Acta Sci. Pol. Hortorum Cultus, 18(2) 2019, 251–262

www.acta.media.pl ISSN 1644-0692 e-ISSN 2545-1405 DOI: 10.24326/asphc.2019.2.22

ORYGINAL PAPER Accepted: 15.04.2019

DETERMINATION OF PHYSICAL AND CHEMICAL PROPERTIES OF CORNELIAN CHERRY (*Cornus mas* L.) FRUITS DEPENDING ON DEGREE OF RIPENING AND ECOTYPES

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ABSTRACT

Cornelian cherry in Poland belongs to the alternative fruit species. The fruits are suitable for fresh consumption, however they can be used for processing: juice, jams, jellies, syrups, tinctures. Fruits are abundant in mineral elements, vitamin C, organic acids, iridoids, anthocyanins and due to that they have health-promoting significance. In this experiment, the fruit quality of several 16-year-old ecotypes in the Lublin region was compared. They were compared in terms of the beginning of fruit ripening and fruit size (length, diameter, mass), fruit shape index, share of stone in the fruit, SSC, TA, SSC/TA, reducing sugar, dry matter content and anthocyanins content. The color of fruit was evaluated in two dates, visually and using HanterLab spectrophotometer. Cornelian cherry fruits began to mature at the beginning of August and at the latest at the end of August. With the increase of the maturity degree, the SSC, reducing sugars, TA, dry matter and anthocyanins increased significantly. There was no difference in the taste of light red fruits and dark red fruits, which were characterized by similar ratio of SSC/TA. Ecotype No. 11, as the earliest maturing, with big round fruits, dark red colored with the highest content of anthocyanins, could be distinguished. As well as ecotypes No. 4 and 5, ripening in mid-August, and having a high ratio of SSC/TA, providing a good taste. Studied ecotypes could be used in breeding programs to incorporate a wide range of quality and agronomic characteristics into a final cornelian cherry cultivar.

Key words: fruit quality, fruit color, fruit taste

INTRODUCTION

Cornelian cherry (*Cornus mas* L.) belongs to the family of dogwoods (*Cornaceae*). It is a tree or shrub reaching the size of 3−8 m, combining the features of a fruit and ornamental plant. Larger clusters of these plants can be found in the Aegean Sea, Mediterranean Sea and the Black Sea and in north-eastern Anatolia, Turkey. Cornelian cherry came to Poland at the turn of the 18th and 19th century as a plant willingly planted at the manor house [Bijelić et al. 2011]. The climatic conditions in Poland are favorable for the proper growth and yielding of this long-lived plant. Even the early flowering period does not limit the quantity of the cornelian cherry yield [Piórecki 2007]. After the end of the juvenile period, the length of which depends on the method of reproduction (3–8 years), cornelian cherry fruiting occurs regularly and every year more abundantly. From one shrub, depending on the age, 15–20 kg of fruit can be

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obtained (5–10 years old shrubs), 50–80 kg (15–20 years old shrubs) [Klymenko 2004]. Cornelian cherry is a cross-pollinated plant, thus it requires the presence of another cultivar for good fruiting. Each variety, as well as seedlings, can be used as a pollinator for all the others. The period of ripening and harvesting of fruit is dependent on weather conditions (temperature and precipitation), as well as cultivar [Piórecki 2007]. The great advantage of cornelian cherry is the possibility of using the fruit at various stages of maturity. Green cornelian cherry fruits can be used for curing like olive fruit [Kucharska et al. 2011]. Large, not fully mature, still without a blush fruits are selected for making the "Polish olives". While the red, hard fruits, but not yet falling from the tree, will be perfect for candies. At this stage, the stone can be easily separated from the flesh using olive pitting equipment. For making juices [Cornea et al. 2016], tinctures, jams and pestil (a type of dried marmalade), only fully ripe fruits are suitable; they can also be frozen [Gasik and Mitek 2008]. Cornelian cherry fruits can also be used for natural acidification of fruit products, due to the high content of organic acids [Nawirska-Oszmiańska et al. 2011]. In addition, due to the high content of pectin, it can be combined with fruits such as strawberries, to improve the structure of jam or marmalade [Rop et al. 2010]. In Poland, cornelian cherry fruits are used mainly by amateurs for the production of tinctures. Tincture from cornelian cherry fruits is a long-ripening product, because alcohol extracts active compounds from the fruit only after 3 months. With time, the tincture acquires a caramel aftertaste, but not almond, which is characteristic for tinctures from other stone fruits such as cherries and apricots [Kucharska 2012]. There are no toxic cyanogenic compounds in cornus seeds, hence tinctures and compotes from cornelian cherry can be made from whole fruits for a long time [Kucharska et al. 2009].

