# Starch-Water Relationships in the Sugar-Snap Cookie Dough System

J. R. Donelson[1,2] and C. S. Gaines[1,3]

Cereal Chem. 75(5):660–664

**ABSTRACT**

Prime starch was extracted from soft and hard wheat flours and ball-milled to produce 100% damaged starch. Small amounts of the ball-milled starch or a pregelatinized starch were added to sugar-snap cookie formulations. Other cookie doughs were produced from prime starch only (no flour) with small amounts of the ball-milled starch added. Starch damages of the resulting substituted soft and hard wheat flours and soft and hard wheat prime starches were determined and compared to diameters of sugar-snap cookies produced from the control and treatments. Soft wheat flour and starches produced larger diameter cookies than their hard wheat counterpart at all levels of damaged starch. Both sources of damaged starch (ball-milled or pregelatinized starch) had similar effects on cookie diameter. Cookies produced from all starch (no flour) were similar to their respective flour controls at ≈8% damaged starch. To produce the same size cookie as that produced by soft wheat flour and starch, hard wheat flour and starch cookie formulations required less damaged starch and had lower alkaline water retention than did the soft wheat flour and starch cookie formulations. Other flours were treated with chlorine gas to pH 4.8. Pregelatinized starch (≈5%) was required to reduce the cookie diameter as much as chlorine treatment did. Results suggest unique quality differences between soft and hard wheat starch as they function in sugar-snap cookie baking. The functional results of those differences are not adequately quantified by the estimation of damaged starch level.

Various studies of soft wheat flour components have revealed that most major flour constituents physically or chemically influence flour quality. Mostly for lack of other baking tests, the effects of those constituents have been evaluated using a standard sugar-snap cookie formula. Flour fractionation and component isolation studies have identified a portion of polar lipids, some or all of the components of the prime starch (including unique surface proteins), tailings fraction, and protein quantity and quality as having strong influences on cookie geometry or hardness.

Lipids, starch tailings, and starch surface proteins all appear critical to soft wheat product baking performance. The free polar glycolipids, digalactosyldiglyceride or phosphatidylcholine, were critically necessary to sugar-snap cookie baking performance of soft wheat flour (Clements and Donelson 1981). When purified, pentosans, hemicellulose, and damaged starch from the tailings fraction greatly reduced cookie diameter (Yamazaki 1955, Sollars and Bowie 1966, Yamazaki et al 1977). The qualitative contribution of starch surface proteins ($M_r$ 15,000 protein, friabilin) to quality differences among soft and hard wheats was recently studied (Greenwell and Schofield 1986; Morris et al 1992, 1994; Bettge et al 1995; Greenblatt et al 1995; Giroux and Morris 1997).

Various physical and chemical properties of starch greatly affect soft wheat flour performance. In fractionation studies, sugar-snap cookie diameter was increased by substituting the isolated prime starch fraction for either the gluten or the tailings fractions (Donelson 1988). Those substitutions lowered the water hydration values of the dough systems. Chlorination of the starch fraction increased starch hydration and reduced cookie spread (Donelson 1990). Those features are interesting because the hydration test is conducted at room temperature, and very little actual gelatinized starch has been observed in baked sugar-snap cookies (Abboud and Hoseney 1984). Apparently, there are large differences in starch characteristics for cookie baking between wheat classes (hard and soft), but relatively little difference among soft wheat starches (Yamazaki et al 1977).

The rheological and hydration characteristics of wheat proteins affect the geometry and texture of sugar-snap cookies. Hou et al (1996) reported that the total glutenin subunits per unit of flour protein correlated negatively with cookie diameter. Within a cultivar (not across cultivars), protein content generally correlates with cookie spread (Abboud et al 1985). Bettge et al (1989) observed a correlation between cookie diameter and alveograph *P* values and protein content. Gaines (1990) mixed sugar-snap cookie doughs for various mixing times and reported that cookies became harder as mixing progressed. The hardness of wire-cut formula cookies was correlated with flour protein content (Gaines 1996).

