Instrumental Measurement of Cookie Hardness. II. Application to Product Quality Variables

CHARLES S. GAINES, ANITA KASSUBA, PATRICK L. FINNEY, and JOHN R. DONELSON[1]

Cereal Chem. 69(2):120-125

ABSTRACT

A probing technique was used to measure the effects of various treatments on the hardness of cookies produced by two laboratory formulations, the AACC micromethod for sugar-snap cookies and a new formula for wire-cut cookies typical of commercial products. The technique was able to quantify hardness differences associated with wheat cultivar, wheat class blending, quality of ingredients, cookie geometry, wheat test weight, kernel shriveling, crop year, and flour protein content. Higher protein content and more kernel shriveling were associated with harder cookies. Higher flour protein content resulted in harder wire-cut formula cookies (as is usually observed in commercial baking); however, sugar-snap cookies were thicker and less hard. Probing was also used to evaluate the hardness of cookies produced from two pairs of flours that were fractionated and then reconstituted with one to three fractions interchanged. Fractions that contributed positively to cookie hardness were tailings, gluten, and water-solubles. Fractions appeared to contribute to hardness in the order of their hydrophilicity.

Makers of the great variety of soft wheat products use flour from soft wheat mainly because it produces a more tender, softer, lighter, and larger product than hard wheat flour. The same products made with hard wheats are harder in texture, denser, and smaller and are generally considered inferior by comparison. The availability of instrumental methods for assessing the hardness or softness of soft wheat products should allow better evaluation of and control over the desirable characteristics that soft wheat imparts to products such as cookies.

Perhaps because reliable instrumental techniques for evaluating cookie texture have not been available, the literature contains few reports of variables that affect cookie hardness. The main quality factors that account for the superior performance of soft wheat in traditional soft wheat products are tested for and demonstrated by low water-holding capacity, kernel softness, and low protein content (Yamazaki 1953, 1954; Yamazaki et al 1968). These characteristics are probably also associated with soft product texture.

Matz (1962) described the texture of cookies as a combined function of the size and shape of the crumb structure, the strength within individual pockets of mostly discrete dough masses, the strength of the contiguous boundaries between those pockets, the moisture content and gradients, and the internal stresses produced during baking and cooling. Commercial bakers often speak of associations between protein content and cookie hardness and between wheat class, location of growth, and crop year and cookie hardness.

Gaines (1990) showed that the development of protein content during mixing produces harder cookies. Alteration of cookie dough protein with protease can have dramatic effects on cookie geometry and texture (Gaines and Finney 1989). Crop year and growth location have large effects on alkaline water retention capacity (AWRC), flour protein content, kernel softness (break flour yield), and sugar-snap cookie spread (Finney et al 1987). Softer-textured wheats with greater break flour yield generally produce cookies with more spread (Gaines 1985, Gaines and Donelson 1985).

Wheat test weight (weight per unit volume) has long been used as a market quality indicator. Historically, lower test weight has been purported to predict lower potential flour yield. Shriveling is one of several factors that lower wheat test weight. Because shriveled grain is more irregular in shape than sound, plump grain, it packs less densely in a volume cup, lowering test weight. Shriveled grain also reduces flour yield (Patterson and Allan 1981, Dick and Matsuo 1988). Test weight only in part reflects the degree of shriveling.

Formulation differences in sugar-shortening ratio can markedly influence cookie geometry (Finney et al 1950) and presumably cookie texture. Changing the particle size of formula sucrose is especially effective in altering cookie geometry (Kissell et al 1973).

Many variables probably affect the hardness of cookies. Fractionation-reconstitution can be used to study the effects of flour, dough, and product treatments. This technique has been used to study the effects of chlorination on cookie flour (Donelson 1990) and cake flour (Gaines and Donelson 1982) and may have potential for cookie texture studies.

Although cookie texture affects consumer acceptance and repeat sales, the evaluation of cookie texture is often too expensive and time-consuming to be routinely included in quality assurance and cultivar quality evaluation programs. Gaines et al (1992) evaluated probing and three-point break techniques for instrumental measurement of the hardness of cookies made from three laboratory formulations, the AACC micromethod and macromethod for sugar-snap cookies (AACC 1983) and a formulation for wire-cut cookies (Slade and Levine in press). The wire-cut formula cookies usually had less variance for the range of hardness evaluated than the sugar-snap cookies. Gaines et al (1992) concluded that the combination of the wire-cut formulation for laboratory cookie production with the probing test for hardness measurement has impressive potential for improving the quality and consistency of commercial cookies and for the prediction of soft wheat quality.

