Content of phenolic antioxidants and selenium in grain of einkorn (*Triticum monococcum*), emmer (*Triticum dicoccum*) and spring wheat (*Triticum aestivum*) varieties

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ABSTRACT

Wheat is worldwide consumed and contributes significantly to the intake of antioxidants with beneficial healthy effects. In the precise two-year field experiments in 2008 and 2009 two varieties of wheat einkorn, two varieties of emmer wheat and three varieties of spring wheat and in 2009 in addition two other spring wheat varieties, three einkorn varieties and three emmer wheat varieties were evaluated for selenium content and antioxidants – total polyphenols (TP). Selenium content was determined by atomic absorption spectrometry with hydride generation technique (HGAAS) and total polyphenols with Folin-Ciocalteau assay. Higher selenium content in grain is related to emmer (58.9–68.4 μg/kg DM) and einkorn (50.0–54.8 μg/kg DM) varieties; in spring varieties selenium content ranged from 29.8 to 39.9 μg/kg DM. Among the varieties with high TP (expressed in gallic acid equivalents) emmer varieties prevail (584–692 mg/kg DM), less represented are einkorn (507–612 mg/kg DM) and spring wheat (502–601 mg/kg DM) varieties. Among varieties significant differences were determined. TP were significantly higher in emmer wheat varieties and one einkorn and one spring wheat variety. Between TP and Se significant linear correlation was determined (r = 0.709).

Keywords: total polyphenol content; Se; antioxidants; minority wheat varieties; HGAAS; Folin-Ciocalteau assay

Natural antioxidants present in food and other biological materials have received considerable attention because of their safety and potential nutritional and therapeutic effects. Antioxidants can scavenge free radicals before they cause damage, or prevent oxidative damage from spreading out. Wheat kernels contain a number of phenolic antioxidants, namely ferulic, vanillic, gentisic, caffeic, salicylic, syringic, *p*-coumaric and sinapic acids as well as vanillin and syringaldehyde (Naczk and Shahidi 2006).

Selenium is another essential naturally occurring trace element for animals and human health with antioxidant properties, which cannot be synthesised in human body and substituted by any other element, but is deficient in at least a billion people worldwide (Lyons et al. 2005a). From environmental and biological points of view, Se is essential in a very narrow concentration range and outside this range deficiency or toxicity occurs (Sager 2006). The narrow margin between beneficial and harmful levels has important implications for human activities (Ducsay et al. 2007). Low dietary Se intake is associated with health disorders including oxidative stress-related conditions, reduced fertility and immune functions or increased risk of cancers (Zeng and Combs 2008). The population minimum intake of selenium likely to meet basal requirements was given as 21 and 16 μg/day for men and women, respectively, with lower values for children and infants extrapolated on the basis of basal metabolic rate. The population mean intake of selenium that would meet the normative requirements was given as 40 and 30 μg/day for men and women, respectively. The US and Canadian recommended dietary allowance (RDA) and the European population reference intake (PRI) are

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set at 55 µg Se/day; the UK reference nutrient intake range is 60–95 µg Se/day for an adult. An intake of 400 µg/day was suggested as a maximum safe dietary selenium intake (approximately 7.5 µg/kg body weight) and moreover, the World Health Organization proposed 400 µg/day as the upper limit as safe as adult population mean intake (Burk and Levander 2005). Selenium intakes above these levels may have cancer-preventive effects. Biomarker levels of nutritional Se status diminish significantly with cardiopathies, hepatopathies or several cancer types (Navarro-Alarcon and Cabrera-Vique 2008). Selenium is a scavenger of toxic metals in the body and in this way is an antagonist of mercury, lead, aluminium and cadmium and through its function with glutathione it acts as a powerful antioxidant helping to combat damage caused by free radicals. Selenium exists in two distinctly different forms – inorganic and organic. Inorganic selenium is the form only found in soils: selenites (IV) and selenates (VI); these forms are assimilated by plants – grasses, cereal grains and nuts and converted to L-selenomethionine and other simple organic species (Whanger 2002, Pyrzyńska 2009). Wheat and wheat products are an important source of Se in the human diet (Lyons et al. 2005a,b). The required Se intake can be obtained from crops produced on selenium-rich soils or by genetic breeding of new suitable accessions that could accumulate more selenium in grains. While many studies were done on the enrichment of soil with Se by fertilization with selenates and fortification of wheat grains (Ducsay et al. 2007, Pyrzyńska 2009), only little attention focused on searching for new selenium-rich genetic wheat sources such as einkorn, emmer and new modern bread wheat cultivars.

In order to enhance the existing knowledge on the content of soluble hydrophilic antioxidants in einkorn and emmer, we focused in this study on the determination of Se and polyphenol contents with the purpose to evaluate new selected wheat varieties. The objective was to explore the genetic variability of selenium contents among the selected cultivated wheat species, i.e. einkorn (*T. monococcum* L.), *T. dicoccum* durum wheat and modern bread wheat varieties in order to improve the nutritional value of bread and other wheat products.

