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ARTICLE

Antioxidant profile of tomato landraces for fresh consumption

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ABSTRACT Tomato is one of the most important and frequently consumed vegetable species in Hungary, as well as a significant vitamin source throughout the year. Due to its antioxidant content, tomato consumption is related to the reduced occurrence of cardiovascular diseases and certain cancer types. In our study, four Hungarian tomato accessions [RCAT030275 (Cegléd), RCAT031012 (Veresegyház), RCAT031095 (Cigánd), RCAT054422 (Jánoshalma)] and a commercial cultivar (Hellfrucht) were investigated according to antioxidant capacity [ferric reducing power (FRAP), total phenol content (TPC) and radical scavenging activity (DPPH)], lycopene and ascorbic acid content. A two year (2013-2014) open field trial was carried out in the certified organic area of SZIE Soroksár Experimental and Educational Station. Our results showed that no significant differences were between the landraces and the variety in DPPH values, while TPC values were higher in both years in the landraces, especially in RCAT031095, and RCAT054422. The lycopene content of RCAT031012, RCAT031095 and RCAT054422 was also higher in both years than those of Hellfrucht. The results demonstrate that small-scale production of the investigated landraces could be marketable.
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KEY WORDS

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Introduction

Tomato is one of the most popular vegetable due to the high number of varieties available, versatile use and advantageous nutritional composition (Tigchelaar 1986). Later it can be regarded as functional food (Jack 1995) as its consumption has a favorable effect on human health (Canene-Adams et al. 2005). Tomato is the most important lycopene source of human, 85% of lycopene consumed originate from tomato (Levy and Sharoni 2004). According to epidemiologic studies, it is suggested that tomato consumption relates to the reduced occurrence of cardiovascular diseases and different cancer types due to carotenoid (Giovannucci 1999) polyphenolic (Vallverdú-Queralt 2012) and vitamin C contents (Adalid et al. 2010).

In the past decades the priority in tomato breeding was to maximize yield, as a consequence, the nutritional values of most modern varieties decreased (Goff and Klee 2006; Klee and Tieman 2013; Tieman et al. 2012). Due to trader and consumer expectations, tomato is harvested in green stage; post-ripened fruits have poor nutritional profile in contrast with those ripened on the vine (Baldwin et al. 2011). To overcome the nutritional loss of modern varieties, several authors suggest reintroducing old varieties and landraces to the production (Male 1999; Rodríguez-Burruezo et al. 2005), in order to enhance nutritional value of novel tomato varieties.

Consumers consider the landraces to be nutritionally richer (Casals et al. 2011) - often without any scientific evidence. Therefore, as a part of a broader study, the aim of this paper is to compare the antioxidant profile of four landraces and a commercial variety for fresh consumption. Except the article by Csambalik et al. (2015), nutritional value of Hungarian tomato landraces was not investigated before.

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Materials and Methods

Plant material

Four Hungarian tomato accessions were selected as appropriate for fresh consumption, three of them are originated from the Central Hungarian Region (Table 1). The landraces were produced together with a control variety, called Hellfrucht (Hild Samen GmbH, Germany) in 2013 and 2014. This commercially available variety gives a round, red, middle-sized

Table 1. RCAT code, origin and fruit characteristics of Hungarian tomato accessions selected for nutritional investigation.

RCAT code	Origin	Year of acquisition	Fruit shape*	Fruit color
RCAT030275	Cegléd	1977	round	orange
RCAT031012	Veresegyház	1987	oblate	red
RCAT031095	Cigánd	1986	flattened	red
RCAT054422	Jánoshalma	2001	elliptic	red

*According to UPOV TG 44/11 Tomato Descriptor

fruit and indeterminate growing habit, similarly to all of the accessions investigated.

The propagation material of landraces was provided by Research Centre for Agrobiodiversity, Tápiószele. The accessions and the variety were produced on the certified organic field of Soroksár Experimental and Educational Station of Szent István University for two years. For the open field propagation, the seedlings were grown in an unheated plastic tunnel both years. The production field was covered by agro textile, under which drip irrigation was established. Each plant was supported by a bamboo pole; side shoots were removed weekly. The production met the standards of organic farming and was free from any chemical treatments. Harvesting was started according to fruit ripening of plants and was conducted weekly. The yield of each accession was measured; the fruits were divided into three fractions: (i) marketable, (ii) cracked, (iii) infected. From the representative sample of each accession, one kg was collected from the marketable group for the measurements. The fruits were free from any visible infection or pest damage. The time of sample collection was adjusted to the maximum weekly yield of each accession and the variety, which was on 14th of August of both years.

Measurements

The samples were chopped and homogenized by a blend mixer after washing at the day of the harvest. The homogenates were filled into Falcon tubes and frozen until the measurements.

The supernatant was collected from homogenates centrifuged at 12 500 rpm and used for antioxidant analyses (FRAP, TPC, and DPPH).

