

# Chemical Composition of Selected Beetroot Juices in Relation to Beetroot Production System and Processing Technology

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## Abstract

Market offer of vegetable juices in Europe is growing, and the vegetable species and processing technologies used become more diversified resulting in a large range of juice types. At the same time consumers look for natural and safe products with pro-health properties. The aim of this study was to evaluate the nutritional composition of selected juices based on beetroots coming from different agricultural systems and processed according to different technologies. Research material consisted of conventional and organic juices marketed in Poland, in that pure pressed juices, fermented juice and juices from concentrate, pure and combined with apple or lemon juice. The concentration of vitamin C, organic acids, total and reducing sugars, phenolic acids, flavonoids and betalains has been determined in the juices. All beetroot juices were abundant in betalains, with higher concentrations of these compounds found in pure beetroot juices when compared to juices combined with apple or lemon. Highest concentration of betanin-3-*O*-glucoside was found in pure conventional juice from concentrate, while highest betanidin content was found in pure organic fermented juice. Highest vitamin C contents were found in pressed organic juices combined with apple and lemon. All juices were abundant in polyphenols, mainly phenolic acids, with highest concentrations of these antioxidants found in conventional pure pressed juice. The study shows that beetroot juices, independently on the beetroot processing technology and agricultural production system, are very valuable products due to the presence of numerous bioactive compounds, especially betalains, in their composition. Therefore beetroot juice consumption should be promoted among consumers.

**Keywords:** beetroot juice, betalains, betanidin, betanin, organic production, phenolic compounds

## Introduction

Vegetables and fruit have an important role in the human diet, and increasing of their consumption is recommended by WHO/FAO and by nutritional experts around the world (WHO, 2003). Sufficient daily consumption of these products could help prevent major diseases, such as cardiovascular diseases and certain cancers (Key, 2011; Wang *et al.*, 2014). A very important group of products in this context are the processed fruit and vegetables, and vegetable juices among them. The market offer and the availability of these products are getting wider (AIJN Liquid Fruit Market Report, 2015). These allow both to expand the consumption of vegetables, and at the same time to enlarge the intake of their bioactive components during the year. Therefore, nutritionists recommend increasing consumption of

vegetable juices instead of replacing natural products with synthetic vitamin-mineral supplements (Liu, 2013). Drinking vegetable juice is one of the ways to increase a dose of essential microelements, vitamins and other antioxidants as well as fiber delivered to the organism (Groele, 2010). Vegetable juices are more easily assimilated in an organism than fresh vegetables, as the squeezing process destroys the fiber structure and releases bound phytonutrients (Rakin *et al.*, 2004). Market offer of vegetable juices in Poland is growing, and the vegetable species, as well as the processing technologies used, become more diversified, resulting in a large range of juice types (Wołosiak and Miłosz, 2012).

Beetroot is one of the valuable vegetables in terms of nutritional value and is increasingly used for juice production. Poland is the largest EU producer of beetroots, with the share of beetroots in the general vegetable harvests reaching nearly 67% (Eurostat, 2016). In recent years, with the increase in

consumer income, the average yearly consumption of fresh beetroots in Poland decreased from 4.5 kg to 2.5 kg per capita, partly in favour of more expensive, imported fruit and vegetables, but also in favour of processed and semi-processed vegetable products. This is most evident in big cities where processed and semi-processed foods, allowing for quick and easy preparation of meals, gain in popularity and where their assortment is constantly growing (Strojewska, 2015).

Owing to high concentrations of minerals, vitamins, flavonoids, phenolic acids, organic acids, sugars, essential oils and dietary fiber, but especially betalains, beetroot has an important role in the human diet (Bogacz, 2010; Petek *et al.*, 2012). From a chemical point of view, betalains are ammonium conjugates of betalamic acid with cyclo-DOPA (betacyanins) and aminoacids or amines (betaxanthins). They can be found in seeds and flowers of plants of most families of the *Caryophyllales* as well as in fruit of *Opuntia ficus-indica* and *Hylocereus polyrhizus* (Strack *et al.*, 2003; Moreno *et al.*, 2008). However, in Europe, the main natural source of betalains (particularly betacyanins) in the human diet is beetroots (Moreno *et al.*, 2008).

