Hybrid Variability and Effect of Growth Location on Corn Fiber Yields and Corn Fiber Oil Composition

Vijay Singh,[1,2] Robert A. Moreau,[3] Armgard E. Haken,[1] Steven R. Eckhoff,[1] and Kevin B. Hicks[3]

ABSTRACT

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The variability in commercial corn hybrids for corn fiber yields, amounts of extractable oil, and levels of individual and total phytosterol components in corn fiber oil was determined. Also, the effect of growth location on fiber yields, fiber oil content, and the levels of individual and total phytosterol compounds was determined. Significant variation was observed in the commercial hybrids for fiber yield (13.2–16.6%) and fiber oil yield (0.9–2.4%). No significant correlation was observed between fiber and oil yields. Significant variations in the commercial corn hybrids were also observed in the individual phytosterol compounds in corn fiber oil: 2.9–9.2% for ferulate phytosterol esters (FPE); 1.9–4.3% for free phytosterols (St); and 6.5–9.5% for phytosterol fatty acyl esters (St:E). Positive correlations were observed among the three phytosterol compounds in the corn fiber oil (R = 0.75 for FPE and St:E; 0.48 for St:E and St; and 0.68 for FPE and St). The effect of location on dependent variables was also significant. The same hybrids grown at different locations showed a variation (range) of 4.0–17.5% for FPE, 4.9–12.2% for St:E, and 1.95–4.45% for St. Relative ranking of hybrids with respect to phytosterol composition was consistent for almost all of the growth locations.

Recent research on corn fiber has shown that an oil can be extracted from the fiber fraction (≈1–3%) and that this oil is very different in composition than commercial corn germ oil (Moreau et al 1996). This corn fiber oil contains high levels of three natural cholesterol-lowering phytosterol components: ferulate phytosterol esters (FPE), free phytosterols (St), and phytosterol fatty acyl esters (St:E). Corn fiber, among other grain fibers, has the highest amount of natural sitostanol (present as ferulate ester) (Moreau et al 1996), and sitostanol esters have been especially effective cholesterol-lowering compounds (Miettinen et al 1996). In addition to cholesterol-lowering compounds, corn fiber oil has antioxidant properties that might have additional health benefits. Because of its nutraceutical properties, corn fiber oil can be a potentially high-value coproduct (up to $8–9/lb) (Hicks 1998) for the corn wet-milling industry. Preliminary experiments indicate that there is considerable variability within hybrids for the amount of corn fiber oil and the level of different phytosterol components.

Hybrid variability in corn affects its processing and results in substantial economic losses for the corn processing industry (Eckhoff 1995). Patentability of hybrids, biotechnology, and development of international markets for superior processing corn has given impetus to the hybrid-specific processing of corn (Eckhoff 1995). Hybrid-specific processing, or selective processing of corn hybrids for different final products (speciality starch, fructose, ethanol, nutraceuticals, or other uses), helps in optimizing the yield and quality of the final product.

Due to the potential high value of phytosterol compounds, hybrid-specific processing might help to ensure the optimal levels of these phytosterol components in corn fiber oil. To determine whether hybrid-specific processing is required, we need to first identify the extent of variability in hybrids for corn fiber yields, amount of oil, and levels of total phytosterol components.

Growth location plays an important role in the yields of final products from corn. The effect of location on the variability of corn fiber oil and phytosterol composition is not known. Singh et al (1996) showed that growth location played an important role in the recovery of starch yields from different corn hybrids. They found that the same hybrid grown at different locations gave different starch yields. However, when compared with other hybrids, the relative ranking of the hybrids in terms of starch yields was the same at all locations. It is possible that similar trends in the recovery of phytosterol compounds can be observed.

The objective of this study was to determine the variability in commercial corn hybrids for corn fiber yields, amount of oil, and level of total phytosterol components for the same growth location and for the same hybrid grown at different locations.