The fruits of cornelian cherry are very valuable because of their health-promoting properties. In folk medicine, cornelian cherry is used as an anti-bacterial, anti-hemorrhagic agent, reducing fever and strengthening. Scientific research confirms beneficial properties that result from the unique chemical composition of fruits. Cornelian cherry fruits are distinguished by the content of iridoid [Kucharska et al. 2015], especially loganic acid, which has therapeutic activity e.g. in the treatment of autoimmune disorders and inflammation, reduces intraocular pressure in the eye, prevents atherosclerosis and hypertriglyceridemia, reduces the level of cholesterol, is indicated in the prevention of civilization diseases, such like diabetes, obesity and cancer [Sozański et al. 2018]. In Yamabe et al. [2010] study, there was also an influence of loganin on the reduction of kidney damage caused by diabetes. In addition to the aforementioned ingredients, cornelian cherry fruits also contain vitamin C [Kostecka et al. 2017], potassium, calcium, phosphorus, magnesium, iron and zinc [Pantelidis et al. 2007].

The aim of this work was to examine how the physical and chemical properties of cornelian cherry fruits change depending on the degree of their maturity, among eleven ecotypes growing in the conditions of south-eastern Poland.

MATERIAL AND METHODS

The experiment was established in a private collection in Dąbrowica, near Lublin (22.454 N; 51.270 E) in Poland in 2014. Values of minimum, maximum, average temperature and rainfall in 2014 are given in Table 1.

The experimental material consisted of 16-year-old ecotypes of cornelian cherry (seedlings) No. 1, 2, 3, 4, 5, 6, 7, 10, 11, 14, 15. The trees were planted on the southern slope East-West, in 2.5 m distance. No chemical spraying was used to protect trees from diseases and pests, and no irrigation. At the beginning of August, agrotextile was laid under the plants to prevent the ripe fruit from falling. Coverage area of the crowns of individual ecotypes awarded with slats to prevent mixing of fruit.

Pomological analyses. In order to determine the dynamics of fruit growth, on July 18, July 30 and August 30, an assessment was made of the diameter and length of fruits growing on the tree (50 fruits from each ecotype). Fruit shape index was calculated according to the formula $I = lenght^2/width^2$ [Jaćimović and Božović 2014].

On July 30 and August 30, 50 fruits from each ecotype were taken and the weight of a single fruit mass of the stone, and the flesh/stone ratio was also calculated.

Table 1. Temperature and sums of rainfall during experimental period in 2014

Month	Minimum air temperature (°C)	Maximum air temperature (°C)	Mean air temperature (°C)	Many-year (1951–2012) averages (°C)	Precipitation (mm)	Many-year (1951–2012) sum (mm)
I	–18.9 (25 I)	8.5 (9 I)	–3.0	–3.7	67.83	23.4
II	–12.3 (1 II)	9.6 (18 II)	1.2	–2.8	14.73	25.8
III	–2.9 (9 III)	20.1 (21 III)	6.0	1.0	47.76	28.0
IV	–2.3 (2 IV)	22.7 (23 IV)	9.7	7.4	50.30	39.0
V	–0.2 (5 V)	26.5 (24 V)	13.4	13.0	242.83	60.7
VI	5.8 (24 VI)	29.2 (9 VI)	15.6	16.3	62.74	65.9
VII	9.0 (2 VII)	30.4 (29 VII)	20.2	18.0	87.37	82.0
VIII	6.8 (22 VIII)	32.8 (4 VIII)	17.8	17.2	93.21	70.7
IX	2.3 (24 IX)	25.3 (12 IX)	14.1	12.6	30.74	53.7
X	–3.4 (27 X)	22.2 (9 X)	9.1	7.6	23.62	40.1
XI	–7.3 (30 XI)	18.6 (6 XI)	4.2	2.6	22.85	38.2
XII	–17.1 (30 XII)	10.4 (19 XII)	0.1	–1.6	52.08	31.4
Annual mean	–	–	9.0	7.3	796.06	558.9
Average for vegetative season (III–X)	–	–	14.2	13.1	590.0	412.1

Color measurement. On July 30, a visual assessment of the color of skin for individual ecotypes was made. On July 30 and August 30, 25 fruits from each ecotype were taken and subjected to color analysis by HunterLab colorimetric spectrophotometer. On August 30, 300 fruits (from the middle parts of the crowns) were taken from each ecotype randomly. Additionally, among the whole pool (without taking into account ecotypes), 15 fruits with a specific maturity degree corresponding to a 7-point bonitation scale were distinguished: 7-point bonitation scale for fruit color: 1 – green fruit, 2 – yellow-green fruit, 3 – yellow-red fruit; 4 – red-yellow fruit; 5 – light red glossy fruit; 6 – dark red fruit; 7 – overripe matte red fruit.

