THE EFFECT OF GROWING SYSTEMS ON THE QUALITY OF CARROTS

Ingrid Bender[1], Ulvi Moor[2], Anne Luik[2]
[1]Estonian Crop Research Institute
[2]Estonian University of Life Sciences
Ingrid.Bender@etki.ee

Abstract
The aim of the research was to evaluate how the quality of carrots is affected by organic and conventional production systems. The experiment was carried out at the Estonian Crop Research Institute in 2009. Conventional treatment received the following amount of nutrients via mineral fertilizers: N 115, P 40 and K 152 kg ha^{-1}. For plant protection, the following pesticides were used: Fenix, Fastac 50, Agil and Signum. In organic cultivation system compost and humic acid solution Humistar were used for fertilization and polypropylene non-woven fabric Agryl P-17 for plant protection. Marketable yield of organic carrots was 8% lower compared to the conventional carrots. Conventional carrots contained pesticide residues and had significantly higher nitrate concentration than organic carrots. The contents of total sugars, phosphorus, potassium, calcium and magnesium did not differ significantly between carrots from different cultivation systems. At harvest, dry matter (DM) content of organically grown carrots was significantly higher, whereas vitamin C and ß-carotene content was significantly lower in organically grown carrots. However, after 5-months of storage, the organic carrots had significantly higher total soluble solids (TSS) and β-carotene content compared to the conventional ones indicating that organically grown carrots were less susceptible to storage conditions.
Key words: β-carotene, conventional, *Daucus carota,* nitrates, organic, yield.

Introduction

The interest of consumption of organic food, including that of vegetables, has been steadily increasing during the last decade in Estonia and also in other countries (Winter and Davis, 2006; Pehme et al., 2007; Dangour et al., 2009; Smith et al., 2009; Matallana González et al., 2010). Vegetables and fruits are important sources of vitamins, minerals, trace elements, dietary fibre and a large variety of beneficial phytochemicals, which might decrease the risk of certain age-related and cardiovascular diseases. Therefore, the dietary guidelines recommend eating at least five portions of fruits and vegetables a day. Several factors are affecting the quality of raw products and the cultivation system is one of them. The composition of organically and conventionally produced vegetables has been studied for years, but further research is still recommended due to insufficient data (Hoefkens et al., 2009; Seljåsen et al., 2013). To add knowledge to the previously mentioned topic, the aim of the present research was to evaluate how the quality of carrots (both at harvest and after storage) is affected by organic and conventional production system.

Materials and Methods

The field experiment was carried out at the Estonian Crop Research Institute at Jõgeva (26°24'E, 58°44'N) in 2009 and was a repetition of the experiment done one year earlier (Bender et al., 2009). Carrots (*Daucus carota*) were cultivated under conventional and organic conditions on plots of 100 m^2 altogether, with four replications per treatment.

For two years before the experiment, cereals were cultivated on the area according to the EU regulations on organic production (Council Regulation No. 843/2007). Soil at the sites was sandy loam. The soil samples were analysed before establishment of the experiment using the following methods: pH – ISO 10390, P, K, Ca, Mg, Cu, Mn – Mehlich III, B – by Berger and Truogi and C_{org} – by NIRS. The nutritional status of the soil was satisfactory and soil acidity favourable for carrot cultivation (Table 1). No pesticide residues, as measured by the method prEN 15662: 2007 NIRS, were present in the soil. All soil samples were analysed in the Laboratory of Agrochemistry at the Estonian Agricultural Research Centre in Saku.

For basic fertilization, 800 kg ha^{-1} of Cropcare 8-12-23 (N 65, P 40, K 152 plus micronutrients) was applied to the conventional plot and 20 t ha^{-1} of green waste compost (analysed by the Laboratory of Agrochemistry at the Estonian Agricultural Research Centre to have N 1.0 g 100 g^{-1}, P 0.20 g 100 g^{-1}, K 0.3 g 100 g^{-1}, pH_{HCl} 6.76) was applied to the organic plot. During the growing period the conventional carrot

Table 1

Soil pH and nutrient status before experiment establishment in 2009

pH_{KCl}	P(ppm)	K(ppm)	Ca(ppm)	Mg(ppm)	Cu(ppm)	Mn(ppm)	B(ppm)	C_{org}(ppm)
7.0	79	105	2800	128	1.9	66	1.15	2.0

plants were fertilized by ammonium nitrate (N 50 kg ha^{-1}) and sprayed with Folicare 18-18-18 (4 kg ha^{-1}), resulting in a total supply of 0.7 kg N, 0.3 kg P and 0.6 kg K ha^{-1}. Organic carrot plants were fertigated at a rate of 1 litre per meter of row with humic acid solution (fertilizer Humistar diluted by 1:20), resulting in a total supply of 1.4 kg K ha^{-1}.

