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Sorbitol and Sugar Composition in Plum Fruits Influenced by Climatic Conditions

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ABSTRACT

The aim of the study was to evaluate changes of sorbitol, glucose, fructose, sucrose, and total sugars of plum fruits in different years under different climatic conditions i.e. air temperature and precipitation. The cultivars investigated in the research were: Topstar, Toptaste, Jojo, Haganta, Tophit, and Top 2000. The fruits were harvested at optimal stage of maturity in the experimental orchard of the Agricultural Institute Osijek. Content of glucose, fructose, sucrose, and sorbitol in the fruits were identified and quantified by high performance liquid chromatography (HPLC). Significant differences were found between sucrose, glucose, fructose, and sorbitol depending on climatic conditions and cultivar. Sucrose was the highest in almost all years. Glucose was the predominant sugar in cultivars Jojo and Top 2000. Fructose and sorbitol contents were lower than sucrose and glucose. Average sugar contents in 2008-2012 period were compared with respect to climatic conditions. A significant effect of year was found for sucrose, sorbitol, total sugar, and dry matter, whereas no effect was found for glucose and fructose contents. Individual sugar contents correlated significantly with each other. The principal component analysis (PCA) showed that plum cultivars were clearly differentiated according to variability of sugar in fruit caused by climatic conditions. The obtained results highlighted that climatic conditions may have significant effect on plum fruit quality and, therefore, it is important to have adequate testing before recommending a cultivar for planting.

Keywords: HPLC, Plum cultivar, Sugar.

INTRODUCTION

Among the stone fruits, plums are extensively distributed, the most variable native and cultivated specie and the most adapted to a wide range of soils and climatic conditions. The fruits show a wide range of size, flavor, color, and texture. Growing plums (*Prunus domestica* L.) in Croatia has been a tradition for long time and this species is widely spread throughout the country because of favorable climatic conditions. The selection of cultivars, depending on local climatic and soil conditions, is important in increasing the area and productivity of these cultures. We search for cultivars with attractive fruit, disease-resistance, high yield, improved fruit quality, and prolonged harvest season as well as those that may be kept in cold storage for a longer time. The large part of plum production in Croatia was basically established on one cultivar called Bistrica, but this cultivar is not suitable for intensive production due to sensitivity to Plum Pox Virus (Druzic *et al.*, 2007). Thus, one of the basic conditions determining profitability of plum production is the introduction of new valuable cultivars suitable for intensive growing in commercial orchards (Crisosto *et al.*, 1997; Blazek and Pistekova, 2009).

Plums are primarily used for fresh consumption as well as for processing. Varietal differences can also contribute to variations in the consumption of raw and

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finished product. Maturity at harvest is the most important factor that determines final fruit quality and storage-life (Siddiq, 2006; García-Marino *et al.*, 2008; Singh *et al.*, 2009; Thammawong and Arakawa, 2010). Fruit ripening is a highly coordinated, genetically programmed, and an irreversible phenomenon involving a series of physiological, biochemical, and organoleptic changes that lead to the development of a soft and edible ripe fruit with desirable quality attributes. A wide spectrum of biochemical changes such as increased respiration, chlorophyll degradation, biosynthesis of flavor and aroma components, increased activity of cell wall-degrading enzymes, and a transient increase in ethylene production are some of the major changes involved during fruit ripening (Prasanna *et al.*, 2007). Sugar content is the most relevant for consumer perception of maturity and it is a factor closely related to the stage of maturity in plum fruits (Manganaris *et al.*, 2008; Nunes *et al.*, 2009). Plums contain three predominant sugars: glucose, fructose, sucrose and sugar alcohol sorbitol; and their content varies with cultivar (Wilford *et al.*, 1997; Usenik *et al.*, 2008). Sorbitol and sucrose contain the two main forms of photosynthetic and translocated carbon and may have different functions depending on the organ of utilization and its developmental stage. The role and interaction of sorbitol and sucrose metabolism was studied in mature leaves (source) and shoot tips (sinks) of peach under drought stress (Lo Bianco *et al.*, 2000). The authors concluded that loss of sorbitol dehydrogenase activity in sinks leads to osmotic adjustment via sorbitol accumulation in the fruit. Glucose and fructose are present in smaller quantities and their relation affects the taste of the fruit. Many factors such as cultivar selection, site of growth, climate, and agricultural practices affect the quality of the fruit (Crisosto *et al.*, 1995; Vangdal *et al.*, 2005; Guerra and Casquero, 2009). Growing of introduced plum cultivars requires determination of not only agronomical but also their quality characteristics under local conditions. The aim of this study was to evaluate variability of glucose, fructose, sucrose, sorbitol and total sugars of plum fruits and their changes in different years under different climatic conditions i.e. air temperature and precipitation.

