Humidity Effects on Textural Characteristics of Sugar-Snap Cookies[1]

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ABSTRACT

Sugar-snap cookies were prepared with a high and a low quality cookie flour and equilibrated for five days at six relative humidities. Textural characteristics of the moisture-equilibrated cookies were evaluated in two independent studies. In the first, relative humidities ranged from 11 to 93%; in the second, the range was from 52 to 79%. Crispness determined as breaking strength using the single blade cell and tenderness using the standard shear compression cell with the Allo Kramer Shear Press were determined in both experiments. In addition, breaking strength and compressibility were determined with the Instron Texturometer for cookies prepared in the second experiment. Storage relative humidity affected significantly all types of textural evaluations. Breaking strength, however, appeared to be the most sensitive test. Over a wide range of storage relative humidities, the relationship was linear. High storage relative humidities were most detrimental as they most often masked the expected differences between cookies prepared with high and low quality flour, but 5–10% variations in relative humidity resulted in minimal differences in textural values. Percentage moisture in the cookies also was significantly affected by and linearly related to storage relative humidity.

The sugar-snap cookie system consists of flour, sugar, leavening, fat, and water. Its quality characteristics depend on results of competition between the sugar and flour components for the limited water available (Yamazaki 1955, 1962). Conditions that favor solution of sugar and its resultant holding of water early in the baking period allow greater cookie spread before setting of the dough. Flour components differ in water holding capacity (Yamazaki 1962; Sollars 1956a, 1956b), thus the type of flour used and the sugar granulation (Fuhr 1962, Kissell et al 1973) affect this competition. The relative humidity in the room in which sugar-snap cookies are prepared and that in the oven also affect cookie quality. In determining quality of new flour types, workers at the Soft Wheat Quality Laboratory condition the oven by baking control cookies each day and restrict testing to room relative humidity of less than 60%.

Relative humidity also affects measurement of textural characteristics of the baked cookie. The purpose of this investigation was to quantify the effect of relative humidity on crispness and tenderness characteristics of these cookies. Two experiments were conducted: one with a broad range of relative humidities ranging from 11 to 93% and a second with a more limited range from 52 to 79%. This information will be useful in establishing conditions to use in textural evaluations of high fiber cookies that are part of a study of the feasibility of using baked products as carriers of dietary fiber.

MATERIALS AND METHODS

Cookie Preparation

Sugar-snap cookies were prepared following a modification of the Micro Method III procedure described by Finney et al (1950). Formulation was increased to prepare six cookies per bake. The entire amount of creamed mass consisting of 63.8% sugar, 31.9% shortening, 1.1% sodium bicarbonate, and 3.2% nonfat dry milk was prepared in a Hobart A-200 institutional mixer and stored at 4–5° C with the appropriate amount brought to room temperature before cookie preparation. Solution A was prepared as described by Finney et al (1950), but solution B was prepared with 43.88 g NH_4Cl and 29.61 g NaCl in 500 ml of deionized water, which is an increase of 10 g of NH_4Cl over the amount given by Finney et al (1950). This adjustment was necessary to produce the desired surface cracking characteristic of a high quality sugar-snap cookie.

A 112.8-g portion of creamed mass was transferred to the bowl of a National nonrecording micromixer, model 100-200A with a head speed of 86 rpm. To this 12 ml of solution A, 9 ml of solution B and 3.5 ml of water were added. After mixing for 3 min, 114.8 g of flour was added and mixed for 10 sec. The dough was scraped from the pins and dislodged from the bottom and sides of the bowl before being pushed across the bowl with seven double strokes. The dough was then mixed for three additional 5-sec intervals and scraped between each mixing.

Cookies were prepared with a high and low quality cookie flour donated by the Soft Wheat Quality Laboratory. The high quality cookie flour was VA 66-54-10, a soft red winter wheat flour with a protein content of 9.8%. The poor quality flour was Shawnee, a hard red winter wheat with a protein content of 9.9%. Moisture of the flours was determined by AACC Method 44-32 and flour weights adjusted to 14% moisture. Common lots of all other ingredients were procured. Room relative humidities ranged from 31 to 45% for Experiment I and 35 to 62% for Experiment II. Cookies (6.03 cm in diameter and 0.63 cm thick) were baked for 10 min in a National Manufacturers Company reel oven at 400° F (204° C). Bakes were alternated so that a bake with high quality flour was followed by a bake with low quality flour.

