# Low-Protein Flour from Hard Winter Wheat: Wet Processing to Improve Breadmaking Potential[1]

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## ABSTRACT

A method to make white pan bread from low-protein wheat flour was tested for technical feasibility. Starting with two hard winter wheat flours, 20% of the flour in a formula was processed wet (water/flour = 2.25) into a protein-rich fraction and a starch fraction. The wet, protein-rich fraction was combined with flour to make pup loaves, and the wet starch fraction was used with soft wheat flour to prepare cakes, muffins, and cookies. Wet processing of 20 g of flour A (9.3% protein) and flour B (12.2% protein) gave 31.5 g and 36.1 g, respectively, of the wet, protein-rich fraction, which contained 5.5 g and 8.1 g dry solids with 28.1% and 27.2% protein (d.b.), respectively. When this fraction was incorporated with the remaining flour in a dough, the "new" flour in the dough increased about 1% in protein (14% m.b.). After baking, the bread showed approximately 86% of the increase in loaf volume expected for the 1% increase in flour protein. The wet starch fraction from 40 g of flour A (containing 22.4 g dry solids with 2.8% protein, d.b.) was added to an egg-foam cake in place of about one-fourth of the cake flour. The starch improved cake volume by 5%. Replacing one-fourth of formula flour in muffins and soft cookies had little or no effect on their appearance or softness.


The baking performance of a bread flour depends in large measure on its protein content. Finney and Barmore (1948) showed a linear correlation between loaf volume and flour protein (8–18%) within a wheat variety. High-protein flour usually costs more than low-protein flour, provided the protein quality for breadmaking is about the same. High protein in bread flour is valued because it increases tolerance in fermentation, make-up, and proofing; improves loaf volume and grain; strengthens the crumb and crust in rolls and bread; permits addition of other grains to produce specialty products; reduces the rate of crumb firming; and improves the nutritional value of bread and rolls. The functional properties of flour proteins in breadmaking have been reviewed (Pomeranz 1978; Ponte 1978; Pyler 1983a,b); however, much wheat is grown for yield and is low in protein.

Wallace (1981) patented a breadmaking process that, in effect, increases the protein content of the starting flour. In this process, a portion of the formula flour is wet processed into two fractions; one is a starch slurry, and the other is the remaining components of the flour in wet form. Removal of the starch increases the protein in the remainder of the flour, which we termed the protein-rich fraction.

Lu et al (1983) examined the Wallace process of preparing white pan bread. They wet processed 20% of formula flour, converted the starch fraction to sweetener using $\alpha$-amylase/glucoamylase, and combined the sweetener and the protein-rich fraction to produce bread with improved grain and volume compared to a control. However, they found that high shear on the flour-water mixture during wet processing gave bread with open grain, and that the sweetener had a brown color that caused the crumb of test loaves to be darker than those of the control. Also, only 50% of the expected increase in loaf volume was achieved.

In this work, two hard wheat flours were examined with the following objectives: a) to use a low-shear process on the flour-water mixtures to separate a starch fraction and a protein-rich fraction with low damage to gluten; b) to determine the yield, protein, and moisture of the two fractions; c) to use the wet, protein-rich fraction to produce bread with optimum volume and grain; and d) to use the wet starch to prepare foam-type cakes, muffins, and soft cookies.

## MATERIALS AND METHODS

### Ingredients and Assay Methods

Protein was determined by Kjeldahl nitrogen, AACC method 46-11; ash by dry combustion, method 08-01; moisture by oven-drying 1 hr at 130°C, method 44-15A; and pH by a glass electrode pH meter, method 02-52 (AACC 1976). Analytical data on flour were reported on a 14% moisture basis.

Flours A and B were wet processed and used in breadmaking. Flour A was a straight-grade flour milled from hard red winter (HRW) wheat grown in eastern Kansas. The wheat was milled in the pilot flour mill at the Department of Grain Science and Industry, Kansas State University. Flour A had 9.3% protein (N ×

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5.7), 0.40% ash, and 14.7% moisture. Flour B was a commercial bread flour obtained from Ross Industries, Inc., Wichita, KS, and had 12.2% protein, 0.46% ash, and 12.9% moisture.

