Different barley cultivars as a source of green mass for improving nutrient balance in human diet

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Abstract

Human diet enriched with young parts of plants (so called „green foods“) can help to improve the balance of the nutrient intake in a natural way. Different selected nutrients (vitamins C and E, total polyphenols, ferulic acid, monosaccharides, activity of superoxide dismutase and catalase, chlorophyll) and minerals (N, P, K, Ca, Mg, B, Cu, Zn, Fe and Mn) were analysed in barley green mass, cut from 3 spring barley materials (malting cultivars Sebastian and Malz and candivar KM1910 with hulless grain) in two defined growth phases (DC 29 and DC 31 by Zadoks) in the years 2005-2007. Results obtained indicate that the contents of nutritional substances are strongly dependent on the growth phase; the influence of the barley genotype (cultivar) and the growth site (locality) are discussed.

Introduction

Diet enriched with so-called „green foods“, i.e. fresh or delicately preserved food of plant origin can help to improve the balance of the nutrient intake in a natural way. Young plant parts are characterized by increased contents of phytonutrients - vitamins, provitamins, antioxidants, and other bioactive substances with protective functions in the humans. Research conducted in the USA and Japan has shown that extracts from young cereal leaves (green mass, taken in the clearly defined growth phases) have marked effects on a number of health disorders including excessive cholesterol levels, blood pressure, immune response and cancer prevention (NISHIYAMA et al. 1994, SHIBAMOTO et al. 1994). The barley grass acts as a free radical scavenger that also reduces inflammation and pain. An extraordinary feature of products derived from young barley is their well-established ability to degrade organophosphate pesticides (DURHAM et al. 1999).

Barley green mass is a rich source of chlorophyll, source of antioxidants, the most important being o-glycosyl isovitexin, superoxide dismutase (SOD), catalase (CAT), vitamins E and C and carotenoids. It also contains significant quantities of macro- and microelements, such as calcium, copper, iron, magnesium, potassium, zinc, etc., and other important nutrient compounds e.g. folate, pantothenic acid, vitamins B1, B2, B6 (ARUOMA and HALLIWELL 1987, KITTA et al. 1992, OSAWA et al. 1992, ACAR et al. 2001, LEE et al. 2003 and others).

However, the nutrients content depends on the growing site, soil quality, climatic conditions, particularly average rainfall, harvest technique (DROUSHIOTIS 1984), and processing of green mass. It is known that the highest concentrations of nutrients are present in the green mass during short period of the vegetation and that the nutrient profiles of green cereal plants change quickly as they grow.

The main aim of our study was to evaluate the contents of the selected nutritional parameters of the green mass taken from different cultivars of barley, cut in two growth phases, grown under various soil and climatic conditions of the Czech Republic.

Materials and Methods

Materials

Three spring barley materials, malting cultivars Sebastian and Malz with hulled grain and a new barley candivar KM1910 with hulless grain were grown in two experimental locations Kromeriz (KM) and Zabcice (ZB), under restricted chemical inputs in the period of 2005-2007. Analytical determination of selected nutrients was carried out in two terms of barley green mass samplings, cut in the defined growth phases: sampling I at growth phase DC 29 and sampling II at growth phase DC 31 (ZADOKS 1974).

Methods

According to the characterestics of the individual substances determined, the samples were analyzed either immediately after harvest - DM (%), chlorophyll and its components - „a“ and „b“ ($mg.g^{-1}$), vitamin C ($mg.100g^{-1}$), activity of vitamin E (and contents of its isomers - alpha-, beta + gama, and delta-tocopherols, T - $mg.kg^{-1}$), activity of superoxide dismutase and catalase ($U.g^{-1}$) or after freezing - ferulic acid ($mg.100g^{-1}$), folates ($\mu g.g^{-1}$). Macroelements (N, P, K, Ca and Mg - %), microelements (B, Cu, Zn, Fe and Mn - $mg.kg^{-1}$) and ash (%) were also determined.

Dry matter was determined using the gravimetric method (DAVÍDEK et al. 1981), content of chlorophyll with the spectrophotometric method (FRÉBORT et al. 1992). Ascorbic acid was determined by titration with 2,6-dichlorphenolindophenol (ČSN ISO 6557/2 Method A). Principle of the assessment of vitamin E content and its isomers is alcaline saponification and extraction of nonsaponified portion of the sample with diethyl ether with subsequent determination using the HPLC method with fluorescent detection.

Phenolic compounds were quantified with the RP HPLC method (ORSÁK et al. 2000).

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The enzyme activity of superoxide dismutase (SOD) was assessed using the kit Ransod after its modification for the plant material (BELCREDIOVÁ et al. 2006). To assess the activity of catalase (CAT), a spectrophotometric method based on the measurement of the drop of absorbance at 240 nm was used (BERGMEYER 1970).

