A Dry-Milling Evaluation of Trickle Sulfur Dioxide-Treated Corn[1]

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ABSTRACT

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Workers at Purdue University have refined the trickle sulfur dioxide (SO_2) process for preserving high-moisture corn while drying it with ambient air. High-moisture corn was treated in bins with 0.2% SO_2 (w/w), using three different procedures—normal trickle, reverse trickle, and treatment in an auger. Chemical analyses of corn dried by these treatments and an untreated control showed only small differences in fiber, ash, and nitrogen. Crude fat content of the SO_2-treated corns was slightly lower than that of the untreated control. Fat acidity values of the untreated corn and of the corn treated with SO_2 in an auger were considerably higher than those of the corn treated by the trickle procedures. Dry milling of the corn samples indicated some lowering of recovery of prime products (grits, low-fat meal, and flour) from corn treated by trickle procedures. However, fat content of prime products from all tests was comparable, generally 0.6% or less.

Laboratory and pilot-plant studies have shown the efficacy of sulfur dioxide (SO_2) when it is used as a fungicide to retard fungal growth on high-moisture corn while the corn is dried with ambient air (Eckhoff et al 1980). The scale of these studies was increased to handle 200 bu of corn in simulation of an "on-farm" situation. This work, performed at Purdue University, corroborated the smaller-scale studies and presented a potential procedure for handling high-moisture corn. In these studies, Purdue workers examined the feasibility of treating a single lot of one variety of the corn with SO_2 by the normal-trickle process (gas is introduced into airstream just downstream from blower and then up through bed of corn), by the reverse-trickle process (gas applied at top of bin and pulled down through grain), and by the addition of SO_2 to the corn in the auger as the bin is filled. Results based on standard microbial analysis showed that the reverse-trickle procedure gave the best microbial control. Evaluation of factors considered important in the acceptability of the SO_2 treatment, such as breakage susceptibility, bulk density, effect on electric moisture meters, and grading, showed that the treatment had no effects or only marginal ones on these factors (Eckhoff et al 1983). We subjected portions of the three SO_2-treated corns, together with a field control sample and an air-dried control sample, to the dry-milling procedure to evaluate their response to milling and the characteristics of the final milled products.

MATERIALS AND METHODS

Materials

The corn samples (Beck's 65× variety) were obtained from the described Purdue University studies and had been subjected to

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treatments as shown in Table I. After removal from the drying bins at the corn moistures shown in Table I, the corn was further dried in the laboratory to the moisture levels shown in Table II. In addition, a sample of the original wet corn was air-dried to provide a control. All samples were stored at 2° C until they were processed.

Methods

Corn was tempered before degermination in three stages from initial moistures (Table II) to 24% moisture. The first stage involved raising the moisture content to 16% for 16 hr, then increasing to 21% for 1.75 hr, and finally increasing to 24% for 15 min before degerming. All tempering was at room temperature (28 ± 5° C). Next, the tempered corn was processed in an experimental horizontal drum degermer operated at 1,650 rpm at a net motor load of about 0.4 HP. All corn had to pass through the 20/64-in. round hole perforated screen surrounding the rotor. Other details of this degermer's construction and operation were published previously by Brekke et al (1971, 1972). Degermer stock was dried to 17 ± 1% moisture in a forced-circulation tray dryer operated at 82° C air temperature and then milled into grits, meal, and other fractions by a roller-milling and grading system based on the flow shown in Fig. 1. The products shown in Table III were recovered. Duplicate runs were made.

AACC approved methods were followed for protein (N × 6.25), crude fiber, ash, starch, fat-acidity value, and crude fat content (AACC 1979). Moisture determinations were made on 10-g samples heated for 30 min in a Brabender oven at 130° C. Residual oil was determined by a gas-liquid chromatographic method described by Black et al (1967). Calculated yield of recoverable oil was based on yield of germ and its fat and moisture content, with residual germ cake assumed to contain 5% fat, db.

RESULTS AND DISCUSSION

Corn treatments and chemical analyses of the corn samples are listed in Table II. The protein values were essentially unchanged, regardless of treatment to the corn, whereas the trend in crude fiber and ash in the SO_2-treated corns appeared to be downward. Starch content in the untreated field control was slightly reduced, which might be attributed to increased microbiological activity in this sample. Crude fat content was reduced, particularly in the samples treated with sulfur dioxide. Perhaps the more dramatic differences were the increase in fat acidity in the untreated field control and in the corn sample to which sulfur dioxide was added while grain was augered into the bin. The corn treated by the trickle processes retained a reasonable level of fat acidity.

