Corn Dry-Milling Studies: Shortened Mill Flow and Reduced Temper Time and Moisture[1]

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ABSTRACT

Experimental dry-milling studies on corn were conducted to establish a shortened mill flow that would reduce the number of operations in the milling process and provide raw materials for possible production of alcohol and/or starch. Results indicated that low-fat grits could be produced without going through the elaborate tempering and roller-milling procedures now used. Reducing corn temper moisture and temper time prior to degerming was shown to be feasible for production of low-fat grits, but the attached hull content was markedly increased when these conditions were used. For more refined uses of corn grits this would be objectionable, but for the applications suggested above some attached hulls should present few or no problems.

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Dry milling of corn produces refined endosperm in varying degrees of particle size, primarily intended for food uses. Principal products of dry milling include grits, meal, flour, germ (oil), and bran. The bran, defatted germ, and low-grade mill streams are combined to make a feed product. The procedures involved in manufacturing refined products, ie, low-fat grits with minimum attached hulls, require a sizable number of milling and separating operations that make the process somewhat complicated and energy intensive (Brekke 1970).

For some applications that utilize endosperm fractions derived from the corn dry-milling process, less refined products would be suitable. For example, lower grade endosperm particles could be used as raw material for alcohol and/or starch production. By applying a shortened mill flow, such fractions can be produced without going through the extensive roller-milling operations necessary for making more refined products. This concept is not new. Jahn (1971), Powell and McGeorge (1975), and Chwalek and Olson (1980) have outlined methodology for combining the corn dry- and wet-milling procedures for production of starch. Grits have been used for many years in the manufacture of beer and beverage alcohol products. More recently, petroleum shortfalls have stimulated a renewal of the manufacture of industrial alcohol from agricultural commodities. Currently, corn is the major source of carbohydrate for this purpose.

We have examined the corn dry-milling process to determine whether suitable fractions for the above purposes can be obtained through a mill flow that reduces the number of refining steps. We also have studied the effects of temper time and moisture on the endosperm products resulting from reduced mill flow.

MATERIALS AND METHODS

Materials

Commercially purchased No. 2 corn had the following chemical analyses: protein, 9.6% d.b.; crude fat, 4.1% d.b.; crude fiber, 2.2% d.b.; starch, 73.6% d.b.; and ash, 1.32% d.b.

Experimental Methods

An abbreviated corn dry-milling process was developed utilizing the NRRC experimental solid rotor machine as the corn degermer. This degermer has been described in detail by Brekke et al (1971), who showed that degerming results on 25-lb lots from using this machine compared favorably with those obtained from using commercial Beall degermers. Beall degermers are used in about 90% of the large U.S. corn dry mills.

The shortened mill flow is shown in Fig. 1. The corn is tempered to the desired moisture content and fed to the degermer. The broken corn particles are then sized by screening and aspirated, resulting in six fractions. Particles larger than 3½ mesh are recycled back through the degermer and amount to about 2%. The sized fractions, containing grits and germ particles, are further separated by a flotation procedure described by Brekke et al (1961), but sodium nitrate solution, sp. gr. 1.30, was used instead of a toluene-carbon tetrachloride mixture at 1.27 sp. gr. In commercial practice, gravity separators would be used for this separation. For the purpose of this study, we considered only the recovery of the −3½, +7 grits fraction because it includes the major products of the dry-milling process, amounting to about 63% of the corn. Other fractions include finer grits and flour (approximately 15%), a germ fraction (approximately 12%), and hulls (approximately 8%). Duplicate tests were made.

Analytical Methods

Protein (N × 6.25), crude fat, crude fiber, starch, and ash were determined according to AACC approved methods (1976). Moisture was determined by heating a 10-g sample in the Brabender Moisture Tester at 130° C for 60 min. Residual oil in fractions was analyzed by a gas-liquid chromatographic method developed by Black et al (1967). Hulls remaining attached to grit particles, expressed as weight percent of hulls per sample, was determined by visual inspection of individual grit particles in two 50-g replicates.

