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Analysis of fresh and processed carrots and beets from organic and conventional production for the content of nutrients and antioxidant activity

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ABSTRACT

In order to popularise organically produced vegetables, two vegetable crops most commonly grown in organic systems in Serbia were studied. This research aimed at investigating differences in phytonutrient content between organically and conventionally produced beet and carrot, in fresh roots, juices pasteurised at different temperatures (70 and 90°C) and dried products. Multivariate analysis (principal component analysis) was used in order to determine the main components accounting for the highest variance, from both systems of production, according to the average content of phytonutrients in beet and carrot. The samples were divided into two clusters, one for carrot and one for beet, each containing two subgroups. The subclusters for beet were: I – BDO, BDC, BJ90C, and BJ900 – dried samples and juices pasteurised at 90°C, from both systems of production; and II – BFC, BFO, BJ700 and BJ70C – fresh beet and pasteurisation at low temperatures. The two sub-clusters for carrot were: I – CDO and CDC – dried samples; and II – pasteurised juices and fresh carrots from both systems of production. In this research, carrot was more stable for processing than beet, as determined for samples from the study area, from both systems of production and for the phytonutrients covered by this research.

Keywords: beet, carrot, organic, conventional, juices, dried products.

ИЗВОД

Да би се извршила популаризација органски произведеног поврћа, испитане су две повртарске врсте које се најчешће гаје у органском систему у Србији. Ово истраживање има за циљ да се испитају разлике у садржају фитонутријената код цвекле и мркве пореклом из органске и конвенционалне производње, код свежих коренова, код сокова пастеризованих на различитим температурама (70 и 90°C) и сушеног производа. Коришћена је мултиваријациона анализа (анализа главних компоненти) како би се одредиле главне компоненте носиоца највеће варијабилности, пореклом из обе производње на основу просечног садржаја фитонутријената код цвекле и мркве. Испитивани узорци налазе се у два кластера, кластер за мркву и кластер за цвеклу, с тим што се у оквиру сваке појединачне групе могу дефинисати по две подгрупе. Подгрупе за цвеклу: I - сушени узорци и сокови на 90°C из оба начина производње; и II - свежа цвекла и пастеризација на нижим температурама. Подгрупе за мркву: I - сушени узорци; и II - остали третмани заједно са свежом мрквом из оба начина производње. У овим испитивањима за мркву се генерално може рећи да је стабилнија за прераду од цвекле, а на основу узорака који су са испитиваног подручја, из два начина производње и за фитонутријенте обухваћене овим испитивањем.

Кључне речи: цвекла, мрква, органска, конвенционална, сокови, сушени производ.

1. Introduction

The reasons for consumers' interest in organically produced food are the safety of the production process for people and the environment (air, soil, water) and high quality standards of the food (both fresh and processed) (Bavec et al., 2010, Domagala-Swiatkiewicz and Maciej, 2012, Kazimierczak et al., 2014). Differences between organically and conventionally produced food have been the subject of a great number of studies in the last twenty years. Beetroot and carrot were among the first organically grown vegetable crops. Beet and carrot are grown easily and do not need

a lot of pesticides in their cultivation. They are used in the human diet throughout the year, both fresh – as a salad – and processed (juices, pasteurised and dried).

Beet is a functional food since it has bioactive compounds that benefit human health (Georgiev et al., 2010). Some studies proved that beet has a positive effect on the clinical picture of diseases such as hypertension, atherosclerosis, diabetes and dementia (Ninfali et al., 2013). Among strong antioxidants, vitamin C neutralises free radicals in the human organism. However, it is thermally labile and is easily lost during thermal processing (Njoku et al., 2011). Besides vitamin C, the total antioxidant activity of

vegetables largely depends on phenol content (Oboh and Rocha, 2008), and beet processing impacts the phenol level in the final product (Ravichandran et al., 2012). The need for organically grown and processed food is higher than demand since the production is economically demanding and yield is lower, which increases the cost of the product. However, numerous studies proved that organically manufactured food products contain more bioactive components (vitamins and phenols) (Bourn and Prescott, 2002; Bavec et al., 2010; Kazimierczak et al., 2014a). Madrau et al. (2009) reported that the average levels of a high number of nutrients decrease with increasing temperature during thermal processing. One of the oldest ways of food preservation is drying (Roberts et al., 2008).