FRAP assay was conducted spectrophotometrically at 593 nm according to Benzie and Strain (1996) with a Hitachi U2900 spectrophotometer. FRAP value was calculated relevant to the activity of ascorbic acid (AA) and expressed as ascorbic acid equivalents. Results were provided in mg AA/l dimension, according to Huang and co-workers (2005). Calibration curve and FRAP reagent were prepared freshly every two hours to avoid influences of AA instability.

The DPPH free radical method was conducted, based on the description of Molyneux and co-workers (2003). From the supernatant, 100 µl was obtained from sample centrifugation and added to 3.9 ml of 6 x 10^{-5} M DPPH solution, kept in the dark for 20 min, then absorbance was recorded at 517 nm with a Unicam Helios Alpha UV-VIS spectrophotometer. Values are shown in percent to the control, where higher values indicate higher antioxidant capacity.

Total phenol content (TPC) was measured using Folin-Ciocalteu's reagent according to the method of Singleton and Rossi (1965). Absorbance was measured at 760 nm with a Hitachi U2900 spectrophotometer and the content of soluble phenols calculated from a standard curve based on gallic acid (GA) concentrations. Results were recorded using mg GA/l dimension.

Ascorbic acid (AA) content was determined by reverse-phase HPLC using an RP-18 column, at 22 °C with a flow speed of 1 L/min. A pH 4.75 buffer made of EDTA and phosphoric acid was used for isocratic elution. Absorbance at 254 nm was measured by UV detector. An extraction solution of 5% phosphoric acid and 0.01% sodium EDTA and a cellulose membrane filter with 0.45 µm pore size were used for sample preparation prior to separation.

Lycopene content was determined with a Unicam Helios Alpha UV-VIS spectrophotometer as described by Fish et al. (2002). Samples were extracted with a solvent containing acetone (with 0.05% BHT), ethanol, and hexane mixture. Absorbance of the extract in the hexane layer was measured at 503nm against hexane as blank solution, and lycopene content was expressed in mg/100 g dimension.

All measurements were performed in triplicate, except for lycopene and DPPH where five replicates were measured. Mean values were compared pairwise with Games-Howell and Tukey post hoc tests. The significance level was 95% ($p<0.05$). All analyses were performed using IMB SPSS Statistics Version 22.

Results

The vitamin C content of investigated accesions and Hellfrucht variety changed between 3.49-8.77 mg/100 g and 2.57-6.22 mg/100 g in 2013 and 2014 (Fig. 1). Regardless to variety, the results of 2014 were significantly lower than those of 2013. In 2013, Hellfrucht, Veresegyház and Jánoshalma significantly differed from Cigánd and Cegléd, while in 2014 there were no significant differences among varieties.

The FRAP values ranged between 17.41-54.47 mg AA/100g and 5.63-21.51 mg AA/100g in 2013 and in 2014, respectively, which differed significantly (Fig. 2). All traits showed significantly lower values in 2014, except those of Jánoshalma. In the first year Veresegyház, while in the second year Hellfrucht gave significantly the highest results.

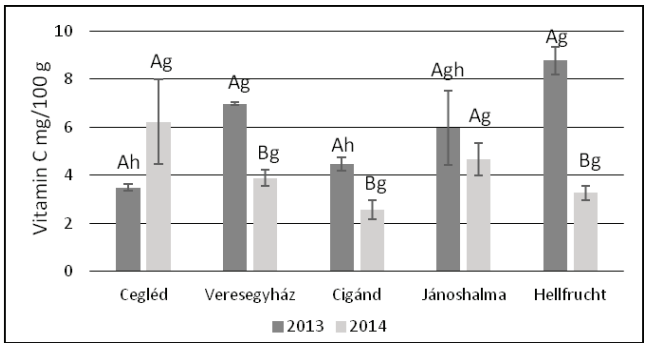

Figure 1. Vitamin C content of tomato accessions and one variety in 2013 and 2014. Capital letters on columns mean significant difference (p≤0.05) between years of each variety. Lower case letters mean significant difference (p≤0.05) between varieties within a year.

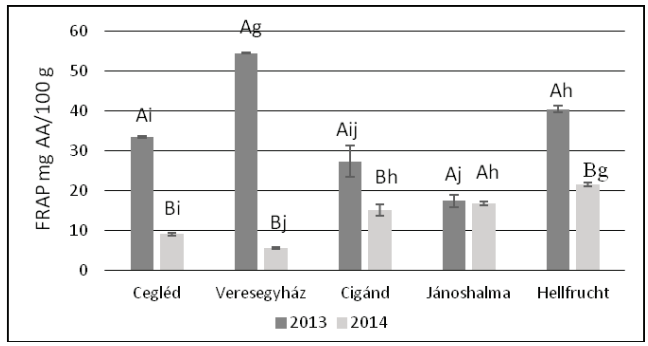

Figure 2. Water-soluble antioxidant power (FRAP) of accessions and one variety in 2013 and 2014. Capital letters on columns mean significant difference (p≤0.05) between years of each variety. Lower case letters mean significant difference (p≤0.05) between varieties within a year.