In this study, we attempted to apply the probe technique to evaluate a range of baking, product, and flour quality variables that likely cause textural hardness differences in cookies, including wheat class blending, wheat cultivar, wheat kernel quality (size, test weight, and shriveling), baking formulation, quality of ingredients, protein content, and product geometry. In addition, we continued to evaluate the new laboratory wire-cut cookie formulation of Slade and Levine (in press).

MATERIALS AND METHODS

Order of Studies and Wheats

The use of the probing technique for evaluating cookie hardness was demonstrated in ten studies. The first study assessed the effects of the quality of shortening and high-fructose corn syrup (HFCS) on the hardness of cookies made with flour from the cultivar Becker (1989 crop). The second study investigated the differences in hardness of cookies made from commercial versus laboratory quality ingredients. In the third study, the effects on cookie hardness of mill mix blending were studied for two pairs of flours produced from milling a blend of soft and hard wheats.

[1]U.S. Department of Agriculture, Agricultural Research Service, Soft Wheat Quality Laboratory, Ohio Agricultural Research and Development Center, The Ohio State University, Wooster 44691. Mention of a trademark or proprietary product does not constitute a guarantee or warranty of a product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

The fourth study demonstrated the influence of cookie geometry (diameter and height) on hardness of cookies made from 22 flours from laboratory and commercial sources. The fifth study showed associations between wheat test weight and cookie hardness for six soft red winter cultivars (Frankenmuth, Auburn, Hillsdale, Lewjain, Nugaines, and Daws) grown at two locations.

The sixth study investigated the influence of kernel size on cookie hardness. The cultivar Titan (35 kg) was separated into three portions based on kernel size with a Carter-Day dockage tester. The large kernels (11%) were retained over 3.6-mm round holes, the medium-size kernels (86%) passed through 3.6-mm holes but were retained over 2.8-mm holes, and the small kernels (3%) passed through 2.8-mm holes.

The seventh study demonstrated the association of kernel shriveling and cookie hardness. Kernels of the cultivar Becker were hand-separated into one sample with only sound, unshriveled kernels, another sample with only shriveled kernels, and a third sample containing 50% (by weight) shriveled kernels, obtained by mixing portions of the first two samples.

The eighth study used four samples of one cultivar (Caldwell) grown at one location to demonstrate the influence on cookie hardness of variations in flour protein content within a cultivar. The ninth study investigated the implications of crop year differences for hardness of cookies made from two sets of four flours (cultivars Caldwell, Hillsdale, Becker, and Compton) from two crop years (1988 and 1989) milled at the same commercial mill.

In the final study, we fractionated flours from the cultivars Becker and Compton (1988 crop) and Becker and Caldwell (1989 crop) and tested cookies made from reconstituted flours with one to three fractions interchanged to demonstrate the relative contributions to cookie hardness of fractions from flours that make relatively hard and soft cookies.

Milling

Except for the ninth and tenth studies, pure cultivars were milled on an Allis-Chalmers laboratory mill (AACC 1983, method 26-32). Breeders' samples were milled using tandem Brabender Jr. Quadrumat mills. Other flours were obtained from commercial mills. Flour protein (AACC 1983, method 46-12), ash (method 08-01), AWRC (method 56-10), wheat test weight (method 55-10), and alveograph values (method 54-30) were determined.

Baking and Hardness Testing

Sugar-snap cookies were made as directed in the AACC micro-method (AACC 1983, method 10-52) for the evaluation of cookie geometry. Wire-cut formula cookies were produced by the method of Slade and Levine (in press), as described by Gaines et al (1992). All baking experiments were replicated on different days.

Products were probed for hardness with an Instron model 1000 universal testing machine by the method of Bourne (1975, 1990), as described by Gaines et al (1992). Cookie hardness was always evaluated two days after baking.

Flour Fractionation and Reconstitution

Two pairs of flours (cultivars Becker and Compton from the 1988 crop and Becker and Caldwell from the 1989 crop) were each fractionated into starch, lipid, tailings, gluten, and water-solubles (Yamazaki et al 1977). Because preliminary investigations showed that the particle size of reconstituted flours affected cookie texture, the lyophilized starch, tailings, gluten, and water-solubles were further ground so that the reconstituted blends of fractions had a mean particle size (AACC 1983, method 50-11) equivalent to that of the unfractionated flours. When this was done, cookies produced from reconstituted flours (without fraction interchanges) were indistinguishable in hardness ($P = 0.05$) from cookies made from the original unfractionated flours, as determined by ranking order difference sensory evaluation as described by Gaines et al (1992). Fractions were recombined into flours with single or multiple fraction interchanges. The hardness of wire-cut formula cookies produced from each recombined flour was evaluated by the instrumental resistance to probing.

