Acta Sci. Pol. Hortorum Cultus, 18(3) 2019, 117–126

www.acta.media.pl ISSN 1644-0692 e-ISSN 2545-1405 DOI: 10.24326/asphc.2019.3.11

ORIGINAL PAPER

Accepted: 21.09.2018

YIELDING AND FRUIT QUALITY OF SELECTED SWEET CHERRY (*Prunus avium*) CULTIVARS IN THE CONDITIONS OF CENTRAL POLAND

Ewa Szpadzik ✉, Tomasz Krupa, Wojciech Niemiec, Ewa Jadczuk-Tobjasz

Department of Pomology, Warsaw University of Life Sciences, Nowoursynowska 159, 02-776 Warsaw, Poland

ABSTRACT

The study involving 5 cherry cultivars was conducted in 2015–2016. The varieties 'Techlovan', 'Summit', 'Sylvia', 'Kordia' and 'Regina' were planted in 2010 in the Experimental Orchard of the Department of Pomology in Warsaw-Wilanów on GiSelA5 rootstock. The aim of the study was to evaluate the production value and dessert fruit quality as well as health proprieties of the tested cultivars' fruits and select the most valuable ones. It was shown that the varieties differed in fruit set and yielding as well as fruit quality (i.e. fruit size, firmness, soluble solid content, acidity) and health benefits (i.e. polyphenol, anthocyanin, and ascorbic acid content). 'Techlovan' trees had the lowest yield, but their fruits were of high quality. 'Kordia' and 'Regina' also provided high quality fruit with high total polyphenol content. In contrast, the 'Sylvia' cultivar had a high yield, but the fruit obtained from it was of poor quality. All tested cultivars had similar vitamin C content.

Key words: *Prunus avium*, yield, polyphenols, anthocyanins, ascorbic acid, health proprieties

INTRODUCTION

The sweet cherry is an important and very valuable orchard species. It is one of the most popular spring-summer fruits across the temperate regions of Europe, highly appreciated by consumers [Ballistreri et al. 2013]. In the last 20 years, dynamic changes in the fruit production of this species have been observed. New varieties appeared – both early and late maturing – and modern, intensive cultivation techniques were implemented [Schuster et al. 2014]. However, as researchers emphasize, currently the production of sweet cherries should prioritize not the quantity, but the quality of the fruit, since this is the main factor – besides yield regularity – that determines the profitability of growing sweet cherries [Błaszczyńska 2012]. The unique properties of sweet cherries, such as sweet taste, attractive color, size, shape and general appearance, influence the consumer acceptance of these fruits and lead to increased demand for them [Serrano et al. 2005, Serradilla et al. 2010, Martínez-Esplá et al. 2014]. Due to this, their production is constantly growing. The demand for high-quality cherries is still greater than the supply – both on global and European markets [Błaszczyńska 2012, Lech et al. 2012, Sen et al. 2014].

Apart from the above-listed features, health-promoting properties are also of great importance to consumers. There is a view in relevant literature that cherry fruit consumption is associated with beneficial effects on human health [Kim et al. 2005, Kosar et

✉ ewa_szpadzik@sggw.pl

al. 2005, Ferretti et al. 2010]. It has been proven that eating sweet cherries reduces the incidence of many diseases. The health-promoting properties of the fruits are related to their strong antioxidant effects [Majhenic et al. 2007, Mulabagal et al. 2009, Faniadis et al. 2010, Yoo et al. 2010, Hussain et al. 2011, Prvulović et al. 2011]. These antioxidant effects of cherries are related to the presence of phenolic compounds in the fruit, the major anthocyanins being cyanidin-3-glucoside and cyanidin-3-rutinoside, while peonidin-3-rutinoside and pelargonidin-3-rutinoside are the minor anthocyanins [Burkhardt et al. 2001, Serra et al. 2011, Ballistreri et al. 2013, Duarte and Silva 2014]. These compounds have been shown to have anti-cancer and anti-inflammatory effects – they reduce the risk of degenerative diseases caused by oxidative stress, such as cancer, cardiovascular disease and stroke [Harakotr et al. 2014, Gonçalves et al. 2017]. However, the antioxidant capacity of cherries depends largely on the cultivar as well as on the climate and conditions, in which the fruits were grown [Usenik et al. 2008, Picariello et al. 2016].

Production of very large, high-quality sweet cherry fruit in the countries of Northern Europe and in Poland is difficult, mainly due to lower insolation, intense precipitation (mostly in summer), shorter growing season compared to countries with warmer climate as well as problems with pollination, occurring partly due to the large number of inter-sterile groups – there are 26 such groups [Schuster et al. 2007]. It is very important to determine which cultivars are the most valuable for Polish region in terms of good yield, high quality fruit characteristics and the beneficial health properties of fruit grown and cultivated in this region.

Many studies have reported on the physical properties of sweet cherries (mainly fruit mass, weight and color) as well as their chemical and nutritional properties [Serrano et al. 2005, Faniadis et al. 2010, Usenik et al. 2010, Liu et al. 2011, Serra et al. 2011]. However, in the available literature, there is little information about the chemical composition or antioxidant properties of sweet cherries grown specifically in Poland. Those issues are investigated in research from countries such as Turkey, Pakistan and the United States, but that research is mainly concerned with cultivars grown there [Liu et al. 2011, Mahmood et al. 2013. 2013, Sen et al. 2014].

