V. Psota, J. Ehrenbergerová, P. Havlová and J. Hartmann

Beta-Glucan Content in Caryopses, Malt and Wort of the Selected Spring Barley Varieties

Beta-glucan content in caryopses, malt and wort was observed at 10 varieties of Czech, Slovak and German origin. Significant inter-variety differences were found out. The impact of a growing site played an important role too, the impact of a year, however, was irrelevant. At the same time the relationship between β-glucan content and further technological features was examined. β-glucan content in barley caryopsis was influenced by a weight of thousand kernels (TKW) and further by the protein content in a caryopsis. The content of β-glucan in malt was influenced by the content of β-glucan in wort, β-glucanase index and malt friability. The content of β-glucan in wort was influenced by β-glucanase index, friability of malt and Kolbach index value. The method of Stepwise Multiple Linear Regression (Stepwise Selection) was used to choose the parameters influencing in the most significant way β-glucan content.

BC 11 Barley

(Descriptors: Barley, β-glucan, caryopsis, malt, wort, malting quality.

Deskriptoren: Gerste, β-Glucan, Karyopse, Malz, Würze, Malzqualität).

1 Introduction

β-glucans are part of cell walls. Cell walls of barley endosperm contain 70 – 75 % of these high - molecular substances (*Vorhagen* et al. 1987). The β-glucan content in barley caryopses of various varieties is different and their concentration usually moves between 2 – 8 % (*Edney* et al. 1993). β-glucan content in barley is an indicator of malt modification and illustrates effects of malting technology on malt and wort. The increased β-glucan content in wort has a number of negative impacts mainly on production economics (*Moll* 1997). From this reason we devote continuous attention to the problems of β-glucans.

2 Material and Methods

2.1 Varieties

β-glucan content in barley caryopses, malt, wort and further features were observed at ten following varieties of spring barley of Czech and foreign provenience: Akcent, Amulet, Atribut (Selgen, CZ), Novum, Kompakt (Hordeum, SK), Forum, Olbram (Monsanto, CR, CZ), Famin (Plant Select, CZ), Lumar (ZVÚ, CZ), Krona (Semundo Saatzucht, D).

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Varieties were each year grown under the same conditions in testing stations of the Central Institute for Supervising and Testing (ÚKZÚZ). Based on the content of nitrogenous substances in caryopses each year (1996 – 1998) four stations were selected from which samples of respective varieties were taken for micromalting and assessment of features presented below. Sieving ratio above 2.5 mm was used for micromalting.

2.2 Micromalting

Samples were micromalted pursuant to recommendations of the Barley Trials Committee EBC *(Guidelines for micromalting EBC barley samples)* valid to the year 1999. Temperature of steeping and germination was 15 °C, temperature at the beginning of kilning was 50 °C and at the end 80 °C. The difference was only in the time of germination and thus in duration of malting. Unlike recommended 168 hours, malting was 24 hours shorter. The shorter time of malting shall emphasize inter-variety differences.

2.3 Caryopses and malt analysis

Signs followed at caryopses, malt and wort were analysed according to EBC methods (1998) and MEBAK (1979). Germination homogeneity was calculated according to authors *Riis*, *Bang-Olsen* (1991). The data on the harvest, classification and TKW were taken from ÚKZÚZ (Central Institute for Supervising and Testing).

2.4 Statistical expression of results

The achieved results were evaluated using the method of residual maximal veracity (*Patterson* and *Thompson* 1974) by the help of REML Programme of the University of Edinburgh (*Robinson*, *Mann* and *Digby* 1995). The differences among effects of years, stations and varieties were tested with the use of multiple t-method. The impact of varieties and environment (years and localities) on the followed parameters was quantified on the basis of dissipation components, estimated from the model with chance effects.

