Nutritional Profile of a Fraction from Air-Classified Bran Obtained from a Hard Red Wheat

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ABSTRACT

Pooled coarse and fine bran (12.5% of the kernel weight) from a hard red winter wheat was air-classified to identify a fraction rich in nutrients. Compared to the original bran, the identified fraction (yield 14%) contained more protein (22.1% vs. 14.9%), ash (14.7% vs. 6.9%), fat (6.1% vs. 2.7%), and soluble fiber (5.2% vs. 2.4%), but less total fiber (24.9% vs. 49.2%). This fraction also contained 24% more Ca, 76% more K, 89% more Zn, 107% more Cu, 109% more Fe, 123% more Mg, 142% more P, 44% more riboflavin, 94% more thiamin, and 117% more niacin than the original bran. All essential amino acids were also present in higher amounts (lysine by 44%) in the identified fraction. The protein efficiency ratio of the identified bran fraction measured 1.8 (casein, 2.5), the apparent protein digestibility 82.6% (casein, 90.8%) and the carcass nitrogen retention 43.8% (casein, 57.4%). Because this fraction is low in fiber, it may be more functional for use in bakery foods than the original bran.

Wheat bran and the closely related mill fraction shorts consist primarily of aleurone layer, seed coat, and the pericarp layer of wheat. They represent about one-fifth of the wheat kernel. Wheat bran typically contains 6–7% ash, 14–16% protein, and 45–50% dietary fiber (Halverson and Zeleny 1988). The fiber in bran is primarily insoluble fiber (Ranhotra et al 1990).

Wheat bran is an effective fecal bulking agent, and, thus, may reduce the risk of certain diseases of the gastrointestinal tract, including colon cancer (Pilch 1987). However, its use in many foods, including bakery products, is limited because of its adverse effect on product quality, especially because of the high level of fiber. Finely ground and air-classified bran may yield one or more fractions with better functional characteristics than that of the original bran. Recently, Posner (1991) reported a method to separate bran using a Pillsbury Huricane Turbo air-classifier. That study focused primarily on identifying a bran fraction high in fiber. However, the fiber, ash, and protein contents of the resultant fractions either differed minimally or were lower as compared to the original bran.

The present study was aimed at identifying a bran fraction high in protein and micronutrients, but one that contained about half of the fiber in the original bran. Such a fraction is likely to be more functional for use in bakery products and could be produced commercially by simply incorporating the process into the existing milling operation. The nutritional profile of this potential fraction is presented here.

MATERIALS AND METHODS

Wheat Bran

Sufficient quantities of bran from a hard red winter wheat milled (flour extraction rate, 74%) in the pilot flour mill at the Department of Grain Science, Kansas State University, were obtained and used in all phases of this study. The bran used was pooled coarse and fine bran, and it represented 12.5% of the kernel weight. The particle size of this bran averaged about 900 μm, and it contained 6.9% ash, 14.9% protein, and 49.2% dietary fiber.

Air-Classification of Bran

In the preliminary (first) phase of this study, bran was ground using a Bauer H-7 grinder (Combustion Engineering, Springfield, OH) with the feed rate set at 6, 3, or 2 lb/hr. The ground bran was then separated in the Pillsbury Huricane Turbo air-classifier. Classifier settings used, and bran fractions obtained, in the preliminary phase (and the subsequent phases) of this study are shown in Figure 1. All fractions were analyzed for ash, protein, and fiber (Table I). Based on these analyses, fraction A (at a

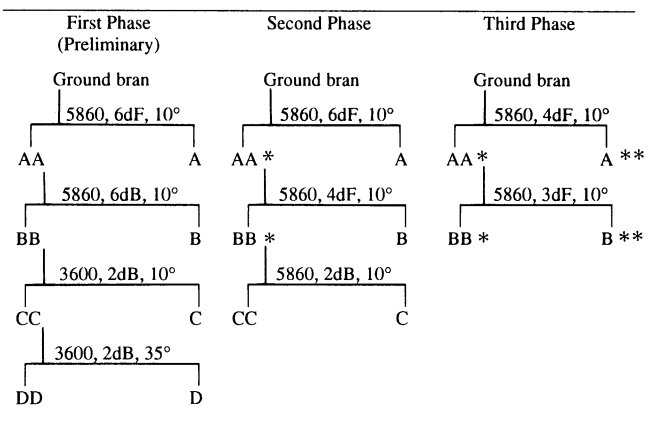

Fig. 1. Air-classification of wheat bran and resultant fractions. Classifier settings: speed (rpm) 5,860 or 3,600; deck setting 2, 3, 4, or 6 deck forward (dF) or deck backward (dB); louver curtain angle 10° or 35°. Bran ground at a feed rate of 6, 3, or 2 lb/hr (first phase), and 4.8 lb/hr (second and third phases). * = Fractions not collected. ** = Median particle size of the combined fractions A and B (third phase) averaged 6.37 μm (range values: 5.96–6.96 μm).