The objective of this study was to compare a few sweet cherry cultivars in terms of their production value, dessert fruit quality and nutraceutical content, and consequently identify the most valuable varieties. These varieties will then also serve as starting points for further research into the improvement of cherry quality in the climatic and soil conditions of central Poland.

MATERIAL AND METHODS

The plant material for this research consisted of five cherry (*Punusavium*) cultivars: 'Techlovan' (Czech Republic), 'Summit' (Canada), 'Sylvia' (Canada), 'Kordia' (Czech Republic) and 'Regina' (Germany). The cherry trees were planted in 2010 in the area of the Experimental Orchard of the Pomology Department in Warsaw-Wilanów on GiSelA5 rootstock. The trees grew on GiSelA 5 rootstock in 4 × 2 m spacing in 4 replications, 3 trees in each replication. All tests were carried out in 2015 and 2016.

Meteorological conditions during testing. Both research seasons were characterized by fairly favorable weather conditions in terms of fruit setting and yielding cherry trees (Tab. 1). In general, 2016 was a cooler year compared to 2015. In both seasons, winter was mild with a small amount of snowfall. In the first three months, significantly higher temperatures were recorded in 2015 compared to 2016. Over the next three months, temperatures in the following years were similar. In 2015, the amount of rainfall in April was higher than in 2016. There were no dangerous spring frosts in both years.

Evaluation of the production value of the varieties. Before the harvest, the number of fruits setting from open pollination was counted from 100 previously counted flowers, then the percentage of fruit set for each cultivar was calculated.

Yielding was recorded from each tree and was converted into a kg/tree ratio.

Research on fruit quality. Twenty fruits with stalks were taken at random from each replication of all the varieties in order to evaluate fruit quality factors – in total 80 fruits of each variety were used (20 fruits × 4 replications).

Fruit size was measured using a fruit scoop. The results are given in mm.

Average fruit weight was measured on an Ohaus TP 200 analytical balance – the results are given in grams.

Soluble solid content (SSC) was measured according to the Polish standard PN-EN 012143: 2000 in juice squeezed from 20 fruits per replication. The SSC was determined using an Atago PR-32 digital refractometer. The results are given in Brix degrees.

Fruit firmness was determined as the value of the force needed to deform the fruit by 3 mm. The markings were made with an Instron Type 5542 tester. A 3 mm diameter plug and 500 N head were used for these markings. The markings were made twice on each fruit, i.e. in the horizontal and vertical plane. The resulting fruit firmness is given in newtons.

Total (titration) acidity of the fruit was determined with a TitroLine by titration with a solution of sodium hydroxide – 0.1 M NaOH. The analyte was 25 ml of extract from 40 g of fruit pulp. Knowing the dilution and normality of the test fluid, the acidity was determined and malic acid concentration was estimated. The results are given as a percentage of malic acid in the fruit, assuming that 1 ml of 0.1 M NaOH binds to 6.7 mg of malic acid.

Analysis of phenolic compounds. Phenolic compounds were separated using the HPLC technique described by Gao and Mazza [1994]. Analysis of the separation and contents of phenolic compounds was performed using a Perkin-Elmer 200 series HPLC kit with a Diode Array Detector (DAD). The separation was carried out using a LiChroCART® 125-3 (Merck KGaA) column with a 1 ml/min flow rate. The column temperature was 22°C. The mobile phase consisted of a water (A) : 20% formic acid (B) : acetonitrile (C) mixture at various concentration gradients. Phenolic compounds were detected at 280, 300, 320, and 360 nm wavelengths by comparing retention times on achieved chromatograms with standard ones. Contents of particular compounds was given in mg/100 g f.w.

Qualitative and quantitative analysis of anthocyanins. An aliquot of 10 g was taken from 100 g of homogenized fruit, and then extracted for 30 min with 25 mL methanol acidified with 1 mL 36% HCl. The mixture was centrifuged in an Eppendorf 4250 centrifuge at 14 000 × g, and the supernatant was collected.

The identification and quantitative analysis of anthocyanins was performed by means of a Perkin-Elmer series 200 HPLC with a Diode Array Detector (UV-DAD), using a LiChroCART® 125-3 (Merck KGaA) column with a 1.0 mL/min flow-rate and detection at 520 nm. The mobile phase was water (A) : 20% formic acid (B) : acetonitrile (C) mixture. The anthocyanins were identified on the basis of a standard and the results were given in mg/100 g f.w.

Ascorbic acid content (vitamin C). Vitamin C content was determined using an HPLC technique. Vitamin C was extracted from the fruit with a mixture of 1% meta-phosphoric and 1% perchloric acids.

The sample obtained from the extraction was purified using a sintered glass crucible. The identification and quantitative analysis of vitamin C was performed with a liquid chromatograph (Waters) equipped with a UV/VIS detector. The separation was performed using a Symmetry C18 column, 5μm, 150 × 4.6 mm, with a 0.8 ml/min flow-rate, detection at 245 nm as well as at the 550 nm wavelength to verify the peak purity. The column temperature was adjusted to 25°C. The mobile phase consisted of a water : ammonia phosphate : meta-phosphoric acid mixture. Vitamin C content results are presented as ascorbic acid (TAA) content in mg/100 g fresh weight (f.w.).