Many who have studied how and why cookie doughs spread during baking have studied differences in doughs produced by hard versus soft wheat flours. Abboud et al (1985) found that heated cookie doughs made from soft wheat flour have lower measured viscosity than doughs produced from hard wheat flour. Hard wheat doughs cease spreading at an earlier time during baking, suggesting their viscosity becomes too great to spread at a lower temperature, unlike doughs produced using soft wheat. Doescher et al (1987a) reported a lower glass transition temperature for hard wheat gluten than for soft wheat gluten. Doescher et al (1987b) observed that protein content was associated with the rate of cookie dough spreading during baking. Rate of dough expansion and the time the dough set during the baking period determined final cookie diameter.

Slade and Levine (1994) asserted that cookie dough made with hard wheat (poor cookie quality) flour exhibits controlled elastic expansion (spreading). It expands to a maximum and then contracts in diameter through a controlled elastic shrinkage. Doughs produced from soft wheat (good cookie quality) flour slowly expand to a maximum diameter and then dramatically collapse. The behavior of poor quality flour is characteristic of elastic recovery in a rubbery thermoset polymer system, whereas the behavior of good quality flour is characteristic of structural collapse in a rubbery, predominantly thermoplastic polymer system.

These theories are based, in large part, on differences between hard (poor quality) and soft (good quality) flours used in the sugar-snap cookie formulation. However, at our laboratory, quality differences among many soft wheat flours ranging from poor to good quality must be evaluated. Yamazaki (1955) reported that sugar-snap cookie baking performance could be expressed in terms of the relationship between flour and water. Treatments that caused an increase in flour hydrophilicity caused reduced cookie spread. Previous reports also indicated that the hydrophilicity of starch has great influence on sugar-snap cookie diameter (Donelson 1990) and cake volume (Donelson 1988).

Yamazaki and Donelson (1976) developed a wheat flour fractionation-reconstitution procedure that permits the direct use of

[1] U.S. Department of Agriculture, Agricultural Research Service, Soft Wheat Quality Laboratory, Ohio Agricultural Research and Development Center, Ohio State University, Wooster, OH 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 also can be suitable.
[2] Retired.
[3] Corresponding author. E-mail: gaines.31@osu.edu

Publication no. C-1998-0805-03R.

dried, ground flour fractions in bake tests. Donelson (1988) showed that normal-appearing sugar-snap cookies could be produced without the gluten fraction, suggesting a simplified baking system model could be used to observe how elevated levels of damaged starch influence cookie spread through starch-water relationships. In this study, two very different sources of damaged starch (ball-milled and pregelatinized) were used to study the effect on hydration and cookie spread for flour-starch combinations and for a model system composed entirely of wheat starch. Also, after the spread-controlling levels of starch damage for the two sources were established, the level of readily available, safe, pregelatinized starch necessary to reduce cookie spread to the same level as that attained by the treatment of flour with chlorine gas was determined.

## MATERIALS AND METHODS

### Flour and Starch

Starch was extracted from a soft wheat cookie flour (protein 9.1%, ash 0.42%) (flour A), a hard wheat flour (protein 12.2%, ash 0.51%) (flour B), and a soft wheat cookie flour (protein 9.4%, ash 0.33%) (flour C). The starch samples were obtained from flours that were free-lipid-extracted using hexane. After lipid extraction, prime starch was isolated using an aqueous flour fractionation procedure (Yamazaki et al 1977). Twelve typical soft red winter wheat (cultivar and crop year blends) flours (flours D–O) were treated with chlorine gas to pH ≈ 4.8 (Kissell and Marshall 1972). Alkaline water retention capacity (AWRC) values were determined in duplicate (AACC 1995). Portions of the starch samples were crushed by ball-milling (U.S. Stoneware Co., Akron, OH) to achieve 100% starch damage (AWRC 424%). Starch damage was determined according to Donelson and Yamazaki (1962). Pregelatinized wheat starch (starch damage 100%, AWRC 759%) was obtained from Midwest Grain Products, Inc., Atchison, KS.