MATERIALS AND METHODS

Corn hybrids were obtained from three commercial seed corn companies (Companies 1–3). Sixteen different corn hybrids (A-1 through A-16) were obtained from Company 1 and were all grown at one location in Iowa. The first two hybrids (A-1 and A-2) were also obtained from 12 other growth locations: three in Iowa, three in Illinois, one in Missouri, one in Pennsylvania, two in Nebraska, one in Tennessee, and one in Indiana. Two hybrids (B-1 and B-2) were obtained from Company 2 and grown at five different locations: two in Ontario, Canada, and one in Wisconsin, one in Minnesota, and one in Illinois. Two hybrids (C-1 and C-2) were obtained from Company 3 and grown at two locations: one in Iowa and one in Nebraska. All of the hybrids were hand-cleaned to remove broken corn and foreign material, packaged in plastic bags, and stored at 4°C until wet-milling. The whole kernel moisture content of the samples was measured using the 103°C convection oven method (AACC 2000). Wet-milling was done using the 100-g laboratory corn wet-milling procedure as outlined by Eckhoff et al (1996). Both fine and coarse fiber fractions were recovered for all of the hybrids. The collected fiber samples were dried for moisture content determination using the two-stage, convection oven procedure (AACC 2000). Because of the small sample size obtained from the commercial seed companies, and due to the precision of the laboratory corn wet-milling procedure (standard deviation <0.49%) (Eckhoff et al 1996), only one experiment was done to determine the fiber yield for each hybrid.

In the first experiment, the variability in terms of fiber yield, oil content, and phytosterol composition of the 16 commercial corn hybrids (A-1 through A-16) from Company 1 was determined. In the second experiment, the effect of 12 growth locations on two hybrids (A-1 and A-2) from Company 1; five growth locations on two hybrids (B-1 and B-2) from Company 2; and two growth

[1] Visiting assistant professor, research specialist, and professor, respectively, Department of Agricultural Engineering, University of Illinois, Urbana, IL 61801. Mention of brand or firm names does not constitute an endorsement by the U.S. Department of Agriculture or the University of Illinois above others of a similar nature not mentioned.

[2] Corresponding author. Phone: 215-233-6714; Fax: 215-233-6559; E-mail: vsingh @arserrc.gov

[3] Lead scientist and research leader, respectively, United States Department of Agriculture, Eastern Regional Research Center, Agricultural Research Service, Wyndmoor, PA 19038.

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locations on two hybrids (C-1 and C-2) from Company 3 was determined. The complete experimental design is shown in Table I.

Dried fiber samples were ground to 20 mesh in a Wiley mill. Fiber samples (4 g) were placed in screw-top vials (55 mL), and 40 mL of hexane was added. The tubes were shaken horizontally for 1 hr in a wrist-action shaker. After extraction, the hexane extracts were filtered through a GF/A glass fiber filter (Whatman Laboratory Products, Clifton, NJ) fitted in a Buchner funnel with gentle vacuum. A small known amount of the sample (snitch) was removed for HPLC analysis as previously outlined by Moreau et al (1996). The rest of the solvent sample was dried under nitrogen and heat (using a N-EVAP analytical evaporator, Organomation Associates, Berlin, MA). The dried sample was transferred to 2-dram vials in a 85:15 chloroform methanol mixture and dried again under nitrogen to measure oil dry weight. The amount of oil in the snitch was also determined based on the oil dry weight from this remaining sample. Two replicates were done for each fiber sample.

Correlation analysis (PROC CORR) was done to measure the strength (*R*) of the relationships between the fiber, oil, and different phytosterol component yields (SAS Institute, Cary NC).

RESULTS AND DISCUSSION

Experiment 1: Different Hybrids Grown at the Same Location

Significant variation was observed in the fiber yield, the amount of oil extracted from the fiber fraction, and the phytosterol composition of the oil among the 16 hybrids from Company 1 (Fig. 1). Depending on the hybrid, values were 13.2–16.6% for fiber yields and 0.9–2.4% for oil recovered from the fiber fraction. No significant correlation was observed in the fiber yields and the amount of oil recovered from the fiber (R = –0.11). depending on the hybrid, the values for corn fiber oil were 2.9–9.2% for FPE, 1.9–4.3% for St, and 6.5–9.5% for St:E. The total percent phytosterol compounds in the corn fiber oil was 12.0–21.6%. The total yield of phytosterol compounds from the corn fiber was 11.9–24.3 mg/100 g of corn (Fig. 2). Significant negative correlation was observed in the amount of oil and the percent FPE recovery from the oil (R = –0.75). Negative correlations were also observed in the amount of oil and the amount of St (R = –0.66), and the amount of oil and the amount of St:E (R = –0.50). Positive correlations were observed among the three phytosterol compounds (R = 0.75 for FPE and St:E, R = 0.48 for St:E and St, and R = 0.68 for FPE and St).