Betacyanins rank among water-soluble pigments. Their stability is low, particularly during heating and storage. Therefore, next to the usually used thermal preservation methods, lactic acid fermentation, both spontaneous and with the use of starter bacteria cultures can be an alternative method of preservation of the beetroot juices squished under high pressure. During lactic acid fermentation of beetroot red pigments are partially recovered, due to the decrease in pH to approximately 4.0. The beetroot juice pigments are optimally stable in an acidic environment (Klewicka *et al.*, 2009). Lactic acid fermentation of vegetables is a common practice to improve shelf life of foods, but also to maintain and improve their nutritional and sensory features (Di Cagno *et al.*, 2013). A great number of lactic acid bacteria were isolated from a variety of traditional naturally fermented foods (Anandharaj and Sivasankari, 2013). Availability of certain nutrients such as minerals, vitamins, as well as acidic nature of vegetables, provides a good medium for lactic acid bacteria. With the success and popularity of sauerkraut, fermentation of many other vegetables, such as e.g. cucumbers, cauliflower, turnips, radishes, celery, carrots and beetroots is gaining in popularity in many countries (Swain *et al.*, 2014).

Vegetable as well as fruit juices are commonly clarified during processing in order to avoid undesirable turbidity, haze, and sediments in the final products. However nowadays there is a rising demand for fruit and vegetable juices with the original characteristics of the fresh products (Hongvaleerata *et al.*, 2008). Therefore such a demand leads to a search for new technologies that are able to improve the quality of the juices. At the same time consumers more often search for freshly pressed juices, which are richer in pectin and bioactive substances coming from raw vegetables, than for clarified products. The turbidity of pressed juices is the result of suspended pectin particles stemming from the plant cell walls, and other disrupted cell materials (Pinelo *et al.*, 2010).

In recent years, the quality of food from organic and conventional farming is a frequent subject of research (Rembialkowska, 2007; Brandt *et al.*, 2011; Hunter *et al.*, 2011; Barański *et al.*, 2014). Most of the studies indicate higher quality of raw materials from organic farming

compared to their conventional counterparts. The differences concern mainly higher sensory quality of organic fruits and vegetables, as well as the higher content of polyphenolic compounds and vitamins in organic agricultural crops compared to conventional ones (Asami *et al.*, 2003; Bavec *et al.*, 2010; Hallmann and Rembialkowska, 2012; Średnicka-Tober *et al.*, 2013; Kazimierczak *et al.*, 2014). This is mainly due to different fertilization and crop protection regimes used in organic and conventional production systems. The use of mineral fertilizers, especially nitrogen, in conventional farming stimulates high biomass production by plants. This can lead to disruption of other processes in plants, resulting in poorer chemical composition of the plant materials (Heeb *et al.*, 2006; Bloksma *et al.*, 2007). The organic production system, based on organic fertilization, generally favours the synthesis of higher amounts of antioxidant substances in plants. Therefore it can be assumed that the preserves and juices obtained from organic vegetables are richer in these pro-health components.

The aim of this study was to evaluate the nutritional composition (*i.e.* concentration of nutrients and bioactive substances, especially betalains) of selected beetroot juices available in the retail sales in Poland. The tested samples included conventional and certified organic products, in that pure pressed juices, fermented juice and juices from concentrate, pure and combined with apple or lemon juice.

## Materials and Methods

### Research material

The research was carried out in 2015 in the Warsaw University of Life Sciences (Poland). Research material consisted of six commercial beetroot juices available on the Polish market. Three of them were produced from organic certified beetroots or beetroots combined with apple and lemon, according to organic farming and processing standards (ORG-L – pressed combined with lemon, ORG-A – pressed combined with apple, ORG-B – pressed fermented pure beetroot juice) and three from conventional raw materials (CONV-B – pressed pure beetroot juice, CONV-A – pressed combined with apple and CONV-CB – pure beetroot juice from concentrate). Organic juices were purchased in specialized organic shop, while conventional ones – in the conventional supermarket. All information about the production system, composition and processing of the juices provided by the juice producers are presented in Table 1.

### Chemical analyses

Beetroot juice samples were analysed for dry matter content, vitamin C, organic acids, total and reducing sugars, polyphenols (flavonoids and phenolic acids) and betalains. All the analyses were carried out in the analytical laboratory of the Faculty of Human Nutrition and Consumer Science, Warsaw University of Life Sciences, using validated protocols and methods.

Dry matter content was determined using gravimetric method according to the Polish standard (PN-EN 12145:2001).

Vitamin C (L-ascorbic acid) content was determined using a spectrophotometric method according to the relevant Polish standard (PN-A-04019:1998). The method involves the oxidation of L-ascorbic acid to dehydroascorbic acid in the

acidic environment using 2,6-Dichlorofenolindofenol. This dye is reduced to the colourless form and at pH 4.2 is pink; the reaction proceeds quantitatively. The weighted fresh beetroot juice samples were extracted in 2% oxalic acid. The solution was filtered. The filtrate was collected and then the acetate buffer (pH 4.0) and xylene were added to the sample. Organic layers were separated and upper layer was transferred to spectrometric cuvette. The light absorbance was measured with wavelength of 500 nm. The result was read from the standard curve.

