)$^{-1}$], whereas Mondeo had the highest γ-tocopherol content [mean = 1048 mg (kg of oil)$^{-1}$]. The contribution of tocotrienols to total the tocochromanol contents was of lesser importance than that from tocopherols. Tocotrienol contents were in the ranges 46−89, 53−164, and 99−230 mg (kg of oil)$^{-1}$ for α-, γ-, and total tocotrienol contents, respectively. In contrast to the tocopherol composition in which γ-tocopherol was highly predominant for all hybrids, the tocotrienol profile exhibited no predominant tocotrienol homologue, as some hybrids existed with higher proportions of α-tocotrienol and others with higher proportions of γ-tocotrienol. Variations were also detected for vitamin E equivalent (vit E equiv), PUFA content, and the ratio of vitamin E equivalent to PUFA (vit E equiv/PUFA ratio) (data not shown). Forty percent of the hybrids displayed a vit E equiv/PUFA ratio below 0.6 mg of α-tocopherol equivalent/g of PUFA, which indicates that the oil that can be extracted from these genotypes is under human and animal vitamin E requirements. The hybrids exhibited significant variations for the studied quality traits, which were especially large for tocochromanol content and composition. Nevertheless, because we studied a relatively small collection of maize, it is possible that more extreme values for the reported traits could be found by screening other plant materials.

α-Tocopherol was significantly positively correlated with β-tocopherol, total tocopherol, α-tocotrienol, γ-tocotrienol, PUFA, and vit E equiv, with the latter correlation being very high ($r = 0.84$**) (Table 5). Kamal-Eldin and Andersson (*9*) found a positive significant correlation between α-tocopherol and linoleic acid, which is the main PUFA present in corn oil. Such a correlation suggests the existence of a possible link between α-tocopherol and linoleic acid, but biochemical studies are needed to confirm this hypothesis. The other tocochromanols showed a lower or no correlation with PUFA. Our results indicate that the vit E/PUFA ratio and the vitamin E value of corn oil can be more easily improved by increasing the α-tocopherol content than by modifying the contents of the other vitamers. α- and γ-tocopherol showed no correlation in this study. Galliher et al. (*8*) found a low significant negative correlation ($r = -0.14$**) between the two tocopherols in corn embryos of a collection of 100 genotypes selected at random from a synthetic corn population. Therefore, our results are in good agreement with those reported by Galliher et al., suggesting that there is probably no relationship between the two homologues in corn. Although the γ form has been described as a direct precursor in the synthesis of α-tocopherol (*12*), it must be indicated that the studies done to elucidate the biosynthetic pathway of tocopherols were carried out in chloroplasts and not in seeds. Moreover, Goffman and Becker (*13*), by studying the tocopherol content in seeds of a collection of *Brassica napus* L., also found no correlation between α- and γ-tocopherol contents. Murkovic et al. (*14*), by evaluating the variation of tocopherol levels in pumpkin seeds (*Cucurbita pepo* L.), found a low positive correla-

Table 4. Means for Individual and Total Tocopherol and Tocotrienol Contents[a] in the Kernel Oil of the 30 Studied Maize Hybrids, Averaged over Two Localities

	tocopherols					tocotrienols			
hybrid	α-T	β-T	γ-T	δ-T	total-T	α-T3	γ-T3	total-T3	total-T + T3[b]
Achat	220	17	1036	71	1344	65	164	230	1572
Afrika	175	10	745	26	955	70	62	132	1087
Algans	172	6	687	20	884	74	87	161	1046
Animus	183	8	652	14	857	79	85	164	1021
Antares	176	6	600	13	795	84	86	169	964
Arsenal	130	0	776	18	924	68	96	164	1088
Atomic	167	6	583	12	767	81	77	158	925
Bahia	83	0	672	17	772	63	76	139	911
Banguy	74	1	874	37	986	50	73	122	1108
Byzance	224	9	680	20	934	84	73	157	1090
Damiler	130	3	796	24	953	70	76	146	1099
Harpun	128	12	671	32	843	63	66	129	972
Helix	195	13	780	30	1018	65	72	137	1155
Jericho	118	4	673	26	821	56	133	188	1009
Lenz	100	0	907	44	1051	57	82	139	1190
Major	193	7	693	19	911	82	65	146	1058
Manatan	101	4	787	35	926	46	53	99	1026
Marignan	81	2	841	47	970	52	70	122	1093
Mondeo	173	9	1048	25	1255	86	94	181	1436
NX 1307	137	0	721	19	877	89	60	149	1026
NX 5111	176	7	753	20	956	60	82	141	1098
NX 6102	166	10	764	25	966	77	76	153	1118
NX 6104	180	12	953	31	1176	77	106	184	1360
NX 6107	177	8	779	24	987	80	78	158	1144
Oldham	78	0	815	43	936	64	88	152	1088
Santiago	276	20	896	50	1242	85	115	200	1442
Stallion	149	10	766	28	954	76	81	157	1111
Symphony	164	9	747	28	949	76	62	139	1088
Tuerkis	145	7	684	18	854	64	58	122	976
Unico	67	0	903	49	1019	53	80	133	1152