Table 1 Analysis of Variance

Source of variation	d.f.	β-glucan in cariopses (%)	β-glucan in malt (%)	β-glucan in wort (mg.dm^{-3})	β-glucan index (%)
		Mean Square	Mean Square	Mean Square	Mean Square
Year	2	0.239 *	0.119 NS	54753.16 **	6.890 NS
Locality	6	1.098 **	0.067 **	19673.66 **	110.629 **
Variety	9	0.673 **	0.191 **	27948.60 **	85.123 **
Residual	102	0.070	0.015	1816.915	12.146

To express relations between β-glucan content in barley caryopsis, malt and wort and β-glucanase and the other followed features correlation analysis was used and the strength of relations was expressed by Pearson's correlation coefficient (r). The method of Stepwise Multiple Linear Regression enabled to quantify the relation between individual "parameters of β-glucans" on one side and the group of technological parameters of malt on the other side.

3 Results and Discussion

3.1 The level and sign variability

Varieties participated in the whole variability of β-glucan content in barley caryopsis at the given variety set highly statistically significantly (Table 1 – 3), roughly from one fifth, and localities nearly from one half. The impact of varieties and lines on β-glucan variability even in the amount of 90 % was observed also by *Ehrenbergerová* et al. (1997). On the contrary *Jackson* et al. (1994) does not report a significant impact of localities on β-glucan content. The influence of followed years was insignificant (3%).

During malting enzymatic apparatus of caryopses was made more active, which stressed the variety impact on β-glucan content in malt (Table 1, 2, 4). Variety impact on the overall variability, (i.e. genetic ratio of variability) was increased and achieved 43 %. On the contrary impact of localities dropped to 14 %.

The variability of individual factors (year, locality, variety) at β-glucanase index (Table 1, 2, 6) was given by the variability of theses factors in two preceding signs. It corresponded more with the β-glucan content in caryopses.

The total variability of β-glucan in wort (Table 1, 2, 5) was divided more or less equally among all factors causing variability. Share of variety impact on the whole variability was the highest (29 %) of all variability sources, still even more significant variety impact was expected.

From the results of evaluation of difference significance in β-glucan content in caryopses among varieties (multiply range analysis) (Table 3) it results that the difference between the variety and the highest and the lowest β-glucan content in caryopses at the given set was only 0,8 %. Nevertheless it was possible to divide the set of the followed varieties into three groups. The first group was formed only by a group Kompakt, which has statistically significantly the lowest β-glucan content in caryopses. Also *Psota*, *Kosař* (1996), *Ehrenbergerová* et al. (1997) and *Psota*, *Jurečka* (2000) determined the lowest β-glucan content at this variety. The second group was formed by varieties Forum, Famin, Krona, Amulet and Olbram. The third group was formed by varieties Novum, Akcent, Lumar and Atribut. The varieties Atribut and Lumar had the highest β-glucan content in caryopses of the whole followed set. Here the variety Lumar with its β-glucan content statistically significantly differed from all the other varieties of the set with the exception of Atribut.

Table 2 Estimated components of variance

	Year	Locality	Variety	Residual
β-glucan content in barley caryopses (%)				
	0.008	0.112	0.050	0.070
%	3.330	46.670	2.830	29.170
SE	0.011	0.068	0.026	0.010
β-glucan content in malt (%)				
	0.000	0.005	0.015	0.015
%	0.000	14.280	42.860	42.860
SE	0.001	0.004	0.008	0.002
β-glucan content in wort (mg.dm^{-3})				
	1897.861	1514.760	2177.529	1818.242
%	25.620	20.450	29.390	24.540
SE	1967.768	968.092	1098.087	254.571
β-glucanase index (%)				
	0.042	13.208	6.090	12.049
%	0.130	42.080	19.400	38.390
SE	0.504	8.131	3.347	1.685

Table 3 β-glucan content in barley caryopses (%)
Method: 95 % LSD

Varieties	n	avarage					
Kompakt	12	3.090	a				
Forum	12	3.351		b			
Famin	12	3.351		b			
Krona	12	3.404		b			
Amulet	12	3.446		b	c		
Olbram	12	3.451		b	c		
Novum	12	3.620			c	d	
Akcent	12	3.625			c	d	
Lumar	12	3.797				d	e
Atribut	12	3.899					e

