Note on the Suitability for Wet Milling of Corn Exposed to High Drying Temperatures at Different Moisture Contents

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Cereal Chem. 58(1):75–76

The yield and quality of starch produced by wet milling of corn is often low when the corn has previously been subjected to high temperatures during artificial drying (Lasseran 1973, Vojnovich et al 1975). In several early studies of the millability of artificially dried corn, the initial moisture content of grain had less effect on wet-milling performance than did the drying temperature (MacMasters et al 1959, Watson and Hirata 1962). However, corn dried from 30 to 15% moisture in one pass through a high-temperature dryer caused a 25% reduction in production capacity of a modern wet-milling plant, and the quality of starch extracted was lower than normal (Freeman 1973). We have also found that the initial moisture content of artificially dried corn affects its value for wet milling (Brown et al 1979). Unfortunately, in our earlier study the effects of initial moisture content were compounded with those of varietal differences among the corn lots tested.

Freeman (1973) and Watson (1960) expressed the opinion that most of the damage that affects the millability of corn dried at high temperatures occurs while the grain is still moist. The innovative drying techniques of dryeration (Foster 1973) and high-low temperature combination drying (Gustafson et al 1976) both expose grain to high-temperature drying air at the beginning of the drying process when the corn is wet. These drying techniques reduce the number of stress cracks and the breakage potential of artificially dried corn.

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0009-0352/81/01007502/$03.00/0

We initiated this study to determine if a critical range of moisture content exists within which the millability of corn is affected by exposure to high-temperature air during drying.

MATERIALS AND METHODS

Grain of an early maturing corn hybrid variety, P.A.G. SX111 (Cargill Grain Co., Ltd., London, Ontario), was harvested by combine for the experiment. Initial moisture content ranged from 29 to 31% (wet basis) at harvest. The wet corn was cleaned over a 4.8-mm (12/64-in.) round-hole sieve in a small separator (A. T. Ferrell and Co., Saginaw, MI), and was then divided into 2-kg lots. Moisture content of grain in each lot was determined by oven drying 50-g samples for 72 hr at 103°C.

The corn lots were dried in baskets made of stainless steel screening. The baskets were 20 cm wide and 33 cm in length, and the depth of grain in each was approximately 4 cm. Each basket of corn was carefully weighed at the beginning of the experiment, and moisture content of the corn as it dried was determined from the weight loss between weighings.

The corn was dried from an average initial moisture content of 30% to the final moisture content of 15% in three stages of five percentage points moisture removal each. In one of the three stages for each corn lot, drying was conducted at a high temperature in a forced air convection oven. Two air temperatures, 80 and 100°C, were used for the high-temperature drying stages.

Corn was dried in the remaining stages by placing the baskets over the screened outlet from a plenum chamber. A small fan attached to the plenum forced air at room temperature (21°C) through the corn in the baskets at a rate of about 5 m^3/min per square meter of screen area.

The drying times for the high-temperature stages varied from 45 to 90 min, and the room-temperature drying stages took many hours to complete. A control group was dried over the entire range of moisture content at room temperature. The seven drying treatments are outlined in Table I. Four replications were made of each treatment.

Suitability for Wet Milling

A steeping index was determined for the grain dried with each treatment to indicate suitability for wet milling. Samples of 750 g each of the dried corn, placed in tubes of stainless steel screen, were suspended within the bed of corn in full-scale steep tanks at the Canada Starch Company plant at Cardinal, Ontario. The samples were removed after the corn had steeped for 32 hr (cover time) at a solution temperature of 52°C. Four replicate samples were steeped from each drying treatment.

The procedure for evaluating the steeped kernels and formulating the steeping index has been described in an earlier study (Brown et al 1979). The maximum steeping index of 300 for a corn lot indicates that all kernels are fully steeped and the protein matrix of the endosperm is dispersed. The lowest index of 100 denotes that all kernels retain intact protein matrix and are therefore inadequately steeped. The correlation between the steeping index of corn and the starch recovery rate upon wet milling in that study indicated that corn with a minimum index of 200 will give normal starch-gluten separation and satisfactory milling performance.

TABLE I
Drying-Air Temperatures (°C) for Different Treatments

Treatment Number	Moisture Content Range (% wet basis) 30–25	25–20	20–15
1	100	21	21
2	80	21	21
3	21	100	21
4	21	80	21
5	21	21	100
6	21	21	80
7	21	21	21

TABLE II
Effect of Drying Treatment on Steeping Index[a] of Corn

Drying Treatment Number	Trial Number 1	2	3	4	Drying Treatment Means[b]
1	160	170	163	168	165 a
2	168	178	174	179	175 a
3	184	183	187	190	186 b
4	190	189	190	189	190 b
5	196	195	203	208	201 c
6	203	210	205	215	208 c
7	219	225	221	235	225 d

[a] A steeping index of 200 or more is correlated with satisfactory milling performance (Brown et al 1979).
[b] Means followed by the same letter do not differ significantly at the 0.01 probability level by Duncan's new multiple range test.

TABLE III
Analysis of Variance for Steeping Index of Dried Corn

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value (Calculated)
Total	27	10,427	...	...
Treatment	6	9,907	1,651.17	66.69[a]
Error	21	520	24.76	...

[a] $P = 0.01$.

RESULTS AND DISCUSSION

The steeping index for each lot of grain is presented in Table II. Analysis of variance (Table III) indicated that significant differences for steeping index of dried grain existed among the seven treatments.

Corn that was dried from 30 to 25% moisture at high air temperatures had the lowest steeping index. High-temperature drying caused a significant reduction in steeping index in all treatments. The magnitude of reduction was lower when the corn was exposed to the high-temperature air at a lower moisture content stage. Corn that was dried with room-temperature air only had the highest steeping index. Only the corn lots dried at a high temperature from 20 to 15% moisture and those not exposed to the high-temperature air had a steeping index of 200 or higher.

No significant difference in corn steeping index was found between the two drying temperatures of 80 and 100°C for the same stage of moisture removal. A wider range of drying temperatures would undoubtedly have shown differences; however, these temperatures represent the drying temperature range normally encountered at grain elevators and farm dryers in Ontario.

The techniques of dryeration and high-low temperature combination drying, which reduce the physical damage (ie, stress cracking and breakage) associated with high-temperature corn drying, are becoming widely accepted. The results of this study indicate that wet-milling performance of grain dried with these techniques may not be improved to the same extent, because they expose wet corn to high-temperature drying air at the beginning of the drying process.

CONCLUSIONS

The suitability of artificially dried corn for wet milling is reduced by exposure to high-temperature drying air. The susceptibility of corn to drying damage increases with the moisture content at the time of exposure.

In comparison with strictly ambient or low-temperature drying, any high-temperature drying treatment, regardless of the moisture content at the time of exposure, will reduce the millability of corn.

Corn harvested at moisture contents above about 25% should be dried for the milling industries at the usual recommended temperature of 60°C or less.

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[Received August 27, 1980. Accepted October 8, 1980]