Result analysis method. Data collected during the research period were statistically developed using a one-way analysis of variance. To compare the averages, the Tukey group test was used with $\alpha = 0.05$ significance level.

RESULTS

Fruit set and yielding of tested varieties. Two-year observations showed that the ‘Techlovan’ cultivar had the least fruit set compared to the others – less than 10% (Tab. 2). The variety with the highest percentage of fruits set was ‘Sylvia’ (about 27% in 2015 and above 30% in 2016). Fruit setting in general was higher in 2016.

Research further showed that the ‘Techlovan’ cultivar also had the lowest yield (Tab. 1). In 2015, the highest yield was harvested from the ‘Sylvia’ trees (about 13 kg/tree). However, in the subsequent research season, cultivars ‘Sylvia’, ‘Kordia’ and ‘Regina’ yielded similar amounts of fruits (about 16−19 kg/tree). The yield of the ‘Summit’ cultivar was comparable to the other varieties.

Table 1. Monthly temperature (°C) and precipitation (mm) in 2015 and 2016 years

Month	Temperature (°C)		Precipitation (mm)	
	2015	2016	2015	2016
January	1.8	–3.5	48	22
February	0.9	–2.7	12	23
March	5.3	2.6	35	25
April	8.4	8.3	42	33
May	13.0	13.5	54	53
June	16.5	16.7	32	67
July	21.4	19.2	54	71
August	23.6	17.4	10	58
September	15.0	13.3	85	43
October	7.1	8.5	31	35
November	4.9	3.1	49	39
December	3.7	–1.1	14	32
Average	10.1	8.0	39.0	41.8

Table 2. Fruit set (%) and yielding ($kg \cdot tree^{-1}$) depending on the cultivar in the years 2015–2016

Cultivar	Fruit set (%)		Yielding ($kg \cdot tree^{-1}$)	
	2015	2016	2015	2016
Techlovan	9.4 a	9.8 a	7.8 a	9.2 a
Summit	18.6 c	26.2 c	10.1 b	13.5 ab
Sylvia	27.1 d	33.1 d	13.0 c	16.1 b
Kordia	14.7 b	20,0 b	9,0 ab	18.1 b
Regina	12.3 b	28,0 c	9.2 ab	19.5 b

Values marked with the same letter are not significantly different within the column

Table 3. Fruit quality depending on the cultivar in the years 2015–2016

Cultivar	Size of fruit (mm)		Average mass of fruit (g)		Firmness (N)		SSC (°Brix)		Acidity (%)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Techlovan	30.0 b	28.4 b	12.45 c	9.73 b	8.0 c	8.0 a	18.55 b	19.66 b	0.65 c	0.74 c
Summit	29.0 b	28.1 b	11.47 bc	9.37 b	6.2 ab	7.8 a	17.00 a	19.00 b	0.58 b	0.66 b
Sylvia	27.6 a	26.6 a	9.37 a	7.77 a	5.7 a	7.0 a	17.47 ab	17.36 a	0.43 a	0.50 a
Kordia	29.3 b	30.0 c	11.32 bc	10.1 b	7,0 b	7.8 a	18.37 b	17.06 a	0.67 bc	0.58 ab
Regina	29,0 ab	28.3 b	11.5 bc	9.12 b	8.7 c	8.1 a	17.58 ab	16.76 a	0.53 b	0.45 a

Values marked with the same letter are not significantly different within the column

Fruit quality. Research showed that the varieties differed in terms of fruit quality. Throughout the research period, 'Sylvia' had smaller fruits compared to other tested cultivars, both in terms of size and weight (Tab. 3).

In the first year of research, 'Sylvia' fruits had the lowest firmness, while high firmness was observed in 'Techlovan' and 'Regina' fruits. But in the second year, the varieties did not differ statistically in terms of this feature.

In both years of research, however, differences were found among the examined varieties with respect to soluble solid content (SSC). In 2015, the 'Summit' cultivar had lower SSC compared to 'Techlovan' and 'Kordia'. The SSC of 'Sylvia' and 'Regina' fruits was similar to that of the other cultivars. In 2016, 'Techlovan' and 'Summit' fruits did not differ in soluble solid content, but they had more extract (about 2°Brix higher content) than 'Sylvia', 'Kordia' and 'Regina' fruits.

As for acidity, 'Sylvia' had the lowest percentage of malic acid content and 'Techlovan' had the highest in 2015. In the second research season, 'Sylvia', 'Kordia' and 'Regina' had comparable acidity (about 0.5%), while 'Techlovan' fruits were distinguished by the highest percentage of malic acid (above 0.7%) – similar to the previous year.

Total polyphenol content. Research showed that variety determined the polyphenol content (Fig. 1). Two cultivars – 'Summit' and 'Sylvia' – had low polyphenol content (about 40 mg · 100 g f.w.$^{-1}$) compared to others. However, in 2016, the total polyphenol content of 'Sylvia' fruits was only slightly lower compared to 'Kordia', 'Regina' and 'Techlovan'. The polyphenol content of 'Kordia', 'Regina' and 'Techlovan' fruits was well above 50 mg · 100 g f.w.$^{-1}$ throughout the two-year research period.