MATERIAL AND METHODS

Plant material. Grain samples of analysed wheat landraces were obtained from the Czech Gene Bank of the Research Institute of the Crop Research Institute in Prague from the harvest 2008 and 2009. In the precise two-year field experiments in 2008 and 2009, two varieties of wheat einkorn (Escana and Schwedisches Einkorn), two varieties of emmer (Kahler Emmer and Rudico) and three varieties of spring wheat (SW Kadrilj, Kärtner Frűher and Granny) were analysed for the selenium content. In 2009, the range was extended to spring wheat varieties Jara and Postoloprtská přesívka 6, three einkorn varieties (*T. monoococcum* ECN 01C0204039, ECN 01C0204040 and ECN 01C0204044) and three emmer wheat varieties (Horny Tisovnik (Malov), *T. dicoccon* (Tapioszele) and *T. dicoccum* No. 8909). Their major characteristics are described in Table 1.

Determination of selenium by hydride generation technique (HGAAS). The content of selenium was determined in digested samples of wheat by AAS with HGAAS. Grain samples were ground finely and microwave-digested in an acid solution using MWS-3+ (Berghof Products + Instruments, Eningen, Germany). 400 mg of the sample was weighed into a Teflon digestion vessel DAP-60S and 2 ml of nitric acid 65%, p.a. ISO (Merck, KGaA, Darmstadt, Germany) and 3 ml H_2O_2 30%, TraceSelect (Fluka, TraceSELECT® Ultra, Schnelldorf, Germany) were added. The mixture was shaken carefully and vessel was closed after 30 min waiting and heated in the microwave oven. The decomposition proceeded for 1 h in the temperature range 100–190°C. The obtained digest was transferred into a 50 ml silica beaker and evaporated to wet residue, then diluted with minimum of 10% hydrochloric acid prepared from HCl 37%, p.a.+ (Analytika, Prague, Czech Republic) and deionised water (Thermo Scientific Fisher Inc. Barnstead Water Purification System, Los Angeles, USA). Formic acid 98%, puriss. p.a. (Sigma-Aldrich, Buchs, Switzerland) in the volume of 1 ml was added for the reduction of nitrogen oxides from reaction mixture. To reduce all selenium compounds in the digest to Se (IV), 5 ml of hydrochloric acid diluted with deionised water 1:1 (v/v) was added and the solution was heated at 90°C for 30 min. Then the digests were transferred to probes and adjusted with 10% HCl to the volume of 10 ml.

The concentration of selenium in the digests of cereal grains was measured by HGAAS technique using Varian AA 280Z (Varian, Mulgrave, Australia) with vapour generation accessory VGA-76 and sample preparation system Varian SPS3. Standard solution ASTASOL (Analytika, Prague, Czech

Table 1. Characteristics of analysed wheat varieties

Wheat species/type	Variety	ECN[1]	BCHAR[2]	Origin	Spike – awnedness (26)[3]	Caryopsis – colour (40))	Glume – colour (35)	Glume – indumentum (36)	Spike density (25)	Plant – height (3)	Powdery mildew (58)	Country of origin
Emmer wheat [*Triticum dicoccum* Schuebl (Schrank)] syn. *Triticum turgidum*, sp. *dicoccon* Schrank	Rudico	01C02-00948	412048	CZE	7 – awned	5 – brown	4 – red	1 – absent	9 – compact	6 – 96–110 cm	9	Czech Republic; legally protected cultivar, Crop Research Institute Prague (2006), ECN 01C0200948
	Kahler Emmer	01C02-03989	412013	DEU	6 – short awned	5 – brown	1 – white, straw-yellow	1 – absent	8 – very dense	6 – 96–110 cm	9	Germany; advanced /improved cultivar, ECN 01C0203989
	T. dicoccon (Tapioszele)	01C02-01282	412048	HUN	5 – long scurs	5 – brown	4 – brown	1 – absent	7 – dense	6 – 96–110 cm	9	not registered[4]
	Krajova-Horny Tisovnik (Malov)	01C02-00117	412013	CSK	4 – scurs	4 – light brown	2 – white, with a gray edge	1 – absent	5 – medium dense	5 – medium 81–95 cm	9	not registered[4]
	T. dicoccum No.8909	01C02-04501	412013	DNK	5 – long scurs	5 – brown	1 – white, straw-yellow	1 – absent	7 – dense	7– 115 cm	9	not registered[4]
Einkorn wheat (*Triticum monococcum* L.)	*Triticum monococcum* L. var. *flavescens* KOERN. Escana	01C02-01503	242002	ESP	6 – short awned	4 – light brown	1 – white, straw-yellow	1 – absent	9 – compact	5 – medium 81–95 cm	8	Spain; traditional cultivar/landrace, seed sample from Gene bank of the Crop Research Institute Prague, ECN 01C0201503
	Triticum monococcum L. var. *vulgare* Schwedisches Einkorn	01C02-04053	242019	SWE	6 – short awned	4 – light brown	1 – white, straw-yellow	1 – absent	9 – compact	6 – 96–110 cm	9	Sweden; traditional cultivar/landrace, ECN 01C0204053
	T. monococcum	01C02-04039	242007	ALB	5 – long scurs	4 – light brown	1 – white, straw-yellow	1 – absent	5 – medium dense	6 – 96–110 cm	9	not registered[4]
	T. monococcum	01C02-04040	242007	ARM	5 – long scurs	4 – light brown	1 – white, straw-yellow	1 – absent	7 – dense	6 – 96–110 cm	9	not registered[4]
	T. monococcum	01C02-04044	242019	ALB	5 – long scurs	5 – brown	4 – brown	1 – absent	5 – medium dense	6 – 96–110 cm	9	not registered[4]

