Optimum Popping Moisture Content for Popcorn Kernels of Different Sizes

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ABSTRACT

A single variety of commercial yellow popcorn was separated into five size-fractions by screening with round-hole sieves of 4.36, 4.76, 5.16, 5.56, and 5.95 mm. Each of the five fractions and the control sample were conditioned to seven moisture content levels ranging from 11 to 14%. The conditioned samples were popped in a Cretor metric weight volume tester. The relationship between expansion volume and moisture content for each size-fraction and the control sample was described by a quadratic equation. The optimum moisture content for popcorn retained on the round-hole sieves at 5.95, 5.56, 5.16, 4.76, and 4.36 mm was determined to be 13.18, 12.91, 12.85, 13.58, and 13.47%, respectively. When the moisture content varies from the optimum value by ±1%, the expansion volume could be reduced by as much as 2%. It was proposed that kernels need only to be separated into two size classes using a 5.16-mm round hole sieve: 1) the suggested moisture content for kernels passing through the sieve would be 13.5%; 2) the suggested moisture content for kernels remaining on the sieve would be 13%.

The optimum bulk moisture content (MC) for maximum expansion of popcorn has been reported by Metzger et al (1989) as 13.5% for oil popping and 14% for air popping. Song et al (1991) reported that kernel size and genotype significantly affect expansion volume and the number of unpopped kernels.

Kandala et al (1987) reported that single-kernel MC in field corn can vary as much as ±0.8% from the bulk value in equilibrated samples. Larger variation is expected in nonequilibrated samples. The optimum MC for maximum expansion of popcorn reported by Metzger et al (1989) did not take into account the variation of bulk kernel moisture. The objective of this research was to determine whether different size kernels have different optimum popping MC.

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MATERIALS AND METHODS

Sample Preparation

A single variety of commercial popcorn (Orville Redenbacher Popcorn Co., Brookston, IN.) was separated with round-hole sieves of 4.36, 4.76, 5.16, 5.56, and 5.95 mm (11/64, 12/64, 13/64, 14/64, and 15/64 in., respectively) using a Carter-Day dockage tester. Popcorn retained on each sieve was collected separately to generate five identifiable size-fractions. The five fractions were labeled by screen size for convenience (4.36, 4.76, 5.16, 5.56, and 5.95 mm). Control samples with a naturally occurring distribution of size were prepared before screening.

Each fraction was dried at 35°C to ~10% MC using a laboratory-type dryer. After the samples were dried, they were rewetted to one of the seven target moisture levels (11, 11.5, 12, 12.5, 13, 13.5, 14%). In cases where moisture difference between initial and target levels was >2%, water was added in steps so that the moisture level of each addition did not increase by more than 2%. This reduced the likelihood of stress-crack formation.

During water addition, the sample was mixed vigorously and stored at 5°C. Subsequently, the samples were mixed daily for the first three days of storage to ensure uniformity of water absorption. After three days of storage, the samples were sealed in two-layer polyethylene bags, placed in a sealed 5-gallon bucket, and stored at 5°C for at least four weeks before popping. A full 6×7×20 factorial design (6 size-fractions, including the control sample; 7 moisture levels; and 20 replicates) was used in popping tests.

Popping Methods

The five size-fractions and the control sample were popped randomly by the same technician, using a Cretor 86 metric weight volume tester (C. Cretor and Co., Chicago, IL). After this procedure, described by Song et al (1991), the expansion volume and the number of unpopped kernels were recorded. Each test used 250±0.5 g of popcorn and 110±5 g of liquid coconut oil. Each sample's MC was determined by drying a 15-g sample at 103±2°C for 72 hr (AACC 1983).

RESULTS AND DISCUSSION

Figure 1 shows the relationship between expansion volume and MC for the five fractions and the control sample. Each point on the figure represents the average of 20 replicates. The standard deviation of the popping volumes ranged from 0.32 to 0.64 cm^3 per gram over 42 treatments (6 size-fractions × 7 moisture levels). The expansion volume increases as the MC increases until it reaches the peak point, then it decreases with further increase of moisture. The optimum expansion volume occurred at a different moisture level for each size-fraction.

A second-order polynomial equation best described the relationship between expansion volume and MC. The best-fit quadratic equation coefficients are listed in Table I. The r-value for goodness of fit varied from 0.86 to 0.99. These equations can be used to predict the expansion volume, providing that the MC is in the 11–14% range.

The optimum MC for oil popping was determined by taking the first derivative of the quadratic equations and equating to zero. The optimum values were 13.47, 13.58, 12.85, 12.91, and 13.18%, respectively, for 4.36, 4.76, 5.16, 5.56, and 5.95 mm (Fig. 2); the optimum MC for the control sample was 13.10%. The calculated maximum expansion volume at optimum MC is shown in Table II. The size effect, similar to that reported by Song et al (1991), was observed here: middle-size-fractions had the highest expansion volume.