Comments:
LSD (0,05) = 0,21476
average values indicated by various letters
are statisticantly different (P = 0,05)

Table 4 β-glucan content in malt (%)

Method: 95 % LSD

Varieties	n	avarage						
Kompakt	12	0.496	a					
Olbram	12	0.597		b				
Forum	12	0.653		b				
Amulet	12	0.679		b	c			
Krona	12	0.686		b	c	d		
Novum	12	0.756			c	d	e	
Akcent	12	0.780				d	e	
Famin	12	0.814					e	
Atribut	12	0.854					e	f
Lumar	12	0.917						f

Comments:
LSD (0,05) = 0,10062
average values indicated by various letters
are statisticantly different (P = 0,05)

Table 5 β-glucan content in wort (mg.dm-3)
Method: 95 % LSD

Varieties	n	avarage					
Kompakt	12	157.531	a				
Krona	12	199.864		b			
Olbram	12	201.114		b	c		
Amulet	12	227.198		b	c		
Novum	12	227.364		b	c		
Forum	12	234.781			c		
Akcent	12	274.531				d	
Lumar	12	280.364				d	
Famin	12	282.614				d	
Atribut	12	317.781					e

Comments:
LSD (0,05) = 34,5239
average values indicated by various letters
are statisticantly different (P = 0,05)

The differences among varieties in β-glucan content in malt (Table 4) were small too, (max difference was 0,4 %). In this set there were only three groups of varieties. The results correspond with preceding variety division with the difference that the activity of enzymes at the variety Famin was probably lower and caused higher values of β-glucan in malt and thus also transfer of this variety into the third group. The activity of enzymes of varieties Kompakt, Atribut and Lumar was on the contrary proportional to β-glucan content in caryopses.

At some varieties the change in order in comparison with the order in Table 3 occurred due to increased β-glucanase activity. β-glucanase activity expressed indirectly by β-glucanase index (Table 6) was the highest at the variety Kompakt, which at the same time corresponded also with the lowest content of BG in caryopses and in malt. The variety order pursuant to enzymatic activity (Table 6) and the variety order pursuant to β-glucan content in malt was principally the same (Table 4) at all varieties.

β-glucan content in congress wort was influenced by further technological procedure, i.e. by mashing, at which physical and enzymatic factors concur. The differences among varieties at this sign were more expressive (Table 5) than at preceding signs. It was possible to divide the observed set into four groups. The first group was again formed only by the variety Kompakt with statistically significantly the lowest β-glucan content in wort. The second group was formed by varieties Krona, Olbram, Amulet, Forum and Novum at which the factors causing β-glucan decomposition were probably more active. The third group was formed by varieties Akcent, Lumar and Famin and the fourth group was again formed by the variety Atribut with statistically evidentially higher β-glucan content in wort in comparison with all the other varieties.

Pursuant to achieved results at the given variety set we can assume that the resulting β-glucan content in wort was the result mainly of the activity of β-glucanase activity of individual varieties in the course of the technological production process of malt and wort. The varieties Famin and Novum were the example of this. Though the variety Famin had a low β-glucan content in a caryopsis, the activity of its enzymatic apparatus was relatively lower and it ranged the variety Famin to varieties with a higher β-glucan content in wort . The opposite is the variety Olbram with the average β-glucan content in caryopses at which due to a higher β-glucanase activity the β-glucan content expressively declined and thus ranged the variety Olbram among varieties with the lowest β-glucan content in wort.

From the aspect of the manufacturing industry the variety Kompakt showed the most favourable values in the β-glucan content in wort. We can conclude that this effect was caused by expressively the lowest β-glucan content in caryopses and first of all by high activity of the enzymatic apparatus degrading β-glucans in the course of the technological process.