Table 1 to be continued

Wheat species/type	Variety	ECN[1]	BCHAR[2]	Origin	Spike – awnedness (26)[3]	Caryopsis – colour (40))	Glume – colour (35)	Glume – indumentum (36)	Spike density (25)	Plant – height (3)	Powdery mildew (58)	Country of origin
Spring bread wheat (*Triticum aestivum* L.)	Granny	01C02-04799	635001	CZE	4 – semi-awned	5 – brown	1 – white, straw-yellow	1 – absent	3 – lax	5 – medium 81–95 cm	7	Czech Republic; registered cultivar, Selgen, Ltd., Plant Breeding Station Úhřetice (2004), ECN 01C0204799
	SW Kadrilj	01C02-04877	635000	SWE	2 – awnless	2 – yellow	1 – white, straw-yellow	1 – absent	5 – interme diate	5 – medium 81–95 cm	8	Sweden; registered cultivar (in CR 2006), Svalöf Weibull AB, ECN 01C0204877
	Kärntner Früher	01C02-03840	635104	AUT	1 – awnless	5 – brown	4 – red	1 – absent	3 – lax	6 – 96–110 cm	6	Austria; registered cultivar, Kärntner Saatbaugenossenschaft Reg. G.m.b.H (1960), ECN 01C0203840
	Jara	01C02-00100	635090	CSK	1 – awnless	5 – brown	1 – white, straw-yellow	1 – absent	5 – interme diate	6 – 110 cm	8.7	CSK Úhřetice Rdkm. Remo/Uhretice400 (1975)
	Postoloprtská přesívka 6	01C02-00043	635090	CSK	1 – awnless	6 – amber brown	1 – white, straw-yellow	1 – absent	5 – medium dense	7– 115 cm	8.5	CSK Rdkm. S-LV Postoloprty (1922–1941)

The classifications were done according to Bareš et al. (1985). [1]identification number of gene bank; [2]taxonomical code (botanical characteristics); [3]number of descriptor, the 1–9 scale in described part expresses state of descriptor of morphological character within the limits 1 to 9 (9 – the highest level, 0 – variable character); in the case of powdery mildew is 9 – very high resistant, 1 – very sensitive; [4]Registration of Plant Genetic Resources in the Czech Republic

Republic) of selenium was used in the preparation of a calibration curve for the measurement. Samples of the grains were analyzed in three replicates. The quality of analytical data was assessed by simultaneous analysis of certified reference material BCR 281 (Ryegrass, Community Bureau of Reference) (4% of all the samples). The accuracy for selenium content determination with respect to the reference material was 96.5%. The background of the trace element laboratory was monitored by analysis of 17.5% blanks prepared under the same conditions, but without samples, and experimental data were corrected by mean concentration of analyte in blanks, and compared with detection limit (mean ± 3 standard deviation of blanks), which was 0.08 ng/ml.

Determination of total polyphenol content with Folin-Ciocalteau assay. Finely ground wheat samples (ca 5.0 g) were weighed into 100 ml volumetric flasks and dissolved after refilling to the mark in methanol. For the total polyphenols (TP) determination 5 ml aliquots of sample solutions were pipetted. The sample extract was transferred into a 50 ml volumetric flask and diluted with approximately 5 ml distilled water. Then, 2.5 ml Folin-Ciocalteau reagent and 7.5 ml of 20% (w/w) Na_2CO_3 were added, adjusted with distilled water to 50 ml, agitated and left to stand at ambient temperature in the dark for 2 h. Absorbance of the sample was measured on a Heλios γ (Spectronic Unicam, Cambridge, UK) at λ = 765 nm against a blank prepared with distilled water. Gallic acid was used for the calibration. The upper and lower range of calibration was not linear. The results were expressed as gallic acid equivalents (GAE) in mg/kg dry matter (DM). Three parallel determinations were carried out.

