Relationships of Selected Flour Constituents to Baking Quality in Soft White Wheat[1]

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ABSTRACT

Cereal Chem. 68(5):508-512

Selected constituents of soft white wheat flour samples from various locations were examined and related to baking quality in order to identify those constituents that are associated with end-use quality. Among the selected constituents, the pentosan fractions were found to be inversely correlated with baking quality. Soluble and enzyme-extractable pentosans were negatively associated with cookie diameter. Cake volume was negatively associated with soluble, enzyme-extractable, and total pentosans.

Wheat quality is judged according to its intended use. The applications of hard wheat are different from those of durum wheat, and the use of soft white wheat is quite different from that of either hard or durum wheat.

Hard wheat flour with high protein content and gluten strength is used mainly for breadmaking. Exceptionally hard durum wheat is best for pasta products. Soft white wheat with low protein content and weak gluten is used for pastry products (Hoseney et al 1988). High protein content has a negative effect on both cookie diameter and cake volume (Kaldy and Rubenthaler 1987). Since many products are produced by the pastry industry, a good quality soft white wheat flour that meets the needs of the various products is required.

Protein content alone, however, is not an adequate measure of quality in bread wheat (Yoshino and McCalla 1966) or soft white wheat (Kaldy and Rubenthaler 1987). In the latter study, flours with similar protein contents gave different cookie diameters among various regions and within the same region. These differences were apparent even when soft white winter and soft white spring wheat were compared. The converse also was true when the same cookie diameter was produced by flours with different protein contents. This study also showed that the influence of cultivar was less pronounced compared with location. The same applied to cake volume. The question arose, therefore, of what other parameters, in addition to protein, have an influence on end-use quality in soft white wheat.

Pentosans, a type of structural carbohydrate consisting mainly of xylose and arabinose (Cole 1967), have been shown to affect the quality of end-products, particularly in hard wheat. Pentosans can absorb an amount of water 10 times their weight because of their hydrophilic nature (Kulp 1968, D'Appolonia and Kim 1976). In hard wheat, pentosans can affect the rheological properties and consistency of flour dough (Hoseney 1984, Amado and Neukom 1985). The total pentosan content of flour has been reported to vary from 1 to 2% (Cerning and Guilbot 1973, Douglas 1981, Abboud et al 1985). Pentosans bind 23% of the water in the dough system (Bushuk 1966). When pentosans were isolated, concentrated, and then added to dough, cookie diameter decreased (Yamazaki 1955). However, no report has been found relating the negative influence of native pentosans on cookie diameter and cake volume. As with pentosans, other carbohydrate constituents also may influence the final product.

Hong et al (1989) showed that pentosan content varied in soft white wheats from different regions. Other studies of soft white wheat flour have shown that geographic location can influence the final quality of soft wheat products (Kaldy and Rubenthaler 1987, Bassett et al 1989).

The purpose of the present study was to examine various pentosan fractions and other carbohydrate constituents (e.g., sugars and fiber) in soft white flour to determine whether they influence end-use quality.

MATERIALS AND METHODS

Twenty soft white spring wheats and five soft white winter wheats were collected from a broad range of growing environments. Of the 20 spring wheat samples, 15 were grown in western Canada (Alberta) and five in Washington State. Of the 15 Alberta-grown samples, from an area within a distance of 500 km, 12 represent the cultivars Fielder (samples 9–17, 20), Owens (sample 18), and Dirkwin (sample 19). The remaining three samples (6–8) represent mixed (commercial) spring wheat cultivars, mainly Fielder and Owens. All were grown in 1984 except sample 14, which was grown in 1983 at the same location as sample 15. Of the five samples from Washington, 21–24 were Fielder, 25 was Owens. Sample 21 was grown in 1981, sample 22 in 1982, samples 23 and 24 in 1983, and sample 25 in 1984. Three of the five winter wheat samples represent Fredrick cultivars grown in 1982 (sample 3), 1983 (sample 4), and 1984 (sample 5); the other two (1 and 2) were mixed (commercial) cultivars grown in 1984. All samples were milled on a Buhler pneumatic laboratory mill at the U.S. Department of Agriculture Western Wheat Quality Laboratory (WWQL), Pullman, Washington. The mean flour yield for all samples was 70.0% (range, 61.2–73.6%; SD, 2.7), mean flour protein, 10.3% (range, 8.4–13.3%, SD, 1.1), and mean flour ash, 0.40% (range, 0.35–0.45%, SD, 0.03).

