Survey of ß-glucan Content of Barley Cultivars Adapted to North Dakota

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Elevated serum cholesterol levels are widely recognized as a significant risk factor for the development of heart disease. In the past decade, dietary modifications which may reduce serum cholesterol levels have become a major concern of a large portion of the American population. These modifications include reduction of total fat and increasing the intake of soluble dietary fiber. Soluble fiber from oat (*Avena sativa* L.) and oat bran have been associated with a hypocholesterolemic effect (Anderson et al., 1984).

As a consequence, the number of oat-based cereals and food products available in the marketplace has increased dramatically. Barley also is an excellent source of soluble fiber and has been associated with cholesterol-lowering effects in humans (Newman et al., 1989). These facts have stimulated increased interest in barley both as an economical source of dietary fiber and as a healthy food ingredient.

The soluble fiber of barley and oats is composed primarily of polysaccharides from the cell walls of the grain. The major soluble components of barley and oat fiber are ß-glucans. ß-glucans recently have been identified as the constituent responsible for the hypocholesterolemic effect of oat bran (Davidson et al., 1991).

ß-glucan content of oat and barley is affected by both genotype and growing conditions, but genetic factors appear to be of greater significance (Stuart et al., 1988; Welch et al., 1991). Total ß-glucan content of oat cultivars has been reported to range from 3.9 to 6.8 percent in the groat (Wood et al., 1991). Approximately 80 percent of the ß-glucans in oats are soluble (Åman and Graham, 1987). Total ß-glucan content of hulled malting and feed barley cultivars has ranged from 2 to 10 percent (Bamforth, 1982). On average, 54 percent of barley ß-glucans are soluble. Cultivars expressing hull-less or waxy endosperm traits are, in general, greater in ß-glucan content (Fox, 1981). Hull-less barley cultivars as high as 16 percent in ß-glucan have been reported (Newman et al., 1989).

The cultivar Wanubet, a waxy hull-less barley, has been grown under contract on a limited acreage in North Dakota since 1989 for sale to food processors. Wanubet yields approximately 30 percent less than hulled cultivars grown in North Dakota because of its weaker straw, susceptibility to disease, and lower genetic yield potential. The majority of hulled cultivars currently grown in North Dakota were developed for malting and brewing use and are inherently low in ß-glucan content. High levels of ß-glucan content in malt can cause filtration and haze problems in the brewing process (Bamforth, 1985; McCleary and Gennie-Holmes, 1985). High yielding cultivars with high ß-glucan content are necessary to satisfy barley producers and the food processing industry.

The barley breeding program at the North Dakota Agricultural Experiment Station has been developing waxy hull-less barley cultivars adapted to North Dakota. As part of the breeding program, a survey was conducted to determine the total and soluble ß-glucan content, alkaline viscosity, grain protein, and percent plump kernels of elite hulled and hull-less barley lines adapted to North Dakota.

Nine barley genotypes representing hulled and hull-less and waxy and non-waxy endosperm were evaluated in this study (Table 1). Entries were grown at Carrington, Minot, and Langdon in 1988 and 1990 and at Carrington, Langdon, and Prosper in 1989. Entries were grown under flood irrigation at Carrington.

Mean total ß-glucan of the nine genotypes was 4.54 percent and ranged from 4.27 to 5.52 percent (Table 2). This range is less than the 2 to 10 percent range reported by Bamforth (1982) yet similar to results reported by other researchers (Åman and Graham, 1987; Henry, 1985). The lower total ß-glucan content of genotypes evaluated in this study may be due to the fact that they were developed in "malting" barley breeding programs in which high levels of ß-glucan in the malt are undesirable.

Waxy Bowman had significantly greater total ß-glucan and alkaline viscosity than all genotypes and significantly greater soluble ß-glucan content than all genotypes except Azure (Table 2). Ullrich et al. (1986) also found that waxy genotypes had greater total ß-glucan content and alkaline viscosity than normal genotypes. Bowman had the lowest total ß-glucan content of all genotypes and no significant difference was observed between Bowman and genotypes with the lowest soluble ß-glucan content and alkaline viscosity.

Mean soluble ß-glucan content as a percent of total (S/T) across genotypes was 55.9 percent (Table 2). Azure had the greatest S/T, 62.6 percent, and Excel the lowest, 52.6 percent. Åman and Graham (1987) observed a greater mean S/T, 55.8 percent, and range, 38 to 69 percent, for barley genotypes adapted to Montana and Sweden.

