Fatty Acid Composition of Oil from Adapted, Elite Corn Breeding Materials

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ABSTRACT: The fatty acid composition of corn oil can be altered to meet consumer demands for "healthful" fats (i.e., lower saturates and higher monounsaturates). To this end, a survey of 418 corn hybrids and 98 corn inbreds grown in Iowa was done to determine the fatty acid composition of readily-available, adapted, elite corn breeding materials. These materials are those used in commercial hybrid production. Eighty-seven hybrids grown in France (18 of which also were grown in Iowa) were analyzed to determine environmental influence on fatty acid content. The parents of the hybrids and the inbreds were classified in one of four heterotic groups: Lancaster, Stiff Stalk, non-Lancaster/non-Stiff Stalk, and Other. *t*-Tests and correlation analyses were performed with statistical significance accepted at a level of $P \leq 0.05$. The findings showed a wide range of fatty acid profiles present in adapted, elite corn breeding materials with ranges for each fatty acid as follows: palmitic acid, 6.7–16.5%; palmitoleic acid, 0.0–1.2%; stearic acid, 0.7–6.6%; oleic acid, 16.2–43.8%; linoleic acid, 39.5–69.5%; linolenic acid, 0.0–3.1%; and arachidic acid, 0.0–1.0%. Small amounts of myristic acid, margaric acid, and gadoleic acid also were found. Three lines had total saturates of 9.1% or less. Thirty-six of the *t*-tests involving hybrids showed significant differences among heterotic groups. There were small but significant correlations among protein, starch and oil content and the amounts of several fatty acids. Results from the corn grown in France vs. Iowa demonstrated a large environmental effect that overwhelmed the genetic differences among lines. This study shows that for some attributes, a breeding program involving adapted corn breeding materials might produce the desired oil. Other types of oil (such as high-oleic) would have to be produced in a different manner, for example, by a breeding program with exotic breeding materials.

JAOCS 72, 981–987 (1995).

KEY WORDS: Adapted corn breeding materials, corn oil, environmental differences, fatty acid composition, genetic differences, oil content, protein content, starch content.

Recent dietary guidelines, recommending a reduction of fat in the U.S. diet to 30% (1), and consumers' increased knowledge of what constitutes "healthful" fats (i.e., lower saturates and higher monounsaturates) have led to efforts by plant breeders to alter the normal fatty acid composition of oil-producing crops. Soybean, canola, and sunflower oils, among others, have been targeted for research to alter their fatty acid compositions to meet various consumer demands: (i) Low total saturated fatty acids: With this type of oil, consumers may more readily get less than 10% of their energy from saturated fat and stay within this dietary guideline recommended by the United States Department of Agriculture (1); (ii) increased monounsaturated fatty acids: Oils with increased monounsaturates (such as the high-oleic varieties of sunflower and safflower) are low in polyunsaturated fatty acids, which are prone to oxidation (2). A high-oleic oil also may help to reduce raised levels of total plasma cholesterol without reducing the high-density lipoprotein (HDL)-cholesterol level (3); and (iii) decreased *trans* fatty acids. *Trans* fatty acids occur in hydrogenated oils used in products such as margarines and shortenings. Oils are hydrogenated to convert liquid oils into semisolid fats and to improve oxidative stability (4). Although we do not know their long-term health effects, the consumption of *trans* isomers may be a nutritional concern. A recent study by Mensink and Katan (5) reported that a diet high in *trans* fatty acids raised total and low-density lipoprotein (LDL)-cholesterol and lowered HDL-cholesterol levels compared to a diet high in *cis* fatty acids. The authors noted, however, that the effect of *trans* fatty acids on serum lipoprotein profiles was similar to that of cholesterol-raising saturated fatty acids. According to Reeves (6), this research should be interpreted with caution, and further studies are needed before the effects of *trans* fatty acids are fully understood. By using an oil naturally high in saturated fatty acids, the consumption of *trans* fatty acids would be decreased. Also, the oil would require less processing, and the product could be perceived by consumers to be more "natural" and, therefore, "healthful."

