Effect of Fat and Sugar in Sugar-Snap Cookies and Evaluation of Tests to Measure Cookie Flour Quality[1]

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ABSTRACT

The effect of fat and sugar on sugar-snap cookie spread was studied. The fat type appeared not to be important, but the amount of fat affected the cookie. The amount of sugar did not affect cookie spread except in non-creamed systems. Sugar particle size also did not affect cookie spread except at the coarsest size (>35 mesh). Protein content, water absorption, starch damage, MacMichael viscosity, alkaline water retention capacity, and pentosan contents were determined for 44 wheat cultivars representing four classes (hard red, club, soft white spring, and soft white winter wheats). Cookie diameters were determined in two different laboratories using slightly different baking procedures. Relatively poor correlations were found among cookie diameter and the other factors studied. In a protein series within a cultivar, a good correlation was found between protein content and cookie diameter. However, the slope of the line was relatively small. Thus, protein content appears to have a minor effect compared to the unidentified genetic factors that strongly affect cookie spread.

Research and testing of soft wheat flour for sugar-snap cookies began in earnest about 1950. During the 1950s several articles concerned with the problem of soft wheat flour quality were published. Since then this problem has received much less attention than other features of cereal chemistry. Because so little is known about the mechanism of the baking process and the factors affecting quality, the flour testing now being done is on an empirical basis (Yamazaki 1959c).

Finney et al (1950a) developed a micro baking test which used only 40 g of flour instead of the 225 g previously required. That test has been widely used for quality evaluation of flours from new cultivars because it is simple, relatively easy to perform with sufficient accuracy, reproducible, and accurately reflects variations in flour characteristics (Yamazaki 1954a).

Before adopting the micro cookie baking test, Finney et al (1950b) studied the effect of varying quantities of ingredients on cookie quality. Their results show that increasing quantities of sugar or ammonium bicarbonate increases cookie spread; shortening has no effect on spread, but does change the cookie texture.

Attempts have been made in the past to adopt a single chemical or physiochemical technique to evaluate flour quality for cookies (Wichser and Shellenberger 1948; Finney and Yamazaki 1953; Yamazaki 1953, 1959a–c; Sollars and Barrett 1964; Minor 1966). However, none of these tests appear to be as satisfactory as test baking. The absence of a physiochemical test to reliably predict cookie quality is primarily because of our lack of knowledge of what factors are responsible for, or contribute to, baking quality. A better understanding of the role played by the various flour components and other formula ingredients during mixing and baking should provide the opportunity to develop a test or tests to determine cookie flour quality.

The objectives in this study were to determine why flour from one cultivar produces larger cookies than another and to determine the effects of variations in fat and sugar on cookie characteristics.

MATERIALS AND METHODS

Materials

The standard soft wheat flour was a commercial cookie flour obtained from Mennel Milling Co., Fostoria, OH. It had a protein content of 9.2%. The standard hard wheat was a commercial flour obtained from Ross Industries-Cargill Inc., Wichita, KS. It had 12% protein and 0.4% ash.

Forty-four wheat flours representing a wide range of flour quality were used. The samples included flours from 3 hard red winter (HRW), 8 hard red spring (HRS), 11 soft white winter (SWW), 11 soft white spring (SWS), and 11 club wheats grown in plots at Pullman and Lind, WA, in 1980. The cultivars and properties are shown in Table I. In addition, a SWW wheat, Nugaines, was grown in a randomized, block experimental design that included both dry land and irrigated plots and different levels of fertilizer; this produced a series of flour samples with a range in protein content (6.3–10.9%). All of the flour samples were experimentally milled at the USDA Western Wheat Quality Lab, Pullman, WA.

Three shortenings were used: 1) a nonemulsified shortening (Durkee D 10), 2) a shortening containing monoglycerides (Crisco), and 3) a nonemulsified oil (Crisco). In addition, the nonemulsified shortening was melted and allowed to cool at room temperature, which would presumably result in fat being in β crystal form rather than in β' form. The small β' crystal form is known to incorporate air more effectively.

Methods

Protein, moisture, and ash were determined according to AACC procedures (1976).