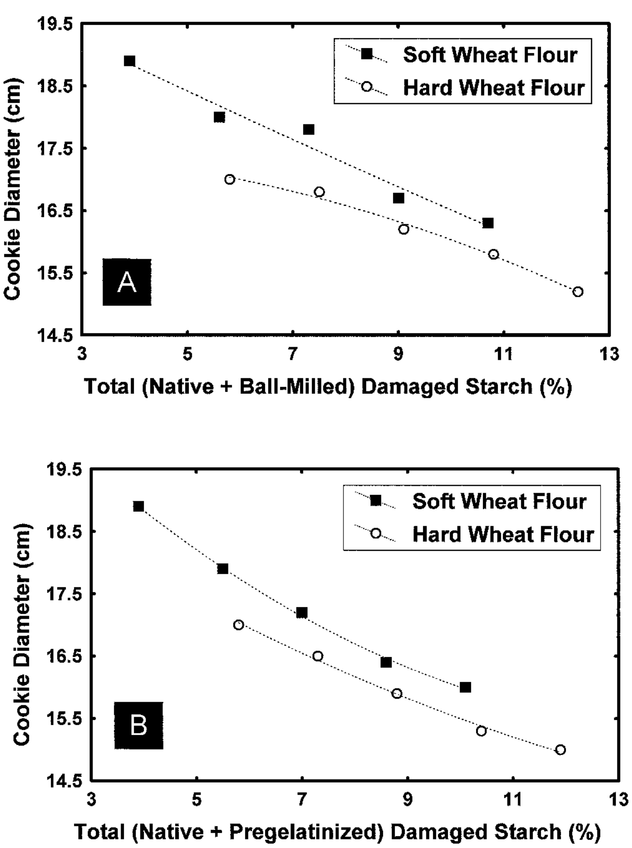


**Fig. 1.** Reduction in cookie diameter by adding ball-milled starch (**A**) and pregelatinized starch (**B**) to sugar-snap cookie formulas using a soft and a hard wheat flour. Least significant difference for cookie diameter = 0.2 cm.

### Baking Procedure

Starch and starch combinations were prepared for baking by reconstituting the extracted lipid in hexane solution based on 40 g of flour, the amount of flour used per dough. Hexane was removed by evaporation. Starch substitution levels were 0, 2, 4, 6, and 8% for flour and 0, 5, 8, and 11% for all-starch cookies.

Sugar-snap cookies (AACC 1995) were baked in duplicate. Cookie diameters are reported as the sum of two cookie diameters. Because of the low liquid requirement of cookie doughs from starch and starch combinations, the concentration of leavening solution B from the standard method was increased so the volume needed per bake could be reduced from 2.0 to 1.2 mL to achieve a dough with a normal consistency. The standard method adjusts doughing water level to achieve a standard subjective consistency. However, despite the increased hydration capacity of the flour-starch combinations, the consistency of the doughs as evaluated during mixing (for pos-

