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Morphological and quality attributes of selected autochthonous apple genotypes from Serbia

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Abstract

Apple is one of the most grown fruits in the world. Traditional apple genotypes represent an important resource that ensures the sustainability of apple production and high diversity of available genotypes. The aim of this study was to analyze the fruit quality and sensory characteristics of 5 autochthonous apple genotypes from Serbia, in order to determine their potential on the market for fresh consumption and processing industry. In order to determine the fruit visual characteristics, morphological traits were studied (fruit ground and over color, percentage and pattern of over color, greasiness of the skin, fruit weight, length and height and fruit shape). In addition, length of the fruit stalk and fruit firmness were determined, as important characteristics for fruit storability. Among the biochemical parameters, total soluble solids and titratable acidity were determined. Sensory analysis was performed for the following traits: attractiveness, taste, aroma, juiciness and astringency. The highest potential for fresh consumption showed 'Šećeruša' and 'Čegarača' genotypes. Genotype 'Đeregarka' is more suitable for processing industry due to its high content of organic acid. 'Crvena Debelokorka' had low taste and aroma ratings (partially due to high astringency), but also the highest fruit firmness, which can result in good storability. The analyzed genotypes showed diverse quality traits and could find their place in the market and in the economy of the small farmers, but also in breeding programs focused on quality and diversity. They should be preserved as an important genetic resource for the sustainability of agriculture.

Key words: apple, traditional genotype, morphological traits, soluble solids, sensory analysis

Introduction

Apple (*Malus domestica* Borkh.) is one of the most cultivated species of fruit trees in the world. Apple production is increasing worldwide and total production averaged 88026492 tones (2017-2021). More than half of the world's apple is produced in Asia. The largest producer is China, which produces almost half of the apple fruit, followed by the USA and Turkey. A positive trend in apple production is also observed in Serbia and the five-year (2017-2021) average of apple production in Serbia -was 468258 tons (FAOSTAT, 2021).

Apple production is influenced by various abiotic and biotic factors. Apples are susceptible to a wide range of pathogens, such as apple scab, powdery mildew, tree root rot disease and fire blight. Among abiotic factors drought and frost stress, low spring temperatures and hailstorms are the most challenging. These factors affect both, fruit yield and fruit quality. Climate change also induces higher risk of biotic stress as unpredictable changes can affect disease and pest management (Moinina et al., 2019). Responses to these challenges depend heavily on traditional varieties, local populations and wild relatives of plant genetic resources for food and agriculture (Bramel and Volk, 2019). They can be important resources for resistance towards different abiotic and biotic stress factors (Balaž et al., 2017; Marić et al., 2016; Mihaljević et al., 2021). Traditional genotypes are often characterized by higher polyphenol content and antioxidant capacity compared to modern cultivars (Lončarić et al., 2021; Preti and Tarola, 2021), which are desirable components from the perspective of nutritional value and importance for human health, as well as beneficial against pathogen attack. The quality of the apple fruit presents complex interaction of morphological and biochemical parameters that are important for consumers. Morphological parameters such as color and fruit size are the first ones which consumers notice. Most consumers prefer red or green fruits (Benković-Lačić et al., 2022; Drkenda et al., 2021), but regarding the fruit size, opinions are different and range from preference for big apples (Drkenda et al., 2021), while another group of consumers prefers small or middle-sized fruits (Benković-Lačić et al., 2022). In addition, fruits should be without damage since the presence of changed color or texture does not look attractive to the consumers. Regarding fruit taste, sugars and organic acids are the most important compounds that determine the subjective perception of the fruit taste. Traditional apple genotypes have higher sugar and lower acid content in compare to modern apple genotypes, which makes them more attractive for both, fresh consumption and processing (Begić-Akagić et al., 2014). Aroma is also important quality attribute of the apple fruits that can affect the perception of the taste. It depends on the content of alcohol, esters, aldehydes, ketones and ethers (Espino-Díaz et al.,

2016). The nutritional value of apple fruit also depends on the components such as vitamin C, carotenoids, flavonoids that are important for the antioxidative defense. Due to these phytonutrients, apples have antimicrobial, antiproliferative, anti-inflammatory, cardio-protective and other beneficial effects on human health (Seenivasan et al., 2022). The aim of this study was to analyze the fruit quality and sensory characteristics of 5 autochthonous apple genotypes, in order to determine their potential in the market for fresh consumption and the processing industry.

