

Preliminary results of ‘Timočanka’ plum cultivar storability

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Received: 2 November 2021; Accepted: 19 November 2021

Abstract. ‘Timočanka’ is a dessert plum cultivar created in Fruit Research Institute, Čačak. Although it has excellent fruit’s physical attributes, its storage potential has not been investigated so far. Commercial quality demands of plum cultivars aimed for fresh consumption mainly refer to physical properties, but nowadays an increased trend in society is healthy consumerism, particularly referring to bioactive compounds. For this reason, the presented study included evaluation of, not only physical properties of plum fruit, but also determination of total phenolic content and antioxidant capacity. No significant changes of fruit weight and soluble solids content after 21 days of cold storage were observed. Fruit firmness’ values were high on both analysis dates, notwithstanding fruit softening occurred during storage. Although ‘Timočanka’ is characterized by relatively low content of total phenols, the values of antioxidant capacity indicate that its consumption can increase the daily antioxidants intake.

Key words: *Prunus domestica* L., storage potential, fruit quality, physical properties, total phenolic content, antioxidant capacity

Introduction

Fruit Research Institute, Čačak (FRI) has a seventy-year long tradition in plum breeding work, which resulted in the development of 18 cultivars and a number of promising hybrids (Milošević et al., 2021). Although some of the released cultivars, such as ‘Čačanska Lepotica’, ‘Čačanska Rodna’, ‘Čačanska Najbolja’ and ‘Čačanska Rana’ are commercially grown worldwide, there are the several ones, perspective, but not so present in orchards. One of these cultivars is ‘Timočanka’. It is a dessert cultivar, derived from the cross ‘Stanley’ × ‘California Blue’, named and released in

2004 (Milenković et al., 2006). The tree is very vigorous, abundant in bearing wood. Flowering season is medium early, occurring almost in the same time as a flowering of ‘Čačanska Lepotica’ (Glišić et al., 2013; Butac et al., 2021). However, it is characterized with medium level of self-fertility and fluctuating bearing (Lukić et al., 2016). ‘Timočanka’ is tolerant to PPV (plum pox virus) (Ogašanović et al., 2007). Butac et al. (2021) emphasized that ‘Timočanka’ showed no PPV symptoms on the leaves or on the fruit under natural infection pressure in the orchard. Its ripening time is medium early, during the first decade of August (Glišić et al., 2013; Lukić et al., 2016). The fruit is lar-

ge (fruit weight above 60 g), with high soluble solids content, which are considered as one of the most important quality parameters of dessert plum cultivars. Furthermore, it is suitable for high density planting, which positively affects yield, fruit size and flesh ratio (Miletić *et al.*, 2019).

Commercial quality demands of plum fruit mainly refer to size, color and firmness, which is an indicator of good transportability. However, consumers' acceptance of plum is considerably determined by taste and aroma (Hoehn *et al.*, 2005). Furthermore, the nutritional value of fruit and health-beneficial properties are becoming more important determinants of consumers' choice. Plums are rich source of bioactive compounds, which play important role in the individual and synergistic contribution to the total antioxidant activity (Voća *et al.*, 2009; Mihalache Arion *et al.*, 2014; Korićanac *et al.*, 2020). Due to high content of phenols and potassium, consumption of plum fruits could effectively reduce the risk of many chronic diseases, such as heart disease and cancer (Byrne *et al.*, 2009).

Although plums, due to their high softening rate, have limited shelf life, meeting consumers' demands means supplying the market with high quality plum fruits for at least three weeks after harvest (Vangdal *et al.*, 2007). Thus, the choice of appropriate cultivar, not only in terms of yield but also in relation to fruit quality and storability, is of a great importance. The objective of this study was to determine the storability of 'Timočanka' fruit, by evaluating its physicochemical properties and antioxidant capacity at harvest and after cold storage.

Materials and Methods

Fruits of examined plum cultivar were harvested when the skin was dark-blue with heavy silvery bloom, and the flesh's color was light yellow. Harvest date was 5th August 2019. The fruits were obtained from the commercial orchard, located near Čačak (43°57'N, 20°19' E, 358 m a.s.l.). The orchard was established in 2005, with planting distance 4 × 2 m. The rootstock was Myrobalan (*Prunus cerasifera* Ehrh.) seedling and training system was spindle bush. All standard agricultural practices, except irrigation, were applied.

