Individual Kernel Moisture Content of Preshelled and Shelled Popcorn and Equilibrium Isotherms of Popcorn Kernels of Different Sizes

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ABSTRACT

Commercial ear popcorn was hand-shelled at 16.5 and 13.6% bulk moisture content. The individual kernel moisture content of ear popcorn increased from the tip to the butt. The maximum difference was four percentage points. No trend was observed in kernel moisture content around the same ring on the cob. Because of this finding, a survey was conducted of individual kernel moisture content for commercially packaged popcorn in glass jars. A wide range (11.5–16.8%) of kernel moisture content was detected. This variation appears to be caused by factors such as growing conditions, mixture of hybrids, and postharvest processing and storage conditions, such as hysteresis caused by overdrying. In addition, an investigation was conducted to determine the equilibrium isotherms of two varieties of commercial shelled popcorn with different kernel sizes. No significant difference was found in equilibrium moisture content with respect to kernel sizes.

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Mechanical damage occuring during shelling of popcorn can reduce the expansion volume by as much as 28% (Walton 1968). Both kernel moisture and cob moisture affect the degree of mechanical damage (Waeti 1967, Walton 1968, McGhee 1971). Nelson and Lawrence (1990) measured the individual kernel moisture content (MC) of field corn at three locations on the ear: near the butt, at the midsection, and near the tip. They found that the butt-to-tip kernel MC difference was significant, with the butt having the highest moisture, and the tip the lowest. In addition, the kernel sizes are different from the tip to the butt. Thus, the potential impact on mechanical damage could be different with respect to kernel size due to a pure kernel size effect and a moisture effect.

Among all factors affecting expansion volume, MC has been considered the most critical (Eldredge and Lyerly 1943, Hoseney et al 1983). The optimum bulk MC has been reported as 13–14% (Eldredge and Thomas 1959). Popcorn of different kernel sizes may have different chemical compositions that affect equilibrium MC at the same relative humidity. Song and Eckhoff (1994) indicated that the optimum MC differed with respect to kernel size. However, it has not been determined whether the different optimum popping moisture is caused by differences in equilibrium MC with kernel size or whether it is caused by environment or other factors.

The objectives of this study were to: 1) measure the individual kernel MC of ear popcorn as the kernel position changes from the tip to the butt; 2) determine the isotherms (relationship between equilibrium MC and equilibrium relative humidity) for popcorn of different kernel sizes; 3) examine whether a correlation exists between kernel size and the equilibrium MC; 4) survey the MC distribution in popcorn from jars taken off the shelf in a grocery store.

MATERIALS AND METHODS

Individual Kernel MC of Ear Popcorn

Commercial popcorn, machine-harvested on the ears at 17–18% MC, was stored at 1.1°C (34°F) for approximately four to six weeks. Two ears were taken out of the cold room and dried for 24 hr at ambient conditions (24.4°C and 38% rh) before shelling. Four additional ears were immediately hand-shelled after being removed from the cold room. Two opposing rows and two rings (one at the butt and one at the tip) were left on each of the four ears for an individual kernel moisture study. Each row or ring of kernels was then hand-shelled and the position was noted. Each kernel was placed in a predried, preweighed bottle (2 cm in diameter and 4 cm in height). Each bottle was immediately covered with a rubber lid. A rack of 100 bottles was dried at 103°C for 72 hr (ASAE 1989). The elapsed time from the start of shelling to the end was <15 min; any drying was considered negligible. Using a Mettler AE160 digital balance interfaced with a personal computer, all weights were taken to ±0.0001 g. MC of the cobs was determined by drying a sample of the cob at 103°C for 24 hr.

The validity of using the oven method for single-kernel moisture measurement, particularly with glass bottles, was determined by comparing the bulk MC (15 g of sample) to the weighted-average MC of 100 individual kernels based on kernel weight. The absolute difference was ±0.2 percentage point.

Isotherm of Shelled Popcorn of Different Kernel Sizes

Two varieties (proprietary hybrids) of yellow shelled popcorn from the 1989 crop were obtained from the Orville Redenbacher Popcorn Co., Brookston, IN. They were first sorted into five size-fractions using a Carter Day Dockage Tester equipped with round hole sieves (4.36, 4.76, 5.16, 5.56, 5.95 mm; or 11/64, 12/64, 13/64, 14/64, 15/64 in., respectively). The isotherms of these five fractions were determined in duplicate by the static desiccator method as discussed by Eckhoff et al (1982) and compared with the isotherm of a control sample (containing mixed sizes of kernels in a natural ratio).

