Wet Milling of Soft-Endosperm, High-Lysine Corn Using Short Steep Times

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ABSTRACT

Soft-endosperm, high-lysine corn was steeped for 8, 12, 18, 24, and 36 hr with 0.2% sulfur dioxide and 0.55% lactic acid at a temperature of 51°C. Laboratory wet-milling procedures were used to fractionate corn and determine product yields. As steep times decreased, the first grind required increased energy input to achieve germ separation. Shorter steep times resulted in less soluble protein release from the germ and less starch release during first grind. Even at short steep times, the germ separated cleanly with good recovery. Results of fiber separation on a Kason Vibroscreen and starch tabling were not substantially different from those of normal dent corn. As steep times decreased, there were: less solids in the steepwater, increased germ yield, constant starch yield, constant starch protein content, increased gluten protein content, increased filtrate solids, and decreased total solids released into process water. Even at 8-hr steep time, starch with less than 0.6% protein was obtained, indicating that an 8-hr steep is sufficient for soft-endosperm, high-lysine corn.

Steeping is a diffusion-limited process. The time required for adequate steeping depends on kernel hardness. Horny endosperm is denser than floury endosperm (Dimler 1966), causing slower diffusion of steepwater in horny endosperm. Watson and Hirata (1954) found that horny endosperm was more difficult to steep because of thicker strands of protein in the protein matrix that were not easily disrupted.

Many researchers have attempted to reduce the time required for steeping by increasing the rate of diffusion. Eckhoff and Tso (1991), using gaseous SO_2, were able to reduce steep times from 36 to 12 hr. Mistry and Eckhoff (1991) developed an alkali-debranning process where the pericarp was chemically removed. The debranned kernels hydrated faster due to reduced diffusional barriers. Gunasekaran and Farkas (1988), investigating the use of high-pressure steeping to reduce hydration time, found that 1,400 psi applied for 5 min, followed by atmospheric steeping, considerably shortened the time required to hydrate corn. The use of a soft-endosperm corn may allow for shorter steep times with the advantage of not requiring a change in present steeping technology.

Wet milling of high-lysine corn has been conducted by Dimler (1966) and Watson and Yahl (1967). They observed greater loss of solids in the steep and process water and higher levels of protein in these fractions. These observations are indicative of oversteeping. The 48-hr steep times used in both studies were too long for the totally soft-endosperm, high-lysine corn used by both researchers. Reducing steep times for a soft endosperm, high-lysine corn should lower solubles released while still allowing for sufficiently rapid diffusion of SO_2 into the endosperm for protein matrix dispersion.

The objectives of this study were to determine the yields and composition of the wet-milling products resulting from steeping soft-endosperm, high-lysine corn using reduced steep times and to evaluate the milling characteristics and advantages of short-steeped high-lysine corn.

MATERIALS AND METHODS

The soft-endosperm, high-lysine corn, Crow Hybrid SL 75, was grown at the Crow Hybrid Seed Corn Co. research farm in Milford, IL, during the 1991 growing season. The corn was dried using low-temperature air. Wet milling was performed using the procedures of Eckhoff et al (1991). The corn was batch-steeped using 0.55% lactic acid and 0.2% sulfur dioxide. After the steepwater was drained from the corn, the volume occupied by the swelled kernels was measured. First grind was performed in a Waring Blendor (Dynamic Corp., New Hartford City, CT) with power input to the blender controlled to maximize whole-germ release. Starch, from previous batches steeped for 8 and 12 hr, was added to the 8- and 12-hr steeped samples to increase specific gravity for germ floatation. Germ was hand-skimmed, and the remaining mash was finely ground in a Quaker City plate mill (Straub Co., Hatboro, PA). Fiber was separated and washed on a Kason Vibroscreen (Kason Corp., Linden, NJ). The remaining starch and gluten slurry was separated by tabling on a 20-ft H beam. Gluten that flowed off the tables was vacuum-filtered with Whatman No. 1 paper in a Buchner funnel.

Moisture contents of all fractions were determined by oven-drying (method S352.1, ASAE 1985). Proximate analysis of crude fat (Randall 1974), crude protein (method 7.033 with mercury catalyst, AOAC 1984), and crude fiber (method 32-15, AACC 1983) were performed at a commercial laboratory.

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TABLE I
Product Yields from Wet-Milled High-Lysine Corn at Various Steep Times

Steep Time (hr)	Product Yields (%, db)						
	Steep Solids	Germ	Fiber	Starch	Gluten	Filtrate Solids	Total
8	1.57 e[a,b]	8.40 a	7.53 b	64.07 a	12.18 a	5.52 a	99.26 b
12	2.59 d	8.32 ab	7.52 b	64.69 a	11.38 ab	5.06 b	99.55 a
18	3.67 c	8.13 b	7.53 b	64.46 a	11.69 a	4.45 c	99.92 a
24	4.35 b	7.87 c	7.47 b	64.94 a	11.17 b	3.89 d	99.69 a
36	4.89 a	7.64 c	7.69 b	64.16 a	11.72 a	3.16 e	99.25 b
Dent 36[c]	4.32 b	7.04 d	9.22 a	64.87 a	10.80 b	2.65 f	98.90 b

[a] Average of two replicates.
[b] Averages with the same letter within same column are not significantly different at a 95% confidence level.
[c] FR618 × LH123 dried at 50°C.