MATERIALS AND METHODS

The study was carried out at experimental orchard of the Agricultural Institute Osijek in eastern Croatia. In 2005, the introduced plum cultivars were planted in the experimental orchard. Plum trees were planted in three rows, where each row represented one replicate. In each row, four plum trees were planted, representing one block of each cultivar. Blocks were randomized with three replications. The soil type was eutric cambisol. Climatic conditions of Osijek area during the vegetation period is shown in Table 1. No irrigation was applied in the orchard. Fertilizers were applied according to soil analysis i.e. in average, 200 kg ha^{-1} NPK (7: 20: 30) in autumn and 250 kg ha^{-1} CAN

Table 1. Temperature and rainfall during the vegetation period in 2008 to 2012 at Osijek.

	Temperature in $^{\circ}$C (Monthly average)					Rainfall in mm (Monthly average)				
Years	2008	2009	2010	2011	2012	2008	2009	2010	2011	2012
April	12.6	14.6	12.4	13.2	12.5	51.6	15.7	71.1	20.4	47.3
May	19.3	19.0	16.5	16.7	16.9	114.5	45.5	120.8	81.2	93.5
June	22.0	23.6	23.2	22.2	24.8	88.9	73.9	234.0	49.9	67.9
July	22.8	23.6	23.2	22.2	24.8	70.1	31	31.5	73.8	47.8
August	23.1	23.5	21.7	23.1	24.1	27.8	61.9	110.8	4.6	4.00
September	15.9	19.6	15.6	20.3	18.9	85.4	2.8	108.4	15.9	32.3

(27% N) in early spring.

The fruits of six plum cultivars (*Prunus domestica* L.), namely, Topstar, Toptaste, Jojo, Haganta, Tophit, and Top 2000 were harvested at the proper stage of maturity. The optimal harvest dates ranged from the end of July to the mid September, depending on the cultivar. In each harvest, fruits were taken from the trees at the height of 1.5 to 2 m, parallel from the edge and the interior of the canopy. An average sample of all the four trees in the block comprising 2-3 kg or 30-40 fruits was taken for analysis. Only undamaged and healthy fruits were taken in the morning, and immediately shipped to the laboratory for analysis. Ten fruits from each replication were used to determine dry matter, sorbitol, sucrose, glucose, fructose, and total sugars.

Seedless plum fruits were thoroughly crushed in an electric mixer. Extraction was performed with water at 50°C for 15 minutes. After filtration, extracts were passed through 0.45 μm syringe filter, just before analyses. Glucose, fructose, sucrose, and sorbitol were analyzed by using a High Performance Liquid Chromatography system series 200 equipped with degasser, isocratic pump, refractive index detector and TotalChrom Navigator (HPLC software) (Perkin-Elmer, Massachusetts, USA). The separation was performed on MetaCharb Ca Plus column (300×7.8), thermostated at 90°C. Twenty μL aliquots were injected into the column and eluted with water at flow rate of 0.5 mL min^{-1}. Standard solution was composed of sucrose, glucose, galactose (internal standard), fructose and sorbitol at concentrations of 5, 10 and 15 mg mL^{-1}. Sugars from aqueous sample extract were identified by their retention time and quantified by peak area using internal standard procedure. Total sugars were represented as the sum of sucrose, glucose, fructose, and sorbitol. All measurements were conducted in four replications. Sugars content were expressed as a percentage of fresh weight of plum.

Analysis of variance (ANOVA) and multiple comparisons (Duncan's post hoc test) were used to evaluate the significant difference of the data at $P< 0.05$. Correlations between traits to reveal possible relationships were calculated from raw data of the 5 years, using the Pearson correlation coefficient at $P\leq 0.05$. Principal component analysis was applied to standardized variables. The principal components scores were plotted for individual observations in relation to the most significant axes whose eigenvalues were greater than 1.0. All statistical analyses were performed using statistical-graphic system "Statistica" (Stat Soft software Inc., Tulsa, OK, USA).

RESULTS AND DISCUSSION

Climatic Conditions

According to the climatic condition data, the years analyzed in our study were significantly different (Table 1). In 2010, there was a lot of precipitation and the average air temperature was lower than in 2008, whereas in 2008 there was less rainfall and slightly higher average air temperature. The other three years had much less precipitation and higher average air temperatures. Growing season 2008 and 2010 were favorable with regard to precipitation and air temperature. In contrast, 2009, 2011, and 2012 were characterized by a water deficit and higher temperatures. Drought was the main weather characteristic of these growing seasons. 2011 and 2012 were two consecutive drought years. According to Rieger and Duemmel (1992), drought stress severely limits successful cultivation of *Prunus* species fruits in arid climates and in areas with shallow soils. In large-fruited species like peach, both yield and quality are negatively affected by drought stress, particularly during the 4-6 week period before harvest, when the fruits increase rapidly in weight and diameter.