Cornelian cherry fruit skin colors, in every degree of maturity, were measured with a portable HunterLab colorimetric spectrophotometer and recorded as Commission Internationale d-Eclairage (CIE) color space coordinates: L^*, a^* and b^*, *Chroma* and *Hue.* The L^* values are the aspect that is most commonly used to indicate the lightness, where 0 is black and 100 is white. The color parameter a^* represents the color changes from negative values (green) to positive values (red). The b^* value represents the color changes from blue (negative) to yellow (positive).

Chemical analyses. From the 30 August, collected fruit from each ecotype, 50 green fruits (G), 50 light red fruits (LR) and 50 dark red fruits (DR) were selected. They were used for chemical analyses, specifying: soluble solids content (SSC), acidity (TA), sugar content, dry matter and anthocyanins (only LR and DR):

− weight of fruit and seeds (g) – using a laboratory scale;

– soluble solids content (SSC) in %Brix – using the Abbe refractometer at 20°C;

– titratable acidity (TA) was determined in % potentiometrically by titrating diluted juice samples to pH 8.1 by 0.01 N NaOH;

– SSC/TA ratio was obtained by dividing data of soluble solids content by the titratable acidity;

– reducing sugar content (%) was measured according to Luff Schoorl Method [Official Methods of Analysis of AOAC International 1995];

– dry matter content (%) – using the oven-drying method.

Total anthocyanin content was estimated spectrophotometrically [Cheng and Breen 1991]. Total anthocyanins were expressed as mg of cyanidine-3-glucoside equivalents per 100 g of fresh pomace.

Statistical analysis. All analyse results were processed using STATISTICA for Windows 5.5A software and statistical differences significances were tested by the HSD Tukey's test.

RESULTS AND DISCUSSION

Typical shapes of the cornelian cherry fruit are: oval, spherical, pear-like and bottle-like. Most cultivars from Bolestraszyce are characterized by pear-like shape of fruit: 'Bolestraszycki', 'Dublany', 'Kresowiak', 'Paczoski' and 'Szafer' [Kucharska et al. 2011]. Generally, among the cultivars, there is a high repeatability of shapes. In the present experiment, the fruit diameter between the first and the second measurement period (within 12 days) increased by 1.45 mm, and within the subsequent 30 days – by 2 mm (Tab. 2). In July, the fruit diameter of most ecotypes exceeded 9 mm, and only fruits of ecotype No. 2 had a diameter of 8.38 mm. At the end of July, all ecotypes had fruit with a diameter above 10 mm, in addition to the ecotype No. 1 (9.98 mm). On August 30, fruits of most ecotypes reached a diameter of 12 mm, in addition to the ecotype No. 6 (11.95 mm). The largest diameter in all examined periods characterized the fruits of ecotype No. 11. In the mentioned periods, the fruits grew less than the width (after 12 days by about 1 mm, and after 30 days by about 1.48 mm). From the beginning of measurements, ecotypes No. 1 and 11 were characterized by the longest fruits, while fruits of ecotype No. 2 were generally the shortest. The weight of fruits in particular dates of measurements was close correlated with their length and diameter (Tab. 3).

Table 2. Fruit width, fruit length and fruit shape index of individual cornelian cherry ecotypes in 3 term of measurements: July 18, July 30 and August 30

Ecotypes No.	Fruit width (mm)			Fruit length (mm)			Fruit shape index (mm)		
	July 18	July 30	August 30	July 18	July 30	August 30	July 18	July 30	August 30
1	9.88 cd	9.98 a	12.94 c–e	14.70 f	14.78 cd	16.65 f	2.24 e	2.19 e	1.67 d
2	8.37 a	10.32 a–c	12.48 a–d	11.82 a	13.24 ab	14.86 a	2.03 b–e	1.65 bc	1.42 ab
3	9.20 bc	10.01 ab	12.60 a–d	13.56 e	14.01 bc	15.18 ab	2.20 de	2.0 e	1.47 a–c
4	10.02 d	12.14 d	13.55 ef	13.36 de	14.95 d	16.03 c–e	1.79 a	1.52 ab	1.41 ab
5	9.22 bc	10.05 ab	12.75 b–d	12.79 b–d	13.17 a	15.50 a–c	1.94 a–c	1.74 cd	1.49 a–c
6	9.08 ab	10.20 ab	11.95 a	12.94 c–e	13.63 a–c	14.97 a	2.04 b–e	1.79 de	1.57 cd
7	9.04 ab	10.13 ab	13.18 de	12.15 ab	13.36 ab	15.76 b–d	1.81 ab	1.74 cd	1.44 a–c
10	9.82 cd	12.18 d	12.18 ab	14.28 f	16.42 e	16.49 ef	2.15 c–e	1.83 de	1.83 e
11	10.83 e	14.22 e	14.24 f	14.54 f	16.56 e	16.66 f	1.82 ab	1.36 a	1.36 a
14	9.04 ab	10.44 bc	12.22 a–c	12.70 b–d	13.35 ab	15.12 ab	1.99 a–d	1.65 bc	1.55 cd
15	9.20 bc	10.00 ab	13.59 ef	13.18 de	13.52 ab	16.06 c–e	2.10 c–e	1.84 de	1.40 a

