NOTE

Wet-Milling Characteristics of High-Temperature, High-Humidity Maize

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High-temperature drying of maize is widely used in the United States to achieve high drying rates. Typical drying temperatures and humidities of commercial dryers range from 70 to 150°C and 0 to 5% rh, respectively. However, high-temperature drying of maize produces increased levels of stress cracking and lower resistance to mechanical impact during handling. High-temperature drying of maize also has a significant effect on wet-milling characteristics. Earlier studies (MacMasters et al 1954, Watson and Hirata 1962, Vojnovich et al 1975, Weller et al 1988) have shown that drying temperatures above 70°C using low-humidity air reduced starch recovery, steepwater solids, and starch paste viscosity.

Estrada (1991) reported that in the temperature range of 71–104°C, drying at high humidity (70–80% rh) reduced the drying rate by up to 44%, reduced the number of multiple stress cracks by 33%, increased the amount of kernels with no stress cracks by 28.7%, and reduced breakage susceptibility. Even though the drying rate was reduced, it was significantly higher than were the drying rates at ambient or near-ambient temperatures using low-humidity air. High-temperature, high-humidity drying may have potential cost-saving benefits by reducing the amount of broken maize during handling. This also would reduce dust, waste, and steepwater solids loss in wet milling due to broken maize.

The objectives of this study were to investigate the wet-milling characteristics of high-temperature, high-humidity dried maize and to compare the characteristics with those of ambient dried maize and of normal high-temperature, low-humidity dried maize, and to compare the Brabender viscosity characteristics of starches obtained from maize samples.

MATERIALS AND METHODS

Sample Preparation

Yellow dent maize of a medium hybrid (FR27 × MO17) with an initial moisture content of 30% (wb) was combine-harvested, placed in polyethylene bags, and stored in a cold room (5°C) until removed for drying. In preparation for drying, samples were removed from the cold room and allowed to equilibrate to room temperature overnight. The samples were dried using the procedure and equipment developed by Estrada (1991). A convection oven modified to a thin-layer dryer with a semiclosed cyclone system was used to provide a wide range of temperature and relative humidity control and to provide complete exposure of the sample to the drying conditions. Maize samples were spread in a thin layer (one to two kernels thick) on a perforated drying tray and dried to a final moisture content of approximately 13–14% (wb).

Two 1,000-g samples of maize were treated by each of the four test drying conditions, i.e., 21°C-18% rh (ambient conditions), 71°C-70% rh, 93°C-80% rh, and 93°C-1% rh. The final moisture contents (wb), as determined by the ASAE method (1986), were 13.9, 14.6, 14.6, and 14.5%, respectively.

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Laboratory Wet-Milling Procedure

The laboratory wet-milling procedure of Eckhoff et al (1991) was used to obtain wet-milling fractions from each of the eight samples (two replicates of the four test conditions). Maize was batch-steeped using an aqueous solution of 0.55% lactic acid and 0.2% sulfur dioxide at 52°C for 36 hr. At the end of the steeping period, the steepwater was drained and the maize was coarsely ground in a Waring blender. Germs were hand-skimmed, and the remaining mash was ground in a Quaker City plate mill (The Straub Co., Hatboro, PA). Fibers were separated and washed on a Kason vibroscreen (Kason Corp., Linden, NJ). Starch-gluten separation was achieved on a 6- × 0.1016-m H-beam. The H-beam (starch table) was set at a 0.057-m incline with a flow rate of 300 ml/min. The gluten fraction that passed off the starch table then was vacuum-filtered using a Buchner funnel with No. 1 Whatman paper.

Moisture content of all fractions were determined using a forced-draft oven (method S352.1, ASAE 1985). The yield of wet-milling fractions (germ, fiber, starch, gluten, steepwater solids, and filtrate solids) was determined as the percentage of initial maize dry solids. The protein content of the recovered starch fraction was determined in duplicate using the micro-Kjeldahl method (method 46-10, AACC 1983). Yields and protein data were statistically analyzed using a least significant difference (LSD) method (Steel and Torrie 1980).

