PROPERTIES OF WHEAT FLOUR PROTEIN IN FLOUR FROM SELECTED MILL STREAMS[1]

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ABSTRACT

The flour protein of eight selected streams from a pilot mill was studied. The protein content of flour streams from four varieties varied from 11 to 25% with the first and fourth midd streams being the lowest and the fifth break flour streams the highest. Yield of wet and dry gluten from the protein of flour streams was rather constant even though the protein contents of streams were markedly different. The protein fractions of two varieties were quantitatively determined by gel filtration. The relative amounts of the flour protein as the protein fractions glutenin, gliadin, albumin, and nonprotein nitrogen were a little different between flour streams, but the differences were not the same between the two varieties tested. Amino acid scores calculated from complete amino acid analysis indicated that lysine and threonine are nutritionally the first and second limiting amino acids, respectively, and the nutritional quality of the protein in different streams varies little.

There is a protein gradient upon moving from the center of the wheat endosperm to the outer sections. Kent (1), in 1966, reported a gradient of 8% protein content at the center to 43% in the subaleurone area for hard wheat; the gradient in soft wheat is much less. Also, he reported the presence of cubical cells just below the aleurone that were 33–54% in protein content. These cells are not as numerous in soft wheats as they are in hard wheats where they form a shell around the endosperm and account for 25% of the total endosperm protein (2).

Milling tends to concentrate various sections of the endosperm into different flour mill streams. Hinton (3) showed a progressive increase in protein content from the first to last break. This large variation in protein content among the various mill streams is believed to be due to the high protein subaleurone endosperm not being as easily reduced during roller milling as the inner endosperm (1). In commercial practice with bread wheat, streams are blended to produce several "grades" of flour varying in protein and ash content. Any unique properties of the protein of flour in an individual stream are not utilized.

No papers on investigating the flour protein in different streams were found in the literature. In this study, mill streams varying widely in protein content were characterized for gluten content, protein fractions, amino acid composition, and nutritional quality.

MATERIALS AND METHODS

Materials

Four hard red spring wheat varieties used for this study were Chris, Waldron, Era, and Red River 68. They were comparably grown at Casselton, N. D., in 1971.

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These four varieties were milled on a pilot mill by the method of Shuey and Gilles (4) after tempering to 15.5% moisture 18 hr before milling. Eight streams selected for this study were first break (1B), fourth break (4B), fifth break (5B), first midds (1M), second midds (2M), fourth midds (4M), bran dust (BD), and tailings (T). The yields of flour and ash content in streams are given in Table I.

Analytical Procedures

Protein and ash contents were determined according to AACC approved methods (5). Percent protein was calculated as 5.7 × percent nitrogen. Wet gluten content was determined on a Theby gluten washer (5), and dry gluten was determined by drying the wet gluten at 95° C in a vacuum oven at 27 in. vacuum for 16 hr. The gluten results are the average of duplicate analysis. Results of the above analyses are expressed on a 14% moisture basis.

The protein of the streams of Chris and Era were fractionated into glutenin, gliadin, albumin, and nonprotein nitrogen fractions by the chromatographic filtration method of Meredith and Wren (6), as modified by Bushuk and Wrigley (7). The molecular weight ranges used to determine relative amounts of protein classes were glutenins over 100,000 MW, gliadin 25,000–100,000 MW, albumins 10,000–25,000 MW, and nonprotein nitrogen under 10,000 MW. Relative amounts of protein in flour fractions were calculated from light absorption at 280 nm on fractions collected from the column. The results are the average of duplicate analyses. The standard deviations of the analyses, as estimated from the range of duplicates (8), were 4.2, 3.4, 1.9, and 2.8% for glutenin, gliadin, albumin, and nonprotein fractions, respectively.

