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Physicochemical Fruit Characteristics of Cornelian Cherry (*Cornus mas* L.) Genotypes from Serbia

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***Abstract*. High variability in the natural population of the cornelian cherry in the region of Serbia is an important genetic potential for use in breeding programs. In the course of a 2-year study, significant differences have been noted in morphometric characteristics (fruit weight and flesh to stone ratio were 2.11 to 6.71 g and 78.52% to 88.74%, respectively) and chemical composition of the mesocarp [content of total dry matter (TSC), soluble solid content (SSC), total acids, total and reducing sugars, sucrose, Ca-pectates, vitamin C, proteins, cellulose, anthocyanins, and tannins was recorded 18.26% to 33.39%, 17.40% to 32.37%, 1.62% to 3.75%, 11.77% to 26.30%, 9.50% to 24.07%, 0.38% to 3.25%, 0.32% to 2.44%, 14.56 to 39.22 mg/100 g fruit, 0.20% to 2.71%, 0.43% to 0.95%, 35.63 to 126.53 mg/100 g fruit, and 0.56% to 1.47%, respectively] of 18 cornelian cherry genotypes from Vojvodina Province. The data were compared and analyzed by multivariate techniques [correlation matrix calculation and principal component analysis (PCA)]. The highest positive correlation was found between TSC–SSC and total sugar–reducing sugar (r > 0.95). Using PCA, different genotypes of cornelian cherry can be grouped in clusters based on similarity in their chemical composition.**

Most wild fruits can be consumed fresh or processed. However, although exceedingly abundant in nutrients, these fruit types have been almost completely neglected in the past decades. Recently, more attention has started to be paid to the study and preservation of plant resources and to selection of wild fruit genotypes from natural populations (Ercisli et al., 2007; Tosun et al., 2009). The cornelian cherry is a semi-domesticated plant that can be used as both food and medicine. In folk tradition, it is a symbol of health, spiritual firmness, stamina, and longevity. The popular saying ‘‘healthy as the cornelian cherry’’ translates aptly into English as ‘‘fit as a fiddle.’’ Furthermore, the cornelian cherry is highly tolerant to diseases and pests, which makes it suitable for production according to the principles of organic agriculture. In ancient times the cornelian cherry had already been used as a medicinal plant as well as a fruit tree with high-quality wood. It had served in the past centuries as a cure for various ailments in the form of teas, balms, and healing creams, but it had also been considered a delicacy (Ercisli et al., 2008). The cornelian cherry mesocarp has a high nutritional value, because it contains biologically a.i. suitable for human consumption. In addition, it contains metabolites important for pharmacy and cosmetics. In Turkey, the cornelian cherry is widely used because of its antioxidant, antiallergenic, antimicrobial, and antihistamine properties (Celik et al., 2006). In some Asian countries the cornelian cherry is the main ingredient of herbal preparations used in the treatment of diabetes (Jayaprakasam et al., 2005; Jia et al., 2003). Cornelian cherry stones and leaves, from which tannins can be easily extracted, are also used as medicinal raw materials (Burmistrov, 1994). With their unique taste, cornelian cherry fruits can be consumed fresh or used in the production of beverages, candies, jellies, and jams. They also serve as ingredients added to various dishes. In these parts of our country, the so-called stirred cornelian cherry jam is particularly popular. It is prepared without cooking and additives but only with some sugar or honey (Bijelić, 2009).

The various bright colors (red, blue, and purple) of fruits, vegetables, and flowers come from anthocyanins, which are used as dietary polyphenols. Anthocyanins contained in fruits tend to reduce coronary diseases and are also used for antidiabetic purposes (Jayaprakasam et al., 2005). As a result of the presence of flavonoids and anthocyanins, the cornelian cherry is considered as a medicinal plant whose fruits have antioxidant properties (Horváth et al., 2007). Also, the cornelian cherry is a potential source of raw materials for phytomedicine (Mamedov and Craker, 2002).