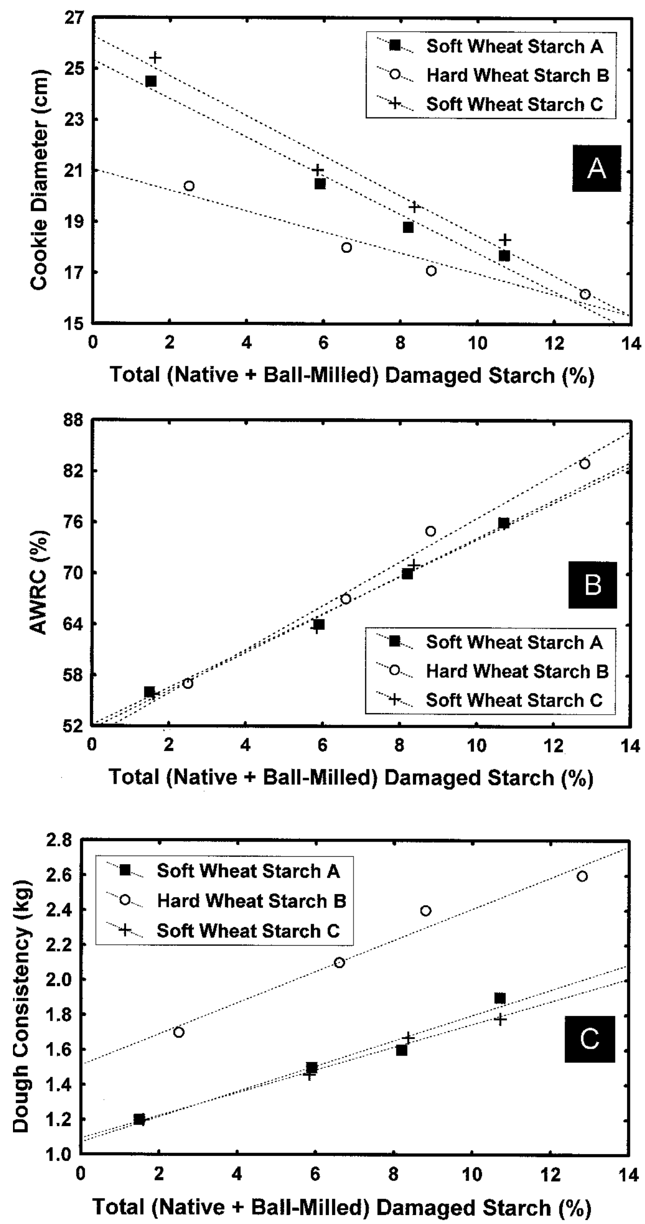


**Fig. 2.** Reduction in cookie diameter (**A**), increase in alkaline water retention capacity (AWRC) (**B**), and increase in cookie dough consistency (**C**) as damaged starch was increased by adding ball-milled starch to sugar-snap cookie formulas containing all soft or hard wheat starch (no flour). Least significant differences: cookie diameter = 0.3 cm; AWRC = 2%; dough consistency = 0.2 kg/g.

sible adjustment of the liquid level) appeared to be unaffected by the added starches. That made it possible to bake the control flours and treatments at the same absorption level.

**Consistency Analysis**

Immediately after mixing, a portion of cookie dough was weighed to 20 ± 0.5 g and formed into a round ball. The dough ball was compressed to one-half of its original height (Instron model 1000). Crosshead speed was 200 mm/min and the platen had a diameter of 3 cm (exceeding the diameter of the compressed dough piece). Starches replaced flours (w/w) in the dough formulations.

**Statistical Analysis**

All bakes and analyses were duplicated. Data were analyzed for analysis of variance and linear regression models analysis using Statistica (StatSoft, Tulsa, OK).

## RESULTS AND DISCUSSION

**Flour-Starch Combinations**

To illustrate the effects of flour-water relationships on cookie spread, whole flours can be ground to increase starch damage and reduce formula water mobility. Sugar particle-size selection can also be used to affect cookie geometry (Matz and Matz 1978). Another way to reduce dough spread during baking is to treat cookie flour with chlorine gas. The present approach is to replace flour with small quantities of compatible, highly hydrophillic pregelatinized starch or highly damaged ball-milled starch.

The addition of increasing quantities of ball-milled prime wheat starch and pregelatinized starch (Fig. 1A and B, respectively) elevated the total level of damaged starch in both the soft and hard wheat flours, and dramatically decreased cookie diameter. At all levels of damaged starch, sugar-snap cookie diameter of the soft wheat flour was larger than that of the hard wheat flour. Cookie diameters were similar for each level of damaged starch regardless of the source (ball-milled or pregelatinized) of added damaged starch. The negative relationship between the highly hydrophillic starches and cookie spread for both flours illustrates the competitive nature of hydrophillic flour components for mobile formula water and the resulting influence over cookie spread (Yamazaki et al 1977). The gross hydrophillic components of a sugar-snap cookie formula are flour and sugar. If flour components are less hydrophillic, more water is available to the sugar to form syrup and decrease the dough viscosity during baking, resulting in greater dough spreading and larger cookie diameter. Elevating the hydrophillic characteristics of flour components directly decreases cookie spread.

A 16.5-cm cookie diameter represents a typically small hard wheat flour cookie spread. To produce a regression-predicted sugar-snap cookie diameter of 16.5 cm, the soft wheat required a mean of 1.4 percentage points more damaged starch from added pregelatinized starch and a mean of 1.8 percentage points more damaged starch from added ball-milled starch (Table I). Those differences suggest a large quality difference between the soft and hard wheat flours. A 16.5 cm diameter is relatively small, but it took considerably more damaged starch for the soft wheat flour to produce that diameter than for the hard wheat. In this study, that quality difference resulted in a reduced cookie diameter that was equal to ≈1.6% damage starch.

