ELSEVIER

Food Chemistry 79 (2002) 251–254

Food Chemistry

www.elsevier.com/locate/foodchem

Analytical, Nutritional and Clinical Methods Section

Analysis of β-glucan content in barley cultivars from different locations of China

Guoping Zhang*, Wang Junmei, Chen Jinxin

Department of Agronomy, Huajia Chi Campus, Zhejiang University, 310029, Hangzhou, China

Received 4 September 2001; received in revised form 9 January 2002; accepted 9 January 2002

Abstract

β-glucan content of barley cultivars collected from various areas of China, as well as from Canada and Australia, were assayed by an enzymatic method. Meanwhile a multi-location trial was conducted to determine β-glucan content of eight barley cultivars in each location. For 164 cultivars, originating from China, β-glucan content ranged from 2.98% for Sumei 21 to 8.62% for QB25, with a mean of 4.58%. Tibet barleys, all of the hull-less type, had the highest β-glucan content. Winter barley cultivars from various areas of China had basically the same β-glucan content as those from Canada and Australia. The seeds produced in Hangzhou had lower β-glucan contents than those produced locally. The effects of cultivars, environments (locations) and their interactions on β-glucan content variation was all highly significant, with the cultivars having the largest effect. The highly significant interaction between cultivars and environment suggests that it is important to plant the appropriate cultivar in a particular area in order to obtain barley seeds with reasonable β-glucan contents.

Keywords: Barley; β-glucan; Cultivar; Environment

1. Introduction

The mixed-linked (1→3), (1→14)-β-D-glucan (hereafter referred to as simple β-glucan) is a cell wall polysaccharide found only in grass and cereals (Carpita, 1996). Compared with other cereals, barley and oats have relatively high β-glucan contents. In barley, β-glucan has become a growing concern at multi-discipline levels due to its positive role in human health when used as food and its potential deterioration on malting. In the brewing industry, a high content of β-glucan in barley may lead to problems such as reduced rate of wort filtration and haze formation in beer, and adversely affect the recovery of malt extract (Barrett, Clapperton, Divers, & Rennie, 1973; McCleary & Glennie-Homes, 1985). The high viscosity of aqueous solutions of barley β-glucan has also been implicated in the problems encountered in the stock-feed industry; therefore it is considered as a anti-nutritional factor, particularly in chicken and poultry diets where it may give sticky droppings and affect nutritional intake, growth and feed conversion efficiency (Hasselman & Thomke, 1982; Wang, Newman, Newman, & Hofer, 1992). On the other hand, positive roles of β-glucan in human nutrition and health, such as lowering of blood cholesterol and blood glucose, increasing mineral and vitamin bio-availability and controlling colon cancer, have been reported (Klopfenstein, 1988; Martinez, Newman, & Newman, 1991).

Variation in barley β-glucan content is associated with genetically controlled starch and hull type. High β-glucan content is reported in hull-less cultivars (Bengtsson, Aman, Graham, Newman, & Newman 1990; Bhatty, MacGergor, & Rossnagel, 1991) and in cultivars with 100% amylopectin (waxy) starch (Ullrich, Clancy, Eslick, & Lance, 1986; Xue, Newman, Newman, & Maguire, 1991). Environment also influences β-glucan content (Fastnaught, Berglund, Holm, & Fox, 1996; Narasimhalu, Kong, Choo, Ferguson, Therrien, Ho, May, & Jui, 1995; Stuart, Loi, & Fincher, 1998). Barley β-glucan contents, reported so far, have ranged from less than 2% to more than 10%, and variation is not only caused by genetics and environment, but is also due to the analysis methodology. The earlier analytical method, by measuring viscosity gave high values, while the enzymatic method, developed by McCleary and

* Corresponding author. Tel.: +86-571-8697115; fax: +86-571-86971117.

E-mail address: zhanggp@zju.edu.cn (G. Zhang).

0308-8146/02/$ - see front matter
PII: S0308-8146(02)00127-9

Glennie-Homes (1985), by use of a specific assay kit, has proved to be a simple procedure given good repeatability.

Barley is one of the most important cereal crops in China; it grows in widely ecological locations and finds manifold uses. Commonly, it is used as a material for malting and feed processing while, in Tibet, barley is a stable food crop. However, there has been little research on β-glucan content in China. The objective of this study was to determine β-glucan content of barley cultivars from different locations and to examine its variation as affected by genotypes and environments.