Experiment I held cookies at relative humidities of 11, 33, 52, 67, 79, and 93%. Fifteen batches of each type of cookie were prepared; five batches of cookies from each type of flour were evaluated for shear (Allo Kramer), breaking strength (Allo Kramer), and moisture. Experiment II held cookies at relative humidities of 52, 57, 67, 71, 75, and 79%. Twenty-five batches of each type of cookie were prepared; five batches of cookies from each type of flour were evaluated for the three previous parameters as well as breaking strength (Instron) and compression (Instron). Cookies evaluated by the Instron were held at −23° C for four to six weeks before being placed in relative humidity chambers.

Relative Humidity Chambers

To hold the cookies at standard relative humidities until textural evaluations, desiccators of known relative humidities were prepared using saturated salt solutions as described by Rockland (1960). The nine solutions used in these two experiments were: lithium chloride (11%), magnesium chloride (33%), magnesium nitrate (52%), sodium bromide (57%), cupric chloride (67%), strontium chloride (71%), sodium chloride (75%), ammonium sulfate (79%), and potassium nitrate (93%). Each of the six labeled cookies from one batch was stored in one relative humidity chamber after cooling for 15 min and cookie diameter and height

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were measured. Cookies were allowed to equilibrate for five days before textural or moisture evaluations in all experiments. Room temperature varied from 20 to 26°C and was higher for the second experiment. Relative humidities of these salt solutions can vary 1% or less from 20 to 30°C (Rockland 1960).

Cookie Evaluation

Cookie spread was determined as width/thickness to assure that there were no significant differences in the quality of cookies baked using a particular quality of flour being tested for textural characteristics. Percentage moisture was determined by AACC Method 44-32. An Allo Kramer Shear Press, model SP 12, equipped with an electronic recorder, model E2EZ, was used with the single blade cell to determine breaking strength or crispness and with the standard shear compression cell to determine tenderness. A 100-lb ring was used with the single blade cell and a 3,000-lb ring was used with the standard shear compression cell. The range used varied from 5 to 50 for the single blade cell and from 1 to 20 for the standard shear compression cell as the relative humidity affected the textural characteristics of the cookies. Cookies were halved to determine breaking strength. The width and thickness of the cookie at the breaking point was determined using calipers. The breaking strength was calculated as pound force per square centimeter broken. The value used in the analysis of variance for each bake was the average of the two halves. Cookies were quartered for tenderness measurements so that two quarters could be positioned in the square cell without overlap. Tenderness of the two cookie halves also was averaged and is calculated as pound force per gram. The Instron Texturometer, model TTBM, was used to determine breaking strength and compressibility of the second set of cookies. For breaking strength, a 1–50 kg load cell was used, calibrated to 5 kg full scale. The range selector was set at 5 and the cross head speed at 50 cm/min. Two halves of each cookie were broken separately and these values averaged to report the breaking strength as kilogram per square centimeter for each bake. The flat round plunger (25.95 cm^2) of the succulometer cell of the Allo Kramer Shear Press was used to compress the cookies half their height or 4 mm for cookies made with high quality flour and 5 mm for those made with low quality flour. The load cell for compression was 50–2,500 kg, calibrated to 250 kg full scale. The range selector was on 5 and the cross head speed set at 5 cm/min. Each cookie was centered under the plunger and the reading reported in kilograms. The conditions used to determine compression were in kilograms, similar to those of Hutchinson and coworkers (1977) who used the Instron to evaluate the effect of emulsifiers on cookie texture.

Data from each experiment were analyzed for variance. Duncan's multiple range test (1957) was used to identify significant differences, which were established by analyses of variance. Correlation coefficients were calculated for the first experiment.

TABLE I
Thickness, Diameter, and Spread of Cookies Baked From High and Low Quality Flours for Textural Evaluations at 11–93% Relative Humidities (Experiment I)

Flour Quality	Allo Kramer Shear Cell	Physical Parameter[a]		
		Thickness[b] (cm)	Diameter[b] (cm)	Spread (W/T)[c]
High	Single blade	5.3 ± 0.2	51.7 ± 1.1	9.8 ± 0.3
High	Standard shear compression	5.1 ± 0.1	51.2 ± 0.5	10.0 ± 0.2
Low	Single blade	6.0 ± 0.2	46.9 ± 0.8	7.8 ± 0.2
Low	Standard shear compression	5.9 ± 0.2	46.0 ± 0.5	7.8 ± 0.2

[a]Mean and standard deviation of the mean for five bakings. Differences between cookie flour types were significant at $p < 0.001$.
[b]Six cookies from one baking.
[c]W/T = width/thickness.