Cookie baking. Cookies were baked using the procedure of Finney et al (1950a). Two cookies were baked in each test at Kansas State University (KSU), and the tests replicated. They were evaluated on the basis of diameter, with greater spread denoting superior flour. Thickness was not measured because of the high correlation between spread factor and cookie diameter. A second baking procedure used at the Western Wheat Quality Laboratory (WWQL) was the same but with a constant 25% moisture level. Stardard deviation for cookie diameter was 0.33 at WWQL and similar (0.37) at KSU.

Water absorption of cookie dough. The amount of water required was determined by the handling properties (dough feel) of each dough.

Starch damage. Starch damage was determined by susceptibility to α-amylase according to the method of Barnes (1978). A fungal amylase (*Aspergillus oryza,* Sigma Chemical Co., St. Louis, MO) was used.

Pentosan. Amount of pentosan in flour samples was determined by acid hydrolysis to furfural (Pussayanawin 1982). After hydrolysis, a 20-μl aliquot was injected into the liquid chromatograph. The column used was a 4.1-mm i.d. × 25 cm Bondapak C-18 (Waters Associates, Milford, MA), 10-μm mean particle size, with a solvent flow rate of 1 ml/min. The mobile phase was prepared by filtering deionized double-distilled water through

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a 47-mm millipore filter (EHMP 047 00) with a pore size of 0.5 μm. Then, water was degassed for 15 min using a Megason ultrasonic generator. An ultraviolet (280 nm) detector was used. A standard curve was constructed from peak areas generated by injecting 20-μl aliquots of standard solutions of acid-hydrolyzed and filtered xylan (containing 65% xylose, from Sigma Chemical Co.). Standard deviation for the determination was 0.066%.

Alkaline water retention capacity. The test described by Yamazaki (1953) was used to determine alkaline water retention capacity (AWRC). Flour was suspended in 0.1 *N* sodium bicarbonate solution, allowed to hydrate for 20 min, and the suspension then centrifuged at 1,000 × *g* for 15 min. The supernatant liquid was discarded and the residue weighed. The weight gain was expressed as a percentage of the flour weight (14% m.b.).