Flour C, used in angel food cakes, was a commercial soft-wheat cake flour from Mennel Milling Company, Fostoria, OH, with 8.8% protein, 0.37% ash, 9.0% moisture, and a pH of 4.8. Flour D, used in muffins and soft cookies, was a commercial pastry flour from Pillsbury Company, Minneapolis, MN, and had 8.1% protein, 0.44% ash, and 11.6% moisture. The shortening used in pup loaves was Crisco from Procter and Gamble Company, Cincinnati, OH; nonfat dry milk was Bread-Lac from Galloway-West Co., Fond du Lac, WI; and yeast was compressed fresh yeast from Busch Industrial Products Corp., St. Louis, MO.

Dried egg whites used in angel food cakes were the spray-dried type P-20 (protein 80%, moisture 8%, pH 7) from Henningsen Foods, Inc., Omaha, NE; and leavening acid was monocalcium phosphate monohydrate from Monsanto Company, St. Louis, MO.

The high-fructose corn syrup used in soft cookies was CornSweet 42 (42% fructose) from Archer Daniels Midland Company, Cedar Rapids, IA. The baking powder used in muffins was Calumet double-acting baking powder from General Foods Corp., White Plains, NY.

### Wet Processing to Separate Flour into Two Fractions

Starch and gluten were gently separated using the procedure of Shogren et al (1969). Flours A and B were fractionated using identical conditions. Flour A or B (20 g, 14% m.b.) and water (5° C, 45 ml) were stirred gently with a glass rod for 5 min to form a smooth slurry. The water to flour ratio was 2.25 (w/w), and the mixture had a pH of 5.8, which was the native flour pH. The slurry was centrifuged for 20 min at 1,000 × *g*, and the supernatant and sediment were removed from the centrifuge bottle and combined. After gentle massaging by hand for 15 min, a coherent, soft, gluten mass separated from the starch slurry. The starch slurry was decanted and allowed to stand 12 hr at 5° C, after which a portion (15 ml) of the supernatant aqueous phase was drawn off and added to the protein-rich fraction. The protein-rich fraction (31.5 g for flour A and 36.1 g for flour B) was stored in the freezer (−5° C) overnight after separation and thawed before test baking. The starch fraction (30.2 g and 25.4 g) was stored in the refrigerator (5° C) overnight. The two fractions were stored for experimental convenience.

**TABLE I**
**Formula for Pup Loaves Using Wet Protein-Rich Fraction from 20 g of Wet-Processed Flour[a]**

| | Control (g) | | Test Loaf (g) | |
|---|---|---|---|---|
| Ingredients | Flour A | Flour B | Flour A | Flour B |
| Flour (14% m.b.) | 100.0 | 100.0 | 93.6[b] | 90.6[c] |
| Water | 59.0 | 63.0 | 35.0 | 38.0 |
| Yeast (compressed) | 2.0 | 2.0 | 2.0 | 2.0 |
| Shortening | 3.0 | 3.0 | 3.0 | 3.0 |
| Nonfat dry milk | 4.0 | 4.0 | 4.0 | 4.0 |
| Sodium chloride | 1.5 | 1.5 | 1.5 | 1.5 |
| Malt (240° L) | 0.15 | …[d] | 0.15 | …[d] |
| Potassium bromate | 0.002 | 0.002 | 0.002 | 0.002 |
| Protein-rich fraction | | | | |
| Solids (14% m.b.) | … | … | 6.4 | 9.4 |
| Water | … | … | 25.0 | 27.0 |

[a] Doughs were mixed to optimum, fermented 180 min at 30° C with 55 min proofing, and baked at 218° C for 24 min.
[b] Sum of flour A (93.6 g) plus protein-rich fraction (6.4 g) from flour A equal to 100 g (14% m.b.) of flour in formula.
[c] Sum of flour B (90.6 g) plus protein-rich fraction (9.4 g) from flour B equal to 100 g (14% m.b.) of flour in formula.
[d] Malt was included in flour B.