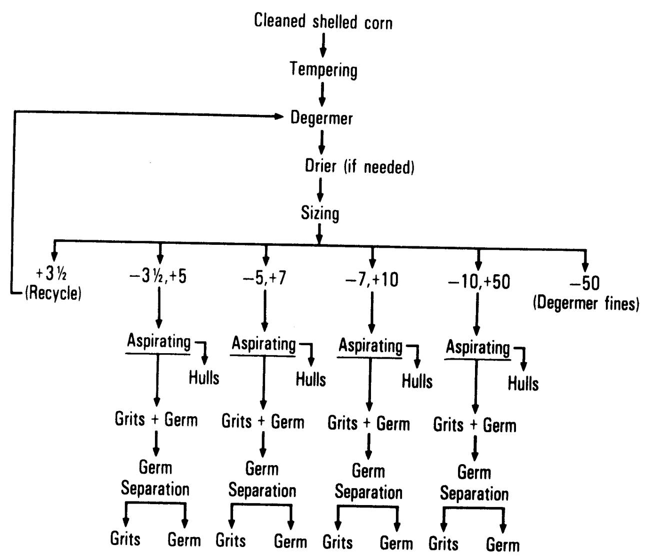

Fig. 1. Shortened flow for dry milling corn.

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The mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

RESULTS AND DISCUSSION

The development of an energy-efficient short-flow dry-milling system for corn depends largely on the elimination of certain milling operations and on the reduction of moisture added to the grain to condition it.

The shortened mill flow shown in Fig. 1 was designed to reduce the refining steps in a conventional corn dry-milling plant. Conventional operations involve passage of the degerminated grain through roller mills, followed by sifting, aspirating, and drying to produce the more refined products, such as flaking and brewers grits and corn meals. These products, which are used for food, have fewer attached hulls and generally contain less fat than the less refined products from the shorter flow.

In addition to the extended operations to recover refined dry-milled products, it is necessary to condition the corn by the addition of moisture. This generally is done in several stages, with the corn ultimately containing 21–24% moisture when it is finally processed. With this quantity of water present in the process, the resulting products will contain excessive moisture that must be removed to prevent product deterioration. This necessitates the use of driers and coolers to reduce product moisture to safe levels.

In our studies, we first examined the effects of the normal tempering sequence and some variations of temper time and moisture on products recovered from the shortened mill flow. Yield and characteristics of the major endosperm fractions are given in Table I.

The normal tempering sequence, in which moisture is added in three steps (ie, to 16% for 16 hr; to 21% for 1.75 hr; and to 23% for 15 min prior to milling), resulted in the best yield of large grits at the lowest fat content. The grits also had a low attached hull count. Oil in the germ was 22.1%. These results would be expected, on the basis of reported results, where extensive tempering is performed.

Tempering the corn in two steps, reducing the time from 18 to 2 hr and the moisture from 23 to 19.4%, gave essentially the same results as the previous test for degermer yield, grit recovery, and fat content of the grits. The oil content of the germ was slightly less, probably due to an increase in hulls remaining with the germ. The attached hull count of the grits was considerably increased.

When the corn was tempered in one step, increasing the moisture from 11.5 to 16% over a 20-hr period, there was an increase in the oil content of the large grits as well as a sizable increase in attached hulls on the grits. This also was noted in a test in which the grain was tempered to 14% over 20 hr; but in this case, although the total yield of −3½, +7 grits did not change much, there was a definite increase in the amount of −5, +7 grits at the expense of the larger grits as compared to the other described tests. Actually, in an experiment where untempered corn (11.5% moisture) was processed through the shortened mill flow, results obtained were comparable to those where grain was tempered to 14% over the 20-hr period. There was slightly more breakage of the endosperm, as indicated by an increased amount of −5, +7 grits; fat contents of the grit

TABLE I
Time and Moisture Effects on Grit and Germ Recovery and Characteristics

Tempering Conditions	Degermer Yield (% as is) −3½, +5	Degermer Yield (% as is) −5, +7	Grit Recovery[a] (Flotation, % as is) −3½, +5	Grit Recovery[a] (Flotation, % as is) −5, +7	Fat Content of Floated Grits (% d.b.) −3½, +5	Fat Content of Floated Grits (% d.b.) −5, +7	Fat Content of Combined Germ (% d.b.)	Attached Hulls on Floated Grits (% as is) −3½, +5	Attached Hulls on Floated Grits (% as is) −5, +7
Three stage									
11.5–16%, 16 hr									
16–21%, 1.75 hr									
21–23%, 0.25 hr	39	30	85	87	1.0	1.1	22.1	21	4
Two stage									
11.5–16%, 1.75 hr									
16–19.4%, 0.25 hr	38	31	84	87	1.2	1.0	20.5	43	11
Single stage									
11.5–16%, 20 hr	38	32	84	88	1.6	1.3	19.0	89	65
11.5–14%, 20 hr	30	38	84	86	1.4	1.1	20.1	89	57
11.5, 0 hr	25	43	90	90	1.3	1.0	20.0	77	57
Least significant difference[b]	7.8	5.8	5.8	4.3	0.45	0.38	3.4	24	13

[a] Percent of degermer yield. Remainder is germ.
[b] $P<0.05$.