Statistical analyses were performed using the software Statistica 7.0 (StatSoft) on the basis of parametrical and non-parametrical tests at the level of significance α = 0.05. Further ANOVA multiple factorial analysis, Tukey HSD test and *t*-test were used for statistical evaluation.

RESULTS AND DISCUSSION

Emmer wheat tetraploid wheat species and einkorn wheat were grown in the Czech territory till the 6th century A.D. when it was replaced by bread wheat. At present, only landraces and wild forms of these species are available in collections of genetic resources. With the aim to extend the spectra of grown crops, the collection of emmer and einkorn genetic resources in the Czech Gene Bank was studied. Accessions later in ripeness, with a good level of resistance to fungal diseases and with a high yield potential were selected from the collection to determine their polyphenol and selenium content.

Total polyphenol content. Three wheat varieties had promisingly high two-year mean TP content (Table 2). Namely, emmer varieties Kahler Emmer and Rudico and einkorn variety Schwedisches Einkorn (787.1 ± 26.1, 734.1 ± 6.8 and 660.8 ± 4.3 mg/kg DM, respectively). Within an extended range of 15 varieties in 2009 (Figure 1), above-average TP content in addition to the above men-

Table 2. Average total polyphenol (TP) content (gallic acid equivalents in mg/kg DM) and selenium content (µg/kg DM) in grains of analysed wheat varieties in 2008 and 2009

Year of harvest	2008		2009		Average 2008/2009	
Wheat variety	TP	Se	TP	Se	TP	Se
Schwedisches Einkorn[1]	735.9 ± 4.4[a]	39.2 ± 4.30[a]	585.6 ± 4.1[a]	54.8 ± 1.11[a]	660.8 ± 4.3[a]	47.0 ± 2.7[a]
Rudico[2]	816.4 ± 8.5[ab]	44.9 ± 1.14[b]	651.8 ± 5.0[b]	59.4 ± 3.47[b]	734.1 ± 6.8[b]	52.2 ± 2.3[b]
Kahler Emmer[2]	882.7 ± 28.4[c]	52.1 ± 3.12[c]	691.5 ± 23.8[c]	65.2 ± 0.75[c]	787.1 ± 26.1[b]	58.7 ± 1.9[c]
SW Kadrilj[3]	664.7 ± 1.5[adc]	75.1 ± 3.85[d]	534.2 ± 20.8[d]	35.2 ± 6.07[d]	599.5 ± 11.2[c]	55.2 ± 5.0[b]
Kärtner Früher[3]	543.3 ± 4.3[d]	19.2 ± 2.15[e]	501.5 ± 13.4[e]	33.7 ± 4.26[e]	522.4 ± 8.9[d]	26.5 ± 3.2[d]
Escana[1]	635.8 ± 3.0[abcd]	27.4 ± 0.34[f]	512.7 ± 8.3[f]	51.7 ± 1.31[e]	574.3 ± 5.7[e]	39.4 ± 0.8[e]
Granny[3]	526.2 ± 9.1[e]	48.6 ± 0.76[g]	600.7 ± 22.3[g]	35.2 ± 2.74[d]	563.5 ± 15.7[c]	41.9 ± 1.8[f]
Mean	686.4 ± 8.46	43.8 ± 2.24	582.6 ± 1.62	47.9 ± 2.82	634.5 ± 11.2	45.8 ± 2.5

[1]einkorn; [2]emmer; [3]spring wheat; each result is the average of three repetitions. Values followed by the same letter in the same column are not significantly different. Different small letters indicate significant differences (P < 0.05) among analyzed wheat varieties in the same column

