Protein Concentrates from Oat Flours by Air Classification of Normal and High-Protein Varieties[1]

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ABSTRACT

Oat groats, as well as first and second flours, from a high-protein variety (Garland) and from a normal-protein variety (Sioux) were finely ground and air-classified to yield fractions with protein contents (nitrogen X 6.25) ranging from 4 to 88%. Air classification of the oat flours produced a unique fraction (83 to 88% protein) not previously observed for wheat, rye, corn, sorghum, or triticale flours. This fraction (2 to 5% by weight) accounted for 14, 16, and 7%, respectively, of the total protein in first and second flours and groats. The next fraction (25 to 29% by weight) with 15 to 39% protein accounted for total protein from flours of 38 to 48%, and with 21 to 29% protein from groats, 31 to 33%. The first and second flours gave a better air-classification response than ground groats, and the high-protein variety gave better results than normal-protein oats. Amino acid analysis of all fractions indicated high-lysine levels from 3.9 to 5.0 g. per 16 g. nitrogen and adequate total sulfur amino acids. Data showed that air classification of oat flours and ground groats produced protein concentrates of good amino acid composition and could provide a new food ingredient suitable for a variety of uses.

At present, demands are large for suitable high-protein ingredients with a bland taste for food uses (1). Oats have good quality protein and a higher protein content than most cereals (2-4). Protein isolation and properties of four varieties of oats (average and high-protein contents) and their dry-milled fractions have been reported (5). This paper describes the results of air classification of oat flours and ground groats from high- and normal-protein varieties to produce fractions high in protein.

MATERIALS AND METHODS

Sioux oats (lot 2795) and Garland oats (lot BH474), both grown in Minnesota in 1970, were purchased from Interstate Seed & Grain Co., Fargo, N.Dak. Garland oats with a protein content (nitrogen X 6.25) of 17.2%, dry basis, represented a high-protein variety; Sioux oats with a protein content of 12.8%, dry basis, an average variety. This lot of Garland oats had unusually high protein content compared with other batches of the same variety in different years, but the Sioux oats had about the same protein level as the same variety from another year reported earlier (5).

Dry Milling

Oats of 12% moisture content were dehulled in an Alpine 160Z Kolloplex pin mill at 1,445 r.p.m. and the groats were separated from hulls by screening and aspirating. A portion of the groats (without tempering) was then milled in a Buhler mill. Break and reduction flours from the Buhler mill were combined to make a first flour. Bran and shorts from Buhler milling were reground in the pin mill at

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4,500, 9,000, and 14,000 r.p.m. with screening across an 8XX sieve after each pass through the grinder. The minus 8XX fractions were combined to give the second flour.

Analytical Methods

Protein content (nitrogen X 6.25) was determined by micro-Kjeldahl nitrogen analysis. Fat, fiber, and ash analyses were carried out by procedures described in Approved Methods of the AACC (6).

Air Classification

The first and second flours from Buhler-milling of a portion of groats were defatted by pentane-hexane extraction before air classification. Because the flours were difficult to handle during defatting, the second portions of the groats were defatted before grinding. The residual fat in the two groats was 1.4% and did not interfere with air classification. Not only the first and second flours, but also the groats were ground three times at 14,000 r.p.m. in an Alpine pin mill.

Air classification of these ground groats and flours was carried out in a Pillsbury laboratory model classifier. Each pass of material through the classifier produced two fractions, one fine and one coarse. With the classifier adjusted for cut points of approximately 15, 18, 24, and 30 μ in successive passes, four fine fractions, progressively increasing in particle size, and a coarse residue were produced from the coarse fractions. In addition, an ultrafine fraction, exceptionally high in protein content and designated as fraction 1A, was collected in an air filter bag during the first pass through the classifier. The normal fine fraction collected during the first pass is identified as fraction 1B.

Amino Acid Analysis

A Beckman Spinco Model 120 amino acid analyzer was used to analyze each sample hydrolyzed in refluxing constant boiling HCl for 24 hr. The hydrolyzed sample was evaporated to dryness, and the residue was dissolved in pH 2.2 citrate buffer. After the peaks were integrated electronically or manually, the amino acid data were computed automatically (7).

RESULTS AND DISCUSSION

Dry Milling

The yields of groats and finer than 20-mesh fraction from Sioux oats were 66 and 11%, respectively, whereas the corresponding yields from Garland oats were 67 and 9%. The yield of groats could have been increased, possibly to 75%, if a purifier had been available to separate hull fragments from material finer than 20 mesh. The protein contents of the nondefatted Garland groats and finer than 20-mesh fraction were 23.3 and 13.5%, respectively, dry basis. If all the finer than 20-mesh fraction from Garland oats were assumed to be groats, then the calculated protein content of the combined groats, 76% yield, would have been 22.1%.