Cyanidin-3-rutinoside. In 2015, the cultivar did not affect the cyanidin-3-rutinoside content of studied cherry fruits (Fig. 2). The average value was about 18 mg · 100 g f.w.$^{-1}$. The influence of the cultivar on the discussed factor was visible in the second research season. In 2016, cultivars 'Kordia' and 'Regina' had significantly higher cyanidin-3-rutinoside content relative to other cultivars – in that year their fruits contained almost twice as much of this anthocyanin. It was also found that fruits of the two above-mentioned varieties were richer in cyanidin-3-rutinoside in 2016 compared to the first research season.

Cyanidin-3-galactoside. Statistical analysis showed that the variety influenced the cyanidin-3-galactoside content (Fig. 3). In the first year of research, the variety with the lowest amount of this component was 'Sylvia', whereas the highest level of cyanidin-3-galactoside was found in the 'Kordia' cultivar fruits. However, this data was not duplicated in 2016, when 'Summit' had lower cyanidin-3-galactoside content than 'Kordia' but also lower than 'Sylvia' and 'Regina'.

Peonidyno-3-rutinoside. In the first research season, no differences were observed in peonidine-3-rutinoside content (Fig. 4). The level of this component

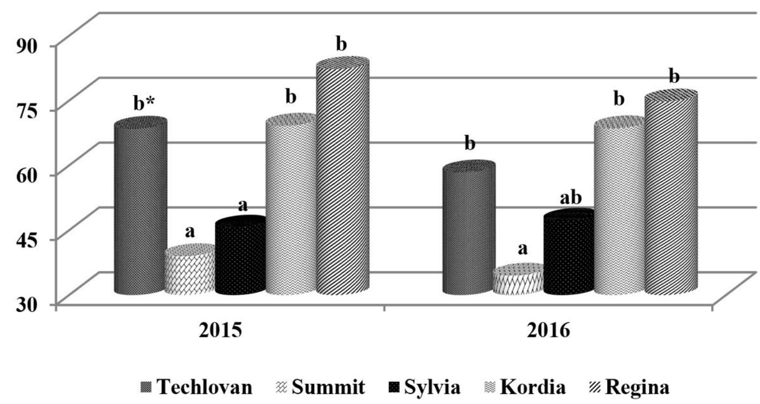

Fig. 1. Total polyphenol content depending on the cultivar in the years 2015–2016 (g f.w.$^{-1}$). Values marked with the same letter are not significantly different within the year

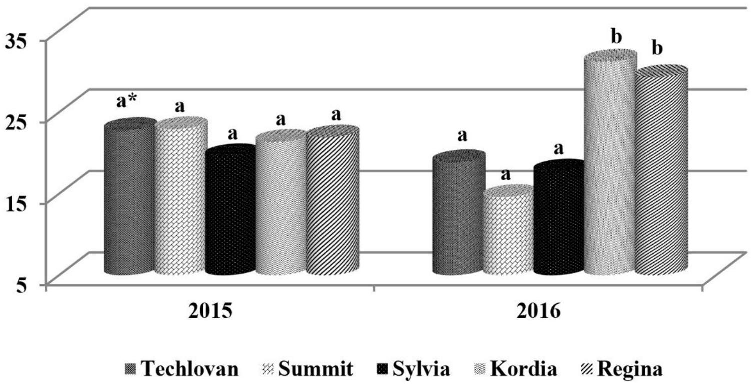

Fig. 2. Cyjanidin-3-rutinoside content depending on the cultivar in the years 2015–2016 (g f.w.$^{-1}$). Values marked with the same letter are not significantly different within the year

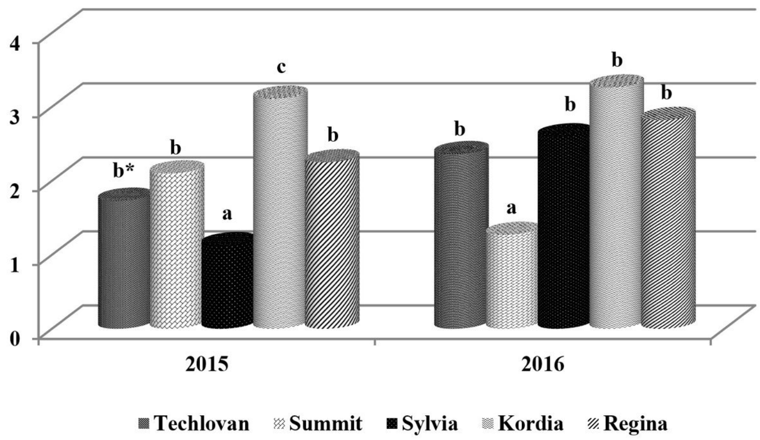

Fig. 3. Cyjanidin-3-galactoside content depending on the cultivar in the years 2015–2016 (g f.w.$^{-1}$). Values marked with the same letter are not significantly different within the year