Hull-less Bowman and Waxy Bowman are near-isogeneic lines of Bowman. They are genetically similar to Bowman except for a one gene difference. Hull-less Bowman differs from Bowman by the presence of the *n* gene conferring the hull-less character. Waxy Bowman differs from Bowman by the presence of the *wx* gene conferring the waxy endosperm character.

The *wx* and *n* genes were responsible, in part, for increasing total and soluble -glucan content and alkaline viscosity of Waxy and Hull-less Bowman over that found in Bowman. The *wx* gene had the greatest effect, increasing total and soluble ß-glucan content 1.25 and 0.68 percentage units, respectively, and alkaline viscosity 1.7 Cs above that of Bowman (Table 2). Total ß-glucan content of Hull-less Bowman was significantly greater than that of Bowman. Soluble ß-glucan content of these two genotypes did not differ significantly; however, soluble ß-glucan content of Hull-less Bowman tended to be greater than that of Bowman.

Ullrich et al. (1986), in a study comparing total ß-glucan content of normal barley and their waxy near-isogeneic pair in several genetic backgrounds, also observed that the *wx* gene caused an increase in total ß-glucan content. The increase ranged from 0.4 to 3.5 percentage units and averaged 1.6 percentage units. The difference they observed in total ß-glucan content between normal and waxy endosperm near-isogeneic pairs was affected not only by the *wx* gene but by the genetic background of the pairs and the environment in which they were grown. Hot, dry growing conditions during grain fill tend to increase total ß-glucan content (Hockett et al., 1987; Ullrich et al., 1986).

Table 1. Phenotype and origin of barley genotypes evaluated.

Genotype	Hull type	Endosperm	Origin
Azure	Hulled	Non-waxy	NDAES[1]
Hazen	Hulled	Non-waxy	NDAES
Bowman[2]	Hulled	Non-waxy	NDAES
Excel	Hulled	Non-waxy	MAES[3]
Robust	Hulled	Non-waxy	MAES
B1602	Hulled	Non-waxy	BARI[4]
B1603	Hulled	Non-waxy	BARI
Hulless-Bowman[2]	Hull-less	Non-waxy	NDAES[5]
Waxy Bowman[2]	Hulled	Waxy	NDAES[5]

[1]NDAES = North Dakota Agricultural Experiment Station
[2]Two-rowed barley
[3]MAES = Minnesota Agricultural Experiment Station
[4]BARI = Busch Agricultural Research, Inc.
[5]Unreleased germplasm from the NDAES

Table 2. Mean total and soluble ß-glucan, alkaline viscosity, plump kernels, and grain protein of nine barley genotypes grown over eight environments in North Dakota, 1988-1990.

Genotype	Total ß-glucan	Soluble ß-glucan	Soluble ß-glucan as % of total	Alkaline viscosity	Grain protein
	%	%		Cs[1]	%
Azure	4.86 d[2]	3.04 bc	62.6 c	2.94 cd	13.8 abc
Hazen	4.51 b	2.43 a	53.9 ab	2.46 ab	14.0 bc
Bowman	4.27 a	2.45 a	57.4 b	2.52 ab	14.1 bc
Excel	4.73 cd	2.49 a	52.6 a	2.51 ab	13.2 a
Robust	4.65 bc	2.46 a	52.9 a	2.29 a	14.3 c
B1602	4.49 b	2.41 a	53.7 ab	2.62 abc	13.6 ab
B1603	4.46 ab	2.48 a	55.6 ab	2.71 bc	14.2 c
Hul Bow[3]	4.74 cd	2.75 ab	58.0 bc	3.47 d	15.7 d
Wax Bow[4]	5.52 e	3.13 c	56.7 ab	4.21 e	15.5 d
Mean	4.54	2.54	55.9	2.63	14.4

[1]Cs = Centistokes
[2]Means followed by the same letter are not significantly different at the ($P<0.05$) probability level.
[3]Hul Bow = Hull-less Bowman
[4]Wax Bow = Waxy Bowman

The effect of genetic background on β-glucan content indicates that when breeding for new cultivars with high β-glucan content, the choice of parents is important. The inherently greater total and soluble -glucan content and S/T value of Azure as compared to other cultivars currently grown in North Dakota (Table 2) suggests that Azure may be a good parent. The development of a hull-less waxy Azure genotype bred by backcrossing the *wx* and *n* genes into an Azure genetic background might produce a cultivar with high total and soluble β-glucan content and excellent agronomic performance.