The data for cookie diameter and cake volume of samples from Alberta and Ontario were obtained from a previous study conducted at WWQL (Kaldy and Rubenthaler 1987). Flour protein and cookie and cake baking of the Washington samples also were analyzed at WWQL. Analyses of various carbohydrate constituents were determined in duplicate and conducted as follows.

Sugars

Sugars were extracted using 80% ethanol (Henry 1985), except that samples were defatted before sugar extraction. Flour samples (0.5 g) were extracted into 25 ml of 80% ethanol.

Glucose was determined using glucose oxidase. A 1-ml portion of the 80% ethanol extract was diluted with 4 ml of water. Then 0.2 ml of this solution was mixed with 5 ml of glucose color reagent, prepared with glucose oxidase (Henry 1985), and incubated at 40° C for 15 min. After equilibrating to room temperature, the absorbance of the solution was read at 510 nm. A glucose standard of 100 μg/ml and a reagent blank also were run with each determination.

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Sucrose and fructose were determined as described by Blakeney and Mutton (1980), except that glucose formed by the hydrolysis of sucrose was determined using glucose oxidase (Henry 1985).

To calculate amounts of sugars, the amount of glucose based on the standard was first calculated and converted to percent glucose. The difference between the amount of glucose before and after invertase treatment was correlated to the amount of sucrose and converted to percent sucrose. From the total apparent fructose, the amount of fructose due to sucrose was subtracted and converted to percent fructose. Total sugar was calculated from the sum of glucose, fructose, and sucrose. The sugars also were expressed as a percent of total sugar. All results then were converted to dry weight basis.

Pentosans

The pentosans were determined as soluble, enzyme-extractable, and total pentosans as described by Hashimoto et al (1987), with the following modifications. All samples were treated with baker's yeast to remove glucose. The enzyme used to extract the enzyme-extractable pentosans was cellulase (Type V, Sigma Chemical Co., St. Louis, MO). For the colorimetric analysis of pentosans, 2 ml of solution were mixed with 2 ml of orcinol color reagent, and the difference of the absorbances at 670 and 600 nm were used (Dische 1962, Kunerth and Youngs 1984).

Nonstarch Polysaccharides

Uronide (pectic substances), total fiber, and cellulose were prepared as described by Faulks and Timms (1985).

Total uronide was analyzed by the method of Scott (1979), with the following modifications. A concentrated chloride borate solution was prepared by dissolving 4 g of sodium chloride and 6 g of boric acid in 100 ml of water, using heat. Then 0.45 ml of hydrolyzate and 0.15 ml of chloride borate solution were mixed together in a test tube, and the procedure was followed as described.

Total fiber was determined by measuring the amount of reducing sugar using 3-hydroxybenzoic acid hydrazide in alkaline solution (Lever 1972, Blakeney and Mutton 1980).

Percent cellulose was determined by analyzing the amount of glucose using the glucose oxidase reagent (Henry 1985).

Amylose

Amylose content was determined using the method of Knutson (1986), with modifications. To extract amylose and starch, flour samples (20 mg) were dispersed in 20 ml of 0.006*M* iodine in 90% dimethyl sulfoxide (v/v) and heated in a water bath at 50°C for 16 hr. By comparing with a standard and correcting for amylopectin, the amylose content of the flour was then determined. However, to express the amylose content as a percent of starch, the amount of starch extracted also was determined, as described by Dubois et al (1956). A 0.25-ml aliquot of sample extract was diluted to 2.5 ml with 90% dimethyl sulfoxide. From this solution, 0.2 ml was used for starch analysis.