2. Materials and methods

One-hundred and eighty-five barley cultivars or breeding lines were collected from the main productive areas of China. Among them, 75 cultivars (lines) came from Tibet (kindly provided by Professor Qiang X-L at the Tibet Institute of Agricultural Research, Lasa, 91.1° E, 29.6° N), 27 from Xingjian (kindly provided by Professor Cao L-P at the Agricultural college, Shihezi University; Shihezi, 87.6° E, 43.7° N), and others from Jiangsu (Yanchen, 118.2° E, 31.5° N), Hunan (Zhangsai, 1130° E, 28.2° N), Hubei (Wuhan, 114.2° E, 30.6° N), Sichuan (Chengdu, 104.1° E, 30.6° N), Shandong (Taian, 117.2° E, 36.2° N), Gansu (Lanzhou, 103.8° E, 36.05° N) and Zhejiang (Hangzhou, 120.2° E, 30.5° N). All of the Tibet barleys were of the hull-less type while other Chinese barleys were the hulled type. Except for Xinjiang, where barley is sown in spring, in all other regions it is sown in winter. In addition, 21 commercial barley cultivars were collected from Canada and Australia for comparative study.

All collected cultivars or lines were planted at the experimental farm of Zhejiang University (Huajia Chi Campus) in early November 1999. The materials were grown in two replicates of two-row plots, 2 m long, 30 cm between rows and 100 seeds per row. The trial was managed according to locally recommended cultural practice. At maturity, thirty spikes of main shoots were harvested from the cultivars with similar mature dates.

According to a previous experiment (Wang, Zhang, Chen, & Ding, 1998), eight two-rowed barley cuitivars with similar growth durations and substantial differences in β-glucan contents were used and grown at six diverse environments of Zhejiang in the 1999–2000 growing season. All cultivars were grown adjacently in the same field and each cultivar consisted of three 2-m-length rows with three replicates. At maturity, 30 spikes of main shoots were harvested from each replicate.

Grain samples were ground through a 0.5-mm sieve in a Cyclotec mill after drying in an oven for 24 h. Total β-glucan was analyzed according to the McCleary and Glennie-Holmes (1985) methods using a commercial kit (Megazyme Ltd. Ireland).

3. Results and discussion

There were great differences in β-glucan contents among the samples, both from the different areas and within the same location (Table 1). For 164 cultivars (lines) from China, β-glucan content ranged from 2.98% for Sumei 21, a commercial cultivar in Jiangsu province, to 8.62% for QB25, a breeding line in Tibet. On average, for all cultivars, the value was 4.58% and approximately two third of samples fell into the range 3.0–5.0%. In terms of location distribution, the cultivars or lines with β-glucan contents higher than 8% were found only in the samples from Tibet, in which the mean of all 75 cultivars was 5.25%, ranked the highest among various collections, and 20% of samples had β-glucan contents higher than 6%. The mean content of 27 Xinjiang cultivars was 5.09%, this being the second highest among collections. Although no cultivar containing more than 8% of β-glucan was found in Xinjiang barley samples, its proportion of cultivars with

Table 1
Frequency distribution of barley cultivars originating from the different areas on the basis of grain β-glucan content

β-Glucan content	Total	Tibet	Xinjiang	Other areas in China		Canada and Australia
				Seeds from original areas	Seeds produced at Hangzhou	
				%		
<3.0	5.34	0	0	3.23	12.9	14.3
>3.0–<4.0	28.6	8.0	7.41	45.2	67.7	38.10
>4.0–5.0	37.4	46.7	51.9	35.5	16.1	28.6
>5.0–<6.0	18.0	24.0	18.5	16.13	3.23	19.1
>6.0–<7.0	6.8	12.0	18.5	0	0	0
>7.0–<8.0	2.91	6.67	3.7	0	0	0
>8.0	0.97	2.67	0	0	0	0
Sample number	164	75	27	62	62	21
Mean	4.58	5.25	5.09	4.24	3.61	4.02
Standard deviation	1.08	1.06	0.92	0.67	0.55	0.81

more than 6% of β-glucan was nearly as high as that in Tibet samples. Sixty-two cultivars from other areas of China had a 4.24% mean β-glucan content, obviously lower than those both from Tibet and Xinjiang. Compared to original seeds, the Hangzhou-productive seeds were significantly lower in β-glucan content, suggesting the modification of β-glucan content by environment. Twenty-one beer cultivars from Canada and Austria were within the range 2.76% for AB168–11 to 5.14% for Gateways 3, with a mean content of 4.02%.