Sugar Content in Plum Fruit

Content of dry matter, individual sugars, and total sugars of the six plum cultivars in five years are shown in Figure 1 (A-F). Analysis of data showed significant differences in dry matter content among years, cultivars, as well as significant interaction between cultivars and year. The dry matter content in five years of the study for the tested cultivars ranged between 16.79 to 21.96% (Table 2). In 2012, all cultivars, except Haganta, had the highest values of dry matter content. Climatic conditions in

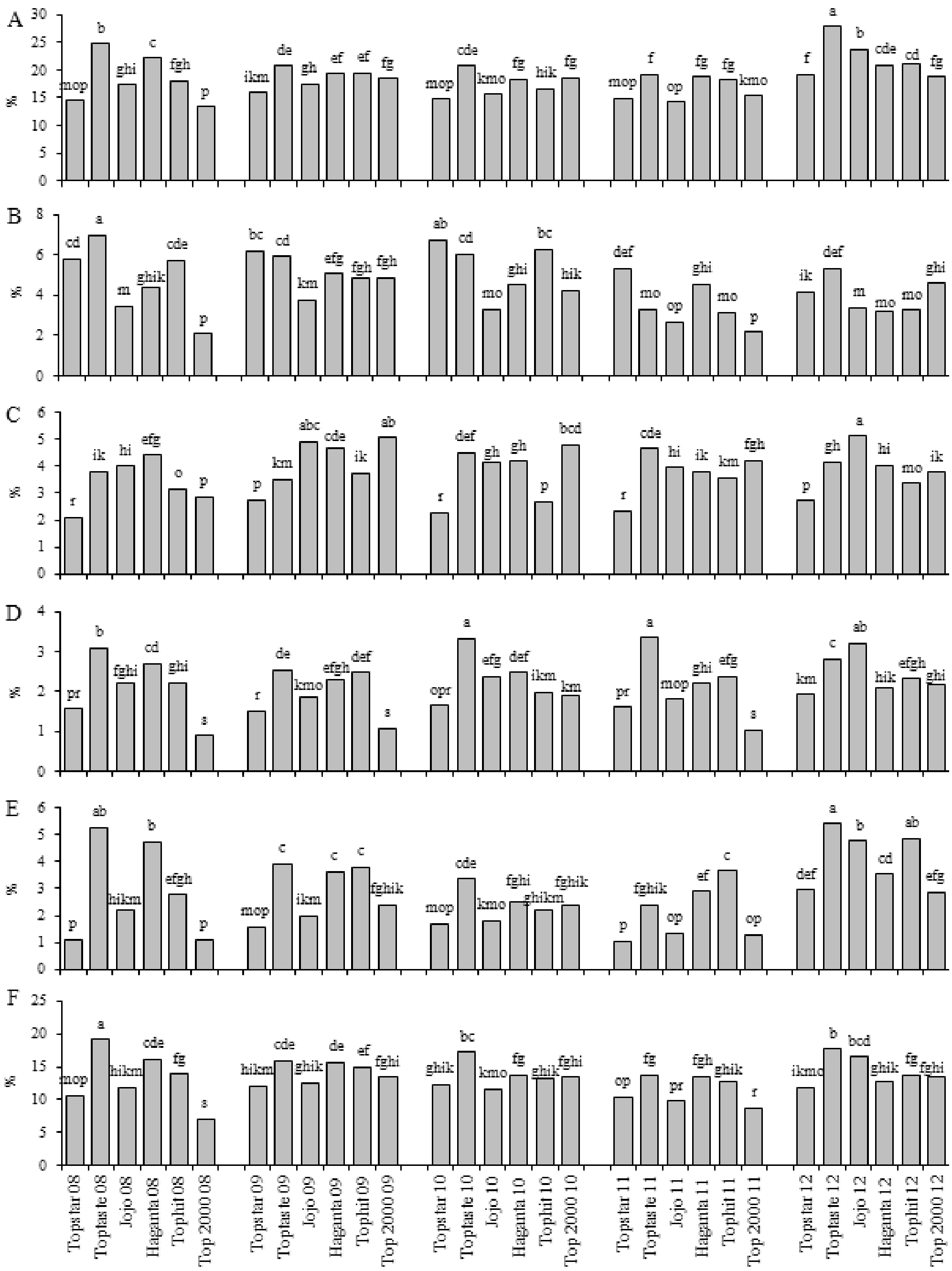

Figure 1. Dry matter (%) (A), sucrose (B), glucose (C), fructose (D), sorbitol (E) and total sugar (F) content (% FW) in fruits of six plum cultivars in different years. Different letters (a–s) denote statistically significant differences in parameters by Duncan's multiple range test at P< 0.05 among harvest years and cultivars.

