ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

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COMPARISON OF CARROT QUALITY CULTIVATED USING CONVENTIONAL, INTEGRATED AND ORGANIC METHOD

PORÓWNANIE JAKOŚCI MARCHWI UPRAWIANEJ METODAMI KONWENCJONALNĄ, INTEGROWANĄ I EKOLOGICZNĄ

Abstract: The experiment was conducted in the years 2006–2008 according to the rules of conventional, integrated and organic methods. Organic cultivation was conducted on a certified organic farm. The investigation focused on carrots 'Flakkee 2' cv. On the basis of average results for the three years of the experiment there was made an assessment of the effect of cultivation method on the quantity and quality parameters of yield, such as average mass of marketable roots, their length and diameter, and content of dry mass, nitrates, soluble sugars, ascorbic acid and carotenoids.

The total yield, mass and length of roots were bigger in organic cultivation. Carrot dry mass content did not differ significantly between yields coming from different cultivation systems. Nitrates contents in the analyzed roots were low constituting 25.5–55.8 % of the admissible norm. The highest amounts were noted in the roots from integrated cultivation. Significantly lower soluble sugar content was also revealed in the roots from the integrated system in comparison with carrots from the other cultivation systems. No differences in ascorbic acid or carotenoid content were shown in carrot roots coming from farms using different cultivation methods.

Keywords: carrots, organic cultivation, integrated cultivation, conventional cultivation, yielding, root quality

Availability of food products on European markets, increasing prosperity of societies and intensification of various civilisation diseases induce consumers to pay attention to the quality of products for consumption. Nutritional value and safety of food products greatly depend on raw material quality. Factors conditioning plant raw product quality and the nutritional value of food manufactured from them include soil and climate, the state of the natural environment and manufacturing technology.

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Products manufactured on organic farms are greatly popular. They are regarded as a source of increased content of vitamins, carotenoids and folic acid [1]. It is commonly known that they also contain considerable amounts of polyphenols which as secondary metabolites are produced in considerable quantities and protect plants against harmful pathogens [2]. Plant products coming from organic production are treated as the richest source of antioxidants [3]. Apart from fresh products such as fruit and vegetables, consumers reach for processed products of organic origin more and more frequently.

Organic products constitute an increasingly bigger portion of agricultural production in most countries. Also in Poland they are winning more and more symphatizers which can be noticed in the growing number of certified organic farms. The objective of organic farming is manufacturing food that promotes good health and well-balanced development of the plant and animal and world as well as of the human being [4].

Comparative research conducted on organic and conventional methods of cultivation in recent years did not provide any synonymous confirmation of a higher quality of products from organic plantations [5]. The differences between the obtained results are ascribed to different factors of the conducted experiments, such as: variety of cultivars, climatic and soil conditions, as well as the date and stage of plant harvest. Conducted analyses of vitamin C content being an important indicator of plant product quality revealed that its concentration was higher or comparable in organic products than in conventional ones [6].

The rule of well-balanced production, being currently promoted in agriculture makes farmers introduce the rules of integrated cultivation. Vegetable exports, wholesale and retail sales or sales for the needs of processing industries will be impossible without the appropriate certificate. Comparison of many vegetable plants conducted by Faller et al [2] showed 10–35 % decrease in yields and increase in dry mass content in case of vegetables from organic cultivation in relation to those from integrated production. No differences in vitamin C content, nitrates or in a majority of macro- and microelements were revealed. However, the results of conducted experiments are not synonymous with these obtained by Woese et al [7] or Leclerc et al. [8]. There is still need for reliable information concerning the real quality of products originating from organic and integrated production as compared with those produced using traditional methods.

Material and methods

The analyses, conducted in three subsequent years 2006, 2007 and 2008, covered ‘Flakke 2’ cv. carrots cultivated according to rules of organic, integrated and conventional production. Organic cultivation was maintained on a certified organic farm which fulfilled the requirements of EC Regulation 2092/91 [9]. The farm is located in the Wisniowa rural district in the Podkarpackie province. It possesses acid brown soils with 2.39 % humus content as well as silt and clay parts constituting 71.74 % of the granulometric composition. The integrated and conventional cultivations were conducted on neighbouring farms with similar soil conditions. Distribution of experimental plantations at small distances from one another allowed to eliminate differences in climatic conditions.

In each method of cultivation the plants were sown in the third year after farmyard manure. The forecrops were root crops followed by cereals. Mineral fertilizers as supplementary treatment were applied in spring in conventional and integrated cultivations, whereas in organic cultivation slurry and certified fertilizers were used.

Minerals were maintained on the following levels: 50–70 mg N · dm^{-3}, 40–60 mg P · dm^{-3}, 120–170 mg K · dm^{-3}, 60–70 mg Mg · dm^{-3}, 1500–2000 mg Ca · dm^{-3}.