Brabender Amylograph

Viscoamylograms of starch samples were obtained using a Brabender Viscoamylograph (model-P110, C.W. Brabender Instruments Inc., South Hackensack, NJ) following the standard amylograph method (method 22-10, AACC 1983). A 30-g (db) starch sample and 3.6 g of carboxymethyl cellulose were dissolved in 450 ml of buffer solution (pH 5.30–5.35, AACC 1983) and viscosity was measured in Brabender units. Carboxymethyl cellulose was used to increase the sensitivity to swelling of starch granules (Tipples 1980). The viscosity data obtained from the amylograms were statistically analyzed using the LSD method of Steel and Torrie (1980).

RESULTS AND DISCUSSION

The yield of the wet-milling fractions from maize dried at 71°C and 70% rh was the same as that for maize dried at ambient

TABLE I
Yields[a] of Fractions Obtained from Wet Milling Yellow Dent Maize Dried Under Different Conditions

Fraction (%)	21°C, 18% rh	71°C, 70% rh	93°C, 80% rh	93°C, 1% rh	LSD[b]
Germ	6.5 a[c]	6.7 a	6.2 a	6.7 a	0.501
Fiber	9.3 a	9.6 c	15.1 a	10.7 b	0.750
Starch	65.1 a	65.0 a	61.1 c	63.4 b	0.639
Gluten	10.8 b	11.2 ab	11.4 a	10.3 c	0.507
Steepwater	3.9 ab	3.6 b	2.7 c	4.2 a	0.444
Filtrate	3.1 a	2.8 a	2.3 b	3.1 a	0.515
Total	98.7 a	98.8 a	98.8 a	98.8 a	1.587

[a] Percentage of dry maize solids.
[b] Least significant difference at the 95% confidence level.
[c] Means with the same letter within a row are not significantly different ($P < 0.05$).

TABLE II
Pasting Data of Starch Obtained from Maize Dried Under Different Conditions[a]

Maize Drying Conditions	Initial Pasting Temperature, °C	Peak Height (BU)	15-Min. Height (BU)	Setback (BU)
21°C-18% rh	69.9 a	683 a	573 b	628 b
71°C-70% rh	68.8 a	750 a	640 a	720 a
93°C-80% rh	69.9 a	660 bc	635 a	745 a
93°C-1% rh	67.1 a	638 c	585 b	715 a

[a] Means followed by the same letter within the same column are not significantly different ($P < 0.05$).

conditions (Table I). The maize dried at 93°C and 80% rh yielded 4% less starch, 0.7% less filtrate solids, 0.8% less steepwater solids, 5.8% more fiber, and 1.3% more gluten than did ambient-dried maize. The germ yields for all samples dried at high temperatures were not significantly different from those of ambient-dried maize.

The lower starch and higher fiber yields from maize dried at 93°C and 80% rh and 93°C and 1% rh compared with those of ambient dried maize are probably due to the combined effects of starch partial gelatinization and protein denaturation caused by high-temperature drying. A denatured protein matrix may cause incomplete release of starch granules from the matrix. Starch granules could be retained with fiber fraction, reducing the starch yield. Weller et al (1988) showed that starch recovery decreased as maize drying temperature increased. They also showed that maize with high harvest moisture when dried at high temperatures had reduced starch recovery. They attributed this to damaged endosperm protein as a result of high-temperature and high-moisture conditions preventing solubilization during steeping, such that the starch was not set free on wet-milling. The yield of steepwater solids from maize dried at 93°C and 1% rh was high, indicating more solids loss during steeping due to a high level of stress cracks, as reported by Estrada (1991). In general, high-temperature drying of maize (above 71°C) reduced the yield of starch, steepwater solids, and filtrate solids.

The high-temperature drying of maize with either high- or low-humidity air appears to have no significant effect on the protein content of the starch obtained by wet milling. The protein content of the recovered starch from the four drying conditions ranged from 0.29 to 0.37% (starch db, LSD = 0.13%). Although studies by Watson and Hirata (1962) and Vojnovich et al (1975) showed that high-temperature drying caused an increase in the protein content of starch, the current finding may be attributable either to the type of maize used or to the laboratory procedure used.