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Table 2. Mean values of dry matter, sucrose, glucose, fructose, sorbitol and total sugar content in the investigated years and cultivars.

Year	Dry matter	Sucrose	Glucose	Fructose	Sorbitol	Total sugars
2008	18.37 b [a]	4.74 a	3.39	2.12 ab	2.87 b	13.11 a
2009	18.58 b	5.13 a	4.10	1.97 b	2.88 b	14.08 a
2010	17.48 bc	5.20 a	3.77	2.29 ab	2.33 bc	13.58 a
2011	16.79 c	3.54 b	3.75	2.07 ab	2.10 c	11.46 b
2012	21.96 a	3.99 b	3.86	2.43 a	4.06 a	14.33 a
Cultivar	**Dry matter**	**Sucrose**	**Glucose**	**Fructose**	**Sorbitol**	**Total sugars**
Topstar	15.86 c	5.66 a	2.43 c	1.65 c	1.68	11.42 c
Top taste	22.71 a	5.53 a	4.12 a	3.03 a	4.06	16.73 a
Jojo	17.70 bc	3.32 b	4.43 a	2.30 b	2.41	12.46 bc
Haganta	19.94 ab	4.35 ab	4.22 a	2.35 b	3.46	14.39 ab
Tophit	18.71 bc	4.67 ab	3.30 b	2.28 b	3.46	13.71 bc
Top 2000	16.23 c	3.60 b	4.13 a	1.42 c	2.02	11.17 c

[a] Different letters (a–c) denote statistically significant differences in parameters by Duncan's multiple range test at $P< 0.05$ among harvest years and cultivars.

this year were characterized by lack of precipitation and higher temperatures during the ripening. The results indicated that climatic condition (absence of rainfall and high daily temperature during maturity) affected dry matter content variability. The highest value of dry matter was observed in Toptaste in all investigated years (Figure 1-A).

Specific sugar contents are well known for contributing to a range of quality traits of fresh fruits such as flavor, texture, and health properties. Main sugars in the investigated plum cultivars were sucrose, glucose, fructose, and sugar alcohol sorbitol (Figure 1, B-F). The studied genotypes revealed considerable variation in sugar contents among the years and cultivars. Sucrose was the major sugar over the studied years in the tested cultivars, with a content of 4.52% (Table 2). Favorable year for sucrose accumulation in fruits was 2010 (Figure 1-B). In 2011 and 2012, sucrose content was significantly lower than in the other years. Significant difference in the percentage of sucrose may be explained by the differences in climate between years. Sucrose is one of the main transport sugars, which are products of photosynthesis in leaves and not produced in fruits, but translocated from other parts of the tree through phloem. During fruit development, high photosynthetic rate is necessary for growth requirements of peach. Under drought stress, sucrose metabolism is only marginally reduced in peach (Lo Bianco *et al.*, 2000). Based on the value of sucrose in 2010, the amount of sucrose in the following two consecutive years was reduced: in 2011 by 34.81% and in 2012 by 23.27%. Genotype to genotype analysis showed that cultivars differed in the content of sucrose. The highest values were observed in Topstar (5.66%) and Toptaste (5.53%) and followed by Tophit (4.67%), Haganta (4.35%), Top 2000 (3.60%) and Jojo (3.32%) (Table 2). The cultivars in this study exhibited considerable genotypic variations in sucrose content, and results are comparable to those of other authors (Usenik *et al.*, 2007, 2008; Bohacenko *et al.*, 2010; Sudar *et al.*, 2011). Other authors suggest that many factors influence sucrose content in peach, including harvesting date, which showed significant negative correlation with sucrose content indicating that harvesting time could present variability among years and, consequently, influence the sucrose and total sugar content among genotypes (Abidi *et al.*, 2011).

Data analysis and Duncan *post hoc* test showed no significant difference in glucose content in the four investigated years. In 2008, the glucose content was notably lower

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than in the other years. Genotype to genotype analysis showed that cultivars differed in the glucose content (Figure1C). Cultivars Jojo and Top 2000 contained the highest amount of glucose (4.43 and 4.13%, respectively). Glucose was the predominant sugar in Jojo in all investigated years. Other cultivars contained glucose in the range of 2.43 to 4.22%. Changes in this sugar could be the result of genetic factors affecting the accumulation of glucose in plum fruit.