TABLE I
Composition of Air-Classified Wheat Bran Fractions (Preliminary Phase)

Bran Fraction	Percent Composition[a,b]								
	Protein			Ash			Fiber		
A (fine)	22.2	...	21.6	7.3	...	12.5	14.1	...	28.2
AA (coarse)	14.0	...	12.9	5.5	...	4.6	47.5	...	52.1
B (fine)	16.8	17.0	16.5	8.2	9.0	8.4	33.0	35.6	38.2
BB (coarse)	12.4	12.6	12.1	4.9	4.1	3.6	51.2	53.4	55.5
C (fine)	13.4	13.6	14.2	4.5	5.0	6.0	40.1	44.0	39.9
CC (coarse)	...	...	...	...	...	...	...	...	...
D (fine)	13.8	14.4	13.5	4.6	5.2	4.6	40.1	41.7	45.4
DD (coarse)	13.2	11.8	11.3	5.2	3.7	3.3	56.0	61.2	63.4

[a] Original bran contained 14.9% protein, 6.9% ash, and 49.2% total dietary fiber.
[b] Set of values correspond with bran feed rate of 6, 3, or 2 lb/hr, respectively. Missing values are due to lack of samples.

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feed rate of 2 lb/hr) was selected for further investigations.

Because fraction A had the targeted composition but showed only a 2% yield, changes were made in grinding feed rate and air-classification settings to increase the yield of this fraction. The grinding feed rate was increased to 4.8 lb/hr (Fig. 1), and the four fractions obtained were again analyzed (Table II). Fractions A and B showed nearly similar compositional values that also matched with values for fraction A identified in the preliminary study. Fractions A and B together showed a yield value of 10%. Some further adjustments of the classifier settings (third phase) (Fig. 1) increased the yield of this fraction (fractions A and B combined) to 14%. Large quantities of this fraction were saved for more detailed analytical and animal studies (Tables III–V).

TABLE II
Composition of Air-Classified Wheat Bran Fractions (Second Phase)

Bran Fraction	Percent Composition		
	Protein	Ash	Fiber
A (fine)[a]	20.1	11.8	30.1
B (fine)[a]	19.5	11.1	29.5
C (fine)	16.1	7.9	37.6
CC (coarse)	12.0	3.5	56.2

[a] Yield value (A + B): ~10%.

TABLE III
Composition of Original Bran and Air-Classified Bran Fraction (Third Phase)

	Bran	
	Original	Selected Fraction[a,b]
Macronutrients, %		
Protein	14.9	22.1
Fat	2.7	6.1
Ash	6.9	14.7
Moisture	7.8	7.3
Total fiber	49.2	24.9
Insoluble fiber	46.8	19.7
Soluble fiber	2.4	5.2
Carbohydrates	18.5	24.9
Micronutrients, mg/100 g of sample		
Calcium	105	130
Copper	1.4	2.9
Iron	9.1	19.0
Potassium	1,896	3,333
Magnesium	647	1,443
Zinc	10.9	20.6
Manganese	12.1	10.2
Sodium	5	5
Phosphorus	1,493	3,608
Phytic acid phosphorus	1,012	2,224
Riboflavin	0.36	0.52
Thiamin	0.50	0.97
Niacin	36.2	78.6
Essential amino acids, %		
Arginine	1.01	1.92
Valine	0.46	0.66
Histidine	0.51	0.77
Isoleucine	0.33	0.44
Leucine	0.86	1.25
Lysine	0.57	0.82
Methionine	0.19	0.29
Half cystine	0.18	0.24
Phenylalanine	0.50	0.73
Tyrosine	0.45	0.58
Threonine	0.49	0.67

[a] Yield value: 14%.
[b] The nonselected bran fraction (pooled fractions) contained 13.2% protein, 4.3% ash, 51.1% total fiber, and 0.859% phosphorus (67% as phytic acid phosphorus).