Calculated protein content of the Garland oats, based upon the yield and protein content of each dry-milled fraction, was 17.5% and is in good agreement with the 17.2% obtained by direct analysis. While the spread in protein values between Garland oats and groats might appear to be high, it is primarily a result of the high protein content of this variety, as we found the ratio for protein content of the groats to that of the oats to be about 1.3 whether it be for the Garland or Sioux variety.

TABLE I. AIR CLASSIFICATION OF SIOUX AND GARLAND FIRST AND SECOND FLOURS (DRY BASIS, DEFATTED)

Fraction	Sioux Variety				Garland Variety			
	Yield %	Protein %	Protein % of Total	Ash %	Yield %	Protein %	Protein % of Total	Ash %
First flour ground								
3 X 14,000 r.p.m.		10.1		0.8		15.8		0.9
1A	2	85.6	16	2.7	2	88.4	14	2.5
1B	25	14.9	38	1.2	27	26.9	48	1.1
2	21	8.1	17	0.8	20	11.7	15	0.9
3	29	6.2	19	0.7	33	7.6	16	0.8
4	14	4.4	6	0.4	13	5.7	5	0.7
5[a]	9	4.4	4	0.6	5	5.7	2	0.8
Second flour ground								
3 X 14,000 r.p.m.		15.9		1.6		28.9		2.7
1A	3	85.6	14	3.8	5	87.0	15	3.4
1B	26	24.1	41	2.5	29	39.0	43	3.7
2	20	13.2	17	1.6	21	24.1	19	2.5
3	34	8.2	18	1.2	29	13.2	14	1.9
4	12	7.9	6	1.1	10	12.3	5	1.9
5[a]	6	10.7	4	2.0	7	17.0	4	3.0

[a]Coarse residue.

The yields of first and second flours from Sioux groats were 43 and 25%, respectively, whereas the corresponding yields from Garland groats were 51 and 20%. Sioux bran (plus 8XX fraction) has 25.2% protein and accounts for 32% of the groat weight; Garland bran contains 30.4% protein and represents 29% of the groat weight.

Air Classification of First and Second Flours

Weight distribution, protein, ash, and percentage of total protein of first and second flours after air classification are given in Table I. With Sioux first flour, fraction 1A had 85.6% protein. A comparable high-protein fraction was not obtained after air classification of wheat (8), rye (9), corn (8), sorghum (8), or triticale (9) flours. Protein level in fraction 1B exceeds that of the starting material by 48%. Fractions 1A and 1B account for 54% of total protein.

Table I also shows air-classification results of Sioux second flour. The higher protein content of second flour compared with first flour was reflected in higher protein levels of the classified fractions. Higher protein content was usually associated with high ash for Sioux first and second flour fractions (Table I). Fraction 1B protein level exceeds that of the starting material by 52%. Fractions 1A and 1B account for 55% of total protein.

The yield, protein, ash, and percentage of total protein of air-classified fractions from Garland first flour are summarized in Table I. The higher protein content of Garland first flour compared with Sioux first flour resulted in higher protein levels of all Garland first flour fractions. Fraction 1A has 88.4% protein, and protein level in fraction 1B exceeds that of the starting material by 70%. Fractions 1A and 1B account for 62% of total protein. The protein content of air-classified fractions from Sioux and Garland first flours decreased with increasing particle size (fraction 1A to fraction 5).

TABLE II. AIR CLASSIFICATION OF GROUND SIOUX AND GARLAND GROATS (DRY BASIS, DEFATTED)

Fraction	Yield %	Protein %	Protein % of Total	Fat %	Fiber %	Ash %
Sioux groats ground						
3 X 14,000 r.p.m.		16.3		1.4	1.6	2.6
1A	2	83.3	7			3.1
1B	26	20.8	31	1.3	0.1	2.4
2	16	13.1	12	1.1	0.1	1.8
3	25	9.0	13	0.9	0.9	1.5
4	9	8.4	5	0.9	1.6	1.5
5[a]	22	24.2	32	3.2	5.0	5.2
Garland groats ground						
3 X 14,000 r.p.m.		22.7		1.4	2.2	2.4
1A	2	83.1	7			4.3
1B	26	29.4	33	1.3	0.0	2.0
2	16	18.7	13	1.2	0.0	1.7
3	24	12.3	13	1.1	0.9	1.6
4	8	11.8	4	1.2	2.0	1.7
5[a]	24	29.2	30	2.8	6.4	4.2

[a]Coarse residue.