TABLE I
Analytical and Baking Data for the Wheat Flour Used

Class or Subclass	Cultivar	No.[a]	Protein[b] (%)	Ash[b] (%)	Starch Damage (%)	Pentosan (%)	Water Absorption (%)	Alkaline Water Retention Capacity (%)	KSU[c] Cookie Diameter (cm)	WWQL[c] Cookie Diameter (cm)	Viscosity (°M)[d]
HRW	Hatton	51	8.9	0.50	7.65	2.09	27.50	...	7.84	8.35	...
	77-99	57	11.0	0.45	5.24	2.40	28.75	62.8	8.18	8.09	...
	Hatton	81	9.8	0.39	5.98	2.18	27.50	64.2	7.54	8.09	...
HRS	Sawtell	65	9.8	0.46	5.60	1.97	28.50	56.4	7.87	8.22	...
	Borah	63	11.2	0.41	5.02	2.24	28.75	60.4	8.02	8.40	...
	Wared	62	11.4	0.43	5.81	1.67	28.75	59.4	8.02	8.01	...
	Wampum	66	10.7	0.48	5.68	1.76	29.50	59.4	8.02	8.32	...
	Peak 72	61	11.3	0.39	4.74	2.15	29.25	60.8	7.87	7.94	...
	Peak 72	86	13.3	0.39	6.07	2.06	28.75	67.8	7.24	7.75	...
	Wared	87	11.8	0.40	5.09	1.82	28.75	64.8	7.87	8.04	...
	Sawtel	90	11.1	0.40	5.31	2.23	27.50	...	8.18	8.05	...
SWW	McDermid	44	8.1	0.44	4.10	1.95	25.50	55.4	9.93	9.32	38
	Luke	45	9.8	0.46	3.08	2.00	26.25	54.0	8.96	9.04	67
	Daws	47	7.8	0.48	3.20	2.38	25.50	60.6	8.96	8.64	59
	Stephens	48	8.4	0.44	3.36	2.14	25.50	56.2	8.81	9.14	41
	Greer	50	7.2	0.47	4.15	2.27	26.25	60.0	8.81	8.84	33
	0R68007	56	9.1	0.48	5.08	1.92	25.75	55.2	8.33	8.62	60
	77-294	58	8.8	0.46	3.98	2.02	26.25	59.4	8.81	8.76	76
	Nugaines	57	8.8	0.37	4.14	2.01	26.50	58.6	8.33	8.49	102
	Luke	76	9.6	0.37	3.07	1.94	26.25	55.6	8.51	9.05	79
	Sprague	77	9.6	0.37	4.80	2.58	26.25	58.2	8.51	8.69	98
	Daws	79	9.0	0.38	3.68	2.29	26.50	...	8.51	8.46	113
SWS	Baart	59	9.7	0.49	3.24	1.98	25.50	...	9.14	8.92	82
	Twin	60	10.2	0.54	3.52	2.22	27.50	54.6	8.51	8.80	88
	Urquie	64	9.2	0.52	3.60	1.92	26.50	57.0	8.81	8.71	85
	Walladay	67	9.1	0.48	3.09	2.04	26.25	53.8	8.51	9.00	83
	Waverly	68	10.2	0.44	2.92	1.98	27.25	56.2	8.81	8.65	124
	Owen	69	9.8	0.42	2.72	2.02	26.50	57.0	9.45	8.91	116
	ID 195	70	8.7	0.43	2.87	1.73	26.25	55.4	9.45	8.96	88
	Marfed	84	10.2	0.36	6.24	2.78	26.75	56.8	8.51	8.87	151
	Twin	85	10.2	0.40	2.53	1.85	27.50	54.2	8.96	9.20	89
	Urquie	89	9.8	0.37	3.20	2.12	26.75	56.8	9.45	8.85	116
	Fieldwin	91	9.7	0.35	3.09	2.08	25.75	55.4	9.14	8.90	133
Club	Moro	42	7.2	0.47	3.39	1.85	25.50	55.2	9.14	9.47	34
	Paha	43	9.1	0.46	4.69	1.84	26.75	54.2	9.29	9.40	36
	Barbee	46	9.3	0.47	2.50	2.04	24.25	60.0	9.60	9.06	39
	Faro	49	7.0	0.43	2.96	1.94	26.00	56.0	9.29	9.25	33
	Tyee	52	7.3	0.45	3.55	1.91	25.25	55.6	9.14	9.21	36
	Jacmar	53	9.5	0.48	4.98	1.84	27.50	54.8	9.77	9.39	66
	Crew	59	9.7	0.49	3.66	1.67	26.00	54.8	8.96	9.05	46
	0R7142	55	8.5	0.45	3.26	1.87	26.25	56.6	8.51	8.75	64
	Faro	80	8.8	0.38	4.60	1.99	26.00	58.6	8.81	8.65	79
	Tyee	82	8.2	0.36	2.53	1.84	25.50	56.2	8.96	9.06	76
	Crew	83	8.6	0.36	3.75	1.88	25.75	54.8	8.81	9.04	50
SWW	Nugaines	1	6.3	0.50	4.40	2.68	26.50	...	9.29	...	...
	Nugaines	2	10.9	0.46	4.01	2.37	27.50	...	8.51	...	...
	Nugaines	3	6.9	0.51	4.41	2.68	26.00	...	8.96	...	...
	Nugaines	4	9.0	0.50	5.64	2.42	27.00	...	8.51	...	...
	Nugaines	5	7.0	0.40	4.17	2.39	28.00	...	9.14	...	...
	Nugaines	6	7.4	0.43	3.70	2.08	28.00	...	8.81	...	...
	Nugaines	7	6.6	0.45	3.45	2.46	27.25	...	9.14	...	...
	Nugaines	8	6.8	0.42	3.13	2.34	28.25	...	9.29	...	...
	Nugaines	9	7.9	0.44	3.62	2.34	28.25	...	8.96	...	...
	Nugaines	10	7.6	0.58	4.41	2.48	26.00	...	8.96	...	...
	Nugaines	11	9.5	0.46	4.46	2.44	28.25	...	8.81	...	...
	Nugaines	12	7.0	0.54	4.61	2.48	28.50	...	9.14	...	...