Total acidity was determined according to the relevant Polish standard (PN-EN 12147:2000) based on the neutralization of the total content of acids present in the solution. Water solution of fresh juice sample was titrated with sodium hydroxide until the pH reached 8.0. Total acidity is converted into a corresponding acid, in this case lactic acid. The result was calculated using a formula described in the standard (PN-EN 12147:2000).

Total sugars and reducing sugars content was determined according to the Luff-Schoorl method (Fortuna *et al.*, 2003). A fresh beetroot juice sample (2 ml) was placed in a beaker, next mixed with 100 ml of distilled water. The beaker's content was transferred to a measuring flask. 5 ml of Carrez I and Carrez II liquids were added, mixed and filled with distilled water. The content of the flask was filtered into a conical flask. The filtrate was taken and then 5 ml of concentrated HCl was added. Next step was the acid hydrolysis in a hot (68 °C) water bath. 15 ml of NaOH was added to neutralize the sample. The content of the flask was transferred to a measuring flask and filled with distilled water. The extract was collected from the flask and 25 ml of Luff liquid was added. The sample was heated (in a flask with reflux condenser) until it came to the boil. Then 10 ml of 30% KI, 25 ml of 25% H<sub>2</sub>SO<sub>4</sub>, and a few drops of starch were added to the sample. Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> was titrated until having obtained the white colour of the solution. At the same time, a blank test was performed without the addition of the filtrate. The amount of the sodium thiosulfate used was subtracted from the value of the blank test and the sugar content from the sugar table enclosed to the methodology was read out.

The content of polyphenols (flavonoids and phenolic acids) in beetroot juices was determined by HPLC method, with identification of individual phenolic compounds according to the Fluca and Sigma Aldrich standards with a purity of 99.5% (Shimazu equipment, USA Manufacturing Inc, USA: two pump LC-20AD, controller CBM-20A, column oven SIL-20AC, spectrometer UV/Vis SPD-20 AV) (Hallmann, 2012). Weighted amounts of beetroot juice samples were put into the plastic test tubes, then 1 ml of methanol with 1% ascorbic acid were added, mixed thoroughly by vortex and incubated in an ultrasonic bath (20 min at 20 °C). Then the samples were centrifuged at the speed of 3,920 × g. From the test tube 1 ml of extract was collected and

re-centrifuged at the speed of 22,579 × g. The amount of 500 µl of extract was taken into HPLC vials and analysed. To analyse the phenolic compounds Synergi Fusion-RP 80i column (250 × 4.60 mm) was used. The gradient flow was applied along with two mobile phases – acetonitrile/deionized water (55% and 10%), pH 3.00. Time of the analysis: 36 min, flow: 1 ml min<sup>-1</sup>, wavelength: 280-370 nm. HPLC chromatogram showing a profile of polyphenols in the tested beetroot juice is presented on Fig. 1.

The concentration of betalains in the samples was determined by HPLC method (Slatnar *et al.*, 2015) (Shimazu equipment described above). Betacyanins (betanin-5-*O*-glucoside and betanidin) were identified based on Fluka standards with a purity of 85%. Samples of beetroot juice were poured into plastic tubes with 80% ethanol, next mixed thoroughly by vortex and incubated in an ultrasonic bath (at 30 °C, in darkness). Then the samples were centrifuged at the speed of 3,920 × g. 2.5 ml of supernatant were taken from every plastic tube, next 10n HCl was added and topped up to 10 ml with ethanol. The samples were kept in the fridge for 10 min, next 1 ml of extract was taken up to HPLC vial and analysed. Betacyanins (betanin-5-*O*-glucoside and betanidin) have been identified on the basis of standards of Fluca with a purity of 85%. The column Synergi Fusion-RP 80i (250 × 4.60 mm) (Shimazu) has been used. The isocratic flow was applied along with one phase: 5% acetic acid, methanol and acetonitrile (70 : 10 : 20 v/v). Time of the analysis: 12 min, flow: 1 ml min<sup>-1</sup>, wavelength: 530-540 nm. HPLC chromatogram showing a profile of betalains in the tested beetroot juice is presented on Fig. 2.