In view of the fact that Serbia is rich with cornelian cherry populations, an intensive breeding program has been started at the Faculty of Agriculture in Novi Sad (Bijelić et al., 2008, 2009, 2010) to identify the best genotypes according to their morphological characteristics and chemical composition of the mesocarp and introduce them into intensive cultivation. Also, we show the application of chemometrics—a statistical technique that can directly correlate quality parameters to analytical instrument data collected on food products (Liu et al., 1987). Patterns in the data are modeled; these models can then be routinely applied to future data to predict the same quality parameters. The result of the chemometrics approach is an efficiency gain in assessing product quality (Munck et al., 1998).

Materials and Methods

To identify the best cornelian cherry (*Cornus mas* L.) genotypes in Serbia for purposes of further selection and breeding, over 200 cornelian cherry trees and bushes from different locations in the Vojvodina Province have been labeled. We present the morphometric characteristics (fruit weight and flesh ratio) and chemical composition of fruit mesocarp of 18 genotypes labeled in the course of the 2 study years (2007 and 2008). In these 2 years, fruits of these genotypes were picked at the stage of full maturity to make average samples. Each sample consisted of 50 fruits per genotype, which was used for measurements of morphometric characteristics. After stone extraction, the mesocarp underwent chemical analyses for TSC, SSC, total acids, total and reducing sugars, and contents of sucrose, vitamin C, Ca-pectates, proteins, cellulose, anthocyanins, and tannins. The analyses were performed by conventional methodologies (AOAC, 1984). The mesocarp of fruits from the 2008 harvest was analyzed for ash content and the contents of the following microelements: copper, iron, zinc, manganese, magnesium, calcium, potassium, and sodium. The obtained data for the morphometric characteristics and chemical composition were processed by two-factorial analysis of variance (ANOVA) using STATISTICA 9.1 (StatSoft Inc., 2010). The results are presented in tables providing average values for each of the characteristics examined during the 2-year test period. The mineral composition of the mesocarp of the analyzed cornelian cherry genotypes was processed by one-way ANOVA, because the article presents 1-year results of the mesocarp chemical composition. The significance of differences of the means for the analyzed characteristics was tested by Duncan's test at 0.01% significance. To determine the variability of the characteristics, CV, being a most reliable indicator of the relative dispersion of data, was calculated on average for all genotypes per study year.

Data on chemical content were subjected to multivariate analysis. The correlation matrix was calculated, giving the correlation coefficients between each pair of variables. Each term of the matrix is a number ranging from –1 to +1; the + or – sign indicates a

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positive or negative interdependence between variables (direction), and the absolute value indicates the strength of the interdependence. To identify new meaningful underlying variables and to reduce the dimensions of the data set, we performed a PCA. The results of the analysis are presented in terms of loading and score plots. All calculations and graphic representations were done using the same statistical program.

Results and Discussion

Some morphometric characteristics of the fruit of Cornus mas L. genotypes from Serbia. High variability in the values of fruit weight and flesh to stone ratio (Table 1) was found among the tested cornelian cherry genotypes. During the 2 years of study, a significant impact of the year as a factor was recorded on all parameters. On average for all genotypes under study, fruit weight (3.65 g) and the flesh ratio (84.09%) were significantly higher in 2008 as compared with the 2007 data. Also, the impact of the genotype was highly significant throughout the study period. The values of fruit weight and flesh ratio were higher in 2007 than in 2008, ranging from 2.07 g or 78.52% (CPC9) to 6.71 g or 88.74% (PPC1). Considered per genotype and study year, the fruits of the tested domestic genotypes were larger ($\approx$7 g in the case of PPC1) in relation to the data reported by a majority of other authors (Demir and Kalyoncu, 2003; Güleryüz et al., 1998; Yilmaz et al., 2009). However, our values were within the limits (2.09 to 9.17 g) reported by Yilmaz et al. (2009). The cornelian cherry selection should be primarily focused on larger fruit weight, a characteristic having the highest direct correlation with mesocarp weight (Bijelić et al., 2007; Karadeniz, 2000).