In June 1994, the Environmental Protection Agency issued a ruling that mandates a 30% market for an ethanol blend or its ether derivative in nine U.S. cities for 1996 (7). This will increase ethanol production and, correspondingly, corn oil production. Corn oil has traditionally been popular because it

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is considered superior in flavor and quality, and a premium price traditionally has been paid for it (8). But, with the increased amount of available corn oil and more competition from oils altered in their fatty acid composition, the demand for corn oil will decrease. To increase the value of corn oil, corn oils with different fatty acid compositions need to be developed. New corn oils with different nutritional and functional qualities could open new markets for both food and industrial use.

The development of corn oils with unique fatty acid compositions might be approached in several different ways, one of which is breeding (9). Because high crop yield is the main objective of corn breeders, it is useful to know if variants can be found in adapted, elite breeding materials. Adapted, elite breeding materials are those used in commercial hybrid production. In 1984, Jellum registered a high-stearic acid germplasm called GE180 with about 18% stearic acid (10); however, this line has not been commercially used because of poor agronomic properties.

This study was done to provide information on the variation in fatty acid composition of current Corn Belt breeding materials. The Corn Belt is the part of the United States where most corn is grown, from Ohio to Nebraska and from Missouri to North Dakota. Little information is available. This paper reports data on the differences and the ranges of fatty acid composition found in adapted, elite corn breeding materials. A small number of samples (eighteen) were grown both in Iowa and in France, allowing an environmental comparison. Correlations between fatty acid composition and protein, oil, and starch content also were determined.

EXPERIMENTAL PROCEDURES

Samples. Adapted, elite corn breeding materials (505 hybrids and 98 inbreds) provided by MBS, Inc. (Ames, IA) were evaluated. Four hundred and eighteen of the hybrids and the 98 inbreds were self-pollinated to control pollination and were grown in a nursery near Story City, Iowa, in 1992. These samples represent a good cross-section of commonly-grown Corn Belt materials (Smelser, G., MBS, Inc., personal communication). The remaining 87 hybrids were self-pollinated and grown in France in 1992, and 18 of these were the same as those grown in Iowa.

The male and female parent inbred lines of the corn hybrids grown in each country and the inbred lines grown in Iowa were classified in one of four heterotic breeding groups: Lancaster (L), Stiff Stalk (SS), non-Lancaster/non-Stiff Stalk (N), and Other (O). In the Corn Belt, inbred lines of SS background are commonly crossed and tested in combination with inbred lines of L background to develop hybrids (11). The N breeding group is composed of parents and inbreds with backgrounds known not to be SS or L. The O breeding group is a heterogenous group of parents and inbreds to the extent that their grouping could not be determined.

Fatty acid profiles may change with the kernel position on the ear (12); therefore, one or two kernels from the middle portion of the ear, where intermediate values are found, were taken for analysis. Initial tests were performed on two or three replicate kernels, and the results were not different within the replicates. Therefore, only one kernel per sample was analyzed for additional screening. To confirm the results for the most unusual oils, two or three kernels were analyzed per type, and the results were averaged.

Oil extraction and sample preparation. Corn germs were removed from the kernel by hand. A quick extraction of oil from the corn germs was patterned after a similar procedure designed for soybeans (13). Individual kernel germs were placed in specially manufactured aluminum plates that contained 100 indentations. An opposing aluminum plate that contained 100 pegs was placed over the bottom plate to make a cup-and-piston type arrangement. The entire set-up was placed in a hydraulic press. A pressure of 750 kg/cm^2 was applied to crush the germs and exude the oil. Hexane (0.4 mL) was then added to each indentation and left for 2 h. The hexane does not extract all the oil, but extracts a representative sample (13,14). The hexane/oil sample was mixed with a pipetter, and 0.15 mL was transferred to a 1.5-mL autosampler vial for reaction with 0.4 mL of 1 M sodium methoxide. Complete transesterification of the fatty acids to methyl esters was accomplished in 30 min at 40°C with gentle shaking every 10 min. Water (0.15 mL) was added to each sample, and the hexane layer was allowed to rise. The floating oil/hexane phase was then diluted with an additional 0.9 mL hexane.

