NOTE

Variability in Water Absorption of Germ and Endosperm During Laboratory Steeping of a Yellow Corn Hybrid

Oliver D. Dailey, Jr.[1]

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There have been several reports in the literature on the water uptake of corn kernels and other cereal grains during steeping. In two studies (Fan et al 1965, Gundasekaran and Farkas 1988), the total increase in water absorbed was determined measuring increase in bulk kernel weight. In a third study involving corn, sorghum, and millet, moisture content was determined by drying in a forced-air oven (Oguntunde and Adebawo 1989). Recently, magnetic resonance imaging was used to measure differences in water content and mobility in components of corn kernels during steeping (Ruan and Litchfield 1992, Ruan et al 1992). As part of the studies, moisture changes during steeping were measured in the germ and in the endosperm (Ruan et al 1992). Yaptenco (1993) reported that the final equilibrium moisture content of corn steeped in water containing 0.20% sulfur dioxide (SO_2)and 0.55% lactic acid (LA) at 52°C was 39.4–46.7% (wb), depending on hybrid; equilibrium was reached at 24–36 hr. Some laboratory studies indicated that the addition of either LA (Ruan et al 1992, Haros and Suárez 1999) or SO_2 (Fan et al 1965, Haros et al 1995) results in a change in water absorption in the kernel.

Studies of the rate of hydration of the germ and endosperm components of corn kernels have been limited. Lopes Filho (1995) determined the moisture content of corn germ and endosperm on steeping in water at three different temperatures at soak times of 5–120 min. McKinney (1996) determined the moisture content of corn germ and endosperm on steeping in water containing 2,000 ppm of SO_2 and 0.5% LA (v/v) at 52°C at nine soak times of 30 min to 48 hr.

In this report, the results of a comprehensive study on the hydration of the germ and endosperm components of individual corn kernels in four different steepwater solutions are presented. Objectives of the research included determining what influence the addition of LA, SO_2, or both, to the steepwater exerted on water absorption by the germ and endosperm, and assessment of variability in the hydration of individual kernels. Addition of either SO_2 (Fan et al 1965, Haros et al 1995) or LA (Ruan et al 1992, Haros and Suárez 1999) accelerated the rate of moisture absorption in dent corn hybrids. Accelerated hydration of the kernel could result in shorter steeping times and, consequently, lower milling costs.

MATERIALS AND METHODS

Yellow dent corn (FR1064 × LH59) used in these studies was grown during the 1995 crop season at the University of Illinois's Agricultural Engineering farm (Singh et al 1997). At SRRC it was stored in a cold room at 14.1% wb (germ, 14.4%; endosperm, 14.1%) at 4°C. Before testing, kernels were sifted through a 7-mm round-hole sieve, hand-cleaned to remove foreign matter and broken kernels, and weighed out in 100-g sublot samples. Initial moisture content was determined by drying three 30-g corn samples in a forced-draft oven at 103°C for 72 hr (AACC 2000).

Lactic acid (85.6%) was obtained as a certified ACS reagent from Fisher Scientific Co. (Fair Lawn, NJ). Sodium metabisulfite (97.2%, baker analyzed reagent) was purchased from J. T. Baker Co. (Phillipsburg, NJ). Four soak solutions (deionized water; 0.50% LA [w/v]; 0.20% SO_2 [w/v]; 0.50% LA and 0.20% SO_2 [w/v]) were studied. A 0.20% (w/v) solution of SO_2 was prepared by dissolving 3.053 g of sodium metabisulfite (97.2%) in 1,000 mL of deionized water (Shandera et al 1995).

