https://doi.org/10.17221/232/2019-CJFS

# Selected physical parameters and chemical compounds of different types of tomatoes

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**Citation:** Bojarska J.E., Piłat B., Majewska K.M., Sobiechowska D.A., Narwojsz A. (2020): Selected physical parameters and chemical compounds of different types of tomatoes. Czech J. Food Sci., 38: 28–35.

**Abstract:** The aim of this experiment was to compare selected types and varieties of tomatoes ('Beef-red', 'Beef-orange', 'Olmeca', 'Malinowy', 'Cherry-red', 'Cherry-mini malina', 'Cherry-orange', 'Papryczkowy') by examining their chemical composition and identifying the selected physical properties. The research material consisted of tomato fruit purchased on the regional market (Warmia and Mazury voivodeship, Poland) from one producer. An analysis of colour and texture measurement was performed. Moreover, the total dry matter content, total extract, total acidity, pH value, pectin content, total carotenoids and phenolic compounds, as well as DPPH scavenging activity were determined. The analyses showed that the investigated tomatoes were varied in terms of physical properties and chemical composition. Small-fruited tomatoes were characterized by lower hardness and firmness compared to medium and large tomatoes. Besides they contained significantly more total polyphenols and carotenoids (except for 'Cherry-mini malina'), therefore they have been recognized as an attractive source of health-promoting ingredients for the consumer.

**Keywords:** tomatoes; types and varieties; chemical compounds; physical parameters

Tomatoes (*Lycopersicon esculentum* Mill.) are among the most commonly consumed vegetables, both raw and processed. Their consumption in Europe in 2013 amounted to 26.7 kg per capita and was over 20% higher than the world average. The leading producer of tomatoes in Europe is Italy, from which more than 30% of the European Union harvests come from (Bugała et al. 2017b). The annual harvest of these fruits in Poland is not among the highest in Europe; in 2016 it amounted to 867 000 tons (GUS – Statistics Poland 2017), which is only a few percent of the European Union's harvest. However, their economic importance in Poland is the highest among vegetables, as evidenced by more than 30% of the value of their export and import in the total value obtained for fresh vegetables in 2007–2015 (Bugała et al. 2017b).

The range of available tomato types and varieties presents the consumer with a wide variety of choices. They are a source of many nutrients and health benefits, among others, carotenoids (β-carotene, lycopene, lutein) and flavonoids, with strong antioxidant activity, vitamin E, as well as macro and microelements (Leonardi et al. 2000; Toor & Savage 2005; Kacjan Maršić et al. 2011; Oboulbiga et al. 2018; Renna et al. 2018). The high availability of tomato fruit in various climate zones, as well as their considerable varietal

Supported by Minister of Science and Higher Education in the range of the program entitled 'Regional Initiative of Excellence" for the years 2019–2022, Project No. 010/RID/2018/19, amount of funding 12 000 000 PLN.

https://doi.org/10.17221/232/2019-CJFS

diversity, presented consumers with increasingly difficult choices. The desired high quality of tomatoes is perceived by the consumer through appropriate size, colour and fruit firmness (Batu 2004; Tijskens & Evelo 1994). Smaller tomatoes, initially used for decoration of dishes, are currently more popularly enjoyed, preferred for consumption in the form of a snack or as an addition to salads. Nowadays, both the organoleptic characteristics as well as the increasingly important pro-health values, have an impact on the final consumer selection (Gajc-Wolska et al. 2000; Magkos et al. 2003). The quality of tomatoes of a certain type or variety is genetically determined, but also depends on the agronomic conditions, including plant nutrition, at the time of their growth (Haase et al. 2017; Sikorska-Zimny et al. 2017). The aim of this experiment was to compare selected types and varieties of tomatoes (‘Beef-red’, ‘Beef-orange’, ‘Olmeca’, ‘Malinowy’, ‘Cherry-red’, ‘Cherry-mini malina’, ‘Cherry-orange’, ‘Papryczkowy’), from the point of view of the consumer, by examining their chemical composition and determining their physical properties.