Statistical Analysis

Each cookie was probed 13 times, and the mean hardness value was recorded. Four cookies were evaluated per treatment. Data were analyzed by analysis of variance (n=4) and linear regression. Tabulated means were compared by the least significant difference statistic at the 0.05 level of probability.

RESULTS AND DISCUSSION

Gaines et al (1992) concluded that probing and three-point break techniques could be used to evaluate the hardness of cookies made from two sugar-snap formulations and a wire-cut formulation. The probe technique and the wire-cut formulation were desirable as laboratory procedures. To be most useful to potential users, the probe technique should be sensitive to a wide range of product, baking, wheat, and flour quality variables that affect product hardness. Our studies evaluated a number of these variables.

Study 1: Shortening and HFCS

The type of shortening affects the quality of commercial cookies. Age-related changes in shortening condition also may affect product quality. Older shortening can "weep" oil from the more crystalline material. We replaced a cube of aged, weeping shortening with a newer cube of the same shortening. We also replaced an old container of HFCS that had begun to "cloud" with a new one. In commercial bakeries, HFCS is normally used before it clouds; however, whether clouding would affect cookie texture was unknown.

Table I shows the hardness of wire-cut formula cookies made with old and new HFCS and shortening. Both syrups had the same effect on the resistance of the cookies to probing. However, cookies made with the new shortening were harder, thicker, and smaller in diameter than those made with the old shortening.

Study 2: Ingredients

Commercial and laboratory baking method ingredients can have disparate qualities. Figure 1 shows the difference in the hardness of wire-cut formula cookies made from eight flours with commercial ingredients (commercial bakery sucrose, brownulated granulated brown sugar, and shortening) versus laboratory ingredients (a finer granulation sugar, powdered brownulated brown sugar, and a different brand of shortening). Cookies made with the laboratory ingredient substitutions were less hard than those made with the commercial ingredients. The mean difference in hardness was 11 N. The hardness values for the eight flours were well correlated ($r = 0.91$) between both sets of ingredients.

Study 3: Mill Mix Blends

Two pairs of flours were commercially milled from blends of soft and hard wheats. One pair was produced from a blend of 60% western soft white club and 40% hard red winter wheat from Montana or hard red winter wheat from Kansas. The other pair was produced from a blend of 80% eastern soft red winter wheat and 20% hard red winter wheat from Montana or hard red winter wheat from Kansas. For both soft wheat-based blends, replacing the hard red winter wheat from Montana (protein 13.3%,

TABLE I
Effect of Changes in Ingredient Shortening and High-Fructose Corn Syrup (HFCS) on the Diameter, Height, and Probe Resistance of Wire-Cut Formula Cookies[a]

Shortening	HFCS	Diameter (cm)	Height (cm)	Probe Resistance (N)
Old	Old	8.58 a	0.910 b	21.9 b
Old	New	8.58 a	0.912 b	20.8 b
New	Old	8.26 b	0.967 a	23.5 a
New	New	8.26 b	0.976 a	23.5 a

[a] Means within a column followed by the same letter are not significantly different ($P = 0.05$). Probe was 4.5 mm in diameter. Crosshead speed was 300 mm/min.

alveograph work number 381) with the hard red winter wheat from Kansas (protein 11.8%, alveograph work number 209) produced softer wire-cut formula cookies with more spread (Fig. 2). Figure 2 also reflects the observation that soft white club wheats often produce harder cookies than do soft red winter wheats. Neither the flour protein content nor the mixing strength (as estimated by the alveograph work number) was well correlated with cookie hardness or diameter. Wheat class and location of growth were the predominant influences on cookie hardness and spread.

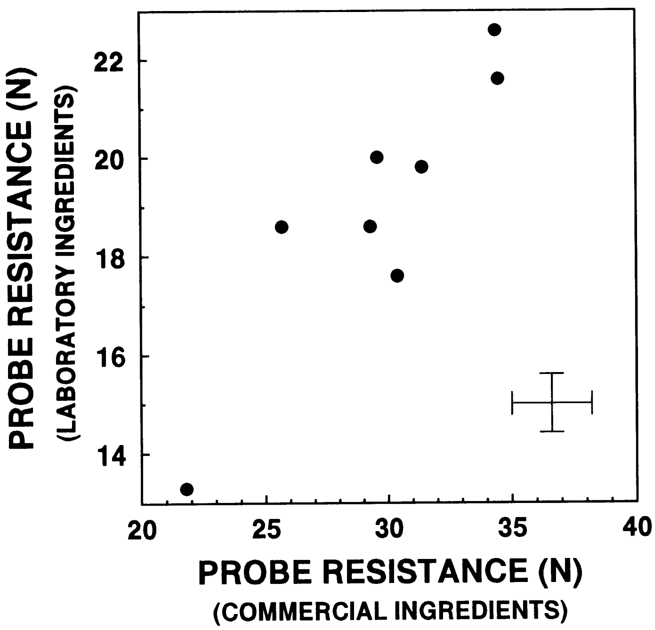

Fig. 1. Hardness of wire-cut formula cookies produced from eight flours with all commercial quality ingredients and with a few substituted laboratory quality ingredients. The crossed error lines indicate the least significant difference values ($P = 0.05$) for the respective axes.