Gas–liquid chromatography. The samples were analyzed for their fatty acid methyl esters on a Hewlett-Packard model 5890 Series II gas chromatograph (Avondale, PA) equipped with a split/splitless injector, a flame-ionization detector, an automatic sampling device, and a 15-M Durabond-23 capillary column (J&W Scientific, Deerfield, IL), which was 0.25 mm i.d. with a film thickness of 0.25μ. The column temperature was programmed from 140 to 200°C at 12°C/min, and the injector and detector ports were set at 250°C. The carrier gas was helium with a flow rate of 100 mL/min. Peak areas of duplicate injections were measured with a Hewlett-Packard 3390A reporting integrator. The standards used were methyl esters of dodecanoate (12:0, lauric acid), tetradecanoate (14:0, myristic acid), hexadecanoate (16:0, palmitic acid), 9-*cis*-hexadecenoate (16:1, palmitoleic acid), heptadecanoate (17:0, margaric acid), octadecanoate (18:0, stearic acid), 9-*cis*-octadecenoate (18:1, oleic acid), 9,12-*cis*-*cis*-octadecadienoate (18:2, linoleic acid), 9,12,15-all *cis*-octadecatrienoate (18:3, linolenic acid), eicosanoate (20:0, arachidic acid), 9-*cis*-eicosenoate (20:1, gadoleic acid), and 13-*cis*-docosenoate (22:1, erucic acid) (Alltech Associates, Deerfield, IL). Theoretical response factors for quantitating the fatty acids were applied to the results as calculated by Craske and Bannon (15).

Protein, oil and starch determinations. The percentages of protein, oil, and starch, reported on a dry-weight basis, were obtained from MBS, Inc. on all Iowa-grown hybrids. The values were determined with a Tecator Infratec near-infrared instrument (Silver Spring, MD) calibrated to standard methods

from the American Oil Chemists' Society [protein, Ba 3-38 and oil, Ba 4-38 (16)] and the Corn Refiners' Association [starch, G-28 (17)].

Statistical analysis. *t*-Tests of the least square (LS) means of fatty acids for each group were done by using the Statistical Analysis System (SAS) release 6.06 (18). SAS also was used to determine correlations between protein, oil and starch content, fatty acid composition, and the correlations between the 18 lines that were grown in both Iowa and France. Statistical significance for the *t*-tests and correlations was accepted at a probability level of $P \leq 0.05$.

To determine the standard error of the mean and the standard deviation for analysis of each fatty acid within a sample, ten samples of Wesson corn oil were analyzed every day for three days. The standard error of the mean for each fatty acid was 0.11% or less, and the standard deviation was 0.54% or less. To determine the differences among kernels on an ear, five kernels from each of two genotypes of corn inbreds (B73 and Ohio 43) were selected from the middle of the ear and analyzed. The standard error of the mean was 0.44% or less, and the standard deviation was 1.08% for 16:0, 0.74% for 18:2, and 0.49% or less for the remaining fatty acids.

RESULTS AND DISCUSSION

Fatty acid composition of Corn Belt dent materials. A wide range of fatty acid profiles was present in these adapted, elite corn breeding materials. Table 1 shows the average values and ranges in fatty acid composition of the 418 hybrids grown in Iowa. Table 2 shows various corn oil compositions reported by previous researchers. The fatty acid profiles of oil from U.S. sources were quite similar to each other. The average 18:2 content shown in Table 1 (59.7%) is slightly higher than the 55.0% reported by Tan and Morrison (19), but more similar to the 58.7% average reported by Beadle *et al.* (20) and the 61.9% average reported by Leibovitz and Ruckenstein (21). The ranges in Table 1 are wider than the ranges reported by Jellum (22) for corn from both Iowa and New Mexico, but more lines were analyzed in the current study. Other researchers have found similar values to the ones listed in Table 2 (23–25). Weber *et al.* (23) found ranges of 20–60% for 18:1 and 25–71% for 18:2 in 5 inbred lines of corn. Jellum's Iowa corn also was less saturated than the corn from warmer New Mexico. The saturation levels of oils listed in Table 1 were similar to those in the other surveys of U.S. corn and generally were lower than saturation levels in oil from most corn of foreign origin.