Carrot seeds of orange colored cv. Jõgeva Nantes were sown on 27 May. After seed sowing the organic plots were covered with polypropylene non-woven fabric Agryl P-17 for two months to control carrot psyllid (*Trioza viridula*) and carrot fly (*Psila rosae*). In the conventional system, the insecticide Fastac 50 was sprayed at 0.3 l ha^{-1} on 15 June and 28 July. The fungicide Signum 0.75 kg ha^{-1} was used on 12 August to control black rot (*Alternaria radiciana).* The soil of the conventional plots was treated with the herbicide Fenix at 2.5 l ha^{-1} two days before the sprouting of carrots and 18 days after seed sowing against couch grass with a herbicide Agil 100 EC at 1.0 l ha^{-1}. The organic plots were weeded twice by hand and hoeing. The crop was harvested manually on 8 October. Crop yield was calculated per hectare.

For postharvest experiment, 5 kg of carrots from both treatments from each replicate (all together 20 kg carrots per treatment) were stored in plastic boxes for recording postharvest loss. Additionally two more boxes (10 kg) of carrots from both treatments were stored for analyses. Carrots were stored for five months in coolstore of Estonian University of Life Sciences. Storage temperature ranged from 2 to 4 °C and RH was 85 to 90%. Postharvest loss (weight of carrots with decay or growth symptoms) was recorded monthly. The storage period finished in spring 2010. Quality analyses were performed at harvest and after 5-months of storage.

After harvest the carrot composition and amount of pesticide residues were determined from each of the replicate organic and conventional plots. Pesticide residues were analysed by gas chromatography in the Laboratory of Agrochemistry at the Estonian Agricultural Research Centre. Dry matter (DM), total sugars and ascorbic acid (vitamin C) were determined in the same laboratory; DM by 71/393 EEC methods, total sugars and vitamin C by using the standard methods. Total nitrogen was determined by Copper Catalyst Kjeldahl Method, (984.13); phosphorus by Stannous Chloride method, ISO/FDIS 15681, AN 5242; calcium by o-Cresolphthalein Complexone method, ISO 3696, AN 5260 in Kjeldahl Digest by Fiastar 5000; magnesium by Fiastar 5000, ASTN90/92 by Titan Yellow method; potassium by Flame Photometric Method, (956.01); nitrates by Fiastar 5000, AN 5201 (nitrate - N, Cd-reduction, ISO 13395), Foss Tecator AB, 2001 (Helrich, 1990). Carrot macronutrients were determined at the Laboratory of Plant Biochemistry of the Estonian University of Life Sciences.

Before and after storage, the total soluble solids (TSS) content (°Brix) was measured using the digital refractometer ATAGO CO., Ltd., Japan and β-carotene was determined in the Health Protection Inspectorate Tartu Laboratory, using T44- HPLC method.

Significant differences between cultivation systems were tested by one-way analysis of variance and the effect of cultivation system and storage by two- way analysis of variance at significance level of $P \leq 0.05$. Mean values followed by the same letter are not significantly different at $P \leq 0.05$ in Figures.

