NOTE

NONWHEAT GRAINS AND PRODUCTS

Enriched Protein- and β-Glucan Fractions from High-Protein Oats by Air Classification

Y. VICTOR WU[1] and ARTHUR C. STRINGFELLOW

ABSTRACT

Cereal Chem. 72(1):132–134

High-protein oat groats were defatted once (1X) or three times (3X) and air-classified. The protein contents of the 1X and 3X defatted materials were 23.4 and 23.5%, respectively; the combined high-protein fine fractions from air classification had protein contents of 30.1 and 32.7%. These fractions accounted for 21 and 24% of the weight (and for 27 and 33% of the total protein) of the 1X and 3X defatted groats, respectively. The coarse residue fraction (>30 μm) from air classification of 1X and 3X defatted groats had β-glucan contents of 16.9 and 17.7%, respectively, compared with 6.1–6.2% in the original defatted groats. These coarse residue fractions accounted for 30 and 28% weight and 82% of total β-glucan of the 1X and 3X defatted groats, respectively. Useful protein shifting was 25% for the 1X and 30% for the 3X defatted groats. Useful β-glucan shifting was 104% for the 1X and 107% for the 3X defatted groats. Air classification of high-protein oat groats may have commercial potential for producing protein concentrate and enriched β-glucan fraction in a single process.

Oats have a relatively high protein content with good nutritional quality when compared to other cereal grains (Jones et al 1948, Hischke et al 1968, Robbins et al 1971). Most cereal grains are deficient in lysine, and the weight of lysine may decrease as protein content increases (Frey 1951, Vavich et al 1959, Munck et al 1970). In oats, amino acid balance is maintained as protein content is increased (Robbins et al 1971, Maruyama et al 1975).

There is a strong positive correlation between blood cholesterol levels and the risk of heart disease (American Heart Association 1986). A number of investigators have shown that consumption of soluble dietary fiber can lower serum cholesterol in humans (Anderson and Chen 1979; Chen et al 1981, 1984; Kritchevsky et al 1984; Judd and Truswell 1985; Van Horn et al 1986). Oats contain soluble fiber, a major component of which is β-glucan.

Knuckles et al (1992) used grinding and sieving to enrich β-glucan content from barley, rolled oats, and oat bran. Hohner and Hyldon (1977) used a wet process to obtain protein, starch, and gum fractions from oat groats. Wood et al (1989) similarly extracted a β-glucan-rich oat gum from oat bran using sodium carbonate at pH 10. Wu and Stringfellow (1973) reported the air classification of oat flours of normal and high-protein contents and found that the fine fraction had increased protein content. Wu et al (1994) reported that air classification of barley flour concentrated the β-glucan in the coarse fraction. Thus, it appeared reasonable that air classification of a high-protein oat flour might produce protein concentrate from fine fractions and an enriched β-glucan fraction from the coarse residue. A process that produces both a protein concentrate and an enriched β-glucan fraction may have advantages over a process giving either product alone. This article describes the enrichment of protein and β-glucan fractions from air classification of partially defatted oat groats from a cultivar with high protein content.

MATERIALS AND METHODS

Preparation of Defatted Oat Groats

Otee oats, lot number WM-DM-2, (23.5% protein, db) are high-protein spring oats developed cooperatively by the Illinois Agricultural Experiment Station and the U.S. Department of Agriculture. The oats were dehulled in an Alpine 160Z Kolloplex pin mill at 1,445 rpm, and the groats separated from hulls by screening and aspirating. The groats were defatted once or three times with a hexane-groats ratio of 2.3:1 (v/w) and air-dried. The once and three-time defatted groats were designated 1X and 3X, respectively.

[1]Biopolymer Research Unit, National Center for Agricultural Utilization Research, ARS, USDA, Peoria, IL.

The mention of firm names or trade products does not imply that they are endorsed or recommended by the USDA over other firms or similar products not mentioned.

