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Fruit Quality of Nine Old Apple Cultivars

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Abstract

The quality of the nine old apple cultivars ('Gelber Bellefleur', 'Carević', 'Čelenka', 'Crvena jesenska rebrača', 'Paradija', 'Paulaner Weinapfel', 'Perovnjača', 'Winter Banana' and 'Zuccalmaggio') was studied. The cultivars 'Gelber Bellefleur', 'Crvena jesenska rebrača', 'Paulaner Weinapfel' and 'Winter banana' had the highest fruit mass, and 'Carević', 'Čelenka', 'Paradija' and 'Zuccalmaggio' the lowest. The cultivar 'Gelber Bellefleur' had the highest fruit height and cultivar 'Čelenka' the smallest. The cultivar 'Perovnjača' had the highest fruit width, and cultivar 'Zuccalmaggio' the lowest. The cultivar 'Paradija' had the highest shape index and cultivar 'Perovnjača' the smallest. Among the red-coloured cultivars, the cultivars 'Carević' and 'Crvena jesenska rebrača' had significantly higher L and a-values, while the cultivar 'Čelenka' had significantly higher Chroma and Hue angles. Hue angle in this cultivar was 72% higher than in 'Crvena jesenska rebrača' and 51% higher than in 'Carević', showing intensive red coloration of this cultivar. Among the yellow-coloured cultivars, 'Winter Banana' had the highest L-value. There were no significant differences in a-values among the cultivars 'Gelber Bellefleur', 'Paradija', and 'Zuccalmagio', which had the highest values. The cultivar 'Paulaner Weinapfel' had the highest b- and Chroma values, and there were no significant differences among cultivars in Hue angle. The cultivar 'Zuccalmaggio' had the highest firmness and 'Paulaner Weinapfel' the lowest. The cultivar 'Crvena jesenska rebrača' had the highest SSC, and 'Perovnjača' the smallest. The cultivar 'Perovnjača' had the highest TA, and there was a significant difference compared to 'Čelenka'. The cultivars 'Crvena jesenska rebrača', 'Paradija', 'Winter Banana', 'Paulaner Weinapfel' and 'Zuccalmagio' had the lowest TA and there were no significant differences among them. The cultivar 'Crvena jesenska rebrača' had the highest SSC/TA ratio, and 'Perovnjača' the lowest. There were no significant differences in seed number per fruit among cultivars. The main disadvantage of these cultivars is the small fruit size, which is an important trait for fresh consumption. Therefore, it is necessary to evaluate improving the fruit size in these cultivars by pruning, fertilizing and thinning before their reintroduction into production.

Keywords: biodiversity, conservation, fruit quality, *Malus* × *domestica* Borkh., pomology

Introduction

Old apple cultivars are generally characterized by quite their unusual pomological traits and have sometimes a lower external appeal with respect to standard apples (Bignami *et al.*, 2003). Low external appearance and biennial bearing are the two main reasons for the loss of interest among apple growers to grow such cultivars. The range of apple cultivars in the European market has been significantly reduced to no more than 12 cultivars (Hecke, 2006). Donno *et al.* (2012) stated that in Italy more than 70% of orchards are planted with cultivar 'Golden Delicious'. This leads to genetic erosion and the loss of many local cultivars (Vujanić-Varga *et al.*, 1994).

In comparison with standard cultivars, old apple cultivars have a wide range in flavour, aroma, sugar and acid-content as well as higher firmness, total polyphenol and flavonoid content, vitamin C concentration and antioxidative potential (Hecke *et al.*, 2006; Radunić *et al.*, 2011; Balík *et al.*, 2012; Donno *et al.*, 2012). Internal quality (flavour, taste, crispness, etc.) ranks above appearance in importance among apple characteristics (Redalen, 1988). Flavour, taste and texture were the main reason for purchasing apples, as indicated by consumers (Harker, 2002), and phenolic compounds are important for prevention of cardiovascular diseases and cancer (Kroon and Williamson, 2005). Increased knowledge in old apple cultivars can help with diversification of the apple market (Itoiz and Royo, 2003; Pereira-Lorenzo *et al.,* 2007; Donno *et al.*, 2012) as well as maintenance of biodiversity and the historical and cultural links they represent (Donno *et al.*, 2012).