Table 6 β-glucanase index (%)
Method: 95 % LSD

Varieties	n	avarage					
Kompakt	12	83.500	a				
Olbram	12	82.467	a	b			
Forum	12	80.234		b	c		
Amulet	12	79.967		b	c		
Krona	12	79.700		b	c		
Novum	12	78.642			c		
Akcent	12	78.275			c	d	
Atribut	12	77.859			c	d	e
Lumar	12	75.467				d	e
Famin	12	75.267				e	

Comments:
LSD (0,05) = 2,82270
average values indicated by various letters are
statisticantly different (P = 0,05)

3.2 Relations among signs

Correlative analysis between β- glucan content in barley caryopses, malt and wort and β-glucanase and the other followed signs at the observed set (Table 7) enabled following statement.

β-glucan content in barley caryopses was statistically highly demonstrative, it was positively influenced mainly by the weight of thousand kernels (TKW) (r = 0.51***) and also by protein content in caryopses (r = 0.37***). The caryopses with a higher TKW have probably more compact structure of the endosperm in the cell walls of which there is a higher β-glucan content. β- glucan content in malt statistically highly significantly influenced the β-glucan content in wort (r = 0.68***), negatively β-glucanase index (-0.83***) and malt friability (-0.66***). The higher enzymatic activity of enzymes degrading β-glucans is reflected on the β-glucanase index and on the lower β-glucan content in malt. β-glucan degrading in the course of malting also change physical qualities of caryopsis which becomes very fragile. Low β-glucan level can naturally favourably influence the β-glucan content in wort.

β-glucan content in wort was statistically highly significantly influenced by β-glucanase index (r =-0.51***), by malt friability (-0.66***) and by the value of Kolbach index (-0.56***). He increasing activity of enzymes degrading β-glucans and increasing fragility of malt favourably influences the β-glucan content in wort. The high activity of proteolytic enzymes degrades cell wall proteins and protein matrix faster and thus probably faster makes β-glucans of wall cells more accessible to their enzymatic destruction.

β-glucanase index had the strongest, statistically highly significant relation to extract in malt solid matters (r = -0.50***). This relation can be caused by the activity of enzymes degrading polysaccharides. The tight relation to viscosity was not unlike other authors confirmed (*Moll* 1997). It was neither possible to find more expressive relation to the homogeneity assessed by the method with Calcofluor nor to germination parameters. One of the courses why these assumed relations were not confirmed, can be the set of followed varieties itself. In this work ten varieties with average to the top malting quality were observed. In

Table 7 Analysis of variance between β-glucan contentin a barley caryopsis, malt and wort and β-glucanase index on the one hand and chosen technological features on the other hand.

	BGC	BGM	BGW	IBG
BGM	0,3501***			
BGW	0,3656***	0,6823***		
IBG	0,2059*	0,8336***	0,5077***	
Protein content in caryopsis	0,3681***	0,2891**	0,2437**	0,0875
Extract yield	0,0818	0,4209***	0,4659***	0,5051***
Relative extract (45 °C)	0,1386	0,1652	0,4058***	0,1109
Kolbach number	0,1402	0,3996***	0,5615***	0,3545***
Diastatic power	0,003	0,0062	0,0406	0,0096
Apparent final attenuation	0,1565	0,2808**	0,4669***	0,2065*
Friability	0,3384**	0,6319***	0,6564***	0,4728***
Protein in malt	0,3524***	0,2739*	0,2322*	0,0841
Total sol. N in wort	0,1454	0,1588	0,3553***	0,2647**
Total sol. N in malt	0,1477	0,1628	0,3540***	0,2703**
Viscosity	0,351***	0,2292*	0,3669***	0,0285
Colour of wort	0,2542**	0,0581	0,3172***	0,0792
Saccharification rate	0,0498	0,0337	0,0074	0,0564
Glassy corns	0,151	0,1309	0,1279	0,0483
Homogeneity (friabilimeter)	0,3082**	0,4300***	0,4918***	0,2802**
Lenght of acrospire	0,3273***	0,1985*	0,3640***	0,0221
Germination energy	0,0831	0,0326	0,1385	0,0019
Germination homogeneity	0,0783	0,0944	0,0059	0,0488
Germination speed	0,1411	0,0484	0,1425	0,1353
1000-Kernel weight	0,5109***	0,0539	0,1582	0,3487***
Modification (Carlsberg)	0,0406	0,4206***	0,3346***	0,4436***
Homogeneity (Carlsberg)	0,3408***	0,2098*	0,1889*	0,0022