Analytical Methods

Protein, fat, β-glucan, and ash were determined in duplicate using standard methods (AACC 1983). Protein content was calculated from micro Kjeldahl (N × 6.25); fat was calculated from petroleum-ether extraction; β-glucan was calculated from an enzymatic procedure using lichenase, β-glucosidase, and glucose oxidase/peroxidase; and ash was calculated from heating at 600°C for 2 hr. Starch was determined by a polarimetric method (Garcia and Wolf 1972).

Air Classification

The defatted groats were ground three times at 14,000 rpm in an Alpine pin mill, and then air-classified into a fine and a coarse fraction in a Pillsbury model 1 laboratory classifier set for a 15-μm cut point.

The air classifier was adjusted to cut points of 18, 24, and 30 μm for successive passes to classify the previous coarse fraction; it gave three additional fine fractions and a coarse residue. The resulting classified fractions were arranged in order of increasing particle size and designated 1B through 5B. In addition, two ultrafine fractions, exceptionally high in protein content and designated as fractions 1A, and 2A–5A, were collected in an air-filter bag attached to the classifier.

Amino Acid Analysis

Each sample was hydrolyzed for 24 hr by refluxing in constant-boiling hydrochloric acid (6*N*, 110°C). The hydrolyzed sample was evaporated to dryness, and the residue dissolved in pH 2.2 citrate buffer. A portion of the acid hydrolyzate was then introduced into a Beckman amino acid analyzer. Amino acid data were computed automatically after the peaks were integrated electronically. Nitrogen recovery was calculated from the amount of nitrogen introduced into the amino acid analyzer divided by the nitrogen recovered from amino acids and ammonia.

Useful Protein Shifting and Useful β-Glucan Shifting

Useful protein shifting, a calculated value for comparing protein displacement after air classification, equals the sum of the protein

TABLE I
Air Classification of Defatted Otee Groats (% db)

Fractions	1X Defatted						3X Defatted					
	Yield[a]	Starch	Protein (N × 6.25)	β-Glucan	Fat	Ash	Yield	Starch	Protein (N × 6.25)	β-Glucan	Fat	Ash
1A, exhaust bag	1		80.1 A[b]	ND[c]	ND	1.9 D	1		65.8 C	ND	ND	1.9 D
2A-5A, exhaust bag			81.3 A	ND	ND	2.0 D	1		75.4 B	ND	ND	1.7 E
1B[d]	20	58.2 B	27.7 D	0.6 H	3.3 D	1.6 F	22	54.8 B	29.0 D	0.6 H	2.2 H	1.5 F
2B	14	66.5 A	22.0 E	0.9 G	3.0 EF	1.5 F	18	65.5 A	19.6 F	1.0 G	2.0 HI	1.5 F
3B	26	67.4 A	16.1 G	2.1 F	3.2 DE	1.8 DE	23	70.7 A	14.0 H	2.2 F	1.9 I	1.7 E
4B	9	57.4 B	14.5 H	3.1 E	2.8 FG	1.8 DE	7	65.7 A	13.7 H	3.7 D	2.0 HI	1.8 DE
5B, coarse residue	30	14.8 C	28.1 D	16.9 B	5.1 A	4.4 B	28	15.3 C	28.2 D	17.7 A	4.1 B	4.6 A
Groats			23.4 E	6.2 C	3.7 C	2.5 C			23.5 E	6.1 C	2.6 G	2.6 C

[a]Yield values are rounded off to the nearest percent.
[b]Means with the same letter in each column, such as protein are not significantly different ($P > 0.05$).
[c]Not determined due to small sample weight.
[d]Fractions 1B through 5B are in order of increasing particle size.

TABLE II
Comparison of Air-Classification Response of Defatted Otee Groats (% db)

Groats	1X Defatted	3X Defatted
Starting material		
Yield	100	100
Protein content	23.4	23.5
β-Glucan content	6.2	6.1
Combined high-protein fine fractions 1A, 2A-5A, 1B		
Yield	21	24
Protein content	30.2	32.5
Amount of total initial protein	27	33
Coarse residue fraction 5B		
Yield	30	28
Protein content	28.1	28.2
β-Gluten content	16.9	17.7
Amount of total inital protein	36	34
Amount of total β-glucan	82	82
Useful protein shifting	25	30
Useful β-glucan shifting	104	107

shifted into the high-protein fractions and out of the low-protein fractions as a percentage of the total protein present in the starting material (Gracza 1959). Useful β-glucan shifting can be defined as the sum of the β-glucan shifted into the high β-glucan fractions and out of the low β-glucan fractions as a percentage of the total β-glucan present in the starting material.