For each experiment, a 500-mL Erlenmeyer flask containing 187 mL of soak solution was sealed with parafilm and placed in a shaker bath (160 rpm) at 52 ± 1°C. At temperature equilibration (1–2 hr), 100 g of corn (337–347 kernels) was added and the flask was resealed with parafilm. At designated time intervals, three (water soak solution only) or five kernels of corn were removed at random for sampling. For water and LA soak solutions, there were 27 time periods ranging from 5 min to 48 hr. For 0.20% SO_2 and 0.50% LA and 0.20% SO_2 solutions, there were 13 representative time periods ranging from 15 min to 36 hr. Each kernel was patted dry of surface water with a paper towel, the tip cap was cut off and discarded, and the remaining kernel separated into germ and endosperm with a razor blade following the procedure of Lopes Filho (1995). Each individual germ and endosperm was weighed immediately in a tared aluminum pan. For moisture determination (wb), the samples were dried in a forced-draft oven at 51°C for 24 hr and for 2 hr at 130°C, put in an ambient-temperature desiccator for 5 min, and then weighed. A total of 15 kernel replicates were made for each of the four soak solutions. For each time period, the mean percentage moisture (wb) and standard deviation for the germ and endosperm components were calculated. The moisture content of the whole kernel was calculated from the data for the germ and endosperm components.

RESULTS AND DISCUSSION

In our laboratory studies, there was no significant difference in the rate of hydration of the germ or endosperm at any time period common to all four steepwater solutions (Figs. 1 and 2). In many instances, there was considerable variation in the moisture content of individual germ and endosperm for a given steep time. In studies of water absorption by kernels of two corn cultivars, Fan et al (1965) observed that adding SO_2 to water had a retarding effect on water absorption at the onset of steeping but an accelerating effect for longer steeping times. However, for DeKalb 3 × 1 dent corn, there was no detectable retardation of the absorption rate. The moisture absorption rate was always higher in SO_2 solution than in water alone. Haros et al (1995) found that the rates of absorption of dent, semident, and flint hybrids in 0.25% SO_2 solution were slightly higher than in water at 45, 55, and 65°C. Ruan et al (1992) observed that 0.55% LA accelerated the absorption rate in yellow dent corn kernels of cultivar FR27 × FR32. The findings of this study indicate that the influence of steeping chemicals on water absorption in the kernel may vary considerably with hybrid selection.

[1] USDA-ARS, Southern Regional Research Center, New Orleans, LA 70124. Phone: 504/286-4514; Fax: 504-286-4367; E-mail: odailey@nola.srrc.usda.gov
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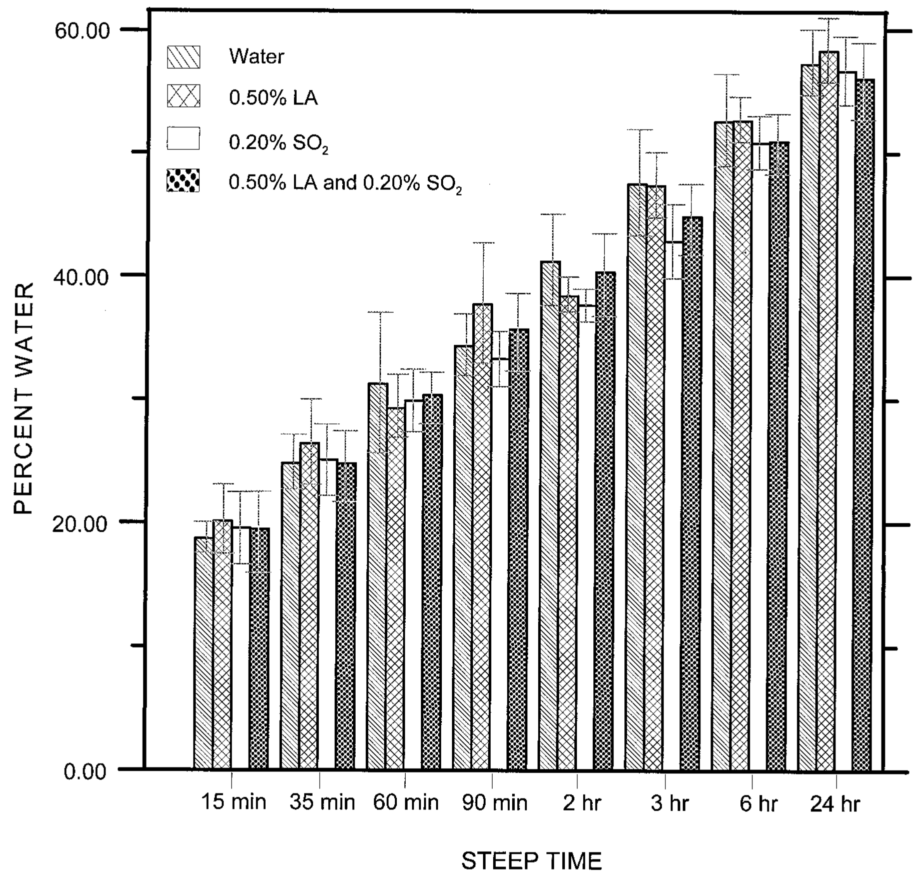