These results show that there is a significant variation in the commercial corn hybrids for the amount of oil and the amount of individual and total phytosterol compounds in the oil. Moreover, the hybrids that have high fiber yield do not necessarily have a large amount of oil in the fiber fractions. An increase in the amount of oil from the fiber fraction of these hybrids corresponded to a decrease in the amount of FPE and, to some extent, St:E and St. A significant relationship exists between the amounts of the three phytosterol compounds; increased amounts of any one of these phytosterol compounds would indicate an increase in the amount of the other two phytosterol compounds. These results suggest that careful selection of hybrids would be required to maximize the recovery of each individual cholesterol-lowering compound from corn fiber. This would also increase profitability because a slight increase in the percentage of these compounds (due to the potential high market value) could make a very big difference in terms of economics.

Experiment 2: Same Hybrid Grown at Different Locations

Significant differences were observed in the amount of the three phytosterol compounds (FPE, St, and St:E) for the same hybrid grown at different locations (Fig. 3). For hybrid 1 (A-1) from Company 1, depending on the location, the values were 4.0–17.5% for FPE, 7.9–13.4% for St:E, and 1.9–4.4% for St. For the second hybrid (A-2), also from Company 1, based on the same locations as hybrid 1, the values were 2.4–9.1% for FPE, 5.6–8.2% for St:E, and 2.0–2.9% for St. These differences in phytosterol composition of hybrids could be attributed to a number of factors including weather, soil fertility, agronomic practices, or other factors. However, an interesting observation was that hybrid 1 was more sensitive to growth location for FPE yields (variation of 13.6% compared with 6.3% for hybrid 2), St:E yields (variation of 5.5 compared with

TABLE I
Corn Hybrids and Growth Locations for Three Commercial Seed Corn Companies

Growth Locations	Hybrids
Experiment 1	
Company 1	
A, Iowa	A-1, A-2, A-3, A-4, A-5, A-6, A-7, A-8, A-9, A-10, A-11, A-12, A-13, A-14, A-15, A-16
Experiment 2	
Company 1	
A, Iowa	A-1, A-2
J, Iowa	A-1, A-2
M, Iowa	A-1, A-2
C, Illinois	A-1, A-2
M, Illinois	A-1, A-2
P, Illinois	A-1, A-2
M, Missouri	A-1, A-2
Nh, Pennsylvania	A-1, A-2
Np, Nebraska	A-1, A-2
Y, Nebraska	A-1, A-2
Uc, Tennessee	A-1, A-2
W, Indiana	A-1, A-2
Company 2	
P, Ontario	B-1, B-2
L, Ontario	B-1, B-2
J, Wisconsin	B-1, B-2
S, Minnesota	B-1, B-2
R, Illinois	B-1, B-2
Company 3	
H, Iowa	C-1, C-2
C, Nebraska	C-1, C-2