No processing or operating problems were encountered in the tempering, degerming, roller-milling, or grading steps. Yields of products resulting from dry milling the SO_2-treated corns are given in Table IV. Milling the air-dried control corn (A) resulted in the typical distribution of grits, meal, flour, germ, and hull fractions. The yield of prime products (first-, second-, and third-break grits, low-fat meal, and flour) was lower than what we usually obtained from the milling flow used—53.1% as opposed to about 60%. This is thought to be attributable to the grain itself, which perhaps was a hybrid with a slightly softer endosperm, because the amounts of meals and flours increased at the expense of the grits. Regardless of treatment, there was no statistically significant difference in prime product recovery, although there appeared to be a trend toward lower recovery from the samples from the trickle SO_2 experiments (C and D).

The untreated field-control corn sample (B) milled somewhat differently than the air-dried control. Although prime product yield was about the same as for A, the first-break grit recovery from B was about half of that from A, with corresponding increases in the amounts of smaller grits and meal. Also, significantly less germ was recovered in B as compared to A, and a lower recoverable oil value is shown. Essentially the same recovery results were obtained from milling the corn treated with SO_2 in the auger (E) as were obtained in the milling of the untreated field-control corn (B).

TABLE I
Conditions of SO_2 Treatments

Feature	Untreated Field Control	Trickle	Reverse Trickle	Auger
SO_2 addition, % (wt SO_2/wt wet corn)	···	0.12 initially 0.05 at 28 days 0.05 at 128 days	0.12 initially 0.05 at 28 days 0.05 at 128 days	Top third (0.38) Middle third (0.10) Bottom third (0)
Time for SO_2 addition, hr	···	2 initially 1 at 28 and 128 days	2 initially 1 at 28 and 128 days	0.33 ···
Air-flow rate,[a] m^3/t	1.1	1.1	1.1	1.1
Initial corn moisture content, %	28.7	28.9	29.1	29.6
Final corn moisture,[b] %	16.4	16.9	16.5	16.4

[a] Drying done at ambient temperatures.

[b] After 170 days of drying.

TABLE II
Chemical Analyses of Corn Samples

Corn Treatment	Moisture (%)[a]	Crude Fat (%)	Crude Fiber (%)	Ash (%)	Protein (N × 6.25) (%)	Starch (%)	Fat Acidity[a] (mg of KOH per 100 g of corn)
Control, air-dried	14.0	4.76	2.55	1.45	8.75	79.8	34.5
Field control, untreated-bin	11.0	4.29	2.49	1.68	8.25	75.8	82.9
Trickle SO_2	11.0	4.01	2.34	1.34	8.50	78.4	45.9
Reverse trickle SO_2	11.7	3.98	2.33	1.33	8.38	79.3	44.6
SO_2 added while corn augered into bin	11.5	3.97	2.15	1.12	8.63	80.0	108.2

[a] As-is basis; all other values are on moisture-free basis.

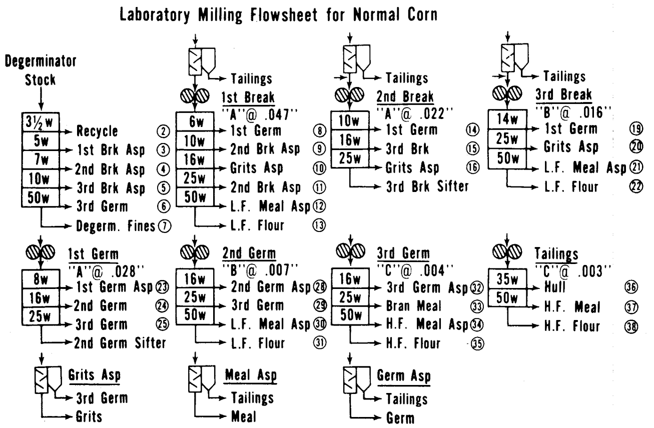

Fig. 1. Roller-milling and grading flow sheet. Degermer stock from treated corn was milled into grits, meal, and other products in this manner. Brk = break; Asp = aspirator; LF Meal = low-fat meal; HF Meal = high-fat meal; w = wire mesh, eg, number of wire meshes per lineal inch of sieve surface.