Vegetable and fruit juices are becoming more and more popular. Thermal processing is the most commonly used way of processing (pasteurisation), which inactivates enzymes and microorganisms that spoil food and thus prolongs the expiry date of juice (Kathiravan et al., 2015). There are different ways of food processing with different effects on the levels of phytochemical compounds in products (Guldiken et al., 2016). The general opinion is that the nutritive quality of food is lost after its thermal processing. However, some thermal processes increased some components of food quality (Ravichandran et al., 2012). It is considered that the key factors for that phenomenon are time and temperature (Guldiken et al., 2016).

Some studies imply that carrot crops grown in organic systems are richer in polyphenols, flavonoids, phenols and total antioxidants (Castro et al., 2014; Oliveira Pereira et al., 2016). Hallmann et al. (2011) found that juice from organic carrot contains more vitamin C, caffeic acid and lutein than conventionally grown carrot. It was also proved that carrot juice is a natural antioxidant, given its high antioxidant activity of polyphenols even after processing (Tingtin et al., 2013). Dried carrot slices can be shelved even longer than 6 months without a big change in quality (Sra et al., 2011). Dried carrot is used for instant soups, for preparing food without oil and as a healthy snack (Lin et al., 1998).

Certified organic farming accounts for 0.44% of the total agricultural area in Serbia (<https://www.makroekonomija>). In order to popularise organic vegetables, two vegetable crops most commonly used in organic systems in Serbia were examined.

This research aimed at finding differences in phytonutrient content between organically and conventionally produced beet and carrot, in fresh roots, juices pasteurised at different temperatures and in dried products. These two vegetables have an important place in crop production. Differences between fresh and dried products and juices from organic and conventional systems of production should be further investigated.

2. Material and method

Beet (cv. 'Bikor') and carrot (cv. 'Nantes SP-80') were obtained from six different organic producers from certified organic farms located in different parts of Serbia: Suvobor, Taraš, Gložanj, Padina, Kikinda and Kisač.

Also, conventionally grown beet and carrot were provided on the same farms. Samples were collected in

October (winter production). The experiment was carried out in 2017 in the Chemical Laboratory of the Faculty of Agronomy in Čačak, Serbia.

Fresh beet and carrot roots, juice thermally processed at 70 and 90°C and dried samples were analysed.

Beet and carrot roots were first washed and macerated in a rotation blender (a centrifugal juicer), and the obtained juice was pasteurised in a water bath at 70°C and 90°C for 15 minutes.

Slices of organic carrot were first blanched at 100°C for 2 minutes in order to inactivate enzymes that impact the quality. Dried samples of organic beet were first blanched at 100°C for 5 minutes, then peeled and cut into thin slices. Prepared samples were dried in a home dehydrator at 50°C–55°C.

Total antioxidant activity (TAA) was determined spectrophotometrically at 517 nm DPPH (1.1-diphenyl-2-picrylhydrazyl) by the method described by Xu et al. (2010).

