THE INFLUENCE OF GENOTYPE AND ENVIRONMENT ON ARABINOXYLAN AND BETA-GLUCAN CONTENTS IN GRAIN OF SPRING BARLEY (HORDEUM VULGARE L.)

Pavel Macháň1, Jaroslava Ehrenbergerová1, Radim Cerkal1, Karolína Benešová2, Kateřina Vaculová3

1 Department of Crop Science, Breeding and Plant Medicine, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic 
2 Research Institute of Brewing and Malting, Plc. Brno, Mostecká 7, 614 00 Brno, Czech Republic 
3 Agrotest fyto, Ltd., Havlíčkova 2787, 767 01 Kroměříž, Czech Republic

Abstract


Arabinoxylan and beta-glucan contents are limiting factors for a wider use of barley production. Arabinoxylan and beta-glucan contents were assessed in grain samples in sets of seven malting hulled varieties, three hull-less lines and one hull-less spring variety grown in the localities of Branišovice, Žabčice, and Kroměříž in 2009 to 2011. Further, the effect of growing technologies on the level of these non-starch polysaccharides was studied. Variability of arabinoxylan contents was affected most significantly by a genotype and growing technology whereas variability of beta-glucan contents was mostly affected by a genotype and growing environment (interaction of year with locality). The highest values of arabinoxylans and beta-glucans were determined in the grain samples of hull-less lines (KM 1057: 6.16% of arabinoxylans and KM 2084: 6.41% of beta-glucans) and on the contrary, the lowest values of arabinoxylans were found in the grain of hull-less variety AF Lucius (3.85%) and lowest amounts of beta-glucans were found in malting variety Radegast (3.92%). The samples of the growing technology without fungicide treatment had on average more arabinoxylans and beta-glucans than the fungicide non-treated ones.

Keywords: hull-less barley, hulled barley, non-starch polysaccharides, growing technology, grain quality

INTRODUCTION

Barley grain is traditionally used as a basic raw material for malt production; it is also used as feed for livestock. Currently its use as food or raw material for production of functional food has been restored (Baik & Ullrich, 2008; Havrlentová et al., 2011). For this use, content of non starch polysaccharides is a limiting quality parameter. The most important non-starch polysaccharides include hemicelluloses, namely arabinoxylans and beta-glucans, basic construction substances of cell walls. Cell walls of the starch endosperm of grain contain 70% of beta-glucans and 25% of arabinoxylans (Lazaridou et al., 2008; Jamar et al., 2011).

Arabinoxylans (also known as pentosans) have a main chain formed by (1→4)-ß-D-xylanopyrosyl units substituted with ß-L-arabinofuranose (Niño-Medina et al., 2009). Specific character of barley arabinoxylans is their esterification with ferulic acid (approximately 0.07% to 0.11% of total mass) (Ehrenbergerová et al., 2012) conferring them antioxidant properties.
Beta-glucans of barley grain are formed by \( \beta-\text{glycosyl residues polymerized by } \beta-(1\rightarrow 3) \) and \( \beta-(1\rightarrow 4) \) bonds. Solubility of beta-glucans declines with their growing molecular weight (Cyran et al., 2002) and increases with higher degree of disruption of regular \( \beta-(1\rightarrow 4) \) structure by \( \beta-(1\rightarrow 3) \) bonds (Lazaridou & Biliaderis, 2007). Arabinoxylan solubility is subject to their molecular weight, arabinose-to-xylose ratio (at least 0.60 of soluble arabinoxylans) and amount of ferulic acid (Li et al., 2005; Izydorczyk & Dexter, 2008).

Arabinoxylans and beta-glucans are capable to create in water viscous solutions and become thus a valuable component of food fiber, on the other side; they can also cause problems at wort filtration during brewing and reduce the nutritional values of feed in livestock (Iji, 1999; Lu & Li, 2006; Baik & Ullrich, 2008; Newman & Newman, 2008; Zavřelová, 2014).