#### Statistical procedures

Three independent replicates of each beetroot juice were analyzed. The results are presented as mean ± standard deviation (SD). Using a Statgraphics 5.1. software (StatPoint Technologies, Inc, Warrenton, Virginia, USA), the data were subjected to a one-way analysis of variance ANOVA, followed by a parametric *post-hoc* Tukey's test ( $\alpha = 0.05$ ). The p-values are given in the tables; if the result of the analysis was not statistically significant it was designated as 'ns'.

#### Results and Discussion

The results on concentration of the analysed compounds in the beetroot juice samples are presented in Tables 2-4 and on Figure 3.

#### Betalains

All beetroot juices were abundant in betalains, however, individual products differed significantly with regard to the concentrations of these chemical compounds. Betanin-3-*O*-glucoside concentrations ranged between 156.45 and 532.42

Table 1. Production system, composition and processing technology of beetroot juices selected for the study

Symbol	Production system	Beetroots (%)	Fruit (%)	Processing
ORG-L	Organic	98	2% lemon juice	Pressed, pasteurized
ORG-A	Organic	70	30% apple juice	Pressed, pasteurized
ORG-B	Organic	100	-	Pressed, lacto-fermented*, pasteurized
CONV-B	Conventional	100	-	Pressed, pasteurized
CONV-A	Conventional	50	50% apple juice	Pressed, pasteurized
CONV-CB	Conventional	100	-	From concentrate, pasteurized

Note: \*Natural, spontaneous lactic acid fermentation

mg 100 g<sup>-1</sup>, while betanidin concentrations between 16.75 and 89.72 mg 100 g<sup>-1</sup>. The identified concentrations were in a range reported in previously published studies (Czyżowska et al., 2006; Szopińska and Gawęda, 2013; Kazimierczak et al., 2014). Higher concentrations of betalains were found in pure beetroot juices when compared to juices combined with other components (apple, lemon). The highest concentration of betanin-3-*O*-glucoside was found in CONV-CB – conventional pure juice from concentrate (higher compared to both pure pressed conventional and the organic juice). Different trend was observed for betanidin. ORG-B and CONV-CB juices were richest in this bioactive compound (Fig. 3). On average, conventionally produced juices contained significantly more betanin-3-*O*-glucoside than organic ones. In contrast, organic juices, on average, were richer in betanidin. However, it should be pointed that the differences in formulations and processing methods of tested individual organic and conventional juice samples cause that the observations with regard to production system effects should be interpreted cautiously. Kazimierczak et al. (2014) found a higher content of betanin-3-*O*-glucoside in organic versus conventional beetroots. However, this was true only for fresh, raw produce, while fermented beetroot juices contained similar levels of betanin-3-*O*-glucoside, independently on the beetroot cultivation system (organic or conventional). As shown by Sakuta et al. (1987), increasing soil nitrogen concentration resulted in higher betacyanin accumulation in the American plant *Phytolacca americana* L. It is so because betalains (including betacyanins) belong to nitrogen-containing colorants (Moreno et al., 2008; Petek et al., 2012). Brandt and Mølgaard (2001) explained that in growing environments rich in readily assimilable nitrogen, i.e. conventional systems, metabolism of plants changes in the direction of intensive production of nitrogen-containing compounds such as proteins and others.

#### Vitamin C and organic acids

Vitamin C and organic acids contents (Table 2) were found to significantly differ between the tested juice variants. Vitamin C concentrations ranged between 4.43 and 20.36 mg 100 g<sup>-1</sup>, while organic acids between 0.34 and 0.81 mg 100 g<sup>-1</sup>.

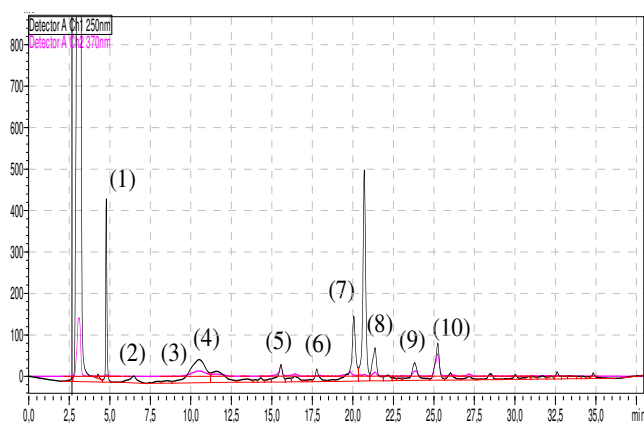


Fig. 1. Chromatographic profile of polyphenols in beetroot juice: (1) gallic acid; (2) chlorogenic acid; (3) caffeic acid; (4) ferulic acid; (5) rutinoid-3-*O*-quercetin; (6) glucoside-3-*O*-quercetin; (7) myricetin; (8) luteolin; (9) quercetin; (10) kaempferol