Levels of β -carotene were determined according to the method of Nagata and Yamashita (1992). The dried ethanol extract (100 mg) was vigorously shaken with 10 ml of acetone–hexane mixture (4:6) for 1 min and filtered through Whatman Grade No. 4 filter paper. The absorbance of the filtrate was measured at 453, 505, 645 and 663 nm. The content of β -carotene was calculated according to the following equation:

$$\beta\text{-carotene (mg/100 ml)} = 0.216A_{663} - 1.22A_{645} - 0.304A_{505} + 0.452A_{453}$$

Pale carrot and beetroot juice was obtained by pressing 100 cm³ of carrot and beetroot juice and mixed with equal quantity of (100 cm³) solution of a mixture of HPO₃ and glacial acid CH₃COOH. Then, the mixture was filtered through creased filter paper. The first 5–10 cm³ of filtered mixture was thrown away and the aliquot part was taken from the rest of the mixture for further investigation. If necessary, the investigated sample was diluted with cooled boiled distilled water so that the aliquot part contained about 2 mg of ascorbic acid. The process of determining ascorbic acid in the sample: – 10 cm³ of filtered sample (containing 5 cm³ of juice and 5 cm³ HPO₃ and glacial acid CH₃COOH) was pipetted into three Erlenmeyer flasks. Each sample was titrated with Tilmans reagent (TR) solution until pale pink, for about 5 seconds. At the same time, solution of TR was titrated and blind tested until pale pink (Cvijović and Aćamović, 2005).

The content of ascorbic acid (mg/ cm³) = (V - V₁) x T x 100/g

V – cm³ of TR solution used for titration in trial testing

V₁ – cm³ of TR solution used in blind testing

T – titre solution TR (mg C₆H₈O₆ /1 cm³ TR solution)

g – juice volume in cm³ in aliquot part of sample

Total phenols in the carrot and beetroot ethanol extracts (20g carrot and beetroot juice in 100cm³ ethanol) were estimated according to the Folin–Ciocalteu method (Singleton et al. 1999). The extract was diluted to the concentration of 1 mg/mL, and aliquots of 0.5 mL were mixed with 2.5 mL of Folin–Ciocalteu reagent (previously diluted 10-fold with distilled water) and 2 mL of NaHCO₃ (7.5%). Aliquots were left for 15 minutes at 45°C, and then the absorbance was measured at 765 nm with a spectrophotometer against a blank sample. Gallic acid (GA) was used to calculate the standard curve. The assays were carried out in triplicate; the results were

the mean values \pm standard deviations and expressed as mg of gallic acid equivalents per gram of dry extract (mg of GA/g).

Total sugar content was determined by Bertrand's method, used for the determination of all carbohydrates with free hemiacetal groups that reduce Cu^{2+} metal ions to Cu^+ from Bertrand I reagent ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$), according to Cvijović and Aćamović (2005).

The method is based on the precipitation of potassium in the form of potassium tetraphenyl borate, its dissolution in acetone and titration of the resulting solution with AgNO_3 solution with the formation of insoluble Ag-tetraphenylborate in acetone. The potassium content was calculated based on the consumption of 0.1 mol dm^{-3} AgNO_3 . The potassium content was expressed in mg/100g of the sample.

Samples from all farms were analysed using average values in 4 replicates, with 10 roots per replicate, from both organic and conventional production.

Correlation among the traits based on the analysed genotypes was determined according to Pearson's matrix at the $p \leq 0.05$ level of significance. Correlation between genotypes and traits was determined by the multivariate technique PCA (principal component analysis) using the statistical software XLSTAT Version 2012.4.02 (Addinsoft, Paris, France). The analysis was performed based on the average values of the investigated parameters.

3. Results and discussion

The analysis of the average values of bioactive components in fresh beet and carrot, in juices pasteurised at different temperatures and in dried products (chips), from organic and conventional production, based on average values from 6 organic farms and 6 conventional producers, revealed different results.