Within columns, different letters indicate significant differences at $P < 0.05$

Table 3. Correlation coefficient (r) fruit width, length and weight in individual term of measurements

		Fruit width			Fruit length			Fruit weight	
		July 18	July 30	August 30	July 18	July 30	August 30	July 30	August 30
Fruit width	July 18	100	–0.15*	–0.03	0.72*	–0.07	0.07	–0.15*	–0.10
	July 30	–0.15*	100	0.09	–0.26*	0.78*	–0.07	0.92*	0.00
	August 30	–0.03	0.09	100	–0.06	0.01	0.71*	0.05	0.62*
Fruit length	July 18	0.72*	–0.26*	–0.06	100	–0.16*	0.14	–0.24*	–0.06
	July 30	–0.07	0.78*	0.01	–0.16*	100	–0.07	0.83*	–0.05
	August 30	0.07	–0.07	0.71*	0.14	–0.07	100	–0.07	0.46*
Fruit weight	July 30	–0.15*	0.92*	0.05	–0.24*	0.83*	–0.07	100	–0.01
	August 30	–0.10	–0.00	0.62*	–0.06	–0.05	0.46*	–0.01	100

Correlation marked with * are statistically significant at the P < 0.05

Table 4. Fruit weight, stone weight and flesh/stone ratio of individual cornelian cherry ecotypes on July 30 and August 30

Ecotypes No.	Fruit weight (g)		Stone weight (g)		Share of stone in the fruit	
	July 30	August 30	July 30	August 30	July 30	August 30
1	0.842 a	1.87 a–c	0.194 cd	0.194 c	23.50 d	10.93 b–e
2	0.980 a	1.68 a	0.165 a–d	0.170 ab	17.43 bc	10.25 a–d
3	0.959 a	1.71 ab	0.196 d	0.185 bc	21.23 cd	11.66 c–e
4	1.420 b	2.04 cd	0.183 a–d	0.187 bc	13.14 ab	10.01 a–d
5	0.880 a	1.80 a–c	0152 a	0.153 a	17.67	9.01 ab
6	0.929 a	1.75 ab	0.167a–d	0.163 a	18.29 b–d	9.59 a–c
7	0.896 a	1.87 a–c	0.190 b–d	0.186 bc	21.62 cd	10.31 a–d
10	1.530 b	1.63 a	0.164 a–c	0.150 a	11.27 a	9.48 ab
11	2.330 c	2.34 d	0.238 e	0.186 bc	10.67 a	8.0 a
14	0.930 a	1.61 a	0.176 a–d	0.195 c	19.53 cd	12.46 e
15	0.910 a	2.02 cd	0.175 a–d	0.169 ab	20.97 cd	8.62 a

Within columns, different letters indicate significant differences at P < 0.05

Cornelian cherry fruits can be more or less elongated, as indicated by the ratio of the length to the width of the fruit. The larger this parameter, the more longer the fruit. At the beginning of measurements (July 18), cornelian cherry fruits were more elongated than in subsequent measurement dates (Tab. 2). This is due to the faster rate of diameter increase than fruit length. The fruits of ecotype No. 1 in all dates of measurements were distinguished by the largest fruit shape ratio, but in the last period (30 August), the highest rate characterized the ecotype No. 10. However, the lowest fruit shape ratio, especially on July 30 and August 30, was marked by the ecotype No. 11.

Another very important physical parameter when evaluating the cornelian cherry fruit is the share of the stone in the fruit. This is particularly important for the industry, that is interested in the largest share in the flesh of the fruit and the least mass of waste during production. In the present studies, the share of stone in the fruit decreased from 17.6% to 11.0% during the month (from 30 July to 30 August). This was caused by the fact that the average mass of the stone on August 30 slightly decreased, whereas the average fruit weight increased from 1.15 to 1.85 g (Tab. 4). The smallest share of stone in the fruit was characterized by ripe fruits of ecotypes No. 11 and 15 (8.0% and 8.62%). However, the highest values of this feature were recorded for ecotypes No. 14 (12.46). The cornelian cherry fruit of the Bolestraszyce cultivars were characterized by larger share of stone in the fruit, reaching even 15.87% and 15.67% in the case of cultivars ‘Kresowiak’ and ‘Bolestraszycki’ [Kucharska 2011]. The lowest values of the mentioned feature were characterized by the fruits of cv. ‘Podolski’. In the fruits of ecotypes from Montenegro [Jaćimowić and Božović 2014], the share of stone in fruits fluctuated from 10.07 to 20.22%. The fruit of cultivars with a high flesh/stone ratio may be a secondary raw material, e.g. for obtaining oil abundant in unsaturated fatty acids [Kucharska et al. 2019].