Total and soluble solids contents and acidity of cornelian cherry fruits. The contents of total dry matter (TSC) and soluble dry matter (Table 1) varied in the range from 18.26% and 17.40%, respectively (PPC1), to 33.39% and 32.37%, respectively (SSC), which is above the previously reported values (Demir and Kalyoncu, 2003; Güleryüz et al., 1998; Karadeniz et al., 2009; Tural and Koca, 2008). The reason for this increase could be the different growing conditions, because the values of these parameters vary considerably not only as a result of the genotype, but also as a result of environmental factors (Demir and Kalyoncu, 2003; Güleryüz et al., 1998). On the 2-year average, the highest SSC content was found in the fruits of SKC, the lowest in the fruits of CPC16 (18.10%), which, however, was not significantly lower than those in APC20 and PPC1.

The genotype KC2 had the highest content of total acids on average for the study period (3.68%). On average for all genotypes, the total acidity was significantly higher in 2008 (2.70%) than in 2007 (2.50%), whereas in other similar studies, this value ranged from 1.24% to 4.69% (Demir and Kalyoncu, 2003; Didin et al., 2000; Güleryüz et al., 1998).

Sugars content in the fruit of cornelian cherry genotypes. On average for all genotypes, significantly higher contents of total (17.74%) and reducing sugars (15.83%) were found in fruits in 2007, whereas the sucrose content was significantly higher in 2008 (Table 1). The contents of total and reducing sugars ranged from 11.77% and 9.50%, respectively (in CPC16 in 2008), to 26.30% and 24.07%, respectively (in TC1 in 2007). On average for both years, the highest sucrose content (3.20%) was found in CA1 and the lowest (0.75%) in Apatinski rani. Other authors (Burmistrov, 1994) reported that the content of sugars in fruits of wild genotypes varied between 9.4% and 17.4% and in selected cultivars between 6.8% and 10.8%, whereas cornelian cherry genotypes from Slovakia (Brindza et al., 2009) contained from 6.5% to 15.1% of total sugars. Cornelian cherry genotypes from Turkey have significantly lower contents of total and reducing sugars (Demir, 2002; Demir and Kalyoncu, 2003; Güleryüz et al., 1998; Yilmaz et al., 2009) in relation to our results, which in their turn are in agreement with the results of earlier studies of cornelian cherry populations from Serbia (Ognjanov et al., 2009).

Contents of Ca-pectates, vitamin C, and proteins in the fruit of cornelian cherry. Cornelian cherry fruits contain a special type of fibers (calcium pectate) that reduce the level of harmful cholesterol (low-density lipoprotein) in human blood and also act as a diuretic. On average for the fruits of all genotypes, contents of Ca-pectates (1.31%) and proteins (1.64%) were significantly higher in 2008, whereas vitamin C was significantly higher in the mesocarp (26.14 mg/100 g fruit) in 2007 (Table 1). Cornelian cherries from Turkey (Güleryüz et al., 1998; Yilmaz et al., 2009) and the Ukraine (Klimenko, 2004) were reported to have much higher contents of vitamin C in relation to the genotype KC2, which was found to have the highest vitamin C content (39.22 mg/100 g fruit) in our study. Vitamin C content is increased in cornelian cherry populations that grow further north (Burmistrov, 1994), reaching 36 to 122 mg/100 g fruit in Central Ukraine. The vitamin C content in the genotypes we studied was in agreement with that reported for Slovakia (Brindza, 2005) and the results of previous studies of domestic cornelian cherry populations (Bijelić et al., 2008, 2011).

Contents of cellulose, anthocyanins, and tannins in the fruit of cornelian cherry genotypes. Fruits and vegetables are sources of natural antioxidants. They contain different antioxidant components, which provide protection from harmful free radicals, reduce the rates of occurrence and mortality from cancer and heart diseases, have antioxidant and anti-inflammatory properties, and a

Table 1. Physicochemical properties of cornelian cherry genotypes from Serbia (average of 2007 and 2008).