Some old apple cultivars, such as 'Wagener' have high yielding potential and many of them carry genes for resistance to pests and diseases, drought tolerance and winter hardiness (Vujanić-Varga *et al.*, 1994; Fischer and Fischer, 2004; Mitre *et al.*, 2009; Tóth *et al.*, 2012), together with unique fruit quality and wide genetic variability (Donno *et al.*, 2012). These traits make them excellent basic material for fruit breeding.

Due to these reasons, many apple genetic resources conservation and utilization programs have been initiated worldwide (Vujanić-Varga *et al.*, 1994; Hokanson *et al.*, 1998; Noiton, 1998; Zhi-Qin, 1999; Gradinariu *et al.*, 2003; Pereira Lorenzo *et al.*, 2003; Pirlak *et al.*, 2003; Ercis-

li, 2004; Holland *et al.*, 2006; Larsen *et al.*, 2006; Mratinić and Fotirić-Akšić, 2011; 2012; Balík *et al.*, 2012).

Many old apple cultivars have been abandoned by growers before the introduction of modern vegetative rootstocks, training forms and cultural practices. To evaluate their potential for reutilization, their response to modern fruit production methods must be known. Due to the insufficient information in the literature, the aim of this study was to evaluate the fruit quality of nine old apple cultivars on vegetative MM106 rootstock.

Materials and methods

The studied cultivars ('Gelber Bellefleur', 'Carevic', 'Celenka', 'Crvena jesenska rebrača', 'Paradija', 'Paulaner Weinapfel', 'Perovnjaca', 'Winter Banana' and 'Zuccalmaggio') were harvested in the apple collection of the Department of Pomology, Faculty of Agriculture, University of Zagreb in Šašinovci (45°51'1" N, 16°10'38" E). Trees were grafted on MM106 rootstock and planted at 5 m between rows and 4 m within rows. Cultural practices were regularly applied.

A sample of randomly picked 10 fruits per cultivar was harvested. The fruits were transported to the laboratory and visually inspected for damage and other defects. After determining fruit mass (g) on an analytical balance (Mettler-Toledo P1210, Mettler-Toledo International Inc., Columbus, USA) and fruit linear dimensions (fruit height and width, both in mm) with a digital calliper (PCE-DCP 200N, PCE Deutschland GmbH, Germany) and calculating fruit shape index as height:width ratio), fruits were selected for determining fruit colour, firmness, soluble solids content (SSC) and titratable acidity (TA).

Colour was measured according to CIE Lab system on a colorimeter Colortec PCM (ColorTec Associates, Inc., Clinton, USA). Colorimeter calibration was done with black and white plates supplied with the instrument and the fruit colour was represented with Hue angle (H°) (McGuire, 1992).

Firmness (kg·cm^{-2}) was measured using an Effegi FT 327 penetrometer (Facchini SRL, Alfonsine, Italy) with 11 mm probe as the average value from four measurements made at opposite fruit sides at the equatorial fruit zone.

The juice from each fruit was extracted with an electric juicer and was used for determination of SSC (°Brix) with a refractometer ATAGO PAL-1 (Atago Co., Ltd., Tokyo, Japan) according to Mitcham *et al.* (1996). Titratable acidity (TA) was determined by titration with 0.1 N NaOH and expressed in percent of malic acid per 100 ml of juice (Mitcham *et al.*, 1996).

Data analysis was conducted with SAS software, version 9.2 (SAS Institute, Cary, NC, USA) using one way ANOVA and Tukey's HSD test at $p \leq 0.05$ level.

