Measurement of the Water Uptake Rate of Crackers

CHARLES S. GAINES and PATRICK L. FINNEY[1]

ABSTRACT

Cereal Chem. 65(6):471–473

Four types of commercial crackers baked by six commercial producers from 12 flours were evaluated by a new, inexpensive method for assessing the internal structure of those products, i.e., water uptake. Data from the sorption method were compared to data from an instrument designed to evaluate the hardness of commercial crackers, the Biscuit Texture Meter (BTM). The BTM had a lower coefficient of variation; however, rate curves from the water uptake method could predict the BTM values with an R^2 of 0.91. Equipment for the water uptake method costs considerably less than the BTM.

Texture is an important aspect of food enjoyment that receives much attention by food researchers (Bourne 1982). The most common baked products for which apparent texture measurements are reported in the literature are bread and, to a lesser extent, cakes (Taranto 1983). Those products easily lend themselves to evaluation by commonly available compression-resistance instruments. Subjective profiles of crackers determined by trained organoleptic panels can be detailed and accurate, but costly. Therefore, many objective techniques have been developed for quick assessment of product structure and quality control. Instruments such as the Instron universal testing machine, Kramer shear press, Fudoh rheometer, General Foods texturometer, and the Biscuit Texture Meter (BTM) produce various data such as shear, puncture, snap, saw time, bending, compression, rupture, penetration, crushing, stretching, vibration, and tension. These disruptions of the cracker reveal information about the hardness of its internal structure.

For a given type of cracker, and especially for a given cracker formulation, the quantitative uptake of water by a cracker is a function of the size, number, and uniformity of air spaces, density, tunnels, fissures, and the pervasiveness of the products' continuous structural (protein) network. Therefore, water uptake rate or percent weight gain of a cracker placed under water for a prescribed time may correlate with other objective measurements of the internal structure of crackers.

The objectives of this study were to evaluate the water uptake method for comparing the structure of crackers by statistically comparing it with the BTM, an instrument specifically designed to measure the hardness of commercial crackers and cookies. The BTM has been shown to rank the hardness of crackers and cookies in an order similar to the ranking of an organoleptic panel (Wade 1968). The panel could distinguish among the hardness of crackers and cookies producing BTM cutting times as close as 3 sec.

MATERIALS AND METHODS

Products Evaluated

Four types of commercial crackers were obtained from a total of six producers, either directly from the producer or locally purchased. Cracker types evaluated were oil-sprayed, rich-tender, graham, and saltine. Three to six packages (boxes) from one commercial lot number were obtained. Products were evaluated in three stages.

BTM Measurements

All products were tested with a BTM (Werner Lahara, Grand Rapids, MI) that measured the seconds required for a circular saw blade to cut a 15-cm path through a vertical stack of crackers. The instrument made 16 sawtooth "bites" per second.

Water Sorption Measurements

For each replication, 10 or 15 crackers (depending on cracker size) were weighed in a wire-mesh kitchen-type strainer and then held in the strainer under water (25°C) in a plastic dishwashing bucket for a prescribed time. A wire-mesh cover was fabricated for the strainer to hold the crackers, which initially tended to float. Crackers were loosely stacked so water could flow around and between them. A preliminary series was necessary to determine at what soaking time water sorption became effectively asymptotic with time. At the end of the soaking time, the strainer containing the hydrated product was held above the water for 30 sec to drain. Without removing the sample, the strainer was partially dried by placing it on absorbent paper towels for an additional 30 sec. The soaked product and strainer were then weighed again, and the weight gain was expressed as percent water sorption.

Study of the water uptake method was accomplished in three stages. The first stage compared estimates of statistical variance of the BTM cutting times and water uptake. For that study, soaking times were chosen for each product that were approximately half of the time necessary to achieve maximum water uptake. The second evaluation stage produced a regression equation to predict BTM cutting times from water uptake rates of crackers from 10 manufacturers or cracker types. To establish water uptake rate curves, soaking time was varied to find the maximum weight gain. At least five shorter times were then chosen to establish a curve. The third evaluation stage checked the prediction equation using a new data set of four types of crackers.