At the harvest twenty fruits were selected for measurements of weight and dimensions, after which

they were stored and used for the aforementioned measurements after cold storage. The fruits were stored for 21 days in a cold chamber (0–2°C and 90–95% relative humidity) in order to determine quality after storage. Fruit weight (g) was measured using an Ohaus Adventurer technical scale (Parsippany, NJ, USA). Fruit length (mm), width (mm) and thickness (mm) were measured using the digital caliper. Twenty fruits were used for measurement of firmness and soluble solid content (SSC) on every analysis' date. Firmness was determined by a hand penetrometer (probe's diameter 8.0 mm, model FT 327, T.R. Turoni, Forly, Italy) in the following way: two measurements were made on opposite sides of the fruit and then averaged in order to obtain the mean value expressed in kg cm⁻². Digital refractometer (Hanna Instruments, Germany) was used for measurements of SSC in the fruit. Titratable acidity (TA) was determined by neutralization with 0.1 N NaOH to pH 8.2, using phenolphthalein as an indicator. The results were expressed as a percentage (%) of malic acid.

In order to determine the total phenolic content (TPC) and antioxidant capacity (AC) of 'Timočanka' fruit, adequate sample preparation was performed in the following way: the pitted fruits were frozen in liquid nitrogen and ground using electric mill; the ground sample (3 g) was stirred with 30 ml of extraction solution (80% aqueous methanol); after 30 min of ultrasonic extraction, the mixture was centrifuged for 5 min at 3.000 rpm, supernatant was filtered and obtained extracts were used for analyses. Folin-Ciocalteu colorimetric procedure (Singleton *et al.*, 1999) was used for evaluation of total phenolic content (TPC) and the results were shown as milligrams of gallic acid in 100 g fresh sample (mg GAE 100 g⁻¹ FW). Antioxidant capacity (AC) was determined by the ABTS assay. ABTS^{•+} radical cation scavenging activity was determined according to the method described by Re *et al.* (1999). The results were expressed as millimoles of Trolox equivalents per 100 g of fresh weight (mmol TE 100 g⁻¹ FW). The analyses were performed in three replicates.

The obtained data were subjected to the one-way analysis of variance (ANOVA, F test). Multiple comparisons of means were performed by the Least Significance Difference (LSD) test with the significance threshold set at $P \leq 0.05$. Statistical analyses were performed using SPSS statistical software package, Version 8.0 for Windows (SPSS Inc., Chicago, IL).

Results and Discussion

Fruit size is an important characteristic in marketing of plums aimed for fresh consumption. The fruits of ‘Timočanka’ used in our experiment were large, with dark-blue skin covered with heavy silver bloom and yellow flesh (Fig. 1). However, the fruits were not uniform; the fruit weight varied from 58.80 g to 94.90 g at harvest, i.e. from 52.98 g to 89.26 g after cold storage. Interestingly, fruit weight was not significantly reduced during storage although transpiration and respiration processes normally occurred (Tab. 1). Butac *et al.* (2021) evaluated eight plum cultivars created in FRI under Romanian ecological conditions and also observed similar fruit weight in ‘Timočanka’ (63.21 g). Analogous findings were reported by Glišić *et al.* (2013), who detected ‘Timočanka’ fruit weight of 66.90 g. Paunović *et al.* (2020) reported the highest values for fruit’s height (52.40 mm) and width (45.10 mm) in ‘Timočanka’, among 13 plum cultivars and the reported values are in compliance with the ones obtained in our study (Tab. 1). Fruit’s height and width did not change significantly during storage.

As a consequence of biochemical changes during storage, particularly structural changes of cell wall polysaccharides, a firmness decline by 22.97% was observed. Firmness after storage was satisfactory, though. Similar results were reported by Casquero & Guerra (2009), who detected firmness decline in European plum cultivar ‘Oullins Gage’ from 11.97–21.78% after twenty days of cold storage, depending on ma-

turity stage at harvest. The same authors emphasized that all groups of plum fruits, regardless of maturity stage, had satisfactory firmness after twenty days of cold storage, which ranged from 1.32 to 3.72 kg cm⁻². Vangdal *et al.* (2007) evaluated fruit quality of several plum cultivars after two and three weeks of cold storage and detected reduction of firmness from 15 to 37%, depending on the tested cultivar.

Due to the strong correlation with taste, SSC, TA and their ratio are one of the most important quality indicators in plums. Hoehn *et al.* (2005) emphasized that for consumers’ acceptance of plum fruit (‘Čačanska Lepotica’) SSC should surpass 14%. In our study ‘Timočanka’ fruit contained something more soluble solids than the aforementioned limiting value regardless of analysis’ date (Tab. 2). In the literature data SSC in ‘Timočanka’ was higher, above 16% (Glišić *et al.*, 2013; Paunović *et al.*, 2020; Butac *et al.*, 2021) and these differences could be explained by various agroecological and climatic conditions in the studies or different maturity level. The SSC slightly increased during storage, while the total acids content decreased, and consequently SSC/total acids ratio increased (Tab. 2), which is in compliance with the previously described behavior of plum fruit during cold storage (Vangdal *et al.*, 2007; Korićanac *et al.*, 2020).