Fructose over the studied years varied from 1.97 to 2.43% (Table 2). ANOVA and Duncan *post hoc* test showed that difference existed only between 2009 and 2012. The highest fructose content was found in Toptaste (3.03%) and lowest in Top 2000 (1.42%) (Figure 1-D). The reducing sugars constituted a transitory storage pool and their concentrations were closely related to metabolism. According to Genard *et al.* (2003), variations in glucose and fructose concentrations were positively related to the metabolic transformation of sorbitol and, to a much lesser extent, to the hydrolysis of sucrose in the early stages of fruit development. The metabolic transformation of glucose and fructose was providing for the synthesis of compounds other than sugars. Glucose was more abundant than fructose in plum cultivars and concentrations of these sugars influenced sweetness, as fructose is 2.3 and 1.7 times sweeter than glucose and sucrose, respectively. Variation in glucose: fructose (G: F) ratio was noted between years and between cultivars. In the five years of investigation, a slight variation was noted (from 1.60-2.34). Among cultivars, Toptaste had lower glucose: fructose ratio (1.36) but sweeter taste than Top 2000 with higher ratio (3.23). Wu *et al.* (2012) established a SUGAR model to predict the partitioning of carbon into sucrose, glucose, fructose, and sorbitol in fruit mesocarp of peach cultivars with normal and high glucose: fructose ratio. The extended model assumes a high G: F ratio to be due to preferential transformation of sorbitol into glucose, preferential utilization of fructose, or preferential conversion of fructose into glucose. The relative rates of sucrose transformation into glucose and fructose differed according to cultivar, but not according to G: F status.

The sorbitol content varied significantly among the years, ranging from 2.10 to 4.06% in 2011 and 2012, respectively (Table 2). Difference in accumulation of this compound may be explained by the annual climatic conditions to which the genotypes were subjected during ripening. Sorbitol is, beside sucrose, the main transport sugar of most species of the R*osaceae,* which is a product of photosynthesis in leaves but, similar to sucrose, translocated in fruit (Lo Bianco *et al.*, 2000). In response to water stress, apple (Wang and Stutte, 1992) and peach (Escobar-Gutiérrez and Gaudillére, 1994) leaves show decrease in sucrose and starch, whereas sorbitol, glucose and fructose increase rapidly. Drought-induced changes in carbohydrate concentrations were related to increased activities of enzymes associated with carbohydrate metabolism. Sorbitol, as the main component of carbohydrates, has important role in osmotic adjustment during water deficit (Li and Li, 2005). Our results showed that in 2012, highest level of sorbitol was noted for all cultivars, except Haganta (Figure 1-E). Significant difference in sorbitol content existed between cultivars. Sorbitol content varied from 1.68 (Topstar) to 4.06% (Toptaste). The highest amount was found in Toptaste in almost all the investigated years, except 2011 (Tophit). Our results agree with the report of Usenik *et al.* (2007).

Total sugar content (the sum of sucrose, glucose, fructose, and sorbitol) in fruits ranged from 13.11 to 14.33% (Table 2). A small yearly variation of total sugar content was found among the years, except for 2011(Figure 1-F). In this year, the low values of sucrose, fructose, and particularly sorbitol reflected on the amount of total sugars which also agreed with dry matter content. Total sugar content is an important quality trait highly related to the taste and aroma of fruit. Sweetness is mostly attributable to mono and disaccharides rather than to other compounds. Proportion of the four sugars found in plum can influence fruit sweetness. Sugar concentrations vary throughout fruit development according to the supply of phloem sugars, changes in fruit metabolism, and dilution caused by increases in fruit volume (Lo Blanco *et al.*, 2000). Data analysis and Duncan *post hoc* test showed that significant difference existed between the cultivars (Table 2). The Toptaste showed the highest amount of total sugar (16.73%), followed by Haganta (14.39%), Tophit (13.71%), Jojo (12.46%), Topstar (11.42%), and Top 2000 (11.17%). Similar data for total sugar content was reported by Usenik *et al.* (2007, 2008), Bohacenko *et al.* (2010), Sudar *et al.* (2011), Milosevic and Milosevic (2012), with specific differences due to the use of different plum cultivars.

Correlations

Table 3 shows the correlation coefficients between climatic conditions and plum sugars. Sucrose content significantly positively correlated with precipitation. On the other hand, sorbitol and dry matter negatively correlated with precipitation. It indicated that a lot of precipitation induced lower sorbitol content and, conversely, less rainfall leads to accumulation of sorbitol in the fruit. It is in agreement with the results of sorbitol content in pear juices produced from irrigated and non-irrigated tree. Juice produced from non-irrigated fruit had increased sorbitol content (Dietrich *et al.*, 2007). Correlation between precipitation and other sugars were not found. Sorbitol, total sugars, and dry matter significantly positively correlated with temperature. No correlation between temperature and other sugars was found. Total sugar positively correlated with all sugars. Sucrose content positively correlated with total sugars, but negatively with glucose. This was probably because some cultivars contained glucose as the dominant sugar. Glucose, fructose, and sorbitol contents highly and positively correlated with each other. In peach and nectarine, Cantín *et al.* (2009) found significant effect of year for soluble sugars, sucrose, and glucose contents, whereas no effect was found for fructose and sorbitol contents. They also found that individual sugar contents correlated significantly with each other and with other fruit quality traits. Response of cultivars to climatic condition is different, which could be explained by differences in genotypes. The highest effect of precipitation and temperature was noted for Tophit in all parameters, except total sugars, followed by Topstar, Toptaste, Haganta, and Top 2000 (Table 4). In Jojo, only temperature effect was noted on all parameters, expect fructose.

