PROTEIN CONTENT OF SUCCESSIVE PERIPHERAL LAYERS MILLED FROM WHEAT, BARLEY, GRAIN SORGHUM, AND GLUTINOUS RICE BY TANGENTIAL ABRASION[1]

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ABSTRACT

The protein content of successive peripheral layers removed by a tangential abrasion process from wheat, barley, grain sorghum, and glutinous rice is shown to differ according to the depth of milling. In general, the higher concentration of protein is near the periphery of the whole grain, but it may be lower in the outermost layer if this layer is high in true bran constituents. The experimental data suggest that the milling technique may be adaptable to production of high-protein-content cereal flours.

In a previous publication (1) the authors reported on an effective laboratory technique which permitted controlled removal of successive layers of the rice kernel with minimum breakage of the residual kernel. Analysis of the fractions removed indicated that the protein distribution of the rice kernel was heterogeneous, and confirmed the occurrence of high-protein-bearing layers on the outer surface of the milled grain, as reported by Primo *et al.* (2,3).

The distribution of protein in other grain has received considerable attention by cereal investigators. Studies on wheat by Cobb (4) and Hinton (5) employing hand-dissection methods, by Morris *et al.* (6,7) using a dental drill for dissecting, and by Pomeranz and Shellenberger (8) by means of histochemical demonstration, all show the kernel endosperm to possess an uneven distribution of protein. The composition of the wheat endosperm also has been reported (9). Similarly, the distribution of protein in component parts of grain sorghum was shown by Hubbard *et al.* (10) using hand scalpel, and Watson *et al.* (11) demonstrated the existence of dense peripheral endosperm cells of high protein content in the kernel. However, similar investigations on the barley grain are not available in the literature.

This study was undertaken to determine the possibility of using the tangential abrasive device to remove successive layers of possible high-bearing protein material from wheat, barley, grain sorghum, and glutinous rice.

Materials, Apparatus, and Methods

Wheat Samples. The hard red winter wheat varieties used in this work were Bison and Triumph grown near Hays and Johnson, Kan-

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sas, respectively, in 1963. The soft red winter varieties used were Vermillion and Seneca grown near Huntington, Indiana, and Sandusky, Ohio, respectively, in 1963. They were obtained from the Northern Utilization Research and Development Division, Peoria, Illinois.

Barley Samples. The barley varieties used were Betzes (B-61-2819), Atlas 46 (B-62-3317), and Trophy (B-63-97). They were obtained from the Barley and Malt Laboratory, Madison, Wisconsin. All three samples were received in the hull[2] and processed as such as starting material.

Grain Sorghum Samples. The grain sorghum hybrids used were Texas 601, RS 610, and a mixed sample referred to as Elevator run. They were obtained from Harvest Queen Mill & Elevator Co., Plainview, Texas. All three samples were received as commercial grain and used as starting material.

Glutinous Rice Samples. Glutinous rice, obtained from South Dos Palos, California, was received as rough rice and was dehulled in the McGill sheller[3] according to a recognized laboratory method (12).

Apparatus. The device used for deep milling was essentially that used by Hogan *et al.* (1). Sample kernels were tangentially abraded with a knurled steel disk (surfaced by Armstrong Standard faced diamond knurls, 33 pitch), 6 in. in diameter and ½ in. thick, which revolved in a horizontal plane at a selected speed (by means of a variable transformer). Mounted vertically above the disk and to one side of its center of rotation was a length of open glass tubing, 2 in. in diameter and 5 in. long, positioned to allow minimum clearance between the lower edge of the tube and the rotating disk. A Plexiglas-covered housing of stainless steel surrounded the disk and tube, serving to collect the material removed.

Methods. Total protein nitrogen of all grains tested and flour fractions removed was determined by the AOAC Official Method (13). Nitrogen determined in this way was calculated as percentage on moisture-free basis. Percentage protein was computed by multiplying the nitrogen percentage by the factor 6.25 to give crude protein (14).

Moisture content of the grain samples and flour fractions removed was determined by the AMS method (15).

All foreign material and broken kernels were removed from the samples tested.

