Fatty-Acid Composition of Oil from Four Kernel Fractions of Corn (Zea mays L.) Inbred Lines[1]

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ABSTRACT

Fatty-acid composition of oil from endosperm, scutellum, coleoptile-plumule, and coleorhiza-radicle kernel fractions of ten corn inbred lines was determined by gas-liquid chromatography. Significant differences were found among kernel fractions and inbred lines for palmitic, palmitoleic, stearic, oleic, linoleic, arachidic, and linolenic acids. All kernel fractions were significantly different from each other in oleic, linoleic, and linolenic acids. The endosperm oil was highest in palmitic, palmitoleic, stearic, and linolenic acids and lowest in oleic acid. The scutellum oil was lowest in palmitic, linoleic, and linolenic acids and highest in oleic acid. High negative correlation coefficients of −0.93 to −0.97 between oleic and linoleic acids were obtained for kernel fractions. Certain other correlation coefficients among fatty acids of kernel fractions were significant but were lower in magnitude. Fatty-acid composition of oil among fractions within inbred lines was more closely related among scutellum and embryo axis (coleoptile-plumule and coleorhiza-radicle) fractions than between endosperm and other fractions.

Commercial corn oil is a by-product of the corn wet-milling industry. Beadle et al. (1) reported the average fatty-acid composition of commercial oil as 11.5% palmitic, 2.2% stearic, 26.6% oleic, 58.7% linoleic, 0.8% linolenic, and 0.2% arachidic. They also reported that composition of oil from corn grown in other countries was usually more highly saturated (higher palmitic and oleic and lower linoleic) than oil from Midwest corn. Commercial oil is quite uniform in fatty-acid composition from year to year and represents the mixture of numerous hybrids grown in the Midwest Corn Belt. Jellum and Marion (2) studied oil composition of nine hybrids grown for 2 years in Georgia, and found oil of all hybrids higher in oleic and lower in linoleic acids than commercial corn oil. Although oil from Midwest corn is uniform in composition, previous reports (3,4,5) have shown considerable variability in oil composition among inbred lines.

Lipid composition of different seed fractions has been studied in other crops (6,7,8,9). In corn, Jellum et al. (10) reported on the oil composition of endosperm and germ of four normal dent inbreds and high-amylose strains back-crossed from one to four generations to the normal recurrent parent. For all back-cross strains and normal inbreds, the endosperm oil was higher in palmitic, stearic, and linolenic acids and lower in linoleic acid when compared with the germ oil. The total lipid content and fatty-acid composition of the oil in the endosperm (source of commercial starch) may be important in the shelf-life or other characteristics of starch used in various food products. Black et al. (11) showed that extractable oil content of corn grits was directly related to storage time, temperature, particle size, and oxygen content of the atmosphere. They also reported that the proportion of

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C-16 saturated fatty acids increased and the proportion of C-18 unsaturated fatty acids decreased during storage of milled corn fractions. The endosperm is separated into starch and gluten (high in protein and xanthophyll pigments) fractions during the wet-milling of corn. Lipids extracted from these endosperm fractions were shown by Baldwin and Sniegowski (12) to be different in fatty-acid composition, unsaponifiable matter, and free fatty acids. Composition of the original endosperm oil may influence the rate and degree of change which occurs in the lipids during storage of corn-starch products. Data are lacking concerning the range which can be expected in fatty-acid composition of oil from the endosperm of genetically diverse corn germ plasm.

Whole corn germs are processed to obtain commercially refined corn oil which is primarily used in the food industry. Fatty-acid composition determines, in part, the quality of the oil obtained. The corn germ consists of several morphologically distinct fractions, the major portion being the scutellum. Embedded in the scutellum is the embryo axis, composed of upper plant parts (coleoptile and plumule) and lower plant parts (coleorhiza and radicle). Composition of oil has not been previously reported for the different fractions of corn germ.

The purpose of this study was to determine the fatty-acid composition of oil from four fractions (endosperm, scutellum, coleoptile-plumule, and coleorhiza-radicle) of the corn kernel and to study the relationship in oil composition among the four fractions. Ten inbred lines were selected for study which had a greater range in oil composition than that reported previously in the literature for corn oil.