[a] No. = Laboratory number.
[b] Results on a 14% moisture basis.
[c] KSU = Kansas State University, WWQL = Western Wheat Quality Lab.
[d] °M = degrees MacMichael.

RESULTS AND DISCUSSION

Effect of Fat Type on Cookie Spread

The first study was concerned with the type of fat and its effect on cookie spread. As shown in Table II, only the doughs containing oil produced cookies with a slightly larger diameter (nonsignificant). Because it was not possible to obtain to obtain a satisfactory creamed mass with oil, the baking experiments were repeated with a noncreamed procedure. All ingredients except flours were mixed to give a uniform mixture; the flour was then added and mixed as in the standard method. All fats gave essentially the same results with the noncreamed procedure (Table II). It thus appears that the type of fat is not an important variable for cookie spread. Similar conclusions were reached by Finney et al (1950b).

The mechanism whereby a noncreamed procedure increased cookie diameter over that of cookies made with creamed sugar and shortening may be related to competition between sugar and flour for the water available in the formula. In the creamed procedure, sugar particles are coated with fat and thus are impeded from solution. The sugar particles are not surrounded by fat in the noncreamed procedure or when using oil, and they tend to dissolve more rapidly, leaving less chance for the flour to compete for the available water.

Effect of Fat and Sugar Quantity on Cookie Spread

Although the type of fat was not important, the amount of fat was (Table III). Increasing the fat from 30% (based on the flour weight) to 35% did not affect cookie spread, but did give a finer top grain. On the other hand, decreasing the fat to 25% gave irregularly shaped cookies with coarse top grains.

As shown in Table IV, increasing or decreasing the sugar level by 10 percentage points from the control of 60% (based on the flour weight) made no difference in cookie diameter using the creamed procedure. However, finer top grains were obtained with the lowest sugar percentage. Using the noncreamed procedure, cookie spread increased as the sugar level was increased from 50 to 70% based on the flour weight.

Effect of Sugar Granulation

Two samples of sugars (superfine and granulated) were sieved for five min on Ro-Tap sieves to obtain a particle size distribution (Table V). Before sieving, the two sugars gave identical results when baked into cookies. As can be seen, there was a small but real shift to a smaller particle size with the superfine sugar. Sugar particle size did not affect cookie spread except at the coarsest size (>35 mesh, Table VI). The cookie spread and other cookie attributes were the same for all fractions smaller than 35 mesh. These conclusions are in agreement with those reported by Kissell et al (1973).

Analytical Tests

Cookies were baked both at KSU and the WWQL. The correlation coefficient between the two sets of data (Fig. 1) was $r = 0.85$. The difference may reflect the difference in the procedure or laboratory to laboratory variation.

Protein content. Flour protein content varied widely (7.0–13.3%) among the 44 flour samples used. The protein content significantly affected cookie diameter when the 44 samples were pooled ($r = -0.59$ KSU, and $r = -0.69$ WWQL). Although neither gave a strong correlation, there was a trend toward smaller cookies with increasing protein content, as shown in the scatter diagram (Fig. 2). If the 11 hard wheats are removed from the analysis, the correlation coefficients are not significant. In this study, soft wheat cookie diameter was not related to protein content. Yamazaki (1954b) has reported similar results.

Water absorption. Water absorption, as determined by dough consistency, ranged from 24.25 to 29.25%, with an average value of 26.75%. The correlation coefficient between water absorption and cookie diameter (KSU) was $r = -0.67$ (Fig. 3).

Starch damage. Starch damage reflects wheat kernel hardness and severity of milling. The mean values of the wheat classes followed a sequence of decreasing starch damage: HR > SWW > SWS > club. The correlation coefficient for starch damage versus KSU cookie diameter was $r = -0.68$ (Fig. 4). Absorption of water by any particular flour depends on the amount of starch damage. However, the relatively low correlation coefficient ($r = 0.62$) between damaged starch and water absorption shows that other factors also affect water absorption.

Pentosan content. In wheat flour there are two major pentosan components, which are water soluble and water insoluble. Total pentosan values for the flours used ranged from 1.67 to 2.58%. Total pentosan content was also found to be a rather poor index of the quality of cookie flour. The correlation between pentosan content and KSU cookie diameter was very poor (Fig. 5). Although pentosans are known to be very hydrophilic flour components, there was no significant correlation between pentosan content and cookie water absorption.

