Yields, quality and nutritional parameters of radish (*Raphanus sativus*) cultivars when grown organically in the Czech Republic

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Abstract

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The potential cultivars of Chinese radish which can be introduced to the organic growing conditions of the Czech Republic was focused. We identified which of selected radish cultivars gave the best yields when grown organically, and which contained the highest contents of nutritionally important compounds, such as vitamin C, monosaccharides, fibre and selected minerals. Three cultivars (Jarola, Miyashige and Red Meat) were grown organically in the open field in Lednice during the years 2008 and 2009. All radish cultivars gave the sufficient yield (33–42 t/ha of marketable yield). The study of nutritional properties showed that cv. Red Meat had a significantly higher content of ascorbic acid (271 mg/kg in 2009). Cv. Miyashige had the highest content of fibre (1.7 g/100 g in 2009). Content of potassium was reasonably high, although there were significant differences between the cultivars. Cv. Jarola had the highest content of calcium (157 mg/kg in 2009).

Keywords: Chinese radish; nutrients; yield; quality evaluation; organic farming

World production of radish is estimated to be about 7 mil. t/year, representing roughly 2% of all vegetables. They are especially important vegetables in Japan, Korea and Taiwan, and Chinese radish is increasingly popular throughout the world because, among other things, it is regarded as having a degree of tolerance to club root infections. Other kinds of radishes may be grown as a leaf vegetable, as a green fertilizer or for their seeds and oil.

According to Stephens (1994), Chinese radish (*Raphanus sativus.* L. var. *longipinatus*) is also known as daikon, Japanese, oriental or winter radish. Several cultivars produce large, rounded roots, while others have an elongated, cylindrical shape. According to Fang (1996), Chinese radish (a member of the Brassica family) is one of the principal vegetables in Asia, especially in China and Japan.

Radish may be consumed raw, cooked or preserved. Some genotypes can be stored for use during winter, while others can be preserved with salt and dried. Apart from the roots, the leaves, stems, seed pods and seedlings of several species are eaten, and radishes are also often used in traditional medicines (Larkom 1991). European cultivars have a hot, astringent flavour, while Chinese cultivars have a long, cylindrical root and a juicier, milder flavour. Radishes have important nutritional properties, helping digestion and the production of

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bile, and the mustard oils present have de-congestant properties (Petříková et al. 2006).

Organic farming belongs to the fastest expanding sectors of the food industry in many European countries for many years (Padel et al. 2008). The increase in consumer demand for organic products in recent years is quite obvious (Willer, Kilcher 2009).

This study was designed to identify which of selected radish cultivars give the best yields when grown organically in the Czech Republic, and which contain the highest contents of nutritionally important compounds, such as vitamin C, monosaccharides, fibre and selected minerals.

MATERIAL AND METHODS

All experiments were conducted on the certified organic trial grounds of the Horticultural Faculty in Lednice (GPS 48°47'N, 16°47'E), 176 m a.s.l. during the years 2008 and 2009. The summer temperature (April to September) was above the long-term average in both years, being 16.9°C and 17.9°C, respectively. Total rainfall was below average in both years, being 269 mm and 297 mm, respectively. An analysis of the soil in 2008 indicated the following composition of elements in mg/kg: NO_3 85, P 456, K 363, Ca 6090, Mg 510.

Three cultivars of Chinese radishes were studied: Miyashige and Red Meat and a European cultivar, Jarola.