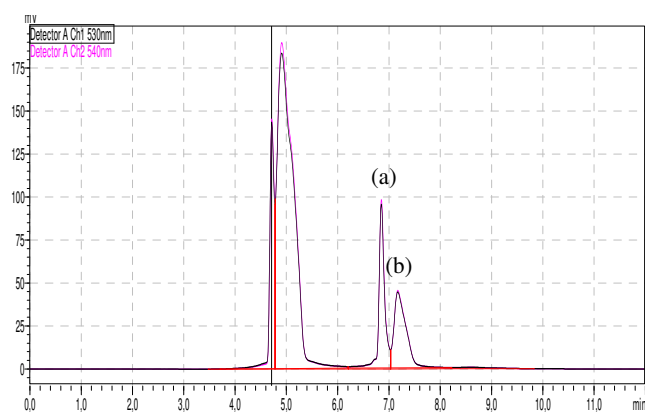


Fig. 2. Chromatographic profile of betalains in beetroot juice: (a) glucoside-5-*O*-betanine; (b) betanidine

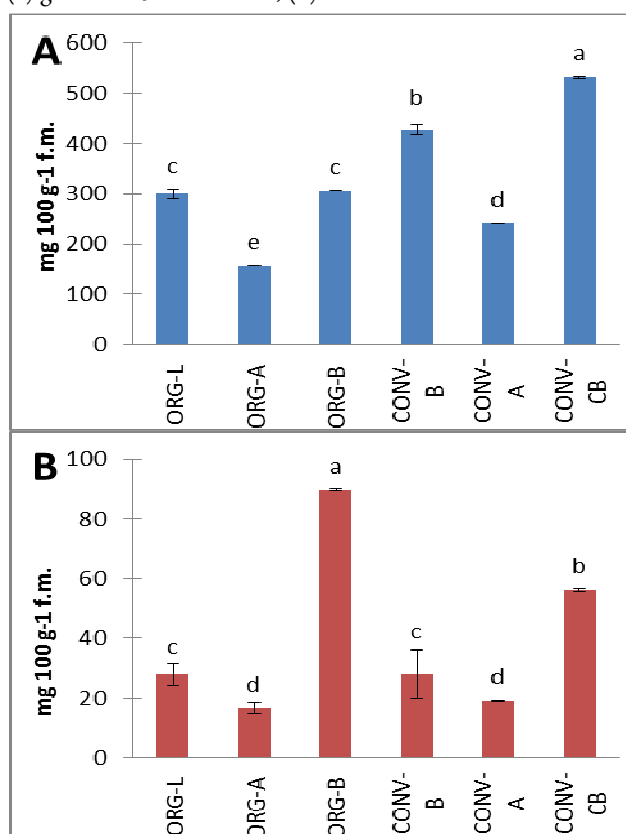


Fig. 3. Betanin-3-*O*-glucoside (Panel A) and betanidin (Panel B) concentration in selected commercially available organic (ORG) and conventional (CONV) beetroot juices (mean ± SD). ORG-L – organic pressed beetroot juice combined with lemon, ORG-A – organic pressed beetroot juice combined with apple, ORG-B – organic pressed fermented pure beetroot juice, CONV-B – conventional pressed pure beetroot juice, CONV-A – conventional pressed beetroot juice combined with apple, CONV-CB – conventional pure beetroot juice from concentrate; means with the same letter are not significantly different at the 5% level of probability (Tukey's test,  $p < 0.05$ )

ORG-B – fermented pure beetroot juice was the most abundant in organic acids. At the same time ORG-L – pressed juice combined with lemon and ORG-A – pressed juice combined with apple contained the highest levels of vitamin C, as lemon and apple fruit are richer vitamin C sources compared

Table 2. Dry matter, vitamin C, sugars and organic acids content (per 100 g of fresh matter) in selected commercially available organic (ORG) and conventional (CONV) beetroot juices (mean  $\pm$  SD)

