Chemical Composition and Antioxidant Capacity of Three Plum Cultivars

Sandra VOĆA (✉)
Ante GALIĆ
Zoran ŠINDRAK
Nadica DOBRIČEVIĆ
Stjepan PLIESTIĆ
Jasmina DRUŽIĆ

Summary

The aim of this study was to determine the chemical composition and antioxidants capacity of three plum cultivars, namely 'Top', 'Elena' and 'Bistrica'. Fruits were harvested and following parameters were determined: dry matter, total acids (TA), total soluble solids (TSS), pH, vitamin C, total phenols, non-flavonoids and antioxidant capacity. Differences between cultivars for most of the chemical parameters were observed. The cultivar 'Bistrica' showed higher values of dry matter, TSS, vitamin C and pH value, while 'Top' had higher total acids value and lowest TSS, dry matter, vitamin C and pH. Total phenolics content varied from 157.70 mg in 'Elena' to 344.10 mg in 'Bistrica', expressed as gallic acid equivalents (GAE), on fresh weight basis. 'Top' contains the highest amount of non-flavonoids among cultivars studied. Therefore, 'Bistrica' and 'Top' show the highest antioxidant capacity, as well. There were significant differences between total phenolics and non-flavonoids content between 'Elena' and other two cultivars, while antioxidant capacity showed no significant difference ($p \leq 0.05$). Total antioxidant capacity of fruits ranged from 3.10 mmol/kg in 'Elena' to 3.17 mmol/kg in 'Top' and 'Bistrica'.

Key words

plum, cultivars, chemical parameters, total phenolics, antioxidant capacity

University of Zagreb, Faculty of Agriculture, Svetošimunska cesta 25, 10000 Zagreb, Croatia
✉ e-mail: svoca@agr.hr

Received: October 8, 2008 | Accepted: April 3, 2009

Introduction

Plums are placed within the *Pronoideae* subfamily of the *Rosaceae*, in the subgenus *Prunophora* and include several species of *Prunus*. The most commonly grown species are *P. domestica* L. (European plum), *P. salicina*, *P. subcordiata* and *P. insititia* (Pijpers *et al*., 1986). Few cultivated varieties of European plums are destined mainly for fresh consumption, while the use of plums dried is becoming widespread (Sansavini & Lugli, 1998).

Growing plums (*Prunus domestica*) in Croatia have been a tradition for long time and this species is widely spread throughout country because of favourable ecological conditions. Plum fruits can be also used for production of plum brandy. The large part of plum production was basically dependent on one cultivar called 'Bistrica', predominantly grown in Croatia. (Družić *et al*., 2007)

In human nutrition plums are valued as a rich energetic source with high protective, dietetic and therapeutic value. Fresh fruits have low calorie content and relatively high nutritive value. They can greatly contribute to human nutrition because of their richness in antioxidants. Plums are also a big natural source of phytochemicals such as flavonoids, phenols, anthocyanins and other phythochemicals for which is determined that they have antioxidant capacity and may help protect cells against the oxidative damage caused by free radicals (Chun *et al*., 2003; Imeh *et al*., 2002; Stintzing *et al*., 2002). Various kinds of antioxidant components in plums may play important roles in the combinative or synergistic contribution to total antioxidant capacity. Plums are characterized by relatively high antioxidant capacity, higher than e.g. oranges, apples or strawberries (Kayano *et al*., 2002; Wang *et al*., 1996). For this reason when evaluating new cultivars we are especially interested in determining its fruit quality based on physical and chemical analyses.

The aim of the study was to compare 'Bistrica' that is traditionally grown in Croatia, with 'Elena' and 'Top' that are new cultivars advised by Hartmann (1998) in terms of their physicochemical properties and antioxidant capacity.

Materials and methods

Materials. In this research fruit composition of three table plum cultivars 'Elena', 'Bistrica' and 'Top' was analyzed. Cultivars 'Elena' and 'Top' were found in 'Jazbina' (45°51'17" N, 16°00'13" E) experimental orchard of Faculty of Agriculture in Zagreb and 'Bistrica' was grown in commercial orchard near Zagreb. Fruits were harvested in September 2006, in full maturity stage. After harvest, fruits were immediately stored in a 2-5 °C refrigerator for two days. The fruits were cleaned to remove all foreign matters as well as immature and damaged fruits. Plums were halved, and seeds were removed by hand. Analyses were performed immediately on fresh halved plums mashed to a pulp. Experiment was set as a random block design with five replications including total 150 fruits for each cultivar.