By comparing the unknown absorbances with the absorbance of the corn starch standard, the amount of starch extracted by the solvent was calculated. The amount of amylose was expressed as a percent of the starch to give the percent amylose content and the results expressed on a dry weight basis.

Hydroxyproline

Hydroxyproline was determined to provide an indication of the amount of protein associated with fiber (Raczynska-

TABLE I
Selected Constituents (%, db) of Soft White Wheat Flours: Sugars and Pentosans

Sample	GLUC[a]	FRUC	SUCR	TSUG	GLTS	FRTS	SUTS	SOPE	EEPE	TOPE
Ontario										
1	0.21	0.99	0.18	1.38	15.22	71.74	13.04	0.43	1.11	1.04
2	0.28	0.89	0.31	1.48	18.92	60.14	20.95	0.45	1.11	1.13
3	0.29	0.98	0.31	1.58	18.35	62.03	19.62	0.49	1.05	1.17
4	0.14	0.74	0.34	1.22	11.48	60.66	27.87	0.37	0.99	1.12
5	0.19	0.73	0.50	1.42	13.38	51.41	35.21	0.46	1.09	1.00
Mean	0.22 b[b]	0.87 b	0.33 a	1.42 b	15.47 b	61.20 b	23.34 a	0.44 a	1.07 b	1.09 b
SE	0.03	0.07	0.04	0.08	1.58	2.50	2.63	0.02	0.02	0.05
Alberta										
6	0.25	1.01	0.26	1.52	16.45	66.45	17.11	0.51	1.04	1.14
7	0.36	0.99	0.29	1.64	21.95	60.37	17.68	0.47	1.20	1.16
8	0.27	1.05	0.27	1.59	16.98	66.04	16.98	0.55	1.20	1.14
9	0.30	0.80	0.23	1.33	22.56	60.15	17.29	0.58	1.20	1.40
10	0.26	0.89	0.29	1.44	18.06	61.81	20.14	0.44	1.22	1.20
11	0.27	1.09	0.20	1.56	17.31	69.87	12.82	0.54	1.16	1.17
12	0.40	1.14	0.15	1.69	23.67	67.46	8.88	0.48	1.19	1.05
13	0.24	1.20	0.11	1.55	15.48	77.42	7.10	0.46	1.20	1.28
14	0.41	1.10	0.04	1.55	26.45	70.97	2.58	0.49	1.19	1.25
15	0.38	1.10	0.13	1.61	23.60	68.32	8.07	0.43	1.20	1.13
16	0.41	1.16	0.06	1.63	25.15	71.17	3.68	0.46	1.22	1.24
17	0.21	1.17	0.14	1.52	13.82	76.97	9.21	0.46	1.18	1.36
18	0.26	0.89	0.09	1.24	20.97	71.77	7.26	0.41	1.12	1.14
19	0.22	0.80	0.18	1.20	18.33	66.67	15.00	0.58	1.22	1.49
20	0.35	1.07	0.12	1.54	22.73	69.48	7.79	0.48	1.26	1.18
Mean	0.31 a	1.03 a	0.17 b	1.51 b	20.23 a	68.33 a	11.44 b	0.49 a	1.19 a	1.22 a
SE	0.02	0.04	0.02	0.05	0.91	1.44	1.52	0.01	0.01	0.03
Washington										
21	0.27	1.47	0.27	2.01	13.43	73.13	13.43	0.40	1.07	1.09
22	0.36	1.44	0.31	2.11	17.06	68.25	14.69	0.46	1.21	1.03
23	0.21	1.67	0.23	2.11	9.95	79.15	10.90	0.46	1.10	1.16
24	0.34	1.63	0.34	2.31	14.72	70.56	14.72	0.45	1.02	1.08
25	0.23	1.00	0.29	1.52	15.13	65.79	19.08	0.42	1.15	1.03
Mean	0.28 ab	1.44 a	0.29 a	2.01 a	14.06 b	71.38 a	14.56 b	0.44 a	1.11 b	1.08 b
SE	0.03	0.07	0.04	0.08	1.58	2.50	2.63	0.02	0.02	0.05