Folates were assayed as 5-methyltetrahydrofolate (main representative of natural folates in plant materials). The determination of 5-methyltetrahydrofolate (5-MTHF) was performed by the RP HPLC method after thermal and enzymatic hydrolysis and purification of the samples using SPE, modified for releasing folates from food matrix (HOLASOVÁ et al. 2004).

Nitrogen was measured on an instrument from the company Leco (Dumas method), contents of macroelements by spectrophotometric method (P), AAS method (Ca, Mg), AES method (K - the samples were prepared by mineralisation according to Kjeldahl) and total ash was measured after sample combustion (ZBÍRAL 1994, JAVORSKÝ 1987, JAVORSKÝ and KREČMER 1987).

Results and Discussion

Barley is apparently the only commonly grown cereal, the caryopsis of which contains vitamin E in all eight isoforms of tocopherols and tocotrienols (PRÝMA et al. 2007). But in the green mass, compared to barley grain, we have detected any tocotrienols - only tocopherols were found. On contrary to our expectations, we have found on the base of the chemical analyses, that only ferulic acid (FA) was present of all the phenolic compounds analyzed (catechine, epicatechine, caffeic, chlorogenic and ferulic acids).

Table 1: **Mean values and the significance of the differences in selected phytonutrients**

Item	CAT[1)] mean	CAT signif.	SOD mean	SOD signif.	FA mean	FA signif.	Folates mean	Folates signif.
				Cultivars				
Malz	631,4	a[2)]	416,4	a	128,2	a	158,9	a
KM1910	684	b	418,1	a	325,7	b	155,9	a
Sebastian	718,5	b	486,3	b	401,3	c	176,7	b
				Years				
2005	600,3	a	382,1	a	N	-	N	-
2006	824,6	b	460,7	b	195,6	a	180,3	b
2007	608,9	a	477,9	c	374,5	b	147,4	a
				Localities				
Kromeriz	663,4	a	362,8	a	349,7	b	188,4	a
Zabcice	692,6	a	517,7	b	220,4	a	139,3	b
				Samplings				
DC 29	883,6	b	464,3	b	327,9	b	142,9	a
DC31	502,4	a	416,3	a	242,2	a	184,8	b

[1)] see Materials and Methods; CAT = catalase, SOD = superoxidismutase, FA = ferulic acid
[2)] means in the same column with the different letters differ significantly at P<0.05, N - no data

In accordance with literature, the mean values of the analysed phytonutrients in the green barley mass were relatively high: CAT - 677 U.g^{-1}, SOD - 338 U.g^{-1}, Vitamin E - 67 mg.kg^{-1}, FA - 284 mg.100g^{-1}, Vitamin C - 309 mg.100g^{-1}, folates - 163 mg.100 g^{-1} and total chlorophyll - 1.93 mg.g^{-1}.

The cultivars differed in the levels of the assessed phytonutrients; the cultivar Sebastian exhibited statistically significantly higher mean values of activity of vitamin E (718.5 catalase, SOD, folates and FA in comparison with two other materials. Only in content of FA, activity of vitamin E and content of the tocopherols mutual differences among all cultivars were highly statistically significant (*Table 1* and *Table 2*).

Comparison of results of the chemical analyses across two terms of sampling has shown, that values of all phytonutrients, with the exception of folates and chlorophyll, were significantly higher in the first sampling (i.e. DC 29), than in the second one. In individual years significant differences in mean values of all studied phytonutrients were determined.

The year 2006 (normal course of weather in spring months) was favorable for activity of catalase and vitamin E, synthesis of vitamin C and folates; for FA content and SOD activity the course of weather in 2007 was the most convenient.

Table 2: **Mean values and the significance of the differences in content of vitamins with an antioxidative effect**

Item	Vit.E[1)] mean	Vit.E signif.	alpha-T mean	alpha-T signif.	beta+gama-T mean	beta+gama-T signif.	delta-T mean	delta-T signif.	Vit.C mean	Vit.C signif.
					Cultivars					
Malz	61,8	a[2)]	59,7	a	11,6	b	1,7	a	500,8	a
KM1910	67,8	b	65,6	b	12,7	c	2,4	b	520,3	b
Sebastian	73,1	c	71,1	c	9,7	a	1,7	a	508	ab
					Years					
2005	74,9	b	73,1	b	12,6	b	1,9	ab	N	-
2006	75,2	b	73,6	b	10,6	a	2,3	b	558,3	b
2007	52,6	a	49,8	a	10,8	b	1,7	a	461,2	a
					Localities					
Kromeriz	68,7	a	66,2	a	11,5	a	1,8	a	477,4	a
Zabcice	66,4	a	64,7	a	11,2	a	2,1	a	542	b
					Samplings					
DC 29	74,5	b	71,9	b	10,5	a	1,5	a	555,4	b
DC31	60,6	a	59,1	a	12,1	b	2,4	b	464	a

[1)] see Materials and Methods
[2)] means in the same column with the different letters differ significantly at P<0.05, N - no data

Some authors (BAMFORTH 1983, BELCREDIOVÁ et al. 2006) have stated, that the amount of SOD in barley grain varies in dependence on a cultivar and locality. Mean values of SOD activity from the locality ZB were significantly higher than from KM (517.7 vs. 362.8 $U.g^{-1}$ for ZB and KM respectively), in other three substances (FA, vitamin C and folates) locality KM showed better results. Only in the activity of CAT and vitamin E, the means between localities were not significantly different.