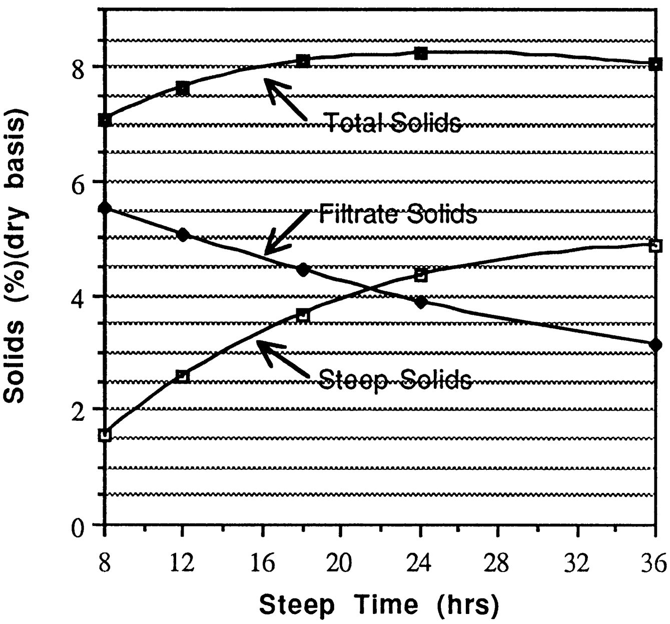

Fig. 1. Steepwater, filtrate, and total solids from wet-milled high-lysine corn at various steep times.

Steeping times were set at 8, 12, 18, 24, and 36 hr, and each treatment level was replicated. A medium dent corn (FR618 × LH123), dried at 50°C and milled using the same procedures, was wet-milled to serve as a comparison for the soft-endosperm, high-lysine corn. Data was analyzed using analysis of variance techniques and Duncan (1955) multiple range test to find significant differences between treatments.

RESULTS AND DISCUSSION

Yield and Composition

Reducing steep times significantly reduced the yield of steepwater solids and increased filtrate solids (Table I and Fig. 1). Less soluble solids leached from the kernels as steep time was reduced, and more solubles were released into the process water as the kernels were milled. The total solids released (steepwater plus filtrate water solids) decreased from 8.05 to 7.09% db as steep time decreased from 36 to 8 hr, respectively. The decrease was caused by less total time of exposure of the kernel and components to the steep and process water. At the 8-hr steep time the total solids released were not significantly different from FR618 × LH123, which is surprising because Dimler (1966) found that high-lysine corn yielded more solubles. The point at which solids are released is not critical to commercial wet milling because all water ends up in the steep tanks; however, the total amount of solids released is important.

The germ yield of high-lysine corn was significantly different at different steep times and was significantly different from FR618 × LH123 dent corn (Table II). The crude protein content of the high-lysine corn germ can be statistically grouped into short steep times (8 and 12 hr) and steep times closer to commercial times (18, 24, and 36 hr). Less soluble protein leached from the germ at short steep times, causing the higher yield and protein content in the germ. The germ of dent corn was significantly lower in protein content than the germ of high-lysine corn at all but the longest steep times. Crude fat, crude fiber, and total oil yield from the germ were nonsignificantly different.

TABLE II
Germ Yield and Composition at Various Steep Times

Steep Time (hr)	Germ Yield (%)	Product Composition (%, db)			
		Crude Protein	Crude Fat	Crude Fiber	Total Oil[a]
8	8.40 a[b,c]	19.50 a	36.18 a	13.59 a	3.04 a
12	8.32 ab	18.92 a	36.79 a	14.07 a	3.06 a
18	8.13 b	17.33 b	34.02 a	16.85 a	2.77 a
24	7.87 c	16.66 bc	37.15 a	16.99 a	2.92 a
36	7.64 c	17.03 bc	45.18 a	14.22 a	3.45 a
Dent 36[d]	7.04 d	16.04 c	41.52 a	16.43 a	2.91 a

[a] Germ yield × crude fat content.
[b] Average of two replicates.
[c] Averages with the same letter within same column are not significantly different at a 95% confidence level.
[d] FR618 × LH123 dried at 50°C.

Reduced steep times had no effect on fiber yield (Table I), although the fiber yield of high-lysine corn was significantly less than the FR618 × LH123 dent corn. The crude protein content of high-lysine corn fiber tended to increase as steep times decreased, probably due to more attached endosperm (Table III). Protein content of the dent-corn fiber was significantly lower than that of the high-lysine corn fiber. The fiber from the dent corn had crude fat content significantly lower than that of the 36-hr steeped high-lysine corn, but not from the other treatments, indicating more broken germ at the 36-hr steep condition.