MATERIALS AND METHODS

Kernel Fractions

Kernels of ten inbred lines with a range of 30 to 70% linoleic acid content of oil were separated by hand into four fractions: endosperm, scutellum, coleoptile-plumule, and coleorhiza-radicle. Separations were made on approximately 15 kernels from the mid-ear section from each of three ears of each inbred. A razor blade was used carefully to remove most of the endosperm from around the germ. Endosperm adhering to the germ and the outer layers of the scutellum were removed and discarded. The pericarp was removed from the remaining germ (free of endosperm) and the germ was split open with the thumbnails to expose the embryo axis. The top (coleoptile-plumule) and bottom (coleorhiza-radicle) of the embyro axis were removed easily with a razor blade. A small section of the embryo axis between the top and bottom portions, which is attached to the scutellum, was removed and discarded. Although kernels were not weighed for this study, total kernel weight and weight of kernel fractions varied among inbred lines. The size of the fractions from the embryo axis was different among inbred lines, but did not appear to be related to whole-kernel size.

Inbred Lines

The original experiment station source of inbred lines was: SH258, GE82, and GE37 (Georgia); CI-84B and CI-90A (USDA); NY140 and X-187 (New York); N31 (Nebraska); Pa36 (Pennsylvania); and W9 (Wisconsin). Inbreds CI-90A, N31, Pa36, and W9 have been released to the seed industry by their respective stations; the

other six have not been released. Except for GE37, which was grown in 1966, all inbreds were grown and self-pollinated at Experiment, Ga., in 1967.

Extraction of Oil

Kernel fractions (in 25-ml. flasks) were extracted overnight in a 2:1 mixture of petroleum ether (Skellysolve F) and absolute methanol. After this, 10 ml. of anhydrous methanol and seven to eight drops of sulfuric acid (95% conc.) were added to each flask and the flasks were then heated in a hot-water bath at 65°C. for about 5 hr. Preparation of the samples after methylation was similar to the procedure described earlier (5). Graveland (13) and Rogols et al. (14) have shown that the amount and type of lipids extracted from starch depend on the solvent system used. A combination of petroleum ether and methanol was used to extract both polar and nonpolar lipids from kernel fractions in this study.

Chromatographic Analysis of Samples

The equipment consisted of a Varian Aerograph Model 1200-2 gas chromatograph, Infotronics Model CRS-11HSB digital integrator, Honeywell ElectroniK 18 recorder, and Elhygen Model E-150 hydrogen generator. The methyl esters of the fatty acids were separated on a copper column 9 ft. by 1/8 in. packed with 8% (by weight) of stabilized diethylene glycol succinate on 80- to 100-mesh Aeropak 30 solid support. Injection port, column oven, and detector were operated at 270°, 220°, and 300°C., respectively. Fatty-acid percentages were determined by peak area normalization. Column performance and detector response were checked with fatty-acid standards of known composition, and the analytical precision was similar to that reported previously by Jellum and Worthington (15).

Statistical Analysis

Analysis of variance was performed on the combined data of inbreds, kernel fractions, and the interaction of inbreds × fractions. A split-plot design was used with inbreds as whole plots and kernel fractions as subplots. Analysis of variance was also made within fractions to determine significant differences among inbred lines. Duncan's Multiple Range Test at the 5% level of significance was used to separate fatty-acid means. Correlation coefficients were calculated among fatty acids for each of the four kernel fractions and for fatty acids among kernel fractions.

RESULTS AND DISCUSSION

Typical chromatograms of the oil from four kernel fractions of GE82 are shown in Fig. 1. Retention time for linolenic acid was 5 min. Although peaks for myristic acid and 17 carbon acids were present, they were not quantitated. As shown in Fig. 1, the amount of myristic acid was different in the oil from the four kernel fractions. Eicosenoic acid (20:1) was separated as a peak immediately after linolenic acid in the scutellum oil and was evident as a peak shoulder in the other oils (Fig. 1).