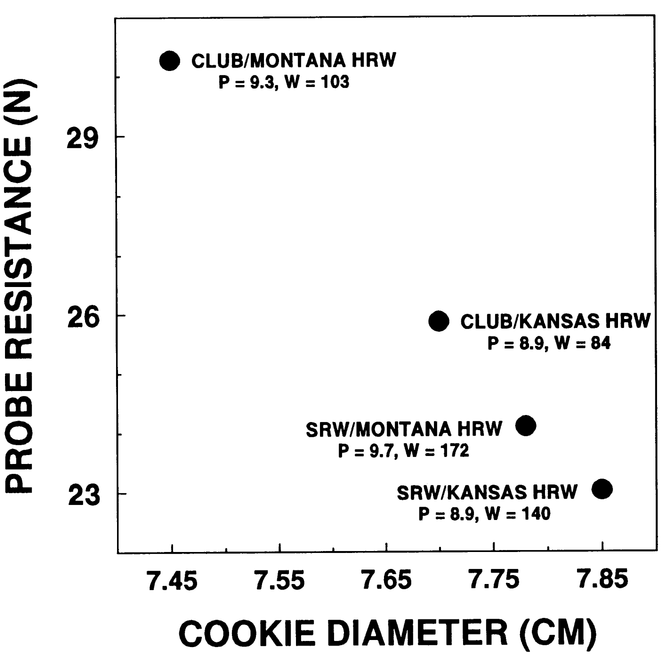

Fig. 2. Probe resistance and diameter of wire-cut formula cookies produced from flours milled from four wheat blends: 60% western soft white club blended with 40% hard red winter (HRW) from Montana or Kansas, and 80% eastern soft red winter (SRW) wheat blended with 20% HRW from Montana or Kansas. *P* denotes the flour protein content and *W* denotes the alveograph work number of the blend.

Study 4: Cookie Geometry

Another common observation in commercial baking is that higher flour protein content and harder kernel texture (less break flour) are associated with smaller, thicker, and harder cookies. The data in Figure 2 also show that smaller-diameter wire-cut formula cookies were harder. But when flour with elevated protein content is used in the two AACC sugar-snap cookie methods, which were formulated to produce large spread, cookies are smaller and thicker but softer. Figure 3 shows the association between cookie diameter, thickness, and probe resistance for sugar-snap cookies made from 22 flours by the AACC micromethod. In contrast to wire-cut formula cookies (Fig. 2), the smaller, thicker micromethod cookies tended to be less hard. This opposite response suggests that sugar-snap cookies may be of limited use in studying cookie texture relative to commercial experience. These findings are currently being investigated further.

Study 5: Wheat Test Weight

Six soft wheat cultivars were each grown in two locations, resulting in differences in wheat test weight, protein content, and shriveling. Samples with lower test weight (from location A) were higher in protein and in break flour yield (had softer kernels) and produced harder micromethod cookies than samples from location B (Fig. 4). Samples from location A also had smaller kernels and considerable shriveling.

Study 6: Kernel Size

Shriveled kernels are usually higher in protein than unshriveled kernels, but they are also smaller. Shriveling usually results in lower test weight. We examined these relationships within two cultivars rather than between cultivars. First, plump, sound kernels of the cultivar Titan were sieved into large, medium, and small kernels. The size of sound kernels did not have a statistically significant effect on wire-cut formula cookie resistance to probing, cookie size, flour ash, flour protein, or AWRC (Table II).

Study 7: Kernel Shriveling

A sample of cultivar Becker was hand-separated into one portion containing all sound, unshriveled kernels, one containing all highly shriveled kernels, and one containing half (by weight) shriveled kernels. A greater proportion of shriveled kernels resulted in harder, smaller, thicker cookies and was also associated with increased flour protein, ash, and AWRC (Table III). Again, thicker wire-cut formula cookies were also harder.