Methods. In harvested fruit we determined the following chemical parameters: total dry matter, soluble solids, pH, total acidity, vitamin C, total phenols (TPC), and antioxidant capacity (DPPH). Measurement of total dry matter was conducted with etalonic method by drying at 105 °C until constant mass (AOAC, 1995). Measurement of total soluble solids was conducted by reading of soluble solids directly from the refractometer scale (AOAC, 1995). pH value was measured using pH-meter; by immersing combined electrode in the homogenized sample and reading the values (AOAC, 1995). Measurement of total acidity was based on potentiometric titration with the solution of sodium hydroxide. This method is used for determination of total acidity of fruits and vegetables and products of fruits and vegetables (AOAC, 1995). Measurement of vitamin C (L-ascorbic acid) was conducted by titrimetric method with 2,6-p-dichlorphenolindophenolom. Method is based on L-ascorbic acid oxidation by 2,6-p-dichlorphenolindophenol into dehydroascorbic acid, until colour of reagent turns into colourless leucobasis, so at the same time it serves as indicator of this reaction. This method is used for determination of ascorbic acid in products of fruits and vegetables (AOAC, 2002).

Total phenolics (TPC), were determined using the Folin-Ciocalteu colorimetric method described by Amerine and Ough (1980) and Singleton and Rossi (1965) with some modification. Phenolics of the fruits were extracted from 10 g of fresh samples using 40 ml of 80 % aqueous ethanol. The mixture was extracted for 20 minutes in inert atmosphere, filtered through Whatman filter paper using a Buchner funnel. Extraction of the residue was repeated using the same conditions. The filtrates were combined and diluted to 100 ml in volumetric flask with 80 % aqueous ethanol. Obtained extract was used for determination of total phenolics. The content of total phenolics was measured as follow: 0.5 ml diluted extracts or standard solution of gallic acid (20-500 mg/L) added to a 50 ml volumetric flask containing 30 ml of ddH_2O, then 2.5 mL of Folin-Ciocalteu's reagent was added to the mixture and shaken. After 5 min, 7.5 mL of 7 % Na_2CO_3 solution was added with mixing and solution was immediately diluted to 50 mL with ddH_2O. After incubation at room temperature for two hours, the optical density of the solution at 750 nm was measured. Total phenolics were expressed as mg of gallic acid equivalents (GAE) per kilogram of fresh weight of edible part of fruit (Amerine and Ough, 1980).

The extract of total phenolics was used for determination of antioxidant capacity using 2,2-diphenil-1-picrylhydrazyl radical method (DPPH) (Brand-Williams, 1995). The method was based on reduction of stable DPPH nitrogen radicals in presence of antioxidants. Results were expressed as mmol Trolox equivalent per kg of fresh weight of edible part of fruits.

All spectrophotometric measurements were performed by UV-visible spectrophotometer UV-1650 PC.

Statistical analysis

According to completely randomized experimental design (with five replications) ANOVA and Tukey's Studentized Range

Table 1. Effects of cultivars on basic plum fruit chemical parameters

Cultivars	Dry matter (g/kg)	TSS (°Brix)	pH	Total acids (g/kg)
	P=0.0850	P=0.0192	P<0.0001	P=0.0041
'Top'	17.39a±0.31	15.80b±1.64	3.49c±0.010	0.695a±0.0873
'Bistrica'	22.01a±1.00	19.75a±0.35	4.02a±0.028	0.403b±0.0012
'Elena'	21.03a±2.97	18.85a±0.46	3.91b±0.026	0.406b±0.0474

Different letters within each column (parameter), indicate that the means are significantly different (P < 0.05)

Table 2. Effects of cultivars on antioxidant compounds contents and antioxidant capacity in plum fruit

Cultivars	Vitamin C (mg/100g F.W.)	Antioxidant capacity (mmol Trolox/kg F.W)	Total phenols (mg GAE/100g F.W.)	Non flavonoids (mg GAE /100g F.W.)
	P=0.0085	P=0.1706	P=0.0197	P=0.0146
'Top'	9.04b±0.61	3.17a±0.051	321.0a±75.2	162.6a±28.5
'Bistrica'	12.05a±0.86	3.17a±0.021	344.1a±40.7	155.8a±3.6
'Elena'	9.24b±0.62	3.10a±0.035	157.7b±30.4	88.3 b ±16.7

Different letters within each column (parameter), indicate that the means are significantly different (P < 0.05)

(HSD) test were performed in order to determine significances of parameters means differences between examined plum cultivars using the commercial software SAS 9.1® (Cary, NC: SAS Institute Inc., USA). Values are presented as the mean ± SD of five replications. P-values lower than 0.05, either from ANOVA or HSD, were considered statistically significant.

Results and discussion

Obtained results are showed in Tables 1 and 2. In Table 1 we can see basic plum fruit chemical parameters of cultivars 'Top', 'Bistrica' and 'Elena'. Cultivar 'Bistrica' had higher content of dry matter (22.01 %), total soluble solids (19.75 °Brix) and pH value (4.02), than cultivars 'Elena' and 'Top', while total acidity ratio (0.403 g/kg F. W.) was the lowest. Cultivar 'Top' had higher total acids value and the lowest TSS, dry matter and pH value. Results showed higher content of dry matter, TSS, and pH value than those reported by Družić *et al.* (2007) for the cultivars 'Elena' and 'Bistrica'.