Desiccators containing various saturated salt solutions were used to provide the range of relative humidities needed. The relative humidities of nine salts selected were: zinc chloride, 7.4%; potassium acetate, 23%; magnesium chloride, 33%; potassium carbonate, 44%; calcium nitrate, 51%; sodium nitrite, 63%; sodium chloride, 74%; potassium chloride, 83.5%; potassium nitrate, 91.5%. Before placing samples into the desiccators, the relative humidity of each salt solution was measured using a 2-wire humidity transmitter (model H2C, Rotronic Instrument Corp.). The salt solutions were maintained at 25±1°C during the tests.

A single layer of popcorn kernels (~15 g) was placed in a petri dish for each size-fraction. Previous experience indicated that three weeks was long enough for a single layer of popcorn to reach equilibrium. At the end of three weeks, the MC of the whole samples (15 g) was determined using the standard oven method (ASAE 1989).

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Individual Kernel MC Distribution of Commercially Packaged Popcorn

Three glass jars of standard yellow gourmet popcorn (Orville Redenbacher) were purchased from a local grocery store to determine the individual kernel MC distribution of packaged popcorn. One hundred kernels were taken randomly from each jar, and the single-kernel MC was determined using the method described previously. Five 100-kernel replicates were run for each jar.

RESULTS AND DISCUSSION

Individual Kernel MC of Ear Popcorn

Popcorn taken directly from cold storage had an average bulk MC of 16.5%, while the cobs averaged 17.3%. The bulk MC was 13.6 and 11.1%, respectively, for the popcorn and the associated cobs dried for 24 hr. Thus, the MC of cobs was higher than that of the kernels for undried ears, and lower than that of the kernels for dried ears; this was due to the higher moisture diffusion rate in the cobs.

Figure 1 shows the individual kernel MC of popcorn from two opposing rows of a typical ear. As the kernel position moves from the tip to the butt, the MC increases (14.8–17.6%). The trend holds for the two rows on the same ear and for several different ears. Thus, if the popcorn is popped immediately after shelling, without conditioning, the total expansion volume would not be maximized.

Figure 2 shows the individual kernel MC for kernels near the tip and butt locations of the same ear. The individual kernel MC fluctuated around the average value from the same ring. No specific trend was observed. The individual kernel MC range was 15.6–16.3% for the tip ring and 16.8–17.7% for the butt ring. The standard deviation was 0.23–0.31%.

Figures 1 and 2 show that the behavior of individual kernel MC on ear popcorn is the same as that of field corn (Nelson and Lawrence 1990). Similar trends existed for the other ears tested.

Individual Kernel MC Distribution of Commercially Packaged Popcorn

The MC of popcorn sold in a grocery store was surveyed. The bulk MC for the three jars labeled A, B, and C was 13.0, 13.5, and 13.4%, respectively. However, the MC range variation was 11.5–16.8% for A; 11.5–16.4% for B, and 11.6–15.9% for C. Figure 3 illustrates the percentage of kernels at different MC levels for A. Similar distributions were observed for B and C. Generally, ~60% of the kernels in each jar had an MC of 13–13.5%. Less than 10% of kernels had an MC below 12.5% or above 15%. Similar type of variation in individual kernel MC was reported by Kandala et al (1987) for field corn.

Isotherm of Shelled Popcorn of Different Kernel Sizes

Table I presents the data of average equilibrium MC of five size fractions and the control sample at nine relative humidities at 25°C. There was some variation in equilibrium MC among