Principal Component Analysis

In order to overview the data for similarities and dissimilarities, PCA was applied on the calculated descriptors of studied compounds and resulted in a two-component model that explained 83.721% of the total variance. PC1 and PC2, respectively, accounted for 60.199% and

Table 3. Correlation coefficients between rainfall, temperature, and sugar content for five years.

Traits	Sucrose	Glucose	Fructose	Sorbitol	Total sugar	Dry matter
Temperature	- 0.031	0.101	- 0.037	0.472*	0.230*	0.446*
Rainfall	0.374*	- 0.051	0.127	- 0.222*	0.118	- 0.202*
Sucrose		- 0.431*	0.120	0.120	0.495*	0.121
Glucose			0.437*	0.333*	0.381*	0.447*
Fructose				0.630*	0.773*	0.652*
Sorbitol					0.821*	0.926*
Total sugar						0.843*

* Significant at $P \leq 0.05$.

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Table 4. Correlation coefficients between rainfall, temperature, and sugar content for plum cultivars.

Cultivar	Climate	Sucrose	Glucose	Fructose	Sorbitol	Total sugar	Dry matter
Topstar	Temperature	- 0.540*	0.788*	0.233	0.556*	0.058	0.700*
	Rainfall	0.719*	- 0.548*	- 0.061	0.080	0.553*	- 0.422*
Toptaste	Temperature	- 0.154	- 0.733	- 0.834*	- 0.611*	- 0.158	0.570*
	Rainfall	0.494*	0.357*	0.492*	- 0.173	0.348	- 0.247
Jojo	Temperature	0.484*	0.829*	0.233	0.612*	0.646*	0.723*
	Rainfall	0.144	- 0.360	0.199	- 0.250	- 0.132	- 0.302
Haganta	Temperature	- 0.235	0.290	- 0.605*	0.623*	0.149	0.517*
	Rainfall	0.233	- 0.273	0.562*	0.706*	- 0.179	- 0.606*
Tophit	Temperature	-0.375*	0.619*	0.558*	0.710*	0.707*	0.779*
	Rainfall	0.881*	- 0.918*	- 0.748*	- 0.846*	- 0.257	- 0.728*
Top 2000	Temperature	0.321	0.124	- 0.546*	0.108	0.101	0.037
	Rainfall	0.463*	0.265	0.935*	0.543*	0.566*	0.567*

* Significant at $P \leq 0.05$.

23.522% of the total variability. Score values for the first two PCs are presented in Table 5 and Figure 2A. The first principal component strongly correlated with the amount of dry matter (r= 0.923) and total sugars, fructose, and sorbitol at 0.882, 0.873, and 0.882, respectively. Another major component was highly correlated with sucrose (r=0.891) while glucose had negative influence (r= -0.693). Dry matter and sucrose had great share in total variance of all the variables. On the plot (Figure 2-B), cultivars differentiated according to observed parameters. Cultivar Topstar was characterized by PC1 negative and PC2 positive value and was separated on the plot according to high sucrose content. Fructose, sorbitol, total sugar, and dry matter were the segregating traits that placed cultivar Toptaste on positive side of scatter plot. Cultivar Jojo, on the negative side of PC1 and PC2, was characterized by high glucose content. Those three cultivars were homogenous while the other investigated cultivars were dispersed on scatter plot.

Table 5. Results of Principal Component Analysis.

	PCA 1	PCA 2
Eigenvalue	3.612	1.414
Difference	2.203	0.828
Percentage (%)	60.199	23.522
Cumulative (%)	60.199	83.721
Eigenvectors		
Sucrose	0.421	0.891
Glucose	0.529	-0.693
Fructose	0.873	-0.075
Total sugar	0.882	0.337
Sorbitol	0.882	-0.124
Dry matter	0.923	-0.154

CONCLUSIONS

This investigation highlighted that climatic conditions may have significant effect on plum fruit quality. Significant differences were found between sucrose, glucose, fructose, and sorbitol depending on year and cultivar. The sucrose was the highest in almost all harvest years. Glucose was the predominant sugar in cultivars Jojo and Top 2000. Fructose and sorbitol content were lower than sucrose and glucose. Average sugar contents in 2008-2012 periods were compared with climatic conditions. Sucrose content had significant positively correlation with precipitation. On the other hand, sorbitol and dry matter negatively correlated with precipitation. It indicated that climatic conditions and the corresponding drought stress lead to accumulation of sorbitol in the fruit. Significant positive correlation was found between temperature and sorbitol and between the total sugars and dry matter. The principal component analysis (PCA) showed that plum cultivars were differentiated according to variability of sugar in fruit

