β-Glucan Content and Viscosities of Barleys and Their Roller-Milled Flour and Bran Products

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ABSTRACT

Total β-glucan, soluble β-glucan, and acid extract viscosity (AEV) of different barleys and their roller-milled products (flour and bran) were determined. Barley genotypes containing low or normal β-glucan (3.8–4.1%) and low AEV (4–5 centiStokes [cS]) or high β-glucan (6.9–7.2%) but medium (51–55 cS) or high (276–290 cS) AEV are reported. The soluble β-glucan content and AEV of malting barleys were significantly higher than those of the feed barleys examined. In 15 diverse cultivars and genotypes of barley dry-milled in an Allis-Chalmers experimental mill, mean milling loss was 7.1%, and flour and bran yields were 69.6 and 30.3%, respectively, of the recovered product. β-Glucan varied from 4.3 to 11.3% in barley, from 3.9 to 9.0% in flour, and from 4.9 to 15.4% in bran, and the β-glucan enrichment in bran was, on average, 1.36-fold. About 95% of barley β-glucan was recovered in the flour and bran fractions (56% in flour and 39% in bran). Milling adjustments can be made to produce coarse, medium, and fine barley flour or bran. Of the three screen sizes tested, the highest bran yield and maximum enrichment of β-glucan was obtained by using a 64 GG (236-μm) screen.

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Barley contains a high concentration, as well as a large range, of the nonstarch polysaccharide (1→3),(1→4) mixed linked β-D-glucans (β-glucan). This is largely due to continuous selection of malting barleys for low β-glucan, differences in two- and six-rowed barleys (Lehtonen and Aikasalo 1987), and availability of the waxy (low amylose) starch gene commonly associated with high β-glucan content (Newman and Newman 1991). Barley genotypes containing 3–16% β-glucan are available. Similarly, barleys with a large range of acid extract viscosity (AEV), a measure of soluble β-glucan, have been described (Bhatty et al 1991). McIntosh et al (1991) reported that water-soluble β-glucan content, because of its viscosity and possible influence on the absorption of nutrients from the small intestine, may be more nutritionally relevant than total β-glucan in relation to a hypocholesterolemic effect. Smith et al (1980) reported acid buffer-soluble β-glucan to be significantly higher in poor-malting barleys than in good-malting barleys.

It is feasible to develop low β-glucan barley for feeding to monogastric animals, particularly broiler chicks, or high β-glucan barley for use in human foods as a source of total dietary fiber (TDF) and soluble fiber (SF). An example of the latter type is Azhul barley, which contains about 11% β-glucan and 20% TDF, of which about one third (7%) is SF, compared with corresponding values for a sample of commercial oats of 4, 9, and 3%, respectively. Roller-milled Azhul barley bran and flour contained 54–57% of TDF as SF compared to 31–34% in oat bran and flour. Barley bran and flour, like oat bran and flour, were hypocholesterolemic in cholesterol-fed rats (Ranhotra et al 1991). High β-glucan barleys and their milled products may be of interest to food processors because of their high TDF and SF.

At present, very little barley is used in human foods except in the West Asia-North Africa region, particularly Morocco, where per capita consumption of barley is 68 kg per year (Bhatty 1991). In Korea, per capita consumption of barley has decreased from 29 kg per year in 1977 to about 8 kg per year in 1987 because of increased consumption of rice and wheat (Bhatty 1991). Barley consumption in the Western countries is negligible at present. It may increase because of its higher TDF and SF content, which might be beneficial in treating hypercholesterolemia and in postprandial glucose management like oat TDF and SF (Anderson et al 1990, Wood et al 1990). Roller-milled barley products, such as bran and flour, are well suited for the use of barley in foods.

This article reports total and soluble β-glucan content and AEV of barleys and the distribution of β-glucan in roller-milled bran and flour fractions of 15 diverse barleys. Because β-glucan is the major component of the SF in barley (Newman and Newman 1991), its level and distribution in bran and flour gives an indication of the potential nutritional qualities of the milled products. Few data on the milling yield of barley and the distribution of β-glucan in roller-milled barley bran and flour have been reported in the literature.

