

Fruit characteristics of some apple cultivars and their clones

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Abstract

Apple is one of the most cultivated fruit trees in the world. Consumers value high quality fruit, with desirable morphological characteristics, good aroma and taste. Given the popularity of red apple fruits, the need for its cultivation is growing. The aim of this research was to analyze the qualitative characteristics of 4 commercial apple cultivars ('Gala', 'Red Delicious', 'Jonagold' and 'Golden Delicious') and their clones ('Schnico Red Gala', 'Scarlet Spur', 'Wilton's', 'Red Jonaprince' and 'Reinders'). Research was carried out on the Radmilovac Experimental Site in a two-year period (2021 and 2022). The following morphological parameters were monitored: weight, height and width of the fruit, index of the fruit, length of the stalk, firmness of the fruit and coloration of the fruit. Also, biochemical parameters were measured: content of soluble solids, total titratable acidity and flavour index. Sensory analysis was performed by scoring fruit attractiveness, taste and aroma. Clones had higher degree of attractiveness due to intense red colour ('Schnico Red Gala', 'Scarlet Spur', 'Wilton's Red Jonaprince') or reduction of rustiness ('Reinders'), in comparison to commercial varieties. In some clones ('Wilton's Red Jonaprince' and 'Scarlet Spur') fruit size was decreased in comparison to parent cultivar. 'Wilton's Red Jonaprince' had the best parameters of biochemical quality – highest soluble solids, titratable acidity and flavor index among all analyzed genotypes. The decrease of quality (soluble solids, acidity and flavor index) is noticed in the clones 'Scarlet Spur' and 'Reinders'. 'Schnico Red Gala' showed the highest increase of sensory properties in comparison to original cultivar ('Gala'). Clone 'Wilton's Red Jonaprince' showed the best overall biochemical quality and sensory traits in comparison to all analyzed genotypes.

Key words: *Malus domestica*, fruit quality, morphological characteristics

INTRODUCTION

Apple is one of the most grown and consumed fruits in the world. In Serbia, the most of the fruit growing areas are planted with plum, followed by apple. The most abundant apple varieties grown in Serbia are 'Idared', 'Gala', 'Golden Delicious', 'Red Delicious', 'Jonagold', 'Braeburn', 'Granny Smith' and 'Fuji' (Magazin et al., 2022).

Apple quality is determined by morphological, organoleptic characteristic and biochemical quality. Morphological quality is determined by fruit size and shape, absence of irregularities and defects and by fruit color. Fruit firmness and texture are also very important quality traits, while the taste is determined by starch content, total soluble solids content and acidity (Musacchi & Serra, 2018). Additional to fruit taste, aroma has the important effect on consumers' preferences toward fruits. It is determined by different volatile compounds: aldehydes, ketones, alcohols, esters and ethers content (Espino-Díaz et al., 2016). Fruit quality is also determined by compounds that have nutritional value for

humans, like different components of antioxidative defense: flavonoids, carotenoids, vitamin C. These compounds have different beneficial effects on human health (Seenivasan et al., 2022).

Morphological and biochemical quality of the mature apple fruits depends on genetic factors and location of growing (Kumar et al., 2018). Red fruit color is one of the most important parameters that attract consumers. Still, one of the globally widespread apple cultivars has yellow skin color ('Golden Delicious'). Because of that, breeding programs are going in direction of providing cultivars with higher percent of red skin color and good quality. Especially important for those breeding efforts are red-colored clones or clones with higher percent of over color (Radović, 2022). Cultivation of bicolor or red-colored clones can be economically beneficial for producers. It can also be beneficial regarding the storage and control of the production losses since high-colored clones do not need prolonged harvest time in order to get desirable color level (Argenta et al., 2021). The quality of these clones should be evaluated further since somatic mutation is maybe affecting other parameters beside fruit colour.

The aim of this research was to evaluate the quality properties of 4 commercial apples cultivars ('Gala', 'Red Delicious', 'Jonagold' and 'Golden Delicious') and their clones ('Schnico Red Gala', 'Scarlet Spur', 'Wilton's Red Jonaprince' and 'Reinders') in order to determine advantages/disadvantages of clones in comparison to related cultivars.