Animal Studies

Animal studies were limited to assessing protein quality by the standard protein efficiency ratio (PER) method of AOAC (1990), except that the test diets contained more fiber than that specified in the method (Table IV). Protein nutritive value was also assessed based on apparent protein digestibility (protein intake corrected for fecal protein loss) and nitrogen balance (based on carcass analysis) studies conducted simultaneously. Total fecal collection was made throughout the four-week study period. The same groups of rats were used for all three determinations.

Analytical Data

Standard AACC (1983) methods were used to determine protein (N × 5.7, N × 6.25 for casein), fat (ether extract), ash, and moisture. Fiber (total, insoluble, and soluble) was determined by the enzymatic-gravimetric method of Prosky et al (1992). Minerals, except phosphorus, were determined by atomic absorption or flame emission (sodium) spectrophotometry using an IL model Video 11 (Allied Analytical Systems, Andover, MA). Total phosphorus was determined colorimetrically (Fiske and Subbarow 1925). Phytate phosphorus was determined by the method of Thompson and Erdman (1982). Thiamin and riboflavin were determined fluorometrically. Niacin was determined by the cyanogen bromide method. Vitamin determinations used the standard AACC (1983) methods. Bran and bran fractions were analyzed for particle size distribution using a Horiba Model CAPA 300-particle size analyzer. This analyzer is designed to measure particle size using a noncontact optical transmission method. Measurements are based on the liquid-phase sedimentation method (dispersion medium, 100% ethanol; medium density, 0.789 g/cm^2; medium viscosity coefficient, 1.20 cp; sample density, 1.3 g/cm^2).

TABLE IV
Percent Composition of Test Diets

Components	Casein Diet	Bran Diet
Casein test material	11.5	...
Bran test material	...	41.2
Vitamin mix	1.0	1.0
Mineral mix	5.9	...
Calcium sulfate	...	0.5[a]
Fiber (cellulose)	10.3	...
Soybean oil	7.9	5.5
Water	4.0	2.0
Corn starch	59.4	49.8

[a] Provided 150 mg of calcium.

TABLE V
Protein Quality of Selected Bran Fraction[a]

	Protein Source	
	Casein	Bran Fraction
Protein efficiency ratio (PER)		
Protein intake, g	38.2 ± 2.8 a	29.3 ± 3.3 b
Body weight gain, g[b]	131 ± 14 a	71 ± 10 b
PER (determined)	3.4 ± 0.2 a	2.4 ± 0.1 b
PER (corrected)	2.5 ± 0.2 a	1.8 ± 0.1 b
Apparent protein digestibility		
Protein intake, g[c]	38.2 ± 2.8 a	26.7 ± 3.0 b
Protein digested, %	90.8 ± 0.4 a	82.6 ± 0.4 b
Nitrogen (N) balance		
N intake, g	6.1 ± 0.5 a	4.8 ± 0.5 b
Increase in carcass N, g[d]	3.5 ± 0.3 a	2.1 ± 0.2 b
N retained, % of intake	57.4 ± 3.2 a	43.8 ± 2.2 b

[a] Values are averages (8 rats per diet) ± standard deviation. Within a row, averages not sharing a common letter are significantly different ($P < 0.05$).
[b] Initial body weight: 47 ± 2 g.
[c] For digestibility studies, protein in bran is calculated using nitrogen conversion factor of 5.7. For the PER study, the method specifies the conversion factor of 6.25.
[d] Initial (0 day) carcass N: 1.1 ± 0.1 g.

Amino acids, except tryptophan, were determined using a Dionex D-300 amino acid analyzer component system (Dionex Corp., Sunnyvale, CA). Hydrolyzed and filtered samples were stored in a freezer until analyzed for amino acids using a single-column accelerated system.

At the end of the PER study, all rats were sacrificed for carcass nitrogen analysis using a slightly modified version of the method of Ranhotra and Johnson (1965). The gut contents of the rats were removed and discarded, the carcasses weighed, autoclaved (121°C, 15 psi, 1.5 hr) in excessive water (the original method autoclaved in hydrochloric acid), thoroughly homogenized in a blender, freeze-dried, and finely ground. Suitable aliquots of the finely ground carcasses were analyzed for nitrogen.

Statistics

Data in Table V (animal studies) were analyzed by analysis of variance using the Statistical Analysis System (SAS 1982).

