A Comparative Study of the Proteins of Wheats of Diverse Baking Qualities[1]

R. A. ORTH[2] and W. BUSHUK, Department of Plant Science, The University of Manitoba, Winnipeg, Canada

ABSTRACT

Flour proteins of 26 wheat varieties, each grown at four stations in western Canada, were studied by solubility fractionation and polyacrylamide disc-gel electrophoresis. The varieties represented a broad spectrum of baking qualities. Statistically significant differences in the proportions of each solubility group were obtained between varieties and locations, the former differences being larger than the latter. Simple correlations between some breadmaking-quality parameters and the proportion of each protein fraction or combination of fractions showed that the proportions of both glutenin and residue protein had a direct effect on baking performance. The proportion of glutenin in the total flour protein was negatively correlated with loaf volume per unit protein, whereas residue protein and loaf volume per unit protein were positively correlated. The ratios of gliadin to glutenin and albumin to globulin were also significantly positively correlated with loaf volume per unit protein. Very minor intervarietal differences in the electrophoretic patterns of the albumins and globulins and large qualitative differences in the gliadins were observed. These differences could not be related to baking quality. No interstation differences in electropherograms were observed within the albumin, globulin, or gliadin fractions of the five varieties examined.

It is now well established (1) that a flour's breadmaking quality is critically dependent on the quantity and quality of its protein. However, a biochemical basis for protein quality has not yet been delineated, although much research has been undertaken with this aim.

The 26 wheats of the 1969 Uniform Quality Nursery, maintained by the Canada Department of Agriculture, provided ideal material to study further the chemistry of protein quality, as these wheats represented a very broad range of baking qualities. These wheats were each grown at four stations in western Canada, and so were useful for investigation of both intervarietal and interstation factors. The properties of the flour proteins investigated and discussed in this paper are the solubility distribution by the modified Osborne technique and electrophoretic mobility of the solubility fractions in polyacrylamide gels.

MATERIALS AND METHODS

The wheat samples used in this study were grown at Saskatoon, Regina, Lethbridge, and Swift Current. All cultivars are common (hexaploid) spring wheats. Further classification of these wheats on the basis of pericarp color and hardness is very difficult because of their broad range in both these properties. Table I lists the 26 wheats, their parentage, and their countries of origin (where available). This

[1]Contribution No. 298, Department of Plant Science, The University of Manitoba, Winnipeg, Manitoba R3T 2N2, with financial assistance from the National Research Council of Canada.

[2]On study leave from the Agricultural Chemistry Division, Victoria State Department of Agriculture, Melbourne, Australia.

TABLE I. WHEATS OF THE 1969 UNIFORM QUALITY NURSERY

Cultivar	Parentage	Origin
Rushmore	Rival X Thatcher	U.S.
Sonora 64	(Yaktana 54 X Norin 10 X Brevor) Yaqui 54[2]	Mexico
Thatcher	(Marquis X Iumillo Durum) X (Marquis X Kanred)	U.S.
Manitou	P.I. 170925 X Thatcher[6] X [(Frontana X Thatcher[7]) Thatcher[6] X Kenya Farmer]	Canada
Marquis	Hard Red Calcutta X Red Fife	Canada
Pembina backcross	Pembina[6] X (Transfer X Pembina[6]) Sr8	Canada
6704	[(Svenno X Ceres) X (Saratov X C.T. 244)] [C.T. 907 X Ceres X Kenya X Canthatch]	Canada
6702	[(Sv7389 X Ceres) (C.T. 244)] [(Park X Reliance) (Koga II X Lee)]	Canada
Fortuna	(Rescue X Chinook) (Frontana X Kenya 58 X Newthatch)	U.S.
Opal		Germany
Kota	Selected from Monad durum	Russia
Pitic 62	Yaktana 54 X (Norin 10 X Brevor)	Mexico
Justin reselection	(Thatcher-Kenya Farmer X Lee-Midal) X Conley	Canada
Comanche X CT736		Canada
Svenno		Sweden
Gaboto	Bagé X (H44 X Sinvalocho X Bagé)	Argentina
Napo 63		Colombia
Aniversario	Reliance X Klein 75	Argentina
Magnif Entrerriano	(Bagé X Sinvalocho) X (Heines Kolben X 38 M.A.)	Argentina
Magnif 41		Argentina
Thatcher backcross	Thatcher crossed with six rust-resistant donors	Canada
Lerma Rojo 64A	[(Yaqui X Norin 10 X Brevor) X Lerma 52] Lerma Rojo[2]	Mexico
Gabo cross	(Bobbin[2] X Gaza) X Maria Escobar X Kenya	Bolivia
E931 cross	E931 - Egypt 86 - 26 X EK_2	India
R37		Italy