Fig. 1. Germ hydration in four steeping solutions. Error bars show standard deviations. LA = lactic acid.

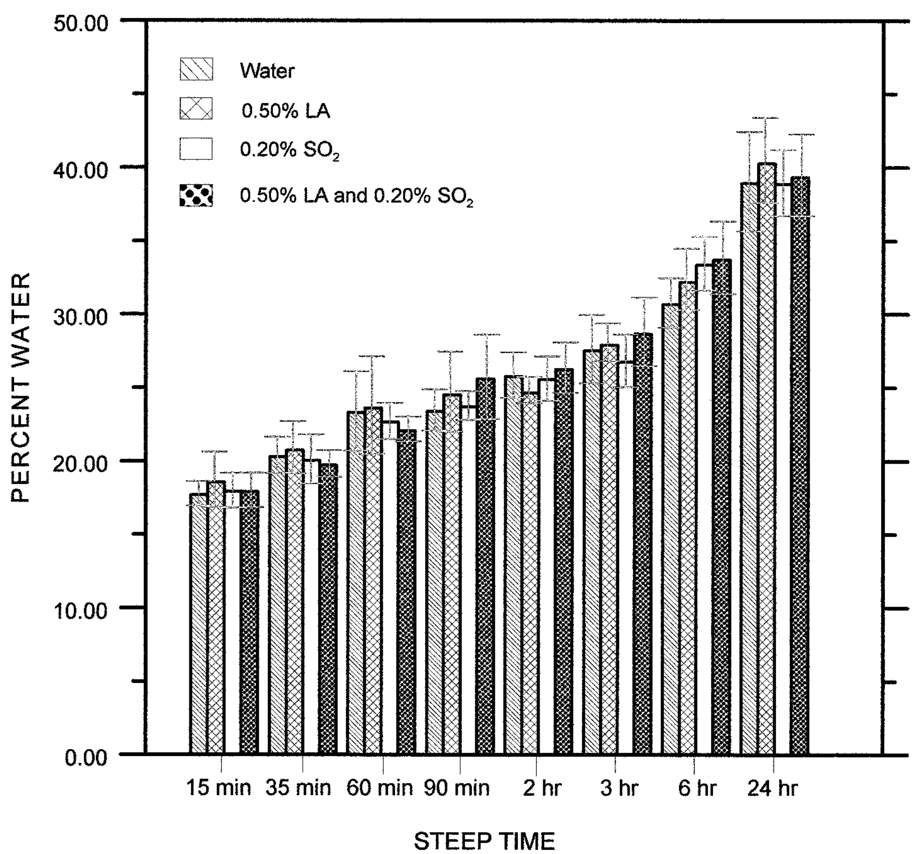

Fig. 2. Endosperm hydration in four steeping solutions. Error bars show standard deviations. LA = lactic acid.