Results and discussion

The cultivars 'Gelber Bellefleur', 'Crvena jesenska rebrača', 'Paulaner Weinapfel' and 'Winter banana' had the highest fruit mass, and 'Carević', 'Čelenka', 'Paradija' and 'Zuccalmaggio' the lowest (Fig. 1), and differences were significant. The fruit mass of cultivars 'Carević' and 'Perovnjača' had intermediate values between these two groups (Fig. 1). Fruit mass was in agreement with the results obtained by other studies for old and local cultivars (Pirlak *et al.*, 2003; Mitre *et al.*, 2009; Mratinić and Fotirić-Akšić, 2011; 2012; Balík *et al.*, 2012). In the cited studies,

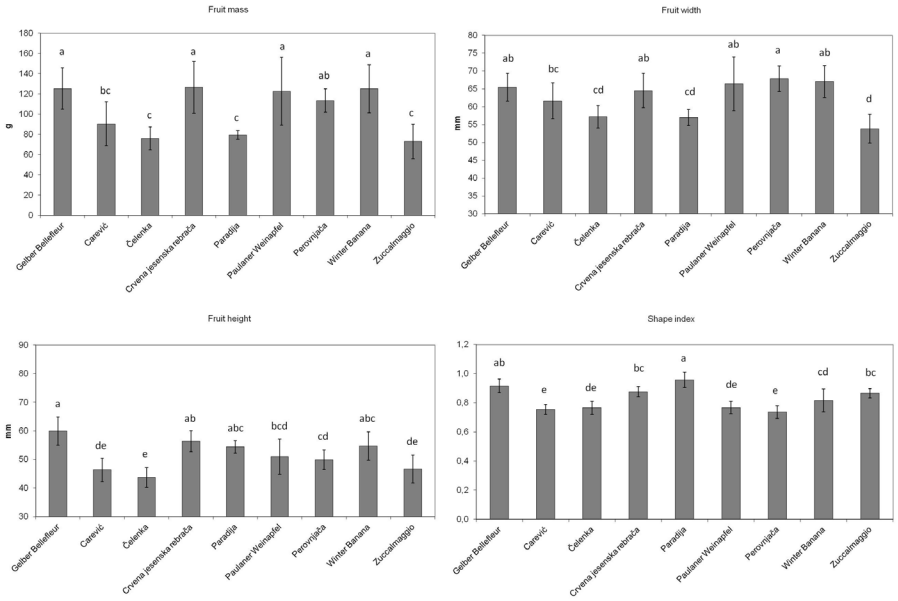

Fig. 1. Fruit mass, height, width and shape index of nine old apple cultivars

Note: Values marked by the same letter do not differ significantly at $p \leq 0.05$ according to Tukey's HSD test. Vertical bars indicate standard deviation

trees were also grafted on MM 106 rootstock, but grown in a closer space and under different ecological conditions (Mitre *et al.*, 2009) or grown on seedling rootstocks in extensive cultural practices (Mratinić and Fotirić-Akšić, 2011; 2012). Therefore, it can be concluded that genetic factors have a stronger influence on fruit mass than ecological conditions, rootstock or cultural practices.

The cultivar 'Gelber Bellefleur' had the highest fruit height and 'Čelenka' the smallest (Fig. 1), and differences were significant. Other cultivars had intermediate values with no significant differences.

Cultivar 'Perovnjača' had the widest fruits, and 'Zuccalmaggio' the narrowest, with a significant difference. There were no significant differences among other cultivars (Fig. 1). The obtained results are comparable to local cultivars found in Turkey (Pirlak *et al.*, 2003).

The cultivar 'Paradija' had the highest fruit shape index, followed by cultivars 'Crvena jesenska rebrača', 'Zuccalmaggio' and 'Winter Banana', and differences were significant. Cultivars 'Čelenka' and 'Paulaner Weinapfel' had significantly lower values and 'Perovnjača' the smallest (Fig. 1). Fruit size is affected by both exogenous (water availability and ambient temperature) and endogenous factors (crop load and genetic differences) as previously reported (Corelli-Grappadelli and Lakso, 2004). The most important factor affecting fruit size in this study are genetic differences, since all other factors were the same (water availability and ambient temperature) or similar (crop load). Fruit size is an important parameter for determining cultivar suitability for fresh consumption. Having this in mind, the fruit size in the studied cultivars was not satisfactory.