TABLE II
Effect of Fat Type on Cookie Diameter

Fat or Oil	Cookie Diameter (cm) Creamed	Noncreamed
Durkee D 10	8.89	9.10
Crisco	8.89	9.09
Crisco Oil	9.07[a]	9.08
Melted D 10	8.93	9.08

[a]Creamed mass was not satisfactory.

TABLE III
Effect of Fat Level on Cookie Diameter

Fat[a] (%)	Cookie Diameter (cm)
20	Irregularly shaped
25	9.20 (not round)
30	8.85
35	8.88

[a]Durkee D 10.

TABLE IV
Effect of Sugar Level on Cookie Diameter

Sugar (%)	Cookie Diameter (cm) Creamed	Noncreamed
50	9.18	8.75
60	9.15	9.30
70	9.18	9.70

TABLE V
Particle Size Distribution of Two Grades of Sucrose

Mesh Size	Weight (%) of Overs Superfine	Granulated
24	...	0.5
35	...	28.0
48	0.5	35.0
70	1.0	25.0
100	49.0	9.0
150	22.0	...
200	22.0	...
Pan[a]	5.0	2.5

[a]Pan = throughs of 200 mesh.

TABLE VI
Effect of Sugar Particle Size on Cookie Diameter (Creamed Procedure)

Overs of Mesh	Cookie Diameter (cm)
35	8.93
48	9.13
70	9.13
100	9.10
150	9.03
200	9.08

Alkaline water retention capacity. AWRC ranged from 53.8 to 67.8% for all samples tested. AWRC values varied greatly, because our study included four wheat classes and many cultivars. A high negative correlation has been reported (Yamazaki 1953) between AWRC and cookie diameter ($r = -0.85$). With the samples used in this study, the correlation coefficient was lower ($r = -0.63$ for the KSU cookie diameters and -0.78 for the WWQL cookie diameters, Fig. 6). Why these samples gave a low correlation is not known. Still, AWRC gave a better correlation than did the other attributes studied.

The AWRC test also was correlated with water absorption ($r = 0.45$). In fact, AWRC and water absorption tests are both indices of flour hydration capacity (Table VII).

MacMichael viscosity. MacMichael viscosity values were obtained on the 33 soft wheat flours. Viscosities ranged from 33 to 151° M and were significantly correlated with protein ($r = 0.47$) and cookie diameter (WWQL, $r = -0.54$, Fig. 7).

The 44 flour samples were divided into four wheat classes to provide a more useful interpretation of the data: hard red (HR), soft white winter (SWW), soft white spring (SWS), and club wheats. The data were then re-evaluated.

Hard red wheats. Because observations were few, we combined hard red spring and hard red winter wheats under the title of HR for a total of 11 samples. As might be expected, this class had higher protein content (8.9 to 13.3%) than did the other classes. Plotting protein content versus cookie diameter (KSU) gave no obvious relationship. HR flours gave the highest values for water absorption and starch damage; however, no significant correlation was found between any of these attributes.

Club wheats. Nearly all of the 11 club wheat cultivars gave cookies with superior diameters. However, cookie diameter was poorly correlated with protein content, water absorption, starch damage, AWRC, and pentosan content. Cookie dough water absorption was significantly correlated with starch damage. Although the reason for bigger cookie diameters from club wheat flours is not known, it is interesting to note that they had relatively low values for water absorption, AWRC, starch damage, and protein content (Table I).