Carrots cultivation, irrespective of the method was conducted on low ridge beds using a single row sowing. Thinning was done every 2–3 cm at the phase of 2–4 true leaves.

In organic cultivation weeds were controled mechanically. Diseases and insect pests prevention was carried out on the strength of natural substances admitted to be used in organic agriculture.

In the integrated method weeds were removed chemically and mechanically. The first spraying after sowing was made on dicotyledonous weeds, the second on unicotyledonous ones. The other weed control measures were done mechanically. Diseases and pests were fighted against when necessary.

The conventional method used exclusively chemical protection.

Immediately after harvest root mass, their length and diameter were determined and the following analyses were performed: content of dry mass was assessed using dryer method at 65 ^{o}C, soluble sugars using anthrone method [10], nitrate by means of ion selective electrode [11], carotenoids in acetone extracts (80 %) using Lichtenthaler--Wellburn formulas [12] and ascorbic acid content by means of iodine method [13].

The obtained results were evaluated using Statistica programme by means of variation analysis according to LSD test at significance level $p = 0.05$.

Results and discussion

The course of meteorological conditions in the subsequent vegetation seasons was diversified. Year 2006 was characterized by mean air temperature accounting for 8.7 ^{o}C. The average temperature in May was 13.5 ^{o}C, in July 17 ^{o}C and in August 21.3 ^{o}C. In the same years rainfall in May was 106 mm, in June 91 mm, in July 16 mm and in August 104 mm.

The year 2007 was characterized by a uniform temperature and rainfall distribution during the vegetation season. Average temperatures from May to September were respectively: 15.6 ^{o}C, 18.9 ^{o}C, 20.0 ^{o}C, 19.1 ^{o}C and 12.5 ^{o}C, whereas the rainfall amounted: 40 mm, 71 mm, 74 mm, 88 mm and 142 mm.

In 2008 the air temperatures were lower than in the previous season, respectively from May to September: 13.6 ^{o}C, 18.0 ^{o}C, 18.7 ^{o}C, 18.9 ^{o}C and 13 ^{o}C. The rainfall in May was 105 mm, in June 87 mm, in July 118 mm and in August 55 mm. The years 2006 and 2008 were similar concerning the course of meteorological conditions.

The results referring to yield quantity and carrot root parameters depending on the method of cultivation were presented in Table 1.

Significantly bigger total yield of carrot roots produced using organic method was revealed in comparison with the yields obtained by means of conventional and

Table 1

Carrot yielding and root parameters depending on cultivation method

Method	Total yield [kg · 10^{-2} · ha^{-1}]				Root mass [g]				Root length [cm]				Root diameter [cm]			
	2006	2007	2008	Average for method	2006	2007	2008	Average for method	2006	2007	2008	Average for method	2006	2007	2008	Average for method
Conventional	32.9 a*	25.45 a	26.98 a	**28.04 a**	109.29 n.s.**	138.85 a	90.05 a	**113.05 a**	15.06 n.s.	17.19 ab	14.18 n.s.	**15.51 a**	4.04 n.s.	4.41 n.s.	3.8 n.s.	**4.11 n.s.**
Integrated	32.82 a	29.69 ab	22.24 a	**28.25 a**	122.73 n.s.	305.66 b	111.29 a	**179.89 b**	13.92 n.s.	16.20 a	14.74 n.s.	**14.95 a**	3.88 n.s.	4.31 n.s.	4.10 n.s.	**4.10 n.s.**
Organic	45.78 b	35.64 b	38.32 b	**39.91 b**	140.31 n.s.	250.47 b	168.27 b	**186.35 b**	16.34 n.s.	18.25 b	16.84 n.s.	**17.14 b**	4.07 n.s.	4.23 n.s.	4.26 n.s.	**4.19 n.s.**
Average for years	**37.55 b**	**30.26 a**	**29.18 a**		**125.45 a**	**231.66 b**	**123.20 a**		**15.11 a**	**17.21 b**	**15.25 a**		**3.99 a**	**4.32 b**	**4.08 a**	

* Values marked with the same letters do not differ significantly as for the interaction and mean values for each feature; ** n.s. – difference statistically not significant.

integrated methods. Only in the second year of cultivation there were no differences between the organic and integrated methods.

In 2006 and 2008 carrot root length did not reveal any important differences conditioned by the method of cultivation. The longest roots were obtained in the second year of the experiments. Significantly shorter roots in comparison with organic carrots were produced using the integrated method in 2007. On the basis of three-year results it was demonstrated that carrots from organic cultivation produced the longest roots. No effect of cultivation method on carrot root diameter was revealed.

