RAPID COMMUNICATION

Effect of Stress Cracks on Corn Wet-Milling Yields

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ABSTRACT

U.S. No. 2 yellow dent corn was randomly probe-sampled from rail cars being shipped to a wet-milling plant from a Corn Belt local elevator. The probe samples were blended together and kernels were sorted into four levels of stress cracks (0, 1, 2, or multiple). Each level of stress cracking was then laboratory wet-milled in triplicate. The only statistically observed differences were in total fiber and in protein content of the gluten meal fraction. The starch yield difference between zero stress cracked corn and multiple stress cracked corn was smaller (0.8%) than would be expected if stress cracking were an indicator of damage to the wet-milling characteristics of the corn.

In the United States, corn (*Zea mays* L.) is usually harvested at moisture contents of 18–25%. In recent years, the dry-down rate of most commercial hybrids has increased to where the average harvest moisture has decreased. However, the producer's desire for a timely harvest, and periodic early frost or wet fall weather necessitate high-temperature drying of at least some of the corn harvest at high moisture. According to a U.S Grains Council producer survey (Anonymous 2001), >50% of the corn dried on-farm is dried at temperatures that exceed the gelatinization temperature of starch (>70°C). The combination of high drying temperatures and high harvest moisture often occurring early in the harvest period can create a grain quality problem.

When corn is dried too quickly, it creates internal endosperm stress cracks in the individual kernels (White et al 1982; Song and Litchfield 1991). Highly stress-cracked corn breaks more easily during handling and shipping, lowering the grade at the destination from that at the origin (Gunasekaran and Muthukumarappan 1993). Studies have also shown that high-temperature-dried corn with high levels of stress cracks may lead to lower starch yields in a wet-milling process (Weller et al 1988). During high-temperature drying, denaturation of proteins and gelatinization of starch may occur inside the corn kernels, making starch-protein separation difficult during wet milling. The result is low starch yields and elevated amounts of protein in the starch fraction (Wichser 1961). At the same time, the protein content of the gluten (protein) fraction is reduced, consequently reducing its value.

Stress cracking occurs in corn during high-temperature drying but it can also occur naturally during field dry-down or low-temperature drying. Generally, the more severe the drying method, the higher the percentage of stress crack kernels and the more likely an individual kernel will have two or more stress cracks. Over a five-year study, stress cracks averaged ≈18% for low-temperature-dried corn compared to 36% for elevator commodity corn, which is corn dried by a variety of methods (Anonymous 2001). In the same report, low-temperature-dried corn from the 2000 crop year averaged 3.9% single stress cracked kernels, 1.5% double stress cracked kernels, and 2.0% multiple stress cracked kernels compared to 5.2, 3.6, and 10.3% single, double, and multiple stress cracked kernels, respectively, for the elevator commodity corn. Seventy-five percent of the low-temperature-dried samples had no multiple stress cracked kernels, compared with only 11% of the elevator samples. Multiple stress cracks may be a good indicator of damage caused by excessive drying temperature. The objective of this study was to evaluate the wet-milling characteristics of different levels of stress cracks in yellow dent commercial corn.

MATERIALS AND METHODS

Sampling and Sample Preparation

U.S. No. 2 yellow dent corn was randomly probe-sampled from rail cars being shipped to a wet-milling plant from a Corn Belt local elevator. The probe samples were blended together in the laboratory and reduced to a 5-kg composite sample using an FGIS approved divider. The sample was sealed in double plastic bags and stored in a cold room (5°C) waiting further testing.

Before milling, the sample was analyzed for stress cracks and categorized according to the procedure described by Thompson and Foster (1963). One modification of the procedure in this study was that a fluorescent light board table was used instead of the incandescent light box Thompson and Foster used. Stress crack categories or treatments were determined for each sample and labeled accordingly. Those kernels with no stress cracks were designated "0", those with one or single stress cracks were designated "1", those with two or double stress cracks were designated "2", and those with more than two or multiple stress cracks designated "M". Sample size in each stress crack treatment was at least 400 g. Most of the multiple stress crack kernels were "checked," that is, at least two stress cracks were either touching or crossing each other.

Wet Milling

From each stress crack treatment (0, 1, 2, and M), a portion of the sample was analyzed for total starch content using a near infrared (NIR) instrument with proprietary calibration. The samples were then wet-milled in triplicate using a laboratory-scale milling procedure (Eckhoff et al 1996). The separated fractions, which included starch, gluten, germ, steepwater solids, and fiber, were dried and weighed to determined percent yield.