Oil Composition of Kernel Fractions

Average fatty-acid composition of oil of each kernel fraction from ten inbred

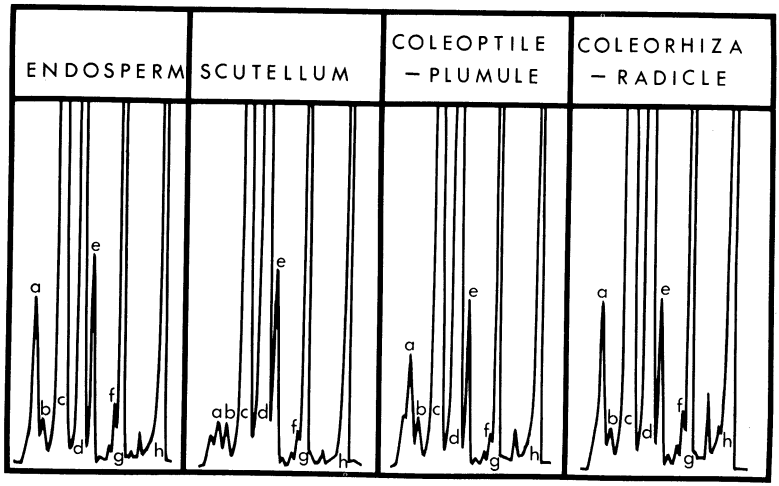

Fig. 1. Typical chromatograms of four kernel fractions of GE82. Identification of peaks as follows: (a) linolenic acid, (b) arachidic acid, (c) linoleic acid, (d) oleic acid, (e) stearic acid, (f) palmitoleic acid, (g) palmitic acid, and (h) solvent peak. Myristic acid peak is seen between the solvent peak and palmitic acid. C-17 fatty acids are evident by peaks between palmitoleic and stearic acids. Retention time for linoenic acid was 5 min.

lines is given in Table I. All kernel fractions were significantly different from each other for oleic, linoleic, and linolenic acids. As compared to other fractions, the scutellum oil had the highest percentage of oleic acid and the lowest percentage of linoleic and linolenic acids. Palmitic acid was highest in the endosperm, lowest in the scutellum, and intermediate in the oil of the two fractions from the embryo axis. The coleoptile-plumule was significantly higher in stearic and arachidic acids than the scutellum, which, in turn, was higher than the coleorhiza-radicle. In the fractions of the embryo axis, the association of high stearic acid content with high arachidic acid and low stearic with low arachidic is of considerable interest when compared with other data (M. D. Jellum, unpublished data) where certain germ-oil samples extremely high in stearic acid (10% or higher as compared to 2% in commercial corn oil) were also high in arachidic acid (1% or higher as compared to 0.2% in commercial oil). The relation between stearic and arachidic acids would

TABLE I. AVERAGE OIL COMPOSITION OF FOUR KERNEL FRACTIONS OF TEN CORN INBRED LINES

Fraction	Fatty-Acid Composition of Oil						
	16:0 %	16:1 %	18:0 %	18:1 %	18:2 %	20:0 %	18:3 %
Endosperm	19.8a[a]	0.36a	2.26a	18.8d	55.5c	0.34b	2.90a
Scutellum	11.3c	0.16c	1.58b	34.6a	51.4d	0.31b	0.62d
Coleoptile-plumule	15.0b	0.13c	2.18a	23.6b	56.3b	0.42a	2.30b
Coleorhiza-radicle	15.3b	0.25b	1.35c	21.3c	59.4a	0.20c	2.12c

[a]Values for a particular fatty acid followed by the same letter are not significantly different as determined by Duncan's Multiple Range Test (5% level).

suggest that arachidic may be derived from stearic acid through a process of carbon chain lengthening.

Oil Composition of Inbred Lines

Fatty-acid composition of the oil of four kernel fractions in ten inbred lines is given in Figs. 2 to 6. Data for palmitoleic and arachidic acids of individual inbreds are not given because of the small amounts present in the various oils. However, analysis of variance of the data for these two fatty acids showed that inbreds were significantly different for all four kernel fractions.

