Nutritional quality of Chinese cabbage from integrated culture

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ABSTRACT: The evaluation of nutritional quality of Chinese cabbage and the effects of cultivar, weed incidence, plant density and growing season were observed in integrated cultivation system. Mean contents of analysed compounds were as follows: 6% of dry matter, 10% of crude fibre, (in mg/kg of f.m.): 2,199 mg K, 289 mg Ca, 146 mg Mg, 111 mg Na, and 316 mg of vitamin C. Mean content of nitrates reached the value of 647 mg/kg. A significant effect of cultivar on the content of all observed substances in cabbage heads excluding magnesium was thus confirmed; however, a decrease of nitrates was found in the treatment with higher plant density. Weed cultivation caused slightly (insignificantly) higher nitrates content in cabbage heads by 100 mg/kg. Growing season showed a significant effect on content of some evaluated compounds. Integrated cultivation of Chinese cabbage could be an adequate approach to ensure nutritionally valuable products with low nitrates content.

Keywords: Chinese cabbage; integrated production; nutritional value; nitrates

Chinese cabbage is a popular vegetable with many benefits; for growers it is the short cultivation period and for consumers its high nutritional quality. Its content of dry matter is around 5%, dietary fibre 10 g/kg, potassium 2,520 mg/kg, calcium 1,050 mg/kg, magnesium 190 mg/kg, sodium 650 mg/kg, and vitamin C 450 mg/kg of fresh matter (USDA 2007). Kawashima et al. (2003) presented content of calcium around 330 mg/kg only, whereas nitrates content may be very high; for instance Chung et al. (2003) described the level of 1,740 mg of nitrates per kg of fresh matter. Yu et al. (2005) studied the effects of genotype on nutritional characteristics of Chinese cabbage and confirmed different heritability of selected nutritional compounds.

Integrated production system could be alternative to the conventional technology, especially for short-term vegetable species. One of the disadvantages of traditional cultivation technique is the fact that in conditions of high nitrogen fertilisation this system could lead to the decrease of nutritional value, in terms of lower vitamin C, total soluble solids and other compounds (Staugaitis et al. 2008). A positive effect of use of organic fertilisers instead of artificial ones is mentioned by Bahadur (2006). The use of farmyard manure led to the increase of vitamin C content by 44%, and similarly, dietary fibre increased. Organic fertilisation is positively preferred in integrated culture.

This work was focused on evaluation of total dry matter, crude fibre, content of potassium, calcium, magnesium, sodium, vitamin C and nitrates as affected by cultivar, plant density, weed incidence and growing season in integrated production system. Mutual correlations among selected nutrients and nitrates were also studied.

MATERIAL AND METHODS

Culture was grown in a field of the Faculty of Horticulture, Lednice in 2002 to 2004. Plant density varied from 4.0 to 7.1 plants per m^2 according to the culture. Fertilisation was done with respect to the soil analysis before each season. Mean content of nutrients in the soil (according to Mehlich III) showed 21 mg N_{min}, 169 mg P, 503 mg K, 373 mg Mg, 3,935 mg/kg Ca, and 7.1 pH. The K:Mg ratio was good. Because of high nutrient contents in 2002 and

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Table 1. Basic technological data

Culture	Autumn 2002	Spring 2003	Autumn 2003	Spring 2004
Cultivar	Nozaki, Parkin	Bilko, Optiko	Nozaki, Parkin	Bilko, Optiko
Plant distance (m)	0.50 × 0.35	0.40 × 0.35	0.50 × 0.35	0.40 × 0.35
	0.50 × 0.50	0.50 × 0.35	0.50 × 0.50	0.50 × 0.35
Planting	18th August	17th April	20th August	21st April
Harvest	29th October	12th June	7th November	19th June

2003 no fertilisation was done. Ammonium sulphate (40 kg per ha) was applied only before spring 2004. The uptake of Chinese cabbage for yield of 40 t per ha was considered in fertilisation. Previous culture was annual flowers.

Single trial plot represented 10 m^2 of net growing area. All treatments were organised in 3 randomly designed repetitions. All cultures were covered after planting by white non-woven textile (17 g per 1 m^2) as a protection measure against pests. Cover was removed after 3–4 weeks.

Tested treatments were: cultivar, plant density, weed regulation (hoeing 1 time per crop), and effect of growing season. Details are presented in Table 1.

Samples for analysis were prepared from 5 typically developed and sized heads of each cultivar. Crude fibre analysis was made according to the Kürschner-Scharrer's method. Content of mineral elements was analysed by capillary isotachophoresis in Ionosep (Recman, CZ). Vitamin C content was analysed by HPLC in C18 column Tessek (Ecom, CZ) and nitrates were analysed by Ion-selective electrodes (Crytur, CZ).