[a]GLUC = glucose, FRUC = fructose, SUCR = sucrose, TSUG = total sugar (sum of GLUC, FRUC, SUCR); GLTS, FRTS, SUTS = glucose, fructose, sucrose (respectively) as a percent of total sugar; SOPE = soluble pentosan, EEPE = enzyme-extractable pentosan, TOPE = total pentosan.
[b]Means within columns followed by the same letter are not statistically different from each other at the 0.05 level according to the least significant difference test.

Bojanowska et al 1989) and its effect on baking quality. It was determined according to the method of Neuman and Logan (1950), with modifications.

Flour samples (100 mg) were weighed into screw-cap culture tubes (16 × 125 mm). After 8 ml of 6*M* HCl was added to each tube, the tubes were sealed with screw caps and heated at 110°C for 22 hr. The hydrolyzates were filtered through a 0.45-μm filter disk over a 0.22-μm filter disk and completely dried over several days in a fume hood at 50°C. The residue was diluted to 4 ml with 0.1*M* (pH 4.5) sodium acetate buffer.

The aliquots for the analysis of hydroxyproline were half those described in the method of Neuman and Logan (1950). Absorbances of the samples were compared with the standard, and the percent hydroxyproline was calculated and expressed on a dry weight basis.

Statistical Methods

The mean values for the various flour components, including cookie diameter and cake volume, were compared among the various growing locations using one-way analysis of variance. The least significant difference test was used for pairwise comparisons, and correlations were calculated, regardless of location, among all the variables (Steel and Torrie 1980).

RESULTS AND DISCUSSION

The analytical data for sugars, pentosans, nonstarch polysaccharides, amylose, hydroxyproline, cookie diameter, and cake volume for the winter and spring soft white wheat flours are summarized in Tables I and II. Correlation coefficients for the various parameters of the wheat flour samples are presented in Table III.

Sugars

All the sugars studied showed some differences among the various locations (Table I). Differences also were found within locations and cultivars, similar to the case of protein content observed earlier (Kaldy and Rubenthaler 1987). A trend was observed for glucose and fructose, in which lower content is associated with larger cookie diameter (Table II). For sucrose, higher content is associated with larger cookie diameter and cake volume. Statistically, these trends are not very strong (Table III).

Pentosans

No significant differences were noted in the means for soluble pentosan among the different locations (Table I). However, within a location, variations in soluble pentosan occurred. Higher soluble pentosan content was associated with smaller cookie diameter and cake volume regardless of region (Table II). This trend was supported statistically for cake volume ($P \leq 0.05$) but not for cookie diameter (Table III).

The means for enzyme-extractable and total pentosan content were significantly higher for the Alberta samples than for the Ontario and Washington samples (Table I). The Ontario and Washington samples were not significantly different from each other, although Ontario represents soft white winter wheat, and Washington represents soft white spring wheat. Within a location, however, differences in enzyme-extractable and total pentosans occurred. Overall, increasing amounts of enzyme-extractable pentosan were associated with smaller cookie diameter and cake