RESULTS AND DISCUSSION

Analyses of variance of thickness, diameter, and spread of cookies used to study the effects of storing cookies at relative humidities from 11 to 93% on their textural characteristics revealed the expected significant differences ($p < 0.001$) in these parameters between cookies prepared with high and low quality flour (Table I). Nevertheless, no significant differences were found among these parameters for cookies used for the two types of textural evaluation, indicating that cookies prepared with one flour type had similar physical attributes before being introduced into the different humidity chambers.

Table II summarizes the means and standard deviations of these means for the Allo Kramer Shear Press textural evaluations of cookies stored in relative humidity chambers ranging from 11 to 93%. Breaking strength curves were sharp with several small breaks indicating breaking of layered structures within the cookie. Force curves (Fig. 1) for cookies stored at low humidities were typical of those examples shown by Bruns and Bourne (1975) for snap cookies. Force curves were much less distinctive for cookies stored

TABLE II
Allo Kramer Shear Press Textural Evaluations and Moisture Levels of Cookies Stored at 11–93% Relative Humidities (Experiment I)[a]

Objective Measure	Flour Quality	Relative Humidity (%)					
		11	33	52	67	79	93
Texture							
Single blade (1 lb/cm^2)	High	4.858 ± 0.929a	2.304 ± 0.589b	2.038 ± 0.627bc	1.692 ± 0.425cd	1.111 ± 0.282de	0.326 ± 0.073f
	Low	2.498 ± 0.848b	1.507 ± 0.269c	1.514 ± 0.266cd	1.256 ± 0.196de	0.788 ± 0.133ef	0.275 ± 0.025f
Standard shear compression cell (1 lb/g)	High	34.41 ± 2.17a	12.97 ± 1.06c	13.38 ± 1.47c	13.65 ± 0.67c	8.46 ± 0.61e	1.37 ± 0.29f
	Low	28.27 ± 1.73b	10.90 ± 0.95d	13.14 ± 0.97c	12.81 ± 1.70c	8.12 ± 0.61e	2.06 ± 0.59f
Moisture (%)	High	2.20 ± 0.15a	4.16 ± 0.14b	5.92 ± 0.17c	8.46 ± 0.10a	11.09 ± 0.15e	17.93 ± 0.54f
	Low	2.39 ± 0.12a	4.06 ± 0.07b	6.38 ± 0.12c	8.60 ± 0.23d	11.58 ± 0.14a	15.60 ± 0.20g

[a]Mean and standard deviation of mean of five bakes, each containing six cookies so that one cookie from each was equilibrated at each relative humidity. For each method of determining textural characteristics as well as for percentage moisture, means with the same letter are not significantly different ($p < 0.05$) (Duncan 1957).

at 79 or 93% relative humidity. Breaking strength force curves also were sharper and more distinct than were the curves using the standard shear compression cell.

Significant differences ($p < 0.001$) were found between flours and among relative humidities for both single blade breaking (crispness) and shearing with the standard shear compression cell (tenderness). Cookies prepared with a low quality flour were less crisp and more tender (Table II). As the relative humidity increased, the cookies became progressively less crisp and more tender. Use of Duncan's multiple range values showed that many of the means of crispness and tenderness of cookies prepared with high or low quality flour and stored at one relative humidity were not significantly different from each other. This was especially true for cookies stored in relative humidity chambers above 52%. Crispness correlated well with relative humidity for high quality ($r = -0.94$) and low quality ($r = -0.89$) flour. Tenderness also correlated well with relative humidity ($r = -0.98$) for cookies with both high and low quality flour. Percentage moisture in these cookies varied from 2.2 to 17.9% and reflected the available moisture in the humidity chambers ($r = 0.95$) (Table II). Since the first experiment established that the relative humidity in which cookies are stored significantly affects textural evaluations, a second experiment was performed using a limited range of relative humidities and included the use of the Instron Texturometer to evaluate the textural characteristics of the cookies.

Analyses of variance of thickness, diameter, and spread of cookies used to study the effect of storing cookies at relative humidities from 52 to 79% on their textural characteristics revealed the expected highly significant differences between cookies prepared with high and low quality flours (Table III). No significant differences, however, were found among these parameters for the cookies used for textural analyses by either cell of the Allo Kramer Shear Press or those for the Instron.