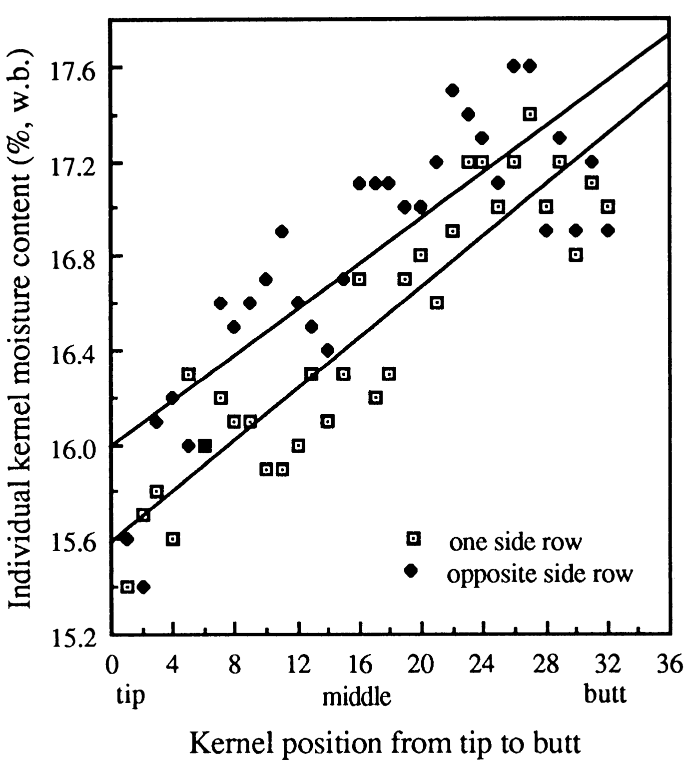

Fig. 1. Individual kernel moisture content in relation to the location on ear popcorn.

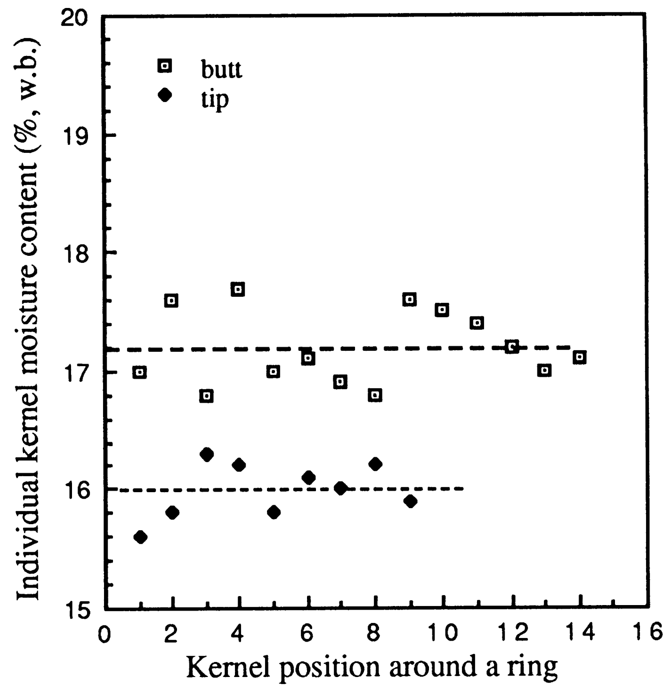

Fig. 2. Individual kernel moisture contents around a tip ring and a butt ring of ear popcorn.

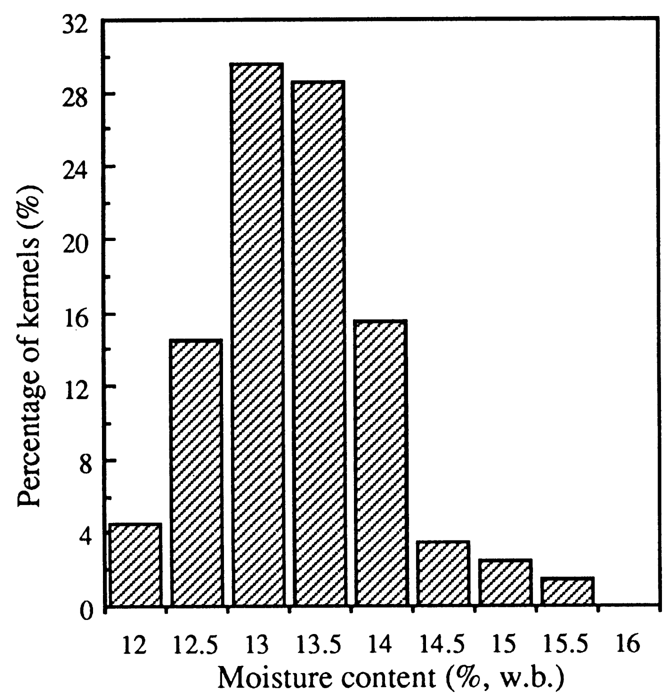

Fig. 3. Individual kernel moisture content distribution in a glass jar of commercially packaged popcorn.

