Available online at www.sciencedirect.com

SCIENCE DIRECT®

Food Chemistry 90 (2005) 773–777

Food Chemistry

www.elsevier.com/locate/foodchem

β-Glucan and mineral nutrient contents of cereals grown in Turkey

Ayhan Demirbas *

Department of Chemical Engineering, Selcuk University, 42031 Konya, Turkey

Abstract

Mixed-linked (1→3), (1→ 4)-β-D-glucan contents of 14 selected cereal grains grown in Turkey, such as barley (*Hordeum vulgaria*), beans, canary seed (*Tropaeolum peregrinum*), corn/maize (*Zea mays*), flax, lentil (*Lens culinaris*), millet (*Panicum miliaceum*), oat (*Avena sativa*), peas, rice, rye (*Secale cereale*), spelt (*Triticum spelta*), spring wheat and winter wheat, were determined quantitatively using enzymatic methods. By using pure β-D-glucanase and β-D-glucosidase in the experiments, (1→3), (1→ 4)-glycosidic bonds of linear polysaccharides found in cell-wall endosperm of plant seeds were hydrolyzed and the resulting β-D-glucans were determined by using glucose oxidase/peroxidase solution and measuring the absorbances at 510 nm in a UV-spectrophotometer. The nutrient mineral contents of the 14 selected cereal grains were studied. Some macronutrients such as K, Ca, Mg, N, P and S, and some micronutrients, such as Zn, Cu, Fe, Mn, Mo, and B, were analyzed by using atomic absorption spectrometric (AAS) methods. A flame photometer was used for determination of potassium. After oven drying of the samples, P was determined by a colorimetric method.

Keywords: β-glucan; Mineral nutrient; Cereal; Turkey

1. Introduction

Cereals are grasses, and monocotyledonous plants. In general, cereals are excellent sources of β-glucans, minerals, vitamins and vegetable proteins. They are also excellent sources of zinc, highly available iron, copper, manganese, molybdenum and boron and provide significant amounts of phosphorus, potassium, calcium, magnesium, and nitrogen.

(1→3)(1→4)-β-D-Glucan (mixed linkage β-glucan), is a major cell wall carbohydrate which is isolated from cereal grains, notably oats and barley. It is used in wound dressings because of its potential to accelerate healing. The biological activity of β-glucan results from its ability to bind macrophage β-glucan receptors and promote macrophage activation.

Several of the nutrients in cereals have known potential, if in adequate amounts, for reducing risk factors for coronary heart disease (CHD). The predominantly polyunsaturated oil (50% linoleic acid) and possibly some of the fibre could lower plasma low density lipoprotein cholesterol (LDL), the vitamin E and selenium are antioxidants, and folic acid might lower plasma homocysteine. Cereals also contain phytoestrogens of the lignan family and several phenolic acids with antioxidant properties. Processing generally reduces the contents of these nutrients and bioprotective substances (Truswell, 2002).

Cereal grains, such as barley, oats, rye and some fungi containing β-D-glucans were used to decrease total blood cholesterol (Anderson et al., 1990; Braaten et al., 1994; Genc, Ozdemir, & Demirbas, 2001; Hegsted, Windhauser, Morris, & Lester, 1993; Ozdemir & Genc, 2001; Sanders & Reddy, 1991).

The β-D-glucans increase the high density lipoprotein cholesterol (HDL) and at the same time decrease levels of the LDL (Inglett, 1993). β-Glucan is a polysaccharide composed entirely of glucose units linked together to form a long polymer chain (Inglett, 1990). De Groot,

* Tel.: +90-462-230-7831; fax: +90-462-248-8508.
E-mail address: ayhandemirbas@hotmail.com.

0308-8146/$ - see front matter
doi:10.1016/j.foodchem.2004.06.003

Luyken, and Pikaar (1963) did a series of studies to determine the cholesterol-lowering properties of barley, wheat, rice and oats reported that only oat diets significantly lowered rat serum cholesterol (Klopfenstein, 1988).

In addition to their cholesterol-lowering and potential cancer-protecting properties, β-glucans maybe useful in controlling blood glucose levels (Klopfenstein, 1988). The (1→3)-β-D-glucans from yeast and other plants have been shown to have anti-tumor and antibacterial activity when injected, as well as cholesterol-lowering activity when ingested by experimental animals (Henry, 1987; Klopfenstein, 1988; Mekis & Bendek, 1987; Wood, 1984).