Shriveling results in less accumulated starch and a higher rela-

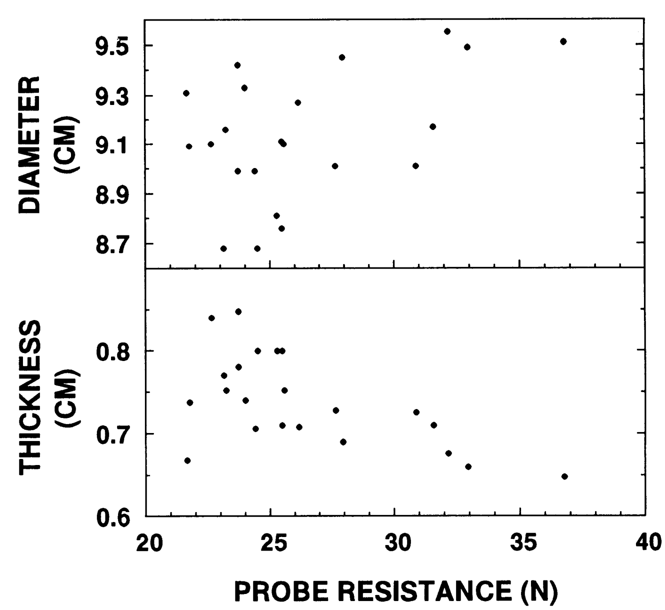

Fig. 3. Effect of cookie diameter and thickness on the hardness of sugar-snap micromethod cookies (probe diameter was 2.0 mm).

tive protein content. However, the relationship between protein content and shriveling may not be one of cause and effect. In our studies, shriveled kernels (not smaller kernels) produced higher-protein flours and harder cookies. The higher protein content of the shriveled samples probably influenced cookie hardness, but the increase in protein (0.6 percentage points) was probably not the sole cause of the 4.7 N increase in probe resistance. This suggests that another aspect of shriveled kernels may influence product texture and/or that protein quality may be different in shriveled kernels.

Study 8: Protein Content

Wire-cut formula cookies were produced from four samples of cultivar Caldwell grown at one location and varying in protein content. Probe resistance increased 5 N as protein content increased 3.1 percentage points (Table IV). As protein content increased, cookie spread was only slightly reduced and thickness was only slightly increased. The regression equation of the relationship between protein content (*PC*) and probe resistance (*PR*) was: $PR = 1.67(PC) + 7.41$ ($R^2 = 0.97$). Within the range of the study, probe resistance increased approximately 1.7 N (8.5%) for each percentage point increase in protein content.

Study 9: Crop Year

Table V shows another example of the relation between cookie hardness and flour protein content both within and across cultivars. Four cultivars from the 1988 and 1989 crop years were evaluated. On average, 1989 samples had less protein (1.5 percentage points), yielded more break flour (8.7 percentage points), and produced softer cookies (4.5 N) than 1988 samples.

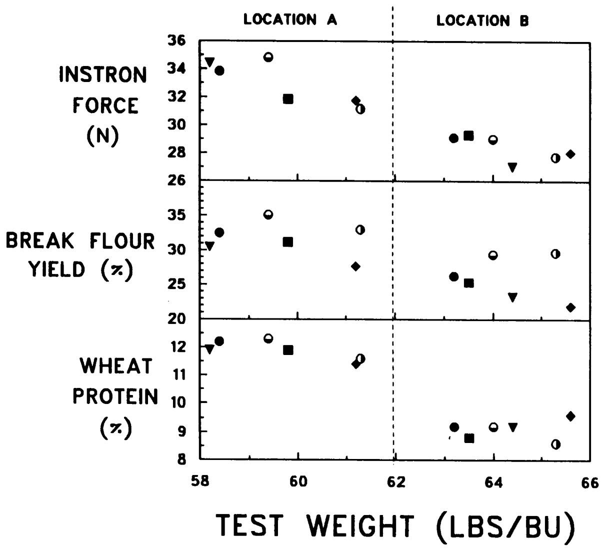

Fig. 4. Probe resistance (Instron force), break flour yield, and protein content of six soft wheat cultivars (square, Frankenmuth; diamond, Auburn; triangle, Hillsdale; bottom-filled circle, Lewjain; side-filled circle, Nugaines; filled circle, Daws) grown in two locations.

TABLE II
Effects of Sound Kernel Size (Cultivar Titan) on Wire-Cut Formula Cookie Hardness and Other Flour Quality Parameters[a]

Kernel Size	Probe Resistance (N)	Cookie Diameter (cm)	Cookie Height (cm)	Flour Ash (%)	Flour Protein (%)	AWRC[b] (%)
Large	20.8	7.8	1.10	0.39	7.8	53.2
Medium	21.0	7.7	1.13	0.38	7.8	53.6
Small	21.9	7.8	1.15	0.38	7.9	53.3

[a] Probe was 4.5 mm in diameter. Crosshead speed was 300 mm/min. None of the means within any column were significantly different ($P = 0.05$).
[b] Alkaline water retention capacity.

Caldwell, Hillsdale, and Becker had lower flour protein content in 1989, and wire-cut formula cookies produced from them were softer.