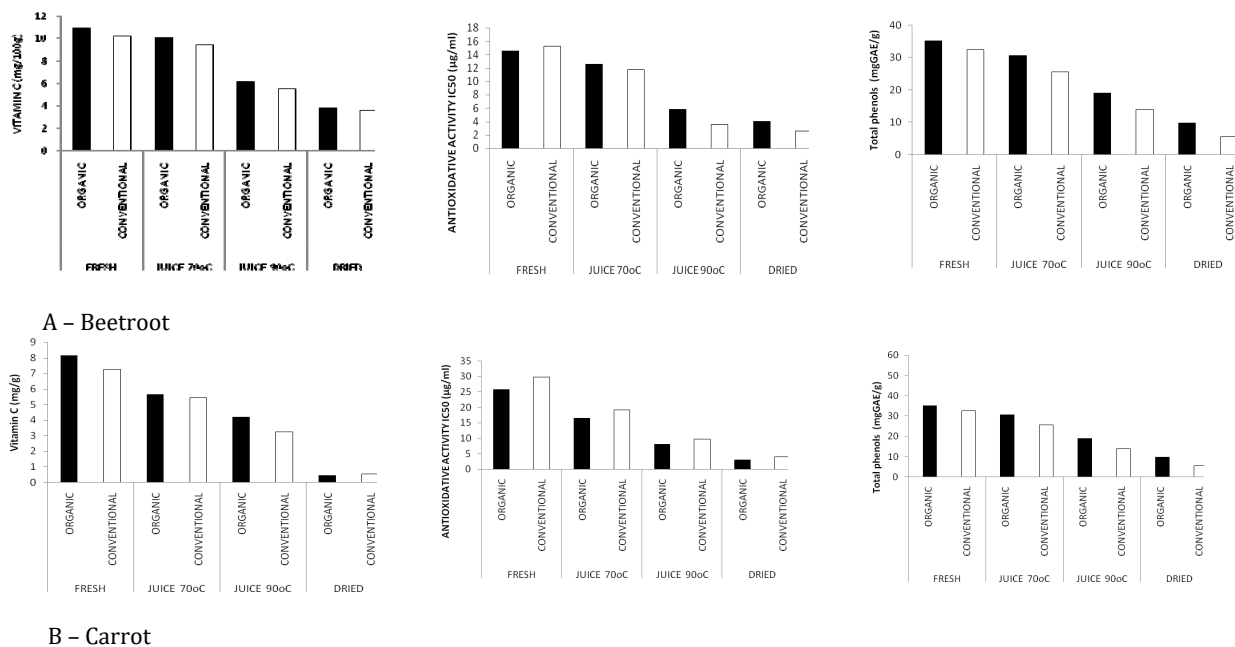


Figure 1. Contents of bioactive components (vitamin C and phenols) and antioxidant activity in fresh beet and carrot and their products, from organic and conventional production, A – beet, B – carrot

The contents of vitamin C, total phenols (Fig. 1 – A) and potassium (Fig. 2, B) were higher in fresh beet and carrot from organic production compared with conventional production. The same was for organic products compared with conventional ones, except for dried carrot, which had higher values in conventional products than in organic ones (Fig. 2, B).

As regards the other bioactive components (β carotene, carbohydrates and total antioxidant activity), higher levels were determined in conventionally produced fresh beet and carrot and their products than in organically produced ones (Figs. 1 and 2).

Differences in the level of carbohydrates in fresh beet were in favour of conventional production

(7.00g/100g) compared with organic production (6.68g/100g) – (Fig. 2, A). In the research conducted by Szopińska and Gawęda (2013), the difference was in favour of fresh beet produced organically (conventional 7.57 g/100g, organic 7.97 g/100g). However, when assessing the level of vitamin C, the same authors obtained significantly higher values in fresh beet from conventional production, as opposed to the results of this research, which showed higher levels under organic system of growing (10.94 mg/100g) than under conventional system (10.21mg/100g), Figure 1. Brandt et al. (2011) found higher levels of vitamin C in organic vegetables compared with conventional crops.