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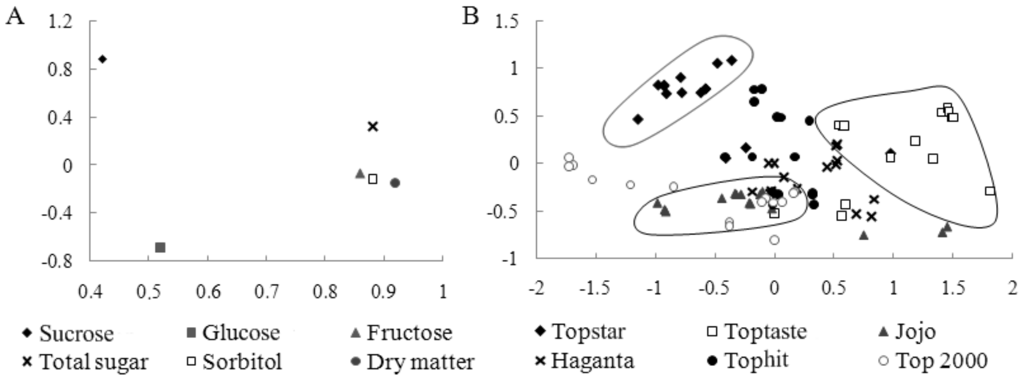

Figure 2. Scatter plots of PCA factors. A: Correlations corresponding to the six variables, B: Discrimination of six plum cultivars according to investigated traits.

caused by climatic conditions. The obtained results showed importance of adequate testing before recommendation for planting.

REFERENCES

1. Abidi, W., Jiménez, S., Moreno, M.A. and Gogorcena, Y. 2011. Evaluation of Antioxidant Compounds and Total Sugar Content in a Nectarine [*Prunus persica* (L.) Batsch] Progeny. *Int. J. Mol. Sci.,* **12:** 6919-6935.
2. Bohacenko, I., Pinkrova, J., Komárková, J. and Paprstein, F. 2010. Selected Processing Characteristics of New Plum Cultivars Grown in the Czech Republic. *Hort. Sci. (Prague)*, **37(2):** 39-45.
3. Blazek, J. and Pistekova, I. 2009. Preliminary Evaluation Results of New Plum Cultivars in a Dense Planting. *Hort. Sci. (Prague),* **36:** 45-54.
4. Cantín, C.M., Gogorcena, Y. and Moreno, M.A. 2009. Analysis of Genotypic Variation of Sugar Profile in Different Peach and Nectarine [*Prunus persica* L. Bastch] Breeding Progenies. *J. Sci. Food Agr.*, **89(11):** 1909-1917.
5. Crisosto, C. H., Mitchell, F. G. and Johnson, S. 1995. Factors in Fresh Market Stone Fruit Quality. *Postharvest News Inf.,* **6(2):** 17-21.
6. Crisosto, C. H., Johnson, R. S., DeJong, T. and Day, K. R. 1997. Orchard Factors Affecting Postharvest Stone Fruit Quality. *HortSci.,* **32:** 820-823.
7. Dietrich, H., Krüger-Steden, E., Patz, C. D., Will, F., Rheinberger, A. and Hopf, I. 2007. Increase of Sorbitol in Pear and Apple Juice by Water Stress, a Consequence of Climatic Change? *Fruit Process.,* **6:** 348-355.
8. Druzic, J., Voca, S., Cmelik, Z., Dobricevic, N., Duralija, B. and Skendrovic Babojelic, M. 2007. Fruit Quality of Plum Cultivars 'Elena' and 'Bistrica'. *Agric. Conspec. Sci.,* **72(4):** 307-310.
9. Escobar-Gutiérrez, A. J. and Gaudillére, J. -P. 1994. Variability in Sorbitol: Sucrose Ratios in Mature Leaves of Different Peach Cultivars. *J. Amer. Soc. Hort. Sci.,* **119(2):** 321–324.
10. García-Marino, N., de la Torre, F. and Matilla, A.J. 2008. Organic Acids and Soluble Sugars in Edible and Nonedible Parts of Damson Plum (*Prunus domestica* L. subsp. *insititia cv*. Syriaca) Fruits during Development and Ripening. *Food Sci. Technol. Int.,* **14:** 187-193.
11. Genard, M., Lescourret, F., Gomez, L. and Habib, R. 2003. Changes in Fruit Sugar Concentrations in Response to Assimilate Supply, Metabolism and Dilution: A Modeling Approach Applied to Peach Fruit (*Prunus persica*). *Tree Physiol.,* **23:** 373-385.
12. Guerra, M. and Casquero, P. A. 2009. Site and Fruit Maturity Influence on the Quality of European Plum in Organic Production. *Sci. Hort.,* **122:** 540-544.
13. Li, T. H. and Li, S. H. 2005. Leaf Responses of Micropropagated Apple Plants to Water Stress: Nonstructural Carbohydrate

Composition and Regulatory Role of Metabolic Enzymes. *Tree Physiol.,* **25:** 495-504.