In hydration studies in water, the germ moisture content ranged from 14.8 ± 2.3% after 5 min to 59.0 ± 3.5% after 48 hr, whereas the endosperm moisture content ranged from 16.8 ± 1.4% after 5 min to 40.2 ± 3.2% after 30 hr. When 0.50% LA was used as the steeping solution, germ moisture content ranged from 16.0 ± 2.2% after 5 min to 59.3 ± 2.7% after 40 hr and moisture content for the endosperm ranged from 17.1 ± 1.2% after 5 min to 40.3 ± 2.9% after 24 hr. With 0.20% SO_2, the germ moisture content ranged from 19.6 ± 2.9% after 15 min to 59.4 ± 2.7% after 36 hr, whereas the endosperm moisture content ranged from 17.9 ± 1.2% after 15 min to 40.6 ± 2.1% after 30 hr. When 0.50% LA and 0.20% SO_2 was used as the steeping solution, germ moisture content ranged from 19.5 ± 3.2% after 15 min to 59.5 ± 2.3% after 36 hr and moisture content for the endosperm ranged from 17.9 ± 1.2% after 15 min to 40.3 ± 2.5% after 36 hr. There was no significant difference in the rate of hydration for any of the 27 time periods common to the water and 0.50% LA solutions.

After 16–20 hr, the equilibrium (peak) moisture content of the germ, endosperm, and whole kernel was approached in all four steeping solutions. At 24 hr, the calculated moisture content of the whole kernel for the four steeping solutions was 41.5 ± 3.0% water; 42.8 ± 2.5% for 0.50% LA; 41.4 ± 2.3% for 0.20% SO_2; and 42.0 ± 2.6% for 0.50% LA and 0.20% SO_2. With water as steeping solution, the highest moisture content (42.7 ± 2.9%) was attained after 30 hr. For 0.20% SO_2 and 0.50% LA and 0.20% SO_2, the values were 42.8 ± 1.8% after 30 hr and 43.0 ± 2.3% after 36 hr, respectively. These findings are in accord with those of Yaptenco (1993).

In the first 5–10 min of steeping in water and 0.50% LA, water absorption in the endosperm exceeded absorption in the germ However, thereafter, the hydration rate of the germ increasingly exceeded that of the endosperm, reaching a peak after 4–4.5 hr. In both solutions, the germ-endosperm hydration ratio leveled off at ≈1.5 after 16 hr. Hydration of the germ and endosperm increased rapidly in all four steeping solutions during the first 3 hr. Ruan et al (1992) found that moisture diffused quickly into the germ in the first 2.5–3.5 hr of steeping at 53°C with 0.55% LA. In steeping studies in water containing 2,000 ppm of SO_2 and 0.5% (v/v) LA, McKinney (1996) reported a linear relationship between increase in moisture content and time during the first 4 hr of steeping. The moisture content increased by 8%/hr in the germ and 2.8% in the endosperm. In these studies, after steeping in water for 4 hr, the moisture content increased on average by 9.2%/hr in the germ and 3.6% in the endosperm; in 0.50% LA, moisture content increased on average by 8.5%/hr in the germ and 3.7% in the endosperm. However, there was no linear relationship between increase in moisture content and time.

This study represents the first reported determination of the hydration of the individual germ and endosperm components of corn kernels during steeping. Weighing of the individual hydrated germ and endosperm should minimize errors due to moisture loss. In studies conducted by Lopes Filho (1995) and McKinney (1996), moisture content was measured using two replicates consisting of a grouping of 20 germ or endosperm components.

CONCLUSIONS

Water absorption experiments were conducted on the hydration of the individual germ and endosperm components of corn kernels steeped in four different soak solutions at 52°C. This research provides a better understanding of the steeping process, specifically on the hydration of the germ and endosperm components of corn kernels and the influence of steeping chemicals. Previous laboratory studies had indicated that the addition of either LA or SO_2 results in a change in water absorption in the kernel. However, in these studies, composition of the soak solution with the addition of either LA or SO_2 or both LA and SO_2 did not significantly affect the rate of hydration of either the germ of endosperm. The high variability in the measured moisture content of an individual germ or endosperm for a given steep time demonstrates that determination of the moisture content of the individual germ and endosperm components of one or a few kernels may not be descriptive of the bulk material. However, determination of the moisture content of the germ and endosperm based on 15 replicates should be representative, in that the calculated equilibrium moisture content of the whole kernel was in agreement with literature reports. In contrast to some previous reports, the composition of the soak solution did not significantly affect the rate of hydration of the kernel; therefore, future research on bulk kernel samples of a variety of hybrids is warranted.

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