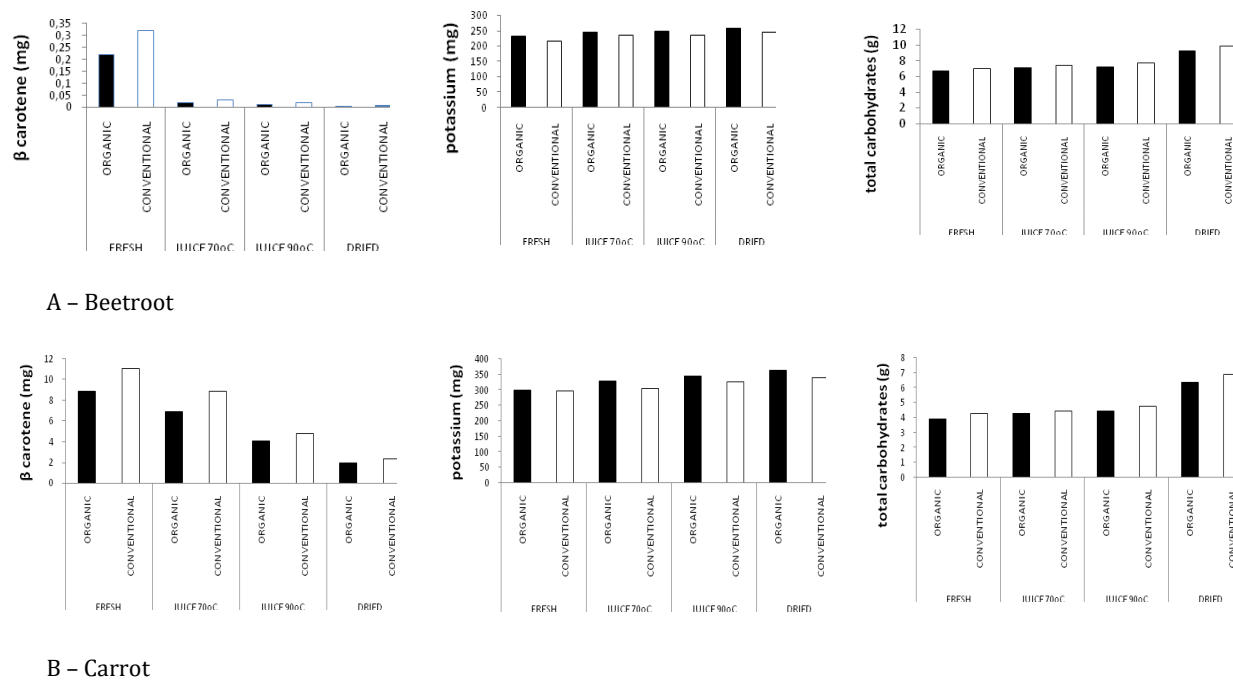


Figure 2. Levels of bioactive components (β carotene, potassium and total carbohydrates) in fresh beet and carrot and their products from organic and conventional production, A – beet, B – carrot

During different processing treatments, the composition of phytonutrients changed. Total phenols content decreased in juice (90°C) and in dried products (by approximately 50% and 70% in organic and conventional production, respectively) (Fig. 1-A), as opposed to Guldiken et al. (2016), who found an increase in total phenols in dried beet (in their research beet was dried to 50% moisture, and in this research it was dried to 15% moisture) and in homemade puree (exposed to high temperatures). Similar results were obtained for total antioxidant activity, i.e. its increase in products obtained by drying, while in our research the antioxidant activity of similar products was decreased (Fig. 1-A).

There was no fundamental difference between organic and conventional juices (Kazimierzczak et al., 2014a). Facts about vegetable products (mostly juices) from organic production have been confirmed in other studies, which can be due to the insufficient use of organic products (Hallmann et al., 2010) and their price. In our research, changes in the contents of bioactive components in processed products were in correlation with their contents in fresh carrot and beet (Figs. 1 and 2).