Comments:

[grey box] a figure marked like this means a negative value.

Table 8 Model fitting results for: β-glucan content in barley cary-opses (%)				
Independent variable	coefficient	std. error	t-value	sig. Level
Constant	0.665476	0.512111	1.2786	0.2036
Protein content in caryopsis	0.169528	0.04775	3.5503	0.0006
1000-Kernel weight	0.023846	0.004053	5.8835	0.0000
R	0.576942			
R-squared (Adj. for d.f.)	0.332862			

Table 9 Model fitting results for: β-glucan content in malt (%)				
Independent variable	coefficient	std. error	t-value	sig. Level
Constant	2.007347	0.274217	7.3203	0.0000
β-glucan content in caryopsis	0.109851	0.030657	3.5832	0.0005
Friability	-0.014715	0.002071	-7.1059	0.0000
Modification (Carlsberg)	-0.010979	0.001953	-5.6216	0.0000
Homogeneity (Carlsberg)	0.005136	0.002291	2.2420	0.0269
R	0.743509			
R-squared (Adj. for d.f.)	0.552806			

Table 10 Model fitting results for: β-glucan content in wort ($mg.dm^{-3}$)				
Independent variable	coefficient	std. error	t-value	sig. Level
Constant	1551.8905	260.2009	5.9642	0.0000
β-glucan content in malt	222.4423	26.876767	8.2764	0.0000
Kolbach number	-3.416645	1.650414	-2.0702	0.0407
Apparent final attenuation	-14.917208	3.159079	-4.7220	0.0000
Colour of wort	-20.785178	7.967736	-2.6087	0.0103
R	0.802520			
R-squared (Adj. for d.f.)	0.644038			

the set the varieties of expressively non-malting character were missing.

Table 7 also reflects to a low stage of dependency of β-glucan content in barley caryopsis, malt and wort and β-glucanase on the individual followed technological signs. That is why groups of technological signs were searched which would have a relation to the β-glucan content in a barley caryopsis, wort and malt and to β-glucanase activity. For this purpose parameters were divided based on time and realistic aspects into three groups.

Within the scope of each group the parameters influencing mostly the given sign were chosen by the Method of Stepwise Multiple Linear Regression (Stepwise Selection). From the Tables 8 –10 it is evident which signs were concerned.

In the case of β-glucan content in barley no reduction of technological features was observed and statistically highly significant relation between β-glucan content in caryopsis and protein content in caryopsis and TKW (Table 8).

On the contrary at the β-glucan content in malt and at β-glucan content in wort by the help of Stepwise Multiple Linear Regression subgroups of technological signs which had in their summary statistically significant relation to the β-glucan content, were selected. The β-glucan content in malt was in statistically highly significant relation to the β-glucan content in caryopses, friability and modification (Carlsberg) and in significant relation to homogeneity (Carlsberg). β-glucan content in wort was in statistically highly significant relation to the following set of signs: the β-glucan content in malt, apparent final attenuation and also Kolbach index and wort colour (significant dependence).