Complete amino acid composition was determined on flour streams of Chris, Era, and Waldron. Samples were hydrolyzed with 6*N* HCl under nitrogen according to the method of Ahmed and McDonald (9). Analysis of the hydrolysates was performed on a Beckman 120B amino acid analyzer by the procedure of Benson and Patterson (10). For more accurate results, cystine was determined as cysteic acid and methionine as methionine sulfone after oxidizing the protein by the method of Moore (11). Tryptophan was determined on the amino acid analyzer by the method of Hugli and Moore (12). The amino acid results are the average of single chromotographic analysis on duplicate hydrolysates.

RESULTS AND DISCUSSION

Protein Content of Selected Streams

Grain protein content (14% moisture basis) was over 14% in all varieties except Era, where the protein content was 13.1%. The protein content of the selected eight mill streams from the wheats varied greatly (Fig. 1). Protein content of the fifth break streams was high (20–25%), as was the fourth break flour streams (16–20%). The lowest protein contents were found in the first and fourth midd streams, but these were not much lower than the bran dust or tailing streams. Kent (1) reported a progressive increase in protein content from first break flour (11.3%) to sixth break flour (21.1%), as well as a small increase in protein between the first and second midd streams (13.9% and 15.5%, respectively). Kent found that the high protein-containing streams were due to a higher percentage of high protein subaleurone cells present in the higher break flours. Similar protein contents were found in our study.

TABLE I
Yield of Flour and Ash Content[a]

Stream	Chris		Waldron[b]		Era[b]		Red River 68[b]	
	Yield %	Ash %	Yield %	Ash %	Yield %	Ash %	Yield %	Ash %
1 Break	1.6	0.46	1.1	0.59	0.9	0.56	1.0	0.63
2 Break	4.0	0.39	3.2	0.50	3.4	0.48	3.2	0.55
4 Break	2.9	0.44	2.8	0.53	2.8	0.53	2.5	0.55
5 Break	1.8	0.68	1.5	0.88	1.3	0.89	1.4	0.84
Break dust	3.6	0.38	2.9	0.48	2.8	0.45	2.7	0.51
1 Midds	12.7	0.26	12.7	0.30	14.7	0.32	13.6	0.32
2 Midds	5.5	0.30	6.3	0.33	7.1	0.35	6.9	0.36
3 Midds	11.0	0.28	12.8	0.33	12.2	0.33	12.9	0.37
4 Midds	9.0	0.29	9.4	0.33	10.0	0.34	10.5	0.35
3 Break	3.3	0.36		0.45		0.44		0.56
1 Sizing	1.7	0.35		0.39		0.40		0.46
2 Sizing	1.3	0.45	14.0	0.42	14.2	0.44	13.5	0.44
5 Midds	5.5	0.28		0.30		0.32		0.39
6 Midds	2.3	0.40		0.45		0.53		0.53
Tail	4.5	0.52	4.4	0.53	4.3	0.62	4.4	0.59
Low grade	2.9	0.91	2.7	0.98	2.3	1.19	2.5	1.01
Low quality	2.6	0.91	2.7	1.05	1.7	1.40	1.7	1.22
Flour extraction, %	76.2		76.4		77.8		76.8	

[a]14% moisture basis.

[b]3 break, 1 sizing, 2 sizing, 5 midds, and 6 midds were combined together without weighing in a previous study.

A correlation coefficient of 0.735** was obtained between protein and ash content given in Table I. Morris *et al.* (13), for endosperm taken from the center and peripheral zones, showed higher ash in the high protein peripheral zones than in the low protein center zones.

Protein Fractions in Selected Streams

Gluten content, as determined by machine washing, was highly correlated with protein content with correlation coefficients of 0.942** and 0.960**, respectively, for wet and dry gluten. Yields of gluten from the protein of streams were calculated, and the results are given in Table II. Gluten yields from stream protein were similar except for the break streams of Red River 68, where gluten was a little lower. The results with Red River 68 suggest that a small part of the lower quality reported for this variety may be due to low gluten in the protein of break streams.