In Table 2 content of vitamin C, total phenols, non-flavonoids and antioxidant capacity of selected cultivars are showed. The amount of vitamin C was the highest in cultivar 'Bistrica' (12.05 mg/100 g F. W.) followed by cultivars 'Elena' and 'Top'. However Družić *et al.* (2007) reported lower vitamin C content in 'Bistrica'. Results of vitamin C content measured by Gil *et al.* (2002) and Ertekin *et al.* (2006) for several commercial cultivars of plums are consistent with our results for cultivars 'Top' and 'Elena'.

The amount of total phenolics in plum cultivars were expressed as mg gallic acid equivalent (GAE) on a fresh weight basis. The total phenolic content of 100 g fresh plums ranged from 157.70 to 344.10 mg GAE (Tab. 2). Based on the total phenolics, the three plum cultivars studied may be classified into two groups, one exhibiting relatively high levels of polyphenolic phytochemicals and the other, low levels (Kim *et al.*, 2003). The cultivars having relatively high concentrations of phenolic phytochemicals were 'Bistrica' and 'Top', whereas the cultivar with lower concentrations was 'Elena'. The total phenolic content of 'Bistrica' and 'Top' were about two-fold higher than that of 'Bistrica'. The work of Kim *et al.* (2003) showed similar results where total phenols for fresh fruit ranged from 174 mg GAE/100 g to 375 mg GAE/100 g for six commercial cultivars of plums. Also according to Chun *et al.* (2003), amount of total phenols in fresh fruit ranged from 138.1 mg GAE/100 g for cultivar NY 9 (New York 9) to 684.5 mg GAE/100 g for 'Beltsville Elite'. Therefore it is apparent that our data are in accordance with their results and much higher than that reported by Gil *et al.* (2002) on several plum cultivars (42.0 -109.2 mg/100 g) grown in California.

Content of non-flavonoids obtained by these researches was not comparable with our results because they expressed non-flavonoid content on a fresh weight basis as mg of catechin equivalent (CE) per 100 g, while we expressed it on a fresh weight basis as mg of gallic acid equivalent (GAE) per 100 g. Among the tested cultivars, 'Top' ranked second highest in total phenolics and had the highest concentration of total non-flavonoids (162.60 mg GAE/100 g), followed by 'Bistrica' (155.80 mg GAE/100 g) and 'Elena' (88.30 mg GAE/100 g) with lowest non-flavonoids. The work of Družić *et al.* (2007) showed lower results where non-flavonoids in fresh fruit ranged from 73.32 mg GAE/100 g for to 105.85 mg GAE/100 g for cultivars 'Elena' and 'Bistrica', respectively.

Total phenolic and total non-flavonoid contents of the plum cultivar 'Elena' was significantly different at a significance level of P < 0.05 than in cultivars 'Top' and 'Bistrica'.

Antioxidant capacity in the analysed plum cultivars ranged between 3.10 – 3.17 mmol Trolox/kg F. W. (Tab. 2). It was noticed that cultivars 'Top' and 'Bistrica' showed similar values of antioxidant capacity (3.17 mmol Trolox/kg F. W.), while in cultivar 'Elena' antioxidant capacity slightly decreased. At the significance level of P < 0.05, antioxidant

capacity, among selected plum cultivars, showed no significant difference. Results obtained by other researchers were not comparable with our results because they expressed antioxidant capacity on a fresh weight basis as vitamin C equivalent antioxidant capacity (VCEAC) assay (Kim *et al*., 2003; Chun *et al*., 2003), or Trolox equivalent antioxidant capacity (TEAC) (Walkowiak-Tomczak *et al*., 2008) using ABTS radical, while we expressed it as mmol Trolox/kg of fresh weight of edible part of fruits using stable DPPH radical.

Wang *et al.* (1996) demonstrated that plums are rich source of antioxidants, and they had 4.4 times higher total antioxidant capacities than apples, the latter being one of the most commonly consumed fruits in our diet. So, the results of this study imply that dietary phytochemicals from plums may supply substantial antioxidants, which, in turn, may provide health-promoting effects to consumers. Also, it needs to be stressed that antioxidant capacity is tightly correlated with specific phenolics compounds (Chun *et al*., 2003; Stintzing *et al*., 2002). But in this study we did not achieve nor analyses nor identification of these individual phenolic compounds.