Results and Discussion

In 2009 the rainy period started on 3 June with a low temperature and night frosts. This ameliorated the growth conditions. The marketable yield of conventional carrots (13.4 t ha^{-1}) was 8% higher than that of organic carrots in 2009. In 2008, the marketable yield of organic carrots was 11% higher than the conventional one (Bender et al., 2009). It has been reported earlier that the organic yield of vegetable is lower than the conventional (Fjelkner–Modig et al., 2000; Mäder et al., 2002). However, Dresbøll et al. (2008) found no differences in carrot yields between the two systems. Improved thermal regime and maintained humidity under the Agryl cover probably raised the organic marketable yield in our experiment in both years. Earlier studies on Chinese cabbage, beetroot and sweet pepper (Moreno et al., 2001; Gimenez et al., 2002; Michalik, 2010) have demonstrated the same effect of non-woven cover. However, Rekika et al. (2008) did not detect the effect of Agryl cover on radish yield at the harvest time. In our experiment, the applied humic acid fertilizer Humistar might have been another contributor to the yield of organic carrots. It is well established that humic acids improve soil chemical and physical quality and, in general, enhance root growth and development (Arancon et al., 2003). Although Lada et al. (2004) found that humic acid application to the soil promoted early seedling emergence of carrot, there was no significant yield difference compared to yield from the control treatment. Karakurt et al. (2009) demonstrated that soil humic acid treatment can be successfully used for increasing yield and improving fruit quality of organically grown pepper.

From the afore analysed pesticide residues one (α-cypermethrin below 0.01 mg kg^{-1}) was detected in 2009, two in 2008 (Bender et al., 2009) in the conventionally grown carrots and none in organically grown carrots. These results concur with those reported by Rembiałkowska and Hallmann (2007), who also found that organic vegetables were free of pesticide residues. According to the EU regulation

No 149/2008, the residues found in conventional carrots in our experiment did not exceed the permitted levels.

Cultivation system did not affect the content of total sugars, P, K, Ca and Mg of carrots in 2009 (data not shown) and also in 2008 (Bender et al., 2009).

Nitrogen content was significantly higher in the conventional than in organic carrots (1.5 and 1.1 g $100g^{-1}$, respectively) and the same result has been indicated in 2008 (Bender et al., 2009). In 2009, organic carrots contained nitrates at a low level, significantly lower than the conventional ones (26.6 and 149.6 mg kg^{-1}, respectively). In 2008, nitrates were not detected in organically grown carrots (Bender et al., 2009). Several studies have affirmed that organic carrots contain significantly less nitrogen and nitrate than do conventional ones (Leclerc et al., 1991; Warman and Havard, 1997; Rembiałkowska and Hallmann, 2007; Lairon, 2009; Seljåsen et al., 2013).

DM content of organically grown carrots was significantly higher than that of conventionally grown carrots (10.6 and 10.1 mg $100g^{-1}$, respectively), but organically and conventionally grown carrots did not differ significantly in their DM content in 2008 (Bender et al., 2009). Some earlier studies have shown that organic crops (including carrots) contained significantly more DM compared to conventional ones (Rembiałkowska, 2007; Sikora et al., 2009; Bender and Ingver, 2012). However, not all studies have confirmed this phenomenon. Therefore, review articles have identified only a trend for higher DM content, for instance, no significant differences have been found for organic vegetables (Woëse et al., 1997; Bourn and Prescott, 2002).

TSS content of organically grown carrots was significantly lower than that of conventionally grown carrots (Figure 1). Similarly, conventional carrot samples had higher TSS compared to organic ones in Ireland (Gilsenan et al., 2008). TSS of organically and conventionally grown carrots was not affected by the cultivation technology in 2008 (Bender et al., 2009).

No significant differences were found between organic and conventional cultivation in content of vitamin C in carrots in 2009 (5.7 and 5.0 mg $100g^{-1}$), therefore was significantly lower in 2008 (Bender et al., 2009). Vitamin content of a plant depends on a number of factors such as climate, genetic properties, fertilizer and soil (Mozafar, 1994). Also, according to Lee and Kader (2000), the content of vitamin C in vegetables depends on several factors, among them preharvest climatic conditions and cultural practices. As reported by Worthington (2001), organic crops (among them carrot) contained significantly more vitamin C than the conventional crops. Sikora et al. (2009) also have found that organic carrots contained significantly more ascorbic acid compared to the conventional ones. However, several scientists (Warman and Havard, 1997; Fjelkner-Modig et al., 2000; Brandt et al., 2011; Bender and Ingver, 2012) could not verify significant differences in vitamin C content caused by different cultivation systems.