Important characteristics defining the consumer and processing usefulness of a given variety, apart from physical parameters, such as the size of the edible part, are chemical properties. The soluble solids content (SSC) is one of the important chemical parameters on the basis of which the suitability of the raw material for processing is assessed. Cornelian cherry, in comparison with other fruits, is characterized by high SSC. According to Pantelidis et al. (2007), cornelian cherry fruits had the highest SSC (14.4%), as compared with gooseberries, red currants, blackberries, and raspberries. Kucharska et al. [2011], assessing Polish edible cornelian cherry cultivars, noted that they contained 16.3% of the SSC, on average. In Slovenian studies [Vidrih et al. 2012] the average content of SSC of the tested ecotypes was 14.1%, in Turkish fruits [Güleryüz et al. 1998] 14.5%, in fruits from Montenegro [Jaćimović and Božović 2014] – 16.7%, in Bosnia and Herzegovina [Drkenda et al. 2014] – 16.9%, in Serbian cornelian cherry [Bijelić et al. 2011] – 22.6%. In the present experiment, the content of SSC increased significantly with the degree of fruit ripening from average 11.45% in green fruits to average 18.19% in dark red fruits (Tab. 6). The content of the SSC in some fruits is closely positively correlated with the feeling of sweetness and richness of taste [Magwaza and Opara 2015]. Among studied ecotypes (Tab. 5), the highest level of SSC was found in the case of ecotypes No. 4, 6 5 and 14 (respectively: 19.8, 19.4, 19.1 i 19.1%). According to Kappel et al. [1996], the minimum SSC for sweet cherries should be above 17%. In this experiment, all ecotypes had DR fruits with SSC above 17%. The fruit taste also determines the SSC/TA ratio, because it is a measure of balance between sugars and acid. The higher its value, the fruits are more suitable for fresh consumption and are considered dessert fruits. In the present experiment, the acid content significantly increased with the degree of maturity, while the SSC/TA of LR and DR fruits was at a similar level. In the studies of Gunduz et al. [2013], the acid content decreased with the degree of acidity, and the ratio of SSC/TA increased. At full maturity, fruits in this experiment were characterized by a higher content of SSC and TA and a lower ratio of SSC/TA (18.1%, 2.71% and 6.76% respectively) compared to Turkish (16.5%, 2.0% and 8.4%, respectively). The ratio of SSC/TA on a similar level to that of the Turkish cornelian cherry reached the DR fruits of ecotypes 4 and 5 (8.20 and 8.27%).

Table 5. Some chemical properties of cornelian cherry fruits in dependence of ecotypes and degree of maturity

Feature	Degree of maturity	No of ecotype										
		1	2	3	4	5	6	7	10	11	14	15
SSC (%)	G	10.91 a–c	12.38 cd	12.05 b–d	10.73 ab	10.99 a–c	10.46 a	12.22 b–d	12.65 d	10.97 a–c	11.14 a–d	11.43 a–d
	LR	14.68 ab	13.93 a	14.24 ab	13.24 a	13.37 a	15.15 a–c	16.11 b–d	16.92 cd	17.12 d	17.43 d	14.11
	DR	17.11 a	17.88 a–c	17.62 a	19.84 d	19.18 cd	19.44 d	17.27 a	17.20 a	17.78 a–c	19.10 b–d	17.63
TA (%)	G	1.95 d	1.76 c	1.60 ab	1.64 b	1.59 a	1.98 d	2.15 f	2.15 f	2.04 e	2.18 f	2.05 e
	LR	2.37 f	2.38 f	1.94 b	2.08 c	1.74 a	2.59 h	2.30 e	2.27 de	2.28 e	2.48 g	2.24 d
	DR	2.59 c	2.64 c	2.72 d	2.42 b	2.32 a	2.91 f	2.72 d	2.89 f	2.77 de	3.00 g	2.81 e
SSC/TA	G	5.60 a	7.0, cd	7.60 d	6.53 bc	6.86 cd	5.29 a	5.69 a	5.88 ab	5.38 a	5.12 a	5.57 a
	LR	6.20 ab	5.86 a	7.33 c	6.37 ab	7.68 c	5.84 a	7.01 bc	7.44 c	7.52 c	7.03 bc	6.29 ab
	DR	6.61 b	6.77 b	6.48 ab	8.20 c	8.27 c	6.67 b	6.35 ab	5.95 a	6.41 ab	6.37 ab	6.27 ab
Reducing sugar (%)	G	5.29 b	5.81 c	7.18 e	5.34 bc	5.47 bc	5.41 bc	6.45 d	6.45 d	5.44 bc	5.72 bc	2.05 a
	LR	6.71 a	8.24 de	8.84 gh	7.94 cd	7.5 b	8.38 ef	8.95 h	8.18 de	6.86 a	7.79 bc	8.57 fg
	DR	11.14 bc	11.85 c	11.03 bc	13.59 d	14.12 d	11.31 bc	10.71 a–c	9.44 a	10.24 ab	11.00 bc	10.48 ab
Dry matter (%)	G	17.17 ab	18.12 ab	16.43 ab	17.36 ab	19.26 b	16.39 ab	18.19 ab	16.77 ab	14.97 a	17.14 ab	17.26 ab
	LR	19.90 ab	21.39 bc	22.11 c	18.97 a	22.08 c	18.53 a	19.10 a	18.98 a	19.53 a	20.22 ab	20.31 a–c
	DR	22.64 a–c	22.86 a–c	22.56 a–c	22.66 a–c	24.66 c	21.11 a	22.92 a–c	21.49 a	23.84 bc	23.67 bc	22.53 a–c
Anthocyanin (mg cyaniding––3–glucose equivalents 100 g^{-1} f.w.)	LR	16.3 g	11.3 cd	11.3 cd	9.2 ab	11.7 d	7.8 a	18.7 h	12.7 de	9.8 bc	14.3 ef	15.3 fg
	DR	98.7 a	120.0 c	140.0 d	98.0 a	250.0 e	103.3 ab	106.7 b	110.0 b	290.0 f	110.0 b	120.0 c