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MATERIALS AND METHODS

Materials

Samples studied included six Canadian registered cultivars of hulled or hull-less barley and eight genotypes of barley having normal or waxy starch that were grown in 1989 at experimental plots at the University of Saskatchewan, Saskatoon. Azhul, a nonregistered, high β-glucan barley developed by R. T. Ramage, U.S. Department of Agriculture, University of Arizona, Tucson, was a gift from C. W. Newman, Montana State University, Bozeman. The hull-less barleys were cleaned of residual hull, and subsamples of the hulled and hull-less barley were ground in a Udy cyclone mill to pass through a 1.0-mm screen. The ground grain (meal) was stored at 5°C.

Barley Milling

The 15 cultivars and genotypes of hulled and hull-less barley were dry-milled in an Allis-Chalmers experimental mill, using a short-flow procedure. The milling procedure essentially consisted of three breaks, three reductions, and six sifting steps. The break, reduction, and clear flour fractions passed through a 70 GG (240-μm) screen and were combined to obtain total flour yield. In one experiment, coarse, medium, and fine flours were obtained by passing the flour through 30 GG (630-μm), 50 GG (375-μm), and 64 GG (236-μm) screens, respectively, in addition to removing break or reduction rolls in the case of coarse or medium flour. Details of the milling procedure have been described previously (Bhatty 1986, 1987).

Analytical Methods

Total β-glucan content of barley, barley bran, and flour was determined by the method of McCleary and Glennie-Holmes (1985), using an assay kit from Biocon (Lexington, KY), AEV as described previously (Bhatty et al 1991), and starch as described by Holm et al (1986), except that the sample was first boiled with 80% ethanol for 30 min and then centrifuged at 2,000 × g for 10 min. The amount of glucose released was determined using the Sigma glucose oxidase/peroxidase kit. After measuring AEV, the acid extracts were neutralized by adding solid sodium bicarbonate and then freeze-dried. Soluble β-glucan also was determined by the method of McCleary and Glennie-Holmes (1985). All analytical data reported are means of at least duplicate determinations; the significance of differences in the means was determined by a t test.

RESULTS AND DISCUSSION

For the last several years, hundreds of selections of barley have been analyzed in this laboratory for β-glucan and AEV in a cultivar development program for production of low or high β-glucan barleys. Those analyses have revealed wide ranges in β-glucan and in AEV. The data given in Table I for the samples in this experiment are examples of such diversity. Normal starch barleys observed had low or normal β-glucan content (3.8–4.1%) and low AEV (4–5 centiStokes [cS]). In contrast, barley genotypes containing waxy starch had high (about 7%) β-glucan but had either medium (51–55 cS) or high (276–290 cS) AEV. Thus, it appears that although waxy starch barleys have high total β-glucan, they may have low or high soluble β-glucan, which is almost entirely responsible for AEV, because the proteins or starch present in acid extracts do not significantly contribute to AEV (Bhatty et 1991). The nutritional implication of soluble β-glucan in hypocholesterolemia has recently been suggested (McIntosh et al 1991). Barley cultivars with high β-glucan content do not always result in proportional response to hypocholesterolemia. Although no direct evidence has been obtained, this response may partially be confounded by differences in soluble β-glucan content. Other factors that may relate to hypocholesterolemic property of barley include growing conditions of barley, starch type, solubility of β-glucan, and possibly the degree of polymerization of β-glucan (Newman et al 1989). Thus, waxy genotypes of barley containing similar β-glucan yet different AEV or soluble β-glucan, such as those reported in Table I, provide contrasting materials for investigations of their hypocholesterolemic effects in animal or human subjects.

AEV has previously been used to distinguish malting and feed barleys (Smith et al 1980). To test this difference, two Canadian malting barleys (Ellice and Harrington) and two feed barleys (Abee and Deuce) were analyzed for total β-glucan, soluble β-glucan, and AEV (Table II). Harrington is the most popular Canadian malting barley cultivar covering about 60% of the malting barley hectarage on the Canadian prairies. The malting and feed barleys had identical mean total β-glucan. The malting cultivars had significantly higher mean soluble β-glucan (1.9%) than the mean of the feed cultivars (1.5%); the intracultivar means of soluble β-glucan expressed as a percentage of total β-glucan were significant as well. The malting cultivars had threefold higher AEV (12.0 cS) than the feed cultivars (4.0 cS), probably because of the malting cultivars' significantly higher soluble β-glucan content. These data confirmed the sensitivity of AEV to small changes in soluble β-glucan, which has a linear effect on AEV. Nevertheless, malting barley cultivars contained more and not less soluble β-glucan and, consequently, had higher AEV values. Although arabinoxylans may be contributing factors to AEV of barley cultivars, our previous study showed that their effect was small as shown by the addition of xylanase to the acid extract (Bhatty et al 1991). Results reported here, which were obtained from fewer barley samples, are different from those reported by Smith et al (1980). They need to be substantiated using a larger and more diverse selection of barley samples.