Except for the endosperm, CI-84B and GE37 were higher in palmitic acid than the other inbreds (Fig. 2). Greater uniformity for palmitic acid was shown among inbreds for endosperm oil than for the other three fractions. Comparisons of stearic acid composition (Fig. 3) of inbred lines among fractions show that the endosperm and coleoptile-plumule of a particular inbred are similar in stearic acid and generally higher than the scutellum. Stearic acid was lowest in the

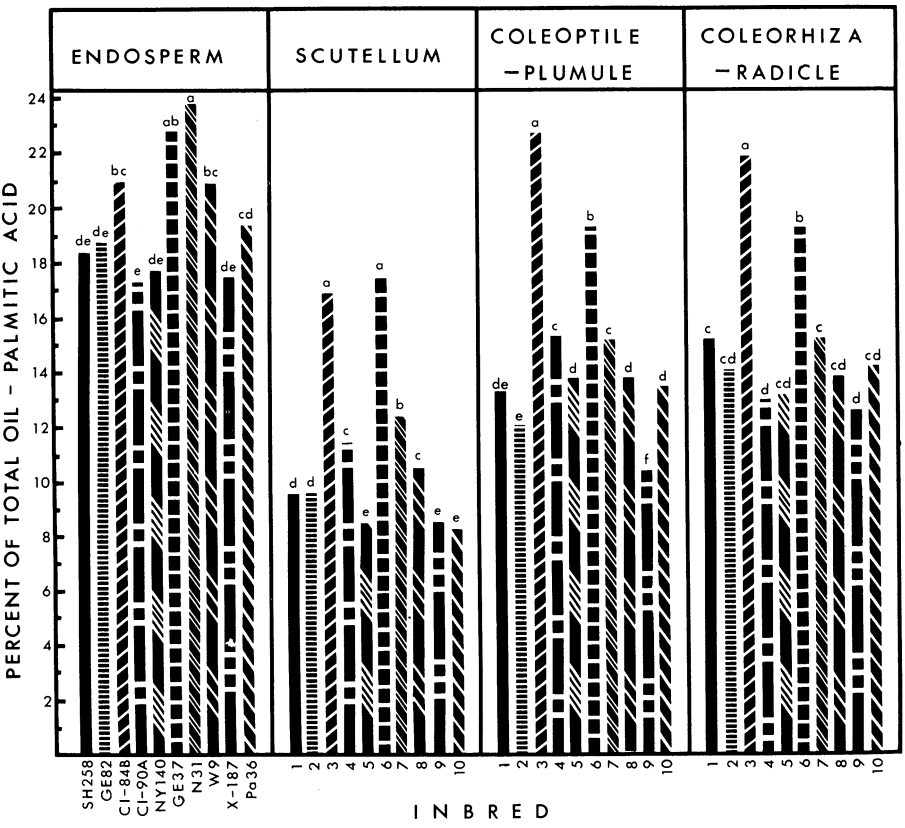

Fig. 2. Percent palmitic acid in oil of four kernel fractions of ten inbred lines of corn. Significant differences among inbred lines for each kernel fraction is shown by letters at the top of each bar. Any bars with a letter in common are not significantly different from each other as determined by Duncan's Multiple Range Test (DMRT) at the 5% level.

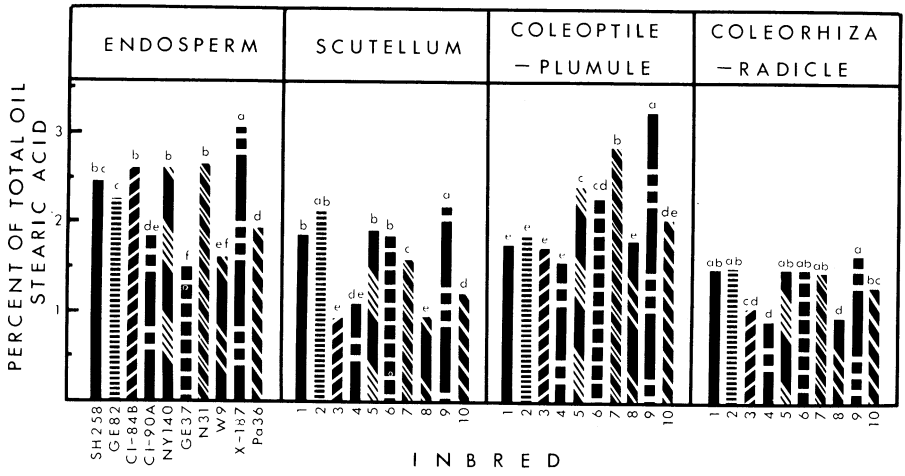

Fig. 3. Percent stearic acid in oil of four kernel fractions of ten inbred lines of corn. DMRT, see caption Fig. 2.