2. Materials and methods

Cereal samples, namely barley (*Hordeum vulgaria*), beans, canary seed (*Tropaeolum peregrinum*), corn/maize (*Zea mays*), flax, lentil (*Lens culinaris*), millet (*Panicum miliaceum*), oat (*Avena sativa*), peas, rice, rye (*Secale cereale*), spelt (*Triticum spelta*), spring wheat and winter wheat were supplied from the eastern part of Turkey in 2001–2002. The air-dried cereal samples were ground with a Tecator Cyclotec which already had a 0.5 mm screen and then dried in an oven at 353 K for 20 h. The β-D-glucanase (EC. 3.2.1.73) from *Bacillus subtilis* was obtained from Fluka (Swiss), β-D-glucosidase (EC. 3.2.1.21) from Fluka Biochemika as lyophilized salt-free powder (6 U/mg) and glucose oxidase/peroxidase (A02466) solution from glucose enzymatique color.

The method for the determination of (1→3), (1→ 4)-β-D-glucan content of cereal grains was developed by McCleary and Glennie-Holmes (1985) and is most appropriate and most accurate with the available equipment in the laboratory. In the procedure, highly purified enzymes were employed. The method should be easy to reproduce in any laboratory. Duplicate samples (0.5 g) of flour were weighed and β-D-glucan depolymerized with purified (1→3), (1→ 4)-β-D-glucanase to oligosaccharides and then hydrolyzed to glucose with specific purified β-glucosidase. Glucose was determined by glucose oxidase/peroxidase solution as sc d-glucose. β-Glucan content was calculated using the glucose quantity found in the Eq. (1):

$$\beta - \text{Glucan(wt\%)} = \Delta E \frac{F}{\text{mg}} \times 27, \qquad (1)$$

where ΔE is the absorbance difference after β-D-glucosidase treatment–blank absorbance, mg, weight of sample, and F, a factor for conversion of absorbance values to μg glucose.

For recovery of K, Mg, Ca, Zn, Fe, Mn, Cu, Mo and B, the grains were digested using a mixture of HNO_3:H_2SO_4:$HClO_4$ (4:1:1) (v:v:v) (20 ml for 2–4 g sample) and heating at 355 K for three hours. After cooling, 20 ml of demineralized water were added, the digest was again heated up to 425 K for four hours and brought to a volume of 25 ml with demineralized water.

Metal ion concentrations were determined as three replicates by Pye Unicam SP-9 atomic absorption spectrophotometer (AAS). A flame photometer (Biotechnical Instruments, Model 8T 624D) was used for determinations of K. After oven-drying of samples, P content was determined by a colorimetric method. N content was determined by the Kjeldahl method. Total S content was determined by the Eschka method. To eliminate the errors derived from matrix effect, a standard addition method was used instead of plotting a calibration curve (Skoog & West, 1981). To apply the standard addition technique, 20 g of organ sample was taken and 1 ml of working solution was added, which contained a determined amount of the metal ion. Standard added sample was analyzed in the same way as that without standard addition. The number of replicates was also three for standard added samples. Before applying the standard addition technique, a calibration curve was obtained to see the linear relationship between absorbance and concentration in the concentration range being worked.

3. Results and discussion

The significant components of cereal grains are mixed-linked (1→3) (1→4)-β-D-glucans derived from endosperm cell walls. All cereals contain β-glucan but some cereal grains have different β-glucan contents. Variations in the β-glucan contents of cereal grains grown under different environmental conditions have been observed (McCleary & Glennie-Holmes, 1985). The wide diversity in β-glucan content could be significant in the commercial utilization of cereals. In human food, a high content of β-glucan (soluble fibre) may be desirable whereas, in animal food, a lower β-glucan content may be preferable (McCleary & Glennie-Holmes, 1985).

Table 1 shows the average β-glucan contents of 14 cereal grains. As can be seen from Table 1, oat grains have the highest β-glucan. The oat grain content ranges from 3.9% to 5.7% of oat grains. Flaxseeds have the lowest β-glucan. The flaxseed content ranges from 0.3% to 0.7%.

