Pie Crust Quality: Influence of Use of Fractionated and Reconstituted Soft Wheat Flour of Varied Protein Content[1]

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ABSTRACT

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Four soft wheat cultivars of varied protein were used to evaluate the effect of protein on pastry quality. To further determine the effect of protein quality on pastry quality, these flours were fractionated into gluten and starch + water solubles. The gluten was subsequently fractionated by pH to vary the glutenin-to-gliadin ratios. Flours were reconstituted to their original protein from whole crude gluten, single gluten fractions, and all gluten fractions in their original proportions. Fractionation patterns among flours from various wheat cultivars differed significantly. Full restoration of original flour properties upon flour reconstitution was not achieved, indicating flour fractionation techniques adversely affected functionality. Among the flours of single pH fraction, flakiness, crust shrinkage, and surface blistering increased as pH of the flour fraction increased, whereas crust surface browning decreased. The flour cultivar significantly affected pastry quality, with protein quantity of the wheat flour cultivar being a determining factor.

Although soft white and soft red winter wheat constitute less than one-fourth of the total U.S. wheat production, soft wheat is utilized in a wide range of commercial products. Cakes, cookies, crackers, doughnuts, pie pastry, and pretzels are some of these. In contrast, hard wheat is used in one major industry—breadmaking, still the largest flour consumer. Thus, early chemical and functional studies were focused on the hard wheats suitable for bread production. Due to changing economy and lifestyle, a significant increase in the use of soft wheat flour has resulted. A higher average standard of living, plus an increased demand for convenience foods, has led to a larger consumption of soft wheat products such as cake mixes, pastry mixes, and ready-to-eat cookies and crackers.

Soft wheat is suited for air-, steam- and chemically leavened products where no fermentation is required for ripening and mellowing of the gluten. The gluten of soft wheat is characteristically weak and produces a light and tender product. Although the functionality of soft wheat in cookies and cakes has been studied using fractionation techniques, limited research has been directed to functionality of flour in pie pastry.

Soft wheat flours to be used for pie pastry should contain in general 8.0–9.8% protein, 0.38–0.44% ash, and have a pH value of 6 (Tsourides 1968). Because flour pigments contribute to a desirable crust color, flours should be unbleached; gluten is also adversely affected by bleaching.

A pie crust should exhibit a small amount of blistering indicative of some strength in the gluten (Kress 1932). The pie crust from a good quality flour will remain dry, tender and flaky; conversely, gummy and soft pie crusts result from poor quality flours (Kress 1936).

Gluten formation in pastry dough was observed by microscopic appearance (Hirahara and Simpson 1961). In all dough types, oval formations of gluten were found surrounding starch granules. Gluten strands in standard doughs had cloudy edges with small fingerlike structures attached. Excess dough manipulation formed definitive gluten strands, with a loss of cloudiness present in standard dough. Dough containing excess water formed a large amount of gluten. Mean breaking strengths were significantly higher for doughs with either excess water or excess manipulation.

Denton et al (1933) observed increased breaking strength of pastry as flour protein content increased; a low-fat formula better distinguished differences among flours. Miller and Trimbo (1970) confirmed that protein content is related inversely to tenderness and observed that increased water in the dough formula attenuates this relationship.

The purpose of this study was to fractionate and reconstitute four soft wheat flours of different protein levels to determine the effect of both gluten quantity and quality on textural characteristics of pastry. Each flour was separated into a starch and water-solubles fraction, and gluten. The gluten was further fractionated by pH, such that subfractions varying in glutenin-gliadin ratios were produced. Flours were reconstituted from the gluten

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subfractions and starch and water-solubles fraction. Pie pastry baked from these flours was evaluated for textural properties.

MATERIALS AND METHODS

Wheat Sample

The four soft wheat cultivars tested were Augusta, Frankenmuth, and Tecumseh, all white wheats, and Hillsdale, a red wheat. All were grown in Michigan State University experimental plots and received 90 lb/acre of nitrogen top dressing. Wheats were milled at the USDA Soft Wheat Quality Laboratory, Wooster, OH, on a Miag Multomat mill with extraction rates of 72.7, 72.5, 72.8, and 75.5% straight-grade flour for Augusta, Hillsdale, Frankenmuth, and Tecumseh, respectively.