## MATERIAL AND METHODS

The research material was fresh fruit of eight types and varieties of tomato (large-fruited: ‘Beef-red’ ‘Beef-orange’, ‘Olmeca’, ‘Malinowy’; and small-fruited: ‘Cherry-red’, ‘Cherry-mini malina’, ‘Cherry-orange’, ‘Papryczkowy’) (Figure 1). Analysed samples, in the amount of 2 kg, were purchased on the local market (Warmia and Mazury voivodeship, Poland) from one producer and they were coming from conventional cultivation. All the tested tomatoes were grown in greenhouses in the same soil and climate conditions, using a uniform set of agrotechnical treatments. They included both small-berry type of cherry tomatoes, having a diameter up to 20 mm, as well as cocktail tomatoes whose diameter was in the range 20–40 mm. The fruits of commercial maturity were tested twice (with a week interval) and stored for 3 days at 6–8 °C until analysis. The fruit quality of each variety was analysed by specifying selected physical parameters and chemical components.

**Texture.** The texture of the tomatoes was determined using the Instron Universal Testing Machine 4301 (Inston, USA) according to the method described by Bojarska et al. (2015). The examined fruit was placed on the UMT Instron tripod (Instron Co., UK), directing the trace of sepal in the horizontal axis. The analysis was carried out at room temperature. The penetration test was applied to measure hardness and firmness of analysed fruits. A cylindrical flat-beheaded mandrel of a diameter of 3 mm, which was moving at a speed of 50 mm min$^{-1}$, penetrated the tested material to a depth of 10 mm. Based on the penetration curves shown in the force-deformation (*F-d*) system, the maximum penetration force $F_{max}$ (N) and the corresponding deformation $d_{max}$ (mm), as well as the maximum penetration energy $E_{max}$ (J) were analysed. The firmness $Z$ (N mm$^{-1}$) of the tomato fruit was calculated according to the formula:

$$Z = F_{max}/d_{max} \text{ (N mm}^{-1}\text{)} \quad (1)$$

**Colour.** CIE $L^*$, $a^*$ , *and* $b^*$ colour analysis was performed using the Konica Minolta Model CR-400 (Konica Minolta, Japan) colourimeter according to the method described by Biller (2003). After calibrating the colourimeter to the white standard, the colour of the peel and flesh (on the cross-section of the fruit) of the tomato fruit was measured. The colour parameters were measured by the light source C. The following colour components were analysed: $a^*$– red colour, $b^*$– yellow colour, and $L^*$– brightness.

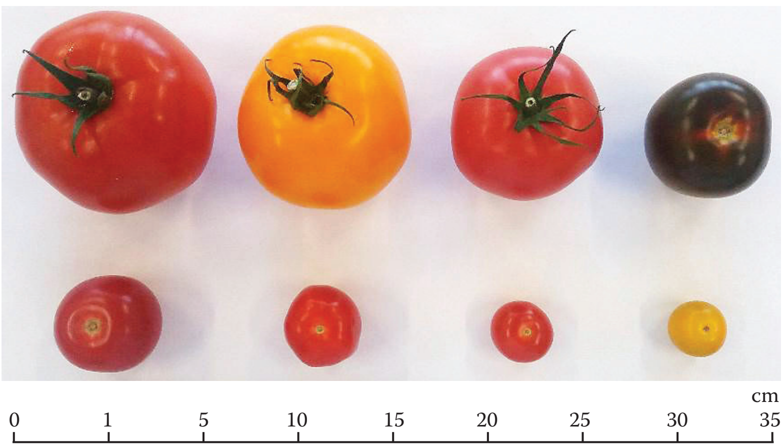


Figure 1. Examined tomato types and varieties

From left, top row: ‘Beef-red’, ‘Beef-orange’, ‘Malinowy’, ‘Olmeca’; lower row: ‘Cherry-mini malina’, ‘Papryczkowy’, ‘Cherry-red’, ‘Cherry-orange’

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**Chemical components.** The contents of the following chemical components: dry matter (PN-EN 12145:2001), total extract (PN-EN 12143:2000), total acidity (PN-EN 12147:2000), pH value (EN 1132:1999), pectin content (AOAC 1990), carotenoids with a RP-HPLC technique (Chen & Yang 1992; Czaplicki et al. 2016), and the total phenolic compounds (AOAC 1990; Singleton et al. 1999), as well as antioxidant activity by trapping the DPPH radical (Moure et al. 2001), were determined. The measurement was performed in zero and 16 min after the addition of a methanolic solution of DPPH ($0.36 \times 10^{-3}$ mol).