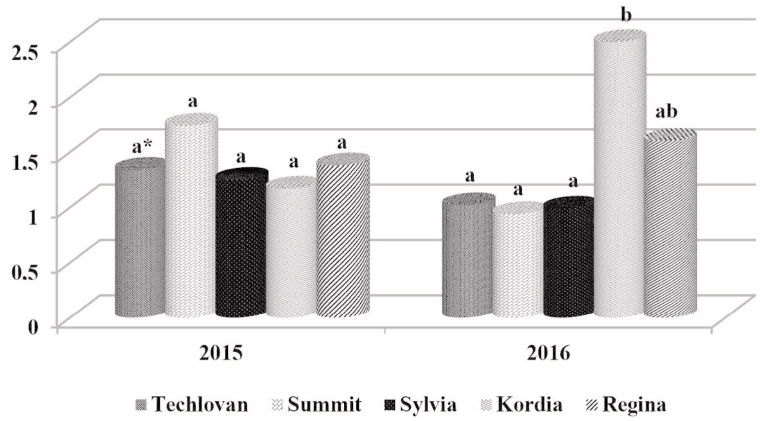

Fig. 4. Peonidyno-3-rutinoside content depending on the cultivar in the years 2015–2016 (g f.w.$^{-1}$). Values marked with the same letter are not significantly different within the year

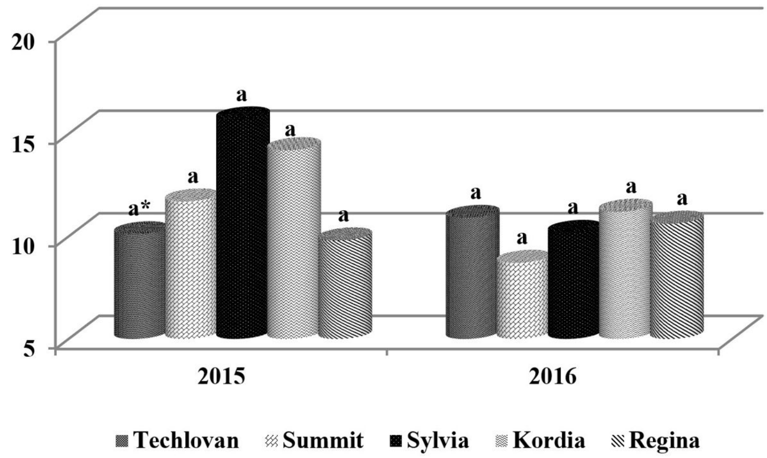

Fig. 5. Vitamin C content depending on the cultivar in the years 2015–2016 (g f.w.$^{-1}$). Values marked with the same letter are not significantly different within the year

was above 1 mg · 100 g f.w.$^{-1}$ in all tested cultivars. However, in the second research season, a significantly higher peonidino-3-rutinoside content was observed in 'Kordia' compared to 'Techlovan', 'Summit' and 'Sylvia' – the amount found in 'Kordia' fruits was over two times higher than in the mentioned cultivars.

Vitamin C content. Research showed that the tested varieties did not differ in terms of vitamin C content (Fig. 5). In the first year of research, the content of ascorbic acid in fruits of studied cultivars ranged from about 10 mg · 100 g f.w.$^{-1}$ in 'Regina' to about 16 mg · 100 g f.w.$^{-1}$ in 'Techlovan'. A year later, the average vitamin C content in the fruits of tested cultivars was lower than in the first year of research and ranged from about 9 mg · 100 g f.w.$^{-1}$ in 'Summit' to slightly above 11 mg · 100 g f.w.$^{-1}$ in 'Kordia'.

DISCUSSION

There are many factors affecting the fruit set and yielding as well as broadly understood fruit quality. These include, among others: genetic features of the variety, rootstock, growing conditions, weather conditions – in winter and in spring as well as during fruit growth – the flowering process and agrotechnical treatments.

The available literature suggests that a satisfactory yield of cherries can be obtained when about 20–30% of flowers set fruits. The fruit set depends, to a large extent, on the course of flowering and temperature conditions [Wociór and Leśniak 1996, Cittadini et al. 2006, Lech et al. 2008].

In 2016, fruit set was generally better than in 2015. It is difficult to explain this fact considering that both seasons were characterized by similar weather conditions, and 2015 was even warmer than 2016. However, what is important, meteorological conditions during the flowering period in 2016 were more conducive to pollination and fertilization of flowers. Despite of similar temperature values, the blooming period, falling in the second half of April, was less conducive to setting fruit in 2015 than the second season, among others because of the rainfall. In 2016, four cultivars – 'Summit', 'Sylvia', 'Kordia' and 'Regina' – set about 20–30% of fruits. In the first year of research, only 'Sylvia set over 20% of fruits.