TABLE II
Moisture Effects on Grit and Germ Recovery and Characteristics

Final Temper Moisture (%)	Degermer Yield (% as is) −3½, +5	Degermer Yield (% as is) −5, +7	Grit Recovery[a] (Flotation, % as is) −3½, +5	Grit Recovery[a] (Flotation, % as is) −5, +7	Fat Content of Floated Grits (% d.b.) −3½, +5	Fat Content of Floated Grits (% d.b.) −5, +7	Fat Content of Combined Germ (% d.b.)	Attached Hulls on Floated Grits (wt. % as is) −3½, +5	Attached Hulls on Floated Grits (wt. % as is) −5, +7
11.5[b]	24	42	90	90	1.3	1.0	19.7	77	57
13[c]	36	32	89	84	1.1	1.1	18.9	80	55
14[c]	37	30	90	83	1.2	0.9	19.7	69	36
16[c]	39	29	90	85	1.1	1.0	20.1	65	27
17[c]	40	27	87	87	1.2	1.2	23.2	30	12
19[c]	37	28	89	84	1.1	1.1	22.7	30	7
23[c]	42	27	90	82	1.1	1.1	24.0	13	4
Least significant difference[d]	9.4	4.3	4.4	6.4	0.32	0.20	3.4	15	5

[a] Percent of degermer yield. Remainder is germ.
[b] Initial moisture content of corn.
[c] Moisture added 15 min before milling.
[d] $P<0.05$.

fractions and the combined germ were about the same.

Similarities exist in certain of the recoveries, particularly in total degermer yield, in grit-germ separation by flotation, and in fat content of grit fractions and combined germ. However, it is evident that tempering does influence the distribution of −3½, +5, and −5, +7 grits and the amount of hulls remaining attached to the grits. The best results were obtained when corn was tempered in three stages to 23%.

We further examined the moisture-time relationship with respect to tempering in an attempt to restrict the time to a minimum while adjusting moisture level to get best overall results. When the shortened mill flow was used, the corn at the initial moisture content of 11.5% was tempered to moisture levels ranging from 13 to 23%. In each of the tests, the precalculated amount of temper water was added to the corn 15 min before milling. Results of this study are given in Table II. Sixty-five to 69% of the corn milled in the degermer was recovered in the −3½, +7 particle size range. The amount of the larger size particles, −3½, +5, increased as the temper moisture increased, with a corresponding decrease in the −5, +7 particles. When the two fractions from the degermer were exposed to the flotation procedure to separate the grit from the germ, the grit recovery from each of the samples varied within a rather narrow range over the complete range of temper moisture levels.

The fat content of the separated grits ranged from 0.9 to 1.3% (dry basis). As noted in Table II, the highest grit fat content was from corn that had not been tempered. Fat content of the combined germ fractions did increase significantly as the temper moisture was increased. As already mentioned, this presumably results from recovery of a cleaner germ fraction at higher moisture levels, ie, presence of fewer attached hulls and/or endosperm particles. Another noticeable effect of temper moisture was the decrease in the amount of hulls remaining attached to the grit particles. At the 17% moisture level, there is a sharp reduction in the quantity of attached hulls, particularly on the finer grits.

CONCLUSIONS

The study shows that it is possible to recover an acceptable yield of large, good-quality grits with respect to fat content through use of minimum tempering and a shortened mill flow. Although best overall results were obtained with the use of the conventional three-stage tempering sequence and the higher final temper moisture (23%), these results were essentially equalled by 15-min tempers to moisture levels of 17% and above. When corn was tempered to less than the 17% moisture level, milling results were not as good, even when tempered as long as 20 hr. A trend toward a lower germ oil content was manifested, and attached hull content increased dramatically. For some more refined uses of corn grits, excessive attached hulls would be objectionable. For applications such as alcohol or starch production, however, some attached hulls should present few problems, if any. The use of minimum tempering and a shortened mill flow for these particular purposes would eliminate the need for elaborate roller-milling processes and drying of the degermed stock.

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