Flour Fractionation

Gluten was first separated from a flour-water dough by hand washing (Dill and Alsberg 1924) and subsequently fractionated by pH. Gluten was allowed to relax overnight under refrigeration, then frozen and freeze-dried. A Stokes model 2003F2 freeze dryer (F. J. Stokes Co., Philadelphia, PA) was used for all freeze-drying. All freeze-dried starch + water-solubles and gluten were stored at −10°C. Approximately 5,100 g of each flour was separated.

Starch + water-solubles material and gluten were ground in a Udy cyclone sample mill (model 3010-030, Udy Co., Fort Collins, CO) equipped with a 40-mesh screen (470-μm openings).

Glutens were fractionated using a slight modification of the method of Shogren et al (1969). Ground gluten was divided into five batches for fractionation. Between 95 and 135 g (depending on flour type) was wetted with distilled water and scissored into 2,856 ml of 0.005N lactic acid and stirred for approximately 5 hr to dissolve the gluten.

The gluten was adjusted to pH 4.7 with 0.1N Na_2CO_3, and then centrifuged for 20 min at 1,000 × g using an IEC 8-20A refrigerated centrifuge operating at 0°C. The supernatant, material soluble at pH 4.7, was decanted and adjusted to pH 5.6 with 0.1N Na_2CO_3 and centrifuged for 20 min at 1,000 × g. The pH 5.6-soluble supernatant was adjusted to pH 5.8 with 0.1N Na_2CO_3, and then centrifuged for 20 min at 1,000 × g. The pH 5.8-soluble supernatant was adjusted to pH 6.1 with 0.1N Na_2CO_3 and allowed to settle because preliminary studies had not produced significant amounts of material insoluble at pH 6.1. The remaining supernatant was used as the fraction soluble at pH 6.1.

Fractions were subsequently frozen in thin layers and freeze-dried. Weights of unground fractions were taken in order to calculate recoveries. Percentage of each fraction recovered was calculated and corrected to a dry-weight basis following moisture determinations. Gluten fractions also were ground in the Udy Cyclone sample mill and recoveries calculated.

According to the method of Shogren et al (1969), gluten fractions were reconstituted singly with the starch-water solubles fraction, and flours were additionally reconstituted having all fractions in their original proportions. All flours were reconstituted to their original protein. Moisture of the reblended flours was readjusted to 10.1 to 12.8%, characteristic of that of the original flours.

Chemical Analyses

Protein and moisture contents of the whole flours and reconstituted blends were determined in duplicate using AACC procedures 46-13 and 44-40, respectively (AACC 1983).

Pastry Preparation

Test bakes for pastry were completely randomized. A lean, low-fat formula was used to place maximum stress on the flour (Matthews and Dawson 1963). The formula consisted of 100 parts whole flour or reconstituted blends, 41 parts shortening (Hyscor all-purpose vegetable shortening, P.V.U. Foods, Inc., St. Louis, MO), and 25.8 parts of a stock salt solution made up of 24 parts water and 1.8 parts salt. The flour samples used included the parent (original) flour plus six reconstituted flours for flour milled from each wheat cultivar. The six reconstituted flours included whole crude gluten, all fractions reconstituted in their original proportions (AFR), material insoluble at pH 4.7, material insoluble at pH 5.6, material insoluble at pH 5.8/6.1, and material soluble at pH 6.1; all reconstituted flours contained the starch + water-solubles fraction. Three bakes were made for each flour variable.

Pastry was mixed according to the procedure of Miller and Trimbo (1970). Doughs were placed in plastic zip-lock bags and allowed to rest at 4°C for 21 to 24 hr. Doughs were conditioned to 12.5°C and rolled to 3 mm. Doughs were cut into square wafers (about 5 cm × 5 cm). Using a specially designed tool, each wafer was pricked with nine equally spaced holes made by 1-mm probes arranged in a 3 × 3 grid. Wafers were baked on stainless steel cookie sheets (3-mm thick) in a four-tray rotary oven (Rotary Hearth Test Baking Ovens, National Manufacturing Co., Lincoln, NE) at 232 ± 1°C for 13 min. After removal from the oven, cookie sheets were placed on wire cooling racks.

Crust shrinkage was determined from the difference in area of four wafers before and after baking. The height of a stack of four wafers was used as an index of flakiness. Observations of surface blistering, as a measure of gluten strength, were made subjectively. A scale of 1.0–5.0 in increments of 0.5 was used.