The protein of the varieties Waldron and Era were separated into glutenin, gliadin, albumin, and nonprotein nitrogen fractions to determine if the quantity of these fractions might differ between mill streams. The small differences in protein fractions among the mill streams of Waldron and Era were not consistent (Table III). Even though the differences were small, the gliadin fraction varied

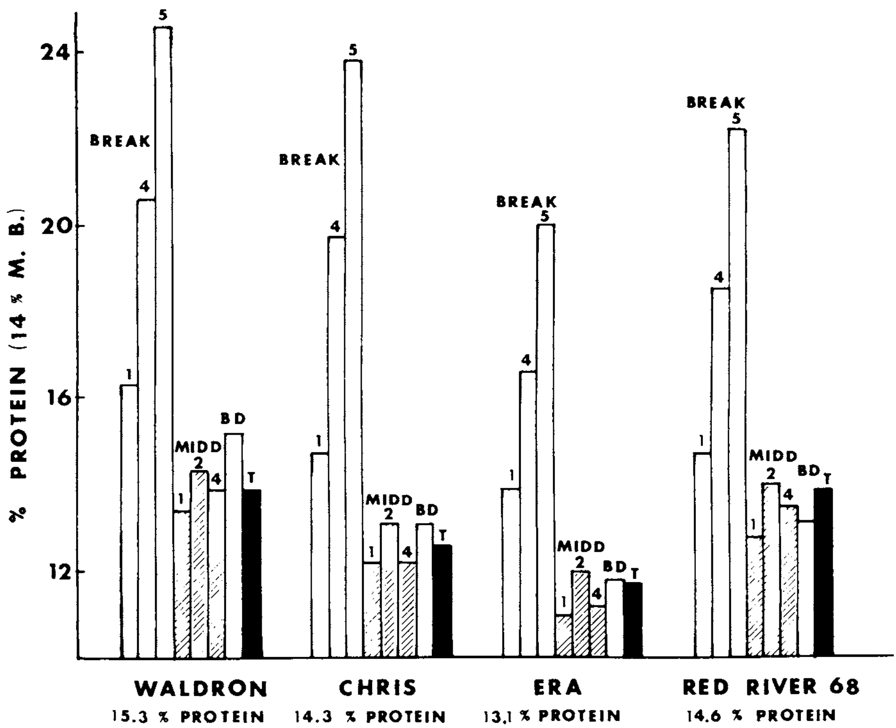

Fig. 1. Protein content of grain samples (bottom) and mill streams (bar graphs); BD = bran dust and T = tailing streams.

TABLE II
Per Cent Gluten Obtained from the Protein in Streams[a]

Stream	Chris		Waldron		Era		Red River 68	
	Wet %	Dry %	Wet %	Dry %	Wet %	Dry %	Wet %	Dry %
1B	322	115	310	103	293	101	255	91
4B	299	108	314	108	297	107	254	95
5B	282	102	268	108	306	100	242	92
1M	309	102	339	113	298	98	297	105
2M	306	104	331	117	298	102	290	101
4M	289	102	333	107	293	100	318	115
BD	307	107	320	116	290	97	274	98
Tail	286	96	294	104	274	92	283	103

[a]Expressed as % of the protein in the flour.

TABLE III
Protein Fractions in Mill Streams

Variety	Stream	Glutenin	Gliadin	Albumin	Nonprotein
		% of total flour protein			
Waldron	1B	26	45	18	10
Waldron	4B	27	44	20	8
Waldron	5B	30	45	19	5
Waldron	1M	27	52	16	5
Waldron	2M	27	43	20	11
Waldron	4M	31	41	19	9
Waldron	BD	27	47	14	12
Waldron	Tail	38	30	12	20
Era	1B	33	34	12	21
Era	4B	33	34	13	19
Era	5B	34	27	16	23
Era	1M	32	42	9	16
Era	2M	35	36	10	18
Era	4M	35	40	9	16
Era	BD	33	35	12	19
Era	Tail	31	31	16	22

TABLE IV
Analysis of Variance of Protein Fractions, Glutamic Acid, Proline, and the Chemical Score of Lysine

Variable	Chris F Values of Source=Stream[a]	Era F Values of Source=Stream[a]	Waldron F Values of Source=Stream[a]
Glutenin		0.188	3.040
Gliadin		4.572*	9.289**
Albumin		7.626**	3.295
Nonprotein N		3.298	6.199**
Glutamic acid	0.789	3.691*	1.080
Proline	0.867	5.499*	0.849
Amino acid score of lysine	3.024	2.051	2.597

[a]Degrees of freedom for source stream = 7 and error = 8.