TABLE I
Equilibrium Moisture Contents at Nine Relative Humidities and 25° C Temperature for Two Varieties and Five Size-Fractions of Popcorn[a]

		Relative Humidity, %								
Variety	**Size, mm**	**7.4**	**23**	**33**	**44**	**51**	**63**	**74**	**83.5**	**91.5**
	4.36–4.76	5.02	7.33	8.59	9.88	10.89	12.39	14.17	17.01	20.14
	4.76–5.16	5.14	7.26	8.59	9.92	10.97	12.26	13.98	16.93	19.22
A	5.16–5.56	5.22	7.29	8.45	9.99	10.93	12.25	14.16	16.87	20.47
	5.56–5.95	5.25	7.38	8.51	9.98	11.01	12.34	14.25	16.86	19.73
	≥5.95	5.34	7.37	8.58	9.91	10.98	12.42	14.14	16.71	19.36
	Control[b]	5.19	7.25	8.49	9.83	10.84	12.33	14.03	16.42	19.55
	4.36–4.76	5.04	7.24	8.50	9.96	10.96	12.17	14.30	17.02	19.86
	4.76–5.16	5.08	7.25	8.53	9.93	10.94	12.13	14.26	16.56	19.85
B	5.16–5.56	5.17	7.30	8.53	10.01	10.94	12.23	14.36	16.46	19.37
	5.56–5.95	5.18	7.31	8.50	9.87	10.95	12.33	14.06	16.74	19.12
	≥5.95	5.28	7.33	8.56	9.87	10.91	12.39	14.40	16.47	20.11
	Control	5.15	7.29	8.46	9.94	10.92	12.49	14.30	16.92	19.03

[a]Standard deviation ranged from 0.23 to 0.41.
[b]Sample from variety A or B containing mixed sizes of kernels in their natural ratio.

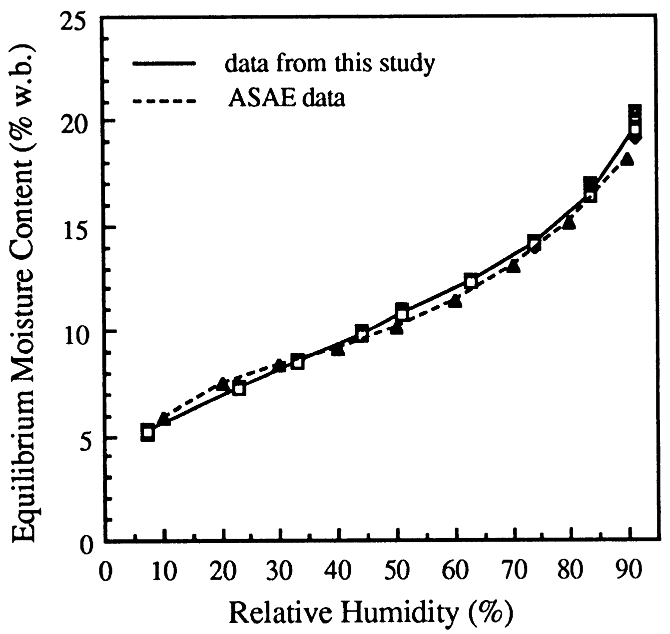

Fig. 4. Equilibrium moisture contents of two varieties and five size fractions of popcorn measured in this study compared with that of standard data (ASAE 1989).

different sizes of kernels. However, there was no consistent trend with respect to the kernel size. The difference in equilibrium MC between the two varieties seemed insignificant. The standard deviation of all the measurements ranged from 0.23 to 0.41.

According to Song and Eckhoff (1994), the optimum MC for popping differed with respect to kernel sizes. Using the same equilibrium conditions (temperature and relative humidity) does not condition all the popcorn of different kernel sizes to optimum MC.

Figure 4 compares the experimental data with data from the ASAE standard (ASAE 1989). There was good agreement between the two sets of data.

The study on equilibrium isotherms indicated that the equilibrium MC did not correlate with kernel sizes. The wide range of individual kernel MC in the jars might be correlated with variations in other physical properties such as kernel density, or it may be related to different growing conditions, different hybrids, and different postharvest processing conditions. For example, if some kernels were overdried and some underdried, hysteresis would prohibit them from reaching the same equilibrium MC.

CONCLUSIONS

The individual kernel MC of ear popcorn increased from the tip to the butt. No significant difference in equilibrium isotherms was found between the two varieties selected. No correlation was found between the equilibrium moisture and kernel sizes. When conditioning several sizes of popcorn kernels to optimum MC values, the kernels have to be conditioned under different equilibrium relative humidities. A large variation in kernel MC was found for commercially packaged popcorn in glass jars, although it was supposedly in an equilibrium condition. The MC of ~60% of the kernels in a commercially packaged jar of popcorn was 13–13.5%. Only 10% of the kernels had an MC below 12.5% or above 15%.

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