MATERIAL AND METHODS

Four commercial apples varieties ('Gala', 'Red Delicious', 'Jonagold' and 'Golden Delicious') and their clones ('Schnico Red Gala', 'Scarlet Spur', 'Wilton's Red Jonaprince' and 'Reinders') were grown at the Faculty of Agriculture, University of Belgrade - Experimental Station »Radmilovac«. Varieties were grafted to M9 rootstock and orchard was established in 2017. The distance of the planted trees was 3.2 x 0.8 m and slender spindle training system was used. Fruit maturity was determined based on ground and over fruit colour changes and starch-iodine test. Mature fruits were collected and their morphological and biochemical properties were analyzed. Research was done during the two-year period – 2021 and 2022.

Among the morphological properties were analyzed: fruit weight and length, shape index, fruit diameter, length of the fruit stalk and ratio of the colour. Over color percent was determined by visual estimation. Also, fruit firmness was measured by hand penetrometer FHT-1122 (Landek Instruments, China).

Among the biochemical parameters, total soluble solids (TSS) were measured by HI96801 refractometer (Hanna Instruments, USA), while total titratable acidity (TTA) was determined by following the protocol of Tyl and Sadler (2017). Total soluble solids and total titratable acidity values were used to calculate flavor index, by using the formula $\text{Flavor index} = ((\text{TSS}/20) * \text{TA}) + \text{TA}$ (Soare et al., 2019).

Sensory analysis was done by 5 panelists, who scored fruit attractiveness, taste and aroma on the rate from 1-10. Fruit was analyzed successively immediately after harvesting. Panelists (two males and three females; 30-50 years old) were professionals trained for performing the sensory analysis.

Mean values were calculated and two factorial ANOVA was performed. Statistical analyses were done by using software STATISTICA 8.0 (StatSoft, Inc., Tulsa, OK, USA).

RESULTS

Analysis of morphological parameters showed that the highest fruit weight had cultivar 'Jonagold' and its clone 'Wilton's Red Jonaprince', while the lowest fruit weight had cultivar 'Gala' and its clone 'Schnico Red Gala' (Table 1). Cultivar 'Gala' and clone 'Schnico Red Gala' had also the lowest fruit length and width, while 'Jonagold' and 'Wilton's Red Jonaprince' had the highest fruit length and width. Shape index was the highest in cultivar 'Golden Delicious' and its clone 'Reinders'. The length of the fruit stalk was uniform among the cultivar, with slightly longer stalk in cultivar 'Jonagold'. Among clones, genotype 'Scarlet Spur' had the lowest stalk length, while clones 'Reinders' had the longest stalk among all analyzed genotypes. Cultivar 'Red delicious' and its clone 'Scarlet Spur' had the lowest fruit firmness among analyzed genotypes. Clones 'Schnico Red Gala', 'Scarlet Spur' and 'Wilton's Red Jonaprince' had significantly higher percent of over colour in comparison to parent cultivars. ANOVA showed significant genotype effect on almost all analyzed parameters, excluding fruit firmness, which

was the only parameter affected by year of growing. Cultivar/year interaction did not affect shape index and length of the fruit stalk.

Table 1. Morphological properties of fruit of apple cultivars and clones (average 2021/2022)

Cultivar/ Clone	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	Shape index	Length of fruit stalk (mm)	Fruit firmness (kg cm ⁻² ⁻¹)	Over colour (%)
Standard cultivars							
‘Gala’	131.2	55.7	65.0	0.86	24.0	6.5	20
‘Red Delicious’	213.2	70.1	79.8	0.88	24.9	5.2	50
‘Jonagold’	252.7	72.5	82.4	0.88	25.8	6.3	30
‘Golden Delicious’	165.8	68.1	73.4	0.93	23.9	6.7	-
Clones							
‘Schnico Red Gala’	139.0	58.3	67.1	0.87	24.4	6.2	50
‘Scarlet Spur’	181.7	66.1	74.5	0.89	21.0	5.4	100
‘Wilton’s Red Jonaprince’	209.9	67.7	79.4	0.85	28.0	5.8	90
‘Reinders’	170.6	67.2	72.8	0.92	30.7	5.9	-
ANOVA	Cultivar (C)	**	**	**	*	ns	-
	Year (Y)	ns	ns	ns	ns	**	-
	C x Y	**	**	*	ns	**	-