Beetroot juice variants	Dry matter (in g)	Vitamin C (in mg)	Total sugars (in g)	Reducing sugars (in g)	Organic acids (in g)
ORG-L	9.60 $\pm$ 0.33 b	18.33 $\pm$ 1.18 a	5.39 $\pm$ 0.10 c	1.96 $\pm$ 0.26 d	0.70 $\pm$ 0.04 b
ORG-A	10.40 $\pm$ 0.44 a	20.36 $\pm$ 2.07 a	6.53 $\pm$ 0.88 b	5.41 $\pm$ 0.65 b	0.72 $\pm$ 0.04 b
ORG-B	5.92 $\pm$ 0.29 d	13.02 $\pm$ 1.18 b	1.73 $\pm$ 0.17 e	1.21 $\pm$ 0.25 d	0.81 $\pm$ 0.02 a
CONV-B	7.63 $\pm$ 0.10 c	10.75 $\pm$ 0.68 c	3.33 $\pm$ 0.34 d	3.12 $\pm$ 0.30 c	0.34 $\pm$ 0.01 e
CONV-A	9.42 $\pm$ 0.11 b	4.43 $\pm$ 0.39 d	7.85 $\pm$ 0.46 a	7.31 $\pm$ 0.71 a	0.48 $\pm$ 0.03 d
CONV-CB	10.21 $\pm$ 0.12 a	15.30 $\pm$ 2.45 b	4.05 $\pm$ 0.67 d	1.21 $\pm$ 0.16 d	0.60 $\pm$ 0.02 c
<b>Average</b>					
ORG	8.64 $\pm$ 2.03	17.24 $\pm$ 3.49 A	4.55 $\pm$ 2.16	2.86 $\pm$ 1.92	0.75 $\pm$ 0.06 A
CONV	9.08 $\pm$ 1.11	10.16 $\pm$ 4.79 B	5.08 $\pm$ 2.10	3.88 $\pm$ 2.65	0.47 $\pm$ 0.11 B
<b>p-value</b>					
Production system	ns	0.0031	ns	ns	< 0.0001
Variant of product	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Note: ORG-L – organic pressed beetroot juice combined with lemon, ORG-A – organic pressed beetroot juice combined with apple, ORG-B – organic pressed fermented pure beetroot juice, CONV-B – conventional pressed pure beetroot juice, CONV-A – conventional pressed beetroot juice combined with apple, CONV-CB – conventional pure beetroot juice from concentrate; means in a column followed by the same letter are not significantly different at the 5% level of probability (Tukey's test,  $p < 0.05$ ); ns, not statistically significant

Table 3. Flavonoids content (mg 100 g<sup>-1</sup> of fresh matter) in selected commercially available organic (ORG) and conventional (CONV) beetroot juices (mean  $\pm$  SD)

Beetroot juice variants	Total flavonoids	Quercetin-3-O-rutinoside	Quercetin-3-O-glucoside	Myricetin	Luteolin	Quercetin	Kaempferol
ORG-L	2.35 $\pm$ 0.02 a	0.25 $\pm$ 0.004 a	0.24 $\pm$ 0.013 a	0.22 $\pm$ 0.007 d	0.15 $\pm$ 0.001 a	0.14 $\pm$ 0.002 a	1.35 $\pm$ 0.002 a
ORG-A	2.13 $\pm$ 0.02 c	0.19 $\pm$ 0.003 c	0.17 $\pm$ 0.07 b	0.20 $\pm$ 0.010 d	0.14 $\pm$ 0.003 b	0.12 $\pm$ 0.006 ab	1.31 $\pm$ 0.002 b
ORG-B	2.24 $\pm$ 0.03 b	0.16 $\pm$ 0.003 d	0.10 $\pm$ 0.005 c	0.39 $\pm$ 0.014 b	0.14 $\pm$ 0.002 bc	0.14 $\pm$ 0.025 a	1.30 $\pm$ 0.003 b
CONV-B	2.02 $\pm$ 0.01 d	0.12 $\pm$ 0.001 e	0.10 $\pm$ 0.006 c	0.27 $\pm$ 0.010 c	0.13 $\pm$ 0.001 cd	0.10 $\pm$ 0.002 c	1.29 $\pm$ 0.001 c
CONV-A	2.22 $\pm$ 0.03 b	0.24 $\pm$ 0.014 a	0.25 $\pm$ 0.011 a	0.19 $\pm$ 0.003 d	0.13 $\pm$ 0.002 d	0.12 $\pm$ 0.005 bc	1.29 $\pm$ 0.003 c
CONV-CB	2.36 $\pm$ 0.03 a	0.21 $\pm$ 0.013 b	0.17 $\pm$ 0.011 b	0.44 $\pm$ 0.029 a	0.14 $\pm$ 0.001 bc	0.10 $\pm$ 0.001 c	1.31 $\pm$ 0.007 b
<b>Average</b>							
ORG	2.24 $\pm$ 0.09	0.20 $\pm$ 0.036	0.17 $\pm$ 0.060	0.27 $\pm$ 0.091	0.14 $\pm$ 0.004 A	0.13 $\pm$ 0.017 A	1.32 $\pm$ 0.024 A
CONV	2.20 $\pm$ 0.15	0.19 $\pm$ 0.054	0.17 $\pm$ 0.065	0.30 $\pm$ 0.109	0.13 $\pm$ 0.003 B	0.10 $\pm$ 0.009 B	1.30 $\pm$ 0.009 B
<b>p-value</b>							
Production system	ns	ns	ns	ns	0.0095	0.0004	0.0135
Variant of product	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	0.0021	< 0.0001