**TABLE II**
**Formula for Angel Food Cakes Using Wet Starch Fraction from 40 g of Wet-Processed Flour A**

| Ingredients | Control (g) | Test Cake (g) |
|---|---|---|
| Cake flour (14% m.b.) | 110.0 | 84.0 |
| Sugar | 314.0 | 314.0 |
| Dried egg whites | 40.0 | 40.0 |
| Monocalcium phosphate monohydrate | 1.5 | 1.5 |
| Sodium chloride | 3.0 | 3.0 |
| Water | 295.0 | 260.6 |
| Wet starch fraction[a] | | |
| Solids (14% m.b.) | … | 26.0 |
| Water | … | 34.4 |

[a] Wet starch fraction from 40 g of wet-processed flour A.

### Test Baking with Pup Loaves

Pup loaves (six replicates) were baked using the straight-dough method optimized for water and oxidant (Finney and Barmore 1945a,b; Finney 1984). Table I gives the formula for the pup loaves. In the test loaves, the wet, protein-rich fraction from 20 g of flour A or B (31.5 g or 36.1 g) was added to the mixer bowl with the other ingredients. Doughs were mixed to optimum consistency, fermented 180 min at 30° C and 90% relative humidity, and punched twice during fermentation at 105 min and 155 min. The doughs were molded on a drum molder at 180 min and panned. After proofing for 55 min at 30° C and 90% rh, proof height was recorded and bread baked 24 min at 218° C (425° F). Loaf weight was taken immediately after baking, and loaf volume was determined by rapeseed displacement. The loaf grain was scored after cooling 1 hr. Loaf volumes were reproduced to ±10 $cm^3$.

### Angel Food Cakes Containing Wet Starch Fraction

Angel food cakes were baked in triplicate using the formula given in Table II. AACC method 10-15 (1976) was followed, except that in the test cakes the wet starch from 40 g of flour A was added at the last folding in stage. Cakes were baked 35 min at 190° C (375° F). After baking, the pans were inverted, cooled for 40 min, and the cakes depanned. Cake heights ($h_d$) were measured immediately after depanning and again ($h_c$) after cooling 3–4 hr. Cake diameters also were measured after cooling. The internal characteristics of cake were scored, and the cake volume was calculated using the equation for a truncated, hollow cone.

The firmness of cake crumb was measured in triplicate on 25-mm cubes cut from the midsection of a cake after storing 12, 36, and 60 hr at room temperature. A Voland-Stevens-LFRA texture analyzer (Voland Corp., Hawthorne, NY), fitted with a 5-kg load cell and a cylindrical probe (25 × 35 mm), was used to measure crumb firmness at a probe speed of 2.0 mm/sec and a compression distance of 4.0 mm.

### Muffins and Soft Cookies

The wet starch was added to a cake-type muffin formula (Table III) and a soft-cookie formula (Table IV) to replace 26% of pastry flour. After creaming and mixing, batter (40 g per muffin) was scaled into aluminum muffin pans fitted with paper liners. Muffins were baked at 193° C (380° F) for 22 min and cooled for 1 hr. Muffin volume was determined by rapeseed displacement, and the firmness of muffin crumb was measured in the same manner as for angel food cakes.

To bake soft cookies, AACC method 10-50D (1975) was followed, but the formula was modified. Cookie dough was mixed, sheeted to 7-mm thickness, and cut with a circular (60-mm diameter) cookie cutter. Cookies were baked on an aluminum sheet at 205° C (400° F) for 10 min. After cooling for 30 min, cookie width and thickness were measured to the nearest millimeter using a ruler fitted with calipers. The breaking force of cookies was determined on an Instron universal testing instrument (model 1132, Instron Corp., Canton, MA) in the compression mode using a 50-kg load compression cell. The Instron was set to give a full-scale deflection of 5 kg, a crosshead speed of 2.5 cm/min, and a chart speed of 25 cm/min. A Plexiglas blade with a rectangular contact area of 1 × 50 mm was used to break a cookie that bridged two supports separated by 5 cm. The average peak height of three measurements was taken as the "breaking force".