The optimum MC had a narrow range (0.73 percentage points from 12.85 to 13.58%) for all the sizes studied. The practical significance of this difference is the impact it has on the popping volume as the MC deviates from the optimum value. Table II shows the percentage variation in expansion volume for MC at ±0.5% and ±1% away from the optimum values for all size-fractions. The maximum reduction in volume was 2% (~1 cm^3/g). This occurred for the smallest kernels when the MC was 1% below the optimum value. Even though 1 cm^3/g in popping volume seems small, the net profit to a commercial popcorn seller increases by 2% for every 1 cm^3/g change in popping volume. A 2% increase

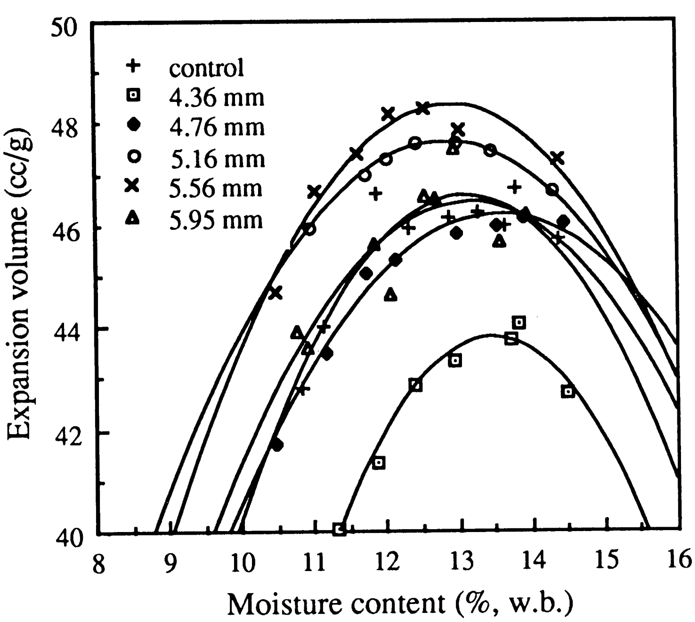

Fig. 1. Expansion volume versus moisture content for five size-fractions and a control sample.

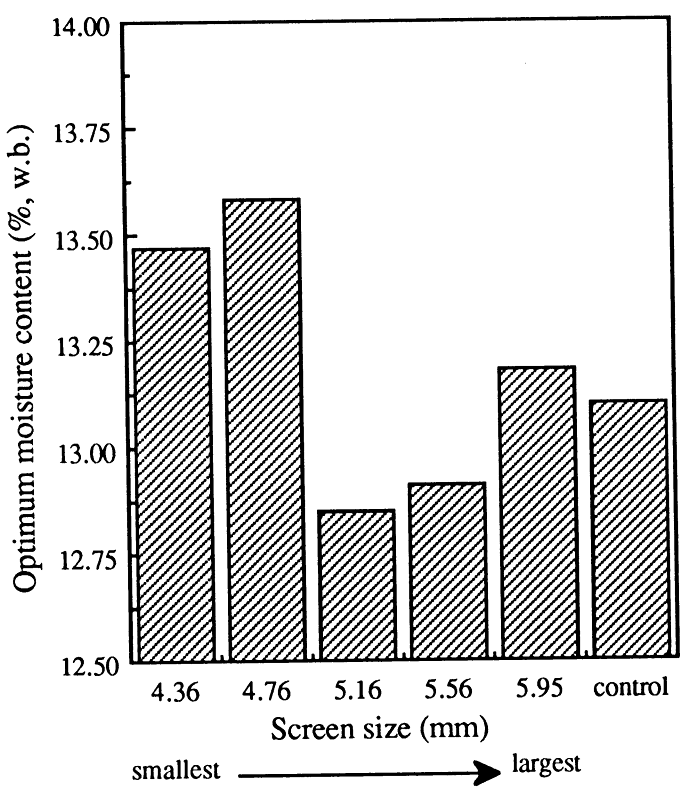

Fig. 2. Optimum moisture content versus screen size.

TABLE I
Constants (C) in the Quadratic Equations for Five Size-Fractions and a Control Sample[a]

Size, mm	C_0	C_1	C_2	Optimum MC	r
Control	−67.51	17.40	−0.6638	13.10	0.92
4.36–4.76	−107.44	22.45	−0.8331	13.47	0.986
4.76–5.16	−35.98	12.09	−0.4450	13.58	0.991
5.16–5.56	−29.02	11.92	−0.4637	12.85	0.997
5.56–5.95	−46.01	14.62	−0.5663	12.91	0.969
≥5.95	−42.09	13.44	−0.5100	13.18	0.864

[a] Quadratic equation: $Vol = C_0 + C_1\,MC + C_2\,MC^2$ where: MC is moisture content (%, wet basis) and Vol is expansion volume (cm^3/g).