Arabinoxylans and beta-glucans have been shown to have a positive impact on human health (Chandalia et al., 2000; Keogh et al., 2003; Behall, et al., 2004; Slavin, 2005; Behall, 2006; Salas-Salvadó et al., 2007; Shimizu et al., 2008; Chen & Raymond, 2008; Babio et al., 2010).

The aim of the study was to determine the ratio of the effect of varieties/lines, environment (localities and years) and growing technologies on beta-glucan and arabinoxylan content and variability in the set of hulled and hull-less varieties and lines of spring barley.

**MATERIALS AND METHODS**

Arabinoxylans and beta-glucans were assessed in grain (Tab. I) of seven malting hulled varieties, three hulled lines and one hull-less spring barley variety grown at the localities of Branišovice, Žabčice, and Kroměříž in 2009 to 2011 (Tab. II).

At each of the localities, field trials were established using a triplicate randomized block design with orthogonally arranged variations. Production of varieties/lines from three blocks was mixed and consequently cleaned and screened by sifting. Fractions selected by a 2.5 mm sieve opening for the hulled, and 2.0 mm for the hull-less genotypes were used for the analyses. Grain was homogenized with laboratory mill (Super Jolly SJ 500).

The experimental materials were grown using two systems: basic technology (so-called “Basic”; fertilizer dose of 30 kg N/ha of pure nutrients, grain dressing and application of herbicides and insecticides: Granstar 75 WG, Mustang Forte, and Nurelle D, without fungicides), and basic technology plus fungicides (so-called “Basic+”; Fandango 200 EC, Prosaro 250 EC, Archer Top 400 EC).

Arabinoxylans were determined by a method described by Douglas (Douglas, 1981). The method is based on a reaction of the sample with acid extract solution. The reaction mixture is heated in a water bath for 25 minutes. Developed reddish-brown to reddish-orange color is measured spectrophotometrically at the wavelengths of 552 and 510 nm. The samples were hydrolyzed with sulfuric acid, subsequently stained with the dye Calcofluor White M2R. Beta-glucans were assessed using a modified method for flow injection analysis (FIA) with spectrophotofluorimetric detection (Aastrup & Jorgensen, 1988).
Water content grain samples was determined by gravimetric method (EBC 3.2). All chemical analyses were conducted twice and values converted to 100% dry matter of grain. Results were evaluated with program STATISTICA 9 with four-factor analysis of variance, the significances of differences between mean values of different varieties and lines, technologies, years and locations were tested at the 5% significance level with the LSD test (Fisher’s exact test). The share of the studied factors and their interactions was expressed as the ratio of the standard deviation of the factor and the standard deviation of the total variance.

RESULTS AND DISCUSSION

Variability in arabinoxylan and beta-glucan contents (Tab. III) was statistically highly significantly (p = 0.001) affected by the variety/line, locality, year, growing technology and their mutual interactions (only the interaction of growing technology with the locality showed...
the significance level of \( p = 0.01 \). The highest effect of the factor on variance of arabinoxylans was found for the genotypes (15.57%), growing technology (12.81%), and multiple interactions (24.56%). The largest share in the total variability in beta-glucan content in barley grain was found for genotypes (23.64%), environment (interaction of a locality and year, 20.66%) and multiple interactions (14.64%). Each share of multiple interactions in the variability of both arabinoxylans, and beta-glucans consists a sum of share of four three-way and one four-way interaction.