Material and Methods

The fruits of 5 autochthonous apple genotypes ('Čegarača', 'Demirka', 'Đeregarka', 'Crvena Debelokorka' and 'Šećeruša') were used for this study (Photo 1). The genotypes are part of the fruit collection of traditional apple genotypes of the Experimental Station »Radmilovac« of the Faculty of Agriculture, University of Belgrade. The apple trees are planted at 4 m ×1.5 m distance and grown in a slender spindle training system. Samples were collected from 3 trees per genotype and 10 fruits were collected from each tree. Fruits were in the stage of physiological maturity and stored for two months, without refrigerator in basement room, until analysis.

Photo 1. The fruits of the analyzed apple genotypes

The morphological characteristics of the fruits were studied: ground and over color of the fruit, distribution and percentage of the over color, greasiness of the skin, fruits shape, length of the fruit stalk, fruit weight (g), width and length (mm) and firmness of the fruit (kg/cm^2). In order to determine distribution of over color, greasiness of the skin, fruit shape and length of the fruit stalk, UPOV descriptor for apple was used (UPOV, 2005). Pattern of over color could be absent or present in different forms: solid flush, solid flush with weakly defined stripes, solid flush

with strongly defined stripes, weakly defined flush with strongly defined stripes and flushed striped and mottled. Greasiness of the skin was rated on the following scale: absent or weak, moderate and strong. Fruit shape scale was used, with 7 different fruit shapes: conical, cylindrical, cylindrical waisted, ellipsoid, globose, obolid or ovoid. Regarding the length of the fruit stalk, cultivars are classified in 5 categories, based on the same descriptor: very short, short, medium, long and very long fruit stalk.

Fruit firmness was measured using a hand penetrometer FHT-1122 (Landek Instruments, China). Among the biochemical characteristics, the content of total soluble solids (°Brix) and the content of organic acids (%) were determined. Total soluble solids (TSS) were determined using HI96801 refractometer (Hanna Instruments, USA), while the total titratable acidity (TTA) was analyzed by the titration method (Tyl and Sadler, 2017). The sensory properties of the fruits were determined by scoring by 3 panelists, which evaluated the appearance, taste, aroma, juiciness and astringency of the fruit. Descriptive statistics (mean value ± standard error) were performed using the Sigma Plot program (version 11.0). Sensory analysis data and fruit firmness data were standardized (0-100%) and presented in the form of a radar plot.

Results and Discussion

The apples analyzed in this study had yellow, green or green-yellow ground color (Table 1). Red cover color was present in genotypes ‘Čegarača’, ‘Demirka’ and ‘Crvena Debelokorka’, while genotype ‘Šećeruša’ had pale red color. The cover color was dispersed in solid flush pattern. The fruits of ‘Čegarača’, ‘Demirka’ and ‘Crvena Debelokorka’ were characterized with high cover color (65-70%), while ‘Šećeruša’ had only 30% of over color. Only genotype ‘Đeregarka’ did not have any over color and was completely green. Greasiness of the skin was strong or absent in examined genotypes.

Table 1. Morphological parameters (ground color, over color, pattern and percentage of the over color and skin greasiness) of analyzed apple genotypes

Genotype	Ground colour	Over colour	Pattern of over colour	Percentage of the over colour (%)	Greasiness of the skin
‘Čegarača’	Green-yellow	Red	Solid flush	65	Absent
‘Demirka’	Yellow	Red	Solid flush	70	Absent
‘Đeregarka’	Green	Absent	Absent	0	Strong
‘Crvena Debelokorka’	Yellow	Red	Solid flush	70	Strong
‘Šećeruša’	Yellow	Pale red	Solid flush	30	Absent

The shape of the fruits was globose, conic or obloid, depending of the genotype (Table 2). The length of the fruit stalk was short (‘Đeregarka’, ‘Crvena Debelokorka’ and ‘Šećeruša’) or medium (‘Čegarača’ and ‘Demirka’). The fruits with the highest weight, height and width were genotypes ‘Šećeruša’ and ‘Demirka’, while the lightest fruits had ‘Crvena Debelokorka’. The lowest fruit height and width were present in the genotype ‘Đeregarka’.