Barley has not been traditionally roller-milled, as have wheat or oats. Only a few studies have been reported on the milling quality of barley (Cheigh at al 1975; McGuire 1979; Bhatty 1986, 1987). To establish milling yields of barley, 15 diverse cultivars and genotypes of hulled and hull-less barleys were roller-milled to obtain flour and bran. Data in Table III show an average milling loss of 7.1% and flour and bran yields of 69.7 and 30.3%, respectively, of the recovered product. The coefficient of variation for flour yield was 1.4% and for bran was 3.3%, indicating that barley can be dry-milled to consistent flour and bran yields. In the Allis-Chalmers experimental mill, the bran and shorts do not separate because barley bran, unlike wheat bran, is brittle and shatters. However, barley bran and shorts may be separated in other mills. Scout hull-less barley dry-milled on a larger scale in a Buhler mill gave the following yields expressed as a percentage of the total recovered product: 74% flour, 15% shorts, and 11% bran.

The 15 barleys ranged in β-glucan from 4.2 to 11.3% (mean of 6.0%), showing a large variability in the nonstarch polysaccharide (Table III). The range in β-glucan content of flour was 3.7–9.0% (mean of 5.0%) and in bran was 4.9–15.4% (mean of 8.2%). Average β-glucan enrichment of the bran was 1.36-fold, which was generally similar to that reported for 11 cultivars of oats by Wood et al (1991), even though the bran yield in oats was, on the average, 53% (range 48–58%). Barley bran in about 30% yield may thus be a "true" bran, approximating the 20–30% outer covering present in hull-less or hulled barley grain (Pedersen and Eggum 1983). The enrichment of β-glucan in barley bran is partly attributable to endosperm cell walls from the subaleurone layer of the grain. The 15 bran samples described in Table III contained 39–50% starch, which gave an indication of the presence of endosperm. There also was the possibility of higher β-glucan content in the subaleurone region, although fluorescence micrographs of different barleys containing low, medium, or high β-glucan showed no such evidence (Bhatty and MacGregor 1988, Bhatty et al 1991). The material balance (recovery) of β-glucan in flour and bran varied from 88.5 to 119% (mean 95%). Thus, almost all of the β-glucan was recovered in flour and bran, with an average of 56% in flour and 39% in bran (Table III).

Flour, and particularly bran, is marketed in different particle sizes. To determine the influence of particle size on flour and bran yields and its effect on β-glucan distribution, Azhul barley containing 11.3% β-glucan was milled to coarse, medium, and fine particle size flour. The flour yield decreased and bran yield increased as flour particle size decreased from 630 to 236 μm because part of the bran passed through 30 to 50 GG screens (Table IV). Because only very coarse bran was left on the 30 GG screen, its β-glucan content was only slightly higher (11.5%) than that of the barley (11.3%) This affected bran β-glucan and its enrichment as well. Therefore, it seemed desirable to mill barley using a fine screen (64 GG) in reduction and break rolls to obtain flour and bran yields of about 70 and 30%, respectively, of the recovered product. The 64 GG milled bran (yield 31.3%) gave

TABLE I
β-Glucan and Acid Extract Viscosity of Normal and Waxy Starch Lines of Barley[a]

Genotype	Starch	β-Glucan (%)	Acid Extract Viscosity (cS)	Description
SB87697	Normal	4.1	5.4	Average β-glucan, low viscosity
SB88490	Normal	3.8	4.4	
SB85738	Waxy	7.2	289.9	High β-glucan, high viscosity
SB85745	Waxy	6.9	275.9	
SB85740	Waxy	6.9	55.0	High β-glucan, medium viscosity
SB85751	Waxy	7.0	51.3	

[a]Data are means of at least duplicate determinations.