Statistical Evaluation

Each product was evaluated 10 times as described above, except for oil-sprayed crackers (five replications). Sorption and BTM data of flour from each producer were evaluated for coefficient of variation and Duncan's multiple range test. Data were evaluated by Kolmogorov-Smirnov goodness of fit to test for normality (Conover 1980, Hull and Nie 1981) and by simple multiple linear regression.

RESULTS AND DISCUSSION

Comparison of crackers by the relative amount of water absorbed was accomplished in three stages. The first compared the relative differences in standard error of the water uptake method and another objective method (BTM) of hardness measurement and thus the ability of both methods to differentiate among the flours (or producers in as much as they use different flours, different product formulations, and production techniques) used to produce each type of cracker.

Comparison of Variance and Ability to Differentiate Among Flour and Product Means

Product widths, heights, calculated densities, and weights revealed that crackers varied greatly among producers (Table I).

[1]Research food technologist and research food technologist, in charge, respectively, USDA Soft Wheat Quality Laboratory, Department of Agronomy, The Ohio State University, Ohio Agricultural Research and Development Center, Wooster 44691.

Mention of a trademark or proprietary product does not constitute a guarantee of warranty of a product by the U.S. Department of Agriculture and does not apply its approval to the exclusion of other products that may also be suitable.

TABLE I
Four Commercial Crackers Measured by the Biscuit Texture Meter and Water Uptake Methods

Cracker Type	Producer	Flour	Individual Cracker Height (cm)	Calculated Cracker Density (g/cm^3)	Biscuit Texture Meter[a] Mean (sec)	Biscuit Texture Meter[a] Coefficient of Variation (%)	Trial Water Uptake[a] Water Uptake Time (sec)	Trial Water Uptake[a] Cracker Weight Measured (g)	Trial Water Uptake[a] Mean (%)	Trial Water Uptake[a] Coefficient of Variation (%)
Oil-sprayed	A	1	0.500	0.358	15.8B	5.3	120	15.9	181.0A	3.8
Oil-sprayed	A	2	0.530	0.341	18.0A	5.5	120	16.0	100.4B	9.6
Oil-sprayed	B	3	0.572	0.315	12.2C	3.7	120	16.3	174.2A	4.5
Rich-tender	A	4	0.451	0.337	13.1B	5.6	10	65.6	64.2C	15.5
Rich-tender	A	5	0.458	0.338	14.1A	4.0	10	65.8	73.1B	12.3
Rich-tender	B	6	0.445	0.432	11.4C	4.5	10	64.2	133.3A	5.8
Graham	A	4	0.560	0.351	14.9A	5.0	30	78.1	85.4B	9.4
Graham	A	5	0.550	0.349	14.9A	6.7	30	76.1	79.2B	7.8
Graham	B	7	0.575	0.315	12.1B	4.7	30	71.7	148.1A	9.2
Saltine	A	8	0.522	0.240	10.0B	12.5	30	28.9	111.4A	20.6
Saltine	B	9	0.537	0.232	13.6A	8.6	30	29.0	97.8A	19.0

[a] Means within a cracker type followed by the same letter are not significantly different at the $P = 0.05$ level of probability.

TABLE II
Biscuit Texture Meter Times and Water Uptake Rate Curve Slopes and Intercepts for 10 Commercial Crackers

Cracker Type	Producer	Biscuit Texture Meter (sec)	Maximum Water Uptake (%)	Time of Maximum Water Uptake (sec)	Water Uptake Rate Plots: Time (x-axis) Intercept (LN[a] sec)	Water Uptake Rate Plots: Water Uptake (y-axis) Intercept (%)	Water Uptake Rate Plots: Slope
Rich-tender	B	11.4	223	90	−1.21	48	39.9
Graham	B	12.1	195	45	−1.73	62	35.8
Oil-sprayed	B	12.2	163	180	−0.06	1	25.8
Saltines	B	13.6	325	180	0.63	−34	53.4
Rich-tender	A	13.6	169	90	−0.87	25	29.4
Graham	A	14.9	152	45	0.35	−16	44.9
Saltines	D	15.8	271	90	1.96	−216	110.4
Graham	E	16.6	179	30	−0.28	13	47.6
Oil-sprayed	C	18.2	137	240	3.12	−185	59.3
Saltines	C	20.2	306	300	2.24	−196	87.5

[a] Natural logarithm.