Protein Analysis

Protein content of starch, gluten, and steepwater solids fractions were analyzed by the Kjeldahl reference procedure (AOAC 1984).

Statistical Analysis

Data were analyzed using analysis of variance (ANOVA) and the Tukey multiple range tests. All statistical analyses were performed at 95% significance level ($P < 0.05$).

RESULTS AND DISCUSSION

Test results showed a trend toward a slight starch yield decrease (0.8%) in the yellow dent corn as kernel stress cracks increased from 0 to M. However, statistically, the differences were not signi-

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TABLE I
Means of Wet-Milling Product Yields and Protein Contents of Starch, Gluten, and Steepwater (SW) Solids Fractions from Stress-Cracked U.S. No. 2 Yellow Dent Commercial Corn

Level of Stress Cracks[a]	Starch (%)		Yield (%)				Protein Content (%)		
	Yield	Recovery	Gluten	SW Solids	Germ	Total Fiber	Starch	Gluten	SW Solids
0	66.5	95.9	12.6	3.92	5.14	11.0b[a]	0.51	40.7a	37.6
1	66.8	96.3	13.4	3.96	5.12	11.1ab	0.53	40.1a	38.7
2	65.7	94.8	12.2	3.96	4.96	11.4ab	0.61	37.7b	39.3
M	65.7	94.8	12.8	3.91	5.77	11.6a	0.65	36.7b	41.8
LSD	1.5	2.2	1.6	0.12	0.83	0.48	0.25	1.9	8.5

[a] Stress cracks: 0, 1, 2, or M (multiple).
[b] Values followed by the same letter are not significantly different ($P < 0.05$).

ficant (Table I). Similar observations were made for starch recovery, defined as the ratio of extracted starch to the total amount of starch present before wet milling. The 0.8% decrease in starch yield is near the minimum level of detectible difference for the milling procedure used, based on weekly replicated samples. In 1998 through 2000, over 100 replicated weekly samples averaged a standard deviation of 0.46% on starch yield (Y. X. Niu, *personal communication*). The starch yield difference between 0 stress cracked corn and M stress cracked corn was smaller than would be expected if stress cracking were an indicator of damage to the wet-milling characteristics of the corn. Singh et al (1997) and other researchers reviewed by Eckhoff (1993) showed that high-temperature drying could affect starch yield by up to 30 percentage points. In this study, 100% multiple stress cracked kernels showed a decrease of <1 percentage point. From this it can be concluded that the mechanisms that cause stress cracks do not strongly correlate with the mechanisms that result in starch yield loss. Percent stress cracked kernels and the extent of stress cracking (multiple stress cracks) does not appear to be a sensitive indicator of drying damage to the wet-milling characteristics of corn. It may be true that the lack of stress cracks or of multiple stress cracks may indicate good retention of kernel wet milling characteristics, but such a conclusion cannot be made from this data.

Statistical differences were observed in total fiber and the protein content of the gluten meal fraction. In the total fiber fraction, statistical differences were observed between the zero and multiple stress crack levels. Although not statistically different, the 1 and 2 stress crack levels have intermediate values that show an increasing trend as stress cracks increase. The gluten meal fraction yield varied from 12.2 to 13.4% but the differences were not statistically significant. The protein content of the gluten meal fraction decreased from 40.7 to 36.7% as the stress cracks increased from 0 to multiple. Both the observed trend in total fiber and protein content of the gluten are consistent with high-temperature-drying damage. When starch is damaged by high-temperature drying, the starch granules tend to partially gelatinize and, as a result, swell and decrease in density. These lighter density granules end up with the gluten fraction, decreasing gluten protein content. An increase in total fiber is often also seen in high-temperature-dried corn, probably a result of protein denaturation.

No other yields or protein content of the fractions were statistically significant, although the protein content of the starch and steepwater solids showed an increasing trend as stress cracks decreased. The increase in the protein content of the starch is what would be expected from high-temperature drying. However, the standard error of measurement was too large to observe significant differences.

CONCLUSIONS

Percent stress cracked kernels and the extent of stress cracking (multiple stress cracks) is not a sensitive indicator of drying damage to the wet-milling characteristics of corn.

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