TABLE 1
Fatty Acid Composition (%) of 418 Corn Hybrids Grown in Iowa[a]

Fatty acid[b]	Average	Range
16:0	11.6	6.7–16.5
18:0	1.8	0.7–4.7
18:1	25.2	16.2–43.8
18:2	59.7	39.5–69.5
18:3	0.8	0.0–3.1
20:0	0.1	0.0–1.0
16:0 + 18:0 + 20:0[c]	13.7	9.0–19.1

[a]Very small amounts of 14:0 (myristic acid), 16:1 (palmitoleic acid), 17:0 (margaric acid), and 20:1 (gadoleic acid) also were found.
[b]Fatty acid methyl esters of 16:0 = palmitic acid, 18:0 = stearic acid, 18:1 = oleic acid, 18:2 = linoleic acid, 18:3 = linolenic acid, and 20:0 = arachidic acid.
[c]Total saturates.

A few studies have examined factors that affect fatty acid composition of corn oil. Corn oil from cooler regions had a higher proportion of unsaturated fatty acids than did corn oil from warmer areas (21). Genetic factors had a much greater influence than did environmental factors (26). Jellum also determined that southern corn leaf blight (27) and nitrogen and boron in fertilizers did not influence fatty acid composition (28).

The differences between fatty acid values of Italian corn as reported by Tan and Morrison (19) and Strocchi (29) were

TABLE 2
Fatty Acid Composition (%) of Corn Oil as Reported by Previous Researchers

16:0[a]	18:0	18:1	18:2	18:3	20:0	Origin	Number of lines analyzed	Reference
11.5	2.2	26.6	58.7	0.8	0.2	United States	42	20
13.1	2.0	27.8	55.2	1.0	0.5	Italy	1	29
11.0	2.0	24.1	61.9	0.7	—	United States	—	21
11.5	2.0	38.7	44.3	1.1	0.6	South Africa	—	
7.6–22.0	0.7–3.8	16.4–43.4	39.2–68.3	—	—	Yugoslavia	490 inbreds	30
14.4–22.4	2.2–4.8	32.0–45.7	0.8–45.8	0.2–6.2	0.3–0.8	Pakistan	10	31
12.0	2.0	29.3	55.0	1.7	—	Illinois	1	19
11.0	1.4	24.1	62.8	0.7	—	France	1	
10.6	1.5	20.3	66.3	1.3	—	Italy	1	
8.4–12.2	1.6–2.3	21.4–37.2	50.5–62.9	—	—	Iowa	1	22
11.8–16.1	1.5–3.0	22.2–35.6	46.3–60.3	—	—	New Mexico	1	
13.6–16.3	2.8–6.6	27.0–36.0	38.7–53.7	—	—	West Pakistan	1	
9.4–12.4	1.9–2.0	21.2–37.7	48.7–65.4	—	—	Yugoslavia	1	
14.1–17.3	2.8–11.5	28.8–35.1	36.7–50.6	—	—	Nepal	1	
13.4–18.2	1.5–5.2	25.9–43.3	38.4–49.3	—	—	Italy	1	

[a]See footnote b in Table 1 for definition of fatty acids.

probably because Strocchi analyzed refined corn oil and Tan and Morrison analyzed certain varieties of waxy maize (Table 2). Strocchi's values were closer than values of Tan and Morrison to the ranges of fatty acids in Italian corn analyzed by Jellum (27). The Yugoslavian corn oils analyzed by Trifunović *et al.* (30) were more saturated than the Yugoslavian oils analyzed by Jellum (22); however, Jellum reported values for only three ears from one line, and Trifunović *et al.* analyzed 490 inbreds. Trifunović *et al.* (30) also reported a palmitic acid range of 7.6–22.0%, whereas the range reported by Jellum was 9.4–12.4% (22). Khan and Khan (31) showed wider ranges in fatty acids for corn from Pakistan than did Jellum, who analyzed six ears from one line.

Values in Tables 1 and 2 reflect the inverse relationship found between levels of 18:1 and 18:2 (22,31). This relationship is illustrated by adding the average 18:1 and 18:2 percentages in each set of data and finding a range of only 83.0 to 86.9%.