TABLE II
β-Glucan and Acid Extract Viscosity of Malt and Feed Cultivars of Canadian Barleys

Cultivar	Type	β-Glucan, % Total (T)	Soluble (S)	S/T × 100	Acid Extract Viscosity (cS)
Ellice	Malt	3.9	1.7	44	8.4
Harrington	Malt	4.1	2.1	50	15.6
Mean[a]		4.0	1.9	47	12.0
Abee	Feed	4.1	1.4	33	3.7
Deuce	Feed	3.9	1.6	40	4.2
Mean[a]		4.0 NS	1.5**	36**	4.0**

[a]Differences in the means were not significant (NS) or significant (**) ($P < 0.01$) by a t test. Data are means of duplicate determination.

TABLE III
Milling Yields and β-Glucan Distribution in Roller-Milled Flour and Bran Fraction of Different Barleys

Cultivar/Genotype	Type	Milling Loss (%)	Milling Yields, %		β-Glucan, %			β-Glucan	
			Flour[a]	Bran[a]	Meal	Flour	Bran	Enrichment of Bran (fold)	Recovery of Bran + Flour (%)
Abee	Hulled, feed	3.7	70.0	30.0	4.4	4.0	4.9	1.11	92.4
Deuce	Hulled, feed	5.3	69.3	30.7	4.3	3.9	5.2	1.20	93.8
Ellis	Malt	5.3	69.5	30.5	4.2	4.0	5.0	1.18	97.6
Harrington	Malt	8.9	68.5	31.5	4.5	4.0	5.4	1.21	91.1
Scout	Hull-less	7.8	68.7	31.3	5.6	4.5	7.8	1.39	91.1
Tupper	Hull-less	10.1	70.2	29.8	4.6	3.7	6.3	1.36	87.0
Azhul	Hull-less, waxy	7.8	71.6	28.4	11.3	9.0	15.4	1.36	88.5
SB85738	Hull-less, waxy	11.6	68.6	31.2	7.9	6.6	11.5	1.46	90.8
SB85740	Hull-less, waxy	8.2	69.6	30.4	7.6	6.4	12.5	1.65	99.1
SB85745	Hull-less, waxy	9.4	69.5	30.5	7.6	6.3	11.8	1.56	94.7
SB85751	Hull-less, waxy	6.8	71.6	28.4	7.7	6.3	10.2	1.32	89.6
SB86106	Hull-less, normal	7.0	68.6	31.4	5.6	4.2	8.1	1.45	91.1
SB87697	Hull-less, normal	5.2	70.0	30.0	4.5	3.8	6.3	1.41	95.6
SB88490	Hull-less, normal	1.3	71.1	28.9	4.9	4.5	6.3	1.30	100.0
SB86132	Hull-less, normal	5.9	69.6	30.4	5.6	5.0	7.7	1.38	118.8
Mean		7.1	69.7	30.3	6.0	5.0	8.2	1.36	94.7
SD		2.6	1.0	1.0	2.0	1.5	3.2	0.1	7.7
CV		36.6	1.4	3.3	33.3	30.0	39.0	7.4	8.1

[a] Percentage of total recovered product, milled singly.

TABLE IV
Distribution of β-Glucan in Flour and Bran Fractions of Azhul Hull-Less Barley (11.3% β-glucan) Milled Through Different Screens in an Allis-Chalmers Experimental Mill

Screen Size			Flour Yield[a]	Bran Yield[a]	Bran β-Glucan	Enrichment
Number	Micrometers	Texture	(%)	(%)	(%)	(fold)
30 GG	630	Coarse	71.3	28.7	11.6	1.03
50 GG	333	Medium	71.1	28.9	14.1	1.25
64 GG	236	Fine	68.7	31.3	15.5	1.37
LSD[b]			1.5	1.5	0.3	0.04

[a] Percentage of recovered product; milled in duplicate.
[b] Least significant differences calculated from analysis of variance.

a β-glucan enrichment of 1.37-fold, which was similar to the average obtained on milling 15 cultivars of barley (Table III).