The wide diversity in β-glucan content could be significant in the commercial utilization of barley. Since the enzymatic method of measuring β-glucan content was developed by McCleary and Gennie-Holmes (1985), grain β-glucan contents among barley cultivars have been reported to range from 3.0 to 8.2% (Aman & Graham, 1987; Carr, Glatter, Jeraci, & Lewis, 1989; Fastnaught et al., 1996; Henry, 1987; Lehtonen & Aikasalo, 1987). The wider range of β-glucan content for the barley collections in this study may be attributed to more samples and the greater differences in the environments of a particular cultivar origin. The higher β-glucan content in Tibet barley cultivars may be at least partly related to their hulless type and is desirable in light of their use as feed.

In China, more and more malt barley is being imported with the increase of beer production, as local barley is considered to be inferior, in malting quality, to imported barley. One of the reasons for inferior quality is attributed to high β-glucan content. In this experiment, we found that most of the cultivars, except for those from Xinjiang, had β-glucan contents not higher than those from Canada and Australia, indicating that β-glucan content is not a predominant factor leading to inferior malting quality in Chinese-productive barley. Moreover, the barley grown in Zhejiang had a much lower β-glucan content. Therefore, the higher β-glucan content in malt for Chinese-productive beer barleys should be attributed to lower β-glucanase activity in grains.

Variance analysis for β-glucan content of eight barley cultivars, grown at six locations in Zhejiang, showed that the effects of cultivars, locations and their interaction were all highly significant (Table 2). Comparatively, cultivars shared a larger contribution to the variation in β-glucan content than locations or interaction.

On average in six locations, β-glucan content of eight cultivars in this study ranged from 3.24% for Zhepi 4 to 4.62% for Xue 92–47, with a mean of 3.95% (Table 3). The cultivars differed widely in the coefficient of variation (CV) when planted at different locations. Thus, Xuemei 3 and ZAU 7 had the greatest and least CV, respectively, suggesting a great difference among cultivars in their response to environment in terms of β-glucan content.

On average among eight cultivars, β-glucan content of six locations ranged from 3.86% for Yuyao to 4.14% for Teizhou (Table 4). Although the locations also differed significantly, the absolute difference between the highest and lowest was much smaller than that between cultivars. Coefficient of variation in β-glucan content for eight cultivars grown within a location was smaller than for a cultivar grown in the different locations.

Genetic and environmental variations in the β-glucan content of barley have been reported in several studies (Aastrup, 1979; Henry, 1986; Molina-Cano, Francesch, Perez-Vendrell, Ramo, Voltas, & Brufau, 1997). Genetic factors have been found to be the more important (Henry, 1986; Molina-Cano et al., 1997). In this study, significant differences among cultivars are also found, irrespective of planting locations, and cultivars differ in the variation of β-glucan content over locations. The

Table 2
Variance analysis on β-glucan contents of eight barley cultivars grown at six locations

Source of variation	df	SS	MS	*F* value
Total	95	28.4276	0.2992	
Cultivar	7	18.5734	2.6533	64.51**
Location	5	2.8298	0.5660	13.76**
Interaction	*35*	5.0502	0.1443	3.51
Error	48	1.9741	0.0411	

** Significant at 0.01 probability level.

Table 3
Means and coefficients of variation of β-glucan contents corresponding to barley cultivars grown at six locations

Cultivar	β-Glucan%	CV%
Xu92–47	4.62[a]	12.3
ZAU 7	3.90b	9.81
Xumai 3	4.54a	21.9
ZAU6	4.04b	12.2
92–11	3.81b	11.7
ZAU 3	3.49c	10.4
Zhepi 4	3.92b	18.8
Zheyuan 18	3.24d	11.9

[a] Means within a column followed by a different letter are significantly different ($P < 0.05$).

Table 4
Means and coefficients of variation of β-glucan contents of eight barley cultivars grown at each location

Location	Mean%	CV%
Hangzhou	4.07a[a]	7.45
Jiaxing	4.06a	6.03
Yuvao	3.68b	7.84
Quzhou	3.99a	8.94
Taizhou	4.14a	7.82
Lishui	3.75b	7.68

[a] Means within a column followed by a different letter are significantly different ($P < 0.05$).

interaction of cultivar and location is also highly significant, suggesting the importance of cultivar selection in a particular area.

Acknowledgements

The authors are deeply indebted to both the National Natural Science Foundation of China (No. 39870506) and Zhejiang Natural Science Foundation (No. 397259) for their support to this project.

References

Aastrup, S. (1979). The relationship between the viscosity of an acid extract of barley and its β-glucan content. *Carlsberg Research Communications*, *44*, 381–393.