Our research showed that organic carrot had higher levels of total phenols, vitamin C and potassium, both in fresh and processed products (Figs. 1B and 2

B). Similar results were obtained by Hallmann et al. (2011), who found a higher level of vitamin C in organic carrot. Tingtin et al. (2013) reported that the antioxidant activity of polyphenols remained in carrot juices after processing. Different results were found during the pasteurisation of juices and preservation of total polyphenols and carotene by Mendelová et al. (2016), who found a decrease in total carotenoids and polyphenols. Based on their research and comparisons of changes in carotenoids and total polyphenols, the loss of carotenoid level due to the impact of temperature was significantly higher than the loss of polyphenols. Our results were in accordance with this research regarding total phenols and β -carotene in juices pasteurised at 70 and 90°C. At a pasteurisation temperature of 90°C, losses were higher than at 70°C (Figs. 1B and 2B).

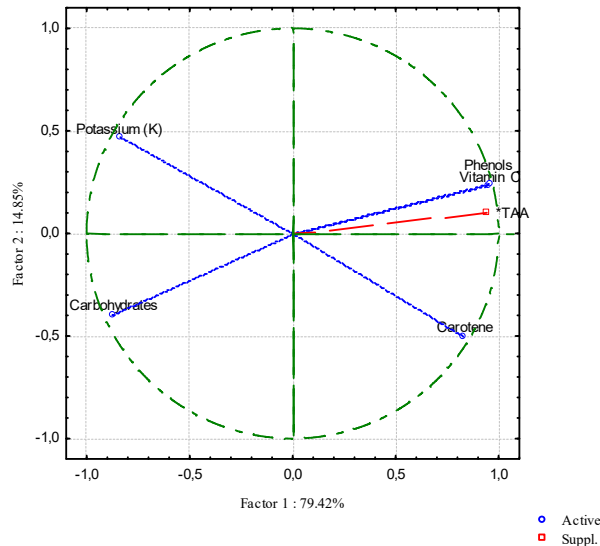
Based on the principal component analysis (PCA), the components PC1 and PC2 determined 95.25% of the total variance in fresh roots and products of beet and carrot grown in organic and conventional systems (Table 1.) A high proportion (78.8%) of the variance explained by the first two basic variables was determined by Paciulli et al. (2016) in their research on the quality of juice obtained by different processing technologies.

Table 1.
Eigen value

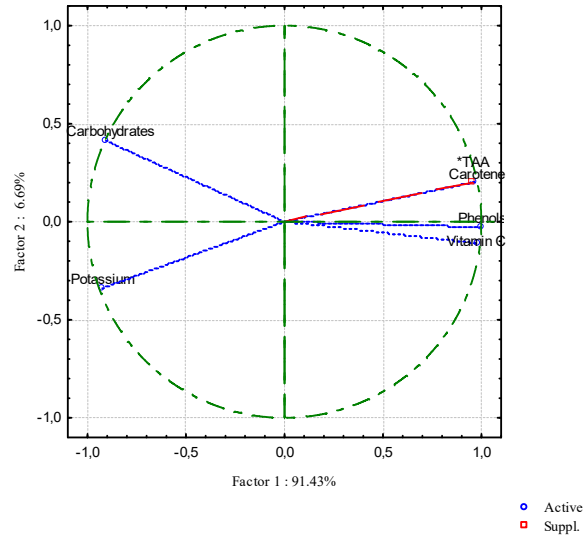
Value number	Eigen value	% total	Cumulative Eigen value	Cumulative %
1	3.034	60.680	3.034	60.680
2	1.729	34.573	4.763	95.253
3	0.199	3.982	4.968	99.235
4	0.030	0.597	4.992	99.831
5	0.008	0.169	5.000	100.000

The research proved the impact of evaluated factors (levels of potassium, carbohydrates, beta carotene, vitamin C and total phenols) on the total antioxidant activity of fresh roots and products. Total antioxidant activity was mostly affected by the total level of phenols and vitamin C, and less intensively by the content of beta carotene, since its level in beet was

low. This position of the vectors implies high correlativity of TAA and investigated traits. The angle of TAA and potassium, as well as the angle of TAA and total carbohydrates indicated that this correlation was low and that total antioxidant activity did not depend on these two factors (Fig. 3, A).