Various cereal grains were grown under different environmental conditions but the effects of environmental factors on β-glucan content were not significant (Saastamoinen, Plaami, & Kumpulainen, 1989). Barley β-glucan content ranges from 3.2% to 4.6%. β-glucans form viscous solution and they can cause problems, for instance in the brewing industry, such as causing very slow filtration. Among the β-glucan contents of barley, that grown in the USA ranked the highest (7.2%) and in Canada the lowest (1.7%). Table 2 shows

Table 1
Average β-glucan content of cereal grains grown in Turkey

Grain	β-Glucan content of grain (%)	
	The lowest	The highest
Barley	3.2	4.6
Beans	2.4	3.5
Canary seed	1.1	2.3
Corn/maize	0.5	1.3
Flax	0.3	0.7
Lentils	0.4	1.1
Millet	0.5	1.0
Oat	3.9	5.7
Peas	0.3	0.7
Rice	0.4	0.9
Rye	0.7	1.5
Spelt	0.6	1.2
Spring wheat	0.6	1.1
Winter wheat	0.5	1.0

the average β-glucan content of cereal grain samples grown in different countries (Genc et al., 2001).

Oats is the major cereal crop in Turkey, and it is used as an animal feed. The β-glucan content of oats grown in the USA was the highest (6.6%) and that of oats grown in Sweden the lowest (2.2%) of all (Genc et al., 2001). Rye is like barley and oats; however the β-glucan contents of rye samples are much lower than those of barley or oats. Wheat grains also contain β-glucan but in lower concentrations than barley, oat or rye grains (Table 1). The increase in β-glucan content due to poor environmental conditions could not be attributed to similar growing times and mean temperatures because, in the entire sample material, there was no correlation between β-glucan content and grain yield.

Rye grain is valued for its energy (3300 kcal/kg) and protein content. Crude fibre is low and resembles wheat more than barley. The energy content of the rye grain is between those of barley and wheat, for both swine and cattle. The vitamin contents of rye grain are similar to other cereals.

Table 3 shows the average macronutrient contents of cereal grains grown in Turkey. As can be seen from Table 3, the flax grain has the highest K content (3.28 ± 0.86%). The rice grain has the lowest concentration of K (1.84 ± 0.21%). The rye grain has the highest Ca content (0.28 ± 0.9%) and the barley grain has the lowest Ca content (0.14 ± 0.05%). Beans have the highest Mg content (0.32 ± 0.09%). The oat grain has the lowest Mg content (0.16 ± 0.05%). Peas have the highest N and S contents (4.68 ± 0.86% and 0.20 ± 0.06%, respectively). Rice and corn have the lowest N and S contents (1.94 ± 0.25% and 0.08 ± 0.02%, respectively). Corn has the highest P content (0.42 ± 0.11%) and the flax has the lowest P content (0.22 ± 0.22%).

The average micronutrient contents of cereal grains grown in Turkey are given in Table 4. As can be seen from Table 4, peas have the highest Zn and B contents (44.6 ± 4.0 and 12.4 ± 2.45 mg/kg, respectively). Barley grains have the highest Cu and Mo contents (21.4 ± 1.8 and 6.48 ± 0.72 mg/kg, respectively). Lentil grains have the highest Fe and Mn contents (64.5 ± 7.1 and 53.8 ± 5.6 mg/kg, respectively). Corn, lentils, winter wheat, flax, rice and rice have the lowest Zn, B, Cu, Mo, Fe and Mn contents (17.0 ± 1.5, 8.45 ± 0.91, 6.84 ± 0.6, 2.76 ± 0.34, 9.58 ± 0.8, and 11.6 ± 1.2 mg/kg, respectively).

4. Conclusion

In this study, mixed-linked (1 → 3), (1 → 4)-β-D-glucan contents and 3 macronutrient (K, Ca and Mg) and 6 micronutrient (Zn, Cu, Fe, Mn, Mo, and B) contents of 14 selected cereal grains grown in Turkey were determined quantitatively using enzymatic and AAS methods, respectively. N, P, and S contents were determined by the Kjeldahl, colorimetric and Eshcka methods, respectively.

Various cereal grains were grown under different environmental conditions but the effects of environmental factors on β-glucan content were not significant. Barley and oat grains have β-glucan contents higher than the other cereals.