Corn oil is a by-product of wet milling corn for starch. A subgroup of 53 hybrids analyzed in our study represents 90% of the corn planted in the Corn Belt (Gary Smelser, MBS, Inc., personal communication). When the fatty acid profile of this group (data not shown) was compared to values in Table 1, the averages were the same except for 16:0 and 18:3, which differed only by 0.1 percentage point. The ranges also were slightly narrower in the group representing fewer lines.

The average values for each fatty acid of the Corn Belt corn grown in France (data not shown) were within two percentage points of the average values reported by Tan and Morrison for corn grown in France (19). The fatty acids of the Corn Belt corn grown in France also were similar to data shown in Table 1, except the French-grown corn was 1.3 percentage points less saturated than the Iowa-grown corn, with most of the difference being made up of 18:1. The ranges also were narrower, but fit within the ranges shown in Table 1.

Statistical comparisons of fatty acid composition among corn breeding heterotic groups. Statistical differences were computed among the average fatty acid values of all possible corn types from the United States and France, including hybrid or inbred, and SS, L, N, or O. Table 3 shows comparisons of the Iowa-grown hybrids having significant differences for a fatty acid. There were 55 possible *t*-tests for each fatty acid plus total saturates. From a total of 330 possible comparisons, 36 *t*-tests were significant. In general, hybrids containing L inbred as a parent had a higher 18:1 content than did hybrids with an SS inbred as a parent except when the L was crossed with an SS. A cross of an O inbred with SS or L in a hybrid always resulted in a higher 18:1 content than when O was absent as a parent. Having an L in only one of the hybrids involved in a comparison always lowered 18:2 content as compared with a hybrid having SS as a parent, except in the four instances when L was mated with an SS. The differences in the 18:1 and 18:2 contents among all significant comparisons were about 1 to 5%, and again demonstrate the inverse relationship found between 18:1 and 18:2 (22,31). The presence of SS in a hybrid gave slightly, but significantly, higher 16:0, total saturates, and 18:3 contents than did the presence of L.

Comparisons among breeding groups for the inbreds (bottom of Table 3) agreed with the findings for the hybrids in that SS inbreds had higher 18:3 contents and were more saturated than L inbreds. There were no significant differences in 18:1 and 18:2 contents among the breeding groups.

Table 4 shows the comparisons among breeding groups for the hybrids grown in France. Few conclusions can be drawn about these data. The sample sizes were small, and there were only four comparisons with an L parent. It seems that the presence of SS and L resulted in a higher 18:1 content than did the presence of N. It was difficult to draw conclusions about differences between SS and L in corn grown in France.

Although the differences in fatty acids reported among the various corn breeding groups were statistically significant, the averages of each fatty acid within the groups deviated from each other by only about one to five percentage points; therefore, the practical significance of this finding is limited. The ranges of fatty acids also were similar among corn heterotic groups.

When comparing the 18 hybrids grown in both Iowa and France, there were no significant correlations between the two countries for each fatty acid. Therefore, in this study, the environmental differences overwhelmed the genetic differences. The inverse relationship between 18:1 and 18:2 for each group again was confirmed.

Correlations between protein, oil and starch content, and fatty acid composition. Although many significant correlations between protein, oil and starch, and fatty acid composition were noted, the importance of these results is limited because the correlations ranged between only –0.11 to +0.22 (data not shown). Small but significant negative correlations were noted between protein content and levels of 18:0, 18:1, and 18:3, and a positive correlation occurred between protein content and 18:2. There also were small but significant positive correlations between oil content and levels of 18:1 and 18:2 and between starch content and levels of 18:0, 18:1, 18:2, and 18:3. Trifunović *et al.* (30) found that variations in corn oil level resulted in changes in fatty acid composition, particularly in the relative amounts of 18:1 (positive correlation) and 18:2 (negative correlation).