AWRC values for the control, 2, 4, 6, and 8% substitution levels were 54, 63, 72, 83, and 93% for the soft wheat substitution with pregelatinized starch; 64, 68, 75, 84, and 92% for the hard wheat substitution with pregelatinized starch; 54, 59, 63, 68, and 72% for the soft wheat substitution with ball-milled starch; and 64, 68, 73, 79, and 81% for the hard wheat substitution with ball-milled

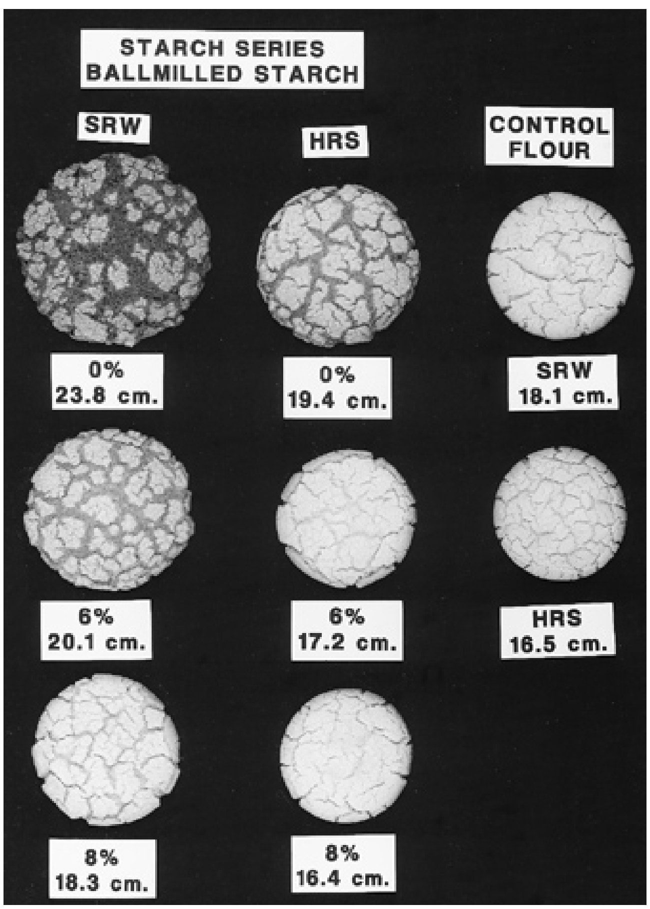


**Fig. 3.** Representative cookies from starch and starch combinations containing 6 and 8% ball-milled starch. SRW = soft red spring; HRS = hard red spring.

**TABLE I**
**Predicted Damaged Starch Values (%) Using Damaged Starch to Produce a Constant Cookie Diameter (regressed to 16.5 cm)**

| | Pregelatinized Starch | Ball-Milled Starch |
|---|---|---|
| Soft | 8.6 ± 0.6[a] | 9.9 ± 1.2[a] |
| Hard | 7.2 ± 0.5 | 8.1 ± 0.7 |

[a] 95% confidence level.

**TABLE II**
**Predicted Damaged Starch and Alkaline Water Retention Capacity (AWRC) Values for Two Cookie Diameters from Soft and Hard Wheat Starch Substituted for Flour**

| | Cookie Diameter (cm) | Predicted Damaged Starch (%) | Predicted AWRC (%) |
|---|---|---|---|
| Soft | 18.6 | 8.9 ± 1.8[a] | 71.5 ± 6.0[a] |
| Hard | 18.6 | 6.1 ± 2.9 | 66.4 ± 6.7 |
| Hard | 16.7 | 10.5 ± 3.4 | 77.9 ± 7.7 |

[a] 95% confidence level.

**TABLE III**
**Sugar-Snap Cookie Diameter: Control and Treated with Chlorine Gas**

| Flour | Control | Chlorine Treated to pH 4.8 |
|---|---|---|
| D | 17.6 | 16.7 |
| E | 18.0 | 16.9 |
| F | 17.7 | 17.0 |
| G | 17.6 | 16.9 |
| H | 17.7 | 16.7 |
| I | 17.6 | 16.4 |
| J | 17.9 | 17.0 |
| K | 17.3 | 16.5 |
| L | 17.5 | 16.7 |
| M | 18.1 | 17.1 |
| Mean | 17.7 | 16.8 |

starch. The literature implies that hard wheats have more of the highly hydrophillic pentosan-rich tailings fraction than do soft wheats, or that the hard wheats tailings fraction is more hydrophillic (Yamazaki 1955, Sollars and Bowie 1966, Sollars 1973, Sollars and Rubenthaler 1975, Yamazaki et al 1977). However, there may also be important functional and biochemical differences between soft and hard wheat starch.