Table 2. Morphological parameters (fruit shape, length of the fruit stalk, fruit weight, fruit height and width) of analyzed apple genotypes

Genotype	Fruit shape	Length of the fruit stalk	Fruit weight (g)	Fruit height (mm)	Fruit width (mm)
‘Čegarača’	Globose-obloid	Medium	180.47 ± 7.31	63.4 ± 0.92	75.57 ± 1.19
‘Demirka’	Conic	Medium	210.50 ± 11.27	68.43 ± 0.78	78.87 ± 1.56
‘Đeregarka’	Obloid	Short	110.44 ± 23.97	54.23 ± 3.22	64.48 ± 4.22
‘Crvena Debelokorka’	Conic	Short	101.89 ± 3.48	57.93 ± 1.27	64.73 ± 0.56
‘Šećeruša’	Globose	Short	227.09 ± 19.66	67.62 ± 2.27	82.6 ± 2.90

Biochemical analysis related to total soluble solids showed the highest content in the ‘Crvena Debelokorka’ genotype, while ‘Đeregarka’ genotype had the lowest sugar and the highest acid content (Table 3). The lowest total titratable acidity was present in genotype ‘Čegarača’. The firmest fruits had the genotype ‘Crvena Debelokorka’, while the lowest fruit firmness was recorded in the genotypes ‘Demirka’ and ‘Šećeruša’.

Table 3. Biochemical parameters (total soluble solids and titratable acidity) and fruit firmness of analyzed apple genotypes

Genotype	Total soluble solids (°Brix)	Total titratable acidity (%)	Fruit firmness (kg/cm^2)
‘Čegarača’	14.90 ± 0.15	0.69 ±0.04	4.60 ± 0.25
‘Demirka’	16.00 ± 0.20	0.73 ±0.03	3.33 ± 0.33
‘Đeregarka’	14.80 ± 0.23	1.18 ±0.04	4.88 ± 0.75
‘Crvena Debelokorka	18.23 ±0.19	0.81 ±0.04	6.79 ± 0.55
‘Šećeruša’	16.67 ±0.47	0.80 ±0.05	3.41 ± 0.40

Sensory analysis showed that the best appearance had genotype ‘Đeregarka’ (Table 4), but also the lowest taste and aroma scores. A low taste and aroma rating were also present in genotype

'Crvena Debelokorka', which had the highest astringency. In contrast, the genotype 'Čegarača' had high taste and aroma rating, and the highest juiciness. The genotypes 'Demirka' and 'Šećeruša' also had good taste and aroma ratings, and satisfactory juiciness scores.

Table 4. Sensory analysis (appearance, taste, aroma, juiciness and astringency) of analyzed apple genotypes

Genotype	Appearance (1-10)	Taste (1-10)	Aroma (1-10)	Juiciness (1-3)	Astringency (1-3)
'Čegarača'	3.67 ± 0.33	8.33 ± 0.33	9.67 ± 0.33	2.5 ± 0.29	1.00 ± 0.00
'Demirka'	8.00 ± 0.58	7.33 ± 0.33	8.33± 0.33	2.00 ± 0.00	1.00 ± 0.00
'Đeregarka'	8.33 ± 0.33	2.33 ± 0.33	2.00 ± 0.00	2.33 ± 0.33	1.00 ±0.00
'Crvena Debelokorka'	5.33 ± 0.3	3.00 ± 0.58	2.67 ± 0.33	1.00 ± 0.00	2.33 ± 0.33
'Šećeruša'	8.00 ± 0.33	8.5 ± 1.00	7.5 ± 0.33	2.5 ± 0.33	1.00 ± 0.00

Based on these results, two of the most perspective genotypes 'Šećeruša' and 'Čegarača' (Figure 2) were presented by radar plots which highlighted their sensory attributes.