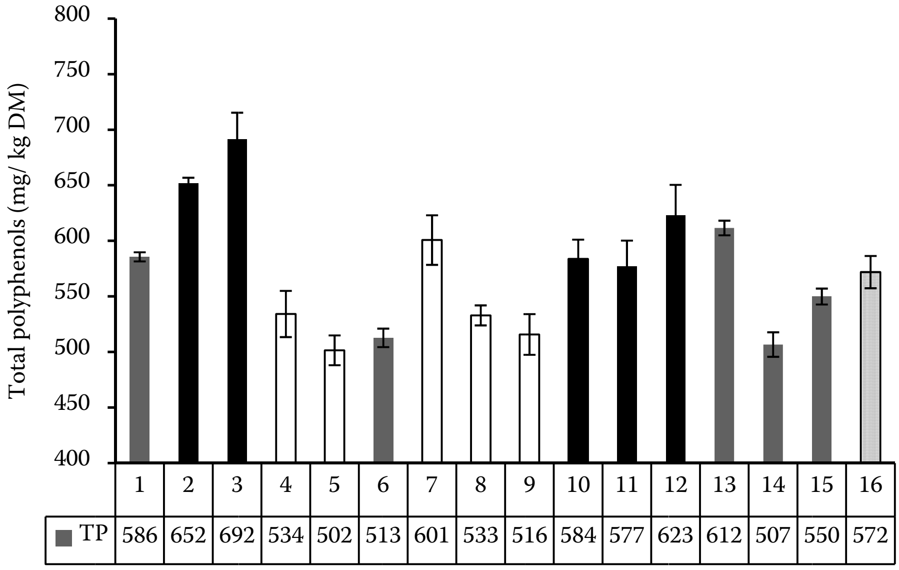


Figure 1. Total polyphenol content (average ± standard deviation – gallic acid equivalents in mg/kg DM) in einkorn, emmer and spring wheat varieties in 2009. 1 – Schwedisches Einkorn; 2 – Rudico (emmer); 3 – Kahler Emmer; 4 – SW Kadrilj; 5 – Kärtner Früher; 6 – Escana (eikorn); 7 – Granny; 8 – Jara; 9 – Postoloprtská přesívka 6; 10 – Krajova-Horny Tisovnik (Malov); 11 – *T. dicoccon* (Tapioszele); 12 – *T. dicoccum* No. 8909; 13 – *T. monococcum* 01C0204039; 14 – *T. monococum* 01C0204040; 15 – *T. monococcum* 01C0204044; 16 – average content of analysed varieties

tioned emmer varieties Kahler Emmer (691.5 ± 23.8 mg/kg DM) and Rudico (651.8 ± 5.0 mg/kg DM) and einkorn Schwedisches Einkorn (585.6 ± 4.1 mg/kg DM) were found in emmer varieties Krajova-Horny Tisovnik (Malov) (583.7 ± 17.4 mg/kg DM), *T. dicoccum* Schübl. No. 8909 (623.0 ± 27.4 mg/kg DM) and *T. dicoccum* Schrank. (Tapioszele) (577.0 ± 23.2 mg/kg DM) and einkorn *T. monococcum* L. ECN 01C0204039 (611.6 ± 6.6 mg/kg DM). Within spring wheat, Granny was found as a promising variety (600.7 ± 22.3 mg/kg DM). Among the varieties with high TP emmer varieties prevail, less represented are einkorn and spring wheat varieties. In 2009, the average content of total polyphenols was lower (582.6 ± 14.0 mg/kg DM) than in 2008 (686.4 ± 8.5 mg/kg DM). It could be due to a higher total rainfall in spring and a lesser precipitation in June as well as above-average temperature during the growing season as compared to the long-term average (Table 3). All varieties showed statistically significant between-year differences ($P < 0.05$).

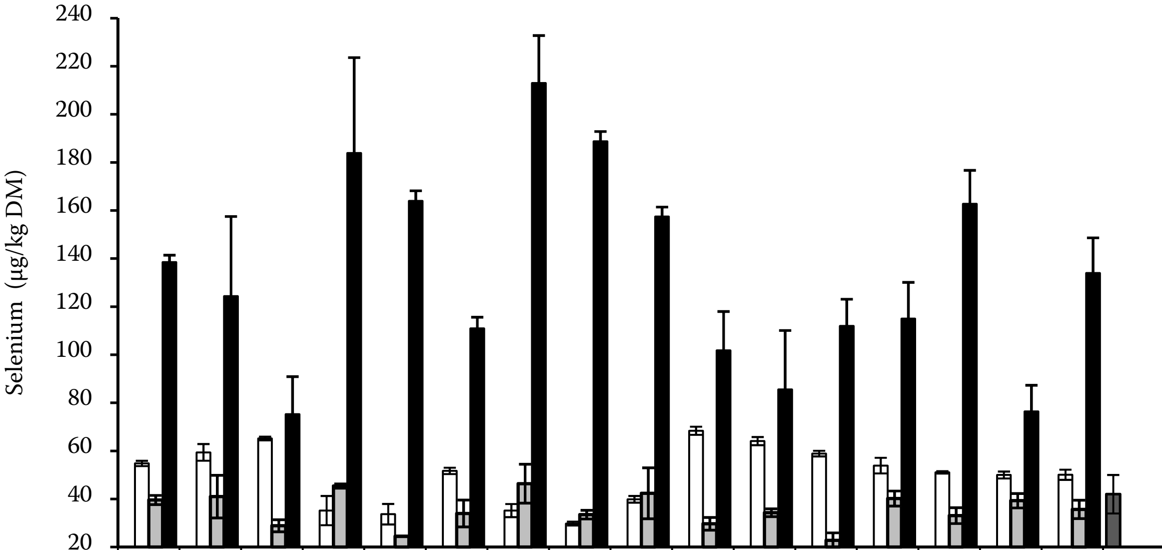
We found higher TP contents in einkorn and durum wheat in comparison with spring bread wheat. It corresponds with the findings of Liyana-Pathirana and Shahidi (2007) who determined higher amounts of phenolic acids acid in durum wheat (free vanillic acid, esterified ferulic acid and free sinapic acid 1.24 ± 0.06, 46.0 ± 0.12 and 0.19 ± 0.002 mg/kg crude extract, respectively). Although environmental factors play an important role in antioxidants concentration in cereals, the genetic component is predominant with high heritability