**All-Starch Cookies**

The relationship between hydration and cookie spread was also evaluated in a simple model system in which starch was entirely substituted for flour. Aliquots of prime wheat starch from respective soft and hard wheat hexane-extracted flours were ball-milled to obtain complete starch damage, maximizing potential water hydration. Combinations were prepared with those starches and their redundant parent prime starches. After restoration of the free lipid, the samples were baked in the usual manner. Values for cookie diameters, water hydration (AWRC), and dough consistency values are shown in Fig. 2. As in the flour-starch data above, substituting ball-milled starch for native prime starch in an all-starch cookie model system also decreased cookie spread and increased water hydration (AWRC) for the soft and hard wheat starch doughs. Additions of damaged starch content increased dough consistency, as measured at room temperature (20°C). Cookie diameters were higher for the soft wheat starch at all levels of damaged starch. In contrast, dough consistency values for the hard wheat starch were higher at all levels of damaged starch and three of the added levels of damaged starch produced higher AWRC values for the hard wheat starch. The room temperature consistency measurements are additional objective evidence that the competition for water in a sugar-snap cookie dough system influences dough viscosity and negatively affects cookie baking performance. At a given AWRC value, the consistency of the hard wheat starch cookies was much greater than those of the soft wheat starch cookies. One of the characteristics of Approved Method 10-52 (ACC 1995) is that water is adjusted based on dough-feel to the operator. Hard wheat flour doughs always require more doughing water than do soft wheats.

Figure 3 shows typical cookies for the all-starch cookie treatments. The appearance and size of all-starch cookies were normal (like the control) at ≈8% damaged starch. It is important to note that the only protein in this cookie formula was 3% (starch basis) nonfat dry milk.

The internal crumb scores of starch cookies were similar to those of the control flour cookies when the diameters of the starch cookies were close to the diameters of the original flour. For the two soft wheat flour-starch cookies, the internal crumb scores were 7 for the control flour and 0, 0, 4, and 7 for 2, 4, 6, and 8% substitution levels, respectively. For the hard wheat flour-starch cookies, the internal crumb scores were 9 for the control flour and 0, 5, 7, and 8 for 2, 4, 6, and 8% substitution levels, respectively. Higher scores represent better, fine grain structure.

All starch cookies were more sensitive to the addition of damaged starch than starch-substituted flour cookies. Slopes were 0.38 and 0.45 cm/% of damaged starch for the soft wheats and 0.67 cm/% of damaged starch for the hard wheat starch. Regression analysis (Table II) of the all-starch cookies revealed that the soft wheat starch cookie formulation required 8.9 ± 1.8% damaged starch to produce the same 18.6-cm cookie as that of the original soft wheat flour from which the starch was extracted. The hard wheat starch formulation required 10.5 ± 3.4% damaged starch to produce the same 16.7-cm cookie as that produced by the original hard wheat flour. Also, 6.1 ± 2.9% damaged starch was required to produce the same size all-starch cookie as that produced by the original soft wheat flour (18.6 cm). There was a mean of 2.8% starch damage less and 5.1 AWRC percentage points less for the hard wheat to produce 18.6-cm cookies. Clearly, something else contributed to reducing the cookie diameter of the hard wheat starch formula cookies besides damaged starch. In contrast to the flour-starch formula, these quality differences between the soft and hard wheat starches are observed in an all-starch cookie formula. Thus, apparently there is a quality difference between hard and soft wheat starch, particularly as evidenced by its hydration at room temperature and by the way it functions in a cookie formulation during baking.