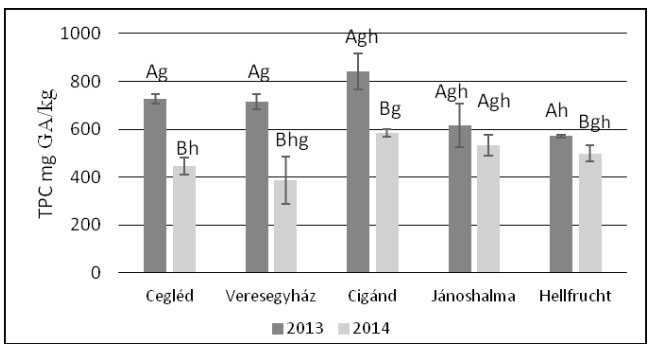

Figure 3. Total Phenolic Content of accessions and one variety in 2013 and 2014. Capital letters on columns mean significant difference (p ≤ 0.05) between years of each variety. Lower case letters mean significant difference (p≤0.05) between varieties within a year.

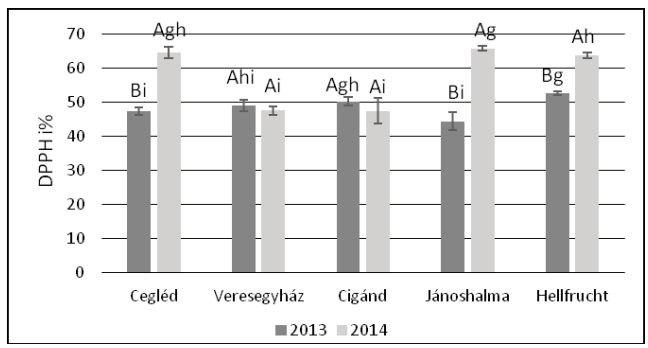

Figure 4. DPPH values of accessions and one variety in 2013 and 2014. Capital letters on columns mean significant difference (p≤0.05) between years of each variety. Lower case letters mean significant difference (p≤0.05) between varieties within a year.

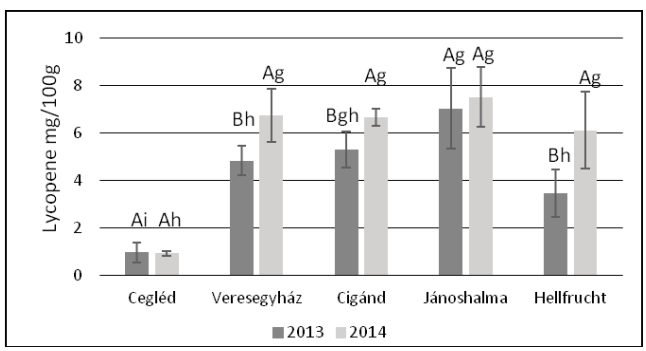

Figure 5. Lycopene content of accessions and one variety in 2013 and 2014. Capital letters on columns mean significant difference (p≤0.05) between years of each variety. Lower case letters mean significant difference (p≤0.05) between varieties within a year.

The effect of year was significant on TPC content of investigated accessions and the variety (Fig. 3). The values ranged between 571-841 mg GA/kg and 387-584 mg GA/kg in 2013, and in 2014, respectively. Hellfrucht gave significantly lower results in 2013, while in 2014 only Cigánd differed significantly from Cegléd accession. The TPC of all accesions was higher than Hellfrucht in 2013, Cegléd and Veresegyház differed significantly from the variety. The second year showed lower differences among the samples.

The DPPH values of samples ranged between 44.35-52.59% in 2013 and 47.38-65.72% in 2014 (Fig. 4). The year had no significant influence on the results by Veresegyház and Cigánd. However, in the case of Cegléd, Jánoshalma and Hellfruct, the values of the second year were significantly higher than in the first year. In the first year, Hellfrucht gave significantly the highest results, while Jánoshalma and Cegléd gave significanly lower results. In the second year, Jánoshalma and Cegléd showed the highest results, while Cigánd and Veresegyház gave the lowest ones.

The year had no significant effect on the lycopene content of the investigated samples of Jánoshalma and Cegléd (Fig.

5). However, in case of Veresegyház, Cigánd and Hellfrucht, the values of the first year were significantly lower than those of the second year. In 2013, the values ranged between 3.45-7.02 mg/100 g, while in 2014 it was 6.09-7.48 mg/100 g, except the orange colored Cegléd accession, which had an extremely low lycopene content under 1 mg/100g in both years. The highest results were given in both years by Jánoshalma, differing significantly from Hellfrucht, Veresegyház and Cegléd in 2013. All accessions exceeded the values of the variety in both years.