TABLE II
Selected Contents and Characteristics of Soft White Wheat Flours

Sample	FIBR[a] (%, db)	URON (%, db)	CELL (%, db)	AMYL (%, db)	HPRO (%, db)	CODI (cm)	CODIC[b] (cm)	CAVOL (ml)
Ontario								
1	2.36	0.012	0.65	37.1	0.045	9.15	9.01	1,275
2	2.56	0.033	0.59	41.5	0.043	9.41	9.30	1,325
3	2.40	0.015	0.66	37.9	0.044	9.05	9.05	1,245
4	2.39	0.024	0.62	40.0	0.043	9.25	9.05	1,290
5	3.02	0.023	0.88	39.3	0.043	9.19	9.12	1,295
Mean	2.55 a[c]	0.021 a	0.68 a	39.2 a	0.044 a	9.21 a	9.11 a	1,286 a
SE	0.09	0.004	0.04	1.1	0.001	0.08	0.06	21
Alberta								
6	2.60	0.025	0.65	34.9	0.042	8.92	8.85	1,260
7	2.93	0.034	0.76	35.2	0.038	9.11	9.13	1,235
8	2.69	0.021	0.60	31.8	0.041	8.51	8.63	1,175
9	2.13	0.006	0.54	33.8	0.042	9.25	9.21	1,135
10	2.84	0.026	0.77	35.8	0.045	8.90	8.91	1,205
11	2.48	0.009	0.63	33.2	0.044	8.62	8.67	1,250
12	2.59	0.025	0.59	37.3	0.044	8.89	8.83	1,250
13	2.66	0.024	0.64	34.9	0.045	9.06	8.90	1,270
14	2.58	0.030	0.53	32.1	0.042	8.81	8.85	1,180
15	2.77	0.037	0.59	28.4	0.042	8.79	8.82	1,165
16	2.68	0.035	0.50	30.9	0.040	8.97	8.96	1,250
17	2.82	0.037	0.69	30.8	0.042	9.06	8.92	1,225
18	2.76	0.022	0.67	29.8	0.043	9.04	8.87	1,260
19	2.77	0.029	0.56	28.2	0.041	8.89	8.81	1,205
20	2.90	0.025	0.60	29.5	0.046	8.76	8.81	1,160
Mean	2.68 a	0.026 a	0.62 a	32.4 b	0.042 a	8.91 b	8.88 b	1,215 b
SE	0.05	0.002	0.02	0.7	0.001	0.05	0.05	12
Washington								
21	2.47	0.022	0.56	29.8	0.030	9.01	9.01	1,344
22	2.77	0.021	0.72	31.0	0.032	8.70	8.74	1,370
23	2.60	0.016	0.71	30.9	0.029	8.89	8.94	1,295
24	2.44	0.023	0.58	33.9	0.031	8.91	9.03	1,205
25	2.52	0.025	0.70	34.5	0.029	9.16	9.06	1,235
Mean	2.56 a	0.021 a	0.65 a	32.0 b	0.030 b	8.93 b	8.96 ab	1,290 a
SE	0.09	0.004	0.04	1.1	0.001	0.08	0.06	21

[a]FIBR = fiber, URON = uronide; CELL = cellulose, AMYL = amylose in starch, HPRO = hydroxyproline, CODI = cookie diameter, CODIC = cookie diameter corrected, CAVOL = cake volume.
[b]Corrected to 9% protein.
[c]Means within columns followed by the same letter are not statistically different from each other at the 0.05 level according to the least significant difference test.

TABLE III
Correlation Coefficients Among Selected Parameters in Soft White Wheat Flours