A – fresh and processed beet



B – fresh and processed carrot

Figure 3. Projection of variables in samples of fresh and processed beet and carrot from organic and conventional production, based on correlation among investigated factors (A– beet, B–carrot)

The projection of the correlation among investigated factors relative to TAA in fresh and processed carrot, regardless of the system of growing, was slightly different than in beet. Antioxidant activity in carrot had the highest impact on the level of beta carotene, with which it was in the strongest correlation. TAA was highly correlated with total phenols and the level of vitamin C. A weak or lack of correlation was found between antioxidant activity and the levels of carbohydrates and potassium (Fig. 3, B).

Both graphs and the analysis of both vegetable crops indicated that the main antioxidant activity was exhibited by beta carotene, vitamin C and total phenols.

Eigenvalue showed that the first components were responsible for total variation for both root vegetables and both systems of production. The highest impact on the first component was made by the level of carbohydrates (0.967) and beta carotene (-0.945), while the other component was impacted by vitamin C (-0.988) and potassium (0.723), in both cases with different signs in front of the number (Table 2).

Table 2.

Factor coordinates of the variables, based on correlations

Investigated traits	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Carbohydrates	0.967	0.085	0.212	0.110	-0.023
Vitamin C	0.036	-0.988	-0.127	0.075	0.038
β -carotene	-0.945	-0.014	0.324	0.016	0.038
Potassium (K)	-0.658	0.723	-0.182	0.107	0.009
Total phenols	-0.878	-0.472	0.016	0.026	-0.071
Total antioxidant activity*	-0.733	-0.606	0.222	0.146	0.044

The strongest impact on factor 1, regardless of the system of production and processing technique, was exhibited by BDC (2.548) and BDO (2.118), i.e. dried beet from conventional and organic production, which had positive values, as well as by CFC (-2.695) and CFO (-2.407), i.e. fresh carrot from conventional and organic production. Factor 2 had the highest impact on variability in CDO (dried carrot from organic production) – 2.521 and CDC (dried carrot from conventional production) – 2.233 (Tab. 3). The other factors were not considered since they explained 5% of

total variation. The negative value of antioxidant activity indicated that handling and processing of carrot and beet caused a decrease in this activity. Since it is a dependent variable (a supplement factor), it was highly impacted by the active factors (for example, thermally unstable vitamin C) and it is understandable that it had the strongest impact on this factor in a negative manner, i.e. it caused its decrease. Here, the system of production was not a significant factor.

Table 3.
Factor coordinates of the observed treatments, based on correlations

Treatments	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
BFO (beetroot, fresh, organic)	0.779	-1.844	-0.444	0.101	-0.069
BFC (beetroot, fresh, conventional)	1.069	-1.792	-0.1473	-0.113	-0.101
BJ700 (beetroot, juice 70°C, organic)	0.961	-1.364	-0.420	0.257	-0.020
BJ70C (beetroot, juice 70°C, convl.)	1.270	-1.206	-0.227	0.087	0.097
BJ900 (beetroot, juice 90°C, organic)	1.306	-0.139	-0.115	-0.263	0.0428
BJ90C (beetroot, juice 90°C, convl.)	1.718	-0.018	0.170	-0.372	0.115
BDO (beetroot, dried, organic)	2.118	0.780	0.5107	0.137	-0.061
BDC (beetroot, dried, conventional)	2.548	0.801	0.800	0.112	0.005
CFO (carrot, fresh, organic)	-2.407	-0.963	0.171	0.036	0.129
CFC (carrot, fresh, conventional)	-2.695	-0.825	0.774	0.080	0.080
CJ700 (carrot, juice 70°C, organic)	-2.059	0.111	-0.155	0.089	-0.075
CJ70C (carrot, juice 70°C, convl.)	-2.216	-0.163	0.480	-0.087	-0.108
CJ900 (carrot, juice 90°C, organic)	-1.312	0.959	-0.682	-0.040	0.104
CJ90C (carrot, juice 90°C, convl.)	-1.280	0.910	-0.226	-0.247	-0.157
CDO (carrot, dried, organic)	-0.008	2.521	-0.441	0.143	0.068
CDC (carrot, dried, conventional)	0.214	2.233	-0.050	0.080	-0.051