Table 3. Weather conditions during the vegetation period in the years 2008 and 2009 and comparison with long term period 1971–2001

Year		February	March	April	May	June	July	August	Vegetation period
2008	R	6.8	31.4	57.6	70.6	42.8	88.4	72.2	369.8
	T	3.9	4.4	8.7	14.7	18.8	19.1	19.0	12.7
2009	R	19.8	27.7	29.0	63.4	66.9	67.8	61.8	336.4
	T	0.1	4.6	13.6	14.4	15.7	19.3	20.3	12.6
Mean 1971–2001	R	16.8	37.6	24.2	109.2	69.0	79.0	20.8	356.6
	T	–0.2	3.8	7.9	13.3	16.2	18.1	18.1	11.0

R – sum of rainfalls (mm); T – mean temperature (°C) values. Wheat is a staple human food supplying a significant source of antioxidant compounds (Baublis et al. 2000, Miller et al. 2000). Einkorn and durum wheat could play together with new accessions of bread wheat in breeding of new genotypes with high carotenoids and tocols that may have a synergistic effect (Hidalgo et al. 2006, Brandolini et al. 2008, Hejtmánková et al. 2010). Due to valuable functions and the content of phenolic compounds, wheat products may constitute a valuable source of phenolic compounds in the human diet.

Selenium content. Four wheat varieties showed promisingly high two-year mean selenium content (Table 2, Figure 2). Emmer varieties Kahler Emmer (58.7 ± 1.94 µg Se/kg DM) and Rudico (52.2 ± 2.31 µg Se/kg DM), spring wheat Kadrilj SW (55.2 ± 4.96 µg Se/kg DM) and einkorn variety Schwedisches Einkorn (47.0 ± 2.71 µg Se/kg DM) distinguished with higher selenium content. In 2009 the investigated set was extended to spring wheat varieties Jara and Postoloprtská přesívka 6, three einkorn varieties (ECN 01C0204039, ECN 01C0204040 and ECN 01C0204044) and three emmer wheat varieties (Horny Tisovnik [Malov], Tapioszele and *T. dicoccum* No. 8909). In these 15 varieties also roots and stems were analysed for selenium content, which were taken during the growth stage according to Zadoks decimal system code 3-(30) (stem starts to elongate, first node detectable), on May 20 and June 4, 2009 (Figure 2). Grain contained an average of 50.1 µg Se/kg DM, stems 35.7 µg Se/kg DM and roots 134 µg Se/kg DM. The selenium content in the soil at the site where the varieties were grown was assessed as low (42.0 ± 8.0 µg Se/kg DM), because the normal range of 70–120 µg Se/kg DM was reported for the soils in the Czech Republic (Velíšek 1999). In the Czech Republic the content of selenium in the soil is relatively poor and therefore the content in crops should be taken into account. Grain, stems and roots contained 118, 85 and 319%, respectively, as compared with the soil, i.e. roots had 2.68 times higher selenium content than grain. Thus, considerable quantities of selenium accumulate in wheat grains, while the great content in the roots remains in soil for further use by other crops. In 2009, the average content in caryopses of



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
■ Soil																	42.0
□ Grain	54.8	59.4	65.2	35.2	33.7	51.7	35.2	29.8	39.9	68.4	64.1	58.9	53.9	51.1	50.0	50.1	
▒ Stems	39.6	41.0	28.9	45.4	24.5	34.0	46.4	33.5	42.4	29.7	34.3	22.8	40.2	33.1	39.3	35.7	
■ Roots	139	124	75	184	164	111	213	189	158	102	86	112	115	163	76	134	

Figure 2. Selenium content (average ± standard deviation in µg/kg DM) in grains, stems and roots of einkorn, emmer and spring wheat varieties in 2009. 1 – Schwedisches Einkorn; 2 – Rudico (emmer); 3 – Kahler Emmer; 4 – SW Kadrilj; 5 – Kärtner Früher; 6 – Escana (eikorn); 7 – Granny; 8 – Jara; 9 – Postoloprtská přesívka 6; 10 – Krajova-Horny Tisovnik (Malov); 11 – *T. dicoccon* (Tapioszele); 12 – *T. dicoccum* No. 8909; 13 – *T. monococcum* 01C0204039; 14 – *T. monococum* 01C0204040; 15 – *T. monococcum* 01C0204044; 16 – average content of analysed varieties; 17 – soil