information should be helpful in classifying some of the cultivars on the basis of color and hardness.

Approved methods of the AACC (2) were used for evaluation of milling and breadmaking quality. Wheats were milled on an experimental Buhler mill. The test-baking procedure was the remix test of Irvine and McMullan (3). This method exaggerates differences in baking quality between weak and strong flours.

Because loaf volume is known to depend on both protein quantity and protein quality, it was considered that loaf volume per unit protein (ULV) would be a better index of intrinsic protein quality than total loaf volume. This factor was used to rank the wheats at Saskatoon, as shown in Table II. The ULV values will be used in correlations discussed below. Flour protein values are also shown in Table II.

Flour proteins were fractioned by the modified Osborne procedure described by Chen and Bushuk (4). This fractionation gives five solubility fractions: 1) Water-soluble proteins (albumins); 2) salt-soluble proteins (globulins); 3) aqueous ethanol-soluble proteins (gliadins); 4) dilute acetic acid-soluble proteins (glutenins); and 5) insoluble or residue protein. The extractions were done in a cabinet at 5°C. to minimize the possible side effects of proteolytic enzymes and thermal denaturation. Protein content of each fraction was determined by the Nessler

TABLE II. LOAF VOLUME PER UNIT PROTEIN AND FLOUR PROTEIN FOR 26 VARIETIES FROM FOUR STATIONS

Cultivar		Saskatoon		Regina		Lethbridge		Swift Current	
Number	Name	ULV[a]	FLP[b]	ULV	FLP	ULV	FLP	ULV	FLP
1	Rushmore	63.3	14.3	51.7	15.2	54.7	14.3	55.6	14.3
2	Sonora 64	63.2	14.4	53.2	13.5	56.4	12.9	55.5	13.5
3	Thatcher	62.5	14.3	52.5	14.4	54.9	13.6	56.3	12.5
4	Manitou	59.7	14.4	49.2	14.9	50.3	13.8	53.1	13.8
5	Marquis	58.5	13.8	51.6	13.9	52.6	13.8	53.6	12.3
6	Pembina backcross	58.3	15.1	53.2	14.8	47.8	15.0	54.2	13.8
7	6704	58.2	13.2	54.0	13.8	57.9	12.4	55.7	11.4
8	6702	57.4	13.7	49.1	13.8	52.2	13.1	54.2	12.7
9	Fortuna	56.6	12.9	52.2	14.0	44.8	13.1	47.4	13.0
10	Opal	55.3	10.9	50.3	11.5	59.5	11.1	56.5	10.7
11	Kota	53.7	15.7	52.4	15.9	55.0	13.8	55.3	12.9
12	Pitic 62	53.3	11.4	50.0	11.6	50.0	9.9	51.1	11.1
13	Justin reselection	52.4	15.4	44.8	15.5	55.0	14.1	54.4	13.3
14	Comanche X CT736	51.7	13.4	49.3	13.7	46.0	12.8	53.0	11.8
15	Svenno	51.0	13.7	52.1	14.0	51.0	11.9	54.1	14.1
16	Gaboto	50.0	14.6	52.8	14.6	56.8	12.2	55.1	13.2
17	Napo 63	48.2	12.3	46.2	12.5	45.8	12.5	48.9	12.5
18	Aniversario	47.4	15.5	34.5	15.4	58.6	13.0	55.8	13.8
19	Magnif Entrerriano	45.5	12.7	45.5	12.0	48.5	12.0	47.5	11.5
20	Magnif 41	44.8	14.8	44.2	15.5	41.0	14.9	42.6	15.6
21	Thatcher backcross	43.8	14.9	33.6	14.7	22.7	14.2	38.9	13.8
22	Lerma Rojo 64A	41.2	13.1	40.5	13.2	37.5	12.4	41.2	13.8
23	Carazinho	39.6	13.8	42.5	13.6	46.8	11.3	49.7	12.7
24	Gabo cross	39.0	14.6	42.2	13.2	39.0	12.1	46.9	12.1
25	E931 cross	34.7	15.3	33.3	14.9	...	15.1	...	14.1
26	R37	33.4	12.8	31.8	12.0	30.5	10.9	30.6	11.4