Conclusions

Various levels of phenolic phytochemicals may possibly result from cultivars, geographic origin, growing seasons and other agricultural practices. Since all three selected cultivars used in this study were grown in the same location under similar growing conditions, the variation in basic chemical composition and antioxidants capacity could be results of genetic variability of these plum selections.

Cultivars 'Top', 'Elena' and 'Bistrica', considering determined chemical parameters, showed good fruit quality for fresh consumption. In the research 'Bistrica' showed higher values of dry matter, TSS, pH, vitamin C and total phenols, while 'Top' had higher values of total acids and non-flavonoids. It can be concluded that although 'Elena' obviously has some favourable characteristics, cultivars 'Top' and 'Bistrica' had higher total phenolics content, non-flavonoides and antioxidant capacity. Although, cultivar Elena showed no significant difference in antioxidant capacity. Therefore, an increased consumption of this fruit is recommended in our diet.

Literature

Amerine M.A., Ough C.S.: Methods for Analysis of Musts and Wines, John Wiley and Sons, New York, USA (1980) pp.187–188,192–194

AOAC. (1995.). Offi cial methods of analysis (16th ed.). Washington, DC: Association of Official Analytical Chemists.

AOAC. (2002.). Offi cial methods of analysis (17th ed.). Washington, DC: Association of Official Analytical Chemists.

Brand-Williams W., Cuvelier M.E., Berset C. (1995). Use of a free radical method to evaluate antioxidant activity. *Lebensm.Wiss. Technol.* 28: 25-30.

Cao, G., Sofic, E., Prior, L.R., 1997. Antioxidant and prooxidant behavior of flavonoids: structure–activity relationships. Free Radic. Biol. Med. 22, 749–760.

Chun, O.K., Kim, D.O., Moon, H.Y., Kang, H.G., Lee, C.Y. (2003). Contribution of Individual Polyphenolics to Total Antioxidant Capacity of Plums. *Journal of Agricultural and Food Chemistry* 51: 7240-7245.

Družić, J., Voća, S., Čmelik, Z., Dobričević, N., Duralija, B., Skendrović Babojelić, M. (2007). Fruit Quality of Plum Cultivars 'Elena' and 'Bistrica'. *Agriculture Conspectus Scientificus*, 72 No.4: 307-310.

Ertekin, C., Gozlekci, S., Kabas, O., Sonmez, S., Akinci, I., (2006) Some physical, pomological and nutritional properties of two plum (*Prunus domestica* L.) cultivars. *J. Food Eng.* 75: 4, 508-514.

Gil, M. I., Tomas-Barberan, F. A., Hess-Pierce, B., Kader, A. (2002) Antioxidant capacities, phenolic compounds, carotenoids, and vitamin C contents of nectarine, peach, and plum cultivars from California. *J. Agric. Food Chem*., 50: 4976-4982.

Hartmann, W. (1998). New plum cultivars from Hohenheim. *Acta Horticulturae* 478: 171-174.

Imeh, U., Khokhar, S. (2002). Distribution of Conjugated and Free Phenols in Fruits: Antioxidant activity and Cultivar Variations. *Journal of Agricultural and Food Chemistry* 50: 6301-6306.

Kayano S., Kikuzaki H., Fukutsaka N., Mitani T., Nakatani N., 2002. Antioxidant activity of prune (*Prunus domestica* L.) constituents and a new synergist. *J. Agric. Food Chem.* 50: 3708-3712.

Kim, D. O., Jeong, S. W., Lee, C. Y., (2003). Antioxidant capacity of phenolic phytochemicals from various cultivars of plums. *Food Chem.* 81: 321–326.

Pijipers, D.; Constant, J. G.; Jansen, K. *The Complete Book of Fruit.* Multimedia Publications (UK) Ltd.: London, 1986; pp 98-103; Rosaceae - plum, cherry plum, damson, sloe.

Sansavini, S., & Lugli, S. (1998). La coltura del susino e la produzione di prugne secche in Italia. *Rivista di Frutticoltura*, 10: 19–26.

Singleton V.L., Rossi J.A. (1965). Colorimetry of total phenolics with phosphomolybdic phosphotungstic acid reagents. *Am. J. Enol. Vitic.* 16: 144–158.

Stintzing, F. C., Stintzing, A. S., Carle, R., Frei, B., & Wrolstad, R. E. (2002). Color and antioxidant properties of cyanidin-based anthocyanin pigments. *Journal of Agriculture and Food Chemistry*, 50: 6172–6181.

Walkowiak-Tomczak, D., Regula, J., Lysiak, G. (2008). Physico-chemical properties and antioxidant activity of selected plum cultivars fruit. *Acta Sci. Pol., Technol. Aliment.* 7 (4): 15-22

Wang, H., Cao, G., & Prior, R. L. (1996). Total antioxidant capacity of fruits. *Journal of Agricultural and Food Chemistry*, 44:701–705.

acs74_48