## RESULTS AND DISCUSSION

### Fractionation of Bread Flour

Two hard wheat flours were wet processed in this work. Flour B (12.2% protein) was a good quality bread flour; it was examined to determine whether the wet-processing technique could improve the volume of bread made from a relatively high-protein flour. After processing, the high-protein flour could be used in specialty breads. Flour A, which was also a good-quality bread flour except for its low protein content (9.3% protein), was subjected to the Wallace process to test the suitability of the new flour to produce white pan bread.

To ensure the most gentle treatment of flour components, starch was separated from bread flour using the hand-washing procedure of Shogren et al (1969). Lu et al (1983) reported that the least damage to gluten was achieved by hand washing. Starting from 20 g of flour A (9.3% protein on 14% m.b.) and 45 ml of water, a starch fraction and a protein-rich fraction were obtained according to the scheme shown in Figure 1. The starch fraction contained 19.0 g of water and 11.2 g of dry solids of which 2.8% (d.b.) was protein. Thus, the yield of starch was about 60% of the flour weight versus a theoretical yield of 70%. The protein-rich fraction from 20 g of flour A contained 26.0 g water and 5.5 g dry solids of which 28.1% (d.b.) was protein. When 20 g of flour B (12.2% protein on 14% m.b.) was wet-processed using 45 ml of water, the starch fraction contained 16.7 g water and 8.7 g dry solids (2.7% protein, d.b.), and the protein-rich fraction, 28.0 g water and 8.1 g dry solids (27.2% protein, d.b.). During wet processing, about 2.5% (0.5 g) of total dry solids and 6% (2.9 g) of water were lost.

Flours A and B behaved differently during wet processing. The gluten ball of flour B was more cohesive and stronger, and the separation was easier than for flour A. In addition, flour B produced more gluten than flour A because of its higher protein content. The baking results presented later in this paper show that it is not necessary to highly purify the starch fraction when the wet starch is directly incorporated into cakes, muffins, or cookies. However, adding small amounts of sodium chloride (0.5% of flour weight) to the flour-water mixture improved the separation of gluten from starch.

The optimum absorption of flour for breadmaking and the water in the wet, protein-rich fraction dictate the amount of flour that can be wet processed for breadmaking. If instant dry yeast were used instead of compressed yeast, and dry sucrose and salt added, up to 45 g of flour A theoretically could be wet processed for breadmaking.

Because the Wallace process is a closed system with no effluent streams, only small amounts of water are used. If the process is to be used on a commercial scale, the gentle mixing of the flour-water

**TABLE III**
**Formula for Muffin Using Wet Starch Fraction from 40 g of Wet-Processed Flour A**

| Ingredients | Control (g) | Test Muffin (g) | Procedure |
|---|---|---|---|
| Honey | 47 | 47 | Cream together |
| Brown sugar | 33 | 33 | at low speed |
| Salad oil (Crisco) | 20 | 20 | for 6 min. |
| Unsalted butter | 20 | 20 | |
| Sodium chloride | 2.5 | 2.5 | |
| Whole eggs | 82 | 82 | Mix in slowly |
| Vanilla | 2 | 2 | at low speed. |
| Pastry flour | 100 | 74 | Blend dry ingredients |
| Baking powder | | | together, add to |
| (double acting) | 7.0 | 7.0 | creamed mixture, |
| Nonfat dry milk | 6.6 | 6.6 | and mix at low speed |
| Cinnamon | 0.3 | 0.3 | for 3 min to make a |
| Wet starch fraction | | | smooth mixture. |
| Solids (14% m.b.) | ··· | 26 | |
| Water | ··· | 34 | |
| Water | 41 | 7 | Blend in at low speed for 3 min, scale individual muffins 40 g each, bake muffins at 380° F for 22 min. |