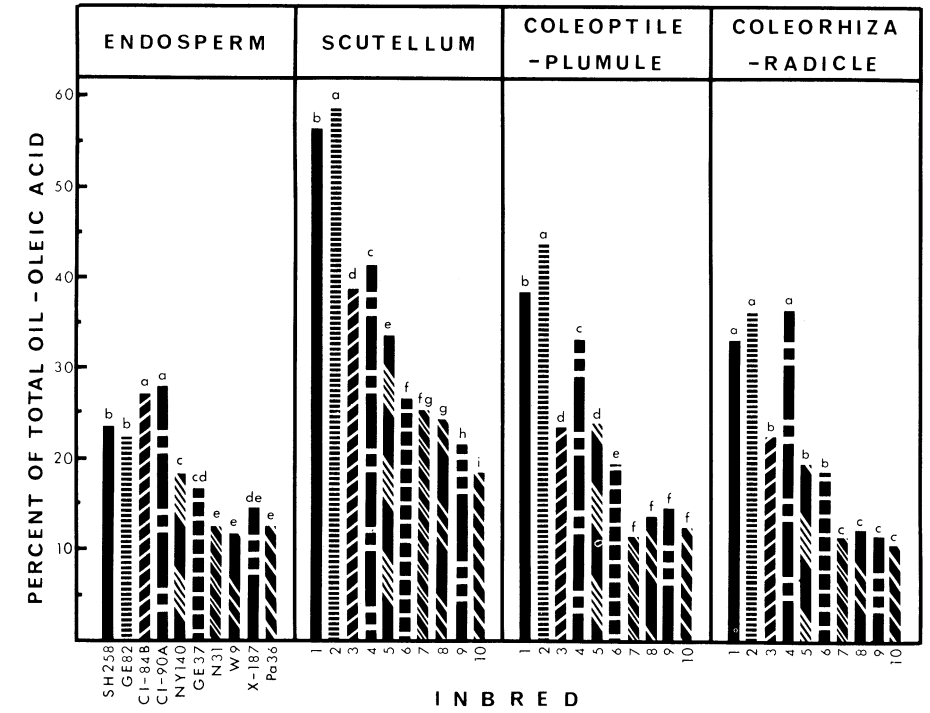

Fig. 4. Percent oleic acid in oil of four kernel fractions of ten inbred lines of corn. DMRT, see caption Fig. 2.