All analyses were performed in triplicate, except for texture and colour parameters, where the number of replicates was $n = 10$ and $n = 20$, respectively. The results were statistically analysed using the Statistica 12.0 program (StatSoft Inc., USA) performing the Duncan test at the significance of level $P < 0.05$. Besides, a linear correlation analysis was performed ($P < 0.05$) to check the relationship between the tested features (Bower 2013). The error bars on the graphs represent the standard deviation.

## RESULTS AND DISCUSSION

The texture of the tomato types and cultivars was determined by analysing the maximum penetration force ($F_{max}$), the fruit firmness ($Z$), and the maximum penetration energy of the fruit ($E_{max}$) at the given test deformation. The parameter $F_{max}$ was from 8.80 N (‘Cherry-mini malina’) to 21.40 N (‘Olmeca’), while the fruit’s firmness was from 0.89 N mm$^{-1}$ (‘Cherry-mini malina’) to 2.43 N mm$^{-1}$ (‘Beef-red’) (Figure 2). The parameter $E_{max}$ observed in the studied tomato types/cultivars ranged from $3.2 \times 10^{-2}$ J (‘Cherry - mini malina’) to $9.4 \times 10^{-2}$ J (‘Olmeca’) (Figure 3). The average values of texture parameters differed significantly. It was noticed that small-fruited tomatoes were characterized by lower values of maximum penetration force, firmness and maximum penetration energy, by approximately 29, 38 and 35%, respectively. According to Kowalczyk et al. (2011), the hardness of the peel and flesh and the firmness of the fruit depend on the harvest date, the culture medium on which they are grown and their variety. As reported by Cantwell et al. (2009), the lower firmness of small fruits is associated with the higher content of acids and sugars. The described regularity was also observed in the conducted studies. Small-fruited tomatoes were characterized by lower hardness as well as higher content of total extract and total acidity.

The types and varieties of tested fruits differed in colour and intensity. The parameters determined for the peel and flesh on the CIE $L^*$, $a^*$, and $b^*$ scale are shown in Table 1. The values of the $a^*$ parameter, corresponding to the red colour, ranged from 2.56 (‘Cherry-orange’) to 22.09 (‘Malinowy’) for peel and from 1.42 (‘Cherry-orange’) to 25.52 (‘Malinowy’) for flesh. The highest saturation of yellow $b^*$, as a characteristic trait, was observed in the varieties ‘Beef-orange’ and ‘Cherry-orange’. The values of the $L_p^*$ parameter determining the peel brightness of the tested samples ranged from 32.88 (‘Olmeca’) to 51.68 (‘Beef-orange’). The colour of the fruit, its intensity and saturation, depend on the variety and the ripeness stage of the fruit. Zalewska-Korona & Jabłońska-

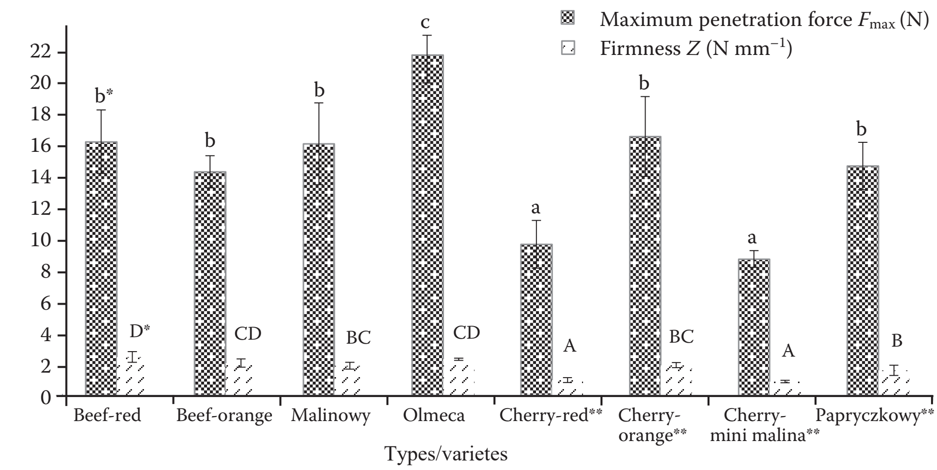


Figure 2. The values of the maximum penetration force $F_{max}$ and firmness $Z$ in the examined types/varieties of tomatoes