Sowing dates in the two seasons were 22. 7. 2008 and 27. 7. 2009. For each cultivar there were three repetitions placed next to each other, bounded with next rows of radish to avoid the side effect. One repetition consists of one row with subsequent thinning, to leave a final spacing of 0.45 × 0.20 m (40 plants). The plants were covered throughout the growing period with a PP unwoven textile (17 g/m^2, Pegatex® S, PEGAS NONWOVENS, Znojmo, Czech Republic) as a protection against potential pests, and irrigated in dry periods with a sprinkler system. In both growing seasons digging and hoeing operations were conducted to control weeds and aerate the soil. All plants were harvested by hand pulling, trimmed to remove the leafy part and then thoroughly washed before subsequent analysis. Two samples – plants (pulp and peel) from each repetition were selected for chemical analysis. There were 6 values available for each cultivar. The yield of radishes was assessed on the basis of specific quality parameters as set out in the Czech standards for radishes (ČSN 463127:2003). In addition, the contents of certain nutritionally important compounds were measured in each cultivar: vitamin C, monosaccharides (fructose and glucose), crude fibre and four minerals – potassium, calcium, magnesium and sodium. The analyses of ascorbic acid were performed by RP-HPLC (ECOM, České Meziříčí, Czech Republic) in a LCO-101 column at 254 nm according to Arya et al. (2000) with slight modification. Monosaccharides (total glucose and fructose) were analyzed using a reflectometer RQflex (Merck, Darmstadt, Germany). Levels of ionogenic cations (potassium, sodium, calcium and magnesium) were established by electrophoretic methods (capillary isotachophoresis) using a double capillary analyzer IONOSEP 2002 (Recman, Ostrava, Czech Republic) following the method described by Blatny et al. (1997). Crude fibre was determined from dried and ground samples by oxidative hydrolysis using FibreBags (Gerhardt GmbH, Königswinter, Germany). Ascorbic acid, minerals and monosacharides were determined from fresh samples.

Data were analysed by analysis of variance (factor cultivar and year) and the differences between cultivars were evaluated using the LSD test at a probability of $P = 0.05$ (Statistica 8.0, StafSoft Inc. 1984–2007).

RESULTS AND DISCUSSION

Yield assessment

The cv. Jarola was chosen as a standard by which the other two were judged. The yields of radishes in individual quality categories for the year 2009 are shown in Table 1. Cv. Jarola had higher yields than the two other cultivars in both years. Cvs Miyashige and Red meat had similar total yields, but the marketable yields were lower than those achieved by OST (2003) for Chinese radish (37–49 t/ha), although similar to, or higher than, those achieved by Tindall (1983) (15–20 t/ha) and Quin (1995) (22 t/ha). The yields best correspond to those achieved by Pasda et al. (2001), when yields ranged from 11 to 32 t/ha, depending on the amount of fertilization. Additionally, the average weight of individual roots did not reach the figure of around 2.5 kg reported by Tindall (1983).

Even though cv. Jarola achieved a higher total yield in both years, there was little difference in the marketable yields of these three cultivars. Kli-

Table 1. Overall summary of yields and average root weight of both years

Cultivar	Quality categories	2008			2009		
		yield (t/ha)	share (%)	average weight (kg)	yield (t/ha)	share (%)	average weight (kg)
Miyashige	1. class	28.2^{g}	73	0.42^{bcdef}	28.3^{g}	59	0.49^{ef}
	2. class	8.2^{abcd}	21	0.39^{bcde}	11.9 ^{bcd}	25	0.62^{f}
	rejects	2.2^{a}	6	0.09^{a}	7.7^{abcd}	16	0.23^{abc}
	total yield	38.6			47.9		
Jarola	1. class	24.8^{efg}	51	0.45^{cdef}	25.4^{fg}	50	0.50^{ef}
	2. class	17^{def}	35	0.47^{def}	10.6^{abcd}	21	0.90^{g}
	rejects	6.9^{abc}	14	0.30^{abcde}	15.2^{cde}	30	0.25^{abcd}
	total yield	48.7			51.2		
Red Meat	1. class	27.1^{g}	77	0.25^{abcd}	24.6^{efg}	57	0.30^{abcde}
	2. class	5.6^{abc}	16	0.27^{abcd}	9.4^{abcd}	22	0.45^{cdef}
	rejects	2.3^{ab}	7	0.21^{ab}	9.4^{abcd}	22	0.37^{bcde}
	total yield	35			43.4		

$^{a–g}$different letters represent significant differences among cultivars and among years

MENT (2009) also studied the yields of cv. Jarola when grown organically, and recorded 73% Class 1, 22% Class 2 and 5% rejects, compared to 51%, 35% and 14% respectively in this study, which was carried out in the same growing season. There were only minimal differences between the other two cultivars in 2008. In 2009 each of the cultivars in this study had a higher share of Class 2 roots compared to the results reported by KLIMENT (Table 1).