[a] Contents measured in milligrams per kilogram of oil. [b] Total-T + T3 = sum of total tocopherol and tocotrienol contents, expressed in milligrams per kilogram of kernel oil.

Table 5. Correlations among Tocopherol and Tocotrienol Contents,[a] Vitamin E Equivalents,[b] PUFA,[c] and the Vitamin E/PUFA Ratio in 30 Maize Hybrids[d,e]

	β-T	γ-T	δ-T	total-T	α-T3	γ-T3	total-T3	t-T + T3	vit E equiv	PUFA	vit E/PUFA
α-T	0.68**	−0.01^{NS}	−0.10^{NS}	0.34**	0.62**	0.27**	0.51**	0.40**	0.84**	0.41**	0.77**
β-T		0.15*	0.23**	0.42**	0.29**	0.25**	0.35**	0.44**	0.68**	0.25**	0.64**
γ-T			0.66**	0.93**	−0.13^{NS}	0.43**	0.30**	0.90**	0.52**	0.11^{NS}	0.52**
δ-T				0.65	−0.36**	0.40**	0.17*	0.62**	0.28**	0.07^{NS}	0.25**
total-T					0.07^{NS}	0.51**	0.46**	0.99**	0.79**	0.25**	0.75**
α-T3						0.10^{NS}	0.54**	0.16*	0.49**	0.25**	0.77**
γ-T3							0.89**	0.61**	0.52**	0.23**	0.46**
total-T3								0.59**	0.66**	0.31**	0.60**
t-T + T3									0.83**	0.28**	0.79**
vit E equiv										0.41**	0.93**
PUFA											0.06^{NS}

[a] Tocopherol and tocotrienol contents expressed in milligrams per kilogram of seed. [b] Vitamin E equivalents expressed in milligrams of α-tocopherol equivalent (0.6 mg α-tocopherol = 1 IU). [c] PUFA expressed in grams per kilogram of oil. [d] Abbreviations: t-T + T3 = sum of total tocopherols and tocotrienol contents. [e] The symbols * and ** indicate significance at the 0.05 and 0.01 probability levels, respectively; NS means nonsignificant.

tion between α- and γ-tocopherol. Kurilich et al. (*15*) also reported an absence of correlation between the two tocopherol homologues but in fresh tissue from subspecies of *Brassica oleracea*. All of these reports suggest that biosynthesis of α-tocopherol in seeds could follow an alternative pathway, although further investigations are needed to confirm this hypothesis. γ-Tocopherol contributed significantly to the total tocopherol and tocochromanol contents, as indicated by the high correlation coefficients found. This homologue did not show a significant correlation with PUFA. The total tocopherol and total tocotrienol contents were positively correlated, suggesting that increasing the tocopherol content could positively affect the tocotrienol concentration in corn oil. α-Tocotrienol was not correlated with γ-tocotrienol. The total tocotrienol content was more closely related to the γ-tocotrienol content ($r = 0.89$**) than to the α-tocotrienol content ($r = 0.54$**). The high positive correlation found between vit E equiv and the ratio vit E/PUFA, and the absence of a correlation between PUFA and this ratio suggests that increasing the vitamin E value can be more effective in improving the vit E/PUFA ratio than changing the fatty acid profile in corn oil. Considering the variation found for the analyzed quality traits and the fact that many hybrids show a vit E/PUFA ratio that is under the recommended value for human and animal consumption, breeding efforts must be concentrated on improving the oil quality of these genotypes by increasing the vitamin E content.

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