Breaking strength was measured using a Texturepress system (model T-2100-C) equipped with a model FTA-100 force transducer and a model CA-I single-blade shear cell (Food Technology Corp., Rockville, MD). Before shearing, wafers were measured for width and thickness of area to be sheared. Samples were tested between 55–70 min after removal from the oven. Four wafers were broken for each test. Breaking strength is reported as the pounds of force per square centimeter broken.

Differences in surface browning reaction were measured using a Hunterlab model D25-2 Color Difference Meter (Hunter Associates Laboratory, Inc., Reston, VA). The instrument was standardized with a yellow tile (Standard no. C2-15327) with assigned values of $L = 78.5$, $a = -3.2$, and $b = +23.4$. Three readings were taken for each determination by rotating the glass container one third.

Statistical Analyses of the Data

Using Mstat (Michigan State University 1982), a two-factor factorial analysis of variance was performed to determine if any significant differences existed in the main effects of flour source and type of reconstituted flour, for the mean values of flakiness, crust shrinkage, surface blistering, breaking strength, and surface browning (L, a, and b). Values for both crust shrinkage and redness (a) were coded +5.0 to eliminate negative values during analysis of variance. Reported means are decoded. Significant interactions between main effects for these dependent variables were also determined. When significant differences were found among flour means from the different wheat cultivars, or means for type of reconstituted flour, Duncan's multiple range test of the ranking subprogram of Mstat was used to compare and rank them. When a significant interaction between main effects was found, a least significant difference (LSD) value was determined, also using Mstat.

Correlations among individual dependent variables and flour protein content were also determined with Mstat.

RESULTS AND DISCUSSION

Flour and Fraction Composition

The moisture and protein contents of the parent flours are shown in Table I. Moisture of the parent flours varied by less than 0.5%. Protein ranged from 8.0 to 10.8%.

The normal ranges of protein and moisture contents for pastry flours are 8.0–8.5% and 13.0–13.5%, respectively (Preonas et al 1967, Pyler 1973). Matz (1972) recommended a lower range for protein of 7.0–8.5%. An extended range of 8.0–9.8% protein and 12.0–14.0% moisture was stated by Tsourides (1968) as being ideal for pie baking.

The gluten fractions, obtained by solubilizing gluten in dilute lactic acid and adjusting to various pH levels, differed in their

distribution and protein contents (Table I). Weight distributions and protein content also differed among the flours milled from the different wheat cultivars. In preliminary studies with both bread and cake flour, insignificant amounts of the insoluble gluten fraction at pH 6.1 of Shogren et al (1969) were recovered. Thus, the soluble material at pH 5.8 was not centrifuged following adjustment to pH 6.1. No insoluble material at pH 6.1 settled from Augusta gluten. Small amounts of insoluble gluten at pH 6.1 settled without centrifugation from Hillsdale and Frankenmuth suspensions. Tecumseh was, however, particularly aberrant. Large amounts of insoluble material at pH 6.1 settled.

As compared with the other varieties, Tecumseh has a complex parentage, very similar to that of Arthur soft red winter wheat. One of the crosses for Tecumseh consisted of Purkof, a semihard red winter wheat (Everson et al 1974). Since the hard winter wheats used by Shogren et al (1969) similarly contained appreciable amounts of material insoluble at pH 6.1, possibly the inclusion of a semihard variety in the pedigree of Tecumseh influences the type of protein, as characterized by isoelectric precipitation.

The material insoluble at pH 6.1, obtained from settling, was combined with the gluten insoluble at pH 5.8 from the corresponding flour. Thus, this fraction is referred to as insoluble gluten at pH 5.8/6.1. Only the gluten designated as insoluble at pH 5.8/6.1 from the Augusta wheat cultivar is primarily material insoluble at pH 5.8.

Although Hillsdale had protein content similar to Augusta, its fractionation pattern resembled those of the higher protein flours (Table I). As protein increased from that of Hillsdale to Tecumseh, the percentage of insoluble material at pH 4.7 obtained increased from 38.8 to 48.1%. The percentages of other fractions decreased as content of flour protein increased; the insoluble material at pH 5.6 decreased by more than half, from 5.9 to 2.1%. The protein contents of the various fractions also are shown in Table I. As the pH of the gluten fraction increased, protein similarly increased.