**TABLE IV**
**Formula for Soft Cookie Using Wet Starch Fraction from 40 g of Wet-Processed Flour A**

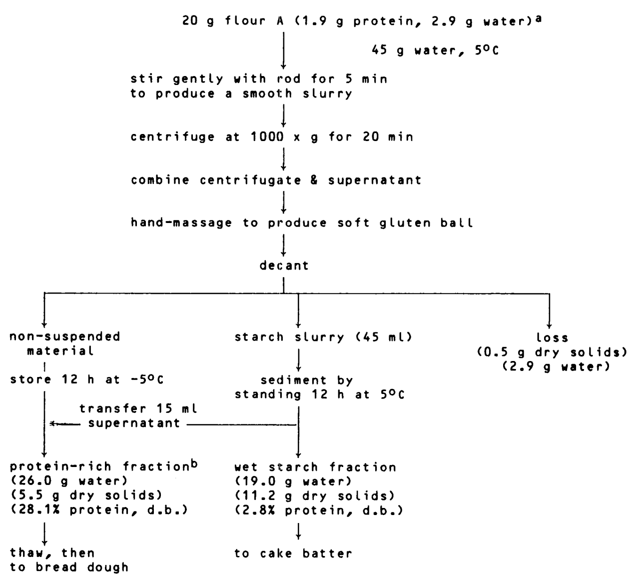
| Ingredients | Control (%) | Test Cookie (%) |
|---|---|---|
| Pastry flour | 100 | 74 |
| Sucrose | 40 | 40 |
| HFCS (42% fructose) | 35 | 35 |
| Shortening | 35 | 35 |
| Whole eggs | 16 | 16 |
| Nonfat dry milk | 3 | 3 |
| Sodium chloride | 2 | 2 |
| Sodium bicarbonate | 1 | 1 |
| Water | 12.5 | ··· |
| Wet starch fraction | | |
| Solids (14% m.b.) | ··· | 26 |
| Water | ··· | 12.5[a] |

[a]The starch fraction separated from 40 g of flour A contained 26 g of solids and 34 g of water. Some of the water (22 g) in the starch fraction was discarded. The 22 g discarded represented 24% of the initial water added to wet process the flour.

**TABLE V**
**Pup Loaves Containing Wet Protein-Rich Fraction from Wet-Processing of 20 g Bread Flour**

| Loaf ($n = 6$) | Absorption (ml) | Flour Protein, % (14% m.b.) | Loaf Wt (g) | Volume ($cm^3$) | Bread Grain |
|---|---|---|---|---|---|
| Control loaf, flour A | 59 | 9.3 | 142.3 ± 0.5 | 756 ± 8 | S[a] |
| Test loaf, A | 60 | 10.2 | 143.1 ± 0.5 | 810 ± 8 | S |
| Control loaf, flour B | 63 | 12.2 | 143.9 ± 0.5 | 878 ± 10 | S |
| Test loaf, B | 65 | 13.2 | 145.5 ± 0.5 | 935 ± 10 | S |

[a]S = Satisfactory.




[a]Flour weight adjusted to 14% m.b. Water given includes moisture in flour. Flour B (20 g) contained initially 2.5 g protein and 2.6 g water.

[b]For flour B, the protein-rich fraction contained 28.0 g water, 8.1 g dry solids with 27.2% protein on dry basis; the wet starch fraction contained 16.7 g water, 8.7 g dry solids with 2.7% protein, d.b.

**Fig. 1.** Scheme for wet processing flours A and B.

**TABLE VI**
**Characteristics of Angel Food Cake Containing Wet Starch Fraction from 40 g of Wet-Processed Flour A**

| Cake[a] | Depanned Cake Height, $h_d$ (cm) | Cooled Cake Height, $h_c$ (cm) | Volume ($cm^3$) | Grain | Compression Force[b] (g) | | |
|---|---|---|---|---|---|---|---|
| | | | | | 12 hr | 36 hr | 60 hr |
| Control | 8.5 ± 0.1 | 8.1 ± 0.1 | 2930 ± 40 | Medium | 56 ± 4 | 65 ± 4 | 73 ± 4 |
| Test cake | 8.9 ± 0.1 | 8.5 ± 0.1 | 3090 ± 40 | Fine | 45 ± 4 | 54 ± 4 | 64 ± 4 |

[a]Triplicate cakes. Test cake contains wet starch from flour A to replace 24% of cake flour (14% m.b.).
[b]Compression force was the average of three replicate readings. Cakes were stored at 20°C after baking for 12, 36, and 60 hr before measuring. $LSD_{.05} = 9.07$ for compression force.

slurry might be done with a ribbon blender as in the Martin process (Knight 1984), or a Morton continuous starch-gluten extractor (Morton 1965, Anderson 1974). To prevent microbial problems, the wet gluten and starch would have to be used soon after separation.