The causes of diversified yield quantity or carrot root parameters may be attributed to the influence of climatic conditions in the subsequent years. Intensive rainfalls at the initial period of cultivation in 2006 and 2008 contributed to a considerable soil compaction, whereas a lack of mechanical measures in the integrated and conventional method during the vegetation season prevented an improvement of the root growth conditions. Rainfall deficiencies occurring in summer (July 2006) and strong insolation might have caused slowing down of the growth rate. As was demonstrated by Krzesinski and Knaflewski [14] carrot root diameter is associated with average root mass and their length which is determined by the environmental conditions. Carrot roots are shorter if the air and soil temperatures are higher.

The quality of carrot roots was determined among others on the basis of dry matter and nitrates content assessments (Table 2). The method of cultivation did not affect root dry mass content in the first and third year of the analyses. In the second year the smallest content was determined in carrot roots cultivated using organic method. Roots coming from integrated cultivation did not differ with respect to dry matter content from the roots cultivated using conventional method. Comparison of results obtained in the subsequent years of cultivation showed the lowest content of dry matter in the third year of the experiments, irrespective of the cultivation method, which may be the result of moisture availability during the whole vegetation season. Multiannual averages did not reveal any significant differences in dry matter content in carrot roots cultivated using different methods.

Table 2

Contents of dry mass and nitrates in carrots depending on cultivation method

Method	Dry mass [% f.m.]				$N\text{-}NO_3$ [mg · dm^{-3} juice]			
	2006	2007	2008	Average for method	2006	2007	2008	Average for method
Conventional	12.65* n.s.**	13.52 b	11.39 n.s.	12.51 n.s.	158.66 n.s.	155.75 n.s.	144.00 n.s.	152.27 a
Integrated	13.23 n.s.	13.17 b	10.79 n.s.	12.39 n.s.	188.25 n.s.	279.25 n.s.	195.00 n.s.	220.83 b
Organic	12.88 n.s.	11.80 a	11.35 n.s.	12.01 n.s.	127.50 n.s.	188.50 n.s.	60.75 n.s.	125.58 a
Average for year	12.94 b	12.83 b	11.18 a		158.09 n.s.	207.83 n.s.	133.25 n.s.	

* Values marked with the same letters do not differ significantly as for the interaction and mean values for each feature; ** n.s. – difference statistically not significant.

The obtained results are different from the ones reported by Fjelkner-Modig et al [15] who demonstrated higher content of dry mass in organic vegetables in comparison with those from integrated production. Also Rossi et al [16] wrote about increased dry matter in tomatoes from organic cultivation in comparison with conventional one. Nitrate content in carrot roots remained on a low level, constituting between 25.5 and 55.8 % of the norm [11].

Significantly higher nitrate content was registered in the roots from integrated cultivation. The lowest contents were noted in carrot roots grown using organic method but the differences in comparison with the roots from the conventional cultivation are insignificant. The obtained results are not in accordance with the research of Woese et al [7] who demonstrated lower nitrate levels in organic products in comparison with conventional ones.

The contents of the other analyzed chemical components in carrot roots were presented in Table 3.

Soluble sugars content differed depending on the applied method and the year of cultivation. The lowest soluble sugar content was determined in carrot roots cultivated using integrated method, while the highest one in carrot roots from conventional cultivation. Sugar content in organic carrot was comparable with its content in carrots produced by means of traditional method. The year 2008 turned out to be the least favourable for sugar synthesis in carrot roots. On average the greatest quantity of sugar was detected in carrots from 2007. The cause of the obtained results may be sought in the course of thermal and moisture conditions in the analyzed years. Wet and cool summer in 2008 contributed to a limited sugar synthesis in carrot roots.

No differences in ascorbic acid content were noted in carrot yields obtained using different methods. Carrots harvested in 2007 contained apparently higher quantities of this compound. Higher temperatures in June, July and August of the analyzed year in comparison with the analogous months of the other years of the experiment might have been the cause of the changes. Wunderlich et al [17] revealed slightly higher but statistically insignificant content of vitamin C in spring broccoli from organic cultivation as compared with broccoli from the conventional one. Worthington [18], who compared vitamin C contents in various organic vegetables, found its increase between 17 and 52 % in lettuce, spinach, tomato and cabbage in comparison with conventionally grown vegetables, whereas in carrots this vitamin content was by 6 % lower. On the other hand, Rossi et al [16] demonstrated lower content of vitamin C in tomatoes from organic farming as compared with the fruit grown using conventional and integrated method. Also Magkos et al [6] published divergent data in this scope. Mozafar [19] reported that ascorbic acid level was conditioned by nitrogen fertilization and pesticide residue, however various plants responded differently to these factors.