Table 2. Weather conditions of the experimental site between 1-14 August 2013 and 2014.

Year	Precipitation (mm)	Average minimum temperature (°C)	Average maximum temperature (°C)	Average temperature (°C)
2013	0.8	13.33	31.55	22.65
2014	94.8	16.16	29.72	22.19

Discussion

The results clearly show the influence of weather conditions on the investigated parameters. The vegetation period of 2013 was rather arid with a moderately high average temperature; that of 2014 was rich in precipitation and the temperature was generally lower than in the previous year (Table 2). The statistical analysis showed significant effect of the year on every parameter, except of lycopene. The main environmental factor of lycopene synthesis is temperature (Helyes et al. 2006; Ishida 1999), which showed no significant difference between the two years. Indeed, the time of exposure to sunlight was different in the two years, as the second year took significantly higher amounts of precipitation and the clouds could shade the plants. This effect is demonstrated in the results of vitamin C content. According to the literature (Davies and Hobson 1981; Dumas et al. 2003), vitamin C synthesis strongly correlates with the exposure to sunlight with the exception of Cegléd. All accessions, as well as Hellfrucht gave lower results in the second year. Cegléd accession with orange colored fruits had a different reaction to the theoretically lower exposure to sunlight: vitamin C results could be doubled in the first year.

The effect of increased precipitation is well demonstrated on the FRAP results and a lower extent on TPC results. In both parameters, the results of the second year are lower, due to the 'diluting' effect of heavy rainfall. As 20-30% of FRAP values are given by vitamin C content (Cano et al. 2003), Veresegyház and Hellfrucht rich in ascorbic acid, so it could maximize the FRAP values over the other accessions. FRAP also measures phenolic content as water-soluble antioxidants, and TPC method is not selective to phenolic components, it also reacts with vitamin C (Apak et al. 2007; Balogh et al. 2010; Singleton et al. 1999). In contrast with its low vitamin C content, the relatively high FRAP values of Cegléd accession is supported by its higher TPC results. It can be concluded, that Veresegyház and Hellfrucht are rich in ascorbic acid and phenolic components. Cegléd and Cigánd are characterized rather by high phenolic content and Jánoshalma contains lower amount of both components. To overcome the selectiveness of antioxidant measurement methods, the application of three or more methods is suggested (Hegedűs et al. 2010; Huang et al. 2015). According to literature, including our previous experiences (Csambalik et al. 2015) the summarized discussion of the applied antioxidant capacity measurement methods is reasonable. Both analyses indicated the relatively higher antioxidant capacity of Veresegyház and Hellfrucht in 2013. The outstanding TPC result of Cegléd and Cigánd was not supported by the other two methodologies. In this year, TPC was rather an outlying factor; this might be due to the higher average temperature, which supports the synthesis of phenolic components (Rivero et al. 2001). In 2014 FRAP was the method, which showed gradually lower values, but these results were generally in coherence with the other two methodologies. The weather conditions of the second year were favorable for Cigánd, Jánoshalma and Hellfrucht from the viewpoint of antioxidant capacity. In contrast with the high DPPH values of Cegléd, FRAP and TPC results did not support the high antioxidant power of that accession.

Being a fat-soluble antioxidant, lycopene levels of samples does not influence water-soluble antioxidant measurement results. However, significant differences exist between the samples for that trait. As was expected, due to its color, Cegléd accession is poor in lycopene. The moderately lower average temperature of the second year had a favorable impact on the lycopene levels, although this effect was not significant in case of all the samples. This might be due to the relatively low variance of temperature over the two years. In both years, Jánoshalma accession gave the highest results, in contrast with its rather low water-soluble antioxidant power. This means, that lycopene could be the main advantage of this accession. With the exception of Cegléd, all accessions had higher lycopene content than Hellfrucht, in both years. This could be a genetically encoded advantage of accessions over commercial varieties.

Conclusion

Landraces are considered as old varieties with lower yield quality and quantity, but with more favorable nutritional value, in contrast with modern commercial varieties and hy-

brids. Our study aimed to investigate the antioxidant profile of four Hungarian tomato accessions for fresh consumption and to compare the results with a commercial variety. The results showed, that no general statements can be drawn as differences among the investigated accessions exist. The comparison of accessions and the variety showed that no great differences are given between the two groups. Hellfrucht variety can be characterize by relatively high ascorbic acid content, by a moderately high antioxidant power and by low lycopene content among investigated accessions. From the point of water-soluble antioxidant power, Veresegyház and Cigánd are promising, while Jánoshalma is valuable due to its high lycopene content. After investigating the yield characters of these accessions, small-scale production could be marketable.

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