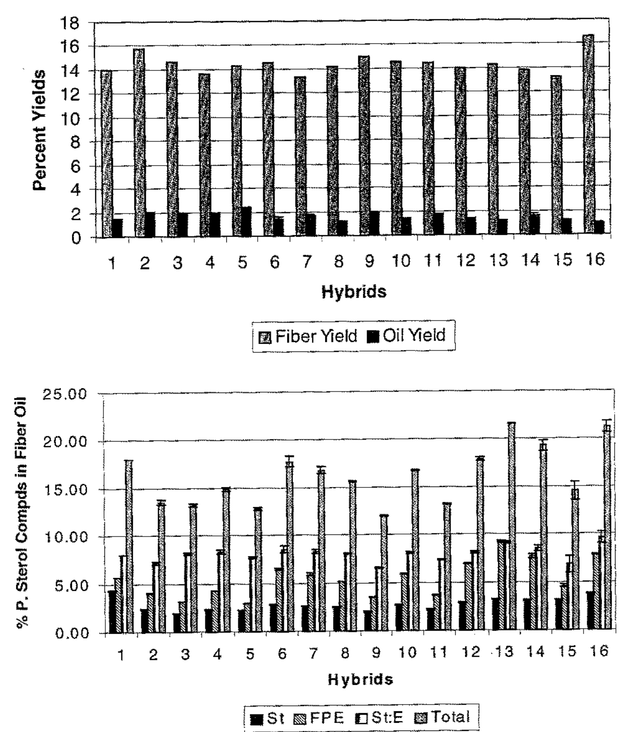

Fig. 1. Fiber, oil, and percent phytosterol compounds in oil of 16 corn hybrids from Company 1 grown at location A in Iowa. St = free phytosterols, FPE = ferulate phytosterol esters, St:E = phytosterol fatty acyl esters.

2.6% for hybrid 2), and St yields (variation of 2.5% compared with 0.9% for hybrid 2). These results suggest that sensitivity of the hybrids (for the amounts of phytosterol compounds) for the same growth location varies. Using wet-milling to recover fiber, followed by extraction of phytosterol compounds from the fiber, it is possible that certain hybrids can be identified which have high yields of phytosterol compounds and are less sensitive to growth location (in other words, low variation in the yields for the same phytosterol compounds with growth location). Significant variations in the amounts of FPE, St:E, and St with growth location were observed for hybrids from Company 2 (Fig. 4) and Company 3 (Fig. 5).

When the phytosterol composition of two of these hybrids were plotted for all growth locations, some interesting results were observed. The plot (Fig. 6) of hybrids 1 and 2 from Company 1 indicates that a hybrid that gave a high yield of FPE compared with the other hybrid for a particular growth location would likely have a high yield of FPE for all of the other growth locations, even if the magnitude of the yield (for all of the hybrids) was affected by the environment or other factors. The same trend was observed in 11 of the 12 locations for St:E and St yields for the hybrids from Company 1. Moreover, for the one location for which hybrid 2 gave a higher yield for St:E and St, the difference in the yield was not very big (<1%). Similar trends were observed for phytosterol compounds in corn fiber oil for hybrids from Companies 2 and 3 (data not shown).

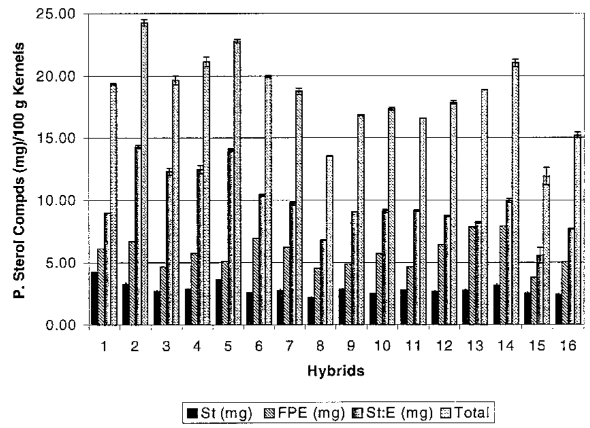

Fig. 2. Ferulate phytosterol esters (FPE), free phytosterols (St), phytosterol fatty acyl esters (St:E), and total phytosterol compound yield of 16 corn hybrids from Company 1 grown at location A in Iowa.