[a]ULV = based on % protein on a dry basis.

[b]FLP = flour protein (N X 5.7) on a 14.0% moisture basis.

procedure described by Williams (5). The proportion of each protein fraction was expressed as percent of total flour protein. The nitrogen recovery in the fractionation varied from 87 to 97%. Material losses are attributed to two factors: 1) Loss of low-molecular-weight materials during dialysis of the salt extracts; and 2) cumulative effect of incomplete recoveries due to normal experimental error in the multi-step fractionation procedure.

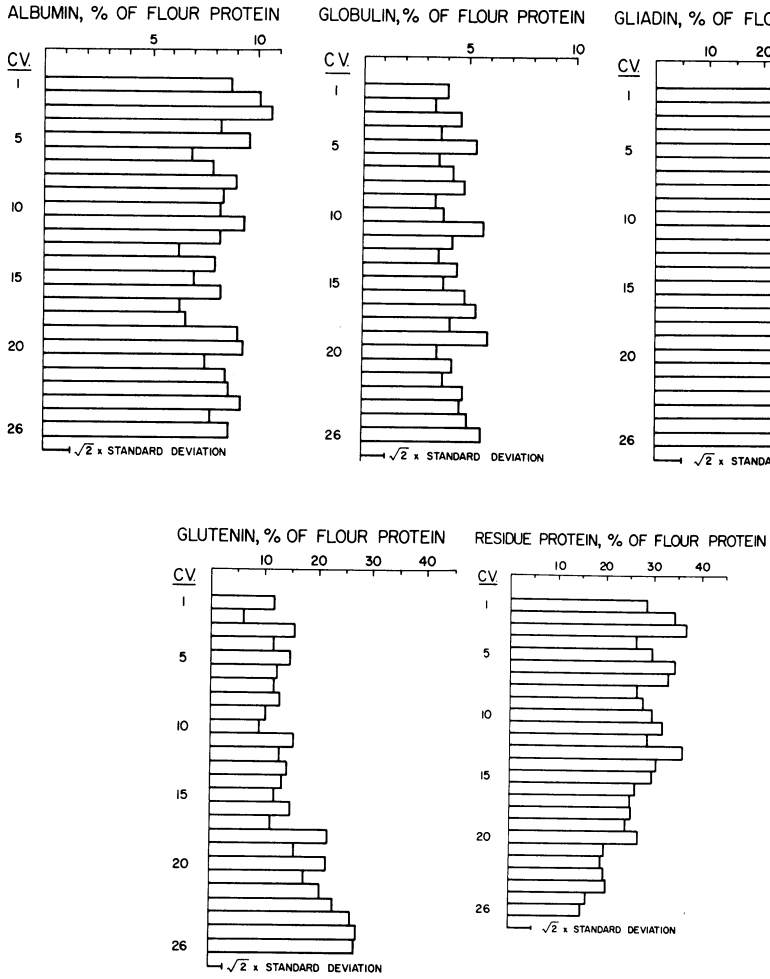
To determine the significance of differences in protein-solubility distributions, a Manitou (a Canadian variety of hard red spring wheat) flour was fractionated seven times and the standard error in the determination of the proportion of each protein fraction was calculated. This error is indicated in appropriate figures.

Polyacrylamide disc-gel electrophoresis was performed with the modified Davis procedure described by Chen and Bushuk (4). The running pH of this system was 3.2, and not 3.8, as erroneously stated in the previous publication (4).