Statistical analysis was computed in the Unistat software (Unistat, USA) with the analysis of variance (Tukey test) and Pearson correlation analysis, all at 95% probability.

RESULTS AND DISCUSSION

Mean results are displayed in Table 2. Mean dry matter content was 6.4%, which is a higher level

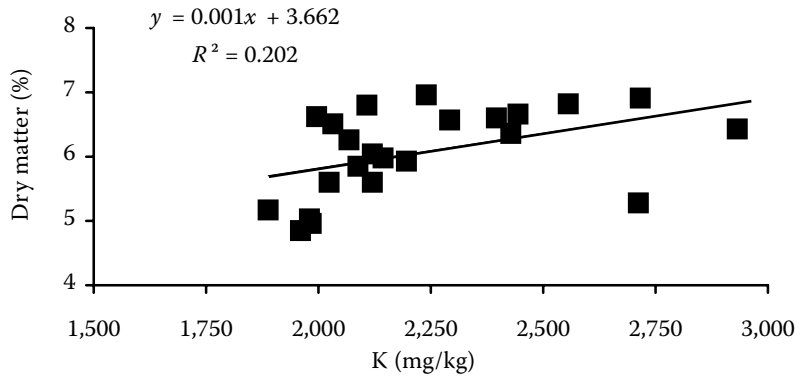

Fig. 1. Correlation between dry matter and potassium content

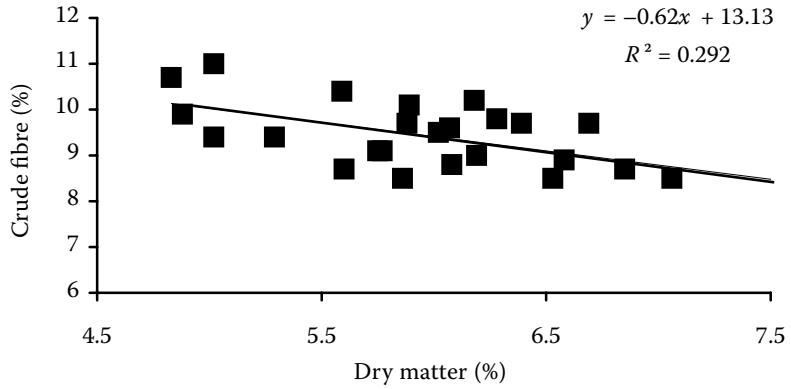

Fig. 2. Correlation between crude fibre and dry matter content

Table 2. Mean content of selected compounds in Chinese cabbage

Cultivar	Dry matter	Crude fibre	K	Na	Ca	Mg	Vitamin C	NO_3^-
	(%)		(mg/kg)					
Bilko	6.2	10.3	2,125	100	219	142	344	455
Nozaki	6.1	9.6	2,026	138	279	143	302	686
Optiko	6.1	10.9	2,357	93	261	153	288	490
Parkin	7.3	9.3	2,289	114	396	145	331	955
Mean	6.0	10.0	2,199	111	289	146	316	647
p value	0.003	0.0108	0.0109	0.0224	0.0000	0.3886	0.0366	0.0000
Effect of cultivar	**	*	*	*	**	ns	*	**
Culture								
Spring	6.1	10.6	2,236	97	239	147	316	473
Autumn	6.7	9.5	2,158	126	337	144	316	821
p value	0.0360	0.0001	0.4522	0.0018	0.0014	0.6917	0.9899	0.0000
Effect of culture	*	**	ns	**	**	ns	ns	**
Plant density								
0.5 × 0.35 m	6.6	9.8	2,177	124	314	144	322	705
0.5 × 0.5 m	6.6	9.5	2,180	119	330	144	312	813
0.4 × 0.35 m	6.0	10.6	2,207	90	234	150	309	488
p value	0.3642	0.0100	0.8870	0.0078	0.0274	0.7269	0.6756	0.0038
Effect of plant density	ns	**	ns	**	*	ns	ns	**
Hoeing								
Without	6.4	9.9	2,179	118	296	147	314	666
With	6.6	9.7	2,187	115	317	142	319	754
p value	0.3019	0.5083	0.9373	0.7525	0.4653	0.5413	0.7309	0.2498
Effect of hoeing	ns	ns	ns	ns	ns	ns	ns	ns