Brabender Amylograph characteristics of starches from maize dried at high temperature and high humidity (71°C and 70% rh and 93°C and 80% rh) were significantly different from the characteristics of starch obtained from ambient-dried maize (Table II). Both high-temperature, high-humidity dried maize samples (71°C and 70% rh and 93°C and 80% rh) had similar Brabender characteristics (Fig. 1). The initial pasting temperature for starch from the maize dried at 93°C and 1% rh was lower than that of the other three starches, indicating some starch partial gelatinization due to the drying treatment. The peak viscosities of starches from 93°C-80% rh and 93°C-1% rh drying were lower than were those of starch from ambient-dried maize, indicating lower starch viscosity during heating and cooking. The viscosities of starch from maize dried at 71°C and 70% rh and 93°C and 80% rh 15 min after heating to 95°C were higher than those of starch from ambient-dried maize and maize dried at 93°C and 1% rh, indicating lower shear thinning. Starches from the three maize samples dried at high temperatures had higher cooled paste viscosity than did ambient-dried starch, indicating increased starch viscosity after cooking.

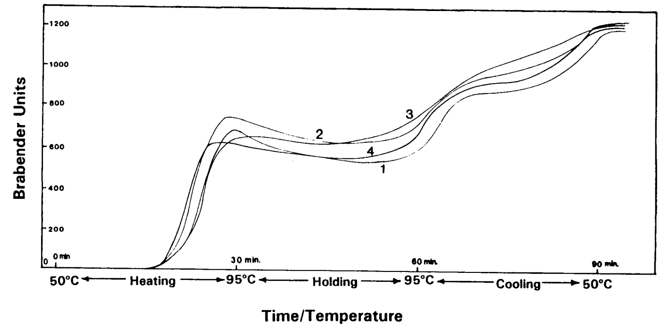

Fig. 1. Brabender Amylograph curves of starch from different drying conditions. 1) 21°C-18% rh; 2) 71°C-70% rh; 3) 93°C-80% rh; 4) 93°C-1% rh. Amylograph determined with a heat/cool rate of 1.5°C/min.

CONCLUSIONS

Maize dried at high temperature and high humidity (71°C and 70% rh) showed no significant difference from the ambient-dried maize in wet-milling characteristics. Maize dried at 93°C and 1% rh had lower starch yield than did maize dried at 93°C and 80% rh, indicating that the combined effect of high temperature and high humidity was more detrimental. The protein contents of the starch fractions were not affected by the type of drying conditions used in this study. The Brabender viscosity characteristics of starches from maize dried at 71°C and 70% rh and 93°C and 80% rh were similar to each other but different from those of ambient-dried maize. Viscosities of starches from maize samples dried at 93°C were lower than those of ambient-dried maize starch. High-humidity drying of maize caused more shear thinning of starch than did ambient drying.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC, 8th ed. Method 22-10, approved May 1960, revised October 1982; Method 46-10, approved April 1961, revised September 1985. The Association: St. Paul, MN.

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS. 1985. Moisture measurement—Grain and seeds. ASAE Standard S352.1. Page 62 in: ASAE Standards, Engineering Practices and Data Adopted by the American Society of Agricultural Engineers. R. H. Hahn, M. A. Purschwitz, and E. E. Rosentreter, eds. The Society: St. Joseph, MI.

ECKHOFF, S. R., RAUSCH, K. D., FOX, E. J., TSO, C. C., PAN, Z., and MISTRY, A. H. 1991. An improved laboratory procedure for wet-milling research. (Abstr.) Cereal Foods World 36:699.

ESTRADA, J. A. 1991. Thin-layer drying of yellow dent maize and high-temperature high-humidity conditions. M.S. thesis. University of Illinois: Urbana-Champaign.

MACMASTERS, M. M., EARLE, F. R., HALL, H. H., RAMSER, J. H., and DUNGAN, G. H. 1954. Studies on the effect of drying conditions upon the composition and suitability for wet-milling of artificially dried maize. Cereal Chem. 31:451.

STEEL, R. G. D., and TORRIE, J. H. 1980. Principles and Procedures of Statistics, 2nd ed. McGraw-Hill: New York.

TIPPLES, K. H. 1980. Uses and applications. In: The Amylograph Handbook. W. C. Suey and K. H. Tipples, eds. Am. Assoc. Cereal Chem.: St. Paul, MN.

VOJNOVICH, C., ANDERSON, R. A., and GRIFFIN, E. L., Jr. 1975. Wet-milling properties of maize after field shelling and artificial drying. Cereal Foods World 20:333.

WATSON, S. A., and HIRATA, Y. 1962. Some wet-milling properties of artificially dried maize. Cereal Chem. 39:35.

WELLER, C. L., PAULSEN, M. R., and STEINBERG, M. P. 1988. Correlation of starch recovery with assorted quality factors of four maize hybrids. Cereal Chem. 65:392.

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