G – green fruit; LR – light red fruit; DR – red fruit
Within rows, different letters indicate significant differences at P < 0.05

Table 6. Mean of chemical characteristics of cornelian cherry fruits in different degree of maturity

Degree of fruit maturity	SSC (%)	TA (%)	SSC/TA	Reducing sugar (%)	Dry matter	Anthocyanin (mg cyaniding-3-glucose equivalents 100 g^{-1} f.w.)
G*	11.45 a	1.92 a	6.05 a	5.94 a	17.30 a	–
LR	15.12 b	2.24 b	6.78 b	8.00 b	20.01 b	12.6 a
DR	18.19 c	2.71 c	6.76 b	11.36 c	22.76 c	140.6 b

G – green fruit, LR – light red fruit, DR – red fruit
Within column, different letters indicate significant differences at P < 0.05

Table 7. Reference of individual stages of maturity on the bonitation scale (1−7) of the color of cornelian cherry fruit to a value of *L**, *a**, *b**, *Chroma* and *Hue*

Fruit color (scale 1–7)	*L**	*a**	*b**	*Chroma*	*Hue*
1	47.01 e	7.66 a	56.88 e	62.05 c	81.20 f
2	52.97 f	22.71 b	48.99 d	49.61 ab	66.71 e
3	44.80 e	24.56 b	42.45 d	48.16 ab	61.93 e
4	35.70 d	37.04 c	41.78 d	55.98 b–d	48.62 d
5	16.77 c	53.85 e	33.88 c	63.74 d	31.96 e
6	10.00 b	50.87 d	18.81 b	54.31 bc	20.32 b
7	2.93 a	41.41 c	2.67 a	41.50 a	3.63 a

Point bonitation scale for fruit color: 1 – green fruit, 2 – yellow-green fruit, 3 – yellow-red fruit, 4 – red-yellow fruit, 5 – light red glossy fruit, 6 – dark red fruit, 7 – overripe matte red fruit

Table 8. Skin color values *L**, *a**, *b**, *Chroma* and *Hue* and visual assesment of fruit color of individual cornelian cherry ecotypes on July 30

Ecotypes No.	*L**	*a**	*b**	*Chroma*	*Hue*	Visual assesment of fruit colour
1	51.10 b–d*	12.56 a	53.77 cd	55.58 bc	77.11 ef	light yellow
2	48.62 bc	18.25 ab	54.84 d	57.91 bc	71.73 c–f	light yellow
3	47.15 ab	22.28 bc	55.46 d	60.28 c	68.88 cd	light yellow
4	52.84 cd	12.48 a	55.64 d	57.19 bc	77.62 f	green
5	47.52 ab	20.77 a–c	55.12 d	59.11 bc	69.53 c–e	light yellow
6	49.84 b–d	13,31 a	52.96 cd	55.03 b	76.38 d–f	green
7	43.24 a	22.47 bc	51.61 c	56.43 bc	66.64 bc	green, some with blush
10	61.56 e	28.45 c	45.69 b	54.79 b	58.67 b	light yellow, some with blush
11	53.42 d	45.35 d	38.10 a	60.06 c	41.00 a	yellow, 40% fruits with blush
14	48.19 b	18.38 ab	54.16 cd	57.64 bc	71.55 c–f	green, some with blush
15	59.0 e	15.54 ab	46.11 b	48.68 a	71.23 c–f	light yellow, some with blush
Mean	51.13	20.89	51.22	56.61	68.21	

