Dry Milling and Physical Characteristics of Alkali-Debranned Yellow Dent Corn

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ABSTRACT

The physical characteristics and dry-milling performance of alkali-debranned and untreated yellow dent corn were compared using standard laboratory procedures. The debranned corn had approximately the same amount of protein and oil but half the crude fiber content of the untreated corn. The yields of No. 5, 7, and 10 grits were much higher for debranned corn than for untreated corn, with the milling evaluation factor for debranned corn at 454, compared to 277 for the untreated corn. Debranned corn degermed much faster, resulting in cleaner and easier separation of germ. Although the germ fraction obtained from the debranned corn was lower in yield, it was higher in oil content and thus 35% less germ would be required to extract the same amount of oil as from untreated corn. The crude fiber content of grits and germ fractions obtained from debranned corn was 40–50% less than that obtained from untreated corn. The bran obtained by debranning the corn contained more crude fiber than that contained in the hull obtained by aspiration of untreated dry-milled corn.

Tempering of corn for dry milling is performed to soften the pericarp and the germ for easy removal during degermination. The pericarp is separated from the endosperm and germ fractions by aspiration. However, some pericarp and endosperm remain attached to the separated germ. Efforts to obtain cleaner endosperm and germ products often result in fewer flaking grits and broken germ and thus in decreased oil recovery.

Several pretreatments or tempering steps have been developed for corn to improve the yield of premium flaking grits and to enhance oil recovery from the germ (Brekke 1965, 1966, 1967, 1968). Earlier pretreatment procedures tested included alkali treatment before degermination to improve the effectiveness of tempering (Wagner 1942, Hansen 1949). Such alkaline pretreatments were developed to debran corn and utilize the bran-free corn for further processing. The advantages touted for such a process included higher oil yield, more grits, and a reduction in the number of aspirators and roller mills and in the overall cost of processing. In these alkaline process patents, no data or information on the dry-milling performance of the debranned corn was published. Weinecke (1962) treated corn with 0.1% sodium hydroxide and degermed it to increase the yield of larger unchecked grits and germ. In the first two studies (Wagner 1942, Hansen 1949), corn was debranned but not tested for dry-milling performance; in the second study (Weinecke 1962), corn was not debranned, but only dry milling characteristics were studied using the pretreatment.

The objective of this work was to obtain debranned corn using an alkaline treatment and to study and compare the physical characteristics and dry-milling performance of the debranned and untreated yellow dent corn.

MATERIALS AND METHODS

Materials

Untreated corn. Yellow dent corn of a medium hard variety (FR1141×FR4326) was obtained locally from the 1989 crop. The corn was dried in a forced draft air dryer (Blue-M, model Pom-256c-2, airflow 80 ft/min) from 20% to 12–13% moisture (wet basis) at room temperature (25°C). The product was screened over a 6.35-mm screen and handpicked to remove foreign material and broken corn. The dried, clean corn was placed in moisture-proof bags, sealed, and stored at room temperature.

Alkali-debranned corn. The debranning process used was a modified form of a process developed by Blessin et al (1970). The dried and cleaned corn (100 g), as mentioned above, was soaked in 200 ml of a 6% sodium hydroxide solution at 57°C for 8 min. It was then rinsed free of alkali and placed in a hydro-abrasor for debranning. The hydro-abrasor consisted of a plastic bristle brush rotating at 160 rpm over a 4-mesh, 150-mm (in diameter) circular screen with a continuous water spray. The peeled bran was washed through the 4-mesh screen and collected over a 100-mesh screen below. The water was recirculated until all the corn was free of bran (generally 3–5 min). The bran was dried and the corn was used for dry milling.

Dry milling. Four corn samples were drawn from the dried, clean corn. Two samples were used as untreated corn and were dry milled separately using identical procedures as described below. The other two samples were debranned individually to obtain debranned corn. The wet debranned corn samples were dry milled separately using the procedure described below.