RESULTS AND DISCUSSION

Preliminary Studies

The four sets of fine and coarse bran fractions analyzed showed a distinct pattern of distribution of protein, ash, and fiber. Within each set, the fine fraction invariably contained more protein and ash, but less fiber than did the coarse fraction (Table I). Among all eight fractions collected, fine fraction A from the grinding feed rate of 2 lb/hr was highest in ash (12.5%), near highest in protein (21.6%), and contained an acceptable (28.2%) level of fiber. This fraction, however, showed a low yield value. Subsequent changes made in the classifier settings and the grinding feed rate increased the yield to 10% in the second phase (Table II) and to 14% in the third phase (Table III) of the study. Before the targeted fraction was obtained in large quantities, the experiment (air-classification) was repeated twice. The median particle size of the targeted fraction banded in a narrow range (Fig. 1) in all three collections. This suggests that the compositional value of the targeted fraction is likely to change minimally if the classifier settings are maintained as shown (Fig. 1).

Composition of Selected Bran Fraction

The bran fraction finally selected for detailed evaluation (third phase) contained 48% more protein, 113% more ash, and 126% more fat than that of the original bran (Table III). This fraction also contained twice as much soluble fiber compared to the original bran, although its total fiber content was only half as much as the original bran. These differences may be due to a simple dilution effect: insoluble fiber was fractionated (decreased) but not the soluble fiber.

The selected fraction was also high in several micronutrients. It contained 107% more copper, 109% more iron, 76% more potassium, 123% more magnesium, and 89% more zinc than did the original bran (Table III). These are all critical nutrients in our diet. The increase in calcium content was modest. While manganese showed a slight decrease, phosphorus content showed an increase of 142%. Most of this phosphorus occurred as phytic acid phosphorus: 62% in the selected fraction and 68% in the original bran (Table III). Although phytic acid may interfere with the absorption of certain mineral elements such as zinc (Ranhotra et al 1979), it is usually sufficiently hydrolyzed in products such as yeast-fermented baked foods and would not be a source of nutritional concern. Both test materials were virtually free of sodium.

The selected bran fraction also contained 44% more riboflavin, 94% more thiamin, and 117% more niacin than did the original bran (Table III). It likely also contained higher levels of certain other vitamins such as folic acid, pyridoxine, and pantothenic acid, but this was not documented.

Unlike most other nutrients, the nutritional value of protein in foods depends both on the amount present and its quality. The essential amino acid profile is the major determinant of protein quality. All essential and semiessential amino acids were present in appreciably higher amounts in the selected bran fraction as compared to the original bran. Lysine, the most limiting amino acid in cereal protein, was present at a level 44% higher than that of the original bran (Table III).

The pooled fractions from air-classification in the third phase of the study (Fig. 1), which accounted for the other 86% of the bran sample, was analyzed for only a few components (Table III). It contained less protein, less ash, less phosphorus, and less phytic acid phosphorus than did the original bran. It did, however, contain a little more fiber (51.1% vs. 49.2%).

Biological Evaluation of Protein Quality

Protein quality of the selected bran fraction was assessed based on the PER method as well as on protein digestibility and nitrogen balance measurements (Table V). The PER (corrected) value obtained for the bran fraction averaged 1.8, which is nearly three-fourths of the value (2.5) typically assigned to casein. PER values for whole wheat flour and the bran fraction generally fall in the range of 1.0–1.5 (Satterlee et al 1981). Thus, the higher PER value of the selected bran fraction would mean an improvement in protein quality of grain-based foods when the selected fraction is incorporated in the formula.

Protein in grain-based foods is usually less well-digested compared to that in milk, as the results in Table V seem to suggest. The digestibility of protein in the selected bran fraction was 8.2% lower as compared to casein. This may, in part, be due to the adverse effect of naturally occurring fiber on protein digestibility (Ranhotra et al 1971). A similar pattern emerged when increases in carcass nitrogen (nitrogen balance) between the two groups of rats are compared. While casein-fed rats showed a nitrogen retention efficiency of 57.4%, such an efficiency was 13.5% lower in rats fed the selected bran fraction. The differences between the two groups of rats were of a narrower magnitude for protein digestibility than they were for PER and nitrogen retention measurements, apparently because the later measurements consider not only the differences in protein digestibility, but also the differences in the efficiency of utilization of digested or absorbed amino acids.

CONCLUSIONS

Although the selected bran fraction contains less fiber than the original bran, it otherwise reveals an impressive nutrient profile. This is true not only when compared with values typical for wheat bran, but also when compared with values typical for whole wheat flour. This fraction is also lighter in color than whole wheat flour. These characteristics may allow for the successful commercial incorporation of this fraction in a variety of grain-based foods.

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