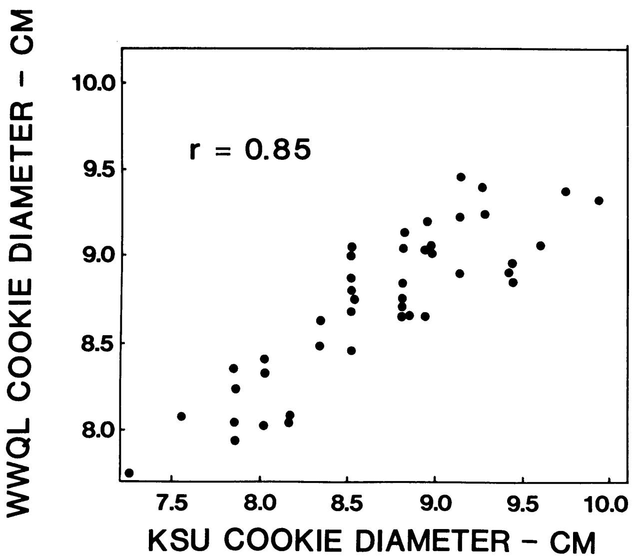

Fig. 1. Scattergram of diameter of cookies test baked at Kansas State University (KSU) vs. those baked at the Western Wheat Quality Laboratory (WWQL).

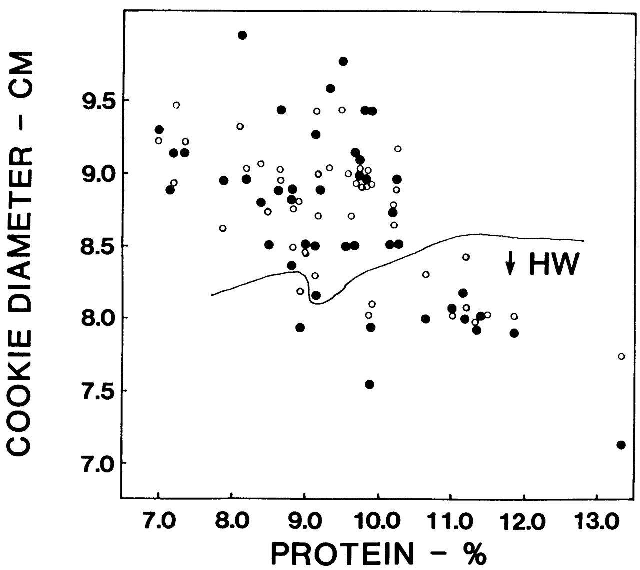

Fig. 2. Scattergram of protein content vs. cookie diameter (o = data from Western Wheat Quality Lab, $r = -0.69$, ● data from Kansas State University, $r = -0.59$. Values below the line are for Hard Wheat (HW) samples.

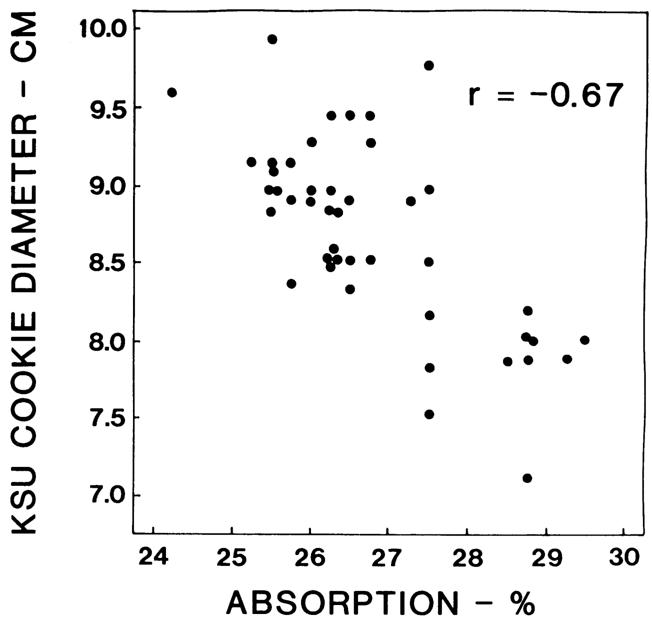

Fig. 3. Scattergram of water absorption vs. Kansas State University cookie diameters.