Note: ORG-L – organic pressed beetroot juice combined with lemon, ORG-A – organic pressed beetroot juice combined with apple, ORG-B – organic pressed fermented pure beetroot juice, CONV-B – conventional pressed pure beetroot juice, CONV-A – conventional pressed beetroot juice combined with apple, CONV-CB – conventional pure beetroot juice from concentrate; means in a column followed by the same letter are not significantly different at the 5% level of probability (Tukey's test,  $p < 0.05$ ); ns, not statistically significant

to beetroots and significantly enriched the juices in this particular compound. However, surprisingly, CONV-A – conventional pressed beetroot juice combined with apple contained the lowest vitamin C level within all tested juices, despite being mixed with an apple juice.

On average, organic juices contained more vitamin C and organic acids compared to the conventional ones. This supports many authors findings showing higher contents of vitamin C in organically compared to the conventionally cultivated fruit and vegetables (Brandt *et al.*, 2011) and can be explained by the nitrogen fertilization strategy used in conventional agriculture – increased fertilization tends to reduce the contents of ascorbic acid and other carbon-containing chemical compounds in plants (Stefanelli *et al.*, 2010). The same tendency in terms of vitamin C content was described by Kazimierczak *et al.* (2014) – fermented beetroot juices from organic production were found to contain significantly more vitamin C than the conventional ones. However, in the cited study no effect of the production system (organic/conventional) on the content of organic acids in pure fermented beetroot juices has been identified.

### Sugars and phenolic compounds

All the tested beetroot juice samples were a rich source of both total and reducing sugars, but also phenolic compounds. However, individual products differed significantly with regard to the concentrations of these chemicals. Total sugars ranged between 1.73 and 7.85 g 100 g<sup>-1</sup>, reducing sugars between 1.21 and 7.31 g 100 g<sup>-1</sup>, total polyphenols between 22.78 and 129.31 mg 100 g<sup>-1</sup> and phenolic acids between 20.43 and 127.30 mg 100 g<sup>-1</sup>. One of the parameters with relatively low variation between the analysed samples were flavonoids, with concentrations ranging from 2.02 to 2.36 mg 100 g<sup>-1</sup>. Considering the individual products, the highest concentrations of total sugars, reducing sugars, quercetin-3-O-glucoside and quercetin-3-O-rutinoside were found in CONV-A – conventional beetroot juice combined with apple. The highest contents of total polyphenols, phenolic acids, including gallic acid, were found in CONV-B – pure pressed beetroot juice from conventional production. ORG-L – organic beetroot juice combined with lemon was the most abundant in chlorogenic acid and total flavonoids, including most of the identified individual compounds from this group. The highest level of total flavonoids, including myricetin as well as caffeic

Table 4. Polyphenols and phenolic acids content (mg 100 g<sup>-1</sup> of fresh matter) in selected commercially available organic (ORG) and conventional (CONV) beetroot juices (mean ± SD)