**Highly significant,* significant, ns – not significant at $p = 0.05$

compared to the literature (USDA 2007). The lowest value showed cv. Nozaki and Optiko (6.1%), the significantly highest value was in cv. Parkin (7.3%). Higher dry matter content was recorded in the autumn cultures (6.7%) than in the spring ones (6.1%) and this difference was significant. The highest plant density resulted in the lowest dry matter content (6.0%), if compared to the 6.6% at looser densities. However, this effect was not confirmed by statistical analysis. The hoeing had no importance for the dry matter content. Correlation analysis showed a significant positive correlation to the potassium content (Fig. 1) in spring cultures ($r = 0.6$, $p = 0.0363$), and a negative correlation to the crude fibre content (Fig. 2) in all seasons ($r = –0.54$, $p = 0.0382$). Results of Yu et al. (2005) showed a positive effect of increasing dry matter content on vitamin C, but in our experiments variable correlations to the vitamin C content were found – positive in spring 2003 ($r = 0.84$, $p = 0.0003$), but negative in spring 2004 ($r = –0.74$, $p = 0.0074$).

Crude fibre content was in the range of 9.3% (cv. Parkin) to 10.9% (cv. Optiko); this was quite a high content among leafy vegetables. Contrary to the dry matter results, spring growing season showed significantly higher crude fibre content (10.6%) to the autumn (9.5%). There is not a clear explanation for the significantly higher crude fibre content in higher plant density (10.6%) compared to the lower plant densities (9.5 to 9.8%). The effect of hoeing was not significant.

Mean potassium content was 2,199 mg/kg and such value fully corresponds to the USDA (2007) data. Cv. Nozaki reached the significantly lowest content of 2,026 mg/kg, while cv. Optiko reached 2,357 mg/kg. Potassium level was not affected by season, plant density and hoeing.

Mean level of calcium was 289 mg/kg. Similar values for calcium were published by Kawashima (2003), while USDA (2007) reported a 3-fold higher content. The lowest value showed cv. Bilko (219 mg

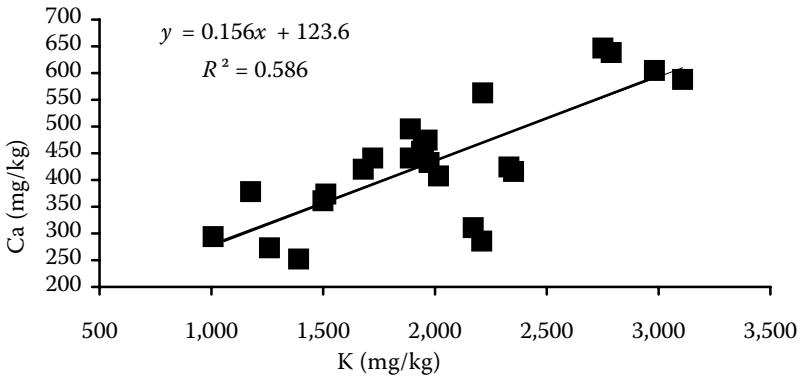

Fig. 3. Correlation between calcium and potassium content

per kg), while cv. Parkin had 396 mg/kg, found as statistically the highest level. Statistically higher calcium content was found in autumn seasons (337 mg/kg), those levels were by 100 mg/kg higher than the spring cultures; it corresponds with significantly lower content of calcium in plant density of 7.1 per m^2 (234 mg/kg) compared to the content of 314 to 330 mg/kg in plant distance of 0.5 × 0.35–0.5 m. The effect of hoeing was not found. A significant correlation between potassium and calcium (Fig. 3) showed the correlation coefficient $r = 0.77$ ($p = 0.0079$) in autumn 2002, but spring cultures brought such effects as well.

Magnesium content was relatively very similar among cultivars, with the mean value of 146 mg/kg, and similar to the previously reported levels (USDA 2007). No significant effect of cultivar on its content was found. The results of Yu et al. (2005) showed that not all nutrients depend on genotype. There was no significant effect of growing season, plant density and hoeing on magnesium content, either.

Mean content of sodium was only 111 mg/kg, which is rather low compared to the data of USDA (2007). In cv. Optiko there was only 93 mg/kg, compared to the significantly highest content (138 mg/ kg) in cv. Nozaki. Significantly higher content was in the autumn culture (126 mg/kg), as against 97 mg/kg in spring. The highest plant density showed the significantly lowest sodium content (90 mg/kg). Looser plant distance showed levels higher by 20–24 mg. The effect of hoeing was not confirmed.