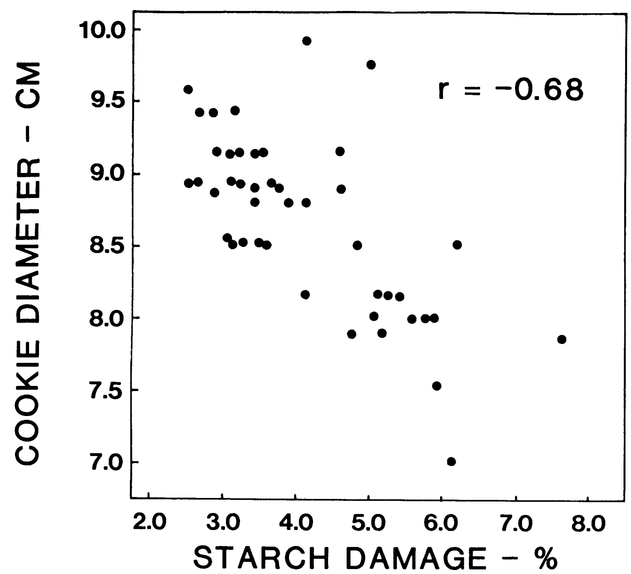

Fig. 4. Scattergram of starch damage vs. Kansas State University cookie diameters.

Soft white spring wheats. Cookie diameter for SWS flours ranged from 8.51 to 9.45 cm. Again, cookie diameter was poorly correlated with protein content, water absorption, starch damage, AWRC, and pentosan content. In this series a surprisingly high and unexplained correlation (0.90) was found between starch damage and pentosan content.

Soft white winter. Cookie diameter of flours from SWW wheats ranged from 8.46 to 9.32 cm (WWQL) and from 8.33 to 9.93 cm

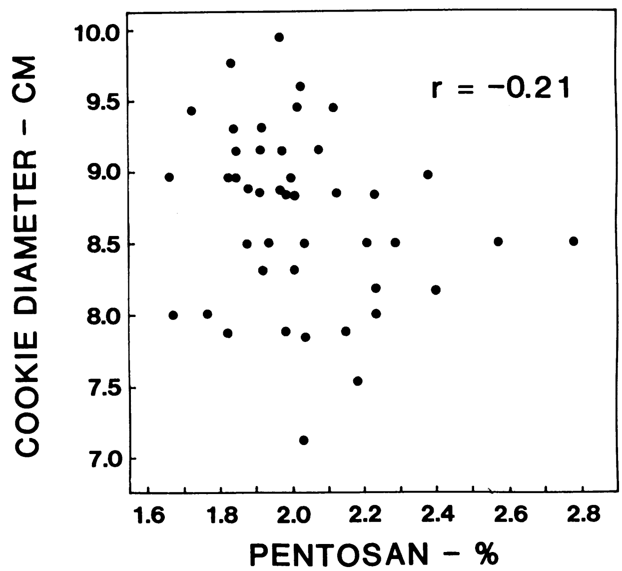

Fig. 5. Scattergram of pentosan content vs. Kansas State University cookie diameters.

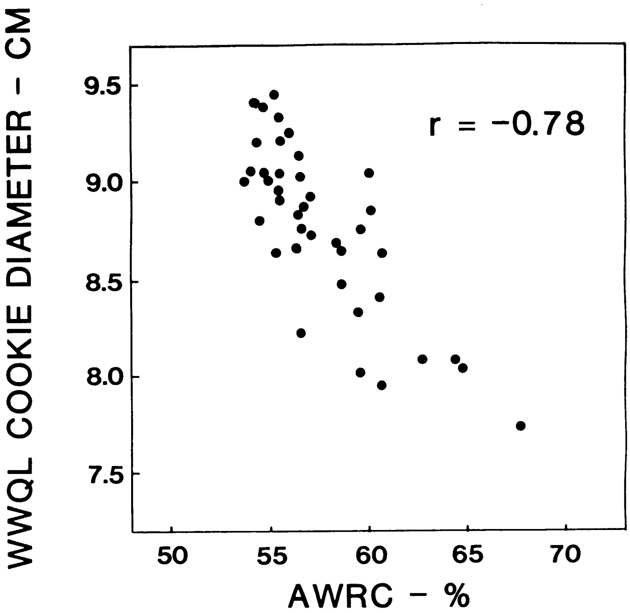

Fig. 6. Scattergram of alkaline water retention capacity (AWRC) vs. Western Wheat Quality Lab cookie diameters.