Untreated corn. A standard milling procedure was developed after preliminary tests to establish the proper method of tempering and feeding the degermer and to determine proper separation procedures. The following procedure was used for the milling studies, and the results expressed are the average of two independent runs.

A 500-g sample of untreated corn was pretempered to 16% moisture for 14–16 hr. This was necessary because the sample was stored at low moisture (12% wb) and to reduce stress crack formation during tempering (Brekke 1967). After pretempering, the corn sample was sealed in a plastic bag and tempered in two steps (Eman et al 1981). First, distilled water was sprayed on the corn to bring the moisture content to 21%. After the corn had been tempered for 1.75 hr, additional water was sprayed on the corn to bring it to 24% moisture. The corn was tempered for 15 min and degermed in a laboratory horizontal drum degermer. Details of this degermer's construction and operation were published previously by Brekke et al (1971, 1972). The degermer was operated at a set speed, and corn was gravity-fed to the mill through a hopper. Milling time was recorded for each sample.

After degermination, the product was screened for 30 sec on a 3½-mesh sieve and then aspirated to remove hulls. The material remaining on the 3½-mesh sieve was passed a second time through the degermer and then combined with the product from the first pass. The combined material was dried in a 45°C dryer for 1 hr to a moisture content of 17.0 ± 1% (wb). The dried stock was separated by screening over 5-, 7-, and 10-mesh sieves for 2 min using a rotary screen shaker. The 5-, 7-, and 10-mesh fractions were floated in a sodium nitrate solution to separate the lighter germ pieces from the denser endosperm (Brekke et al 1961). For overs from the 5- and 7-mesh sieves, the solution was adjusted to a specific gravity of 1.275, and for the stock

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over the 10-mesh sieve, a 1.220 specific gravity was used. All fractions were weighed at each step before and after fractionation.

A milling evaluation factor (MEF) was calculated using the following equation:

$$MEF = \frac{\text{Grits}}{\text{Thrus of 10W}} \times (\text{Grits} + \text{Thrus of 10W})$$

where grits = (grit over 5W) + (grit over 7W) + (grit over 10W).

This factor is similar to the MEF presented by Eman et al (1981). However, since he used a complete milling process, he included factors for the amount of flour and meal produced.

Debranned corn. The normal moisture content of debranned corn following debranning was 24% (wb). Preliminary milling tests conducted on debranned corn dried to 16% mc (wb) following debranning resulted in poor dry-milling performance. The yield of large grits (>10W) was low, and all endosperm fractions contained small germ pieces. The germs had attached endosperm pieces, which resulted in poor germ separation. Holding the debranned corn for 1 hr following debranning was found to be a better procedure. It resulted in a higher yield of large grits with germs free of attached endosperm pieces. The germs were not broken into pieces and thus were easily separated. The same milling and separation procedure was used for debranned corn as described for untreated corn.

Sample Analysis

Samples were obtained from the debranned corn and dried from 24% moisture to approximately 12.5% moisture using a forced-draft oven at 25°C. The dried debranned corn and the untreated corn were analyzed in duplicate to determine physical and chemical characteristics.

Untreated and debranned corn were analyzed for moisture content according to the ASAE Standard 5352.1 (ASAE 1984) by oven-drying at 103°C for 72 hr. Test weight was determined using a Boerner test weight apparatus (USDA 1953). Kernel hardness was measured using the floater test, and true density was determined using the ethanol column test. Procedures for these tests are described in Paulsen and Hill (1985).

The untreated and debranned corn samples and the dry-milled germ, grit (+5W, +7W, and +10W), and 10W thrus fractions obtained from both types of corn were sent to a commercial laboratory for analysis of moisture (AOAC 1980, 14.002), protein (AOAC 1980, 14.068), fiber (AOAC 1980, 14.020), ash (AOAC 1980, 14.006), pH (AOAC 1980, 14.022), and oil (AOAC 1980, 14.019). All the data expressed were calculated on a corn dry-weight basis.