Table I also shows air-classification results of Garland second flour. Fraction 1A has 87% protein, and protein level in fraction 1B exceeds that of the starting material by 35%. Fractions 1A and 1B account for 58% of total protein. High-protein Garland first and second flour fractions are, in general, associated with high-ash contents. The high-protein content of Garland second flour gave higher protein levels of air-classified fractions as compared with Garland first flour or with Sioux second flour. The protein level of air-classified Garland and Sioux second flour fractions decreased with increasing particle size, in general, except fraction 5 (coarse residue) had higher protein than fractions 3 and 4.

Air Classification of Ground Groats

The yield, protein, fat, fiber, ash, and percentage of total protein of air-classified groats fractions appear in Table II. Air classification of ground Sioux groats yields a fraction having 83.3% protein from the air filter bag similar to the high-protein fractions from air-classified Sioux first and second flours. Protein level in fraction 1B exceeds that of the starting material by 28%, and fractions 1A and 1B account for 39% of total protein.

With Garland groats, fraction 1A has 83.1% protein, and protein level in fraction 1B exceeds that of the starting material by 30%. Fractions 1A and 1B account for 40% of total protein. For both Sioux and Garland groats the higher protein contents of the fractions were, in general, associated with higher ash; and protein level decreased with increasing particle size, except fraction 5 has higher protein than the starting material. The fiber content of the air-classified groat fractions increased with particle size.

Table III summarizes some milling results and compares air-classification response of ground groats, first and second flours from Sioux and Garland oats. The protein content of first flour from milling is considerably lower than that of the groats for Sioux and Garland. The protein content of Sioux second flour is about

TABLE III. COMPARISON OF AIR-CLASSIFICATION RESPONSE[a]

Sample	Sioux			Garland		
	Ground Groats	First Flour	Second Flour	Ground Groats	First Flour	Second Flour
Starting material						
Yield	100	43	25	100	51	20
Protein	16.3	10.1	15.9	22.7	15.8	28.9
Maximum range of protein contents	8.4 to 83.3	4.4 to 85.6	7.9 to 85.6	11.8 to 83.1	5.7 to 88.4	12.3 to 87.0
Combined high-protein fractions 1A and 1B						
Yield	27	27	29	28	30	34
Protein	24.3	19.6	29.7	32.8	31.8	45.6
Protein, total	39	54	55	40	62	58
Combined low-protein fractions 2–4						
Yield	51	64	66	49	65	59
Protein	10.2	6.5	9.7	14.4	8.5	16.8
Protein, total	30	42	41	30	36	38
Coarse residue fraction 5						
Yield	22	9	6	24	5	7
Protein	24.2	4.4	10.7	29.2	5.7	17.0
Protein, total	32	4	4	30	2	4
Protein shifted, total	43	54	52	37	64	47

[a]Yields and analyses are expressed as percent dry basis with yields based on products recovered from the groats or flour being classified.

the same as that of the groats, whereas that of Garland second flour is considerably above that of the groats. The difference in milling response of the two oats is indicated by the yield of first and second flours and their protein levels. The flours and ground groats after air classification had protein contents ranging from 4 to 88%. This wide range of protein contents makes it possible to mix the fractions in various proportions to gain any desired protein level to fit individual requirements.

Combining fractions 1A and 1B (27 to 34% by weight of starting material) will give from 19.6 to 45.6% protein, will account for 39 to 62% of total protein, and will provide a most useful ingredient for various foods. The coarse residue fractions of the flours had low-protein content (4 to 17%) and low yield (5 to 9%), whereas those of the groats had high-protein content (24 to 29%) and high yield (22 to 24%). The difference is understandable because groats contained all the bran and shorts, and these fractions normally have a protein content higher than groats (5). The high content of protein, fat, and fiber in fraction 5 is consistent with this condition (Table II).

Protein shift is calculated from the sum of the protein shifted into the high-protein fractions and out of the low-protein fractions as a percentage of the total protein present in the starting flour or groats (10). Sioux and Garland groats had comparable protein shift of 43 and 37%, respectively, but have considerably different initial protein contents (16.3 and 22.7%). Sioux first and second flours, 10.1 and 15.9% initial protein, showed a similar protein shift, 54 and 52%, respectively.