The variations precluded standardization of product weight that would allow the amount of water weight gained to indicate relative internal structure. Therefore, product weight was allowed to vary, and the weight percentage of water gained over a standardized time was used to compare products.

Soaking crackers usually produced two populations of data at any particular soaking time: one with lower, less variable values resulting from undamaged sound products and the other with larger, more variable values resulting from products that were cracked or chipped, allowing a faster rate of water uptake. Only undamaged product should be evaluated.

Soaking times less than those required for maximum water uptake were used to compare sample variability among BTM and uptake data, because those times produced a more dynamic state of water sorption. The coefficient of variation was computed for each product type and flour combination. Generally, the coefficients of variation for the water uptake method were larger than those for the BTM. Coefficients of variation calculated from the pooled variances of the cracker replication study were 6.4 and 11.9% for the BTM and water uptake methods, respectively. The Kolmogorov-Smirnov goodness of fit tests showed data from both methods were normally distributed. The Duncan's multiple range test for significance among flour means within each product found two additional comparisons (flours 1 and 3 and flours 8 and 9) of the BTM to be significantly different (Tables I and II).

Comparing Products Using Maximum Water Uptake and Uptake Rate

The next evaluation step used water uptake data to predict BTM cutting time, thus determining how well data from the two very different methods were correlated. The 10 replications in the first study required two to three standard sized packages of commercial product (usually 100 individual pieces). If that amount of product is available, another method is possible using water uptake rate. Therefore, instead of soaking in water to a specified time, products were allowed to take up water to their maximum capacity (until just asymptotic with time as determined by trial and error). Maximum water uptake of crackers ranged from 137 to 325% (Table II).

Additionally, to establish water uptake rate curves, five to six sorption percentages at times equal to and less than that required for maximum uptake were used to plot uptake percentages over the logarithm of time. The water uptake rate of crackers is relatively parabolic with time, but the relationship varies greatly with cracker type. For example, oil-sprayed crackers take up water more slowly. Therefore, log transformation of soaking time to a more linear treatment is useful for plotting.

For some types of crackers, water uptake data under 10 sec should not be used, because it is very erratic until much of the air is displaced and the steadier rate of capillary activity can influence the measurements. Therefore, log transformation will not necessarily produce time-axis intercept values near zero. The intercept values place the data line with respect to slope and elevation. Times required for maximum uptake and the individual plotted uptake axis intercepts did not completely distinguish between cracker types. There was also considerable variation in uptake slopes and in the time-axis intercepts within a product type. Cracker slopes ranged from 25.8 to 110.04. Cracker time-axis intercepts ranged from −1.73 to 3.12. Therefore, a combination of maximum water uptake and time and the uptake rate (slope and

TABLE III
Actual and Predicted Biscuit Texture Meter (BTM) Cutting Times

Cracker Type	Producer	Actual BTM (sec)	Predicted BTM (sec)	Absolute Residual (sec)
Saltine	B	10.0	13.1	3.1
Rich-tender	A	13.2	14.9	1.7
Oil-sprayed	A	15.8	14.3	1.5
Oil-sprayed	F	18.0	19.1	1.1

intercepts) was evaluated to better characterize cracker structure.

The best simple multiple linear regression equation for predicting BTM cutting times from sorption rate curves was

$$t = 52.01 + 0.096(M) - 7.92(L) - 0.146(Y) - 0.52(S)$$

where t = BTM cutting time (sec), M = maximum water uptake (%), $L = \log_e$ time of maximum water uptake (logsec), Y = sorption axis intercept from plot of water uptake and log time, and S = slope of plot of water uptake and $\log_e$ time.

The R^2 value of the equation is 0.91 ($r = 0.96$), the standard error of estimate is 1.1 sec, and the F ratio of the equation is 13.2 at a 0.007 level of probability. All independent variables had Student's t statistics that were less than a 0.013 level of probability. Although there are four terms, the equation characterizes only two independent variables, maximum water uptake (amount and time) and rate of uptake (slope and elevation).