The part of total gluten protein contributed by each gluten fraction is given in Table II. Gluten protein recoveries and losses are also provided. Gluten protein contributed by material insoluble at pH 4.7 again increased with flour protein among the Hillsdale, Frankenmuth, and Tecumseh flours. Again, the gluten protein contributed by the other fractions decreased as the protein of these flours increased.

TABLE I
Percentage by Weight and Protein Content of Gluten Fractions Separated from Four Wheat Cultivars by pH

Parent/ Gluten Fraction	Cultivar			
	Augusta	Hillsdale	Frankenmuth	Tecumseh
Parent flour				
% Moisture[a]	11.1	10.8	10.9	11.2
% Protein[a,b]	8.0	8.1	9.0	10.8
Percentage by weight[c] of gluten fractions				
pH 4.7-Insoluble	61.0	38.8	45.2	48.1
pH 5.6-Insoluble	2.2	5.9	3.7	2.1
pH 5.8/6.1-Insoluble	6.1	16.7	14.4	14.3
pH 6.1-Soluble	30.7	38.6	36.7	35.5
Protein content (%)[a,b] of gluten fractions				
pH 4.7-Insoluble	36.4	21.0	31.1	34.4
pH 5.6-Insoluble	67.0	66.3	68.4	69.3
pH 5.8/6.1-Insoluble	76.0	74.8	76.8	78.2
pH 6.1-Soluble	79.7	77.0	78.5	79.9

[a] $n = 2$.
[b] N × 5.7; expressed on a dry weight basis.
[c] Expressed on a dry weight basis.

TABLE II
Percentage of Total Gluten Protein Contributed by Each Gluten Fraction, Obtained by Precipitating at Various pH Levels[a]

Gluten Fraction	Percentage of Total Gluten Protein (%)			
	Augusta	Hillsdale	Frankenmuth	Tecumseh
pH 4.7-Insoluble	39.9	14.5	23.8	27.2
pH 5.6-Insoluble	2.7	7.0	4.3	2.4
pH 5.8/6.1-Insoluble	8.3	22.2	18.8	18.3
pH 6.1-Soluble	44.0	52.9	48.7	46.5
Total recovery	94.9	96.6	95.6	94.4
Gluten protein loss	5.1	3.4	4.4	5.6

[a] Expressed on a dry basis.

Baking Test for Pastry

Flakiness means for each reconstitution type are provided in Table III. Pastry wafers from the parent flours were significantly more flaky than all others, except those from reconstituted flours from pH 6.1-soluble material. Wafers baked from reconstituted flours from pH 5.6-insoluble material were significantly less flaky than all other types, except those from reconstituted flours from pH 4.7-insoluble material. Among the single-fraction reconstituted flours, flakiness increased generally with pH. Thus, it appears that flakiness of pastry increases with a probable increase in gliadin-to-glutenin ratio. This is in agreement with Shogren et al (1969), who observed higher loaf volume in bread baked from more alkaline flours.

Flakiness means for parent flours milled from each of the four wheat cultivars also are given in Table III. Pastry wafers baked from Tecumseh flour were significantly more flaky than those from the other flours. No differences were seen among the other flours.

Crust shrinkage of pastry wafers progressively increased as the pH of the fraction increased among the flours of the single-fraction reconstitutions (Table III). Consistent with flakiness results, this also seems to indicate that less gluten strength or development was present in the fractions insoluble at lower pH, which contain probable higher glutenin. These results suggest that a higher gliadin ratio in flour could contribute to greater crust shrinkage in pastry.

Crust shrinkage means for parent flours milled from each of the four wheat cultivars also are shown in Table III. Pastry wafers baked from Frankenmuth flours exhibited significantly less shrinkage than that of Tecumseh flours. Augusta and Hillsdale flours were not significantly different from those of the other varieties. As crust shrinkage increased, the pastry strip height increased.