RESULTS AND DISCUSSION

Air Classification

Yield, starch, protein, β-glucan, fat, and ash contents of 1X and 3X defatted Otee groats after air classification are given in Table I. Yield data for each fraction was rounded off to the nearest percent. Otee groats had 7.8% fat (db) (not shown in Table I). More than 50% of this fat was removed by defatting once with hexane.

The 1X defatted groats had 23.4% protein. Fraction 3B had the highest starch content (67%) among the five major fractions 1B through 5B, and fraction 5B had the lowest starch content (15%). Fractions 1B and 4B had lower starch content than fractions 2B and 3B. Fractions 1B and 5B had higher protein content than the groats, and fractions 3B and 4B were lower in protein. Although the fractions 1B and 5B had similar high-protein contents, they were not identical. Fraction 1B had very fine soft particles and was considerably lower in both ash and fat as compared to the coarse hard particles in fraction 5B. The largest fraction by weight was fraction 5B, which accounted for almost a third of the groats weight. It is unusual to find an increase in protein for coarse residue, although similar results were observed with fractionated sorghum flour (Stringfellow and Peplinski 1966). For wheat flour, coarse residue protein value approaches that of the starting flour (Peplinski et al 1964, Stringfellow and Peplinski 1964,). Fractions 1A and 2A-5A, ultrafine material collected in low yield from the exhaust air bag, had 80–81% protein. β-Glucan contents increased with increasing particle size from fractions 1B to 5B, and there was a large increase in β-glucan content between fractions 4B and 5B. Fraction 5B had higher ash and fat contents than the 1X defatted groats, but other fractions had lower ash and fat contents.

The air-classified fractions from 3X defatted groats (Table I) followed the same general pattern as the 1X defatted groats. However, fractions from the lower fat groats gave lower protein content for fractions 2B–3B. β-Glucan content of fractions 4B and 5B were higher than the corresponding fractions from 1X defatted groats.

Combined high-protein fractions of both the 1X and 3X defatted groats are compared with the coarse high β-glucan fraction in Table II. The combined high-protein fine fractions from 1X defatted groats had a protein content of 30.2% and accounted for 21% of the groats weight and 27% of the total protein. The corresponding combined high-protein fine fractions from 3X defatted groats had a protein content of 32.5% and accounted for 24% of the weight and 33% of the total protein.

The coarse residue fractions had higher protein contents than the groats and accounted for 28 and 30% of the weight and 34–36% of the total protein of the groats (Table II). The coarse residue fraction had much higher β-glucan contents than the groats (16.9–17.7% vs. 6.1–6.2%) and accounted for 82% of the total β-glucan of the groats.

The yield, amount of total initial protein, and amount of total β-glucan of the combined fractions 2B, 3B, and 4B (not included in Table II because they were lower in both protein and β-glucan than the starting material) can be readily obtained by subtracting the sum of combined high-protein fine fractions 1A, 2A-5A, 1B, and coarse residue fraction 5B from 100%.

Useful Protein Shifting and β-Glucan Shifting

Useful protein shifting of 1X defatted groats was 25%. The 3X defatted groats had an useful protein shifting of 30% (Table II). For comparison, the useful protein shifting of Garland defatted groats with 1.4% fat was 37% (Wu and Stringfellow 1973).

When material with 10% initial β-glucan content was separated by air classification into fraction 1 with 33.3% yield and 30% of β-glucan content and fraction 2 with 66.7% yield and zero β-glucan content, the β-glucan shifting was 133%. A useful β-glucan shifting value of more than 100% is thus possible. Our useful β-glucan shifting values of 104 and 107% in Table II showed that air classification of defatted Otee groats was an excellent method to yield enriched β-glucan fraction.