The cv. Red Meat had the lowest overall yields in both years, but nevertheless still had the same total weight of Class 1 roots when compared to the others. This could be because the quality criterion, a minimum diameter of 40 mm, was designed for cultivars with a long root, like Jarola and Miyashige, rather than for more rounded, turnip-like cultivars like Red Meat, with a greater diameter. The high proportion of radishes assigned to Class 2 in all three cultivars was due to poor shape and cracking, which naturally results in downgrading.

A strong positive correlation between the average weight of roots (kg) and total yield (t/ha) was only seen in the cv. Miyashige (r = 0.72) and Jarola (r = 0.74) in 2008.

Evaluation of nutritional parameters

Ascorbic acid

The results of the analyses of ascorbic acid content in the three radish cultivars are shown in Fig. 1. The lowest content of ascorbic acid were found in the cv. Jarola in 2009 (105 mg/kg), and the highest was measured in cv. Red Meat in 2009 (271 mg/kg). Cv. Red Meat was found to contain significantly higher contents than the chosen standard, cv. Jarola, being 74% higher in 2008 and 158% higher in 2009. In both cultivars, Red Meat and Miyashige, content of ascorbic acid did not vary significantly between the two years of this study, although those in cv. Jarola did, being lower in 2009.

Ascorbic acid content in cv. Jarola in 2008 (149 mg/1,000 g) was comparable to that published by JURICA (2008). Under organic growing conditions the content ranged from 147–189 mg/kg, depending on the spacing and the year. Similar results (175 mg/kg) were obtained by KOPEC (1998). The results for cvs. Jarola and Miyashige were lower than the 220 mg/kg reported by the USDA (2010) and the 244 mg/kg re-

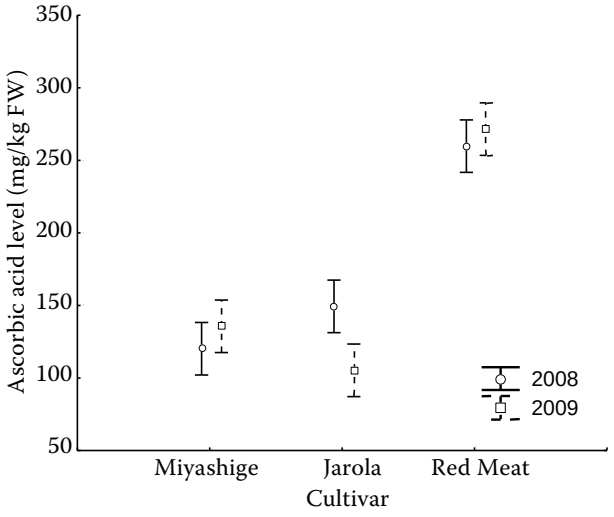

Fig. 1. Ascorbic acid content in the radish cultivars (n = 6)

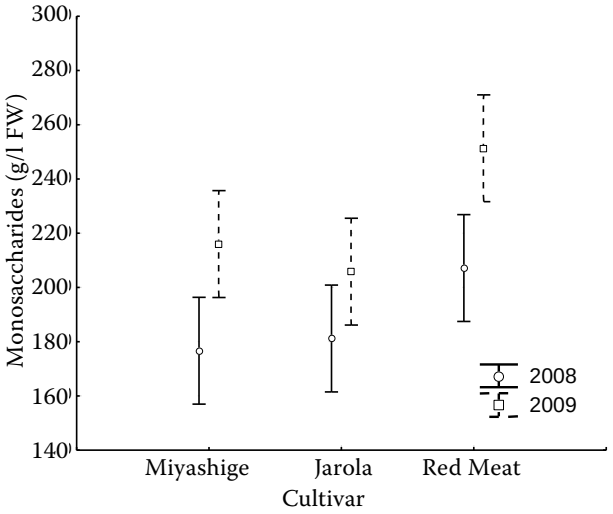

Fig. 2. Monosaccharides content in the radish cultivars (n = 6)
Note: Error bars represent standard deviation