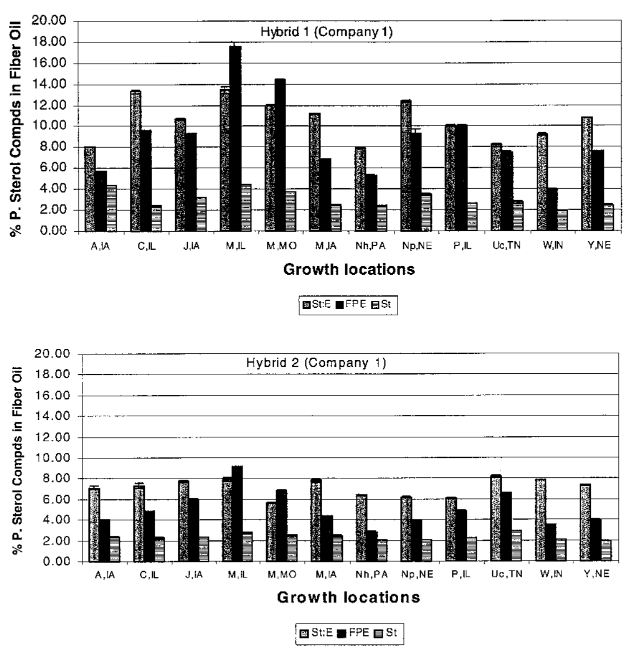

Fig. 3. Percent phytosterol compounds in fiber oil of corn hybrids 1 and 2 (A-1 and A-2) from Company 1 grown at 12 locations in the United States. St = free phytosterols, FPE = ferulate phytosterol esters, St:E = phytosterol fatty acyl esters.

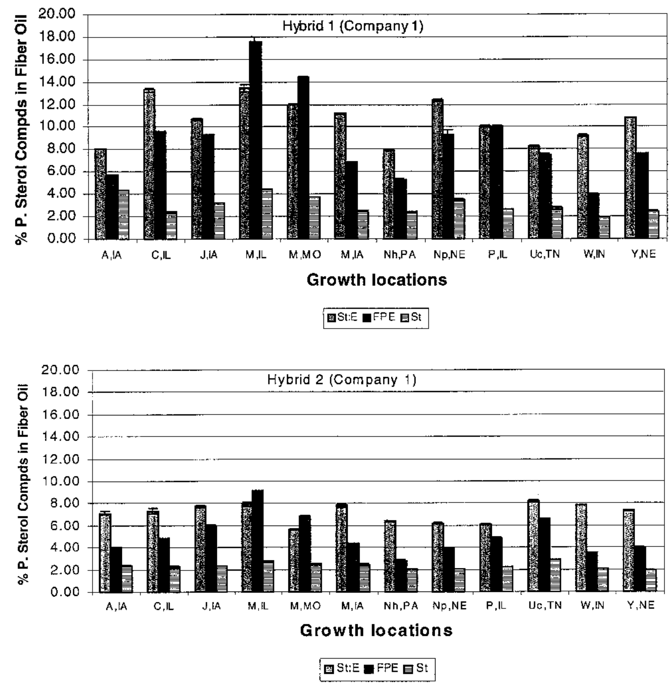

Fig. 4. Percent phytosterol compounds in fiber oil of corn hybrids 1 and 2 (B-1 and B-2) from Company 2 grown at two locations in Canada and three locations in the United States. St = free phytosterols, FPE = ferulate phytosterol esters, St:E = phytosterol fatty acyl esters.