Plums are considered a rich source of bioactive compounds, particularly phenolics, which have health-promoting effect. However, the content of total phenolics is largely dependent on cultivar. Sahamishirazi *et al.* (2017) evaluated the TPC in 178 plum cultivars and



Fig. 1. Fruits of ‘Timočanka’ plum cultivar
Sl. 1. Plodovi sorte Timočanka

Tab. 1. Physical properties of 'Timočanka' plum fruit

Tab. 1. Fizičke osobine ploda sorte Timočanka

Analysis' date Vreme merenja	Fruit weight Masa ploda (g)	Fruit height Dužina ploda (mm)	Fruit width Širina ploda (mm)	Fruit thickness Debljina ploda (mm)	Fruit firmness Čvrstina ploda (kg cm ⁻²)
Harvest/Berba	74.53 ± 11.39	55.78 ± 0.59	48.80 ± 1.20 a*	47.46 ± 1.20	4.18 ± 0.07 a
21 days/21 dan	68.05 ± 10.87	52.91 ± 1.88	46.03 ± 1.08 b	46.03 ± 1.08	3.22 ± 0.22 b

* Mean values followed by different letters within a column represent significant difference according to the LSD test ($P \leq 0.05$)/Prosečne vrednosti u kolonama praćene različitim malim slovima statistički su značajno različite prema LSD testu ($P \leq 0.05$)

Tab. 2. Chemical properties of 'Timočanka' plum fruit

Tab. 2. Hemijske osobine ploda sorte Timočanka

Analysis' date Vreme merenja	SSC RSM (%)	Total acids Ukupne kiseline (%)	SSC/Total acids RSM/Ukupne kiseline	TPC/Ukupni fenoli (mg GAE/100 g ⁻¹ FW)	AC/Antioksidativni kapacitet (mmol TE/100 g ⁻¹ FW)
Harvest/Berba	14.11 ± 0.69	0.78 ± 0.01 a*	18.16 ± 0.88	31.43 ± 2.14 a	0.63 ± 0.01 a
21 days/21 dan	14.29 ± 0.88	0.75 ± 0.02 b	19.16 ± 1.58	14.52 ± 2.18 b	0.56 ± 0.02 b

* Mean values followed by different letters within a column represent significant difference according to the LSD test ($P \leq 0.05$)/Prosečne vrednosti u kolonama praćene različitim malim slovima statistički su značajno različite prema LSD testu ($P \leq 0.05$)

detected wide range of values, from 38.45 to 841.50 mg GAE 100 g⁻¹ FW. On the other side, range of the TPC in the study Mihalache Arion et al. (2014) was smaller, from 60 to 364 mg GAE 100 g⁻¹ FW, depending on cultivar. The same authors stated that summer cultivars contained lower amount of TPC in comparison with the late-ripening, autumn cultivars. 'Timočanka' had low content of TPC (31.43 mg GAE 100 g⁻¹ FW) and surprisingly it decreased during storage (14.52 mg GAE 100 g⁻¹ FW) (Tab. 2). Low content of TPC is cultivar characteristic and similar findings was observed by Tomić et al. (2019), who evaluated individual phenolics in several cultivars created at FRI as well as in few autochthonous plum cultivars. According to the cited authors, 'Timočanka' had three-fold lower content of neochlorogenic acid and procyanidin B2 and ten-fold lower content of rutin, which are the most abundant phenolics in plum fruit, in comparison to 'Čačanska Lepotica', also medium-early ripening cultivar. Antioxidant capacity determined by ABTS method was 0.63 mmol TE 100 g⁻¹ FW at the harvest and it slightly decreased during storage. The obtained values were in accordance with the data reported for European plum cultivars by Mihalache Arion et al. (2014). The obtained results of AC of 'Timočanka'

fruit indicates that the examined cultivar had greater AC in comparison to German cultivars 'Top' and 'Elena', examined by Voća et al. (2009). Although in our previous study on changes of bioactive compound and AC during storage of plums an increase of TPC and AC was observed (Korićanac et al., 2020), the behavior of 'Timočanka' was different, which indicates that changes of antioxidants during storage are cultivar dependent. It is established that summer cultivars generally show a decrease of TPC and AC during storage (Mihalache Arion et al., 2014).