TABLE II
Maximum Expansion Volume and Optimum Moisture Content (OMC) Along with Percentage Decrease in Expansion Volume for Moisture Variation of ±0.5 and ±1%

	OMC		Maximum Expansion Volume	Optimum Moisture Content	OMC	
Size, mm	−1%	−0.5%	(cm^3/g)	(%)	+1%	+0.5%
Control	−1.27	−0.32	46.4	13.47	−0.34	−1.20
4.36–4.76	−2.01	−0.46	43.8	13.58	−0.48	−1.69
4.76–5.16	−0.91	−0.22	46.1	12.85	−0.24	−0.95
5.16–5.56	−0.88	−0.23	47.6	12.91	−0.23	−0.88
5.56–5.95	−1.16	−0.29	48.4	13.18	−0.29	−1.14
≥5.95	−1.03	−0.26	46.4	13.10	−0.26	−1.06

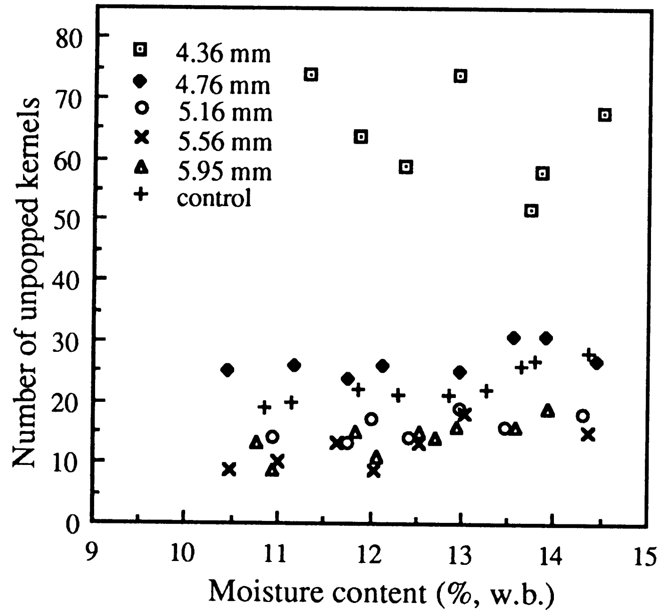

Fig. 3. Number of unpopped kernels versus moisture content for five size-fractions and a control sample.

in profit is significant for an industry handling millions of pounds of popcorn per year. When popcorn quality is poor (average popping volume ~35 cm³/g), 1 cm³/g is equivalent to a 3% change in net return. The impact is tremendous.

Because of the narrow range in optimum MC for the five size-fractions, it would not be practical to separate popcorn into five fractions. The optimum MC of the smaller kernels (4.36 and 4.76 mm) was higher than that of the larger kernels (5.16, 5.56, and 5.95 mm) (Fig. 2). The average optimum MC for kernels at 4.36 and 4.76 mm was 13.52%. The average optimum MC for kernels at 5.16, 5.56, and 5.95 mm was 12.98%. Perhaps, separating shelled popcorn into two fractions using only the 5.16-mm round-hole sieve would best serve to maximize expansion volume at a minimal cost. Practically, the target MC for the smaller size (≤5.16 mm) should be 13.5%, whereas for larger kernels, (≥5.16 mm) should be 13%.

The number of unpopped kernels did not vary much with the MC (Fig. 3) for the range studied (11–14%). The observed variation in unpopped kernels among different sizes of kernels agreed with previous findings (Song et al 1991). The 1,000-kernel weights for the variety studied were 89.3, 105.2, 124.5, 131.6, and 156.3 g, respectively, for kernel sizes at 4.26, 4.76, 5.16, 5.56, and 5.95 mm. Thus, the weight percentage of unpopped kernels would be (in order of small to large kernels): 2.3, 1.0, 0.7, 0.58, and 0.75%. Similar findings were reported by Song et al (1991).

CONCLUSIONS

The optimum MC was different for different-sized kernels. Smaller kernels required slightly higher moisture to achieve the maximum expansion. The optimum values for sizes 4.36, 4.76, 5.16, 5.76, and 5.95-mm were 13.47, 13.58, 12.85, 12.91, and 13.18%, respectively. The optimum value for the control (no size separation) was 13.1%. Studies also showed that when the MC varied by ±0.5% from the optimum moisture level, the expansion volume varied by a maximum of ±0.5%. However, when the moisture varied by ±1% from the optimum value, the expansion volume could be reduced as much as 2% (1 cm³/g). It was proposed that, when kernels were separated by kernel size, only two classes were needed: for kernels passing through a 5.16-mm round-hole sieve, the suggested MC would be 13.5%; for kernels remaining on the 5.16-mm round-hole sieve, the suggested MC would be 13%.

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