**Treatment and Environmental Effects**

The samples from the Basic technology (4.79% and 4.74%) provided statistically significantly more arabinoxylans and beta-glucans versus the Basic+ technology (4.48% and 4.63%) (Tab. IV). When comparing growing technologies, in the Basic- and malting varieties provided generally less arabinoxylans, and hull-less genotypes provided generally more arabinoxylans. For example malting variety Blaník provided in the Basic+ growing technology significantly more arabinoxylans, than in the Basic technology (5.26 versus 4.30%), on contrary hull-less line KM 2084 provided significantly more arabinoxylans in Basic-technology, than in Basic technology (4.29 versus 3.82%). In terms of growing malting barley as a raw material for malt production or feed for livestock, conventional farming (with use of fungicides) causes the formation of harmful secondary metabolites (mycotoxins). Lower contents of non-starch polysaccharides in feeds in monogastric animals. Positive effects of non-starch polysaccharides on digestion (1999) support the opinion about the improper use of stand on variety of arabinofuranosyl and beta-glucans appears as more advantageous. On the average contents statistically significantly. On the average of genotypes, growing technologies, and years of growing, the lowest average arabinoxylan content (Tab. IV) was detected in grain from the locality Kroměříž (4.45%). The locality Kroměříž also provided statistically significantly lower content of beta-glucans (4.48%). The highest beta-glucan content was found in the grain samples from Branišovice (4.83%), the highest arabinoxylan content was determined in samples from Branišovice and Žabčice (4.70% and 4.76%, respectively). The sugar-beet locality (Kroměříž) with its significantly lower values of non-starch polysaccharides thus appears more suitable for malt production than the maize production area (Branišovice, Žabčice). On average of the genotypes, localities, and growing technologies, the samples from 2009 (Tab. IV) gave statistically significantly more arabinoxylans (4.83%) than the samples from 2010 and 2011 (4.52% and 4.56%, respectively). Arabinoxylan contents in the samples from 2010 and 2011 did not differ statistically significantly. Statistically significantly lowest average beta-glucan content was detected in the samples from 2010 (4.43%), versus the samples from 2009 (4.79%) and 2011 (4.83%).

The lowest amount of arabinoxylans on average of the genotypes and growing technologies (Tab. V) was determined in the samples from 2011 from the locality Kroměříž (4.29%) and in the samples from 2010 from Kroměříž and Branišovice (4.38 and 4.40%, respectively). The highest arabinoxylan content was recorded in the samples from 2009 from Kroměříž (4.69% and 4.76%)}
from the locality Branišovice from 2009 (4.97%). Statistically significantly lowest beta-glucan content versus the other variants was identified in the samples from the locality Žabčice from 2010 (3.87%). The highest level of beta-glucans in the set was determined in the samples from the locality Žabčice from 2009 and 2011 (5.20 and 5.15%, respectively); no statistically significant difference was found between these two samples.

The higher effect of the interaction between the localities and years was also observed in beta-glucan content by Zhang et al. (2001) and Grausgruber et al. (2010). According other authors, beta-glucan content in grain is affected by the course of weather; hot and dry weather during formation of caryopses is subsequently reflected in higher beta-glucan content in grain (Güler, 2003; Ehrenbergerová et al., 2008; Tiwari & Cummins, 2008; Dickin et al., 2011).

On average of all varieties, a significantly higher level of beta-glucans than in 2010 was found in Žabčice (Fig. 1) in 2009 and 2011 when drought was recorded during the vegetation periods.

### Genotypic Variation

Figs. 2 and 3 show the variability of arabinoxylan and beta-glucan contents in average of the individual localities, growing years and technologies. Of the malting varieties, the variety Bojos exceeded in its statistically significantly lowest arabinoxylan content (4.27%, Fig. 2), than other malting varieties. Low levels of arabinoxylans and lowest levels of beta-glucans among malting varieties were detected in the variety Radegast (4.70%, Fig. 2; resp. 3.92%, Fig. 3). Relatively low average values of arabinoxylans were further detected in the malting varieties Kangoo (4.70%) and Jersey (4.66%). Of the malting varieties, Bojos had the lowest beta-glucan content (4.03%, Fig. 3).

The set of the studied varieties also included hull-less genotypes intended for food production – the variety AF Lucius and lines KM 1057, KM 2084, and KM 2283. The line KM 2084 provided statistically significantly more beta-glucans (6.41%) than all other genotypes. Similarly, Prýma et al. (2000) and Grausgruber et al. (2010) found higher beta-glucan content in the hull-less waxy genotypes and some genetic resources. The line KM 2283 also exceeded in higher content of beta-glucans (5.62%, Fig. 3). On the other hand, the line KM 1057 gave the most arabinoxylans (6.16%) and less beta-glucans (3.37%). Due to a low content of beta-glucans in grain, the line KM 1057 appears as perspective for livestock feeding. The hull-less variety AF Lucius contained statistically significantly the least arabinoxylans (3.85%) and higher content of beta-glucans (4.86%).