Carotenoid content in carrot roots grown using different methods did not differ significantly. While comparing the composition of tomatoes cultivated using organic, integrated and conventional method, Rossi et al [16] did not notice any differences in β-carotene content in fruit from various cultivations. Leclerc et al [8] reported that β-carotene content in carrots depended on nitrogen dose, irrespectively of the applied

Table 3

Contents of selected components in carrot roots depending on cultivation method

Method	Soluble sugars [% f.m.]				Ascorbic acid [mg %]				Carotenoids [μg · g^{-1} f.m.]			
	2006	2007	2008	Average for method	2006	2007	2008	Average for method	2006	2007	2008	Average for method
Conventional	5.80 b*	6.46 b	5.13 ab	5.80 b	6.60 n.s.**	9.00 n.s.	6.27 n.s.	7.35 n.s.	42.79 b	46.32 n.s.	43.65 b	44.3 n.s.
Integrated	5.37 a	5.84 a	4.53 a	5.25 a	6.62 n.s.	9.82 n.s.	5.86 n.s.	7.43 n.s.	36.45 a	57.45 n.s.	38.12 a	44.00 n.s.
Organic	5.73 b	5.55 a	6.04 b	5.77 ab	6.46 n.s.	7.92 n.s.	6.43 n.s.	6.93 n.s.	42.36 b	49.02 n.s.	39.5 a	43.6 n.s.
Average for year	5.62 ab	5.95 b	5.23 a		6.56 a	8.91 b	6.18 a		40.33 a	50.93 b	40.42 a	

* Values marked with the same letters do not differ significantly as for the interaction and mean values for each feature; ** n.s. – difference statistically not significant.

form. Fertilization with big nitrogen doses causes a decline in the level of this compound in plants.

The obtained data show that organic carrot produced the highest root yield which did not differ from carrots grown using conventional method as for the content of sugars or nitrate accumulation level. Carrots produced using integrated method were of the worse quality, since with the yield similar to conventional carrots, they had the least content of soluble sugars in comparison with carrots produced using the other methods.

Conclusions

1. Carrots from conventional cultivation showed significantly lower yield of marketable roots and smaller mass and length of roots. Dry matter content in roots was the highest in comparison with its content in roots from the other cultivations, but differences were not significant. The roots from this cultivation had significantly more sugars as compared with the roots from integrated cultivation.

2. Carrots grown according to the rules of integrated production yielded on the level of plants cultivated using conventional method. They had noticeably greater mass of marketable roots in relation to carrots grown in a traditional way, however no differences in the length of roots coming from both compared cultivations were found. Carrots from integrated production had the highest nitrate content, whereas their sugar content was the lowest as compared with carrots grown using the other methods.

3. Organic method allowed to obtain the highest marketable yield, mass and the length of carrot roots. Nitrates content was the lowest but did not differ significantly from the content in the roots from conventional cultivation. These carrots were characterized by a similar sugar level as carrots cultivated in a conventional way.

4. No significant differences were stated concerning carrot root diameter, dry matter content, ascorbic acid or carotenoids in carrot roots cultivated using various methods.

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Abstrakt: Doświadczenie prowadzono w latach 2006–2008 z zachowaniem zasad produkcji konwencjonalnej, integrowanej i ekologicznej. Uprawa ekologiczna prowadzona była w gospodarstwie certyfikowanym. Badaniami objęto marchew odmiany 'Flakkee 2'. Na podstawie średnich wyników z trzech lat doświadczeń oceniono wpływ metody uprawy na ilość plonów oraz ich parametry jakościowe, takie jak: średnia masa korzeni handlowych, ich długość i średnica oraz zawartość suchej masy, azotanów, cukrów rozpuszczalnych, kwasu askorbinowego oraz karotenoidów.

Plon ogólny, masa i długość korzeni były największe w uprawie ekologicznej. Zawartość suchej masy marchwi nie różniła się istotnie w korzeniach marchwi pochodzącej z różnych systemów uprawy. Zawartość azotanów w badanych korzeniach była mała i stanowiła 25,5–55,8 % dopuszczalnej normy. Najwięcej azotanów wykryto w korzeniach pochodzących z uprawy integrowanej. Statystycznie istotnie niższy, w stosunku do marchwi z pozostałych upraw, poziom cukrów rozpuszczalnych wykazano w korzeniach marchwi pochodzącej również z tego systemu uprawy. Nie wykazano różnic w zawartości kwasu askorbinowego oraz karotenoidów w korzeniach marchwi pochodzącej z różnych systemów uprawy.

Słowa kluczowe: marchew, uprawa ekologiczna, uprawa integrowana, uprawa konwencjonalna, plonowanie, jakość korzeni