RESULTS AND DISCUSSION

Intervarietal Differences in Protein-Solubility Distribution

Significant intervarietal differences (for Saskatoon wheats) were evident for each protein group. Figures 1 through 5 show the varieties arranged in order of decreasing ULV at Saskatoon.



Figs. 1–5. Proportion of various protein-solubility fractions in flours of 26 wheat varieties grown at one location. Top row: Water-soluble protein (albumin), salt-soluble protein (globulin), and aqueous ethanol-soluble protein (gliadin). Bottom row: Dilute acetic acid-soluble protein (glutenin), and residue or insoluble protein.

Figures 1, 2, and 3 show definite intervarietal differences in the proportion of albumin, globulin, and gliadin proteins, respectively; but there is no obvious trend between ULV and the proportion of each of these proteins.

ULV was inversely related to the proportion of glutenin protein (Fig. 4). This solubility group of proteins showed the greatest variation between varieties—from a low of 6 to a high of 27.4%.

Definite intervarietal differences in the proportion of residue protein were observed (Fig. 5). The residue protein made up from 15 to 36.5% of the total flour protein, and averaged 26.9%. A trend indicating a direct relationship between ULV and the proportion of residue protein is evident from Fig. 5.

To illustrate further the relationships shown in Figs. 4 and 5, the proportions of glutenin and residue proteins were correlated with various breadmaking-quality parameters. Simple correlations for these and other components of the protein-solubility distribution are given in Table III.

The linear regression of ULV on the proportion of residue protein is shown in Fig. 6. The proportion of residue protein yielded significant positive correlations with all the quality parameters which are related to dough strength, namely, ULV, farinograph dough-development time, farinograph mixing-tolerance index, and the Zeleny sedimentation value. On the other hand, the proportion of glutenin protein was negatively correlated, at the 1% level of significance, with all these quality parameters.

The observation that residue protein is important to baking performance, indicated by its highly significant correlations with loaf volume per 100 g. flour, ULV, dough-development time, mixing-tolerance index, and Zeleny sedimentation value, is in general agreement with results obtained in previous studies. Pomeranz (6) reported that flours of poor quality had a greater proportion of protein dispersible in 3M urea or, conversely, less protein insoluble in this solvent. Dronzek et al. (7) concluded that differences in the protein-solubility distribution could be related to the breadmaking qualities of three common bread-wheat varieties and the

TABLE III. CORRELATIONS BETWEEN SOME QUALITY PARAMETERS AND THE PROTEIN-SOLUBILITY DISTRIBUTION FOR THE SASKATOON WHEATS

Variables	Simple Correlation Coefficient
Loaf volume vs.:	
Proportion of albumin protein	+0.21 ns
Proportion of globulin protein	−0.40*
Proportion of gliadin protein	−0.09 ns
Proportion of glutenin protein	−0.67**
Proportion of residue protein	+0.82**
Loaf volume per unit protein vs.:	
Proportion of albumin protein	+0.20 ns
Proportion of globulin protein	−0.35 ns
Proportion of gliadin protein	+0.23 ns
Proportion of glutenin protein	−0.86**
Proportion of residue protein	+0.85**
Gliadin to glutenin ratio	+0.70**
Albumin to globulin ratio	+0.43*
Dough development time vs.:	
Proportion of residue protein	+0.67**
Proportion of glutenin protein	−0.49**
Gliadin to glutenin ratio	+0.41*
Mixing tolerance index vs.:	
Proportion of residue protein	−0.75**
Proportion of glutenin protein	+0.67**
Gliadin to glutenin ratio	−0.34 ns
Zeleny sedimentation value vs.:	
Proportion of residue protein	+0.83**
Proportion of glutenin protein	−0.64**

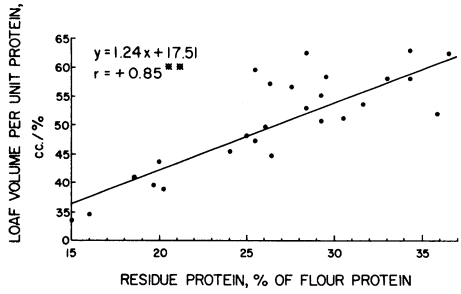


Fig. 6. Regression of ULV on the proportion of residue protein.