The problem of fruit quality is widely discussed in scientific literature. Quality is of key importance especially in fruits intended for fresh consumption. It also affects the economic value of a given variety. One of the most important features that consumers pay attention to when choosing cherries is their size. It is known that large fruits are more often chosen by consumers than small fruits. Cultivars with large fruits have very high market value [Bieniek et al. 2011]. The dominant opinion in the literature is that the varieties studied in this project have large fruits, although it mainly refers to their mass [Schoedl et al. 2009, Błaszczyńska 2012, Głowacka and Rozpara 2014, Milinović et al. 2016]. The results obtained seem to only partially confirm this opinion. It was found that 'Sylvia' was characterized by rather small fruits – both in terms of weight and size. Similar results regarding this variety were also obtained by Usenik et al. [2015], as well as Gjamovski et al. [2016]. The remaining varieties had large fruits, which confirms findings of the abovementioned researchers.

In this research project, the tested varieties also differed in terms of firmness, extract content and titratable acidity. These differences were also visible between fruits harvested in different research years. These parameters have been discussed in the scientific literature, among others by Poll and Petersen [2003], Schoedl et al. [2009], Hajagos et al. [2012], Gjamovski et al. [2016]. In these experiments, it was stated that extract content in the fruits, as well as their acidity, is modified by meteorological conditions during fruit maturation. High temperature and insolation increase the sugar synthesis in fruits. The authors also note that it is well known that the amount of organic acids in fruits decreases as they ripen. Unripe fruits have more acids, fewer extracts and fewer anthocyanins than ripe fruits. The soil conditions also have significant influence on these characteristics.

Consumers are increasingly appreciating fruits not only for their taste but also for their health benefits. The content of individual phenolic compounds as well as anthocyanins and vitamin C may be different in fruits of various cherry cultivars, which further depends on many different factors (i.e. genotype, rootstock, cultivation method, availability of water and minerals, degree of maturity as well as atmospheric conditions – mainly light and temperature) [Gonçalves et al. 2004, Faniadis et al. 2008, Prvulović et al. 2011, Popescu et al. 2014]. Researchers agree that the antioxidant activity of the sweet cherry may be affected by several factors, such as maturity at harvest, genetic differences and pre-harvest environmental conditions [Prior et al. 1998, Dragovic-Uzelac et al. 2007, Mirdehghan and Rahemi 2007]. Therefore, it is difficult to clearly compare the results obtained in this study to those reported by researchers working in other climatic regions and different agrotechnical conditions.

According to Polish literature, vitamin C content in sweet cherries is on average 5–10 mg% [Rozpara 1999, Sitarek 2004]. Results obtained in this study basically confirm these reports. But, as mentioned by Ballisteri [2013], genetic factors may modulate the composition and concentration of phytochemicals.

CONCLUSIONS

'Sylvia' trees yield the most, although this cultivar's fruits are the smallest. Furthermore, this variety does not seem very attractive in terms of quality characteristics and is unlikely to gain much recognition among consumers.

The 'Techlovan' cultivar has high fruit quality – fruist are even impressive in size and weight, have adequate firmness and soluble solid content. However, fruit set and yields leave much to be desired. Further research is needed to solve this problem.

The 'Summit' variety is very interesting, with its large and nice fruits of appropriate quality. Its good yielding is also worthy of attention.

The 'Kordia' and 'Regina' cultivars are characterized by high fruit quality, but their yield may be poor if the weather conditions are unfavorable during blooming time.

'Techlovan', 'Kordia' and 'Regina' have high total polyphenol content, while the amount of this component in 'Summit' and 'Sylvia' fruits is rather low.

In terms of anthocyanin content, the 'Kordia' and 'Regina' cultivars are worthy of attention. Their fruits were the most abundant in anthocyanins, but the results were not statistically proven in all research years.

All tested varieties have similar vitamin C content. None of them is distinctive in this respect.

Further investigations are needed to evaluate the impact of the environment and other factors, such as climate, soil characteristics and cultivation techniques, as well as to confirm obtained results.

ACKNOWLEDGMENTS

The research was funded by the statutory funds of Warsaw University of Life Sciences, Department of Pomology.

REFERENCES

Ballistreri, G., Continella, A., Gentile, A., Amenta, M., Fabroni, S., Rapisarda, P. (2013). Fruit quality and bioactive compounds relevant to human health of sweet cherry (*Prunus avium* L.) cultivars grown in Italy. Food Chem., 140, 630–638.

Bieniek, A., Kawecki, Z., Kopytowski, J., Zielenkiewicz, J. (2011). Yielding and fruit quality of Lithuanian sweet cherry cultivars grown under the climatic and soil conditions of Warmia. Folia Hort., 23(2), 101–106.

Błaszczyńska, B. (2012). Uprawa czereśni. Hortpress, Warszawa, 431 pp.

Burkhardt, S., Tan, D.X., Manchester, L.C., Hardeland, R., Reiter, R.J. (2001). Detection and quantification of the antioxidant melatonin in Montmorency and Balaton tart cherries (*Prunus cerasus*). J. Agric. Food Chem., 49, 4898–4902.

Cittadini, E.D., Ridder, N., Peri, P.L., Keulen, H. (2006). A method for assessing frost damage risk in sweet cherry orchards of South Patagonia. Agric. For. Meteorol., 141(2), 235–243.

Duarte, A.P., Silva, B.M. (2014). Nutritional and phytochemical potential of *Prunus avium* L. In: Natural products. Research reviews, Gupta, V.K. (ed.), vol. 4. M/S Daya Publishing House, Nova Delhi, 185–202.