Amino Acid Composition

Combined high-protein fine fractions 1A, 2A-5A, 1B, (21–24% yield of defatted groats) may have potential as a protein

TABLE III
Essential Amino Acid Composition of 3X Defatted Otee Groats and Air-Classified Fractions (g/16 g nitrogen recovered)

Amino Acid	Groats	Fraction				Recommendations for Children[a]	
		1A Exhaust Bag	2A-5A Exhaust Bag	1B	5B Coarse Residue	2–5 yr.	10–12 yr.
Isoleucine	4.1	4.0	4.7	4.2	3.9	2.8	2.8
Leucine	7.8	7.4	8.4	7.8	7.5	6.6	4.4
Lysine	4.1	3.9	4.4	4.1	4.6	5.8	4.4
Methionine + cystine	3.3	3.7	3.5	3.4	4.4	2.5	2.2
Phenylalanine + tyrosine	9.8	9.9	10.6	10.2	9.5	6.3	2.2
Threonine	3.4	3.3	3.1	3.5	3.5	3.4	2.8
Tryptophan	1.3[b]	...	...	...	...	1.1	0.9
Valine	5.5	5.5	5.4	5.7	5.6	3.5	2.5

[a]WHO (1985).
[b]Average of 21 samples of oat groats (Drake et al 1989).

concentrate in human food. To evaluate the nutritional value of these fractions, the essential amino acid composition of 3X defatted Otee groats and air-classified fractions are compared with the recommended amino acid pattern (WHO 1985) for preschool child (2–5 years) and a school child (10–12 years) in Table III. The essential amino acid composition of 1X defatted Otee groats and air-classified fractions were very similar to 3X and are not shown. The air-classified fractions had very similar amino acid composition when compared with the groats. Although Otee groats had much higher lysine content than most cereals, they were still deficient in lysine when compared with the WHO recommendation for a preschool child, although adequate for school age child. Other essential amino acids of these fractions, however, met or exceeded the WHO recommendation for children.

CONCLUSION

Air classification of 1X defatted high-protein oat groats may have commercial potential for producing protein concentrate and enriched β-glucan fraction in a single process. However, air classification of the 3X defatted oat groats resulted in only moderate increase of total initial protein in the combined high-protein fractions, but no increase in the amount of total β-glucan in the high β-glucan fraction. It appeared that air classification of 3X defatted groats led to little worthwhile gain over 1X defatted material.