Garland first flour had the highest protein shift of 64%, and the second flour protein shift of 47% (from 28.9% original protein) was nearly as good as that for Sioux second flour having much lower initial protein. Garland flours and groats respond well to air classification, especially in view of their high initial protein contents; their responses are also better than for Sioux. Comparable high-protein wheat flours would give much lower protein shift values. When percentages of total protein in fractions 1A and 1B, as well as protein shift, are compared, flours give better response than ground groats. For reference, the protein shift for wheat flours covers a range from 24 to 85% for an eight-part classification (11-13). If the same separation procedure were used for oats, the protein shift values would expectedly be somewhat more than the values reported here for five-part separation.

Amino Acid Analysis

Amino acid compositions of Garland oat groats and their air-classified fractions are shown in Table IV. All fractions have good lysine values (3.9 to 5.0 g. per 16 g. nitrogen) and adequate total sulfur amino acids (2.5 to 4.5 g. per 16 g. nitrogen). The amino acid data were analyzed statistically based on relative standard deviations in determinations of amino acids (14). The difference between the highest and lowest amino acid values is statistically significant.

Although there are no large differences in amino acids among the fractions, some patterns were observed. The values for specific amino acids are similar for fractions 1B and 2 (29.4 and 18.7% protein) and also for fractions 3 and 4 (12.3 and 11.8% protein). Differences in amino acid values are noted between the following groups of milled products: fraction 1A; fractions 1B and 2; fractions 3 and 4; and fraction 5. The most change is noted between fractions 1A and 5.

Fraction 1A had the highest level of total sulfur amino acids (Table IV). The water-, alcohol-, and acetic acid-soluble proteins from oats have respective lysine

TABLE IV. AMINO ACID COMPOSITIONS OF GARLAND OAT GROATS AND THEIR AIR-CLASSIFIED FRACTIONS (g. AMINO ACID PER 16 g. NITROGEN)

Amino Acids[a]	Groats	Fraction					
		1A	1B	2	3	4	5
Lysine	4.1	4.2	3.9	3.9	5.0	5.0	4.2
Histidine	2.2	2.7	2.4	2.2	2.4	2.4	2.2
Ammonia	2.6	3.7	3.0	2.9	2.6	2.6	2.8
Arginine	7.0	8.6	7.5	7.1	7.7	7.6	7.2
Aspartic acid	8.1	9.3	8.1	8.0	8.7	9.2	5.9
Threonine	3.3	3.9	3.3	3.3	3.9	4.2	2.7
Serine	4.6	5.5	4.6	4.7	5.1	5.4	3.9
Glutamic acid	20.9	29.2	24.6	23.3	21.9	22.6	17.2
Proline	6.1	6.8	5.8	5.6	5.6	6.6	4.7
Glycine	4.8	5.2	4.5	4.5	5.5	6.1	3.9
Alanine	4.4	5.5	4.7	4.7	5.8	6.4	4.0
Half-cystine	1.9	2.6	1.8	1.8	1.7	1.8	1.7
Valine	5.2	5.8	5.2	5.2	6.0	6.3	4.4
Methionine	1.7	1.9	1.5	1.1	0.8	1.2	1.1
Isoleucine	3.8	5.0	4.2	4.0	4.4	4.8	3.0
Leucine	7.4	9.3	7.9	7.6	8.1	8.7	5.9
Tyrosine	3.9	5.1	4.1	4.0	4.2	4.4	3.0
Phenylalanine	5.3	7.1	5.9	5.6	5.6	5.7	4.1

[a]Tryptophan not determined.

contents of 8.1, 0.7, and 2.9 g. per 16 g. nitrogen (5). The higher lysine contents of fractions 3 and 4 compared with those of fractions 1B and 2 suggest that more water-soluble protein is in fractions 3 and 4 while more alcohol- or acetic acid-soluble proteins, or both, are in fractions 1B and 2.

Air-classification results on oat flours and ground groats indicate that oat protein concentrate with good amino acid composition can be produced at low cost. Although flours give better air-classification response than ground groats, oat groats are easier to make. The high-protein variety (Garland) gives better air-classification response than oats having a normal protein content (Sioux). Although small in quantity, the unique fraction that is almost pure protein from air classification of oats may have special significance. The recent and continuing genetic improvements in protein level of oats add even further significance, because the high-protein variety we studied gave the best air-classification response. Further refinement of the air-classification procedure to optimize the process may increase the yield of high-protein fractions and make oat protein concentrate still more economical.

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