TABLE III
Flakiness, Crust Shrinkage, Surface Blistering Score, and Breaking Strength Means for Flours Milled from Various Wheat Cultivars as Well as Reconstitution Types

Flour	Height of a Stack of Four Wafers (cm)	Crust Shrinkage (%)	Surface Blistering Score[a]	Breaking Strength (lb force/ cm^2 broken)
Parent flours[b,c]				
Tecumseh	3.4 a	14.3 a	2.0 a	1.1 a
Frankenmuth	2.9 b	9.2 b	2.0 a	1.8 a
Hillsdale	2.9 b	10.3 ab	2.7 a	1.3 a
Augusta	2.7 b	11.4 ab	2.0 a	1.4 a
Reconstitution type[c,d]				
Parent flours	3.0 c	11.3 c	2.2 de	1.4 a
Whole crude gluten	2.5 ef	10.0 cd	2.7 cd	1.8 cd
AFR[e]	2.7 de	7.2 e	4.4 b	2.2 bc
pH 4.7-Insoluble	2.3 fg	2.4 f	1.9 e	2.2 bc
pH 5.6-Insoluble	2.2 g	3.2 f	2.1 e	1.7 d
pH 5.8/6.1-Insoluble	2.7 de	8.4 de	3.2 c	1.7 d
pH 6.1-Soluble	2.8 cd	9.3 cde	4.5 b	2.6 b

[a] 1 = Very slight; 5 = very high.
[b] $n = 3$.
[c] Wheat cultivar and reconstitution type analyzed separately. Means followed by the same letter are not significantly different at $\alpha = 0.01$.
[d] $n = 12$.
[e] All fractions reconstituted in original proportions.

Miller and Trimbo (1970), by varying dough formulations and treatments, observed 0–35% crust shrinkage in pastry. With 10.6% flour protein and 40% vegetable shortening (based on flour weight) in the formula, a crust shrinkage of 8% was found by these workers. Miller and Trimbo (1970) noted that thickening of pastry strips accompanied crust shrinkage; this occurrence was also observed by Matthews and Dawson (1963).

Among the surface blistering score means for reconstitution type (Table III), pastry wafers from AFR flours and reconstituted flours from material soluble at pH 6.1 were significantly more blistered than all other types. Again, for the single-fraction reconstituted flours, as the pH increased, the surface blistering score similarly increased. With surface blistering as an indicator of gluten strength, these results are consistent with those for flakiness and crust shrinkage. Thus, the probable higher gliadin ratio of the higher pH gluten fractions is once more indicated as contributing more to gluten strength.

Breaking strength means for each reconstitution type also are given in Table III. Pastry baked from reconstituted flour using the pH 6.1-soluble fraction had a significantly higher breaking strength than the other types, with the exception of AFR and reconstituted flours from the pH 4.7-insoluble fraction. Although not significantly different from some other variables, the pastry baked from parent flours had the lowest breaking strength of all reconstitution types. The flours fractionated with extremes of pH, that is 4.7 and 6.1, yielded the toughest pastry wafers. The fraction insoluble at pH 4.7 contained noticeable amounts of bran particles and starch not removed during gluten washing; thus more of the fraction was required in reconstituting to the original protein of the flour. These nonprotein components may have contributed to the increased breaking strength.

TABLE IV
Color Value Means for Flours Milled from Four Wheat Cultivars and Various Reconstitution types

Flour	Color[a]		
	L	*a*	*b*
Parent flours[b,c]			
Tecumseh	69.3 a	−0.1 a	20.5 a
Frankenmuth	68.7 a	−0.4 a	20.7 a
Hillsdale	69.2 a	−0.7 a	19.7 a
Augusta	71.7 a	−1.2 a	19.7 a
Reconstitution type[c,d]			
Parent flours	69.7 b	−0.6 e	20.2 c
Whole crude gluten	60.8 d	2.8 cd	21.5 b
AFR[e]	64.1 cd	2.4 d	21.6 b
pH 4.7-Insoluble	56.9 e	3.8 c	21.0 b
pH 5.6-Insoluble	51.4 f	6.2 b	20.9 bc
pH 5.8/6.1-Insoluble	63.8 cd	2.1 d	21.7 b
pH 6.1-Soluble	65.6 c	1.9 d	21.7 b

[a] *L* (0 black, 100 white), *a* (+ red, − green), *b* (+ yellow, − blue).
[b] $n = 3$.
[c] Wheat cultivars and reconstitution types analyzed separately. Means followed by the same letter are not significantly different at $\alpha = 0.01$.
[d] $n = 12$.
[e] All fractions reconstituted in original proportions.