Within columns, different letters indicate significant differences at $P < 0.05$

According to Kucharska et al. [2011], reducing sugars constitute the main part (90%) of sugars contained in the cornelian cherry fruits. The greatest amount of reducing sugars contained the fruit of the cv. ‘Szafer’ (14.7%), and the least cv. ‘Florianka’ (9.9%). In the present experiment the content of reducing sugars increased with a degree of maturity from 5.94% in green fruits to 11.3% in DR fruit (Tab. 6). Among ripe fruits, the most reducing sugars were found in the case of ecotype No. 5 and 4 (14.1 and 13.5%), while the lowest in ecotype No. 4 – the least (9.44%). Along with the increase in fruit maturity, the content of dry matter increased significantly: from 20.0% in green fruits to 22.7% in DR. The fruits of ecotype No. 5 were distinguished by the highest values of the mentioned characteristic at each fruit ripening degree. In Klymenko [2004] studies, the dry matter content ranged from 20.1% (‘Wydubieckij’) to 24.0% (‘Radost’). The dry matter content in fruit, in addition to genetic traits, may also depend on growing conditions, cultural and technical treatments [Sochor et al. 2014].

Table 9. Skin color values *L**, *a**, *b**, *Chroma* and *Hue* of individual cornelian cherry ecotypes on August 30 and the date of the first fruit fall

Ecotypes No.	*L**	*a**	*b**	*Chroma*	*Hue*	First ripe fruit fall
1	36.92 f	36.21 ab	44.64 d	61.15 c	54.09 a	August 22
2	25.72 b–d	39.78 ab	29.10 b	55.54 bc	42.88 a	August 13
3	25.77 b–d	37.32 ab	29.21 b	53.83 b	38.41 a	August 29
4	26.49 c–e	35.77 ab	30.59 b	53.20 b	40.04 a	August 13
5	21.48 a	27.04 a	22.00 a	40.06 a	96.08 b	August 13
6	29.30 e	47.55 b	27.49 b	52.78 b	38.25 a	August 7
7	28.13 de	38.51 ab	30.65 b	55.09 b	42.83 a	August 13
10	29.15 e	37.20 ab	39.08 c	57.84 bc	47.69 a	August 7
11	22.70 ab	43.04 b	29.23 b	57.15 bc	36.24 a	August 4
14	24.43 a–c	37.83 ab	28.73 b	53.81 b	52.42 a	August 14
15	29.26 e	33.87 ab	29.66 b	53.37 b	40.37 a	August 13
Mean	27.21	37.55	26.53	54.03	56.21	

Within columns, different letters indicate significant differences at $P < 0.05$

The content of anthocyanin increases with the degree of cornelian cherry fruit ripeness from the light yellow to dark red fruit stage [Gunduz et al. 2013]. These changes result from the decomposition of chlorophyll and synthesis of anthocyanins in mature fruits. The color of cornelian cherry is varied from yellow, pink, through red to almost black, which depends on the concentration of anthocyanins [Klymenko 2004]. According to Kucharska et al. [2011], dark red fruits contain anthocyanins above 100 mg/100 g. In the present experiment, almost all ecotypes at full RF maturity stage contained more anthocyanins. Only ecotypes No. 1 and 4 had 98.7 and 98.0 mg cyaniding-3-glucose equivalents 100 g^{-1} f.w. Most anthocyanins were found in fruits of ecotype No. 11. In the present study, the amount of anthocyanins ranged from 98.0 to 290.0 mg cyaniding-3-glucose equivalents 100 g^{-1} f.w. and this is in agreement with the results published by Cetkovska et al. [2015], in which fruits of 'Jolico' had 61.0 and 'Ruzyňskŷ' 253.8 mg·kg^{-1} and Pantelidis et al. [2007], in which fruits of 'Vermio' had 223.0 mg cyaniding-3-glucose equivalents 100 g^{-1} f.w.

Color is the basic distinguishing feature of fruit quality. Cornelian cherry fruits change color from green, through yellow-green, yellow-red, red-yellow, light-red, dark-red and finally red, as they ripen (Tab. 7). It can be determined using the bonitation scale, as well as measuring devices. Hunter *L**, *a**, *b** color space is a 3-dimensional rectangular color space based on Opponent-Colors Theory.