Genotype	Fruit wt (g)	Flesh ratio (%)	TSC (%)	SSC (%)	Total acids (%)	Total sugars (%)	Reducing sugars (%)	Sucrose (%)	Ca-pectates (%)	Vitamin C (mg/100 g)	Proteins (%)	Cellulose (%)	Anthocyanins (mg/100 g)	Tannins (%)
APC9	2.26 j[z]	82.33 e	23.68 fg	21.35 i	2.73 efg	16.37 h	14.93 i	1.82 f	1.08 f	27.77 e	1.27 j	0.73 cd	36.35 r	1.17 ab
APC20	2.26 j	82.28 e	22.09 ij	18.20 l	1.73 j	14.02 k	11.51 s	2.43 d	0.37 k	34.06 c	0.67 m	0.49 g	49.40 n	0.79 def
CPC9	2.45 i	79.24 g	24.37 e	20.85 jk	2.04 i	16.30 h	14.10 l	2.09 e	1.28 e	24.25 h	1.79 ef	0.74 cd	66.26 j	1.09 abc
CPC16	3.95 cd	86.26 b	20.24 k	18.10 l	2.85 cde	13.49 l	11.81 p	1.62 g	1.13 f	21.03 k	1.31 j	0.59 efg	77.67 h	1.21 a
KC1	3.86 d	84.09 cd	23.57 gh	22.55 g	2.99 bcd	15.98 hi	14.42 k	1.62 g	1.58 c	26.41 g	1.05 k	0.56 fg	74.75 i	0.89 d
KC2	3.48 ef	84.59 c	21.77 j	20.40 k	3.68 a	13.78 kl	11.66 r	2.07 e	0.52 j	38.87 a	0.24 n	0.55 fg	53.22 m	0.73 f
SKC	3.96 cd	79.21 g	30.84 a	29.38 a	2.83 de	21.45 c	20.17 b	1.22 i	1.57 c	23.39 i	0.69 m	0.60 defg	49.30 n	0.86 de
Apat. rani	3.93 cd	85.80 b	23.23 h	21.25 ij	2.60 fg	17.22 g	16.45 f	0.75 j	0.74 hi	16.22 p	1.97 cd	0.89 ab	104.82 c	1.08 bc
Bačka	4.11 c	82.44 e	24.03 ef	21.90 h	2.72 efg	20.68 d	18.90 d	1.23 i	0.67 i	14.96 r	1.65 gh	0.77 bc	116.38 a	1.02 c
CA1	3.33 fg	80.86 f	25.12 d	24.10 e	3.03 bc	19.07 e	15.83 g	3.10 a	2.14 a	16.93 o	2.19 a	0.72 cde	44.37 p	1.21 ab
R1	4.34 b	87.67 a	22.30 i	20.70 k	2.57 g	14.57 j	13.08 m	1.44 h	0.80 gh	22.23 j	1.74 fg	0.68 cdef	89.82 f	1.10 abc
PPC1	6.37 a	88.29 a	19.68 l	18.50 l	2.12 hi	14.67 j	12.86 n	1.27 i	1.44 d	21.11 k	1.88 de	0.52 g	47.60 o	1.08 bc
TC1	3.15 h	83.62 d	29.85 b	28.48 b	2.78 ef	25.23 a	23.01 a	2.13 e	0.80 gh	18.95 n	1.30 j	0.89 ab	57.53 k	0.76 ef
CSC1	2.45 i	82.81 e	26.56 c	24.65 d	3.14 b	22.14 b	19.40 c	2.66 c	0.68 i	20.26 l	2.09 ab	0.92 a	114.06 b	1.14 abc
KDC1	4.06 c	85.67 b	26.98 c	25.45 c	2.60 fg	18.30 f	15.37 h	2.85 b	1.27 e	34.28 b	1.43 i	0.62 defg	90.95 e	0.76 ef
KDC3	3.51 e	86.29 b	25.18 d	23.30 f	2.23 h	20.28 d	17.63 e	2.63 c	0.90 g	29.66 d	0.86 l	0.68 cdef	56.13 l	1.03 c
KIC1	3.29 gh	83.91 d	26.67 c	24.73 d	2.04 i	15.76 i	14.58 j	1.18 i	1.98 b	19.86 m	1.56 h	0.56 fg	98.34 d	1.03 c
KKC1	3.62 e	86.17 b	25.25 d	22.80 g	2.13 hi	14.87 j	12.48 o	2.36 d	1.03 f	26.97 f	2.04 bc	0.60 defg	80.48 g	1.17 ab