TABLE III
Products Recovered from Roller-Milling and Grading System

Product	Mill Streams Used	Particle Size Range
Grits, first break[a]	10	−10 + 16 Mesh
Grits, second and third breaks[a]	16,20	−16 + 25 Mesh
Low-fat meal[a]	12,21,30	−25 + 50 Mesh
Low-fat flour[a]	13,22,31	−50 Mesh + pan
High-fat meal	34,37	−25 + 50 Mesh
High-fat flour	35,38	−50 Mesh + pan
Germ fraction	23,28,32	+16 Mesh
Bran meal	33	−16 + 25 Mesh
Hull fraction	36	+35 Mesh
Degermer fines	7	−50 Mesh + pan
Recycle stock	2	+3.5 Mesh

[a] Blended to make a prime-product mix.

TABLE IV
Yield of Products from Dry Milling of SO_2-Treated Corn
(percent as-is basis)

	Treatment[a]					
Measurement	**A**	**B**	**C**	**D**	**E**	**LSD[b]**
Degerminator fines	6.70	6.09	7.56	6.39	6.45	5.04
Low-fat meal	10.88	12.23	12.71	13.45	12.90	2.84
Low-fat flour	6.84	6.61	7.92	8.21	7.26	2.27
First-break grits	9.51	4.35	1.37	1.54	3.72	2.52
Second- and third-break grits	25.88	29.88	26.24	27.23	28.80	6.62
High-fat meal	9.57	11.08	11.99	15.99	9.11	5.04
High-fat flour	5.58	5.90	7.67	7.93	6.35	2.02
Bran meal	4.25	4.16	4.04	3.71	4.70	2.23
Hull	8.67	9.56	8.93	8.92	10.03	2.31
1,2,3 Germ	12.11	10.13	11.54	11.79	10.65	1.82
Prime products[c]	53.11	53.07	48.24	50.43	52.68	11.88
Recoverable oil, lb/cwt[d]	2.30	1.78	1.95	2.17	1.98	0.51

[a] A = air-dried control, B = untreated field control, C = trickle SO_2, D = reverse trickle SO_2, E = treated with SO_2 in the auger.

[b] Least significant difference.

[c] Low-fat meal, low-fat flour, first-, second-, and third-break grits.

[d] Calculated value.

Results from the dry milling of corn dried by the trickle process (C) and by the reverse-trickle process (D) showed a statistically significant reduction in the yield of first-break grits. The finer endosperm particles appeared to be distributed among all of the remaining endosperm fractions, but to a significantly greater degree in the high-fat meal (D) and the high-fat flour (C and D). As already noted, recovery of prime products from these two treatments was a little less than from either of the controls (A and B). Recoverable oil values were not significantly different from the controls or treatment E.

The fat contents of the prime products were satisfactory regardless of treatment, with no significant differences noted between the controls and the treated corn (Table V). Degerminator fines from corn treated with SO_2 in the auger (E) had a significantly higher fat content than any of the other corns under test. Fat was somewhat lower in bran meal from treated samples of grain.

TABLE V
Fat Content of Products from Dry Milling of SO_2-Treated Corn
(percent moisture-free basis)

	Treatment[a]					
Measurement	**A**	**B**	**C**	**D**	**E**	**LSD[b]**
Degerminator fines	0.52	0.42	0.31	0.30	0.69	0.129
Low-fat meal	0.47	0.54	0.57	0.33	0.45	0.182
Low-fat flour	0.43	0.49	0.35	0.31	0.48	0.162
First-break grits	0.46	0.51	0.55	0.45	0.55	0.202
Second- and third-break grits	0.59	0.55	0.51	0.43	0.60	0.256
High-fat meal	1.04	1.13	0.68	0.64	1.04	0.370
High-fat flour	0.68	0.57	0.37	0.47	0.64	0.311
Bran meal	3.04	3.95	1.01	2.23	2.27	1.541
Hulls	1.58	2.48	1.82	1.43	2.28	1.934
1,2,3 Germ	24.80	26.46	23.91	25.46	25.86	4.588

[a] A = air-dried control, B = untreated field control, C = trickle SO_2, D = reverse trickle SO_2, E = treated with SO_2 in the auger.

[b] Least significant difference.

Although not of statistical significance, the fat content of the high-fat meal and flour from the trickle-process corns (C and D) were less than those of the controls (A and B). This might substantiate the increased yields of these fractions, ie, the fine endosperm particles with lower fat contents end up in the high-fat meal and flour and dilute the normally higher fat in the fractions. The fat content of the recovered germ was essentially the same in all tests.

With the exception of the lower recovery of the first-break grits from the SO_2-treated corns, dry milling of these materials essentially paralleled the processing of the air-dried control corn. These results, showing a reduction in the larger grits, are similar to those reported by Eckhoff et al (1983).

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