Among the red-coloured cultivars, 'Carević' and 'Crvena jesenska rebrača' had significantly higher L- and a-values, while 'Čelenka' had significantly higher Chroma and Hue angle (Tab. 1). Hue angle in this cultivar was 72% higher than in 'Crvena jesenska rebrača' and 51% higher than in 'Carević', showing nice and intensive red coloration of this cultivar.

Among the yellow-coloured cultivars, 'Winter Banana' had the highest L-value, with a significant difference. There were no significant differences in a-values among the cultivars 'Gelber Bellefleur', 'Paradija', and 'Zuccalmagio' which had the highest values. The cultivar 'Paulaner Weinapfel' had the highest b- and Chroma value. There were no significant differences among the cultivars in Hue angle (Tab. 1).

The cultivar 'Zuccalmaggio' had the highest firmness and 'Paulaner Weinapfel' the lowest. The cultivars 'Gelber Bellefleur', 'Winter Banana' and 'Crvena jesenska rebrača' had intermediate values and there were no statistical differences among them (Fig. 2). Similar firmness was found in modern apple cultivars (Mikulič Petkovšek *et al.*, 2009; Drogoudi and Pantelidis, 2011). Crop load can affect fruit firmness (Wünsche *et al.*, 2005; De Salvador *et al.*, 2006; Saei *et al.*, 2011), but in this study, crop load was similar in all cultivars. Therefore, the observed differences among cultivars are more the result of genetic factors.

The cultivar 'Crvena jesenska rebrača' had the highest SSC and 'Perovnjača' the lowest. All other cultivars had intermediate values with no significant differences (Fig. 2). SSC was similar to other studies with old apple and local cultivars (Mratinić and Fotirić-Akšić, 2011; 2012) but higher than in standard cultivars (Iglesias *et al.*, 2008) and local cultivars found in Turkey (Pirlak *et al.*, 2003) and Czech Republic (Balík *et al.*, 2012). However, some modern standard cultivars achieve SSC values similar to those in our study (Mikulič Petkovšek *et al.*, 2009; Drogoudi and Pantelidis, 2011). High SSC in the present study might be partly attributed to low crop load (Wünsche *et al.*, 2005; Saei *et al.*, 2011), though its effect was the same in all studied cultivars since there were no differences in crop load between cultivars. Therefore, it can be concluded that, although SSC depends on other factors such as ecological conditions, rootstock and cultural practices, the observed differences in SSC in this study are the result of genetic factors.

Tab. 1. Colour of old apple cultivars (mean ± SD)