The above regression equation for the relationship between protein content and probe resistance predicts a reduction in probe resistance of only 2.5 N for a 1.5 percentage point reduction in protein content. Again (if the regression equation is applicable), this suggests that variables associated with crop year other than protein content influence cookie hardness. One might say that 1989 was a "softer" crop year. Even the 1989 Compton wheat, which had a higher flour protein content than in 1988, produced only slightly harder cookies; perhaps the "softer" 1989 crop moderated the increase in Compton cookie hardness, which might otherwise have been greater. Certainly, a variety of flour quality factors related to crop year can have large effects on cookie texture. Each cultivar may have a different slope for the relationship between cookie hardness and flour protein content. Yet the regression equation calculated from the data for these four flours ($PR = 1.53[PC] + 8.46$) is similar to that calculated from the data in Table IV: probe resistance increased approximately 1.5 N (7.8%) for each percentage point increase in protein content.

Study 10: Fractionated and Reconstituted Flours

Flours from two pairs of cultivars were fractionated. One flour in each pair produced harder wire-cut formula cookies, and the other produced softer cookies. One to three fractions were inter-

TABLE III
Effects of Percentage of Shriveled Kernels (Cultivar Becker) on Wire-Cut Formula Cookie Hardness and Other Flour Quality Parameters[a]

Shriveling (%)	Probe Resistance (N)	Cookie Diameter (cm)	Cookie Height (cm)	Flour Ash (%)	Flour Protein (%)	AWRC[b] (%)
0	25.3 a	8.2 a	1.02 b	0.40 a	8.8 c	50.8 c
50	27.2 b	7.8 b	1.10 a	0.42 a	9.0 b	53.9 b
100	30.0 c	7.8 b	1.15 a	0.45 b	9.4 a	56.5 a

[a] Means within a column followed by the same letter are not significantly different ($P = 0.05$).
[b] Alkaline water retention capacity.

TABLE IV
Effect of Protein Content on the Hardness, Diameter, and Height of Wire-Cut Formula Cookies Produced from Cultivar Caldwell Grown at One Location[a]

Protein Content (%)	Probe Resistance (N)	Cookie Diameter (cm)	Cookie Height (cm)
6.9	19.2 a	8.0 a	1.00 a
8.1	20.3 a	7.9 b	1.04 b
9.0	22.5 b	7.9 b	1.05 b
10.0	24.3 c	7.8 c	1.06 b

[a] Means within a column followed by the same letter are not significantly different ($P = 0.05$).

TABLE V
Protein Content and Break Flour Yield of Wheats from Two Crop Years and the Associated Probe Resistance of Wire-Cut Formula Cookies[a]

	1988 Crop			1989 Crop		
Cultivar	Probe Resistance (N)	Protein Content (%)	Break Flour (%)	Probe Resistance (N)	Protein Content (%)	Break Flour (%)
Caldwell	24.4	9.3	30.4	15.9	7.7	39.2
Hillsdale	22.1	10.8	25.8	18.8	8.3	34.6
Becker	29.0	10.1	28.6	22.1	6.9	39.2
Compton	22.5	8.6	25.3	23.1	10.0	31.6
Mean	24.5	9.7	27.5	20.0	8.2	36.2

[a] All differences between crop years were significant ($P = 0.05$) except for Compton probe resistance.

changed when flour pairs were reconstituted. Differences in hardness of the pairs of cookies made from the interchanged reconstituted flours were measured with the probe technique and compared with differences between the control reconstituted flours with all original flour fractions (no fractions interchanged). A fully effective interchange would be one that completely reversed the difference in hardness between the original harder and softer cultivars; that is, the difference in probe resistance would be the same in magnitude but opposite in sign. A less than complete shift, from positive to less positive or to negative differences between the pairs, indicated that the interchanged fractions contributed to hardness.

In the first fraction interchange, between 1988 cultivar Becker, which produced harder cookies, and 1988 cultivar Compton, which produced softer cookies, interchanging the starch fraction had the least effect on the difference in hardness of wire-cut formula cookies, followed in increasing order by lipid, tailings, gluten, water-solubles, gluten plus tailings, gluten plus water-solubles, and gluten plus water-solubles plus tailings (Fig. 5A). In the second fraction interchange, between 1989 cultivar Becker, which produced harder cookies, and 1989 cultivar Caldwell, which produced softer cookies, an additional fraction combination, water-solubles plus tailings, was added. The lipid fraction contributed the least to cookie hardness, followed in increasing order