Aman, P., & Graham, H. (1987). Analysis of total and insoluble mixed-linkage β-glucan in barley and oat. *Journal of Agricultural Chemistry*, *35*, 704–709.

Barrett, J., Clapperton, J. F., Divers, D. M., & Rennie, H. (1973). Factors affecting wort separation. *Journal of the Institute of Brewing*, *79*, 407–411.

Bengtsson, S., Aman, P., Graham, H., Newman, C. W., & Newman, R. K. (1990). Chemical studies on mixed-linked β-glucans in hulless barley cultivars giving different hypocholesterolaemic response in chickens. *Journal of Science and food Agriculture*, *52*, 435–455.

Bhatty, R. S., MacGergor, A. W., & Rossnagel, B. G. (1991). Total and acid-soluble β-glucan content of hulless barley and its relationship to acid-extract viscosity. *Cereal Chemistry*, *68*, 221–227.

Carpita, N. C. (1996). Structure and biogenesis of cell walls of grasses. *Annual Review of Plant Physiology and Plant Molecular Biology*, *47*, 445–476.

Carr, J. M., Glatter, S., Jeraci, J. L., & Lewis, B. A. (1989). Enzymatic determination of β-glucan in cereal-based food products. *Cereal Chemistry*, *67*, 226–229.

Fastnaught, C. E., Berglund, P. T., Holm, E. T., & Fox, G. J. (1996). Genetic and environmental variation in β-glucan content and quality parameters of barley for food. *Crop Science*, *36*, 941–946.

Henry, R. J. (1986). Genetic and environmental variation in the pentosan and β-glucan contents of barley, and their relation to malting quality. *Journal of Cereal Science*, *4*, 269–277.

Henry, R. J. (1987). Pentosan and (1→3) (1→4)-β-glucan concentrations in endosperm and wholegrain of wheat, barley, oat and rye. *Journal of Cereal Science*, *6*, 253–258.

Hasselman, K., & Thomke, S. (1982). Increasing levels of β-glucanase on productive value of barley diets for broiler chickens. *Animal Feed Science Technology*., *7*, 351–358.

Klopfenstein, C. F. (1988). The role of cereal β-glucan in nutrition and health. *Cereal Foods World*, *33*, 865–869.

Lehtonen, M., & Aikasalo, R. (1987). β-glucan in two and six-rowed barley. *Cereal Chemistry*, *64*, 191–193.

Martinez, V. M., Newman, R. K., & Newman, C. W. (1991). Barley diets with different fat sources have hypocholesterolemic effects in chickens. *Journal of Nutrition*, *122*, 1070–1076.

McCleary, B. V., & Glennie-Homes, M. (1985). Enzymatic quantification of (1→3) (1→4)-β-D-glucan in barley and malt. *Journal of the Institute of Brewing*, *91*, 285–295.

Molina-Cano, J. L., Francesch, M., Perez-Vendrell, A. M., Ramo, T., Voltas, J., & Brufau, J. (1997). Genetic and environmental variation in malting and feed quality of barley. *Journal of Cereal Science*, *25*, 37–47.

Narasimhalu, P., Kong, D., Choo, T. M., Ferguson, T., Therrien, M. C., Ho, K. M., May, K. W., & Jui, P. (1995). Effects of environment and cultivar on total mixed-linkage β-glucan content in eastern and western Canadian barleys *(Hordeum vulgare* L.). *Canadian Journal of Plant Science*, *75*, 371–376.

Stuart, I. M., Loi, L., & Fincher, G. B. (1988). Varietal and environmental variations in (1→3, 1→4)-β-glucan levels and (1→3, 1→4)-β-glucanase potential in barley: relationships to malting quality. *Journal of Cereal Science*, *7*, 61–71.

Ullrich, S. E., Clancy, J. A., Eslick, R. F., & Lance, R. C. M. (1986). β-glucan content and viscosity of extracts from waxy barley. *Journal of Cereal Science*, *4*, 279–286.

Wang, L-J., Newman, R. K., Newman, C. W., & Hofer, P. J. (1992). Barley β-glucans alter intestinal viscosity and reduce plasma cholesterol concentration in chicks. *Journal of Nutrition*, *122*, 2292–2297.

Wang, J., Zhang, G., Chen, J., & Ding, S. (1998). Variation in β-glucan content among barley genotypes and its relationships with some characters. *Journal of Zhejiang Agricultural University*, *24*, 253–254.

Xue, O., Newman, R. K., Newman, C. W., & Maguire, C. F. (1990). Waxy gene effects on β-glucan, dietary fiber content and viscosity of barley. *Barley Newsletter*, *34*, 89–92.