There is a need for standardization to improve the traceability and transferability of measurements [Panthar et al. 2013]. In the present experiment, it was found that with the increase of the maturity degree, values of *b** and *Hue* decreased, while values of *a** increased (Tab. 7). Fruits in the yellow-green and yellow-red stages did not differ in terms of the values of *a**, *b**, *Chroma* and *Hue*, and only the *L** values were much higher at the stage when fruits started turning yellow rather than the yellow-red stage. In the last stage of maturity, overripe matte red fruit, in most cases the fruits, were characterized by a clear change in all values in relation to the values obtained at earlier stages, in addition to values similar to the red yellow fruit stage. This may be due to the change in the structure of both the skin and the flesh consisting in a large decrease in the hardness of the fruit and the matting of the skin. In the light red glossy fruit (5), fruits were hard and clearly shiny. In dark red fruit (6), the fruits became dark red and slightly dull, while in the overripe stage matte red fruit (7), the fruits were clearly lighter and matte. A brighter feeling of red in the last degree of dogwood fruit ripeness underlines the decrease in *a** and *Chroma*, while a very large decrease in the **L*, *b**, and *Hue* values can be explained by the matting of the skin. The color assessment of cornelian cherry fruit made on July 30 (Tab. 8) indicates that the average values of *L**, *a**, *b**, *Chroma* and *Hue* were on the levels 51.13, 20.89, 51.22, 56.61 and 68.21, respectively, which is closest to the corresponding values in stage 2 (yellow-green) 52.97, 22.71, 48.99, 49.61 and 66.71 (Tab. 5). This is also confirmed by visual assessment of the coloring of fruit made on July 30 (Tab. 6), on the basis of which most ecotypes had the light yellow or light yellow with some blush (ecotype No. 1, 2, 3, 4, 10 and 15). The fruit of ecotype No. 11, the maturity stage of which was visually defined: "yellow 40% fruits with blush", were characterized by the highest *a** and *Chroma* values (45.35 and 60.06) and the lowest *b** (38.10), which corresponds to values between stages 4 and 5 (red yellow fruit and light red gloss fruit).

On August 30, when the next color assessment was carried out, the fruits of most ecotypes started fruit drop from 17 days (No. 2, 4, 5, 8, 14 and 15). The fruits of ecotype No. 11 and 10 were harvested from 26 and 23 days (Tab. 8). However, the fruits of ecotype No. 1 and 3 began to mature at the latest, only on August 22. In the second period of fruit color determination, the highest values of *a** (43.04) characterized fruits of the earliest ripening ecotype No. 11 (Tab. 9). On the other hand, fruits of the latest ripening ecotype No. 1 were distinguished by the values of *L** (36.92), *b** (44.64) and *Chroma* (61.15). Small differences in *Hue* between ecotypes testify to a similar shade of color. Only ecotype No. 5 was distinguished by significantly higher *Hue* values. Palonen and Weber [2019] studying fruit color in raspberry genotypes stated that concentration of anthocyanins were highly correlated with color. The values of all surface color were very close correlated with anthocyanins content, especially *Hue* (negative correlation) and a*/b* (positive correlation). In the present experiment, the fruits of ecotype No. 11 were characterized by the highest content of *a* *, *b* * and the lowest *Hue*. Nalbaldi et al. [2011] stated that one of studied genotype had maximum lightness *L** = 26.10, redness *a** = 24.72 and *Chroma* = 26.01. In the study of Tural and Koca [2008], maximum values of cornelian cherry fruit color were: *L** = 19.69, *a** = 15.59 and *b** = 6,64. Gunduz et al. [2013] found that dark red fruits had *L** = 29.8, *a** = 36.6, *b** = 14.6, *Chroma* = 39.7 and *Hue* = 20.7. In this study, the mean values of fruit color on August 30 were: *L** = 27.21; *a** = 37.55, *b** = 26.53, *Chroma* 54.03 and *Hue* 56.21. These results showed that our cornelian cherry fruits were lighter and had higher redness value. Considering the market point of view, the lightness and redness of cornelian cherry are important feature. Additionally, redness (*a**) can be a good indicator of the maturity of these fruits.

It should be emphasized that cornelian cherry for commercial plantation should be propagated by grafting [Bijelić et al. 2016]. Only such plants are characterized by quick entry into the fruiting period and produce high quality fruit.

CONCLUSIONS

Cornelian cherry belongs to alternative fruit species. In Poland in Bolestraszyce, only a dozen varieties have been bred There is a need to breed new varieties adapted to our conditions and meeting the expectations of consumers. The fresh fruit market is looking for the highest quality cultivars, and in the case of cornelian cherry, it is a large fruit with a high content of flesh, with high content of soluble solids and anthocyanins. The studied ecotypes could be used in breeding programs to incorporate a wide range of quality and agronomic characteristics into a final cornelian cherry cultivar. Based on the results of this experiment, we can distinguish ecotype No. 11 as the earliest maturing one, with big round fruits, dark red color, with the highest content of anthocyanins. Also ecotypes No. 4 and 5, ripening in mid-August, and having a high ratio of SSC/TA, providing a good taste. The quality of fruit also depends on their degree of maturity. In this experiment, the cornelian cherry fruits began to mature at the beginning of August and at the latest at the end of August. With the increase of the degree of maturity, the SSC, reducing sugars, TA, dry matter and anthocyanins increased significantly. There was no difference in the taste of fruit LR and DR, which were characterized by similar ratio of SSC/TA.

ACKNOWLEDGMENTS

The research was financed from the own resource of the Department of Horticulture and Nursery of the University of Life Sciences in Lublin (currently, the Department of Pomology, Nursery and Enology) – OKS/DS/1.

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