Parameter	GLUC[a]	FRUC	SUCR	TSUG	GLTS	FRTS	SUTS	SOPE	EEPE	TOPE	FIBR	URON	CELL	AMYL	HPRO	CODI	CODIC
FRUC	0.29	...															
SUCR	−0.42*[b]	−0.12	...														
TSUG	0.37	0.93**	0.16	...													
GLTS	0.82**	−0.24	−0.58**	−0.22	...												
FRTS	0.09	0.69**	−0.67**	0.39	−0.11	...											
SUTS	−0.57**	−0.46*	0.93**	−0.21	−0.51**	−0.80**	...										
SOPE	0.16	−0.17	−0.11	−0.15	0.30	−0.12	−0.08	...									
EEPE	0.47*	−0.08	−0.53**	−0.15	0.60**	0.14	−0.48*	0.41*	...								
TOPE	−0.03	−0.21	−0.46*	−0.37	0.25	0.19	−0.31	0.57**	0.42*	...							
FIBR	0.10	−0.07	−0.01	−0.04	0.12	−0.08	0.00	−0.08	0.44*	−0.04	...						
URON	0.29	−0.03	−0.22	−0.04	0.29	0.03	−0.20	−0.29	0.25	0.11	0.60**	...					
CELL	−0.42*	−0.14	0.58**	−0.02	−0.45*	−0.34	0.56**	−0.25	−0.11	−0.39	0.51**	−0.04	...				
AMYL	−0.29	−0.40*	0.56**	−0.23	−0.23	−0.59**	0.65**	−0.21	−0.48*	−0.38	−0.25	−0.15	0.32	...			
HPRO	−0.02	−0.68**	−0.28	−0.72**	0.39	−0.26	−0.01	0.23	0.23	0.28	0.12	0.02	−0.05	0.29	...		
CODI	−0.38	−0.40*	0.29	−0.35	−0.19	−0.36	0.43*	−0.37	−0.40	0.00	−0.26	0.06	0.15	0.60**	0.06	...	
CODIC	−0.19	−0.24	0.42*	−0.10	−0.13	−0.44*	0.46*	−0.29	−0.39	−0.06	−0.29	0.02	0.13	0.58**	−0.11	0.92**	...
CAVOL	−0.29	0.26	0.36	0.29	−0.51**	0.05	0.26	−0.48*	−0.43*	−0.49*	0.02	−0.06	0.32	0.31	−0.33	0.27	0.18

[a]GLUC = glucose, FRUC = fructose, SUCR = sucrose, TSUG = total sugar (sum of GLUC, FRUC, SUCR); SUTS = glucose, fructose, sucrose (respectively) as a percent of total sugar; SOPE = soluble pentosan, EEPE = enzyme-extractable pentosan; TOPE = total pentosan; FIBR = fiber; URON = uronide; CELL = cellulose; AMYL = amylose in starch; HPRO = hydroxyproline, CODI = cookie diameter, CODIC = cookie diameter corrected, CAVOL = cake volume.
[b]*, ** = Significantly different at $P \leq 0.05$ and $P \leq 0.01$, respectively.

volume, regardless of region (Table II). This was supported statistically where enzyme-extractable pentosans correlated negatively with cookie diameter ($P = 0.0505$) and cake volume ($P \leq 0.05$) (Table III). Cake volume also correlated negatively with total pentosans ($P \leq 0.05$).

Nonstarch Polysaccharides

Total fiber, uronide (pectic substances), and cellulose were not significantly different among the various locations (Table II). The variation was greater within than among locations. Fiber correlated with uronide and cellulose. However, there was no correlation of fiber, uronide, or cellulose with cookie diameter or cake volume. Consequently, fiber, uronide, and cellulose appear to have no influence on end-use quality of soft white wheat.

Amylose

The amylose content was significantly higher in the Ontario samples than in the Alberta or Washington samples (Table II). Alberta and Washington samples were not different from each other. Higher amylose content was associated with larger cookie diameter. This trend was supported statistically ($P \leq 0.01$) (Table III). However, amylose appears to have no effect on cake volume.

Hydroxyproline

Hydroxyproline content was lowest for the Washington samples (Table II). Alberta and Ontario samples were not different from each other. Hydroxyproline content was quite uniform within a location. It showed no influence on cookie diameter or cake volume (Table III).

Cookie Diameter

Cookie diameter is an important measurement in evaluating the quality of soft white wheat flour; a larger diameter indicates better quality flour. The Ontario samples had the largest cookie diameter and were significantly different from the Washington or Alberta samples (Table II). The samples from Washington and Alberta did not differ significantly from each other in cookie diameter but differed in cake volume (discussed later). Variations in cookie diameter also were found within locations. Combining all locations, enzyme-extractable pentosan was negatively associated with cookie diameter ($P = 0.0505$).