Dragovic-Uzelac, V., Levaj, B., Mrkic, V., Bursac, D., Boras, M. (2007). The content of polyphenols and carotenoids in three apricot cultivars depending on stage of maturity and geographical region. Food Chem., 102, 966–975.

Faniadis, D., Drogoudi, P.D., Vasilakakis, M. (2008). Effects of cultivar, orchard elevation, and storage on fruit quality characters of sweet cherry (*Prunus avium* L.). Sci. Hortic., 125, 301–304.

Faniadis, D., Drogoudi, P.D., Vasilakakis, M., (2010). Effects of cultivar, orchard elevation, and storage on fruit quality characters of sweet cherry (*Prunus avium* L.). Sci. Hortic., 125, 301–304.

Ferretti, G., Bacchetti, T., Belleggia, A., Neri, D. (2010). Cherry antioxidants: from farm to table. Molecules, 15, 6993–7005.

Gao, L., Mazza, G. (1994). Quantitation and distribution of simple and acylted anthocyanins and other phenolic in blueberries. J. Food Sci., 57, 1057–1059.

Gjamovski, V., Kiprijanovski, M., Arsov, T. (2016). Evaluation of some cherry varieties grafted on Gisela 5 rootstock. Turk. J. Agric. For., 40, 737–745.

Głowacka, A., Rozpara, E. (2014). Examination of the suitability of different pollinators for four sweet cherry cultivars commonly grown in Poland. J. Hort. Res., 22(1), 85–91.

Gonçalves, B., Landbo, A.K., Knudsen, D., Silva, A.P., Moutinho-Pereira, J., Rosa, E., Meyer, A.S. (2004). Effect of ripeness and postharvest storage on the phenolic profiles of cherries (*Prunus avium* L.). J. Agric. Food Chem., 52(1), 523–530.

Gonçalves, A.C., Bento, C., Silva, B.M., Silva, L. R. (2017). Sweet cherries from Fundão possess antidiabetic potential and protect human erythrocytes against oxidative damage. Food Res. Int., 95, 91–100.

Hajagos, A., Modl, P., Spornberger, A., Végvári, G. (2012). The effect of rootstocks on the development of fruit quality parameters of some sweet cherry (*Prunus avium*L.) cultivars, 'Regina' and 'Kordia', during the ripening process. Acta Univ. Sapien. Agric. Environ., 4, 59–70.

Harakotr, B., Suriharn, B., Tangwongchai, R., Scott, M.P., Lertrat, K., (2014). Anthocyanins and antioxidant activity in coloured waxy corn at different maturation stages. J. Funct. Foods, 9, 109–118.

Hussain, A.I., Anwar, F., Iqbal, T., Bhatti, I.A.. (2011). Antioxidant attributes of four Lamiaceae essential oils. Pak. J. Bot., 43(2), 1315–1321.

Kim, D.O., Heo, H.J., Kim, Y.J., Yang, H.S., Lee, C.Y. (2005). Sweet and sour cherry phenolics and their protective effects on neuronal cells. J. Agric. Food Chem., 53, 9921–9927.

Kosar, M., Kafkas, E. Paydas, S., Baser, K.H.C. (2005). Phenolic composition of strawberry genotypes at different maturation stages. J. Agric. Food Chem., 52, 1586–1589.

Lech, W., Małodobry, M., Dziedzic, E., Bieniasz, M., Doniec, S. (2008). Biology of sweet cherry flowering. J. Fruit Ornam. Plant Res., 16, 189–199.

Lech, W., Doniec, S., Małodobry, M., Dziedzic, E. (2012). Problemy z zapylaniem czereśni i propozycje doboru zapylaczy. In: Czynniki wpływające na plonowanie i jakość owoców roślin sadowniczych, Tomala K. (red.). Plantpress, Warszawa, (14), 107–115.

Liu, Y., Liu, X., Zhong, F., Tian, R., Zhang, K., Zhang, X. (2011). Comparative study of phenolic compounds and antioxidant activity in different species of cherries. J. Food Sci., 76, 633–638.

Mahmood, T., Anwar, F., Bhatti, I.A., Iqbal, T. (2013). Effect of maturity on proximate composition, phenolics and antioxidant attributes of cherry fruit. Pak. J. Bot., 45(3), 909–914.

Majhenic, L., Skerget, M., Knez, Z. (2007). Antioxidant and antimicrobial activity of guarana seed extracts. Food Chem., 104, 1258–1268.

Martínez-Esplá, A., Zapata, P.J., Valero, D., Garcia-Viguera, C., Castillo, S., Serrano, M., (2014). Preharvest application of oxalic acid increased fruit size, bioactive compounds, and antioxidant capacity in sweet cherry cultivars (*Prunus avium* L.). J. Agric. Food Chem., 62, 3432–3437.

Milinović, B., Dragović-Uzelac, V., Kazija, D.H, Jelačić, T., Vujević, P., Čiček, D., Biško, A., Čmelik, Z. (2016). Influence of four different rootstocks on phenolic acids and anthocyanin composition of sweet cherry (*Prunus avium* L.) cvs. 'Kordia' and 'Regina'. J. Appl. Bot. Food Qual., 89, 29–37.