### CONCLUSIONS

Variability in arabinoxylan and beta-glucan contents was statistically highly significantly affected by the variety/line, locality, year, technology and by most of their mutual interactions. The highest
effect of the factor on variance of arabinoxylans was found for the genotypes, growing technologies, and multiple interactions. The largest share in the total variability in beta-glucan content in barley grain was found for genotypes, interaction of a locality and year, and multiple interactions. Since genotype had the highest share on variability of both non-starch polysaccharides than all the other factors and their interactions, selection of proper genotype is the most crucial for desired amount of arabinoxylans and beta-glucans in barley grain. Of the malting varieties, the variety Bojos exceeded in its arabinoxylan content (4.27%), this variety contained also low amounts of beta-glucans (4.03%). Variety Radegast exceeded in low levels of arabinoxylans and beta-glucans (4.70%, resp. 3.92%). Relatively low average values of arabinoxylans were further detected in the malting varieties Kangoo (4.70%) and Jersey (4.66%). The line KM 2084 intended for food production provided statistically significantly more beta-glucans (6.41%) than all other genotypes. The line KM 2283 also contained higher amount of beta-glucans (5.62%). On the other hand, the line KM 1057 gave the most arabinoxylans (6.16%) and least beta-glucans (3.37%). Due to a low content of beta-glucans in grain, the line KM 1057 appears as perspective for livestock feeding. The hull-less variety AF Lucius contained statistically significantly the least arabinoxylans (3.85%) and higher content of beta-glucans (4.86%). This hull-less variety can be also recommended for feed production. When grown in the Basic+ technology malting varieties provided generally less arabinoxylans, and hull-less genotypes provided generally more arabinoxylans.

Results showed in this work give overview about concentration and variability of arabinoxylans and beta-glucans, therefore can be used to prefer suitable varieties and growing technologies for diverse uses of barley grain production (malt, food, and feed).

SUMMARY

Barley is traditionally used for malt production, but also as feed and food. For this use, content of non-starch polysaccharides is a limiting quality parameter. Non-starch polysaccharides are capable to create in water viscous solutions and become thus a valuable component of food fiber, but on the other hand they can cause problems at wort filtration during brewing and reduce the nutritional values of feed in livestock. This work deals with determination of contents of non-starch polysaccharides in the set of eleven different barley genotypes with hulled malting varieties, hull-less lines and hull-less variety. Set of eleven barley genotypes was grown in Branišovice, Kroměříž, Žabčice, in two different growing technologies, in the years from 2009 to 2011. Arabinoxylans were detected by method described by, beta-glucans were determined after sample hydrolysis in sulfuric acid with flow injection analysis.
with spectrofluorometric detection. Levels of significance and share of variability for named factors and their interactions was determined. A significant difference between growing technologies, localities, years and genotypes was found. Genotypes suitable for malt production, food and feed usage were identified. The highest values of arabinoxylans and beta-glucans were determined in the grain samples of hull-less lines (KM 1057: 6.16% of arabinoxylans and KM 2084: 6.41% of beta-glucans) and on the contrary, the lowest values of arabinoxylans were found in the grain of hull-less variety AF Lucius (3.85%) and lowest amounts of beta-glucans were found in malting variety Radegast (3.92%). Lines KM 2084 and 2283 can be recommended for production of functional foods. Both these lines are also potentially suitable as a genetic material for further breeding of varieties with good adaptability capable of producing high concentrations of beta-glucans in grain. Barley grown in system with fungicide treatment provided in average grain with significantly lower levels of both non-starch polysaccharides (4.48% arabinoxylans and 4.63% beta-glucans), than the system without fungicide treatment (4.79% arabinoxylans and 4.74% beta-glucans).

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Contact information
Pavel Macháň: xmachan1@node.mendelu.cz