4 Summary

In ten varieties of Czech, Slovak and German origin b – glucan content in caryopses (BGc), in malt (BGm) and in wort (BGw) was followed. Varieties and localities participated significantly on the total variability of BGb. Years influence was insignificant. The variety impact was increased at BGm but the influence of locality declined. The total variability of BGw in wort was divided more or less equally among all factors causing variability. According to BGw content the set can be divided into four groups. The first group was formed only by the variety Kompakt with the lowest content of BGw. The other group was formed by the varieties Krona, Olbram, Amulet, Forum and Novum, The third group was formed by varieties Akcent, Lumar and Famin and the fourth group was formed by the variety Atribut with the higher BGw. BGc was statistically highly significantly, positively influenced mainly by the weight of thousand kernels and by protein content in a caryopsis. BGm influenced BGw, the β – glucanase index and malt friability. BGw was influenced by the β – glucanase index, friability of malt and by the value of Kolbach index. In the case of BGc the relation between the β – glucan content in a caryopsis and protein content in a caryopsis and TKW was proved. BGm was in relation to the β – glucan content in caryopses, friability and modification (Carlsberg) and in a significant relation to homogeneity (Carlcberg). BGw was in the relation to the β – glucan content in malt, apparent final attenuation and also to Kolbach index and wort colour.

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5 Zusammenfassung

Psota, V., Ehrenbergerová, J., Havlová, P.,und Hartmann, J.: Beta-Glucangehalt von Gerste, Malz und Bierwürze der ausgewählten Sommergerstensorten — Monatsschrift für Brauwissenschaft 55, Nr. 1/2, 10 – 14, 27, 2002

BC 11 Gerste

Der Beta-Glucangehalt von Gerste, Malz und Bierwürze wurde bei 10 Sorten tschechischen, slowakischen und deutschen Ursprungs ermittelt. Dabei wurden signifikante Unterschiede zwischen den Sorten festgestellt. Auch der Standort der Pflanzen spielte eine wichtige Rolle, während der Einfluss des Jahrgangs ohne Belang war. Gleichzeitig wurde das Verhältnis zwischen dem Beta-Glucangehalt und weiteren technischen Merkmalen untersucht. Der Beta-Glucangehalt von Gerste wurde durch ein Gewicht von tausend Körnern (TKW) und außerdem durch den Proteingehalt der Samenkörner beeinflusst. Der Beta-Glucangehalt von Malz wurde durch den Beta-Glucangehalt von Bierwürze, den Beta-Glucanase-Index und die Auflösung (Reife) von Malz beeinflusst. Der Beta-Glucangehalt von Bierwürze wurde durch den Beta-Glucanase-Index, die Reife (Auflösung) von Malz und den Wert des Kolbach-Indexes beeinflusst. Zur Auswahl der Parameter, die den Beta-Glucan-gehalt am signifikantesten beeinflussen, wurde das Verfahren der stufenweisen multiplen linearen Regression (stufenweise Selektion) verwendet.

Psota, V., Ehrenbergerová, J., Havlová, P., et Hartmann, J.: Teneur en béta-glucanes de l'orge, du malt et du moût de bière en provenance de variétés d'orges de printemps sélectionnées — Monatsschrift für Brauwissenschaft 55, Nr. 1/2, 10 – 14, 27, 2002

BC 11 Orge

La teneur en béta-glucanes de l'orge, du malt et moût de bière a été déterminés dans 10 variétés en provenance de Tchéquie, Slovaquie et Allemagne. On a observé des différences significatives entre les variétés. Le lieu de culture des plantes joue également un rôle important mais l'influence annuelle était sans importance. On a examiné en même temps le rapport entre les béta-glucanes et d'autres paramètres technologiques. La teneur en béta-glucanes de l'orge est influencée par le poids de mille grains (PMG) et de plus par la teneur en protéines de l'orge. La teneur en béta-glucanes du malt est influencée par la teneur en béta-glucanes du moût de bière, l'indice glucanase et la friabilité du malt. La teneur en béta-glucanes du moût de bière est influencée par l'indice de glucanase, la friabilité du malt et par les valeurs de l'indice Kolbach. La méthode de régression multiple linéaire par étape a été choisie pour mettre en évidence les paramètres influençant la teneur en béta-glucanes.

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