### Pup Loaves

The straight-dough breadmaking method described by Finney (1984) was used to verify the beneficial effects of increased gluten in dough prepared by the Wallace process. To compensate for the starch fraction removed from 20 g of bread flour and the solids lost during hand washing, 13.6 g of flour A and 10.6 g of flour B were added to the bread formula (Table I) along with the 80 g of remaining flour. Table V gives the results of the test baking of bread.

Finney (1979) derived a family of regression lines that correlates loaf volume to flour protein in HRW wheats of varying protein quality. The regression lines were derived from HRW wheats grown in the early or mid-1970s. In this work, regression lines were used to predict the increases in loaf volume expected in the breads made by the Wallace process. The regression lines to be used in the prediction for flour A were located from its protein content and the volume of its control loaf. Then, increasing the flour protein on the regression line for flour A by one percentage point indicated that the volume of bread should increase by 70 $cm^3$. In a similar manner, the theoretical increase for flour B was found to be 65 $cm^3$.

Wet processing 20 g of flour increased the protein content of the flour in the breads from 9.3% to 10.2% for flour A and from 12.2% to 13.2% for flour B (both 14% m.b.). At the same time, the volume of the loaves increased 54 $cm^3$ and 57 $cm^3$, respectively, compared to control loaves. The increase in loaf volume observed was approximately 86% of the potential increase expected for flour A, and 88% that for flour B. The color, symmetry, grain, texture, and flavor of test loaves were comparable to those of control loaves. It is worth noting that the doughs containing the protein-rich fractions from the wet-processed flours felt much stronger than control doughs, indicating that the increased amounts of gluten in the test doughs improved dough handling properties.

### Angel Food Cakes

We made angel food cakes to determine whether the wet starch fraction could be incorporated directly into the mixer. In foam-type cakes, a low-protein flour is desirable, and wheat starch is often added to dilute flour protein. Dubois (1959) showed that wheat starch may be used advantageously in angel food cakes and other foam-type cakes. He found that substituting wheat starch for as much as 30% of cake flour in an angel food cake formula increased volume; improved grain, texture, and eating properties; and contributed to extended shelf life.

In this work, approximately 24% of cake flour (14% m.b.) was replaced with the wet starch fraction (14% m.b.), and the formula water adjusted appropriately. Because dried egg whites were used in the cake formula, the water in the wet starch posed no problem in balancing the cake formula. When the wet starch was added to the foamed cake batter, little loss of foam was observed.

With 24% starch replacement of cake flour, the cake volume increased 160 $cm^3$ (5% of the total volume) and the crumb grain was finer than that of the control cake (Table VI). Crumb tenderness, as measured by the Voland texture analyzer, was significantly improved at the 5% confidence level. Replacing 24% of cake flour with pure, dry, wheat starch gave the same results as using the wet-starch fraction. An untrained taste panel found that the cakes with added starch seemed to have a softer texture than a control (data not given). These results agree with those of Dubois (1959).

When the wet starch replaced 26% of pastry flour (14% m.b.) and some of the water in the muffin formula, muffin volume was 114 $cm^3$ for test muffins and 110 $cm^3$ for the control. No significant improving effects on muffin appearance and texture were observed, but neither were detrimental effects.

To test the starch in soft cookies, 40 g of flour A was fractionated to give a wet-starch fraction containing 22.4 g dry solids and 38 ml water. After the starch sedimented, part of the aqueous supernatant (22 ml) in the starch fraction was discarded to prevent excess water in the cookie formula. This 22 ml represented approximately 24% of the initial water added to the flour.

Replacement of 26% of the flour (14% m.b.) in the soft cookie with wet starch failed to cause any effect on cookie softness, probably because the high levels of high-fructose corn syrup, sugar, and shortening in the formula were more important to cookie characteristics. Cookie width was 84.0 mm and 83.0 mm, cookie thickness 8.0 mm and 8.5 mm, and width/thickness ratio 10.5 and 9.8, respectively, for the test cookies and the control.