Highly significant differences were found between flour types and among relative humidity levels for all four measurements of texture summarized in Table IV. Moisture levels in these cookies also increased as the storage relative humidity increased (Table V). In general, 5–10% differences in relative humidities did not result in significant differences in textural evaluations. Relative humidity at which cookies were stored had little effect on data obtained using the compression cell of the Instron. Significant differences between individual means for cookies prepared with high and low quality flour occurred only for cookies stored at a relative humidity of 75%. In contrast, crispness or breaking strength data obtained using the

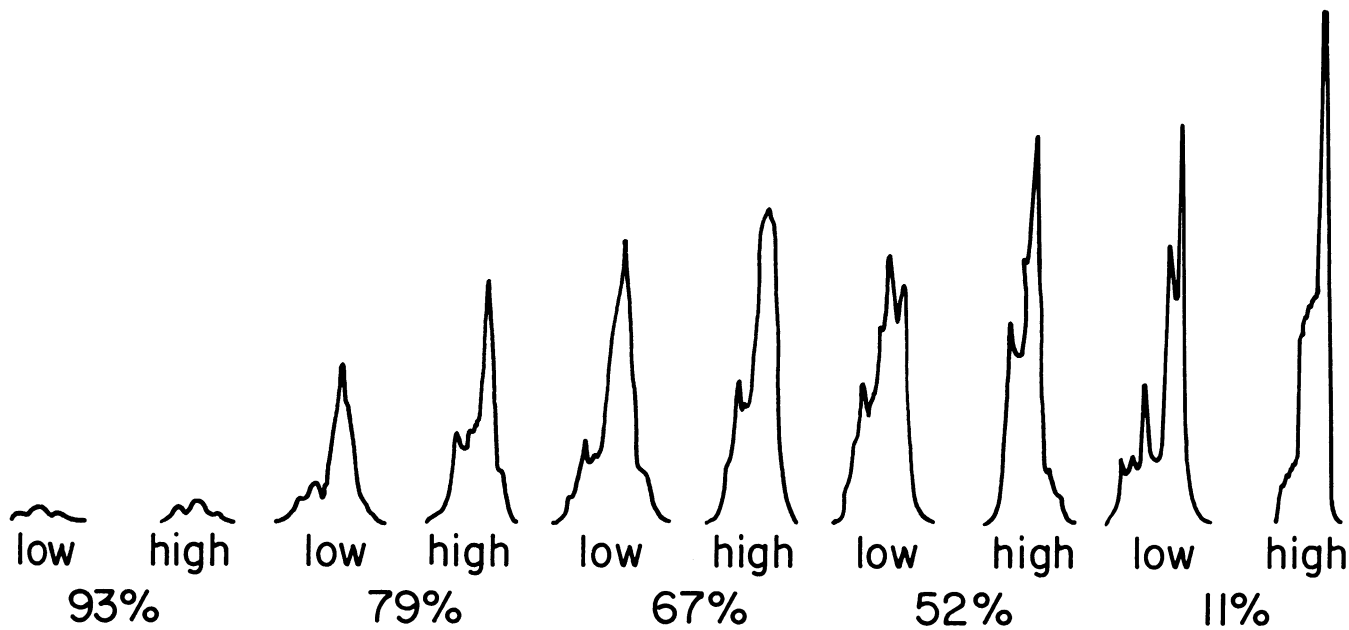

Fig. 1. Sample breaking strength curves of high and low quality cookies stored at various relative humidities.

TABLE III
Thickness, Diameter, and Spread of Cookies Baked From High and Low Quality Flours for Textural Evaluations at 52–79% Relative Humidities (Experiment II)

Flour Quality	Testing Instrument	Type of Cell	Physical Parameters[a] Thickness[b] (cm)	Diameter[b] (cm)	Spread (W/T)[c]
High	Shear press	Single blade	5.0 ± 0.3	51.2 ± 0.7	10.4 ± 0.8
		Shear compression	4.8 ± 0.1	51.2 ± 0.5	10.6 ± 0.4
	Instron	Single blade	4.8 ± 0.1	51.5 ± 0.6	10.7 ± 0.2
		Shear compression	4.8 ± 0.1	51.4 ± 0.4	10.7 ± 0.2
Low	Shear press	Single blade	5.8 ± 0.3	46.7 ± 0.3	8.1 ± 0.4
		Shear compression	5.7 ± 0.1	46.5 ± 0.5	8.2 ± 0.2
	Instron	Single blade	5.6 ± 0.1	47.0 ± 0.4	8.4 ± 0.2
		Shear compression	5.7 ± 0.2	47.1 ± 0.5	8.3 ± 0.3

[a]Mean and standard deviation of the mean for five bakings. Differences between cookie flour types were significant at $p < 0.001$.
[b]Six cookies from one baking.
[c]W/T = width/thickness.