The data on characteristics and composition of corn, milled fractions, and milling yields were statistically analyzed (Steel and Torrie 1980) to determine the least significant difference between the untreated and debranned corn at a 5% significance level.

RESULTS AND DISCUSSION

The composition and physical characteristics data (Table I) show that debranned corn has approximately 45% less crude fiber than the untreated corn. The protein and oil contents of the debranned corn were higher than that of the untreated corn. This is because of the relative increase in the proportion of corn endosperm components by removal of pericarp. The debranned corn also had a higher ash content, due to absorption of alkali during the debranning process. An increase in the pH of the debranned corn also indicated absorption of alkali during debranning.

The test weight for debranned corn at similar moisture content was significantly lower than that of untreated corn. The removal of pericarp by the alkali-debranning process removes the smooth waxy layer from the surface of the kernel. This resulted in uneven packing of corn kernels and more void spaces in the test-weight measurement container. However, the true density of the debranned corn was higher than that of the untreated corn. This was because of the removal of the low-density pericarp layer from the corn. The debranned corn had a lower number of floaters than the untreated corn. The removal of the pericarp and increase in the density may have caused the corn to sink.

Debranned corn required less time to degerm than the untreated corn (Table II). This indicated that using debranned corn can increase the capacity or throughput of the particular degerminator used in this study. Debranned corn (Table II) had a higher yield of grits over mesh sizes 5, 7, and 10 and a lower yield of thrus of the 10W fraction. The germ yield was considerably lower for debranned corn. A small amount of pericarp product was obtained from the aspirator, which consisted of tip caps and the hylar layer of the kernels not removed during the debranning process. The higher MEF value for debranned corn indicates a better milling performance (Brekke 1970).

It was observed that the grits obtained from the debranned corn had a size and shape configuration similar to that of grits from untreated corn. However, the grits from debranned corn were slightly dull and more yellow than the untreated corn. This was because of the exposure of the pigment-rich aleurone layer after debranning. Although no formal organoleptic evaluation was performed on the dry-milled fractions, the preliminary sensory testing indicated similar odor and taste characteristics for the untreated and debranned corn. There was no objectionable odor in the grits or germ fractions. The fractions had a slightly alkaline taste, similar to that of alkaline-cooked corn products.

Corn oil extracted from the germ is a valuable product. However, when germs are not fully separated from the endosperm in the degerminator, a dry miller not only loses oil yield but also runs the risk of having excessive oil in the grit, meal, and flour products. Ideally, the grit oil content should be 0.4–0.6% to be considered to have complete germ and hull separation. This was true for the oil content of grit from the debranned and the untreated corn (Table III). However, the oil content of debranned grits over mesh sizes 7 and 10 was slightly higher than that of

TABLE I
Comparison of Corn Composition and Physical Characteristics of Debranned Corn and Untreated Corn[a]

	Untreated	Debranned	LSD[b]
Oven moisture, %	12.60	12.96	0.69[c]
Protein, % (as-is basis)	7.24	7.49	0.19
Oil, % (as-is basis)	3.14	3.38	0.06
Crude fiber, % (as-is basis)	2.29	1.24	0.15
Ash, % (as-is basis)	0.12	1.27	0.24
pH	6.59	8.06	0.10
Test weight, lb/bu	60.3	55.16	0.53
True density, g/cm^2	1.276	1.297	0.012
Floaters, %	50	39	7

[a]Data represent average of four determinations.
[b]Least significant difference at 5% significance level.
[c]No significant difference.