Although barley products such as flakes, grits, and pearl barley flour are commercially available for use in foods, roller-milled barley flour and bran have the most potential in food applications. Roller-milled barley flour is a versatile ingredient and may be used for making pastry, cookies, muffins, cakes, and flat breads or used as a food thickener. Similarly, barley bran has many applications in ready-to-eat cereals, high-fiber breads, cookies, and muffins. Several of these uses have been listed and recently reviewed (Newman and Newman 1991).

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LITERATURE CITED

ANDERSON, J. W., SPENCER, D. B., HAMILTON, C. C., SMITH, S. F., TIETYEN, J., BRYANT, C. A., and OELTGEN, P. 1990. Oat-bran cereal lowers serum total and LDL cholesterol in hypercholesterolemic men. Am. J. Clin. Nutr. 52:495-499.

BHATTY, R. S. 1986. Physiochemical and functional (breadmaking) properties of hull-less barley fractions. Cereal Chem. 63:31-35.

BHATTY, R. S. 1987. Relationship between acid extract viscosity and total soluble and insoluble β-glucan contents of hulled and hulless barley. Can. J. Plant Sci. 67:997-1008.

BHATTY, R. S. 1991. Dietary and nutritional aspects of barley in human foods. In: Proc. Int. Barley Genet. Symp., 6th., Helsingborg, Sweden.

BHATTY, R. S., and MacGREGOR, A. W. 1988. Gamma irradiation of hulless barley: Effect on grain composition, β-glucans and starch. Cereal Chem. 65:463-470.

BHATTY, R. S., MacGREGOR, A. W., and ROSSNAGEL, B. G. 1991. Total and acid-soluble β-glucan content of hulless barley and its relationship to acid-extract viscosity. Cereal Chem. 68:221-227.

CHEIGH, H.-S., SNYDER, H. E., and KWON, T.-W. 1975. Rheological and milling characteristics of naked and covered barley varieties. Korean J. Food Sci. Technol. 7:85-90.

HOLM, J., BJOREK, I., DREWS, A., and ASP, N. G. 1986. A rapid method for the analysis of starch. Starch/Staerke 38:224-226.

LEHTONEN, M., and AIKASALO, R. 1987. β-Glucan in two- and six-rowed barley. Cereal Chem. 64:191-192.

McCLEARY, B. V., and GLENNIE-HOLMES, M. 1985. Enzymic quantitation of (1→3)-(1→4)-β-glucan in barley and malt. J. Inst. Brew. 91:285-295.

McGUIRE, C. F. 1979. Roller milling and quality evaluation of barley flour. Page 89 in: Proc. Jt. Barley Util. Semin., Suweon, Korea.

McINTOSH, G. H., WHYTE, J., McARTHUR, R., and NESTEL, P. J. 1991. Barley and wheat foods: Influence on plasma cholesterol concentrations in hypercholesterolemic men. Am. J. Clin. Nutr. 53:1205-1209.

NEWMAN, R. K., and NEWMAN, C. W. 1991. Barley as a food grain. Cereal Foods World 36:800-805.

NEWMAN, R. K., NEWMAN, W. C., and GRAHAM, H. 1989. The hypocholesterolemic function of barley β-glucans. Cereal Foods World 34:883-886.

PEDERSEN, B., and EGGUM, B. O. 1983. The influence of milling on the nutritive value of flour from cereal grains. 3. Barley. Qual. Plant. Plant Foods Hum. Nutr. 33:99-112.

RANHOTRA, G. S., GELROTH, J. A., ASTROTH, K., and BHATTY, R. S. 1991. Relative lipidemic responses in rats fed barley and oat meals and their fractions. Cereal Chem. 68:548-551.

SMITH, D. B., MORGAN, A. G., and AASTRUP, S. 1980. Variation in the biochemical composition of acid extracts from barleys of contrasting malting quality. J. Inst. Brew. 86:277-283.

WOOD, P. J., BRAATEN, J. T., SCOTT, F. W., RIEDEL, D., and POSTE, L. M. 1990. Comparisons of viscous properties of oat and guar gum and the effects of these and oat bran on glycemic index. J. Agric. Food Chem. 38:753-757.

WOOD, P. J., WEISZ, J., and FEDEC, P. 1991. Potential for β-glucan enrichment in brans derived from oat (*Avena sativa* L.) cultivars of different (1→3),(1→4)-β-D-glucan concentrations. Cereal Chem. 68:48-51.

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