*Values with the same letter in the column do not differ significantly ($P < 0.05$) according to Duncan’s test; **small-fruited types and varieties

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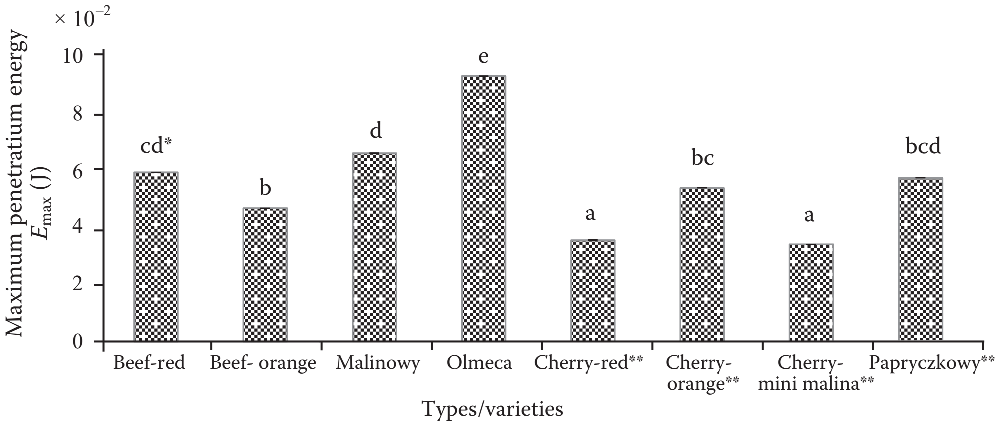


Figure 3. The maximum penetration energy $E_{max}$ in the examined types/varieties of tomatoes

*Values with the same letter in the column do not differ significantly ($P < 0.05$) according to Duncan's test; **small-fruited types and varieties

Ryś (2012) examined the colour of ground tomatoes. They obtained slightly higher values of the *a** parameter, at the level of 22.72–34.01, and the *b** parameter, at the level of 14.53–28.86. According to Ordóñez-Santos et al. (2008), the tomato colour parameters *a** and *b** were at the levels of 9.55–21.09 and 4.91–18.85, respectively. Similar results were obtained in studies by Kacjan Maršić et al. (2011), carried out on oval, oblong and cherry tomatoes. The following values were obtained for the colour parameters: *a** 19.8–26.7, *b** 26.3–29.5, and *L** 42.0–45.5.

The content of dry matter in the tested tomato fruit was from 5.00% ('Beef-red') to 8.82% ('Cherry-orange'), while the total extract was from 4.58% ('Papryczkowy') to 7.83% ('Cherry-orange') (Table 2). The average parameters set for the small-berry types or varieties are noticeably higher (7.01 and 6.00%, respectively) than for large types/varieties (5.92 and 5.23%), respectively. The total acidity of the tested tomato types/varieties was from 0.32 g 100 $g^{-1}$ of fruit 'Beef-red', to 0.61 g 100 $g^{-1}$ of fruit 'Cherry-orange' (Table 2). It was slightly higher in small-berry fruit types/varieties (0.50 g 100 $g^{-1}$) compared to large-fruited types/varieties (0.35 g 100 $g^{-1}$). The pH value was from 4.18 ('Cherry mini-malina') to 4.42 ('Olmeca'). The dry mass of the examined tomatoes, the total extract content and the total acidity determined in this work were similar to those obtained by Abukhovich & Kobryń (2010), respectively: dry mass of 4.97–8.09%, total extract of 2.41–4.36%, total acidity of 0.36–0.50 g 100 $g^{-1}$. Converging results of the dry matter content were also found by Hernández Suárez et al. (2008), from 5.9% to 6.2%. In studies conducted by Zalewska-Korona et al. (2013), the mean dry matter content in tomatoes was 5.95%, the total extract was 4.38% and the average total acidity was 0.3 g 100 $g^{-1}$. The results of total acidity