TABLE IV
Textural Evaluations of Cookies Stored at 52–79% Relative Humidities (EXPERIMENT II)[a]

Cell Used	Flour Quality	Relative Humidity (%) 52	57	67	71	75	79
				Shear Press			
Single blade (lb/cm^2)	High	3.327 ± 0.694ab	3.515 ± 1.190a	2.755 ± 0.608bc	2.114 ± 0.800cd	1.565 ± 0.347def	0.887 ± 0.434fg
	Low	2.013 ± 0.498d	1.813 ± 0.277de	1.766 ± 0.473de	1.248 ± 0.258efg	1.088 ± 0.196efg	0.622 ± 0.096g
Standard shear compression (lb/g)	High	17.11 ± 3.79a	16.46 ± 3.25a	13.37 ± 1.64b	11.22 ± 2.68bc	8.33 ± 1.21cd	4.70 ± 1.62ef
	Low	13.33 ± 2.31b	13.28 ± 2.10b	10.82 ± 0.77bc	9.20 ± 1.54cd	7.36 ± 0.90de	4.20 ± 1.07f
				Instron			
Single blade (kg/cm^2)	High	0.920 ± 0.102a	0.960 ± 0.161a	0.693 ± 0.062bc	0.657 ± 0.067bcd	0.677 ± 0.019bc	0.590 ± 0.105cde
	Low	0.734 ± 0.083b	0.698 ± 0.086bc	0.556 ± 0.060de	0.528 ± 0.056e	0.520 ± 0.022e	0.383 ± 0.087f
Compression (kg)	High	122 ± 14ab	120 ± 14ab	125 ± 13a	114 ± 12ab	99 ± 11ab	45 ± 15d
	Low	106 ± 17ab	97 ± 19ab	95 ± 11abc	92 ± 15bc	69 ± 14cd	45 ± 11d

[a]Mean and standard deviation of mean of five bakes, each containing six cookies so that one cookie from each was equilibrated at each relative humidity. For each method of determining textural characteristics, means with the same letter are not significantly different ($p < 0.05$) (Duncan 1957).

TABLE V
Moisture Levels[a] of Cookies Stored at 52–79% Relative Humidities (Experiment II)

Relative Humidity (%)	Flour Quality High	Low
52	6.60 ± 0.15a	6.67 ± 0.18a
57	7.16 ± 0.17b	6.96 ± 0.25ab
67	8.37 ± 0.10c	8.46 ± 0.42c
71	9.03 ± 0.17d	9.16 ± 0.44d
75	9.76 ± 0.26e	10.07 ± 0.51e
79	11.38 ± 0.07f	11.43 ± 0.34f

[a]Mean and standard deviation of mean of five bakes, each containing six cookies so that one cookie from each bake was equilibrated at each relative humidity. Means with the same letter are not significantly different ($p < 0.05$) (Duncan 1957).

single blade cell with the Instron for cookies prepared with high and low quality flour differed significantly at each relative humidity investigated (Table IV). From these data, testing compression seems less useful in distinguishing cookie quality than the other textural characteristics evaluated.

When the Allo Kramer Shear Press was used to evaluate crispness, that property differed significantly between cookies prepared with high and low quality flour for those cookies stored at relative humidities from 52 to 71%. Tenderness determined using the standard shear compression cell with the Allo Kramer Shear Press also differed significantly between cookies similarly prepared and stored at relative humidities of 52 and 57%.

Some changes in textural properties of cookies can occur upon freezing since crispness or breaking strength of cookies prepared with high quality flour evaluated without freezing using the Allo Kramer Shear Press ranged from 3.3 to 0.9 lb/cm^2, whereas comparable values for high quality cookies tested with the Instron ranged from 2.0 to 1.3 lb/cm^2 (Table IV). Lower force readings also were obtained for low quality cookies that were frozen. Shear press values for the second experiment were higher for cookies stored at 52% and lower for cookies stored at 79% relative humidity than for the first. This may have been related to slight differences in techniques of dough handling that occurred between the two experimenters involved or to the slightly higher preparation room relative humidities that occurred during the second experiment. All textural evaluations of cookies prepared in a room with a relative humidity of 62% were consistently higher than those prepared with room relative humidities of 35%. It is possible that high room relative humidities resulted in more free water in the dough. Spread values also were slightly greater for the bakes prepared when the room relative humidity was 62%.

Thus, storage relative humidity does affect the crispness and tenderness of sugar-snap cookies. Over a wide range of storage relative humidities, this relationship was linear. High storage relative humidities are more of a problem than low storage relative humidities, as they most often obscure the expected differences between cookies prepared with high and low quality flour. If storage relative humidities differ only 5 to 10%, these humidity differences apparently would not significantly affect the textural results obtained. Use of the single blade cell to determine breaking strength of crispness with either the Allo Kramer Shear Press or the Instron Texturometer most often resulted in the expected significant differences between the cookies prepared with high and low quality flour at each relative humidity evaluated.

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