Yield or protein content of starch was not affected by steep times (Tables I and III). One of the principal indicators of understeeped corn is poor protein separation from the starch granules. Even at an 8-hr steep time, starch contained less than 0.6% protein, indicating that an 8-hr steep is sufficient for this soft-endosperm, high-lysine corn. The protein content of starch from the FR618 × LH123 dent corn was significantly lower, indicating a more complete separation than that observed in the high-lysine corn. This is consistent with the findings of Watson and Yahl (1967), who showed that starch gluten separation is more difficult with high-lysine corn.

Gluten yield was not affected by steep time (Table I), although the protein content of the gluten was significantly lower for the high-lysine corn than for the dent corn (Table III) . The total protein (yield × percent of protein) in the gluten fraction was 3.57, 3.34, 3.30, 3.20, and 3.16% for 8, 12, 18, 24, and 36-hr steep times, respectively. The 8- and 12-hr steeps were statistically different from the 24 and 36-hr steeps (LSD = 0.14%). Shorter steep times resulted in significantly more protein recovered in

TABLE III
Fiber, Starch, and Gluten Composition at Various Steep Times

Steep Time (hr)	Product Composition (%, db)					
	Crude Protein			Crude Fat		Crude Fiber
	Fiber	Starch	Gluten	Fiber	Gluten	Fiber
8	13.36 a[a,b]	0.53 a	29.46 b	1.40 ab	4.06 a	15.16 a
12	12.93 a	0.58 a	29.41 b	1.46 ab	2.96 a	15.34 a
18	12.65 a	0.56 a	29.27 b	1.57 ab	2.94 a	14.57 a
24	12.32 a	0.49 a	28.70 b	1.23 ab	3.57 a	16.33 a
36	11.13 a	0.51 a	26.96 b	1.89 a	3.43 a	19.03 a
Dent 36[c]	9.88 b	0.24 b	35.41 a	1.12 b	3.07 a	15.38 a

[a] Average of two replicates.
[b] Averages with the same letter within the same column are not significantly different at a 95% confidence level.
[c] FR618 × LH123 dried at 50°C.

the gluten fraction. The dent-corn gluten had a higher protein content, again indicating a more complete separation of starch from gluten.

Wet-Milling Characteristics

The corn before and after steeping had appearance similar to normal dent corn. The percentage increase in volume of the kernels ranged from 50 to 56% ± 3.3%, and treatments were not significantly different. Watson and Yahl (1967) raised concerns about crown collapse from an underdeveloped endosperm, causing large increases in steeped volume compared to that of dent corn. This variety of high-lysine corn did not have a substantial difference in steeped volume as compared to that of dent corn.

The first grind for the 8- and 12-hr steeps required increased energy input to release germ from the kernel. The germ separated cleanly for all samples, with little germ damage. Germ skimming for the 8- and 12-hr steeps required starch addition to increase the Bé to 9.5–10. The germ floated well in the remaining treatments without added starch, and all samples were similar to normal dent corn with respect to germ separation.

Fiber separation and starch tabling of soft-endosperm, high-lysine corn were not different from that of normal dent corn separations, but there were differences in the amount of decant water required for starch tabling. Short steeps had less decant water because more soluble solids were released during milling, whereas longer steeps had more solubles released during steeping and less solubles released during milling and, therefore, less decant water.

Gluten filtering was rapid. The time to filter 3 L of gluten slurry ranged from 20 to 60 min. Average times to filter were 41.6, 38.7, 34.7, 35.8, and 45.8 min for steep times of 8, 12, 18, 24, and 36 hr, respectively. There was a wide variation in filtering times within each sample with no significant differences between treatments.

Economics

Decreasing the steep time from 36 to 8 hr resulted in more recovered protein in the gluten fraction; this will increase the amount of gluten meal, a by-product more highly valued than gluten feed. At a current market value of $240 per ton, the increased value amounts to 8.9¢ per bu.

In addition to increased gluten meal from traditional wet milling, there are other benefits of using soft-endosperm, high-lysine corn. Some commercial ethanol plants temper corn for 6 hr, grind, and recover the germ. The remaining corn fraction goes to the fermentation tanks for the production of alcohol. This high-lysine corn, steeped for 8 hr, can be fractionated into quality by-products, and the remainder can be fermented into alcohol. Another benefit of this corn would be for plant restart after maintenance. Some millers leave steeped corn standing in the tanks waiting for restart. This can lead to processing problems (poor starch separation and gluten filtering) when the plant comes back on line . The use of this high-lysine corn would allow the plant to have freshly steeped corn ready for milling in as little as 8 hr. Shorter steep times also increase the capacity of existing corn wet-milling plants, reduce capital requirements for construction of new plants, improve process control, and reduce in-plant inventory of corn.

CONCLUSIONS

Soft-endosperm, high-lysine corn, with steep times as short as 8 hr, can be fractionated into products with composition similar to 36-hr steeped dent corn. No significant processing differences exist between 8-hr and 36-hr steep times for soft endosperm, high-lysine corn. Total oil recovery at steep times less than 36 hr was decreased. An 8-hr steep time will yield soluble solids in the range of normal dent corn.

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