AABB tetraploid wheats derived from them. Two of the common wheats had both better baking quality and a higher proportion of residue protein than their related tetraploids. The third tetraploid had the same baking quality as its common counterpart and also contained the same proportion of residue protein.

It is now possible to qualitatively formulate a protein-solubility distribution characteristic of a flour of good breadmaking quality. It should contain a large proportion of insoluble or residue protein (above 25%) and a small proportion of acetic acid-soluble protein. Although not as critical, a high ratio of gliadin to glutenin seems beneficial. This, however, may merely be an artifact of the relatively constant proportion of gliadin and the presence of a low proportion of glutenin in the better varieties.

Interstation Differences in Protein-Solubility Distribution

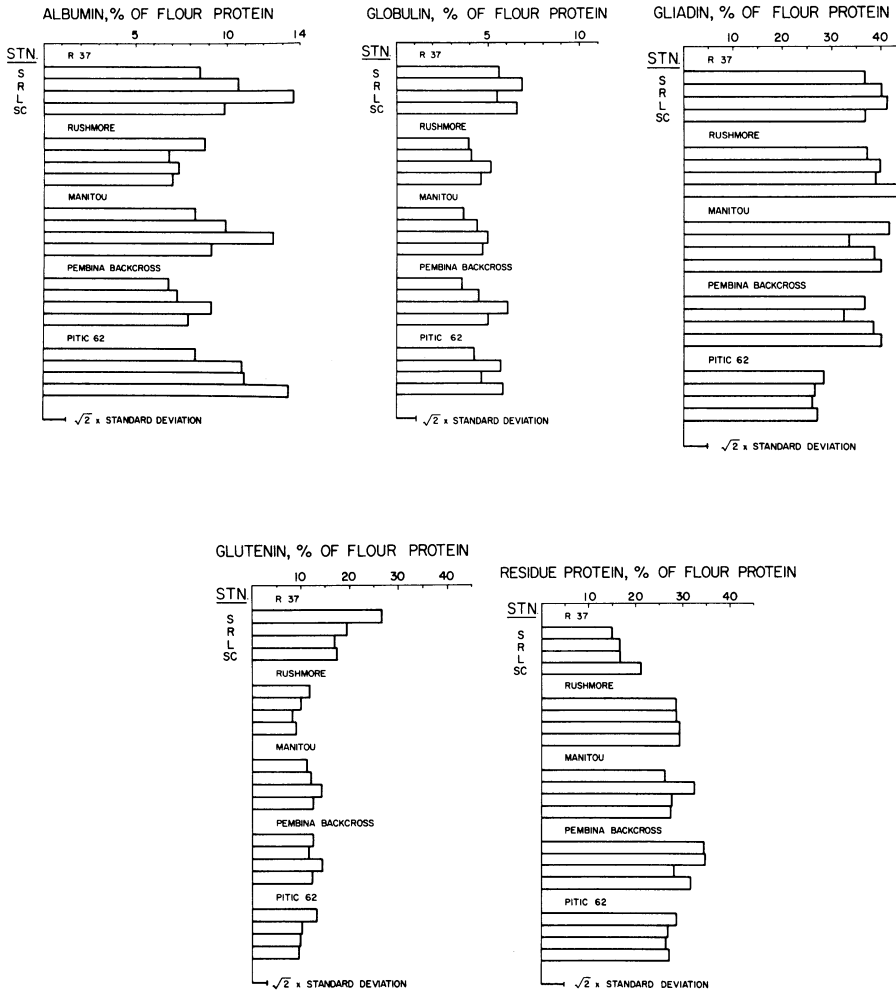
The five varieties used for this portion of the study were selected to represent extremes in baking quality. These comprised Rushmore, Manitou, and the Pembina backcross, which produced high loaf volumes for all stations; Pitic 62, with intermediate loaf volume; and the Italian variety, R37, which gave the lowest loaf volume for each station.