Mirdehghan, S.H., Rahemi, M. (2007). Seasonal changes of mineral nutrients and phenolics in pomegranate (*Punica granatum* L.) fruit. Sci. Hortic., 111, 120–127.

Mulabagal, V., Lang, G.A., DeWitt, D.L., Dalavoy, S.S., Nair, M.G. (2009). Anthocyanin content, lipid peroxidation and cyclooxygenase enzyme inhibitory activities of sweet and sour cherries. J. Agric. Food Chem., 57, 1239–1246.

Picariello, G., De Vito, V., Ferranti, P., Paolucci, M., Volpe, M.G. (2016). Species- and cultivardependent traits of Prunus avium and Prunus cerasus polyphenols. J. Food Compos. Anal., 40, 50–57.

Poll, L., Petersen, M.B. (2003). Influence on harvest year and harvest time on soluble solids, titrateable acid, anthocyanin content and aroma components in sour cherry (*Prunus cerasus* L. cv. "Stevnsbær"). Eur. Food Res. Technol., 216, 212–216.

Popescu, S., Velciov, A.B., Rivis, A., Costescu, C., Petolescu, C. (2014). Antioxidant activity and phenolic content of sweet cherries (*Prunus avium* L.) from west and south west of Romania. Bul. UASVM Food Sci. Technol., 71(2), 215–217.

Prior, R.L., Cao, G., Martin, A., Sofic, E., McEwen, J., O′Brien, C., Lischner, N., Ehlenfeldt, M., Kalt, W., Krewer, G. (1998). Antioxidant capacity as influenced by total phenolic and anthocyanin content, maturity, and variety of Vaccinium species. J. Agric. Food Chem., 46(7), 2686–2693.

Prvulović, D., Malenčić, D., Popović, M., Ljubojević, M., Ognjanov, V. (2011). Antioxidant properities of sweet cherries (*Prunus avium* L.) – role of phenolic compounds. Int. J. Biol. Biom. Agric. Food Biotech. Engineer., 5(11), 676–679.

Rozpara, E. (1999). Nowoczesna uprawa czereśni. Hortpress, Warszawa.

Schoedl, K., Denk, A., Hummelbrunner, S., Modl, P., Forneck, A. (2009). No improvement in fruit quality through chemical flower thinning in sweet cherry (*Prunus avium* L.). J. Sci. Food Agric., 89, 1236–1240.

Schuster, M., Flachowsky, H., Köhler, D. (2007). Determination of self-incompatible genotypes in sweet cherry (*Prunus avium* L.) accessions and cultivars of the German Fruit Gene Bank and from private collections. Plant Breed., 126, 533–540.

Schuster, M., Gfare, C., Wolfram, B. (2014). New results of sour cherry breeding in Germany. Acta Hortic., 1020, 71–75.

Sen, F., Oksar, R.E., Golkarian, M., Yaldiz, S. (2014). Quality changes of different sweet cherry cultivars at various stages of the supply chain. Not. Bot. Hort. Agrobot. Cluj-Napoca, 42(2), 501–506.

Serra, A.T., Duarte, R.O., Bronze, M.R., Duarte, C.M.M. (2011). Identification of bioactive response in traditional cherries from Portugal. Food Chem., 125, 318–325.

Serradilla, M.J., Martín, A., Hernandez, A., López-Corrales, M., Lozano, M., Guía Córdoba, M. (2010). Effect of the commercial ripening stage and postharvest storage on microbial and aroma changes of 'Ambrunés' sweet cherries. J. Agric. Food Chem., 58, 9157–9163.

Serrano, M., Guillén, F., Martínez-Romero, D., Castillo, S., Valero, D. (2005). Chemical constituents and antioxidant activity of sweet cherry at different ripening stages. J. Agric. Food Chem., 53, 2741–2745.

Sitarek, M. (2004). Uprawa czereśni karłowych. Plantpress, Kraków.

Usenik, V., Fabćić, J., Štampar, F. (2008). Sugars, oganic acids, phenolic composition and antioxidant activity of sweet cherry (*Prunus avium* L.). Food Chem., 107, 185–192.

Usenik, V., Fajt, N., Mikulic-Petkovsek, M., Slatnar, A., Stampar, F., Veberic, R. (2010). Sweet cherry pomological and biochemical characteristics influenced by rootstock. J. Agric. Food Chem., 58, 4928–4933.

Usenik, V., Stampar, F., Mikulic Petkovesk, M., Kastelec, D. (2015). The effect of fruit size and fruit colour on chemical composition in 'Kordia' sweet cherry (*Prunus avium* L.). J. Food Comp. Analysis, 38, 121–130.

Wociór, S., Leśniak, A. (1996). Wpływ pogody w czasie kwitnienia na zapylenie i owocowanie wiśni odmiany Łutówka. Roczn. Nauk Roln. ser. A, 112(1–2), 155–165.

Yoo, K.M., Al-Farsi, M., Lee, H., Yoon, H., Lee, C.Y. (2010). Antiproliferative effects of cherry juice and wine in Chinese hamster lung fibroblast cells and their phenolic constituents and antioxidants activities. Food Chem., 123, 734–740.