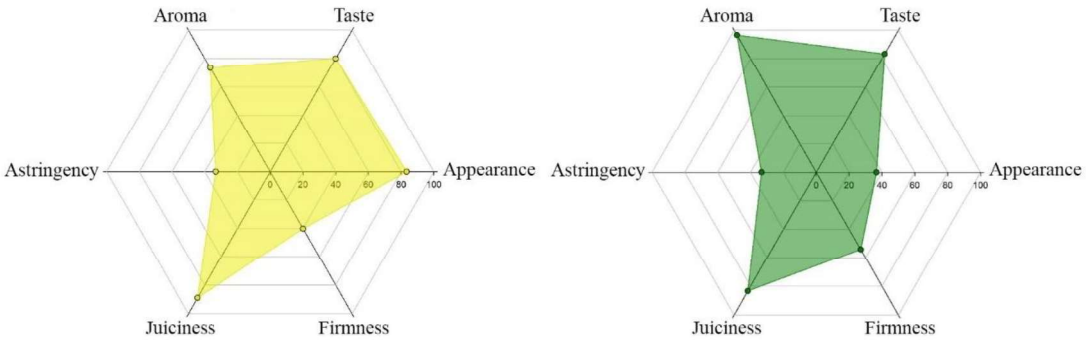

Figure 2. Radar plot of two selected genotypes - 'Šećeruša' (yellow) and 'Čegarača' (green)

Disccusion

Most of the analyzed apple genotypes had red over color, which is considered the most attractive (Dumanoglu et al., 2018) as consumers assume that red fruits are sweeter and have better overall quality (Musacchi and Serra, 2018). Therefore, breeders usually aim to produce apples with completely red or predominantly red fruits, with a high proportion of the over color. Fruit color is determined by environmental and genetic factors, and exhibits high heritability, resulting in genotypes with a higher degree of red color (Zheng et al., 2020). From this point of view, our genotypes 'Demirka' or 'Crvena Debelokorka' are promising and interesting for breeding programs. The genotype 'Šećeruša' had a pale red over color, which is becoming more popular worldwide, and even overcoming the popularity of the red over color. Due to the pale red blush, this genotype could be also interesting for future breeding programs (Musacchi

and Serra, 2018). However, green-yellow is considered the most attractive ground color by most of the consumers (Dumanoglu et al., 2018). This ground color is present in the genotype 'Čegarača'. Non-red genotypes (green and yellow color) should have other desirable properties in order to overcome the color unattractiveness and to be more appreciated by consumers (Normann et al., 2019). 'Čegarača' was also characterized by the most uneven fruits, which had variable fruit shape: globose, obloid and globose-obloid. On the contrary, genotype 'Đeregarka'had a uniform fruit shape.

All studied genotypes belonged to the group of medium or small apple fruits, which is in the commercial production considered as a disadvantage. However, some research showed that consumers in this geographical area prefer middle-sized (Dumanoglu et al., 2018) or small fruits (Benković-Lačić et al., 2022), considering that those fruits are grown in non-intensive agricultural systems and healthier (Skreli and Imami, 2012). Length of the fruit stalk was medium in genotypes 'Čegarača' and 'Demirka', while the other genotypes had a short length of the stalk. Genotypes with longer fruit stalk are more desirable in commercial fruit orchards since these fruits are more difficult to detach from the tree and the harvest is much easier in compare to short stalk genotypes. Fruits with long stalk are usually collected with the stalk, while the short stalk is easy to be pulled out of the fruit during harvest, which affects the storability of the fruit (Radović, 2022). Salkić et al. (2017) reported similar results to the ones obtained in this study, where traditional genotypes with long stalk are rare, which presents their disadvantage regarding their use in production and storability.

Apple fruits differ in soluble solids content based on genotype, but also on environmental conditions. Soluble solids content is the mostly determined by sugar content, which affect the most fruit taste and nutritional value. The sweetness of the fruit is determined not just by the overall sugar content, but also the presence and the ratio of the individual sugars (glucose, fructose, sucrose and sorbitol). Our results showed that fruits of 'Crvena Debelokorka' had the highest value of total soluble solids and medium level of acids content. High soluble solids content can affect fruit taste since the most of the consumers prefer sour-sweet apples (Benković-Lačić et al., 2022). The optimal ratio is present in the fruit 'Šećeruša' since it had relatively high soluble solids and moderate acid content, so it is expected that fruits of 'Šećeruša' would have a good sensory property.