Cultivar	Lightness	a- value	b- value	Chroma	Hue angle
Yellow cultivars					
'G. Bellefleur'	63.90 ± 8.65 ^{c}	-5.23 ± 8.05 ^{a}	39.80 ± 9.52 ^{c}	41.29 ± 7.24 ^{c}	94.14 ± 19.65 ^{a}
'Paradija'	69.89 ± 2.04 ^{ab}	-6.55 ± 2.00 ^{a}	42.13 ± 3.67 ^{bc}	42.68 ± 3.55 ^{c}	98.94 ± 2.83 ^{a}
'P. Weinapfel'	68.50 ± 2.79 ^{bc}	-6.92 ± 2.84 ^{ab}	51.24 ± 9.55 ^{a}	51.78 ± 9.51 ^{a}	97.87 ± 3.29 ^{a}
'Petrovača'	66.36 ± 1.85 ^{bc}	-9.73 ± 0.86 ^{ab}	38.40 ± 3.67 ^{c}	39.63 ± 3.62 ^{c}	104.30 ± 1.46 ^{a}
'Winter Banana'	74.77 ± 3.33 ^{a}	-11.69 ± 3.50 ^{b}	47.74 ± 5.72 ^{b}	49.34 ± 5.01 ^{b}	104.17 ± 4.98 ^{a}
'Zuccalmaggio'	66.13 ± 2.82 ^{bc}	-6.53 ± 1.32 ^{a}	39.11 ± 2.51 ^{c}	39.68 ± 2.43 ^{c}	99.55 ± 2.13 ^{a}
Red cultivars					
'Carević'	47.03 ± 4.53 ^{a}	13.25 ± 3.86 ^{a}	24.90 ± 7.10 ^{ab}	28.87 ± 4.83 ^{a}	60.31 ± 12.95 ^{b}
'Čelenka'	37.39 ± 4.15 ^{b}	-0.41 ± 8.36 ^{b}	29.56 ± 7.55 ^{a}	30.70 ± 7.33 ^{a}	91.14 ± 16.49 ^{a}
'CJR'	44.44 ± 5.38 ^{a}	12.40 ± 2.46 ^{a}	17.69 ± 6.25 ^{b}	22.18 ± 4.18 ^{b}	53.12 ± 14.35 ^{b}

Note: values followed by the same letter within the same column and group of cultivars (Red or Yellow) are not significant do not differ significantly at $p \leq 0.05$ according to Tukey's HSD test: G. Bellefleur - Gelber Bellefleur, P. Weinapfel - Paulaner Weinapfel; CJR - Crvena jesenska rebrača

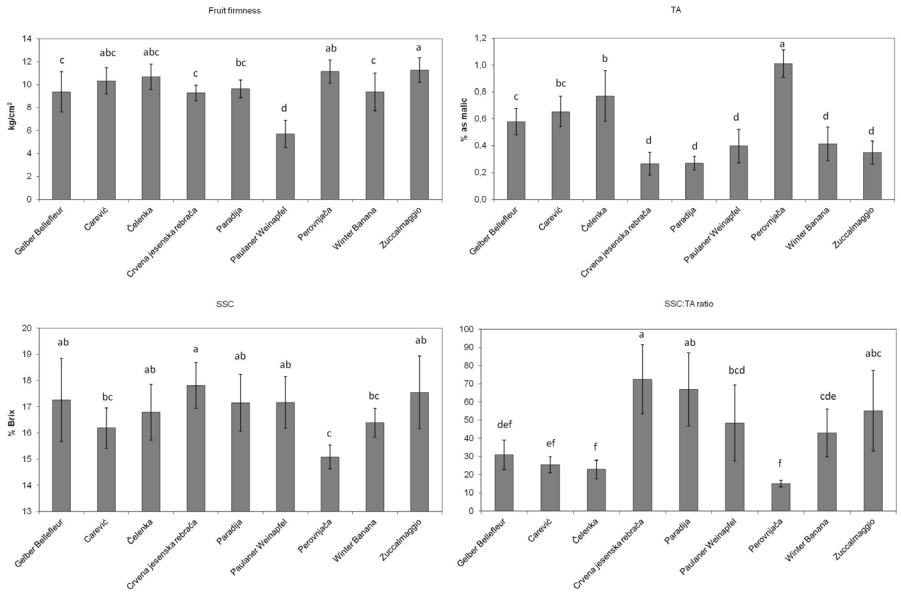

Fig. 2. Fruit firmness, SSC, TA and SSC: TA ratio of nine old apple cultivars

Note: Values marked by the same letter do not differ significantly at $p \leq 0.05$ according to Tukey's HSD test