In our experiment, no significant differences in β-carotene content were found between organic and conventional carrots (Figure 2), but conventional cultivation system significantly increased β-carotene content of carrots in 2008 (Bender et al., 2009). Rembiałkowska (2003) has demonstrated that organic carrots had less β-carotene. Contrarily, Sikora et al. (2009) reported that organic carrots contained significantly more carotenoids, such as β-carotene and lutein. The same was confirmed by Hoefkens et al. (2009) on literature-based comparison. The Danish scientists Søltoft et al. (2011) and Seljåsen et al. (2013) demonstrated in their reviews that the content of carotenoids in carrot roots was not significantly affected by the agricultural production system. Mentioned results indicate that the formation

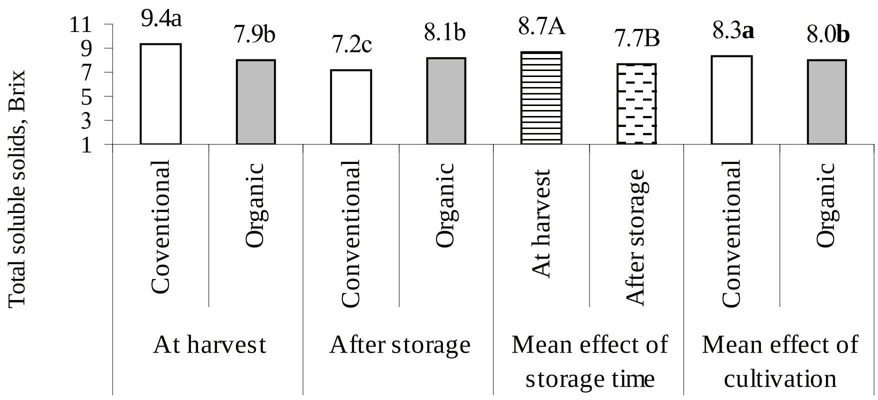

Figure 1. Total soluble solids content of organically and conventionally cultivated carrots cv. Jõgeva Nantes at harvest (October 2009) and after 5-months of storage (March 2010).

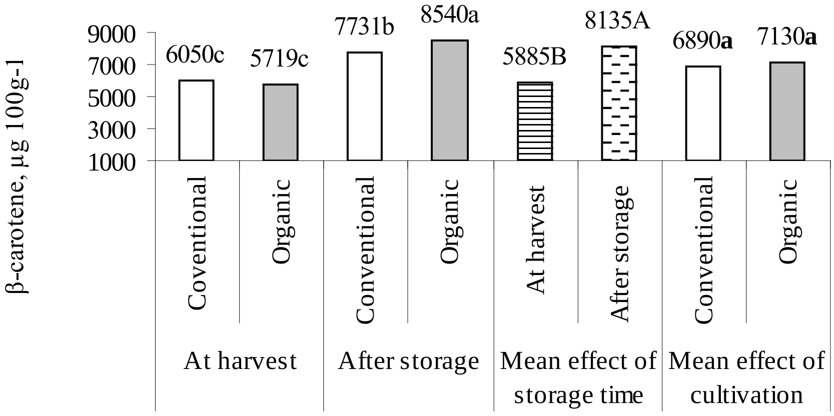

Figure 2. β-carotene content of organically and conventionally cultivated carrots cv. Jõgeva Nantes at harvest (October 2009) and after 5-months of storage (March 2010).

of secondary metabolites is often more dependent on the yearly different weather conditions, and this influence overshadows the possible effect of cultivation system.

After 5 months of storage, the average postharvest loss of organic carrots was 17% and of conventional carrots 19% (data not shown). The cultivation system had no significant effect on postharvest loss. During storage, TSS content of conventional carrots had significantly decreased, whereas TSS content of organic carrots remained unchanged (Figure 1). β-carotene content of both organic and conventional carrots had significantly increased during storage (Figure 2). Previously mentioned result is in agreement with earlier studies reporting that β-carotene content increases at storage temperatures above the freezing point (Howard et al., 1999). It is important to note, that after storage the organic carrots had significantly higher TSS and β-carotene content compared to the conventional ones.

Conclusions

The yield of the conventionally grown carrots was higher compared to organically grown carrots. The cultivation system did not significantly influence the content of analysed mineral elements and total sugars, but the quality of conventional carrots was significantly decreased by their high nitrate content and some pesticide residues. Organic carrots did not contain pesticide residues and contained nitrates at low level. At harvest, ß-carotene content was significantly lower in organically grown carrots. However, after 5-months of storage, organic carrots had significantly higher TSS and β-carotene content compared to the conventional ones indicating that organically grown carrots were less susceptible to storage conditions.

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