[z]Values in the same column with different letters are significantly different at $P < 0.01$ according to Duncan's multiple range test.
TSC = total dry matter; SSC = soluble solid content.

number of other health benefits (Shui and Leong, 2006; Wang et al., 1996). These features are a convincing reason to increase the consumption of fruits, which are natural sources of beneficial substances (Pawlowska et al., 2010). The contents of anthocyanins and tannins (Table 1), on average for all genotypes (73.02 mg/100 g fruit or 1.04%), were significantly higher in 2007 than in 2008, whereas the cellulose content (0.67%) did not vary between the study years. Also, on average for the study period, there were no significant differences among the genotypes with highest cellulose contents (CSC1, TC1, and the selection Apatinski rani), the obtained values ranging within the limits (Klimenko, 2004). In consequence to the interaction between the genotypes and study years, the highest content of anthocyanins was recorded in the selection Bačka and the lowest in APC9 (126.53 mg/100 g fruit and 35.63 mg/100 g fruit, respectively), both in 2007. The obtained results are within the limits proposed by one of the authors (Tural and Koca, 2008), lower than the values stated by the other (Klimenko, 2004), but compared with anthocyanin contents in other fruit species (Pantelidis et al., 2007), it can be stated that cornelian cherry fruits are a good source of anthocyanins. Concerning the average tannin content for both years, there was no significant difference between the genotype with the highest tannins content (CPC16) and the genotypes CA1, R1, KKC1, and CPC9. Cornelian cherry fruits are superior in tannin content to many other fruit species. Stones and leaves, from which tannins can be easily extracted, are recommended for use as medicinal raw materials. Wild cornelian cherry genotypes in natural populations contain 2400 mg/100 g tannin (Burmistrov, 1994), as stated previously by other authors (Kalyoncu, 2002; Yalcinkaya, 1999).

Minerals content in the fruit of cornelian cherry genotypes. Table 2 shows the content of mineral substances in the mesocarp of cornelian cherry fruits from the 2008 vegetation period. High variability was found among the genotypes in the contents of different elements in the fruit mesocarp. Very high variation coefficients were registered for the contents of calcium and magnesium (CV = 97.13% and CV = 96.01%, respectively). High variations were found for the values of sodium and manganese (74.88% and 68.14%, respectively). PPC1 had the highest ash content (1.23%), which, however, was not significant in relation to the ash contents of TC1 CSC1, CA1, SKC, and KC2. The genotype CPC9 was distinguished for the highest contents of copper (1.47 ppm), magnesium (160.90 ppm), calcium (526.00 ppm), and potassium (9171 ppm), whereas CPC16 had the highest value of iron (9.06 ppm). The genotype TC1 was richest in zinc content (2.12 ppm), and APC9 was richest in manganese (1.59 ppm).

Our results showed that the fruits of domestic cornelian cherry genotypes had much higher levels of microelements than genotypes in Turkey (Demir, 2002), but their contents of potassium and magnesium were significantly lower than those reported for genotypes in Slovakia (Brindza, 2005).

Data analysis. The highest significant positive correlations were observed between TSC and SSC ($r = 0.9708$) and total sugar–reducing sugar ($r = 0.9801$). Significant positive correlations were also observed between fruit weight and flesh ratio ($r = 0.6122$), TSC and total sugar ($r = 0.7845$), SSC and total sugar ($r = 0.7965$), TSC and reducing sugar ($r = 0.7792$), SSC and reducing sugar ($r = 0.7959$), proteins