Figure 4. shows grouping of both systems of production including all parameters evaluated in this research. The best quality parameters were found in fresh beet, from both organic and conventional production, and were located in the fourth quadrant and distant from the origin of the coordinate system. The furthest treatments for carrot were in the third quadrant for both systems of production. The worst, i.e.

the products with the highest loss of bioactive components were dried products, and they were located in the first quadrant, both for beet and carrot. Products in the zone of the coordinate lines (apices were closer to the centre of the coordinate system) had average values of the investigated parameters compared with fresh and dried roots.

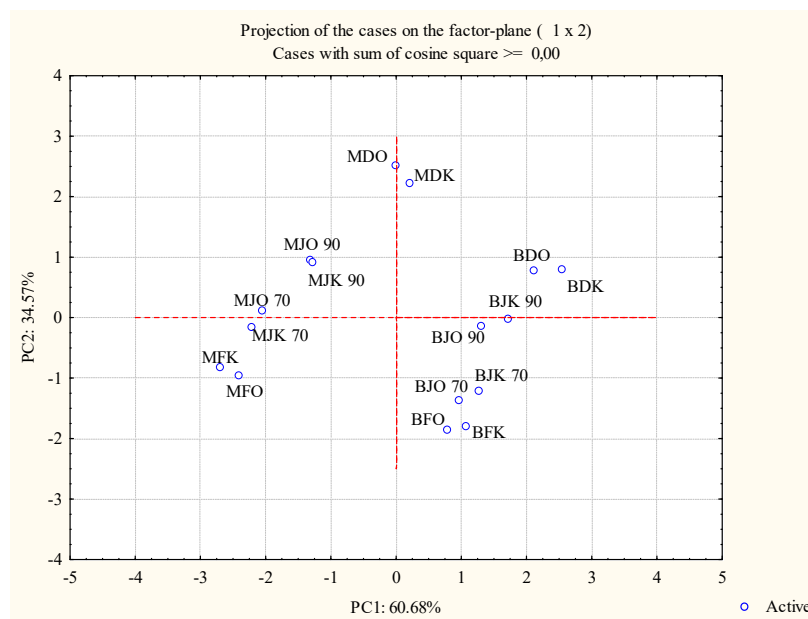


Figure 4. PCA biplot of the first and second principle components

Figure 4 shows the order of treatments for carrot and beet. The samples occurred in two clusters, one for carrot and the other for beet. Each cluster contained two subclusters. The subclusters in the beet cluster were: I – BDO, BDC, BJ90C, BJ900 – dried samples and juices produced at 90°C from both systems of production; and II – BFC, BFO, BJ700 and BJ70C – fresh beet and beet pasteurised at low temperatures. In the carrot cluster, the two subclusters were: I – CDO and CDC i.e. dried samples; and II – pasteurised juices and fresh carrot from both systems of production. In this research, carrot was generally more stable than beet, as determined for samples from the study area, from both systems of production, and for the phytonutrients covered by this research.

4. Conclusion

Carrot and beet, commonly grown in organic vegetable production in Serbia, were analysed in this study. Differences in the contents of phytonutrients (vitamin C, total phenols, total antioxidant activity, β -carotene, potassium and total carbohydrates) between crop samples from organic and conventional growing systems, as well as the effect of processing were determined. Generally, this study indicated higher stability of the phytonutrients in carrot, compared with beet, after thermal treatment at different temperatures.

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