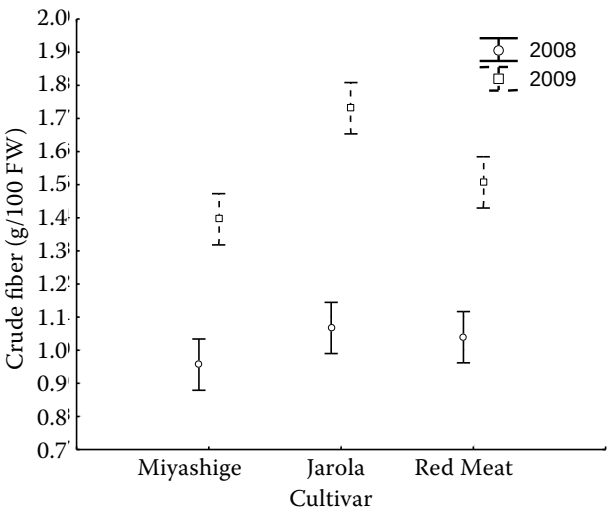

Fig. 3. Crude fibre content in the radish cultivars (n = 6)
Note: Error bars represent standard deviation

ported by Fineli (2010). The figures for cv. Red Meat corresponded better with previously published results, lying within the range of 142–334 mg/kg for Chinese radishes recorded by Lu et al. (2008).

Monosaccharides

The results for monosaccharides are shown in Fig. 2. The highest content were found in cv. Red Meat (251 g/l in 2009), and overall contents were higher in 2009 than in 2008. Monosaccharide content (glucose and fructose) were measured in g/l of pressed juice, and so cannot be compared with the figure of 2.4 g/100 g for monosaccharides and disaccharides combined published by Matportalen (2006). Even so, these results are in line with subjective sensory perceptions of sweetness, which rank cv. Red Meat as the sweetest, but this has yet to be confirmed by formal tasting trials.

Crude fibre

In both years cv. Jarola had the lowest content of fibre, 0.96 and 1.4 g/100 g , in 2008 and 2009, respectively, whereas cv. Miyashige had the highest, 1.1 and 1.7 g/100 g, in 2008 and 2009, respectively. The differences were most pronounced in 2009 (Fig. 3). Cv. Red Meat in 2008 had similar content of fibre to the other cultivars, but in 2009 it was significantly lower than in cv. Miyashige. There were significant differences observed between the two growing seasons, and in 2009 all the cultivars contained markedly higher contents of fibre, which corresponds to the higher content of dry matter seen in this year.

Fibre contents are comparable to the following published observations for radishes: 1.1 g/100 g (Kopec 1998), 1.3 g/100 g (Matportalen 2006), 1.6 g/100 g (USDA 2010) and 1.6 g/100 g (Fineli 2010). Lu et al. (2008) reported fibre content in Chinese radishes ranging from 0.4 to 1.8 g/100 g.

Minerals

Potassium. The content of potassium varied between 2,621 mg/kg for Miyashige in 2009, and 3,388 mg/kg for the same cultivar in 2008 (Table 2). No significant differences between the years were seen in either cvs Jarola or Red Meat. The higher contents recorded in cv. Red Meat in 2008 were not statistically significant. The range of values recorded (2,621–3,388 mg/kg) is clearly higher than the figure of 2,270 mg/kg published by the USDA (2010), but corresponds with other, previously published figures such as 2,540 mg/kg (Matportalen 2006) and 3,220 mg/kg (Kopec 1998). The results for cv. Jarola are slightly lower than the 3,608 mg/kg achieved by Jurica (2008) when also growing it under organic conditions in the same year, and much lower than the 4,900 mg/kg reported by Fineli (2010).