Table 1. Colour parameters of peel and flesh in tested tomato fruit

| Type/variety | Peel colour | | | Flesh colour | | |
|---|---|---|---|---|---|---|
| | $L_p$ | $a_p$ | $b_p$ | $L_f$ | $a_f$ | $b_f$ |
| 'Beef-red' | 39.25$^{c*}$ | 19.15$^{d}$ | 24.78$^{d}$ | 47.46$^{a}$ | 21.54$^{d}$ | 16.83$^{a}$ |
| 'Beef-orange' | 51.68$^{e}$ | 9.91$^{c}$ | 48.82$^{f}$ | 59.39$^{c}$ | 4.63$^{b}$ | 41.01e |
| 'Malinowy' | 36.48$^{b}$ | 22.09$^{e}$ | 16.50$^{b}$ | 50.57$^{ab}$ | 25.52$^{e}$ | 26.19$^{b}$ |
| 'Olmeca' | 32.88$^{a}$ | 6.14$^{b}$ | 23.63$^{d}$ | 52.65$^{b}$ | 18.16$^{c}$ | 28.60$^{bcd}$ |
| 'Cherry-red'** | 35.32$^{b}$ | 18.06$^{d}$ | 20.90$^{c}$ | 50.88$^{ab}$ | 16.46$^{c}$ | 28.84$^{bcd}$ |
| 'Cherry-orange'** | 44.17$^{d}$ | 2.56$^{a}$ | 36.82e | 58.47$^{c}$ | 1.42$^{a}$ | 31.11$^{d}$ |
| 'Cherry-minimalina'** | 33.94$^{a}$ | 18.61$^{d}$ | 12.65$^{a}$ | 53.09$^{b}$ | 16.66$^{c}$ | 29.53$^{cd}$ |
| 'Papryczkowy'** | 33.13$^{a}$ | 21.22e | 20.19$^{c}$ | 51.14$^{ab}$ | 23.82$^{e}$ | 27.04$^{bc}$ |

*L* – the brightness; *a* – the yellow colour; *b* – the red colour; *values with the same letter in the column do not differ significantly ($P < 0.05$) according to Duncan's test; **small-fruited types and varieties

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Table 2. The selected fruit quality parameters in studied types and varieties of tomatoes

| Type/variety | Dry matter (%) | Total extract (%) | Total acidity (g 100 $g^{-1}$) | pH value | Pectins (g 100 $g^{-1}$) |
|---|---|---|---|---|---|
| 'Beef-red' | 5.00[a*] | 4.63[a] | 0.32[a] | 4.31[e] | 0.39[c] |
| 'Beef-orange' | 5.66[c] | 4.77[a] | 0.38[c] | 4.23[c] | 0.24[a] |
| 'Malinowy' | 5.79[d] | 5.17[b] | 0.38[c] | 4.35[f] | 0.34[b] |
| 'Olmeca' | 7.22[f] | 6.33[c] | 0.34[b] | 4.42[g] | 0.40[c] |
| 'Cherry-red'** | 7.61[g] | 6.17[c] | 0.54[f] | 4.26[d] | 0.40[c] |
| 'Cherry-orange'** | 8.82[h] | 7.83[d] | 0.61[g] | 4.20[b] | 0.55[d] |
| 'Cherry-mini malina'** | 6.16[e] | 5.42[b] | 0.44[e] | 4.18[a] | 0.33[b] |
| 'Papryczkowy' ** | 5.44[b] | 4.58[a] | 0.41[d] | 4.26[d] | 0.40[c] |

*Values with the same letter in the column do not differ significantly ($P < 0.05$) according to Duncan's test; **small-fruited types and varieties

do not differ from the values presented by Gupta et al. (2011), obtained for different tomato genotypes (0.50–0.54 g 100 $g^{-1}$). In addition, convergent values of total acidity and pH to those obtained in this experiment were presented by Mendez et al. (2011) (0.30–0.72 g 100 $g^{-1}$ and pH 3.96–4.75).

The pectin content was from 0.24% ('Beef-orange') to 0.55% ('Cherry-orange') (Table 2). It was found that the content of the tested compound was higher in the fruits of the small-fruited types/varieties, especially 'Cherry-orange', which could be related to the higher ratio of the fruit surface to its mass and the location of the pectin under the fruit peel.