**Comparison with Chlorine Treatment**

In effect, adding damaged starch to reduce cookie spread is similar to the increasingly popular use of chlorine gas to restrict dough flow during baking. Table III gives the sugar-snap cookie diameters of 10 soft wheat flours before and after treatment with chlorine gas to achieve pH 4.8. Reduction of diameters averaged 0.9 cm. Two other soft wheat flours were each treated with 1, 2, 3, and 4% substitution of pregelatinized starch for flour, analyzed for AWRC, and baked into sugar-snap cookies (Table IV). The control flours also were treated with chlorine gas, and the resulting flour was also analyzed and baked. Regression analysis revealed that a substitution level of 4.6 ± 0.5% pregelatinized starch was required for the cookie diameter from flour N to equal the cookie diameter of the chlorinated flour N. A substitution level of 5.6 ± 1.7% pregelatinized starch was required for the cookie diameter from flour O to equal the cookie diameter of the chlorinated flour O. With respect to cookie diameter reduction, it is noteworthy that the pregelatinized starch produced higher AWRC values than did treatment with chlorine gas. Additional study may indicate that higher absorptions could cause difficulties, but control of cookie diameter using pregelatinized starch may be cheaper, softer, and more acceptable than use of chlorine gas.

## CONCLUSIONS

At all levels of damaged starch studied, diameters of sugar-snap cookie were larger for cookies produced from the soft wheat flour than from the hard wheat flour. At each level of addition, both sources of damaged starch (ball-milled or pregelatinized starch) produced similar cookie diameters. Thus, the effects of added damaged starch in the standard sugar-snap cookie formulation were

**TABLE IV**
**Diameter and Alkaline Water Retention Capacity (AWRC) of Sugar-Snap Cookies Treated with Chlorine and Added Pregelatinized Starch**

| | Pregelatinized Starch | | | Chlorine Treated | | |
|---|---|---|---|---|---|---|
| Flour | Substitution Level (%) | Cookie Diameter (cm) | AWRC (%) | pH Level | Cookie Diameter (cm) | AWRC (%) |
| N | 0 | 18.2 | 55.0 | 4.6 | 16.7 | 59.7 |
| N | 1 | 17.8 | 56.4 | | | |
| N | 2 | 17.6 | 59.8 | | | |
| N | 3 | 17.2 | 61.3 | | | |
| N | 4 | 16.9 | 64.5 | | | |
| O | 0 | 17.8 | 53.5 | 4.7 | 15.9 | 60.5 |
| O | 1 | 17.7 | 56.9 | | | |
| O | 2 | 17.2 | 61.6 | | | |
| O | 3 | 16.7 | 65.0 | | | |
| O | 4 | 16.6 | 68.5 | | | |

independent of source. It is possible to produce starch cookies equivalent in size and appearance to flour cookies produced using control unfractionated flours by adding ≈8% damaged starch. Pregelatinized starch (≈5%, equivalent to ≈4% added damaged starch) was required to reduce cookie spread similar to that produced by treating flour with chlorine gas to pH 4.8. Those results suggest that in addition to different levels of damaged starch, there are functional biochemical differences between soft and hard wheat starch. The differences are evident as starch hydrates at room temperature and as it functions in a cookie formulation during baking. Hard wheat starch has a fundamentally different property than soft wheat starch. Likely, an aspect of prime, undamaged hard wheat starch creates higher viscosity in the dough during baking, perhaps because it has greater affinity for water than does soft wheat starch in cookie formulations. The starch fraction may be a critical defining quality factor between hard and soft wheat classes, in addition to class differences among flour proteins.


## ACKNOWLEDGMENT

We gratefully acknowledge the technical assistance of Leona Horst of this Laboratory.


## LITERATURE CITED


Abboud, A. M., and Hoseney, R. C. 1984. Differential scanning calorimetry of sugar cookies and cookie doughs. Cereal Chem. 61:34-37.

Abboud, A. M., Hoseney, R. C., and Rubenthaler, G. L. 1985a. Factors affecting cookie flour quality. Cereal Chem. 62:130-133.

Abboud, A. M., Rubenthaler, G. L., and Hoseney, R. C. 1985b. Effect of fat and sugar in sugar-snap cookies and evaluation of tests to measure cookie flour quality. Cereal Chem. 62:124-129.