Calcium. The content of calcium varied between 157 mg/kg (for cv. Jarola in 2009) and 126 mg/kg (for cv. Red Meat in 2009). However, no cultivar showed significant differences. Although cv. Jarola seems to have the highest content and cv. Red Meat the lowest, the differences were minimal (Table 2). The results are in line with those of Jurica (2008), who recorded 176 mg/kg for cv. Jarola in organic production, and also close to the figure of 220 mg/kg reported by Matportalen (2006), but otherwise the overall contents are lower than obtained in other

Table 2. Average content of minerals in the radish cultivars

Year	Cultivar	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Na (mg/kg)
2008	Jarola	2,968^{ab}	140^{a}	102^{b}	139^{b}
	Miyashige	3,388^{b}	136^{a}	103^{bc}	–
	Red Meat	3,282^{b}	129^{a}	117^{c}	194^{bc}
2009	Jarola	2,799^{a}	157^{a}	103^{bc}	192^{bc}
	Miyashige	2,621^{a}	130^{a}	87^{a}	238^{c}
	Red Meat	3,019^{ab}	126^{a}	90^{ab}	221^{c}

$^{a–c}$different letters represent significant differences among cultivars and among years

studies: 270 mg/kg (USDA 2010), 410 mg/kg (Fineli 2010) and 516 mg/kg (Kopec 1998).

Magnesium. The lowest content of magnesium was recorded in cv. Miyashige in 2009 (87 mg/kg), and the highest in cv. Red Meat in 2008 (117 mg/kg). Cv. Jarola showed no significant differences between the two years, but in 2008 the content in cv. Miyashige was 18% higher and in cv. Red Meat 31% higher than in 2009. The figures for cvs Miyashige and Red Meat correspond, especially in 2009, with the figure of 80 mg/kg recorded by Matportalen (2006) and those for cv. Jarola with the 118 mg/kg recorded by Jurica (2008). Other figures in the published literature are higher: 160 mg/kg (USDA 2010), 190 mg/kg (Fineli 2010) and 260 mg/kg (Kopec 1998).

Sodium. The observed contents of sodium are shown in Table 2. The highest contents (238 mg/kg) were recorded in cv. Miyashige in 2009, and the lowest (139 mg/kg) in cv. Jarola in 2008. However differences were not significant. In 2008 the contents of sodium in cv. Miyashige were below the limits of detection, despite repeated attempts of measurement. Previously published figures for sodium content in radishes are as follows: 210 mg/kg (USDA 2010); 320 mg/kg (Kopec 1998) and 350 mg/kg (Fineli 2010). Comparable results were reported in cv. Jarola by Jurica (2008), who recorded a range of 135–164 mg/kg, depending on the plant spacing and the year in question.

CONCLUSION

The yields seen in the two foreign cultivars, Miyashige and Red Meat, were reasonably similar in both years and corresponded to those reported in other studies. Cv. Red Meat gave the lowest overall yields in both years, even though the weight of Class 1 roots was the same as the other cultivars. The time from sowing to harvest was as claimed by the producers (50–55 days), from which it can be deduced that these cultivars are suited to our conditions. When grown under the protective covering of a textile fabric, no other protection against pests was required. It can be concluded that all radish cultivars are suitable for being grown organically in the Czech Republic.

The study of nutritional properties showed that cv. Red Meat had significantly higher contents of ascorbic acid in both years when compared to the standard cv. Jarola. Contents of monosaccharides were a slightly higher in cv. Red Meat in 2009. Cv. Miyashige had the highest content of fibre. Contents of potassium were reasonably high, although there were significant differences between the cultivars. Cv. Jarola had the highest contents of calcium, though these were not statistically significant. The other parameters under investigation showed considerable variation between the two years, and the results cannot therefore be easily summarized.

Koudela and Petříková (2008) noted a significant influence of year on the content of vitamin C, minerals, and dietary fibre for sweet fennel.

Cv. Red Meat appears to be a promising cultivar but a detailed evaluation of the nutritional properties of these two cultivars cannot be made without further laboratory tests. In assessing the significance of the content of these various compounds, one must not forget the importance of certain other nutritional parameters, such as glucosinolates and other compounds with anti-oxidant properties, which are commonly found in members of the Brassica family (Dixon 2006). The content of glucosinolates in Chinese broccoli, for instance, could be one of the most promising areas for future investigation.

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