The actual BTM values versus values predicted from the water uptake method using the above equation are plotted in Figure 1. The mean absolute residual of predicted versus BTM values is 0.7 sec.

Evaluating the Prediction Equation

The prediction equation was checked by evaluating the water uptake rates of four new crackers, one of which was from a different manufacturer than used previously. The other three crackers were different lots of the crackers used to establish the prediction equation. Table III shows the actual BTM cutting times of those crackers, the values predicted by the above equation, and the absolute residual difference between the two. The mean absolute residual difference was 1.9 sec, which is less than the 3-sec range reported for taste panel sensitivity (Wade 1968).

CONCLUSIONS

A low-cost water uptake method for comparing the structure of commercial crackers was reported and statistically compared to data from a machine (BTM) designed to compare product hardness by sawing through a stack of crackers. The coefficient of variation of the water uptake method was somewhat larger than that of the BTM. However, the water uptake method (with data expressed as rate components) could predict BTM cutting times using a simple multiple linear regression equation. The cost of materials required for the water uptake method essentially depends on the cost of a balance accurate to two decimal places, considerably less than the cost of the BTM. The water uptake method can be used in two modes of application: 1) the amount of water taken up at a specified time can be used to compare treatments or variables within a product, e.g., different flours, sugars, mixing times, etc.; and 2) the amount of water taken up over various times can be used to compare the above-mentioned variables as well as different product types. However, the second mode requires additional data analysis, i.e., log conversion, plotting, and slope and intercept determination. If the rate of water uptake of crackers can predict the relative texture of crackers as measured by the BTM, it is possible that water uptake may correlate to other types of objective or even subjective measurements.

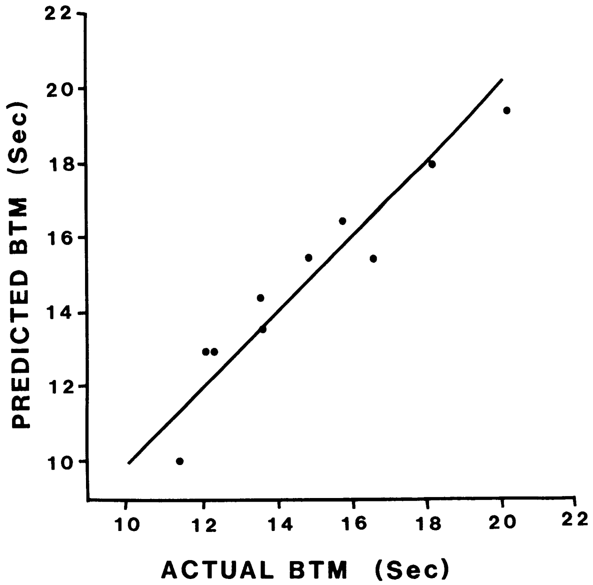

Fig. 1. Actual Biscuit Texture Meter (BTM) versus BTM times predicted from water sorption rates of 10 types/producers of commercial crackers.

LITERATURE CITED

BOURNE, M. C. 1982. Food Texture and Viscosity: Concept and Measurement. Academic Press: New York.

CONOVER, W. J. 1980. Pages 344-363 and 462-463 in: Practical Nonparametric Statistics, 2nd ed. John Wiley & Sons: New York.

HULL, C. H., and NIE, N. H. Pages 220-222, 224 in: 1981 SPSS Update 7-9. New Procedures and Facilities for Releases 7-9. McGraw-Hill: New York.

TARANTO, M. V. 1983. Structural and textural characteristics of baked goods. In: Physical Properties of Foods. M. Peleg and E. B. Bagfley, eds. Avi Publishing Co.: Westport, CT.

WADE, P. 1968. A texture meter for the measurement of biscuit hardness. Rheology and Texture of Foodstuffs. Monogr. 27. Soc. Chem. Ind. London 27:225.

[Received October 8, 1987. Revision received May 30, 1988. Accepted June 22, 1988.]