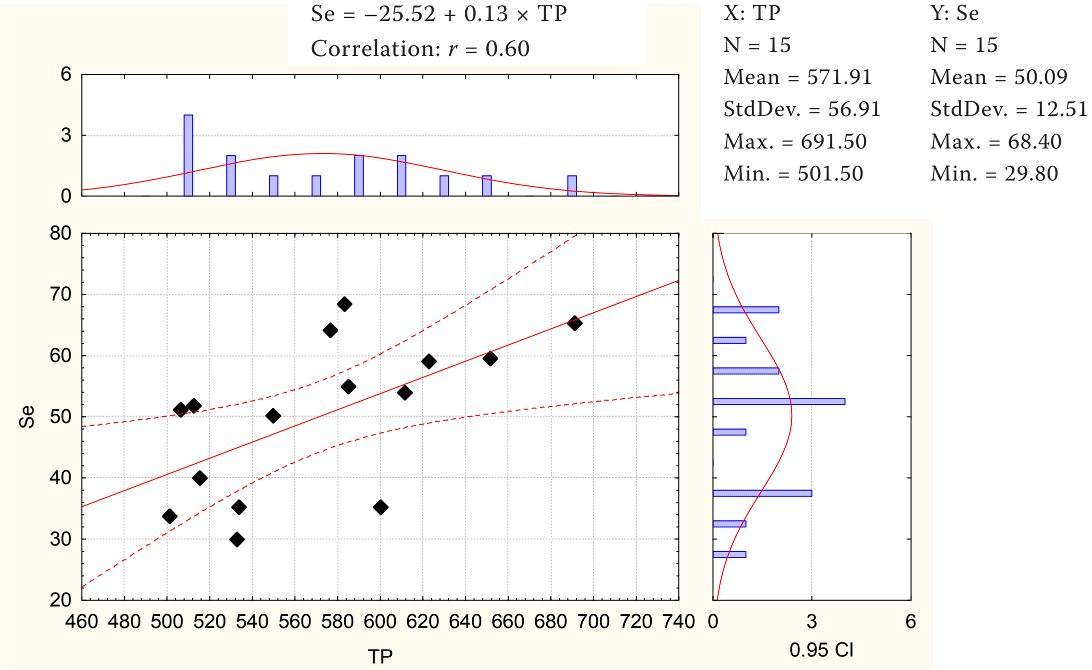


Figure 3. Linear correlation between selenium and total polyphenol (TP) content in wheat varieties analysed in 2009

analysed wheat varieties was slightly higher (47.9 ± 2.82 µg Se/kg DM) as compared with 2008 (43.7 ± 2.24 µg/Se kg DM). Two possible ways of increasing the selenium content seem to be feasible – by fertilization with selenium (as selenite at different doses into the soil or in solution by spraying the foliage) or by selection and use of varieties with a greater capacity to accumulate selenium. In the experiment in 2009 (Figure 2) promising varieties with high content of selenium were emmer varieties Kahler Emmer (65.2 ± 0.75 µg Se/kg DM) and Rudico (59.4 ± 3.47 µg Se/kg DM) and einkorn variety Schwedisches Einkorn (54.8 ± 1.11 µg Se/kg DM). Among other analysed varieties emmer Krajova-Horny Tisovnik (Malov) (68.4 ± 1.69 µg Se/kg DM) and *Triticum dicoccum* (Tapioszele) (64.1 ± 1.69 µg Se/kg DM) and einkorn *Triticum monococcum* ECN 01C0204039 (53.9 ± 3.25 µg Se/kg DM) were characterized by high content of selenium in the grain. On the contrary, the lowest content of selenium showed Jara variety (29.8 ± 0.78 µg Se/kg DM); emmer variety Krajova-Horny Tisovnik (Malov) accumulated 2.30 times more selenium in comparison with Jara variety. The obtained results showed that the selenium accumulation among cultivars of wheat was different and that significant differences between varieties with higher ability to accumulate selenium dominated in emmer and einkorn wheat species.

Trace element contents vary greatly among cereals and with the location where they are grown, especially for Se (Zhao et al. 2007). They are found mainly in the bran fraction, especially in the aleurone layer. Essential question about these compounds is their bioavailability, as it is reduced by the phytic acid present in high concentrations in whole-grain cereals. However, phytic acid can be broken down by phytases in a pre-fermentation step, such as that occurring in sourdough breads at pH 5–5.5 (Leenhardt et al. 2005). Wheat and wheat products are an important source of Se in the human diet (Hawkesford and Zhao 2007). A dietary survey carried out in the UK in 1995 estimated that cereals and cereal products (mainly wheat) contributed 18–24% to the total Se intake. Wheat produced in western and northern Europe generally contained less Se than that produced in North America because of the difference in soil Se status (Hawkesford and Zhao 2007).

The genotype × environment studies showed that most of the variation in grain Se was due to available soil Se (Lyons et al. 2005a). However, some studies permit possibility that genotypic differences in comparison with background soil may exist in wheat varieties; they are likely to be small in comparison with background variation (Lyons et al. 2005b). Our results indicate that some emmer and einkorn accessories could be good Se sources without using Se fertilizers, where also high soil toxic and economic aspects of some fertilizers doses should be taken into consideration. However, emmer and einkorn wheat varieties showed also high Se content and thus they may be promising sources of this nutritionally appreciated grain constituent.