Genotype 'Đeregarka' had the undesirable TSS/TTA ratio, with high titratable acidity and low soluble sugars, which affects fruit taste. Still, high content of organic acids indicates the potential of this genotype for long storage, as well as in the processing industry since acid content is important for the quality of the products and their sanitary safety. Literature data

show a correlation between fruit color and titratable acidity, since non-red genotypes have higher titratable acidity in comparison to red ones (Kumar et al., 2018), which is also the result of this study related to 'Đeregarka' genotype.

Fruit firmness was the highest in 'Crvena Debelokorka', and this trait is important for storability of the fruit, and in a close relation to the other fruit rheological properties. Low firmness of fruit during storage time is related to fruit transpiration and water loss, which lead to changes in fruit properties (Fathizadeh et al., 2021).

Appearance fruit score in sensory analysis showed that consumers from Serbia considered green genotype 'Đeregarka' (with no over color), as the most attractive. The lowest taste and aroma ratings were recorded in this genotype. Its fruits had high titratable acidity and low soluble solids content, which indicates that taste was perceived as sour and unpleasant. Still, juiciness of the fruits was rated as good, which in combination with high sourness and high acid content can determine this genotype potential for processing industry. 'Demirka' also was rated as genotype with attractive fruits because of its red color, but also the genotype 'Šećeruša', which confirms the conclusion that pale red fruits are becoming more popular among consumers (Musacchi and Serra, 2018). On the other side, the fruit quality of 'Šećeruša', characterized with high soluble solids and moderate acid content, was confirmed by sensory analysis.

On the contrary, genotypes 'Čegarača' and 'Crvena Debelokorka' had the least attractive fruits. The low attractiveness of the "Čegarača" fruit could be caused by the fact that fruits were visually unequal - fruit shape varied between globose, obloid and globose-obloid. Despite the intense red color and small sized fruits of 'Crvena Debelokorka', low attractiveness of fruits was related with fruit damage by apple scab (*Venturia inaequalis*), which affected consumers preference (Kelley et al., 2010). Genotypes sensitive to apple demand higher expenses of production and does not suit consumers' preference for less treated apples. 'Crvena Debelokorka' had high soluble solids in ratio to acids, which imply the taste is too sweet, without desirable sourness (Benković-Lačić et al., 2022). Also, aroma of fruits was low, which possibly affected the perception of taste since (Charles et al., 2019). Also, the astringency of fruits was high. Astringency is not just a problem for fresh fruit consumption, but also for the processing industry since it makes juices unpleasant and slightly bitter (Heinmaa et al., 2017). In combination with apple scab sensitivity, this genotype is not suitable for wider production.

Conlusions

Analyzed genotypes showed different morphological, biochemical and sensory attributes. Two genotypes have especially high potential as the genotypes for fresh consumption – 'Šećeruša' and 'Čegarača'. Regarding the fruit attractiveness, genotype 'Šećeruša' is the most interesting because of the new market demands toward pale red fruits. The fruits of genotype 'Đeregarka' are not suitable for fresh consumption, but could be interesting for the processing industry due to high organic acid content. This genotype has also very good potential for long term storability, which is an important quality trait. It is also important to note it was the most attractive genotype for consumers, although it is widespread opinion of preference for fruits with intense red color. It seems that consumers rated this genotype based on fruit size and irregular shape, as the proof of the fruit authenticity and traditional origin. Genotype 'Crvena Debelokorka' had high astringency and the lowest ratings regarding taste and aroma. Also, it is sensitive to apple scab, which makes it unsuitable for wider consumption. Still, it is important to notice that local communities maintained this genotype during the time, which implies it can show full potential in different agroecological conditions. All analyzed genotypes are saved in the fruit orchard collection at the Faculty of Agriculture, which presents an important step in the *ex situ* conservation of these genotypes. The management of these plant genetic resources should also include *in situ* conservation and return of these fruits on the markets.

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