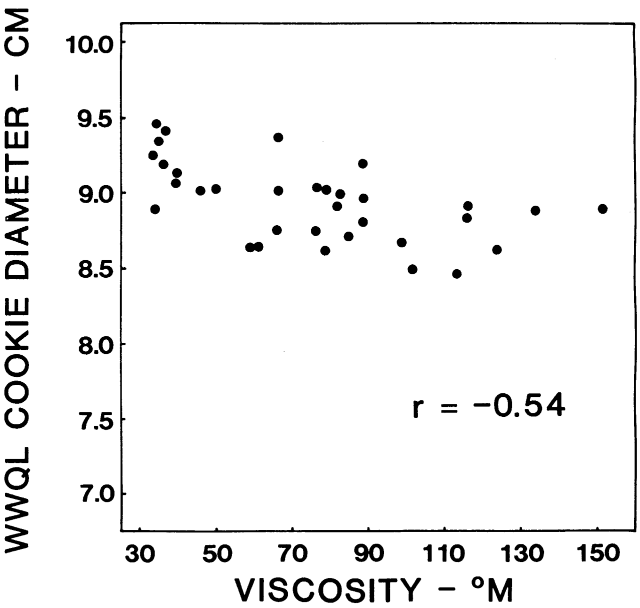

Fig. 7. Scattergram of MacMichael viscosity (° M) vs. Western Wheat Quality Lab cookie diameters.

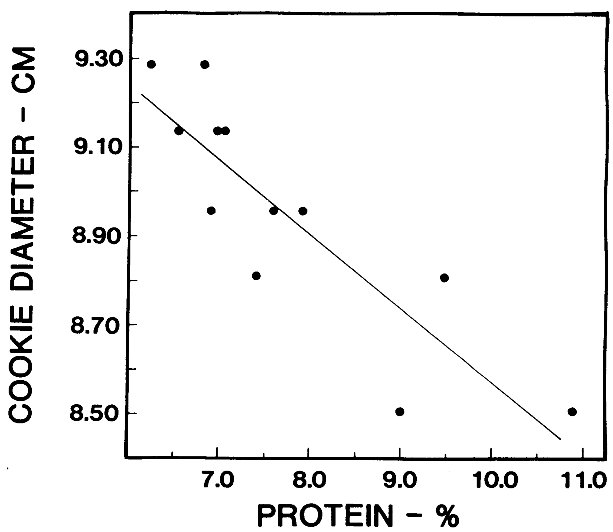

Fig. 8. Protein content vs. Kansas State University cookie diameters for the protein series.

TABLE VII
Correlation Coefficients[a] for Data from the Four Wheat Classes

	Water Absorption	Cookie Diameter KSU[b]	Cookie Diameter WWQL[b]	Starch Damage	Alkaline Water Retention Capacity	Pentosan	Viscosity
Protein	0.70**	−0.59**	−0.69**	0.44*	0.54**	0.09	0.67*
Water absorption	...	−0.67**	−0.66**	0.62**	0.45*	0.03	0.01
KSU cookie diameter		...	0.85**	−0.68**	−0.63**	−0.21	−0.28
WWQL cookie diameter			...	−0.63**	−0.78**	−0.23	−0.54*
Starch damage				...	0.52**	0.24	0.01
Alkaline water retention capacity					...	0.27	0.08
Pentosan						...	0.43
Viscosity							...

[a]* Significantly different at $P<0.05$, ** $P<0.01$.
[b]KSU = Kansas State University, WWQL = Western Wheat Quality Lab.

(KSU). No significant correlations were found between the various attributes for the soft white wheats.

Protein series. Nugaines, a soft white winter wheat, was grown at one location under both dry land and irrigated conditions, with different fertilizer levels, to produce wheats of different protein contents. By using a single cultivar and a single location, the effect of genetic variation and location was eliminated. Yamazaki and Lamb (1962) have shown that both location and season can be important factors; thus, both were standardized in this study.

In this series protein content was highly negatively correlated ($r = -0.87$) with cookie diameter (Fig. 8). The slope of the line is -0.16. Thus, within this cultivar, protein content had an effect on cookie diameter. There appears to be an unidentified genetic factor in wheat that has a major influence on cookie diameter. This genetic effect is large compared to the effect of protein content on cookie spread. Although the Nugaines flours used in this study differed noticeably in their water absorption and damaged starch, these values were not significantly correlated with cookie diameter.

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