Since phenolics include numerous compounds commonly present in plum fruit at relatively low concentrations, their contribution to AC could vary depending on cultivar. Wolf et al. (2019) found moderate correlation ($r = 0.79$) between these two parameters during evaluation of 27 cultivars. We have also observed certain similarities between TPC and AC: a decrease of TPC during storage resulted in reduction of AC, which indicates positive correlation between these two parameters and high contribution of phenolic compounds to antioxidant properties of 'Timočanka' plum fruit.

Conclusion

The preliminary results of our study indicate that ‘Timočanka’ is a cultivar well adapted to cold storage. Its fruit is large, firm, with high content of SCC and high SSC/total acids ratio. Although it is not rich in phenolic compounds, antioxidant capacity is relatively high and stable during storage. Thus, ‘Timočanka’ could be good source of antioxidants even after storage. Since loss of weight and firmness, which are major restraints for plum marketing, were not pronounced during 21 days of cold storage, it can be concluded that ‘Timočanka’ has good storability, which is of particular importance for fresh plums transported to distant markets.

Acknowledgements

This study was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Contract number: 451-03-9/2021-14/200215).

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PRELIMINARNI REZULTATI PROUČAVANJA TRAJAŠNOSTI PLODOVA SORTE TIMOČANKA**Aleksandra Korićanac^{1*}, Ivana S. Glišić¹, Branko Popović¹, Olga Mitrović¹, Nebojša Milošević¹, Ivan P. Glišić²**¹*Fruit Research Institute, Kralja Petra I 9, 32000 Čačak, Republic of Serbia*^{*}*E-mail: akoricanac@institut-cacak.org*²*University of Kragujevac, Faculty of Agronomy, Cara Dušana 34, 32102 Čačak, Republic of Serbia***Rezime**

U cilju zadovoljavanja zahteva trgovaca i kupaca, neophodno je obezbediti kontinuirano snabdevanje tržišta visokokvalitetnim plodovima šljive u što dužem vremenskom periodu, što se može postići gajenjem sorti različitog vremena zrenja i primenom adekvatne tehnologije berbe, čuvanja i pakovanja. Iako se komercijalni zahtevi tržišta prevashodno odnose na fizičke osobine plodova šljive (veličinu, čvrstinu, boju), kupci sve češće obraćaju pažnju na ukus, aromu, nutritivnu vrednost, ali i sadržaj bioaktivnih jedinjenja, koja blagotvorno deluju na zdravlje. Kako bi se očuvao kvalitet plodova, neophodno je ispitati trajanost tj. promene koje se u plodovima određene sorte dešavaju tokom čuvanja.

Timočanka je stona sorta šljive stvorena u Institutu za voćarstvo, Čačak. Iako se odlikuje dobrim proizvodnim osobinama (rano stupanje u rod, tolerantnost na virus šarke šljive, prouzrokovane rde i plamenjače) i krupnim plodom, nema podataka o trajanosti plodova ove sorte. Stoga je cilj istraživanja bilo ispitivanje fizičkih i hemijskih osobina ploda u berbi i nakon 21 dana čuvanja u hladnjači, na temperaturi od 0–2 °C i

relativnoj vlažnosti vazduha od 90–95%. Ubrani plodovi su bili vrlo atraktivnog izgleda: krupni, tamnoplave boje sa obilno prisutnim pepelkom. Plodovi su sadržali 14,11% rastvorljive suve materije (RSM), a odnos RSM i ukupnih kiselina takođe je bio visok. Gubitak mase plodova tokom čuvanja je bio zanemarljiv, a iako su plodovi omekšali njihova čvrstina nakon iskaldištenja bila je zadovoljavajuća. Sadržaj ukupnih fenola bio je nizak (31,43 mg GAE 100 g⁻¹ FW) i opao je tokom čuvanja (14,52 mg GAE 100 g⁻¹ FW), dok je antioksidativni kapacitet ubranih plodova bio relativno visok (0,63 mmol TE 100 g⁻¹ FW) i stabilan.

Na osnovu dobijenih preliminarnih rezultata može se zaključiti da sorta Timočanka ima plodove koji se odlikuju dobrom trajanošću pa se na tržište mogu plasirati nakon čuvanja, a zahvaljujući izraženoj čvrstini mogu podneti transport i do udaljenijih tržišta.

Ključne reči: *Prunus domestica* L., trajanost, kvalitet ploda, fizička svojstva, sadržaj ukupnih fenola, antioksidativni kapacitet