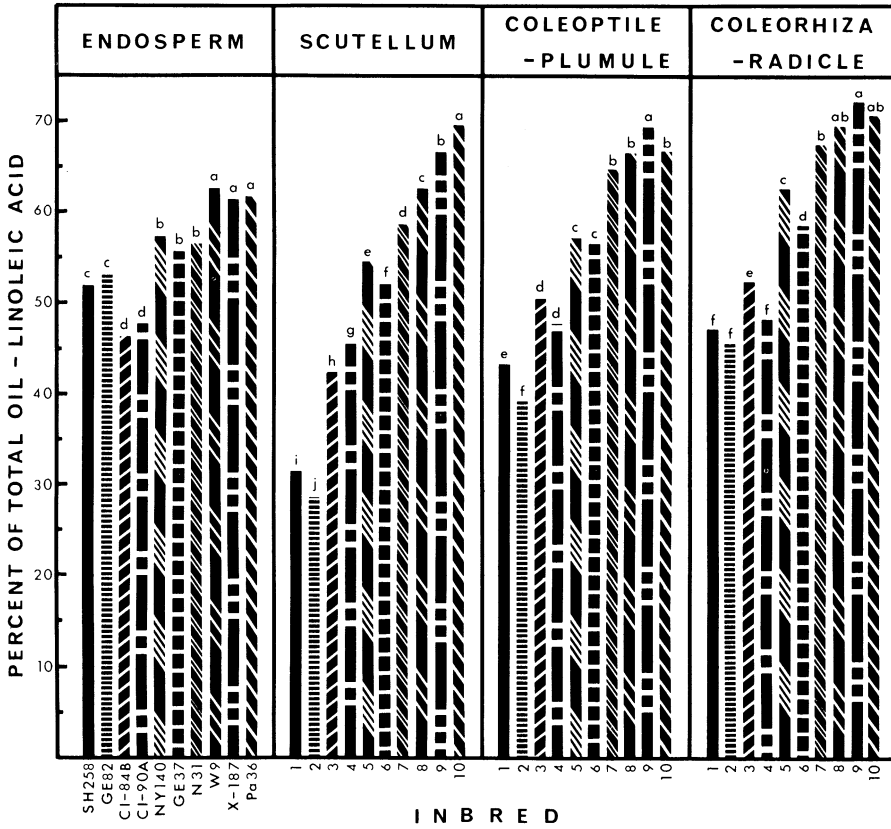

Fig. 5. Percent linoleic acid in oil of four kernel fractions of ten inbred lines of corn. DMRT, see caption Fig. 2.

coleorhiza-radicle and was also the most uniform among inbred lines. Oleic and linoleic acids are negatively correlated as shown by Figs. 4 and 5. A greater range in variability among inbred lines was shown for oleic and linoleic acids in the scutellum than in other fractions. Oleic and linoleic were quite uniform in the endosperm among inbred lines. Except for linoleic acid in the coleoptile-plumule of Pa36, oleic acid was always lower and linoleic higher in the fractions of the embryo axis as compared to the scutellum oil within any of the ten inbred lines. The endosperm had the highest average amount of linolenic acid and scutellum oil had the lowest amount (Fig. 6). Fractions of the embryo axis showed the greatest variability among inbred lines in composition of linolenic acid.

Correlation Coefficients

Correlation coefficents among fatty acids of the four kernel fractions are given in Table II. All fractions had a high negative correlation coefficient between oleic and linoleic acids. Except for the endosperm, the other fractions had a negative

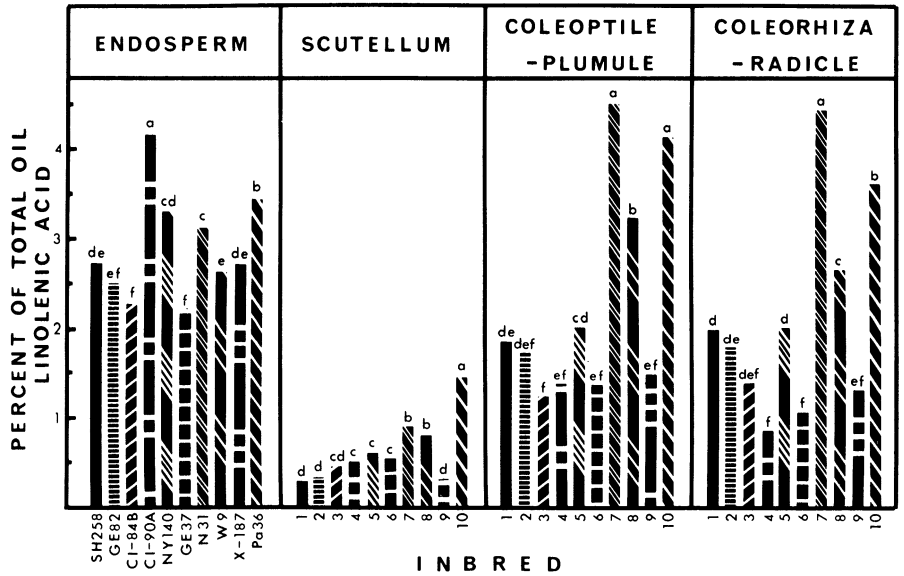

Fig. 6. Percent linolenic acid in oil of four kernel fractions of ten inbred lines of corn. DMRT, see caption Fig. 2.