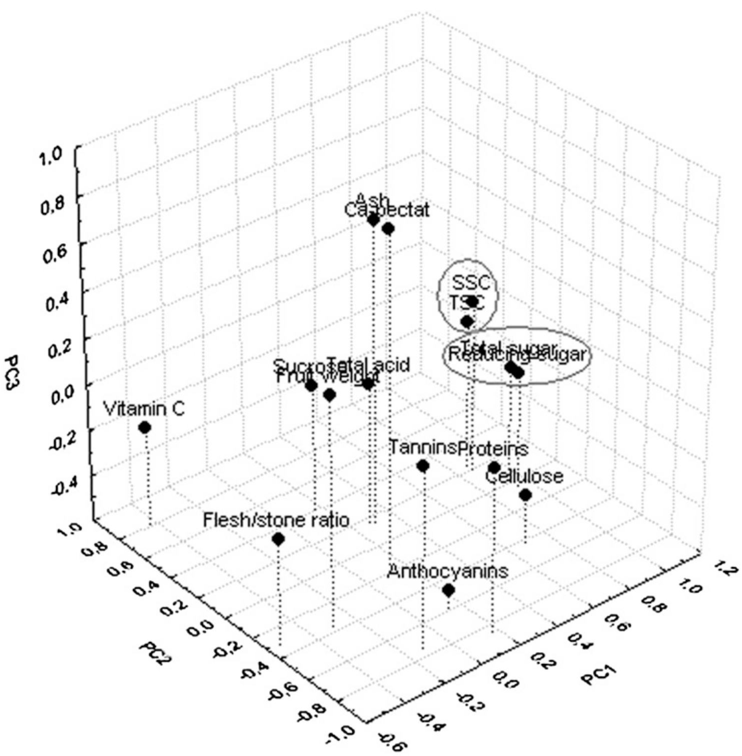

Fig. 1. Graph of loading plot of different chemical constituents in cornelian cherry. SSC = soluble solid content; TSC = total dry matter.

Table 2. Minerals contents in the fruit of *Cornus mas* L. genotypes from Serbia, 2008 (ppm).

Genotype	Ash (%)	Copper	Iron	Zinc	Manganese	Magnesium	Calcium	Potassium	Sodium
APC9	0.86 bcd[z]	0.54 hi	3.12 j	0.89 ghi	1.59 a	133.20 c	402.00 d	5609 c	40.75 s
APC20	0.60 de	0.86 e	3.10 j	0.95 gh	0.24 i	81.60 g	335.60 g	4114 h	45.64 p
CPC9	0.87 bcd	1.47 a	6.67 b	1.58 c	0.43 d	160.90 a	526.00 a	9171 a	78.31 h
CPC16	0.85 bcd	1.30 b	9.06 a	1.26 ef	0.32 gh	138.50 b	340.20 f	5273 e	185.55 c
KC1	0.69 de	1.26 b	3.57 i	1.36 d	0.42 de	127.30 d	516.80 b	4755 g	76.73 i
KC2	1.01 abc	0.90 e	2.38 k	0.97 g	0.32 gh	86.30 f	381.10 e	5491 d	83.37 f
SKC	1.05 ab	1.12 c	4.38 f	1.33 de	0.36 fg	113.20 e	466.50 c	7518 b	111.17 d
Apat. rani	0.59 de	0.90 e	5.47 d	0.86 ij	0.28 hi	10.12 o	24.47 p	1845 r	228.17 b
Bačka	0.61 de	0.64 fg	4.23 g	0.79 j	0.25 i	10.26 mn	27.25 o	2372 o	72.43 j
CA1	1.07 ab	1.15 c	3.95 h	1.19 f	0.27 hi	10.20 mno	27.23 o	3563 l	315.04 a
R1	0.53 e	0.58 ghi	5.63 c	0.84 ij	0.37 efg	10.18 no	59.58 j	1585 s	78.44 g
PPC1	1.23 a	0.62 fgh	4.13 g	0.87 hij	0.28 hi	10.67 l	27.53 o	2659 n	57.20 m
TC1	1.05 ab	0.53 hi	4.20 g	2.12 a	0.40 def	10.30 m	49.83 k	3456 m	62.18 l
CSC1	1.02 abc	1.02 d	5.21 e	1.18 f	1.00 b	10.15 no	38.35 m	3744 j	42.60 r
KDC1	0.74 cd	0.52 i	3.62 i	0.96 g	0.63 c	15.23 j	36.57 n	3652 k	46.36 o
KDC3	0.63 de	0.69 f	5.71 c	1.20 f	0.98 b	21.35 i	42.57 l	2356 p	52.12 n
KIC1	0.84 bcd	1.01 d	4.12 g	0.85 ij	0.64 c	14.10 k	136.23 h	4965 f	86.30 e
KKC1	0.62 de	0.84 e	3.67 i	1.94 b	0.39 def	63.25 h	98.95 i	3965 i	69.33 k

[z]Values in the same column with different letters are significantly different at $P < 0.01$ according to Duncan's multiple range test.