Contents of macroelements (N and K) in green mass were nearly double compared to grain (from 3.96 to 4.16% and from 3.25 to 3.46% for N and K respectively - *Figure 1*), significant differences between the varieties, however, were not found. Especially K is a mineral that tends to be lacking in the processed diet of industrial society.

Interesting dependences were observed for the content of microelements in the assessed localities. Whereas the content of Fe was significantly higher in the Kromeriz (275.6 $mg.kg^{-1}$) than in Zabcice (98.4 mg.kg-1), the opposite was true for Cu (5.6 vs. 9.7 $mg.kg^{-1}$ for KM and ZB respectively). These results could be also adjudicated in relation to the differences, found in the mean activities of enzymes.

On the other hand, significant differences between individual cultivars were found only for mean content of Cu and Mn (*Table 3*).

Evaluation of experimental results showed statistically significant interactions among all sources of variability (cultivars, samplings years and localities,) in most phytonutrients studied, particularly interaction of the year with cultivar and locality.

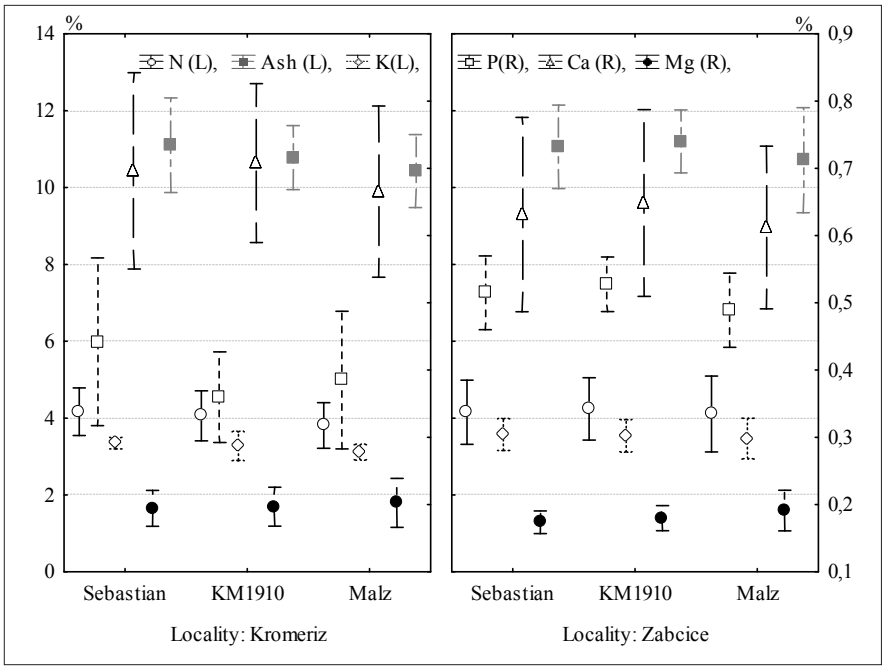

Figure 1: **Variability of the macroelements contens in the cultivars (across localities)**

Conclusions

The results of the study of the selected phytonutrients content in the green barley mass confirmed significant differences on the level of the selected cultivars; however for some substances only.

In terms of concentration of most phytonutrients the first sampling (growth phase DC 29) appeared more appropriate for production of the barley „green foods" than the second one (DC 31). Nevertheless we have to calculate on the lower content of chlorophyll and folates.

In general, all environmental factors, e.g. both years and localities, affected concentration of phytonutrients significantly.

Food supplements based on the parts of green plants have their tradition especially in the East Asian countries. In the USA, New Zealand, and other countries the food supplements called „Barley Grass" or „Green barley grass" have been offered on the market.

Our results have suggested that the exact selection of the cultivars and growing localities can significantly modify nutrient profiles of the desired valuable substances in green mass. They have also revealed that green barley mass could be valuable object of the future dietary studies and processing, even in the growing conditions of the Czech Republic.

Table 3: **Mean content of the microelements in the barley green mass**

Microelements	Items	Cultivars Sebastian	KM 1910	Malz
B	mean[1)]	19,5	20,1	19,3
	signif.	a[2)]	a	a
Cu	mean	8,1	7,4	7,4
	signif.	b	a	a
Fe	mean	203,0	187,1	170,8
	signif.	a	a	a
Zn	mean	24,4	25,1	25,5
	signif.	a	a	a
Mn	mean	38,7	39,9	35,0
	signif.	b	b	a

[1)] $mg.kg^{-1}$, [2)] means in the same row with the different letters differ significantly at P<0.05

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