The total polyphenol content of the tested samples ranged from 38.13 mg gallic acid 100 $g^{-1}$ ('Beef-red') to 74.07 mg 100 $g^{-1}$ ('Cherry-red') (Figure 4). Significant differences between the amount of tested compounds in particular types/varieties of tomatoes were observed, as well as their higher content in the finer fruits, indeed. The antioxidant activity (Figure 5), related to the content of the tested antioxidant substances, in the tested types/varieties reached 9.01% ('Beef-red') to 33.79% ('Papryczkowy'). The content of phenolic compounds (38.13–74.07 mg 100$g^{-1}$) wasconsistent with bibliographic information. Hallmann & Rembiałkowska (2007) determined the total polyphenol content in the tomatoes from organic farming and conventional farming at the level of 46.88 and 33.07 mg gallic acid 100 $g^{-1}$, respectively.

Among the biologically active substances contained in the fruit of tomatoes, carotenoids (including lycopene and carotene) deserve attention. The total carotenoid content of the tested tomato types/varieties ranged from 4.26 mg 100 $g^{-1}$ ('Olmeca') to 18.06 mg 100 $g^{-1}$ ('Cherry-red') (Figure 6). The dominant carotenoid was lycopene, constituting 44.4–59.8% of the total carotenoid content, followed by β-carotene in the amount of 11.3–24.4%.

The small-fruited types and varieties tested in this experiment showed significantly higher carotenoid content than large-fruited, traditionally consumed types/varieties, except for 'Cherry-mini malina'. Minor differences were observed in the qualitative composition of carotenoids – the average lycopene and β-carotene content in fruit of small-berried types and varieties was about 7% higher than in case of the large-fruited ones. The highest content of β-carotene has been observed in small-berried tomatoes. According to Garande and Patil (2014), orange-yellow tomatoes have a significantly higher content of this compound compared to red fruits. Our research does not explicitly indicate such regularity. On the other hand, as reported by Veljović et al. (2012), in the fresh fruit there is more lycopene than in the heat treated fruit. Quite the opposite is the case for the antioxidant activity and the total content of phenolic compounds. The content of biologically active compounds increases after thermal treatment (Veljović et al. 2012).

Strong positive correlations ($P < 0,05$) between total polyphenols content and total acidity (0.888), dry matter (0.743) and extract (0.613), as well as between total carotenoids content and total acidity (0.633) and pectin content (0.574) were assessed. Moreover, a strong negative correlation was noted between the total polyphenols content and fruit firmness (–0.651) and between the content of the total extract and the $a_p$ parameter, determining the red colour of the peel (–0.630).

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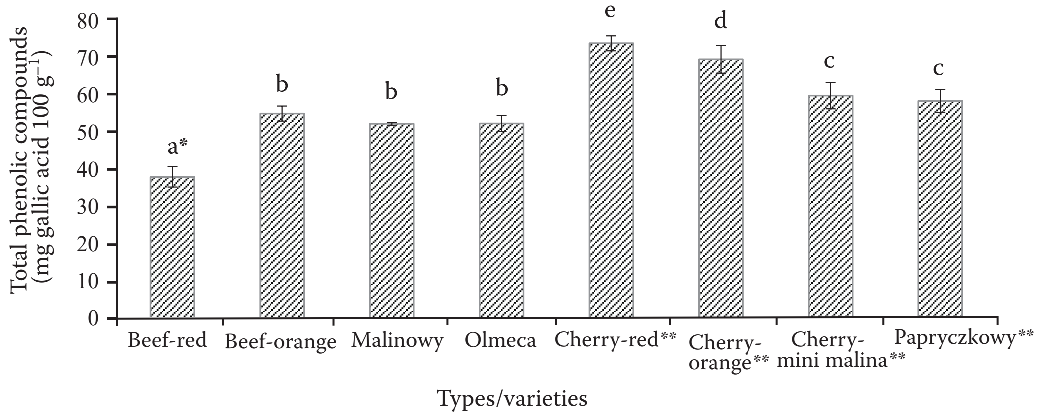


Figure 4. The total polyphenol content in the examined types/varieties of tomatoes

*Values with the same letter in the column do not differ significantly ($P < 0.05$) according to Duncan's test; **small-fruited types and varieties