Corn genotypes with the most unusual fatty acid compositions. Table 5 lists individual corn genotypes with the most unusual fatty acid profiles. The experimental hybrid MBS 2521 × LH82 145-5c (SS × L) had 8.5% total saturates, and the 11090 × LH82 (O × L hybrid) had 9.0% saturates. The parents of these corn hybrids might be used in a breeding program to produce an oil with a desired low percentage of saturates to compete with canola oil (6% saturates). To more quickly develop an oil with high 18:1, unadapted breeding materials may need to be used because the highest 18:1 content found in this survey was 43.8% in 11080 × MBS 2361, an L × (SS × O) hybrid. Inbred L line 11080 had 42.6% 18:1. To compete with the high-oleic varieties of canola, soybean, safflower, and sunflower, an oil with 64–80% 18:1 would be needed (32).

TABLE 3
***t*-Tests with Significant Differences ($P \leq 0.05$) Between Percent Fatty Acid (FA) of Various Corn Breeding Groups Grown in Iowa**

FA[a]	16:0		18:0		18:1		18:1 cont'd.		18:2		18:3		Total saturated	
Hybrid[b]	SS × O[c]		SS × N vs. O × O		L × SS vs. L × O		SS × L vs. O × L		L × SS vs. L × O		L × SS vs. L × O		SS × O vs. O × L	
average	11.9		1.72	2.05	24.4	28.9	23.8	26.8	60.4	56.7	1.05	0.73	14.0	13.1
number	51		18	12	45	15	150	41	45	15	26	10	51	41
Hybrid	SS × O vs. O × L		SS × L vs. SS × N		O × O vs. L × O		SS × O vs. O × L		O × O vs. L × O		O × L vs. L × O			
average	11.9	11.1	1.92	1.73	25.5	28.9	25.1	26.8	59.8	56.7	1.06	0.73		
number	51	41	150	18	12	15	51	41	12	15	24	10		
Hybrid	O × L vs. L × O				O × SS vs. L × O		SS × N vs. O × L		N × O vs. L × O		O × SS vs. L × O			
average	11.1	10.9			26.2	28.9	24.6	26.8	62.0	56.7	1.07	0.73		
number	41	15			50	15	18	41	4	15	42	10		
Hybrid					N × O vs. L × O		SS × L vs. O × N		SS × L vs. L × O		SS × L vs. L × O			
average					23.6	28.9	23.8	26.8	61.0	56.7	0.99	0.73		
number					4	15	150	12	150	15	106	10		
Hybrid					SS × L vs. L × O		SS × L vs. O × SS		SS × O vs. L × O					
average					23.8	28.9	23.8	26.2	59.4	56.7				
number					150	15	150	50	51	15				
Hybrid					SS × O vs. L × O		SS × L vs. SS × O		SS × N vs. L × O					
average					25.1	28.9	23.8	25.1	50.4	56.7				
number					51	15	150	51	18	15				
Hybrid					SS × N vs. L × O				O × SS vs. L × SS					
average					24.6	28.9			58.5	60.3				
number					18	15			50	45				
Hybrid					O × L vs. L × SS				SS × L vs. O × L					
average					26.8	24.4			61.0	58.7				
number					41	45			150	41				
Hybrid					O × SS vs. L × SS				SS × L vs. O × N					
average					26.2	24.4			61.0	58.3				
number					50	45			150	12				
Hybrid									SS × L vs. O × SS5					
average									61.0	8.5				
number									150	50				
Hybrid									SS × O vs. SS × L					
average									59.4	61.0				
number									51	150				
Inbred	L vs. SS										SS vs. L			
average	11.4	12.8									1.38	0.98		
number	27	33									30	21		

[a]See footnote b in Table 1 for definition of fatty acids. [b]Each hybrid is a female × male combination. [c]SS = Stiff Stalk, L = Lancaster, N = non-Lancaster/non-Stiff Stalk, O = Other.

An oil high in saturates could be developed from inbred lines CO255 (SS × O) or 12003 (SS), which have 19.1 and 18.6% total saturates, respectively. Hybrid (MBS2W × MBS7W) × 24W is an SS × L combination with 18.7% saturates. If interesterified, these oils may be saturated enough for use without hydrogenation in all-vegetable margarines and spreads. The fatty acid compositions of fats and oils in typical margarines include 33–52% monounsaturates and 17–19% saturates (33), which is quite similar to the fatty acid composition of inbred line CO255. In addition to the corn genotypes listed in Table 5, there were several other hybrids with 17% saturates. There also is a possibility of producing corn with an oil high in 18:2 (70%) to compete with highly polyunsaturated oils such as traditional sunflower oil. The highest 18:2 content found in this survey was 69.5%, in an SS × L hybrid.