Figures 7 through 11 show the proportion of each protein fraction for the five varieties grown at four locations. The experimental error is also shown in order to indicate differences that are greater than experimental error.

Interstation variability among the albumins and globulins was most evident (Figs. 7 and 8). These differences were of the same order as the intervarietal differences discussed above. The proportions of gliadin, glutenin, and residue (Figs. 9, 10, and 11) were less sensitive to environment, although some differences were obtained.

Electrophoretic Results

Intervarietal differences in the electrophoretic patterns were observed for the albumin, globulin, and gliadin proteins (results not shown). These electropherograms are not shown, since the differences in the patterns of the albumins and globulins were only in a few very minor protein components and are considered insignificant. These could not be related to differences in baking quality. As found by others (8-12), marked intervarietal differences were evident in the patterns of the gliadins. However, as there was no obvious relationship between



Figs. 7–11. Interstation variation in the proportion of various protein solubility fractions in flours of five varieties (S = Saskatoon, R = Regina, L = Lethbridge, and SC = Swift Current). Top row: Water-soluble protein (albumin), salt-soluble protein (globulin), and aqueous ethanol-soluble protein (gliadin). Bottom row: Dilute acetic acid-soluble protein (glutenin), and residue or insoluble protein.

these differences and breadmaking quality, the patterns are not shown. Among the 26 wheats there were many related varieties that gave very similar gliadin electrophoretic patterns; some of these were quite different in baking quality.

No interstation variability in the electrophoretic patterns of the albumins, globulins, or gliadins of the five varieties selected for the interstation comparison was found. As found by others (9–12), the electrophoretic patterns of the varieties studied were governed by genotypic rather than environmental factors.

Acknowledgment

The wheat samples used in this study were grown under the supervision of A. B. Campbell, Canada Department of Agriculture Research Station, Winnipeg. This assistance is gratefully acknowledged.

Literature Cited

1. POMERANZ, Y. Relation between chemical composition and breadmaking potentialities of wheat flour. Advan. Food Res. 16: 335 (1968).
2. AMERICAN ASSOCIATION OF CEREAL CHEMISTS. AACC Approved methods (7th ed.). The Association: St. Paul, Minn. (1962).
3. IRVINE, G. N., and McMULLAN, MARION E. The "remix" baking test. Cereal Chem. 37: 603 (1960).
4. CHEN, C. H., and BUSHUK, W. Nature of proteins in Triticale and its parental species. II. Gel filtration and disc electrophoresis results. Can. J. Plant Sci. 50: 15 (1970).
5. WILLIAMS, P. C. The colorimetric determination of total nitrogen in feeding stuffs. Analyst (London) 89: 276 (1964).
6. POMERANZ, Y. Dispersibility of wheat proteins and aqueous urea solutions – a new parameter to evaluate breadmaking potentialities of wheat flour. J. Sci. Food Agr. 16: 586 (1965).
7. DRONZEK, B. L., KALTSIKES, P. J., and BUSHUK, W. Effect of the D genome on the protein of three cultivars of hard red spring wheat. Can. J. Plant Sci. 50: 389 (1970).
8. BOURDET, A., FEILLET, P., and METTAVANT, FRANCOISE. Sur le comportement electrophoretique des prolamines du blé en gel d'amidon. C. R. H. Acad. Sci. 256: 4517 (1963).
9. LEE, J. W., and WRIGLEY, C. W. The protein composition of gluten extracted from different wheats. Aust. J. Exp. Agr. Anim. Husb. 3: 85 (1963).
10. ELTON, G. A. H., and EWART, J. A. D. Glutenins and gliadins: Electrophoretic studies. J. Sci. Food Agr. 17: 34 (1966).
11. DOEKES, G. J. Comparison of wheat varieties by starch-gel electrophoresis of their grain proteins. J. Sci. Food Agr. 19: 169 (1968).
12. TANAKA, K., and BUSHUK, W. Effect of protein content and wheat variety on solubility and electrophoretic properties of flour proteins. Cereal Chem. 49: 247 (1972).

[Received September 15, 1971. Accepted December 10, 1971]