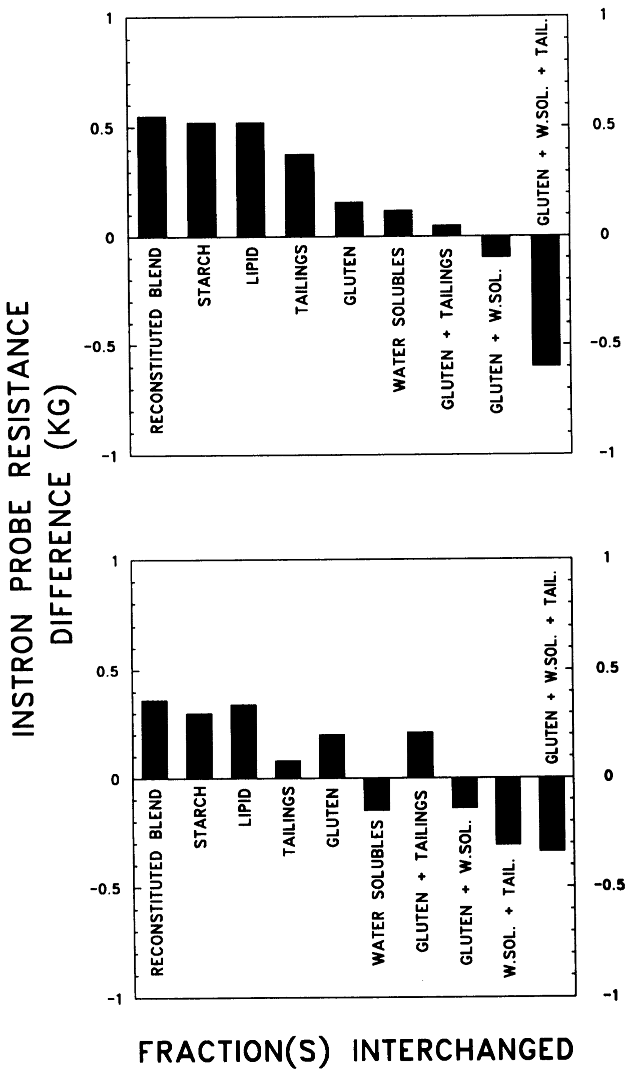

Fig. 5. Difference in probe resistance between cookies made from flour reconstituted from isolated fractions from the 1988 cultivars Becker (which produced harder cookies) and Compton (which produced softer cookies) (A) and from the 1989 cultivars Becker (which produced harder cookies) and Caldwell (which produced softer cookies) (B) with zero (reconstituted blend) to three fractions interchanged.

by starch, gluten plus tailings, gluten, tailings, gluten plus water-solubles, water-solubles, water-solubles plus tailings, and gluten plus water-solubles plus tailings (Fig. 5B). Except for the greater effectiveness of the tailings and water-solubles, these results generally corroborated the results of the Compton-Becker interchange.

The relative effectiveness of interchanging combinations of two or three fractions was generally predictable from the effectiveness of interchanges of the individual fractions. For example, note in Figure 6 that the combination of water-solubles plus tailings was more effective than water-solubles plus gluten, because the tailings fraction was more effective than the gluten fraction. Differences in hardness were fully reversed when the three most individually effective fractions (water-solubles, tailings, and gluten) were interchanged.

The order of effectiveness of fraction interchanges corresponded to the order of hydrophilicity of the fractions: water-solubles are most hydrophilic, followed in decreasing order by tailings, gluten, starch, and lipid. This suggests that the hydrophilicity or lack of it (hydrophobicity) of the fractions, rather than or in combination with inherent or native-state chemical or physical contributions, could have governed their respective effectiveness in each interchange. It is likely that biochemical and biophysical contributors to product hardness require hydration to the extent they normally achieve (if known) in their native, unfractionated state. If so, fractionation and reconstitution studies may be less effective as research tools than evaluations of the hydrophobic-hydrophilic relationships of flour components. These issues are currently being studied further.

CONCLUSIONS

Wire-cut formula cookies, like commercial cookies, tended to be harder when they were smaller and thicker; sugar-snap cookies, by contrast, tended to get softer as they got smaller and thicker. Thus, sugar-snap cookies may have limited value in studies concerned with treatments that alter cookie texture.

A probe technique for measuring cookie hardness was used to investigate a range of wheat, flour, baking, and product variables that affect the hardness of cookies. Probing could measure differences in cookie hardness due to wheat cultivar, wheat class, class blending, ingredients, shortening age, kernel shriveling, flour protein content, and the various contributions of crop year (or break flour). Shriveled kernels and increased protein content were most strongly associated with harder cookies. Combinations of cultivar, crop year, and protein content may be major determinants of cookie hardness and are currently being investigated further. Interchanged flour fractions contributed to cookie hardness in an order corresponding to their hydrophilicity. Water relations appear to be a factor in cookie texture, at least in addition to the biochemical and biophysical contributions of flour components.