[2] The use of the word hull refers to the components known as glumes, palea, and lemma. Samples without these components are referred to as dehulled.

[3] It is not the policy of the Department to recommend the products of one company over those of any others engaged in the same business.

Experimental

By the same procedure and equipment employed on rice samples in the previous publication (1), successive peripheral layers of the wheat kernels were removed and collected as fractions. The fractions removed from the grains, as well as the residual kernels, were weighed at selected intervals to determine the percentage by weight of the original kernel removed in that particular fraction. The residual kernels and the fractions material, along with the original grain, were analyzed for protein and moisture content. Before analysis, all fractions were passed through 20-mesh sieve to remove any broken grains. Embryo or pericarp particles also retained on the sieve mesh were hand-separated as well as possible from the broken grains. These embryo and pericarp particles were ground in the Wiley mill through 60-mesh and mixed with the flour (of that fraction) which passed through 20-mesh.

The same procedure was followed for barley, grain sorghum, and glutinous rice.

Results and Discussion

The weight and protein content of successively removed fractions of the wheat, barley, grain sorghum, and glutinous rice are presented in Tables I, II, III, and IV respectively. Fractions removed throughout this investigation do not necessarily contain only specific layers or component parts of the kernel. The fractions represent the material scoured off by abrasion and expressed as percentage by weight removed from the original kernel.

Wheat. The protein content of fractions removed from the two hard varieties ranged from 11.63 to 24.31% (Table I). The lowest concentrations of protein were obtained in the first fraction of both varieties — Bison 11.63% and Triumph 15.30%, representing 4.54 and 7.09% by weight removed. The highest concentrations of protein, 24.13 and 24.00%, were found in the fourth and second fractions from Bison and Triumph, respectively, representing 6.89 and 5.66% by weight removed. This would seem to indicate that after removal of practically all of the pericarp and aleurone layer in the first fraction, there is a zone of high-protein-bearing material in the kernel of the two hard wheat varieties. This zone is an integral part of the starchy endosperm immediately under the aleurone layer and is 7–8% higher in protein than the original kernel.

The fact that the first fraction, containing the outer layers of the kernel, is lower in protein content than the next fraction was also

TABLE I

WEIGHT AND PROTEIN CONTENT OF SUCCESSIVELY REMOVED FRACTIONS OF FOUR WHEAT VARIETIES
(Dry weight basis)

Variety and Fraction	Kernel Weight Removed	Total Cumulative Weight Removed	Protein in Fraction	Amount of Total Protein in Fraction	Total Cumulative Amount of Protein Removed
	%	%	%	%	%
Bison					
1	4.54	4.54	11.63	3.03	3.03
2	6.96	11.50	21.63	8.63	11.66
3	4.14	15.64	23.88	5.67	17.33
4	6.89	22.53	24.31	9.60	26.93
5	5.24	27.77	24.31	7.30	34.23
6	21.89	49.66	19.32	24.25	58.48
	Protein content: original kernel, 17.44%; residual kernel, 13.13%				
Triumph					
1	7.09	7.09	15.30	6.50	6.50
2	5.66	12.75	24.00	8.14	14.64
3	8.11	20.86	23.07	11.21	25.85
4	10.38	31.24	21.38	13.29	39.14
5	18.51	49.75	18.13	20.11	59.25
	Protein content: original kernel, 16.69%; residual kernel, 12.82%				
Seneca					
1	8.14	8.14	10.25	6.61	6.61
2	6.08	14.22	12.31	5.93	12.54
3	8.41	22.63	12.31	8.20	20.74
4	14.43	37.06	12.69	14.50	35.24
5	13.15	50.20	11.57	12.05	47.29
	Protein content: original kernel, 12.63%; residual kernel, 11.93%				
Vermillion					
1	6.78	6.78	10.68	5.49	5.49
2	7.57	14.35	14.26	8.19	13.68
3	11.60	25.95	13.75	12.10	25.78
4	8.43	34.38	13.62	8.71	34.49
	Protein content: original kernel, 13.18%; residual kernel, 12.31%				

noted for rice (1), and could likewise be attributed to the presence of true bran in the first fraction. However, it is expected that there are some differences in abrasive milling of wheat and rice because of their unlike kernel shape, etc.