Table 2
Average β-glucan content of cereal grain samples grown in different countries (wt%)

Country of origin	Rye		Oat		Barley	
	The highest	The lowest	The highest	The lowest	The highest	The lowest
Australia	2.4	1.4	5.4	2.7	4.6	3.8
Canada	1.5	–	4.9	3.2	–	–
USA	2.9	–	6.6	4.8	7.2	4.3
Finland	1.6	–	–	–	5.2	2.8
Germany	1.3	–	5.0	–	4.9	–
Holland	1.8	1.2	4.6	2.8	4.9	–
Turkey	1.5	0.7	5.7	3.9	4.6	3.2
Russia	2.8	1.8	–	–	–	–
Sweden	–	–	3.2	2.2	4.5	3.0
England	–	–	–	–	6.0	4.0

Table 3
Average macronutrient contents of cereal grains grown in Turkey (wt%)

Grain	K	Ca	Mg	N	P	S
Barley	2.51 ± 0.33	0.14 ± 0.05	0.24 ± 0.06	2.34 ± 0.38	0.27 ± 0.08	0.19 ± 0.05
Beans	2.96 ± 0.52	0.20 ± 0.07	0.32 ± 0.09	2.76 ± 0.39	0.30 ± 0.09	0.15 ± 0.04
Canary seed	1.82 ± 0.21	0.18 ± 0.06	0.28 ± 0.07	2.28 ± 0.32	0.25 ± 0.07	0.11 ± 0.03
Corn/maize	2.18 ± 0.29	0.22 ± 0.07	0.26 ± 0.06	2.06 ± 0.26	0.42 ± 0.11	0.08 ± 0.02
Flax	3.28 ± 0.64	0.24 ± 0.08	0.30 ± 0.08	2.46 ± 0.40	0.22 ± 0.06	0.18 ± 0.05
Lentils	2.37 ± 0.31	0.21 ± 0.07	0.22 ± 0.05	3.24 ± 0.62	0.34 ± 0.09	0.10 ± 0.03
Millet	2.24 ± 0.28	0.23 ± 0.08	0.26 ± 0.06	2.10 ± 0.27	0.40 ± 0.10	0.12 ± 0.03
Oat	1.84 ± 0.21	0.12 ± 0.04	0.16 ± 0.05	2.41 ± 0.45	0.32 ± 0.09	0.12 ± 0.03
Peas	1.96 ± 0.22	0.24 ± 0.08	0.25 ± 0.06	4.68 ± 0.86	0.28 ± 0.08	0.20 ± 0.06
Rice	2.32 ± 0.29	0.26 ± 0.08	0.29 ± 0.08	1.94 ± 0.25	0.26 ± 0.07	0.08 ± 0.03
Rye	3.06 ± 0.62	0.28 ± 0.09	0.23 ± 0.06	2.40 ± 0.39	0.23 ± 0.06	0.12 ± 0.03
Spelt	2.18 ± 0.28	0.18 ± 0.07	0.18 ± 0.06	2.34 ± 0.29	0.34 ± 0.10	0.11 ± 0.03
Spring wheat	2.34 ± 0.39	0.15 ± 0.05	0.17 ± 0.06	2.53 ± 0.34	0.32 ± 0.10	0.10 ± 0.03
Winter wheat	1.95 ± 0.26	0.17 ± 0.06	0.21 ± 0.07	2.08 ± 0.30	0.36 ± 0.11	0.13 ± 0.04

Table 4
The average micronutrient contents of cereal grains grown in Turkey (mg/kg)

Grain	Zn	Cu	Fe	Mn	Mo	B
Barley	42.4 ± 3.8	21.4 ± 1.8	28.7 ± 2.5	29.6 ± 2.6	6.48 ± 0.72	8.73 ± 0.95
Beans	18.4 ± 1.6	10.6 ± 0.8	22.6 ± 2.0	30.4 ± 3.1	4.65 ± 0.48	9.04 ± 1.07
Canary seed	51.6 ± 6.0	12.8 ± 1.4	35.5 ± 3.8	41.6 ± 4.8	3.25 ± 0.30	10.6 ± 1.23
Corn/maize	17.0 ± 1.5	15.3 ± 1.8	24.2 ± 2.3	19.5 ± 2.3	5.32 ± 0.65	11.4 ± 1.26
Flax	26.9 ± 2.2	17.3 ± 2.0	10.4 ± 0.9	12.5 ± 1.3	2.76 ± 0.34	8.45 ± 0.91
Lentils	38.3 ± 2.8	18.0 ± 2.3	64.5 ± 7.1	53.8 ± 5.6	7.32 ± 0.93	10.5 ± 1.22
Millet	18.5 ± 1.6	16.3 ± 1.9	25.0 ± 2.4	20.6 ± 2.5	4.92 ± 0.58	11.6 ± 1.27
Oat	26.4 ± 2.1	14.8 ± 1.3	26.4 ± 2.4	16.9 ± 1.7	3.68 ± 0.45	14.9 ± 2.63
Peas	44.6 ± 4.0	20.9 ± 1.7	18.3 ± 1.6	24.8 ± 2.6	4.08 ± 0.42	12.4 ± 2.45
Rice	32.4 ± 2.8	15.7 ± 1.5	9.58 ± 0.8	11.6 ± 1.2	3.06 ± 0.42	10.8 ± 1.25
Rye	36.0 ± 3.1	18.4 ± 1.9	24.0 ± 2.3	15.1 ± 1.4	3.85 ± 0.51	11.3 ± 1.36
Spelt	18.1 ± 1.8	16.3 ± 1.6	46.8 ± 4.2	23.8 ± 2.4	5.06 ± 0.58	9.78 ± 1.20
Spring wheat	23.4 ± 2.0	7.42 ± 0.8	32.5 ± 3.0	45.8 ± 5.6	5.32 ± 0.61	11.0 ± 1.24
Winter wheat	19.2 ± 1.9	6.84 ± 0.6	40.1 ± 4.3	42.8 ± 5.0	4.25 ± 0.53	9.35 ± 0.96