Cookie Diameter Corrected

The corrected cookie diameter removes the influence of protein content and corrects the cookie diameter to a constant protein of 9% (Table II) by a long-term average correction factor of 0.12 cm per percent of protein (Rubenthaler et al 1985). The Ontario winter wheat samples had the largest corrected cookie diameter and were significantly different from the Alberta but not the Washington spring wheat samples (Table II). The Alberta samples had the lowest corrected cookie diameter but were not significantly different from the Washington samples. When all locations were combined, corrected cookie diameter was associated negatively with enzyme-extractable pentosan ($P = 0.055$)

Cake Volume

Cake volume is also an important measurement in evaluating the quality of soft white wheat flour. Higher cake volume indicates better quality flour. However, a previous study indicates that what makes a good cake flour is not known (Hoseney et al 1988).

The Ontario and Washington samples had significantly larger cake volumes than did the Alberta samples (Table II). The flour samples from Ontario winter and Washington spring wheat were not significantly different from each other. When the data for all locations were combined, cake volume had a negative association with soluble, enzyme-extractable and total pentosans ($P \leq 0.05$). Consequently, with increasing pentosan content, cake volume decreased. This negative correlation appears to indicate that the role of pentosans in cakes is similar to their role in cookies, in which cookie diameter is inversely related to pentosan content.

CONCLUSION

Examination of selected constituents of soft white wheat flour samples from a broad range of growing environments, some grown in different years, revealed differences in locations for sugars, amylose, and pentosans. Differences also were found within locations, even when the same cultivars were examined.

By relating the selected constituents to baking quality, those associated with end-use quality were identified. The pentosan fractions were found to have a negative influence on baking quality. Soluble and enzyme-extractable pentosans were negatively associated with cookie diameter. Cake volume had a negative association with soluble, enzyme-extractable, and total pentosans. Consequently, native pentosans have a negative influence on both cookie diameter and cake volume in soft wheat flour.

ACKNOWLEDGMENT

The authors gratefully acknowledge the statistical assistance of G. C. Kozub.

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[Received September 14, 1990. Accepted March 29, 1991.]

Electrophoretic Study of Some High Molecular Weight Proteins of the Acetic Acid-Insoluble Residue of Wheat Flours[1]

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ABSTRACT

Cereal Chem. 68(5):512-515

Acetic acid-insoluble (residue) protein fractions of flours of seven wheat varieties were studied by sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE). Electrophoretic patterns of unreduced SDS-buffer extracts from flour residue fractions revealed a group of relatively high molecular weight (HMW) proteins having similar electrophoretic characteristics. The HMW proteins of one variety (Neepawa) were characterized further by two-dimensional SDS-PAGE under nonreducing and reducing conditions. The two-dimensional separation showed that the HMW proteins comprised several subunits. Three of these proteins, designated B-2, B-3, and B-4, share some correspondence with the triplet band proteins and appear to be partly composed of four large subunits resolved in pairs with molecular weights of about 56 and 52 kilodaltons.

Considerable evidence exists that residue proteins that remain after extraction of wheat flour with nonreducing solvents play an important role in breadmaking properties. For example, a direct relationship has been observed between the amount of residue protein and functionality, particularly mixing strength of different genotypes (Mecham et al 1962, 1965; Tsen 1967; Orth and Bushuk 1972; Tanaka and Bushuk 1973; Orth and O'Brien 1976). The underlying cause of the observed relationship has been attributed mainly to glutenin that can be released from the residue as polypeptide "subunits" in the presence of reducing agent.

Fewer studies have focused on the composition of the insoluble residue fraction without prior reduction. Singh and Shepherd (1985, 1987), for example, identified a group of relatively high molecular weight (HMW) proteins (150–160 kilodaltons [kDa]) in the unreduced flour and residue fractions. These proteins, originally named triplet band proteins (Singh and Shepherd 1985) and recently renamed triticin (Singh et al 1988), have been impli-

[1]Publication no. 197 of the Food Science Department, University of Manitoba.
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