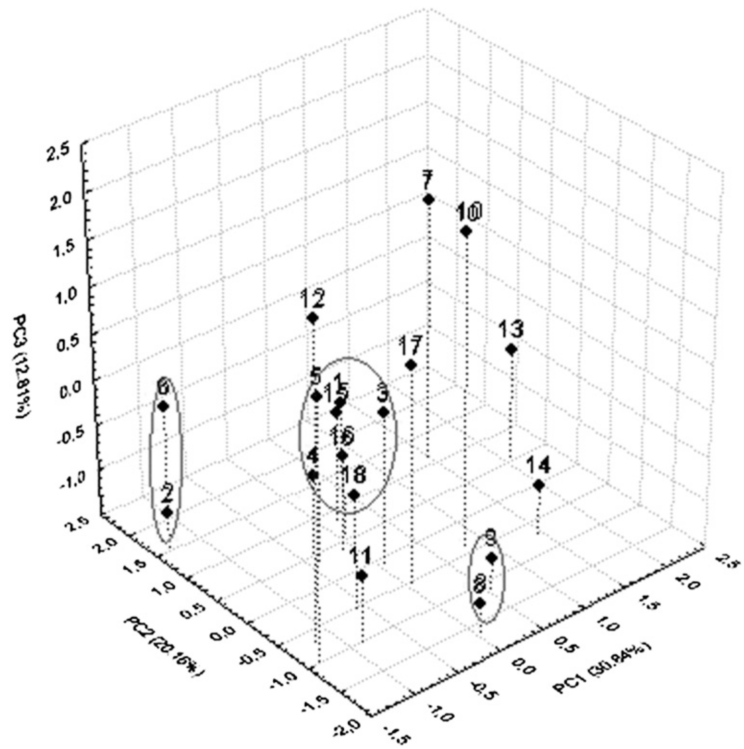

Fig. 2. Graph of scores plot of various cornelian cherry genotypes.

and tannins (r = 0.7308), cellulose and total sugar (r = 0.6799), cellulose and reducing sugar (r = 0.6927), and cellulose and proteins (r = 0.4738). Significant negative correlations were found between flash ratio and TSC (r = –0.4916), vitamin C and proteins (r = –0.6851), cellulose and vitamin C (r = –0.5483), and tannins and vitamin C (r = –0.5470).

The original data set was re-normalized by an autoscaling transformation (data not shown) and different parameters were analyzed by a multivariate approach. The loadings plot (Fig. 1) indicates the direction of each original variable, and the scores plot (Fig. 2) the position of each cornelian cherry sample in the new experimental space of the two independent coordinates. The scores plot (data not shown) indicates that the first three principal components account for 63.8% of the total variance (PC1 = 30.84, PC2 = 20.16, and PC3 = 12.81). As reported in the loadings plot (Fig. 1), two pairs of variables (SSC–TSC and reducing sugar–total sugar) showed the highest level of similarity, which can be described with the highest correlation coefficients between them (r > 0.95). Scores of mentioned variables are the closest in the loading plot.

PCA found different clusters of cornelian cherry based on chemical composition, but one major cluster set was separate and included APC9, CPC9, CPC16, KC1, KDC1, KDC3, and KKC1. Two minor clusters can also be observed in Figure 2 (APC20-KC2 and Apat. rani–Bačka). The results of this study demonstrated that only through a combination of different chemical analyses and chemometric evaluation can we achieve a strictly rigorous guideline for the chemical characterization of cornelian cherry.

In conclusion, the results of this study indicate that the cornelian cherry fruits are a valuable source of different nutrients. Because Serbia is rich in cornelian cherry populations, it is important to continue the breeding program of this fruit species, whose commercial cultivation could be successfully practiced in accordance with the concept of organic agriculture. The best of the selected genotypes were planted in the first collection of cornelian cherry in the region of Serbia and neighboring countries, which is rich material for further research.

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