Mean vitamin C content was 316 mg/kg. Cultivars Optiko and Bilko showed significant differences according to their lowest and highest levels (288 and 344 mg/kg). However, the highest content was still below the mean of 450 mg/kg reported by USDA (2007). On the other hand, Wang et al. (2007) found vitamin C content of 180 mg/kg only. The importance of heritability and different genotype on vitamin C levels was outlined by Yu (2005). The effect of growing season, plant density and hoeing on vitamin C values was not detected. Similarly, the negative correlation between vitamin C and crude fibre content described by Yu et al. (2005) was not confirmed.

Level of nitrates was 647 mg/kg in mean, cv. Parkin showed the significantly highest content (955 mg/kg). As previously reported (Chung 2003), the higher nitrates content was found in autumn culture (821 mg/kg) compared to the spring (473 mg per kg). This effect was ascertained by statistical analysis. The highest plant density also led to the significantly lowest nitrates content (488 mg/kg), while lower canopy densities resulted in the values

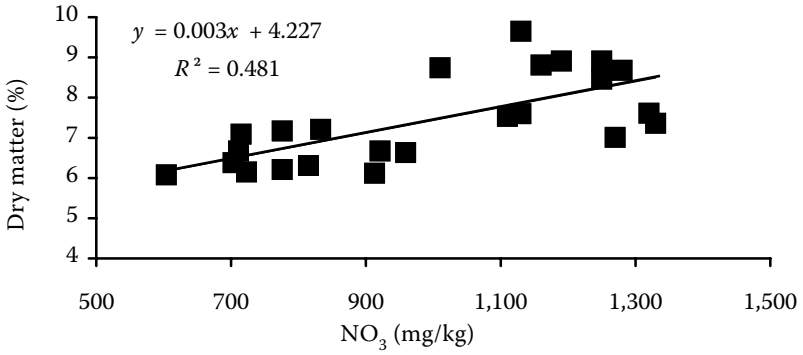

Fig. 4. Correlation between dry matter and nitrates content

from 705 to 813 mg/kg. Hoeing however increased nitrates content in the cabbage heads by nearly 100 mg/kg, this effect was not significant. Correlation between dry matter and nitrates content (Fig. 4) resulted in positive interactions represented by $r = 0.82$ ($p = 0.0000$).

CONCLUSION

Obtained results showed that cultivar is an important factor influencing nutritional value of Chinese cabbage. With the only exception of magnesium, the contents of all other nutrients were significantly different among observed cultivars. Among the evaluated cultivars cv. Parkin showed the highest content of vitamin C, calcium and dry matter. Effect of genotype on nutritional composition was confirmed. Correlations among selected nutrients or nitrates content were found; still, further studies of this issue are needed. The integrated cultivation system resulted in nutritional quality of Chinese cabbage comparable to the conventional agriculture, which was confirmed by relatively close values of analysed and cited contents of nutrients.

Cultivation period has also impact on the contents of nutrients. It is necessary to assure adequate calcium and potassium fertilisation, which is crucial for appropriate storability of cabbage heads, especially in autumn growing. On the other hand, the importance of plant density was not confirmed in many cases. Hoeing did not influence nutritional quality of Chinese cabbage, either; it resulted as a negative measure in approach of lowering the nitrate content. Oppositely, nitrate content was even (insignificantly) increased by this practice.

On the other hand, moderate appearance of weed can balance nitrate uptake from the soil.

The integrated vegetable production could be a suitable approach for growing nutritionally valuable vegetable, if compared to the traditionally grown culture.

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Nutriční hodnota pekingského zelí v integrované produkci

ABSTRAKT: Práce sledovala nutriční hodnotu pekingského zelí ve vztahu k odrůdě, výskytu plevelů, pěstebnímu sponu a termínu kultivace při integrovaném systému produkce. Byly dosaženy následující průměrné obsahy analyzovaných složek: 6 % sušiny, 10 % vlákniny, (v mg/kg čerstvé hmoty): 2 199 mg K, 289 mg Ca, 146 mg Mg, 111 mg Na a 316 mg vitaminu C. Průměrný obsah dusičnanů byl 647 mg/kg. Na obsah všech nutričních látek, s výjimkou hořčíku, měl průkazný vliv genotyp odrůdy. Snížení obsahu dusičnanů bylo doloženo u varianty s hustším pěstebním sponem. Okopávka (neprůkazně) zvýšila obsah dusičnanů v hlávkách asi o 100 mg/kg. Pěstební termín prokázal vliv

na obsah některých analyzovaných složek. Integrovaná produkce pekingského zelí může být adekvátní technologií pro zajištění nutričně hodnotné zeleniny s nízkým obsahem dusičnanů.

Klíčová slova: pekingské zelí; integrovaná produkce; nutriční hodnota; dusičnany

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