Analysis of soluble solids and total acids showed that cultivars ‘Jonagold’ and ‘Wilton’s Red Jonaprince’ had the highest content of total soluble solids and the highest total titratable acidity (Table 2). These genotypes also had the highest flavuor index. Clone ‘Scarlet Spur’ had the lowest total soluble solids and total titratable acidity, and the lowest flavor index. ANOVA analysis showed that cultivar had significant effect on these parameters. Total soluble solids, titratable acidity and flavor index were depended on genotype. Year did not affect significantly soluble solids content, while year/cultivar interaction had no effect on titratable acidity.

Table 2. Biochemical properties of fruit of apple cultivars and clones

Cultivar/ Clone	Total soluble solids (°Brix)	Total titratable acidity (%)	Flavour index
Standard cultivars			
‘Gala’	14.38	0.23	0,40
‘Red Delicious’	15.87	0.25	0,45
‘Jonagold’	16.67	0.32	0,59
‘Golden Delicious’	15.9	0.3	0,54
Clones			
‘Schnico Red Gala’	13.50	0.26	0,44
‘Scarlet Spur’	11.93	0.23	0,37
‘Wilton’s Red Jonaprince’	16.92	0.36	0,66
‘Reinders’	13.80	0.29	0,49
ANOVA	Cultivar (C)	**	**
	Year (Y)	ns	**
	C x Y	**	ns

Clones were rated with higher appearance score in comparison to cultivars (Table 3). Cultivars ‘Jonagold’ and ‘Golden Delicious’ had the best rating regarding taste in comparison to all analyzed genotypes. The highest aroma rating had the cultivar ‘Golden Delicious’ and clone ‘Wilton’s Red Jonaprince’. The best overall rating had cultivar ‘Jonagold’ and its clone ‘Wilton’s Red Jonaprince’, while the lowest total score had cultivars ‘Gala’ and ‘Red Delicious’. Cultivar was significant factor that affected all sensory analysis parameters, while year and cultivar/year interaction affected only attractiveness of the fruit.

Table 3. Sensory fruit properties of apple cultivars and clones

Cultivar/ Clone	Attractiveness (1-10)	Taste (1-10)	Aroma (1-10)	Total score
Standard cultivars				
‘Gala’	6.0	5.7	6.5	18.2
‘Red Delicious’	6.0	5.3	7.0	18.3
‘Jonagold’	8.3	9.2	7.8	25.3
‘Golden Delicious’	7.2	9.3	8.0	24.5
Clones				
‘Schnico Red Gala’	8.0	7.0	7.0	22.0
‘Scarlet Spur’	10.0	5.2	6.5	21.7
‘Wilton’s Red Jonaprince’	10.0	8.7	8.0	26.7
‘Reinders’	9.5	7.2	6.7	23.3
ANOVA	Cultivar (C)	**	**	**
	Year (Y)	**	ns	ns
	C x Y	**	ns	ns

DISCUSSION

Fruit size often determines consumer’s choice of apple fruits. There are significant geographical differences among consumers’ preferences toward certain apple size. Some consumers prefer larger apples with diameter of 7,4 to 7,6 cm (Hampson et al., 2002), and in that size range fits clone ‘Scarlet Spur’ from our research (Table 1). Still, some research from our geographical area showed that consumers prefer small (Benković-Lačić et al., 2022) or medium-sized fruit (Dumanoglu et al., 2018), like ‘Gala’ cultivar. Another two important morphological traits are fruit shape and length of the fruit stalk. Truncate-shaped apples are desirable among consumers (Ostojić et al., 2017). Clones ‘Wilton’s Red Jonaprince’ and ‘Reinders’ had the longest fruits stalks (Table 1). This is an important trait for commercial production due to firmer attachment of apples with long stalk to the tree (Radović, 2022).