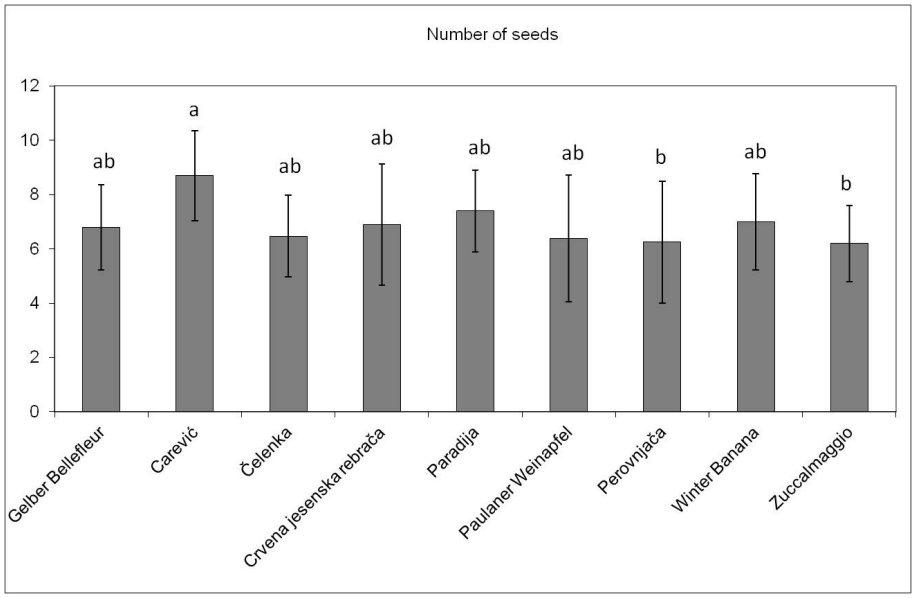

Fig. 3. Number of seeds per fruit in nine old apple cultivars

Note: Values marked by the same letter do not differ significantly at $p \leq 0.05$ according to Tukey's HSD test

The cultivar 'Perovnjača' had the highest TA, and there was a significant difference compared to 'Čelenka'. The cultivars 'Crvena jesenska Rebrača', 'Paradija', 'Winter Banana', 'Paulaner Weinapfel' and 'Zuccalmagio' had the lowest TA and there were no statistical differences among them (Fig. 2). Compared to the results for other apple cultivars, TA was in agreement for all cultivars in this study except for 'Čelenka' and 'Perovnjača', which had higher values. However, in some local cultivars, there is a wide range of TA levels which is in accordance with values obtained in this study (Mratinić and Fotirić-Akšić, 2011; 2012), except for 'Perovnjača' which had higher values (Fig. 2). Pirlak *et al.* (2003) found even higher TA in some local cultivars in Turkey. Balík *et al.* (2012) found lower TA concentrations in local Czech cultivars. Fruit from light cropping trees have higher TA values (Saei *et al.*, 2011), but this factor equally affected trees in this study and did not result in differences among the cultivars.

The cultivar 'Crvena jesenska rebrača' had the highest SSC:TA ratio, and 'Perovnjača' the lowest. Other culti-

vars had intermediate values and there were no significant statistical differences among them (Fig. 2). The cultivars 'Crvena jesenska rebrača', 'Paradija', 'Paulaner Weinapfel', 'Winter Banana' and 'Zuccalmaggio' had high SSC:TA ratio. Moreover, apple cultivars with SSC:TA ratios lower than 20 are suitable for processing and cider production (Lea, 1995) such as 'Perovnjača', while other are more suitable for direct consumption.

The cultivar 'Carević' had the highest seed number per fruit, and 'Zuccalmagio' the lowest. Other cultivars had intermediate values and there were no significant differences among them (Fig. 3). No relationship between seed number and fruit size was established in this study (Zisovich *et al.*, 2012), which further supports the thesis of a strong genetic influence on fruit size.

Conclusions

On the basis results of this study, the cultivar 'Perovnjača' might be suitable for cider production, while the remaining cultivars are more suitable for direct consumption. The internal quality of these cultivars is high, though their fruit size is not satisfactory. Fruit size is an important trait for fresh consumption cultivars. Therefore, it is necessary to evaluate the improvement of fruit size by pruning, fertilizing and thinning before their reintroduction into production.

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