TABLE II
Dry Milling Performance[a] and Yield of Dry-Milled Fractions of Untreated and Debranned Corn

	Untreated	Debranned[b]	LSD[c]
Time to degerm corn in degermer (sec)	19.56	8.95	0.15
Grit yield, %			
Over 5W	34.34	36.09	1.17
Over 7W	22.16	31.51	1.23
Over 10W	6.55	7.63	1.31
Germ yield, %	24.05	19.35	1.53
Thrus of 10W, %	17.06	14.93	0.37
Hull, %			
Obtained by aspiration	5.21	0.69	0.15
Obtained by debranning	···	4.50	···
MEF[d]	277	454	34

[a]Data represent average of two independent runs.
[b]Yields based upon dry corn weight before debranning.
[c]Least significant difference at 5% significance level.
[d]Milling evaluation factor.

TABLE III
Oil Content of Dry Milled Fractions and Oil Yield from Untreated and Debranned Corn[a]

	Untreated	Debranned	LSD
Grit, % db			
Over 5W	0.52	0.54	0.10[b]
Over 7W	0.44	0.54	0.06
Over 10W	0.45	0.52	0.05
Thrus of 10W, % db	0.57	0.90	0.10
Germ, % db			
Over 5W	14.24	20.35	0.31
Over 7W, 10W	5.36	10.58	0.17
Total oil (%) in germ fraction	83.41	83.34	6.35[b]
Pounds of oil from 100 lb of germ	12.38	16.71	0.19
Hull, % db			
Obtained by aspiration	<1.0	···	···
Obtained by debranning	···	0.49	···

[a]Data represent average of four (two determinations on each of the two independent dry milling runs).
[b]No significant difference at 5% significance level.

TABLE IV
Crude Fiber Content of Dry-Milled Fractions from Untreated and Debranned Corn[a]

	Untreated	Debranned	LSD
Grit, % db			
Over 5W	0.99	0.46	0.17
Over 7W	0.73	0.45	0.15
Over 10W	0.86	0.56	0.03
Thrus of 10W, % db	1.90	1.79	0.43[b]
Germ, % db			
5W	5.98	3.26	0.23
7W, 10W	2.44	1.22	0.06
Hull, % db			
Obtained by aspiration	76.00	···	···
Obtained by debranning	···	92.16	···

[a]Data represent average of four (two determinations on each of the two independent dry milling runs).
[b]No significant difference at 5% significance level.

untreated grits. The higher oil content of corn after debranning translated into slightly higher oil content in the grits. The germ fraction from debranned corn was considerably higher in oil content, indicating minimum breakage of germ into the endosperm product and cleaner separation. Thus, debranned corn gave better and cleaner separation of germ from the endosperm with increased oil yield from the germ fraction. Data analysis (Table III) indicates that to extract the same amount of oil, 35% more germ would be required from the untreated corn than from the debranned corn. This can reduce the extraction cost and save time and effort required in oil refining operations. No attempts were made to optimize the degermination process or equipment for debranned corn. Optimization may result in even better germ separation.

The crude fiber content is a fair indication of the amount of pericarp present in a particular product. As indicated in Table IV, the crude fiber content of grits and germ fractions was drastically reduced (40–50%) because of debranning. The bran fraction obtained by alkali debranning had higher crude fiber content, meaning cleaner separation of hulls containing less endosperm product. Lower crude fiber content in raw material corn translates into less aspiration and processing of the dry-milled fraction and, thus, lower costs and product losses.

CONCLUSIONS

The alkali-debranned corn had similar protein and oil content but half the crude fiber content of untreated corn. The debranned corn, when dried following debranning, had undesirable dry-milling performance. However, tempering the debranned corn following debranning at 24% moisture content (wet basis) for 1 hr and degerminating resulted in a higher yield of large grits and increased oil recovery from the germ than was obtained from untreated corn. The debranned corn degermed faster than untreated corn. The grits and germ fractions obtained from debranned corn had half the crude fiber content of untreated fractions. To obtain the same amount of oil, 25% less germ from the debranned corn would be required than from untreated corn. The dry milling of debranned corn required short tempering and less processing, eliminated some apparatus used for aspiration, and at the same time resulted in cleaner, better-quality end products with higher yields.

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