TABLE II. CORRELATION COEFFICIENTS AMONG FATTY ACIDS OF FOUR CORN KERNEL FRACTIONS

Fatty Acids	Endosperm	Scutellum	Coleoptile-Plumule	Coleorhiza-Radicle
Palmitic				
Palmitoleic	0.46*	−0.04	−0.57**	−0.05
Stearic	−0.20	−0.27	−0.30	−0.04
Oleic	−0.41*	−0.05	−0.09	−0.06
Linoleic	0.08	−0.18	−0.20	−0.24
Arachidic	−0.19	0.34	0.50**	0.54**
Linolenic	−0.38*	−0.14	−0.23	−0.09
Palmitoleic				
Stearic	0.12	−0.40*	0.24	−0.19
Oleic	−0.35	−0.40*	−0.34	−0.24
Linoleic	0.17	0.40*	0.48**	0.20
Arachidic	0.05	0.01	−0.48**	−0.35
Linolenic	−0.11	0.59**	0.54**	0.50**
Stearic				
Oleic	0.06	0.24	−0.51**	−0.13
Linoleic	−0.08	−0.20	0.58**	0.11
Arachidic	0.51**	0.51**	0.05	−0.04
Linolenic	−0.02	−0.44*	0.16	0.10
Oleic				
Linoleic	−0.93**	−0.97**	−0.95**	−0.95**
Arachidic	0.55**	−0.16	0.29	0.20
Linolenic	0.05	−0.62**	−0.57**	−0.57**
Linoleic				
Arachidic	−0.55**	0.05	−0.45*	−0.34
Linolenic	0.00	0.63**	0.57**	0.57**
Arachidic				
Linolenic	−0.39*	−0.02	−0.35	−0.38*

TABLE III. CORRELATION COEFFICIENTS AMONG KERNEL FRACTIONS FOR FATTY-ACID COMPOSITION OF OIL

Fraction[a]	Fatty Acid						
	16:0	16:1	18:0	18:1	18:2	20:0	18:3
1 vs. 2	0.61**	0.56**	0.37*	0.72**	0.75**	0.06	0.36
1 vs. 3	0.48**	0.39*	0.51**	0.75**	0.78**	0.47**	0.25
1 vs. 4	0.52**	0.06	0.44*	0.82**	0.84**	0.34	0.20
2 vs. 3	0.91**	0.54**	0.49**	0.96**	0.97**	0.59**	0.78**
2 vs. 4	0.85**	0.41*	0.83**	0.89**	0.94**	0.34	0.68**
3 vs. 4	0.87**	0.52**	0.61**	0.94**	0.97**	0.67**	0.94**

[a]1, Endosperm; 2, scutellum; 3, coleoptile-plumule; 4, coleorhiza-radicle.

correlation coefficient between oleic and linolenic acids and a positive coefficient between linoleic and linolenic acids. Other correlation coefficients were quite low and were not consistent among kernel fractions.

Most of the correlation coefficients (Table III) among kernel fractions were significant for all fatty acids, especially for palmitic, stearic, oleic, and linoleic acids. The relation between oil composition of kernel fractions for the ten inbreds is also evident in Figs. 2 to 6. Correlation coefficients were highest for fatty acids among the germ fractions (scutellum and embryo axis) than between the endosperm and other fractions. Therefore, composition of the oil in the endosperm is more independent from the other fractions than oil composition among germ fractions. Selection for scutellum with oil of a particular composition would influence the oil composition of the embryo axis to a greater degree than oil composition of the endosperm.

CONCLUSIONS

Significant differences were found in fatty-acid composition of oil extracted from each of four kernel fractions of ten corn inbred lines. Breeding and selection of corn with kernel fractions containing oil of a specific fatty-acid composition should be possible. Breeding corn with a specific oil composition in the scutellum would also influence the oil composition in other kernel fractions owing to the high correlation coefficients among kernel fractions for oil composition. Linolenic acid is highly unsaturated and is more subject to oxidation than the other fatty acids in corn oil. Therefore, a low amount of linolenic acid should improve the keeping quality of corn oil and starch products. Because of the large differences among inbred lines and kernel fractions, progress should be possible in reducing linolenic acid content and, thereby, improving the keeping quality of various milled products.

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