TABLE V
Range in Amino Acid Composition of the Mill Streams from Three Varieties of Wheat[a]

Amino Acid	Mill Streams							
	1B	4B	5B	1M	2M	4M	BD	Tail
Lysine	2.0–2.0	1.8–2.0	1.8–2.0	2.0–2.1	2.0–2.2	1.9–2.1	1.9–2.2	2.2–2.4
Histidine	2.0–2.3	2.2–2.2	2.1–2.2	2.1–2.3	2.2–2.3	2.0–2.2	2.1–2.2	2.2–2.2
Ammonia	3.2–4.3	3.7–4.2	3.5–4.0	4.1–4.9	4.0–4.2	4.2–4.5	4.1–4.2	3.3–4.2
Arginine	3.5–3.8	3.6–4.0	3.7–4.1	3.4–3.8	3.6–3.7	3.3–3.9	3.5–4.7	4.0–4.6
Aspartic acid	4.4–5.1	3.5–4.6	3.8–4.4	4.1–4.7	4.2–4.4	4.5–4.6	4.4–5.4	4.7–6.3
Threonine	2.8–3.1	2.8–3.1	2.7–2.9	2.8–3.1	2.9–4.2	3.0–3.3	2.8–2.9	3.0–3.3
Serine	5.1–5.9	5.3–6.0	5.2–5.4	5.4–5.8	5.5–6.1	5.5–5.8	5.1–5.7	5.5–5.6
Glutamic acid	36–40	38–41	37–42	36–39	37–40	35–39	36–39	34–39
Proline	12–14	13–14	12–13	12–13	12–13	12–13	12–15	12–13
Glycine	3.3–3.8	2.9–3.5	3.5–3.7	3.4–3.8	3.4–3.6	3.6–3.7	3.4–3.8	3.7–4.0
Alanine	2.9–3.0	2.7–2.8	2.7–3.1	2.9–3.4	2.7–3.0	3.0–3.1	2.9–3.2	3.2–3.7
Cystine	2.4–2.8	2.2–2.6	2.1–2.6	2.1–2.8	2.3–2.4	2.3–2.7	2.3–2.7	2.5–2.8
Valine	4.2–4.7	4.1–4.4	4.1–4.7	3.9–4.2	3.9–4.1	4.0–4.4	3.9–4.2	4.0–4.6
Methionine	1.8–2.2	1.7–2.1	1.7–2.3	1.7–2.2	1.8–1.9	1.4–2.1	1.9–2.2	1.9–2.2
Isoleucine	3.6–4.1	3.4–4.1	3.7–4.1	2.9–3.5	3.2–3.7	3.2–3.7	3.1–3.7	3.1–3.6
Leucine	6.9–7.5	6.7–7.6	7.0–7.5	6.5–7.1	6.8–7.3	7.1–7.2	6.9–7.7	6.8–7.3
Tyrosine	2.2–3.1	2.5–3.0	2.6–2.9	2.8–2.9	2.4–3.1	3.0–3.3	2.6–3.6	2.7–3.1
Phenylalanine	5.0–5.5	5.1–5.6	5.2–5.6	4.9–5.4	4.9–5.6	5.1–5.7	5.0–6.6	4.9–5.4
Tryptophan	0.96–1.1	0.89–1.0	0.81–1.0	0.98–1.0	0.87–1.0	0.96–1.0	1.0–1.1	1.0–1.1

[a]Grams of amino acid per 16 g N, calculated to 100% N recovery from chromatographic column, except tryptophan.