It was necessary to remove approximately 12–15% by weight of the original kernel to ensure fairly complete removel of the bran layer. Because of the natural shape of the wheat kernel, some bran remained in the crease even after several fractions were removed.

Fractions showing the highest percentage of protein were those fractions removed from the two hard varieties, which likewise were the highest in original protein content. Bison showed practically the same percentage of protein in its highest-protein-bearing fraction as Triumph, but apparently in deeper layers of the kernel.

The two soft varieties gave no fractions which exceeded by very much the total percentage of nitrogen of the original kernel. Fraction 2 of Vermillion showed the highest protein content for the soft varieties, yet was only 1% higher in protein than the original kernel. This property of the soft varieties could very well be related to either the heterogeneous distribution of protein, or the manner in which fractions are removed, e.g., in increments of 6 to 14% by weight.

Pfeifer and Griffin (16), by fine-grinding and air-classification of soft and hard wheat flours, have indicated that a wider range of protein composition was obtainable from the soft wheat flours than from the hard.

The high-protein wheat flour, obtained by removal of the peripheral layers using tangential abrasion milling, has not been evaluated in bakery products or for other conventional uses of wheat flour.

Barley. Data for barley are presented in Table II. The results show that the proteinaceous material, with the exception of the first 11–13% by weight, is more concentrated in the outer portions of the kernel. There was a decrease in the percentage of protein of the fractions

TABLE II
WEIGHT AND PROTEIN CONTENT OF SUCCESSIVELY REMOVED FRACTIONS OF THREE BARLEY VARIETIES
(Dry weight basis)

Variety and Fraction	Kernel Weight Removed	Total Cumulative Weight Removed	Protein in Fraction	Amount of Total Protein in Fraction	Total Cumulative Amount of Protein Removed
	%	%	%	%	%
Betzes					
1	11.87	11.87	10.13	11.51	11.51
2	8.63	20.50	21.44	17.72	29.23
3	14.35	34.85	16.93	23.27	52.50
4	7.02	41.87	12.88	8.66	61.16
5	8.55	50.42	10.32	8.45	69.61
	Protein content: original kernel, 10.44%; residual kernel, 5.81%				
Atlas					
1	11.34	11.34	5.87	6.54	6.54
2	10.60	21.94	18.37	19.11	25.65
3	9.78	31.72	18.25	17.51	43.16
4	9.62	41.34	14.13	13.34	56.50
5	9.06	50.40	11.00	9.78	66.28
	Protein content: original kernel, 10.19%; residual kernel, 6.82%				
Trophy					
1	13.63	13.63	7.50	8.22	8.22
2	9.97	23.60	24.19	19.39	27.61
3	7.10	30.70	21.76	12.42	40.03
4	7.93	38.63	17.88	11.40	51.43
5	12.50	51.13	13.62	13.69	65.12
	Protein content: original kernel, 12.44%; residual kernel, 9.07%				

during scouring as the center of the kernel was approached. The residual kernel, representing 50% of the original kernel, is considerably lower (3–4%) in protein content than the original, starting kernel.

For each variety it was necessary to remove approximately 11–14% by weight of the original barley kernel to obtain a practically dehulled kernel. This fraction (fraction 1) represents the hull layer surrounding the original barley grain, plus some embryo and pericarp layer material. Fraction 2 had the highest protein content and represented material from high-protein-bearing layers in the barley kernel. The portions removed thereafter, fractions 3, 4, and 5, were decreasingly lower in protein content, in that order.

Also, as was found for the wheat varieties, Table II shows that the fractions containing the highest percentage of protein were obtained for the barley variety containing the highest initial protein.