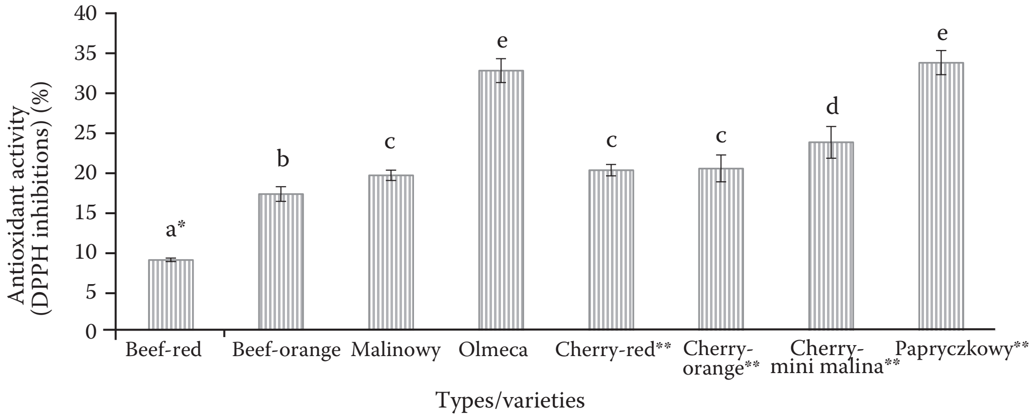


Figure 5. Antioxidant activity of the methanol extracts of the examined types/varieties of tomatoes

*Values with the same letter in the column do not differ significantly ($P < 0.05$) according to Duncan's test; **small-fruited types and varieties

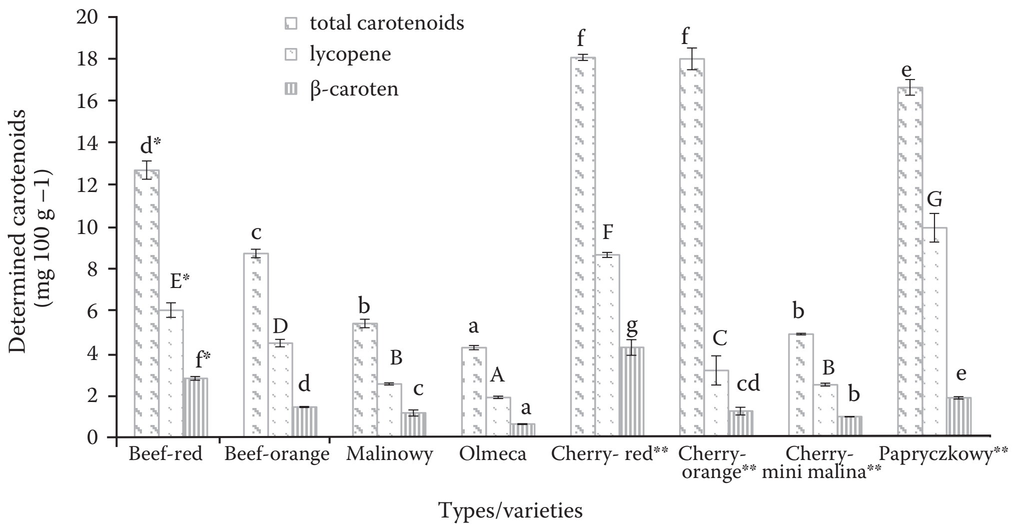


Figure 6. The content of total carotenoids, lycopene and β-caroten in the examined types/varieties of tomatoes

*Values with the same letter in the column do not differ significantly ($P < 0.05$) according to Duncan's test; **small-fruited types and varieties

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## CONCLUSION

The conducted analysis showed that the tested types and varieties of tomatoes were varied in terms of physical properties and chemical composition. It was noticed that small-fruited tomatoes were characterized by lower hardness and firmness compared to medium and large tomatoes. The tested varieties of cherry tomatoes contained significantly higher total phenolic compounds (about 30%) (especially the 'Cherry-red' type), lycopene and β-carotene than medium and large tomatoes. Therefore, in addition to the decorative value, they are of high health value.

**Acknowledgement.** The authors are grateful to MSc. Marta Klisz from University of Warmia and Mazury in Olsztyn, Faculty of Food Science, for technical help in carrying out laboratory tests.

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Received: August 2, 2019
Accepted: December 2, 2019