The wet-processing of wheat flour to remove starch and increase flour protein may be economical when high-protein bread flour is not readily available. The process would require added equipment, floor space, and instrumentation.

## CONCLUSIONS

Up to 20% of a low-protein, hard wheat flour in a pup loaf formula was wet processed to give two streams, a wet protein-rich fraction and a wet starch fraction.

The protein-rich fraction from 20 g of bread flour was combined with 91–94 g of unfractionated flour to give a mixture wherein the flour contained about 1% more protein (14% m.b.) than the native flour. The increased protein in the flour increased bread volume by 86–88% of the theoretically possible increase.

The wet-starch fraction was added to angel food cakes to replace one-fourth of the cake flour (14% m.b.). Cake volume increased 5% and crumb tenderness also improved. Replacement of one-fourth of formula flour in muffins and soft cookies was not detrimental to appearance and texture.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## LITERATURE CITED


AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1976. Approved Methods of the AACC. Methods 02-52 and 08-01, approved April 1961; Methods 10-15 and 46-11, approved October 1976; Method 10-50D, approved February 1975; and Method 44-15A, approved

October 1975. The Association: St. Paul, MN.
ANDERSON, R. A. 1974. Wet-processing of wheat flour. Page 355 in: Wheat: Production and Utilization. G. E. Inglett, ed. Avi Publishing Co., Inc., Westport, CT.
DUBOIS, D. K. 1959. Wheat starch: a key to better cakes. Bakers Dig. 33(6):38.
FINNEY, K. F. 1979. Wheat proteins: what they do. Page 50 in: Wheat Protein Conference, Oct. 16-17, 1978, Manhattan, KS. Agricultural Research Service (North Central Region), S.E.A., U.S.D.A.: Peoria, IL.
FINNEY, K. F. 1984. An optimized, straight-dough, bread-making method after 44 years. Cereal Chem. 61:20.
FINNEY, K. F., and BARMORE, M. A. 1945a. Varietal responses to certain baking ingredients essential in evaluating the protein quality of hard winter wheats. Cereal Chem. 22:225.
FINNEY, K. F., and BARMORE, M. A. 1945b. Optimum vs. fixed mixing time at various potassium bromate levels in experimental bread baking. Cereal Chem. 22:244.
FINNEY, K. F., and BARMORE, M. A. 1948. Loaf volume and protein content of hard winter and spring wheats. Cereal Chem. 25:291.
KNIGHT, J. W., and OLSON, R. M. 1984. Wheat starch: production, modification, and uses. Page 491 in: Starch: Chemistry and Technology, 2nd ed. R. L. Whistler, J. N. BeMiller, and E. F. Paschall, eds. Academic Press, Inc.: Orlando, FL.
LU, P. W., SEIB, P. A., HOSENEY, R. C., LIANG, Y. T., and DREESE, P. 1983. Breadmaking integrated with wet-processing of wheat flour. Bakers Dig. 57(2):10.
MORTON, F. 1965. Yields high-quality gluten. Food Eng. 37(12):83.
POMERANZ, Y. 1978. Composition and functionality of wheat-flour components. Page 585 in: Wheat: Chemistry and Technology. Y. Pomeranz, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.
PONTE, J. G., Jr. 1978. Bread. Page 675 in: Wheat: Chemistry and Technology. Y. Pomeranz, ed. Am. Assoc. Cereal Chem., St. Paul, MN.
PYLER, E. J. 1983a. Flour proteins: role in baking performance. I. Bakers Dig. 57(3):24.
PYLER, E. J. 1983b. Flour proteins: role in baking performance. II. Bakers Dig. 57(5):44.
SHOGREN, M. D., FINNEY, K. F., and HOSENEY, R. C. 1969. Functional (breadmaking) and biochemical properties of wheat flour components. I. Solubilizing gluten and flour protein. Cereal Chem. 46:93.
WALLACE, L. C. 1981. Process for baking bread. U.S. patent 4,248,896. Patented February 3.

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