Our results suggest that the hardness of commercial cookies could be controlled more consistently by controlling cultivar, protein content, and kernel shriveling. The combination of the wire-cut formulation for laboratory cookie production with probing for hardness measurement was demonstrated to be sensitive enough to hardness differences to be useful in the evaluation and prediction of soft wheat cultivar and flour quality.

ACKNOWLEDGMENT

We appreciate the assistance of Lonnie Andrews.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC, 8th ed. Method 08-01, approved April 1961, revised October 1981; method 10-50D, approved February 1975, revised October 1984; method 10-52, approved September 1985, revised November 1989; method 26-32, approved October 1988; method 46-12, approved October 1976, revised October 1986; method 50-11,

approved November 1989; method 54-30, approved October 1984; method 55-10, approved April 1961, revised October 1982; method 56-10, approved October 1986. The Association: St. Paul, MN.
BOURNE, M. C. 1975. Method for obtaining compression and shear coefficients of foods using cylindrical punches. J. Texture Stud. 5:459.
BOURNE, M. C. 1990. Practical texture measurements of cereal foods. Page 557 in: Dough Rheology and Baked Product Texture. H. Faridi and J. Faubion, eds. Van Nostrand Reinhold: New York.
DICK, J. W., and MATSUO, R. R. 1988. Durum wheat and pasta products. Page 507 in: Wheat Chemistry and Technology, Vol. II, 3rd ed. Y. Pomeranz, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.
DONELSON, J. R. 1990. Flour fraction interchange studies of effects of chlorination on cookie flours. Cereal Chem. 67:99.
FINNEY, K. F., YAMAZAKI, W. T., and MORRIS, V. H. 1950. Effects of varying quantities of sugar, shortening, and ammonium bicarbonate on the spreading and top grain of sugar-snap cookies. Cereal Chem. 27:30.
FINNEY, P. L., GAINES, C. S., and ANDREWS, L. C. 1987. Wheat quality: A quality assessor's view. Cereal Foods World 32:313.
GAINES, C. S. 1985. Associations among soft wheat flour particle size, protein content, chlorine response, kernel hardness, milling quality, white layer cake volume, and sugar-snap cookie spread. Cereal Chem. 62:290.
GAINES, C. S. 1990. Influence of chemical and physical modification of soft wheat protein on sugar-snap cookie dough consistency, cookie size, and hardness. Cereal Chem. 67:73.
GAINES, C. S., and DONELSON, J. R. 1982. Contribution of chlorinated flour fractions to cake crumb stickiness. Cereal Chem. 59:378.
GAINES, C. S., and DONELSON, J. R. 1985. Evaluating cookie spread potential of whole wheat flours from soft wheat cultivars. Cereal Chem. 62:134.
GAINES, C. S., and FINNEY, P. L. 1989. Effects of selected commercial enzymes on cookie spread and cookie dough consistency. Cereal Chem. 66:73.
GAINES, C. S., KASSUBA, A., and FINNEY, P. L. 1992. Instrumental measurement of cookie hardness. I. Assessment of methods. Cereal Chem. 69:115.
KISSELL, L. T., MARSHALL, B. D., and YAMAZAKI, W. T. 1973. Effect of variability in sugar granulation on the evaluation of cookie flour quality. Cereal Chem. 50:255.
MATZ, S. A. 1962. Food Texture, pp. 143-144. Avi Publishing Co.: Westport, CT.
PATTERSON, F. L., and ALLAN, R. E. 1981. Soft wheat breeding in the United States. In: Soft Wheat: Production, Breeding, Milling, and Uses. W. T. Yamazaki and C. T. Greenwood, eds. Am. Assoc. Cereal Chem.: St. Paul, MN.
SLADE, L., and LEVINE, H. In press. Structure-function relationships of cookie and cracker ingredients. In: The Science of Cookie and Cracker Production. H. Faridi, ed. Van Nostrand Reinhold: New York.
YAMAZAKI, W. T. 1953. An alkaline water retention capacity test for the evaluation of cookie baking potentialities of soft winter wheat flours. Cereal Chem. 30:245.
YAMAZAKI, W. T. 1954. Interrelationships among bread dough absorption, cookie diameter, protein content, and alkaline water retention capacity of soft winter wheat flours. Cereal Chem. 31:135.
YAMAZAKI, W. T., DONELSON, J. R., and BRIGGLE, L. W. 1968. Micro-tests for soft wheat quality evaluation. Crop Sci. 8:199.
YAMAZAKI, W. T., DONELSON, J. R., and KWOLEK, W. F. 1977. Effects of flour fraction composition on cookie diameter. Cereal Chem. 54:352.

[Received March 29, 1991. Revision received September 16, 1991. Accepted September 16, 1991.]