The oil compositions of rapeseed (34) and soybean (35, 36) have been changed through breeding systems. Because oil composition is a highly heritable trait in corn (37–40), it is probable that the fatty acid composition of corn oil also could be changed.

These results give a starting point for future breeding work of corn designed to produce oils of specific fatty acid compositions. There is much variability in corn oil composition, which could lead to the development of new oils and expand the corn market.

ACKNOWLEDGMENTS

This work was supported by research grants from the Iowa Corn Promotion Board and MBS, Inc. (Ames, IA).This is paper no. J-16048 of the Iowa Agriculture and Home Economics Experiment Station, Ames, IA, Projects no. 3128 and 3082.

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TABLE 4
t-Tests with Significant Differences Between Percent Fatty Acid (FA) of Various Corn Breeding Groups Grown in France

FA[a]	18:0		18:1		18:2		18:3	
Hybrid[b]	O × L[c]	vs. L × O	O × L	vs. O × O	O × O	vs. O × L	L × SS	vs. SS × O
average	1.94	1.61	24.7	27.3	58.0	60.9	0.75	0.92
number	8	8	8	15	15	8	7	9
Hybrid			O × SS	vs. O × O	O × SS	vs. O × O	O × SS	vs. O × L
average			23.9	27.3	62.5	58.0	0.87	0.68
number			6	15	6	15	6	7
Hybrid			SS × L	vs. O × O	SS × L	vs. O × O	SS × O	vs. O × L
average			24.5	27.3	62.1	58.0	0.92	0.68
number			8	15	8	15	9	7
Hybrid			SS × O	vs. O × O	SS × O	vs. O × O	SS × O	vs. O × N
average			23.4	27.3	62.3	58.0	0.92	0.72
number			9	15	9	15	9	3
Hybrid			SS × O	vs. O × N			SS × L	vs. SS × O
average			23.4	27.2			0.75	0.92
number			9	3			7	9
Hybrid			SS × N	vs. O × L				
average			28.4	24.7				
number			4	8				
Hybrid			SS × N	vs. O × SS				
average			28.4	23.9				
number			4	6				
Hybrid			SS × L	vs. SS × N				
average			24.5	28.4				
number			8	4				
Hybrid			SS × O	vs. SS × N				
average			23.4	28.4				
number			9	4				

[a]See footnote b in Table 1 for definition of FA. [b]Each hybrid is a female × male combination. [c]See footnote c in Table 3 for designations.

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TABLE 5
Corn Genotypes with Unusual Fatty Acid Compositions

		Fatty acid						
	Genotype	16:0[a]	18:0	18:1	18:2	18:3	20:0	Total saturates (%)
Low saturates	MBS 2521 × LH82 145-5c[b]	6.9	1.6	23.8	66.1	0.6	<0.5	8.5
	MBS 11090 × LH82	7.2	1.8	29.6	59.8	0.6	<0.5	9.0
	MBS 11008 × LH82	6.7	1.7	28.1	61.3	1.6	0.7	9.1
High 18:1	MBS 11080 × MBS 2361	11.8	2.6	43.8	49.5	0.7	0.9	15.3
	MBS 11080 inbred	11.3	1.9	42.6	41.6	0.8	0.6	13.8
High saturates	CO255 inbred	16.1	2.0	33.8	45.6	0.5	1.0	19.1
	(MBS 2W × MBS 7W) × MBS 24W	16.5	1.4	22.0	57.2	1.4	0.8	18.7
	MBS 12003 inbred	16.5	1.6	21.3	58.6	1.0	0.5	18.6

[a]See footnote b in Table 1 for definition of fatty acids.
[b]LH82 is a Holden's inbred. This genotype was grown in France; three plants grown in Iowa had oil containing 9.0, 11.0, and 11.9% saturates.

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[Received November 7, 1994; accepted June 14, 1995]