ACKNOWLEDGMENT

We thank C. M. Brown of Agronomy Department, University of Illinois, Urbana for Otee Oats.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC, 8th ed. Method 46-13, approved October 1976, reviewed October 1982, revised October 1986; Method 30-26, approved April 1961; Method 32-22, approved November 1989; Method 08-03, approved April 1961. The Association: St. Paul, MN.
AMERICAN HEART ASSOCIATION. 1986. 'Mister Fit' links blood cholesterol to heart disease risk. Cardiovascular Res. Rep. 21:1.
ANDERSON, J. W., and CHEN, W. L. 1979. Plant fiber: Carbohydrate and lipid metabolism. Am. J. Clin. Nutr. 32:346.
CHEN, W. L., ANDERSON, J. W., and GOULD, M. R. 1981. Effects of oat bran, oat gum and pectin on lipid metabolism of cholesterol-fed rats. Nutr. Rep. Int. 24:1093.
CHEN, W. L., ANDERSON, J. W., and JENNINGS, D. 1984. Propionate may mediate the hypocholesterolemic effects of certain soluble plant fibers in cholesterol-fed rats. Proc. Soc. Exp. Biol. and Med. 175:215.
DRAKE, D. L., GEBHARDT, S. E., and MATTHEWS. 1989. Composition of Foods: Cereal Grains and Pasta. Page 50 in: USDA Agric. Handbook 8-20. U.S. Government Printing Office: Washington, DC.
FREY, K. J. 1951. The interrelationships of proteins and amino acids in corn. Cereal Chem. 28:123.
GARCIA, W. J., and WOLF, M. J. 1972. Polarimetric determination of starch in corn with dimethyl sulfoxide as a solvent. Cereal Chem. 49:298.
GRACZA, R. 1959. The subsieve-size fractions of soft wheat flour produced by air classification. Cereal Chem. 36:465.
HISCHKE, H. H., JR., POTTER, G. C., and GRAHAM, W. R. 1968. Nutritive value of oat proteins. I. Varietal differences as measured by amino acid analysis and rat growth responses. Cereal Chem. 45:374.
HOHNER, G. A., and HYLDON, R. G. 1977. Oat groat fractionation process. U.S. patent 4,028,468.
JONES, D. B., CALDWELL, A., and WIDNESS, K. D. 1948. Comparative growth-promoting values of the proteins of cereal grains. J. Nutr. 35:639.
JUDD, P. A., and TRUSWELL, A. S. 1985. Dietary fibre and blood lipids in man. Pages 23-39 in: Dietary Fibre Perspectives. A. R. Leeds, ed. J. Libbey: London.
KNUCKLES, B. E., CHIU, M. M., and BETSCHART, A. A. 1992. β-Glucan enriched fractions from laboratory-scale dry milling and sieving of barley and oats. Cereal Chem. 69:198.
KRITCHEVSKY, D., TEPPER, S. A., and GOODMAN, G. 1984. Diet, nutrition intake, and metabolism in populations at high and low risk for colon cancer. Relationship of diet to serum lipids. Am. J. Clin. Nutr. 40:921.
MARUYAMA, K., SHANDS, H. L., HARPER, A. E., and SUNDE, M. L. 1975. An evaluation of the nutritive value of new high protein oat varieties (cultivars). J. Nutr. 105:1048.
MUNCK, L., KARLSSON, K. E., HAGBERG, A., and EGGUM, B. O. 1970. Gene for improved nutritional value in barley seed protein. Science 168:985.
PEPLINSKI, A. J., STRINGFELLOW, A. C., GRIFFIN, E. L., JR. 1964. Air classification of Indiana, Ohio, and Michigan soft wheat flours. Northwest. Miller 271(2):10.
ROBBINS, G. S., POMERANZ, Y., and BRIGGLE, L. W. 1971. Amino acid composition of oat groats. J. Agric. Food Chem. 19:536.
STRINGFELLOW, A. C., and PEPLINSKI, A. J. 1964. Air classification of Kansas hard red winter wheat flours. Northwest. Miller 270(6):19.
STRINGFELLOW, A. C., and PEPLINSKI, A. J. 1966. Air classification of sorghum flours from varieties representing different hardnesses. Cereal Sci. Today 11:438.
VAN HORN, L. V., LIU, K., PARKER, D., EMIDY, L., LIAO, Y., PAN, W. H., GIUMETTI, D., HEWITT, J., and STAMLER, J. 1986. Serum lipid response to oat product intake with a fat-modified diet. J. Am. Diet Assoc. 86:759.
VAVICH, M. G., KEMMERER, A. R., NIMBKAR, B., and STICH, L. S. 1959. Nutritive value of low- and high-protein sorghum grains for growing chickens. Poultry Sci. 38:36.
WHO, 1985. Energy and protein requirement. Report of joint FAO/WHO/UNU expert consultation, World Health Organization Technical Rep. Ser. 724. World Health Organization: Geneva.
WOOD, P. J., WEISZ, J., FEDEC, P., and BURROWS, V. D. 1989. Large scale preparation and properties of oat fractions enriched in $(1\rightarrow3)(1\rightarrow4)$-$\beta$-D-glucan. Cereal Chem. 66:97.
WU, Y. V., and STRINGFELLOW, A. C. 1973. Protein concentrates from oat flours by air classification of normal and high-protein varieties. Cereal Chem. 50:489.
WU, Y. V., STRINGFELLOW, A. C., and INGLETT, G. E. 1994. Protein- and β-glucan enriched fractions from high-protein, high β-glucan barleys by sieving and air classification. Cereal Chem. 71:220.

[Received March 21, 1994. Accepted November 14, 1994.]