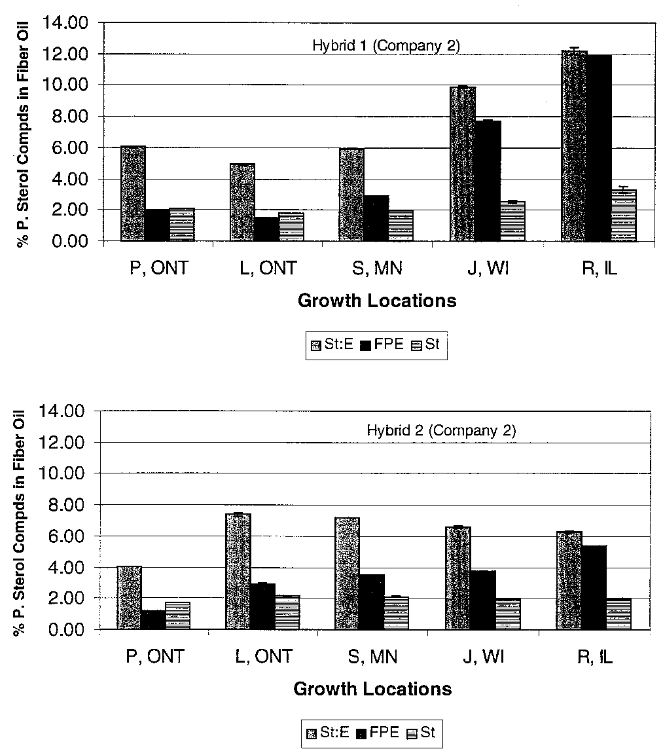

Fig. 5. Percent phytosterol compounds in fiber oil of corn hybrids 1 and 2 (C-1 and C-2) from Company 3 grown at two locations in the United States. St = free phytosterols, FPE = ferulate phytosterol esters, St:E = phytosterol fatty acyl esters.

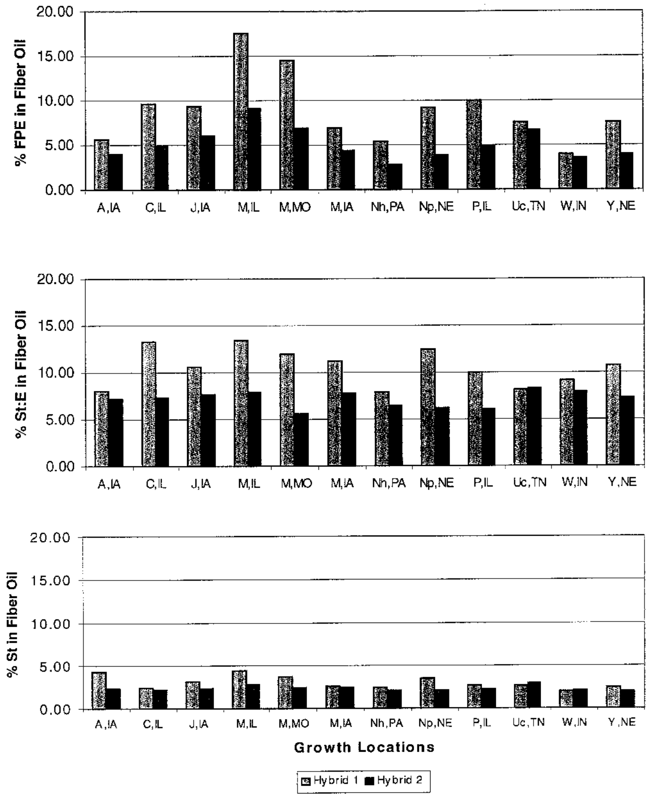

Fig. 6. Comparison of corn hybrids 1 and 2 from Company 1 for yields from 12 locations. St = free phytosterols, FPE = ferulate phytosterol esters, St:E = phytosterol fatty acyl esters.

CONCLUSIONS

Significant variation was observed in commercial corn hybrids in the amount of oil extracted and the levels of phytosterol compounds in the oil. Depending on the hybrid, the values were 0.9–2.4% for oil extracted from the fiber; 2.9–9.2% FPE in the oil; 6.5–9.5% St:E; and 1.9–4.3% St. No significant correlation was observed between the fiber and the oil yields. Positive correlations were observed among the three phytosterol compounds (R = 0.75 for FPE and St:E; R = 0.48 for St:E and St; and R = 0.68 for FPE and St). A strong negative correlation was observed between the corn fiber oil and the FPE yield (R = –0.75). Negative correlations were also observed between oil content and St:E yield (R = –0.50) and between oil content and St (R = –0.66) yield. This variation in commercial corn hybrids indicates that hybrid-specific processing should be done to maximize the yields of these phytosterol (cholesterol-lowering) compounds from corn. Effect of growth location was also significant. The same hybrids grown at different locations showed values of 4.0–17.5% for FPE, 4.9–12.2% for St:E, 1.95–4.45% for St, and 15.1–35.4% for total phytosterol composition.

The relative rankings of the hybrids with respect to phytosterol compounds were consistent for most of the growth locations, although the magnitude of the yields was affected by environmental or other factors. In other words, if a hybrid gave a high FPE, St:E, or St yield (compared with another hybrid) at one location, it would also give a high FPE, St:E, or St yield (compared with the other hybrid) for most of the other growth locations.

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