A bottleneck in any breeding program is evaluation of experimental lines for specific traits. In breeding for high soluble β-glucan barley cultivars, evaluation of β-glucan content will be time consuming and expensive. Identification of a trait that is highly correlated to soluble β-glucan content and inexpensive to measure could increase the efficiency of a breeding program because the correlated trait could be used to identify lines with high soluble β-glucan content. The use of grain protein content, alkaline viscosity, and kernel plumpness to estimate β-glucan content have been investigated by several researchers.

In two studies by Henry (1985, 1986), a positive relationship was observed between total β-glucan content and grain protein content. However, the relationship between the two traits was not strong enough to successfully select for high β-glucan lines by selecting for high protein lines. Ullrich et al. (1986) and Hockett et al. (1987) evaluated the relationship between alkaline viscosity and total β-glucan content. In both studies, a positive relationship significantly different from zero was observed. Ullrich et al. (1986) found a correlation of r=0.55 (P<0.01, n=21) between the two characters. They concluded this relationship was not strong enough to allow successful selection of high β-glucan lines based on alkaline viscosity. Hockett et al. (1987) found a much stronger relationship (r=0.87, P<0.01, n=192). They stated that alkaline viscosity could be used to estimate β-glucan content.

The relationships between total and soluble β-glucan content, alkaline viscosity, grain protein content, and kernel plumpness were estimated by calculating simple correlations (Table 3). Correlations significantly different from zero were found for total vs. soluble-glucan content (r=0.71, P<0.05, n=75), alkaline viscosity vs. soluble -glucan content (r=0.42, P<0.05, n=75), and plump kernels vs. total β-glucan content (r=0.38, P<0.05, n=75). Even though the correlation values were significantly different from zero, the relationships were not strong enough to allow prediction of β-glucan levels using these traits.

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Literature Cited

Åman, P. and H. Graham. 1987. Analysis of total and insoluble mixed-linked (1-3), (1-4)-β-glucans in barley and oats. J. Inst. Food Chem. 35:706-709.

Anderson, J.W., L. Story, B. Sieling, W.L. Chen, M.S. Petro, and J. Story. 1984. Hypocholesterolemic effects of oat bran or bean intake for hyupocholesterolemic men. Am. J. Clin. Nutr. 40:1146-1155.

ASBC. 1976. Methods of analysis of the American Society of Brewing Chemists. ASBC, St. Paul, MN.

Bamforth, C.W. 1985. Biochemical approached to beer quality. J. Inst. Brew. 91:154-160.

Bamforth, C.W. 1982. Barley β-glucans: their role in malting and brewing. Brew. Dig. 22:27.

Davidson, M.H., L.D. Dugan, J.H. Burns, J. Bova, K. Story, and B. Drennan. 1991. The hypocholesterolemic effects of β-glucan in oatmeal and oat bran. JAMA 265:1833-1839.

Fox, G.J. 1981. The effect of the waxy endosperm, short awn, and hulless seed genes upon biochemical and physiological seed characteristics important in barley (*Hordeum vulgare* L.) utilization. Ph.D. Thesis, Abstract no. DE 082-14646, Montana State Univ., Bozeman, MT.

Henry, R.J. 1986. Genetic and environmental variation in the pentosan and β-glucan contents of barley, and their relation to malting quality. J. Cereal Sci. 4:269-277.

Henry, R.J. 1985. A comparative study of the total β-glucan contents of some Australian barleys. Aust. J. Exp. Agric. 25:424-427.

Hockett, E.A., C.F. McGuire, C.W. Newman, and N. Prentice. 1987. The relationship of barley β-glucan content to agronomic and quality characteristics. pp. 851-860. In S. Yasuda and T. Konishi (eds.) Barley Genetics V. Proc. 5th Int. Barley Genet. Symp., Okayama, Japan, 6-11 October, 1986.

McCleary, B.V. and M. Gennie-Holmes. 1985. Enzymatic quantification of (1-3), (1-4)-β-glucan in barley and malt. J. Inst. Brew. 91:285-295.

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

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Table 3. Correlation coefficients between total and soluble β-glucan content, grain protein, alkaline viscosity, and plump kernels of barley grown in North Dakota, 1988 to 1990 (n=75).

	Total β-glucan	Soluble β-glucan	Alkaline viscosity	Plump kernels
Grain protein	.34	.07	.24	.10
Total β-glucan		.71**	.28	.38*
Soluble β-glucan			.42*	.26
Alkaline viscosity				.12

*,**Significantly different from zero at (P<0.05) and (P<0.01) probability levels, respectively.