TABLE V
Correlation Coefficients of Flour Protein Content with Textural Characteristics of Pastry Wafers

Source	Flour Protein Content[a]
Flakiness	0.96
Crust shrinkage	0.81
Surface blistering score	−0.82
Breaking strength	−0.50[b]
Lightness	0.44[b]
Redness	ns
Yellowness	ns

[a] $n = 12$; ns = not significant at $\alpha = 0.01$.
[b] Significant at $\alpha = 0.05$.

Surface browning was determined from measurements of lightness, redness, and yellowness. Lightness mean values for reconstitution types are provided in Table IV. Pastry wafers baked from parent flours were significantly lighter than those baked from all other flour types. The reconstituted flours with a pH 5.6-insoluble material yielded the darkest pastry wafers; they were significantly darker than those from all other reconstituted types. With the exception of the reconstituted flours with pH 5.6-insoluble material, as pH decreased among the reconstituted flours of the single pH fractions, the pastry wafers were darker.

The pastry wafers baked from the reconstituted flours from fractions insoluble at pH 5.6 had significantly redder crust surfaces than those baked from other reconstitution types (Table IV). As with lightness values, when the reconstituted flours from fractions insoluble at pH 5.6 were excluded, pastry wafers were increasingly red as pH of the fraction decreased. Pastry baked from the parent flours was significantly less red and more green than that from other types. The parent flours yielded pastries significantly less yellow than those baked from all other reconstituted types, except the reconstituted flours using the fraction insoluble at pH 5.6 (Table IV).

Among the reconstituted types, the lightness and especially the redness values differentiated most consistently between browning reactions on the various pastry crust surfaces. All pastry types had yellowish surfaces; moreover, the range of values was not as wide as for the redness and lightness values. Redness and lightness values followed the same pattern, and the relationship was generally linear, as lightness decreased, redness increased. Thus, fractions of the lower pH gluten, when reconstituted into flours, yielded the pastry with the most brown crust surface. With the exception of the reconstituted flours from the pH 5.6-insoluble fraction, as the pH of the singly reconstituted flours increased, the browning reaction of these flours decreased. It thus appears that the fractions containing larger amounts of glutenin contributed to greater crust surface browning than did those fractions higher in gliadins.

Table V shows correlations between the textural characteristics of pastry and flour protein. An extremely high correlation was found between flakiness and flour protein ($r = 0.96$ at $\alpha = 0.01$). A pie crust baked from a high-protein flour was found by Miller and Trimbo (1970) to be very flaky compared with pie crust baked from starch without protein. Crust shrinkage was positively correlated with flour protein; this is also in agreement with Miller and Trimbo (1970).

Both surface blistering score and breaking strength were negatively correlated with flour protein. Surface blistering would be expected to be greater in flours of higher protein, since it indicates gluten strength. Also, pastry wafers baked from the higher protein flours would be expected to have higher breaking strengths, due to the potential for greater gluten development. In contrast, Denton et al (1933) and Miller and Trimbo (1970) found a positive correlation between breaking strength and flour protein content. Tecumseh flour was particularly anomalous with regard to breaking strength.

The quantity and quality of protein in pastry flours have a tangible effect on the textural characteristics of pie pastry. From the correlation data, it can be seen that the quantity of protein influences the flakiness, crust shrinkage, surface blistering score, breaking strength, and lightness of pastry wafers. The reconstitution type data shows that the quality of protein, as varied by gliadin-to-glutenin ratio, also influences these factors plus the redness values of pastry wafers. The influence that the gluten fraction type used in the single-fraction reconstituted flours had on these textural characteristics, especially flakiness and crust shrinkage, indicates that gluten development does occur in pie pastry. The amount and type of gluten, as determined by both the wheat cultivar from which the flour is milled and reconstitution type, were probably largely responsible for the statistical differences found among types of pastry. The flours of higher glutenin obtained from material insoluble at pH 4.7 and 5.6 yielded pastry that was less flaky, less shrunken, less blistered, and with a darker crust color. However, the flour pastry of pH 5.6-insoluble

material reconstituted was more tender than reconstituted flour pastry from pH 4.7-insoluble material. Because the flour lipid was not extracted before fractionation, this, too, could have influenced textural characteristics. The gluten fraction at insoluble pH 5.6 had a noticeable greasy feel. Frazier et al (1981) stated that the bound flour lipid is located with the high molecular weight glutenin. Possibly the flour lipid precluded the full extent of gluten development that might otherwise have occurred in the reconstituted flour dough of the pH 5.6-insoluble material.

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