Significant correlation was found between the content of total polyphenols and selenium in the range of seven varieties analysed in the two years (r = 0.709) and also for the total range of all analysed varieties from the year 2009 (r = 0.601, Figure 3).

REFERENCES

Bareš I., Sehnalová J., Vlasák M., Vlach M., Kryštof Z., Amler P., Malý J., Beránek V. (1985): Descriptors list/genus *Triticum* L. Genetic Resources. Research Institute of Crop Production in Prague, *21*: 78.

Baublis A., Decker E.A., Clydesdale F.M. (2000): Antioxidant of aqueous extracts from wheat based ready-to-eat breakfast cereals. Food Chemistry, *68*: 1–6.

Brandolini A., Hidalgo A., Moscaritolo S. (2008): Chemical composition and pasting properties of einkorn (*Triticum monococcum* L. subsp. *monococcum*) whole meal flour. Journal of Cereal Science, *47*: 599–609.

Burk R.E., Levander O.A. (2005): Selenium. In: Shils M.E., Shike M., Ross A.C., Caballero B., Cousins R.J. (eds): Modern Nutrition in Health and Disease. 10th Edition. Lippincot Williams and Wilkins, Philadelphia, 312–325.

Ducsay L., Ložek O., Varga L., Lošák T. (2007): Effects of winter wheat supplementation with selenium. Ecological Chemistry and Engineering, *14*: 289–294.

Hawkesford M.J., Zhao F.J. (2007): Strategies for increasing the selenium content of wheat. Journal of Cereal Science, *46*: 282–292.

Hejtmánková K., Lachman J., Hejtmánková A., Pivec V., Janovská D. (2010): Tocols of selected spring wheat (*Triticum aestivum* L.), einkorn wheat (*Triticum monococcum* L.) and wild emmer (*Triticum dicoccum* Schuebl [Schrank]) varieties. Food Chemistry, *123*: 1267–1274.

Hidalgo A., Brandolini A., Pompei C., Piscozzi R. (2006): Carotenoids and tocols of einkorn wheat (*Triticum monococcum* ssp. *monococcum* L.). Journal of Cereal Science, *44*: 182–193.

Leenhardt F., Levrat-Verny M.A., Chanliaud E., Remesy C. (2005): Moderate decrease of pH by sourdough fermentation is sufficient to reduce phytate content of whole wheat flour through endogenous phytase activity. Journal of Agricultural and Food Chemistry, *53*: 98–102.

Liyana-Pathirana C.M., Shahidi F. (2007): The antioxidant potential of milling fractions from bread wheat and durum. Journal of Cereal Science, *45*: 238–247.

Lyons G.H., Judson G.J., Ortiz-Monasterio I., Genc Y., Stangoulis J.C.R., Graham R.D. (2005a): Selenium in Australia: Selenium status and biofortification of wheat for better health. Journal of Trace Elements in Medicine and Biology, *19*: 75–82.

Lyons G.H., Ortiz-Monasterio I., Stangoulis J.C.R., Graham R.D. (2005b): Selenium concentration in wheat grain: Is there sufficient genotypic variation to use in breeding? Plant and Soil, *269*: 369–380.

Miller H.E., Rigelhof F., Marquart L., Prakash A., Kanter M. (2000): Antioxidant content of whole grain breakfast cereals, fruits and vegetables. Journal of the American College of Nutrition, *19*: 312–319.

Naczk M., Shahidi F. (2006): Phenolics in cereals, fruits and vegetables: Occurrence, extraction and analysis. Journal of Pharmaceutical and Biomedical Analysis, *41*: 1523–1542.

Navarro-Alarcon M., Cabrera-Vique C. (2008): Selenium in food and the human body: a review. Science of the Total Environment, *400*: 115–141.

Pyrzyńska K. (2009): Selenium speciation in enriched vegetables. Food Chemistry, *114*: 1183–1191.

Sager M. (2006): Selenium in agriculture, food, and nutrition. Pure and Applied Chemistry, *78*: 111–133.

Velíšek J. (1999): Food Chemistry II. Ossis, Tábor. (in Czech)

Whanger P.D. (2002): Selenocompounds in plants and animals and their biological significance. Journal of the American College of Nutrition, *21*: 212–223.

Zeng H., Combs G.F. Jr. (2008): Selenium as an anticancer nutrient: roles in cell proliferation and tumor cell invasion. The Journal of Nutritional Biochemistry, *19*: 1–7.

Zhao F., McGrath S., Gray C., Lopez-Bellido J. (2007): Selenium concentrations in UK wheat and biofortification strategies. Comparative Biochemistry and Physiology. Molecular and Integrative Physiology, *146*: 246–246.

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