Grain Sorghum. The data obtained on three samples of grain sorghum show that the protein distribution is heterogeneous in the kernel (Table III). The protein content of the fractions (removed from the grain sorghum), with the exception of the first fraction, decreased as scouring progressed from the outer to the innermost

TABLE III

WEIGHT AND PROTEIN CONTENT OF SUCCESSIVELY REMOVED FRACTIONS OF THREE GRAIN SORGHUM HYBRIDS

(Dry weight basis)

Variety and Fraction	Kernel Weight Removed	Total Cumulative Weight Removed	Protein in Fraction	Amount of Total Protein in Fraction	Total Cumulative Amount of Protein Removed
	%	%	%	%	%
Elevator run					
1	9.72	9.72	10.06	8.55	8.55
2	7.52	17.24	20.13	13.23	21.78
3	7.78	25.02	19.00	12.92	34.70
4	9.05	34.07	15.94	12.61	47.31
	Protein content: original kernel, 11.44%; residual kernel, 9.75%				
Texas 601					
1	6.68	6.68	9.81	5.43	5.43
2	7.53	14.21	27.06	16.90	22.33
3	5.78	19.99	26.93	12.91	35.24
4	6.60	26.59	22.25	12.18	47.42
5	5.67	32.26	18.01	8.46	55.88
	Protein content: original kernel, 12.06%; residual kernel, 8.07%				
RS 610					
1	11.53	11.53	12.88	12.91	12.91
2	8.89	20.42	23.13	17.88	30.79
3	8.93	29.35	24.07	18.68	49.47
4	8.15	37.50	17.38	12.31	61.78
	Protein content: original kernel, 11.50%; residual kernel, 7.75%				

portions of the kernel. In the RS #610 sample, however, material in fraction 3 was highest in protein content, probably because of the greater amount separated in fraction 1 (which probably contains more of the outer endosperm, normally taken off as part of the second fraction). The first approximate 6–12% by weight of the original grain sorghum kernel was apparently almost entirely bran layer, along with some embryo, and is represented by fraction 1.

Results indicate that there exists in the grain sorghum endosperm freed of germ and bran, a fraction of high-protein-bearing material having an average protein content of more than 18%, representing about one-fourth of the weight of the original kernel.

TABLE IV
WEIGHT AND PROTEIN CONTENT OF SUCCESSIVELY REMOVED FRACTIONS OF GLUTINOUS BROWN RICE
(Dry weight basis)

FRACTION	KERNEL WEIGHT REMOVED	TOTAL CUMULATIVE WEIGHT REMOVED	PROTEIN IN FRACTION	AMOUNT OF TOTAL PROTEIN IN FRACTION	TOTAL CUMULATIVE AMOUNT OF PROTEIN REMOVED
	%	%	%	%	%
1	11.25	11.25	16.19	21.59	21.59
2	7.88	19.13	16.06	15.00	36.59
3	9.87	29.00	11.19	13.09	49.68
Protein content: original kernel, 8.43%; residual kernel, 6.12%					

Glutinous Rice. The data given in Table IV indicate the presence of high-protein-bearing material in the rice kernel which is located mostly in the outermost layers. Further, the table also shows that the protein content of the fractions removed from the kernel decreased progressively, going into the kernel.

In our previous paper (1) mention was made of the approximate 4–6% by weight of the original brown rice kernel removed in fraction 1 (low-protein-bearing material except for the embryo), which is lower in protein content than each of the next successive fractions. Fraction 1 of the sample of glutinous brown rice is slightly higher in protein content than the succeeding fraction because of the amount (percentage by weight) removed, and this probably involved further penetration into the high-protein-bearing area of the endosperm.

Summary. Results of this investigation show that by use of an abrasive milling device, the existence of high-protein-bearing layers on the outer portions of several cereal grains is substantiated. The technique described also makes it possible to obtain flour of high protein content in quantity. However, these high-protein flours removed from the several peripheral layers of the different grains have not

been tested in bakery products or for other conventional flour uses.

For hard wheat varieties, flour with protein as high as 24% (dry weight basis) could be realized, whereas the protein content of flours obtained from peripheral layers of soft varieties was about the same as for whole kernels. Barley varieties yielded flour as high as 24% protein also, while grain sorghum gave fractions as high as 27% protein, the highest of the four grains tested. The flour of highest protein content for the rice was 16–19%, practically double that of the original kernel.

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