Beetroot juice variants	Total polyphenols	Total phenolic acids	Gallic acid	Chlorogenic acid	Caffeic acid	Ferulic acid
ORG-L	22.78 ± 0.88 c	20.43 ± 0.90 c	9.32 ± 0.18 d	9.02 ± 1.07 a	1.08 ± 0.05 ab	1.02 ± 0.04 c
ORG-A	73.58 ± 3.98 b	71.45 ± 4.00 b	65.50 ± 4.40 b	4.59 ± 0.24 b	0.93 ± 0.19 b	0.42 ± 0.07 d
ORG-B	37.39 ± 1.01 c	35.15 ± 1.03 c	34.37 ± 1.03 c	0.39 ± 0.07 c	0.22 ± 0.01 e	0.17 ± 0.04 d
CONV-B	129.31 ± 19.26 a	127.30 ± 19.27 a	120.37 ± 19.28 a	5.11 ± 0.38 b	0.49 ± 0.07 d	1.34 ± 0.10 b
CONV-A	66.28 ± 10.26 b	64.06 ± 10.22 b	60.97 ± 10.30 b	1.32 ± 0.06 c	0.68 ± 0.05 c	1.09 ± 0.09 bc
CONV-CB	23.09 ± 0.83 c	20.73 ± 0.84 c	16.44 ± 0.87 cd	0.45 ± 0.03 c	1.13 ± 0.03 a	2.70 ± 0.33 a
<b>Average</b>						
ORG	44.58 ± 22.09	42.34 ± 22.18	36.40 ± 23.77	4.67 ± 3.67	0.74 ± 0.40	0.54 ± 0.37 B
CONV	72.90 ± 46.42	70.70 ± 46.56	65.93 ± 45.38	2.29 ± 2.09	0.77 ± 0.28	1.71 ± 0.76 A
<b>p-value</b>						
Production system	ns	ns	ns	ns	ns	0.0009
Variant of product	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Note: ORG-L – organic pressed beetroot juice combined with lemon, ORG-A – organic pressed beetroot juice combined with apple, ORG-B – organic pressed fermented pure beetroot juice, CONV-B – conventional pressed pure beetroot juice, CONV-A – conventional pressed beetroot juice combined with apple, CONV-CB – conventional pure beetroot juice from concentrate; means in a column followed by the same letter are not significantly different at the 5% level of probability (Tukey's test,  $p < 0.05$ ); ns, not statistically significant

and ferulic acids was found in CONV-CB – conventional pure beetroot juice from concentrate. ORG-B – fermented organic beetroot juice was the richest in organic acids and quercetin.

No significant differences were observed between the tested organic and conventional juices (on average) in terms of dry matter content, total and reducing sugars (Table 2), total polyphenols, total flavonoids and total phenolic acids contents (Tables 3, 4). The same was true for most of the identified individual flavonoids (quercetin-3-*O*-rutinoside, quercetin-3-*O*-glucoside, myricetin) (Table 3) and most of the individual phenolic acids (gallic, chlorogenic and caffeic acid) (Table 4). However, as already mentioned, the differences in formulations and processing methods of the individual organic and conventional juice samples tested in the study do not allow drawing strong conclusions with regard to the organic vs. conventional production system effects on the chemical composition of juices. Over the last 25 years, a significant number of research studies have compared the concentrations of bioactive compounds (*i.e.* phenolics) in plant foods coming from organic and conventional production systems (Brandt *et al.*, 2011). Authors of the most recent and comprehensive meta-analysis summarizing results of more than 300 peer-reviewed comparison studies have concluded that organic crops are, on average, characterized by significantly higher concentrations of antioxidants, including various groups of phenolic compounds, lower concentrations of cadmium and at least four times lower incidence of pesticide residues than their conventional counterparts, when compared across regions and agricultural seasons (Barański *et al.*, 2014). On the basis of the above meta-analysis results one could expect health-promoting superiority of organic compared to the conventional foods.

#### Final considerations and further research

To summarize, the study shows that beetroot juices are very valuable products due to the presence of numerous bioactive compounds, especially betalains, in their composition. The concentrations of these compounds, however, seem to be

affected by both the way of processing and the beetroot agricultural production system, e.g. the organic juice samples tested in the study, on average, showed significantly higher content of vitamin C, organic acids and betanidin, but also luteolin, quercetin and kaempferol in comparison to conventional ones. In contrast, conventionally produced juices had a significantly higher content of ferulic acid and betanin-3-*O*-glucoside than their organic counterparts. It is at the same time important to mention that the variation between individual juice samples representing one production system was also high, showing the importance of other factors (*i.e.* juice processing and formulation) for the tested parameters of chemical composition. Further research, including higher number of tested organic vs. conventional samples and accounting for other relevant factors (not only processing, but also e.g. storage, packing and transport conditions known to affect the quality of processed foods), would be necessary to confirm the findings and/or explain the background of the identified differences (Lee and Kader, 2000; Bloksma *et al.*, 2007).

#### Conclusions

Beetroot juices are very valuable products, mainly due to the presence of numerous bioactive compounds (*i.e.* betalains, flavonoids, phenolic acids and vitamin C) in their composition. Comparison of products processed with the use of different technologies and coming from different (organic / conventional) production systems, did not allow making conclusions about superiority of a particular product. However, the obtained results clearly show that introducing any of the beetroot juices to the consumers' diet can have a great impact on their intake of numerous pro-health compounds. The beetroot juices consumption should therefore be promoted among consumers. Special attention should be paid to organic certified products, which guarantee high standards of production as well as high nutritional and health-oriented value.



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