American Association of Cereal Chemists. 1995. Approved Methods of the AACC, 9th ed. Method 10-52, approved September 1985, revised November 1988, November 1989, October 1991, and September 1992, reviewed October 1994; Method 56-10, approved October 1986, reviewed October 1994. The Association: St. Paul, MN.

Bettge, A., Rubenthaler, G. L., and Pomeranz, Y. 1989. Alveograph algorithms to predict functional properties of wheat in bread and cookie baking. Cereal Chem. 66:81-86.

Bettge, A. D., Morris, C. F., and Greenblatt, G. A. 1995. Assessing genotypic softness in single wheat kernels using starch granule-associated friabilin as a biochemical marker. Euphytica 86:65-72.

Doescher, L. C., Hoseney, R. C., and Milliken, G. A. 1987a. A mechanism for cookie dough setting. Cereal Chem. 64:158-163.

Doescher, L. C., Hoseney, R. C., Milliken, G. A., and Rubenthaler, G. L. 1987b. Effect of sugars and flours and flours on cookie spread evaluated by time-lapse photography. Cereal Chem. 64:163-167.

Donelson, J. R. 1980. Note: Flour fraction interchange studies of effects of chlorination on cookie flours. Cereal Chem 67:99-100.

Donelson, J. R. 1988. The contribution of high-protein fractions from cake and cookie flours to baking performance. Cereal Chem. 65:389-391.

Donelson, J. R. 1990. Note: Flour fraction interchange studies of effects of chlorination on cookie flours. Cereal Chem. 67:99-100.

Donelson, J. R., and Yamazaki, W. T. 1962. Note on a rapid method for the estimation of damaged starch in soft wheat flours. Cereal Chem. 39:460-462.

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. 67:73-77.

Gaines, C. S., Kassuba, A., and Finney, P. L. 1996. Using wire-cut and sugar-snap cookie test baking methods to evaluate distinctive soft wheat flour sets: Implications for quality testing. Cereal Foods World 41:155-160.

Giroux, M. J., and Morris, C. F. 1997. A glycine to serine change in puroindoline b is associated with wheat grain hardness and low levels of starch-surface friabilin. Theor. Appl. Genet. 95:857-864.

Greenblatt, G. A., Bettge, A. D., and Morris, C. F. 1995. Relationship between endosperm texture and the occurrence of friabilin and bound polar lipids on wheat starch. Cereal Chem. 72:172-176.

Hou, G., Yamamoto, H., and Ng, P. K. W. 1996. Relationships of quality of glutenin subunits of selected U.S. soft wheat flours to rheological and baking properties. Cereal Chem. 73:358-363.

Kissell, L. T., and Marshall, B. D. 1972. Design and construction of a reactor for gaseous treatment of flour. Cereal Sci. Today 17:153-155.

Matz, S. A., and Matz, T. D. 1978. Cookie and Cracker Technology. AVI: Westport, CN.

Morris, C. F., Greenblatt, G. A., Bettge, A. D., and Milkawi, H. I. 1994. Isolation and characterization of multiple forms of friabilin J. Cereal Sci. 21:167-174.

Slade, L., and Levine, H. 1994. Structure-function relationships of cookie and cracker ingredients. Pages 23-141 in: The Science of Cookie and Cracker Production. H. Faridi, ed. Chapman and Hall: New York.

Sollars, W. F. 1973. Water-retention properties of wheat flour fractions. Cereal Chem. 50:717-722.

Sollars, W. F., and Bowie, S. M. 1966. Effect of the subfractions of starch tailings on cookie diameter. Cereal Chem. 43:244-260.

Sollars, W. F., and Rubenthaler, G. L. 1975. Flour fractions affecting farinograph absorption. Cereal Chem. 52:420-427.

Yamazaki, W. T. 1955. The concentration of a factor in soft wheat flours affecting cookie quality. Cereal Chem. 32:26-37.

Yamazaki, W. T., and Donelson, J. R. 1976. Effects of interactions among flour lipids, other flour fractions, and water on cookie quality. Cereal Chem. 53:998-1005.

Yamazaki, W. T., and Donelson, J. R., and Kwolek, W. F. 1977. Effects of flour fraction composition on cookie diameter. Cereal Chem. 54:352-360.


[Received February 9, 1998. Accepted June 4, 1998.]