TABLE VI
Amino Acid Score[a] of the Essential Amino Acids

Essential Amino Acid	Flour Mill Stream							
	Chris							
	1B	4B	5B	1M	2M	4M	BD	Tail
Isoleucine	103	103	104	87	92	93	93	90
Leucine	101	103	106	98	103	101	109	103
Lysine	36[b]	33[b]	33[b]	37[b]	40[b]	38[b]	37[b]	44[b]
Methionine + cystine	124	135	120	109	118	123	140	143
Phenylalanine + tyrosine	128	132	135	136	143	146	168	139
Threonine	70[c]	69[c]	67[c]	69[c]	74[c]	82[c]	71[c]	74[c]
Tryptophan	105	92	100	108	102	108	107	109
Valine	95	88	95	79	83	85	84	84
	Era							
	1B	4B	5B	1M	2M	4M	BD	Tail
Isoleucine	94	91	92	74[c]	81	88	87	88

Leucine	106	108	103	92	96	102	98	104
Lysine	37[b]	38[b]	37[b]	38[b]	39[b]	38[b]	40[b]	43[b]
Methionine + cystine	143	134	140	142	120	137	123	123
Phenylalanine + tyrosine	141	142	137	127	120	133	125	129
Threonine	77[c]	78[c]	73[c]	76	72[c]	74[c]	73[c]	82[c]
Tryptophan	116	106	108	107	104	110	109	108
Valine	84	89	83	82	79	88	84	92

	Waldron							
	1B	4B	5B	1M	2M	4M	BD	Tail
Isoleucine	86	86	97	84	83	80	79	78
Leucine	98	95	99	101	99	101	98	96
Lysine	37[b]	35[b]	35[b]	37[b]	36[b]	35[b]	35[b]	41[b]
Methionine + cystine	119	109	108	120	118	107	117	125
Phenylalanine + tyrosine	121	132	133	127	135	139	136	131
Threonine	72[c]	71[c]	73[c]	77[c]	74[c]	74[c]	74[c]	74[c]
Tryptophan	100	96	85	102	91	100	108	108
Valine	86	82	85	86	80	80	79	80

[a]Chemical score calculated using the provisional amino acid scoring pattern of the FAO (15).
[b]First limiting amino acid.
[c]Second limiting amino acid.

significantly between streams for both varieties, while the albumin and nonprotein nitrogen fraction were significantly different for only one of the varieties (Table IV).

Except for the tailing stream, Waldron contained more gliadin than glutenin in the mill streams (Table III). This was not true for Era, where only the first and fourth midd streams contained more gliadin than glutenin, while the rest of the streams contained about equal amounts or more glutenin than gliaden. Waldron streams contained a little more albumin than did Era in all but the tailing stream, and there was also a little less of the nonprotein nitrogen fraction in all streams.

Amino Acid Composition and Nutritional Quality

Complete amino acid composition of the protein in the flour mill streams of Chris, Era, and Waldron were determined. The data of Table V show that the two most abundant amino acids found in gluten, glutamic acid and proline, varied little among mill streams with ranges of 35 to 42 g/16 g N for glutamic acid and 12 to 15 g/16 g N for proline. The difference, however, was large enough to be significant for Era (Table IV). The other amino acids also varied little among the streams. Results for individual streams are given in a thesis (14).

The nutritional quality of the protein in the mill streams was estimated from the amino acid composition using the reference pattern recommended by the 1975 FAO/WHO Ad Hoc Expert Committee (15). The calculated amino acid scores (Table VI) indicated that the first and second limiting amino acids in all streams to be lysine and threonine, respectively, except in the 1M stream of Era, where isoleucine was the second limiting amino acid with a 2% smaller score than threonine. In general, the amino acid scores for the first limiting amino acid were quite similar with no significant differences indicated for lysine by analysis of variance (Table IV). Thus, the nutritional quality of the protein in different streams appears to be similar. This conclusion is also supported by the fairly small differences in protein fractions found among streams (Table III). These differences would not be expected to cause significant changes in the nutritionally limiting amino acids lysine, threonine, isoleucine, and valine because their variation in protein classes of wheat flour (16) is too small.

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