Source: Genc et al. (2001).

The macro and micronutrient contents of cereal grains are generally not very different from each others.

References

Anderson, J. W., Spencer, D. B., Hamilton, C. C., Smith, S. F., Tietyen, J., Bryant, C. A., & Oeltgen, P. (1990). Oat-bran cereal lowers serum total and LDL cholesterol in hypercholesterolemic men. *American Journal of Clinical Nutrition, 52*, 495–499.

Braaten, J. T., Wood, P. J., Scott, F. W., Wolynetz, M. S., Lowe, M. K., Bradley-White, P., & Collins, M. W. (1994). Oat β-glucan reduces blood cholesterol in hypercholesterolemic subjects. *European Journal of Clinical Nutrition, 48*, 465–474.

De Groot, A. P., Luyken, R., & Pikaar, N. S. (1963). Cholesterol-lowering effect of rolled oats. *Lancet, 2*, 303–307.

Genc, H., Ozdemir, M., & Demirbas, A. (2001). Analysis of mixed-linked (1→3), (1→ 4)-β-D-glucans in cereal grains from Turkey. *Food Chemistry, 73*, 221–224.

Hegsted, M., Windhauser, M. M., Morris, K., & Lester, S. B. (1993). Stabilized rice bran and oat bran lower cholesterol in humans. *Nutrition Research, 13*, 298–387.

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

Inglett, G. E. (1990). Hypocolesterolemic β-glucan amylodextrins from oats as dietary fat-replacements. In *Presented for the symposium on β-glucans: Biotechnology and Nutrition, 199th National American Chemical Society Meeting, Boston, MA*, 22–27 April, (Abstr. p. 5).

Inglett, G. E. (1993). Amylodextrins containing β-glucan from oat flours and bran. *Food Chemistry, 47*, 133–136.

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

Mekis, E., & Bendek, G. (1987). Modified flourometric flow-injection analysis (FIA) method for the determination of (1→3), (1→4)-β-D-glucan. *Journal of the Institute of Brewing, 93*, 396–398.

McCleary, B. V., & Glennie-Holmes, 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.

Ozdemir, M., & Genc, H. (2001). β-Glucan contents of cereal grains grown in Turkey. *Energy Education Science and Technology, 7*, 10–17.

Sanders, T. A. B., & Reddy, S. (1991). The influence of rice bran on plasma lipids and lipoproteins in human volunteers. *European Journal of Clinical Nutrition, 46*, 161–172.

Saastamoinen, M., Plaami, S., & Kumpulainen, J. (1989). Pentosan and β-glucan content of Finnish winter rye varieties as compared with rye six other countries. *Journal of Cereal Science, 10*, 199–207.

Skoog, D. A., & West, D. M. (1981). *Principle of instrumental analysis* (2nd ed.). Tokyo, Japan: Holt-Saunders.

Truswell, A. S. (2002). Cereal grains and coronary heart disease. *European Journal of Clinical Nutrition, 56*, 1–14.

Wood, P. J. (1984). Physiochemical properties and technologial and nutritional significance of cereal β-glucans. In V. F. Rasper (Ed.), *Cereal polysaccharides in technology and nutrition* (p. 35). American Association of Cereal Chemistry, St. Poul, MN.