Some research showed that crucial traits for consumers are taste and colour of the apple fruit (Ostojić et al., 2017). Red fruit color is considered as the most attractive (Jesionkowska et al., 2006), but some research showed that consumers prefer red light-colored or green skin apples (Ostojić et al., 2017; Benković-Lačić et al., 2022). Our research showed that red clones had better rating regarding the appearance than cultivars with little or no red colour. ‘Schnico Red Gala’ becomes red very early, which means it can be harvested at the beginning of august on lower altitudes, when the price on the market is the highest (Magazin et al., 2022). ‘Scarlet Spur’ is completely red clone, with the maximum rating of fruit attractiveness. According to some literature data, this clone has very sweet fruits with optimal soluble solids/acidity ratio and high ratings on crunchiness and consistency grown in the region of Sicily (Italy) (Farina et al., 2017). Although it got the red colour in our research, its fruits had the lowest soluble solids content and lowest flavour index. Possible reason for these results is present climate differences among Sicily and Belgrade region in Serbia. Clone ‘Reinders’ is a non-red clone, but it scored better on attractiveness rating in comparison to ‘Golden Delicious’. Possible reason is lower degree of undesirable rustiness on ‘Reinders’ fruits (Radović, 2022).

Research showed that different clones of 'Gala' grown in Brasil have little difference in comparison to the parent cultivar regarding fruit weight, fruit firmness, total soluble solids and total acidity (Argenta et al., 2021). Our research showed similar results for 'Gala' cultivar regarding fruit weight, length, and diameter and shape index, but not regarding the soluble solids content and titratable acidity (Table 2), which is probably a result of differences among climate where fruits were grown. In clone 'Schnico Red Gala' total soluble solids decreased and total titratable acidity increased in comparison to 'Gala', but not on a larger scale. Still, it affected significantly the sensory analysis and 'Schnico Red Gala' scored higher in all sensory analysis parameters in comparison to 'Gala'. In clones 'Scarlet Spur' and 'Reinders' it is present a decrease of soluble solids and flavor index in comparison to parent cultivars. Fruit firmness was not significantly affected by genotype. This is in accordance with literature data, which showed that this genotype has similar range of the fruit firmness at the moment of harvest (Đurović, 2021). Our research showed significant effect of year and year/cultivar interaction on fruit firmness. Some research of genetic and environmental control of fruit firmness showed that some QTLs (quantitative trait loci) will be only expressed in the specific growing conditions, thus the environment effect on fruit firmness should not be underestimated (Chagné et al., 2014).

The potential of clones for production of high-quality apples should be further researched from the perspective of phytonutrients (vitamin C, phenols, carotenoids...) and different locations/altitudes for growing in Serbia.

CONSLUSION

1. Our research showed that clones have better attractiveness related to increase of red colour ('Schnico Red Gala', 'Scarlet Spur', 'Wilton's Red Jonaprince') or reduction of rustiness ('Reinders') in compare to parent cultivars. The most attractive fruits are the ones with the highest percent of red colour - 'Scarlet Spur', 'Wilton's Red Jonaprince'.
2. Different positive and negative changes of morphological parameters of fruit quality were recorded. Clone 'Reinders' had decreased fruit firmness in comparison to 'Golden Delicious', which can affect fruit storability. Fruit size is also negatively affected in the case of clones 'Wilton's Red Jonaprince' and 'Scarlet Spur' in comparison to cultivars.
3. On biochemical level, total soluble solids and total titratable acidity in clones varied differently in comparison to cultivars. The decrease of quality is noticed in the clone 'Scarlet Spur' and 'Reinders', while increase of biochemical components of quality and flavor index is present in 'Wilton's Red Jonaprince' and 'Schnico Red Gala'.
4. 'Schnico Red Gala' showed the highest increase of sensory properties in comparison to original cultivar ('Gala'), while the 'Wilton's Red Jonaprince' had the highest sensory evaluation score, followed by 'Jonagold'. 'Wilton's Red Jonaprince' showed the best overall biochemical quality and sensory traits. It should be considered for wider growing.

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