14. Lo Bianco, R. L., Rieger, M. and Sung, S. J. S. 2000. Effect of Drought on Sorbitol and Sucrose Metabolism in Sinks and Sources of Peach. *Physiol. Plantarum,* **108(1):** 71-78.
15. Manganaris, G. A., Vicente, A. R. and Crisosto, C. H. 2008. Effect of Pre-harvest and Post- harvest Conditions and Treatments on Plum Fruit Quality. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources,* **3(9):** 1-9.
16. Milosevic, T. and Milosevic, N. 2012. Phenotypic Diversity of Autochthonous European (*Prunus domestica* L.) and Damson (*Prunus insititia* L.) Plum Accessions Based on Multivariate Analysis. *Hort. Sci. (Prague),* **39(1):** 8-20.
17. Nunes, C., Rato, A. E., Barros, A. S., Saravia, J. A. and Coimbra, M. A. 2009. Search for Suitable Parameters to Define the Harvest Maturity of Plums (*Prunus domestica* L.): A Case of Candied Plums. *Food Chem.,* **112:** 570-574.
18. Prasanna, V., Prabha, J. F. and Tharanathan, R. N. 2007. Fruit Ripening Phenomena : An Overview. *Crit. Rev. Food Sci. Nutr.,* **47:** 1-19.
19. Rieger, M. and Duemmel, M. J. 1992. Comparison of Drought Resistance among Prunus Species from Divergent Habitats. *Tree Physiol.,* **11:** 369-380.
20. Siddiq, M. 2006. Plums and Prunes, In: "*Handbook of Fruit and Fruit Processing*", (Eds.): Hui, Y. H. and Barta, J.. Blackwell publishing Ltd, Oxford, UK, PP. 553-564.
21. Singh, S. P., Singh, Z. and Swinny, E. E. 2009. Sugars and Organic acids in Japanese Plums (*Prunus salicina* Lindell) as Influenced by Maturation, Harvest Date, Storage Temperature and Period. *Int. J. Food Sci. Tech.,* **44(10):** 1973-1982.
22. Sudar, R., Jurkovic, Z., Dugalic, K., Tomac, I., Jurkovic, V. and Viljevac, M. 2011. Sorbitol and Sugar Composition of Plum Fruit during Ripening. *Proc. of 46th Croatian and 6th International Symposium on Agriculture,* Opatija. PP. 1067-1071.
23. Thammawong, M. and Arakawa, O. 2010. Starch to Sugar Conversion in "Tsugaru" Apples under Ethylene and 1-methylcyclopropene Treatments. *J. Agr. Sci. Tech.*, **12:** 617-626.
24. Usenik, V., Fajt, N. and Stampar, F. 2007. Pomological and Phenological Characteristics of Some Slovenian Plum Cultivars. *Acta Hortic.,* **734:** 53-59.
25. Usenik, V., Kastecec, D., Veberic, R. and Stampar, F. 2008. Quality Changes during Ripening of Plum (*Prunus domestica* L.). *Food Chem.,* **111:** 830-836.
26. Vangdal, E., Meland, M., Mage, F. and Doving, A. 2005. Prediction of Fruit Quality of Plums (*Prunus domestica* L.). *Acta Hortic.,* **674:** 613-617.
27. Wang, Z. and Stutte, G. W. 1992. The Role of Carbohydrates in Active Osmotic Adjustment in Apple under Water Stress. *J. Amer. Soc. Hort. Sci.,* **117(5):** 816-823.
28. Wilford, L. E., Sabarez, H. and Price, W. E. 1997. Kinetics of Charbohydrate Change during Dehydration of d'Agen Prunes. *Food Chem.,* **59:** 149-145.
29. Wu, B. H., Quilot, B., Genard, M., Li, S. H., Zhao, J. B., Yan, J. and Wang, Y. Q. 2012. Application of a SUGAR Model to Analyze Sugar Accumulation in Peach Cultivars that Differ in Glucose–fructose Ratio. *J. Agr. Sci.,* **150(1):** 53-63.

اثر شرایط آب وهوایی روی مقدار سوربیتول وقند ها در میوه آلو

ک. دوگالیک، ر. سودار، م. ویلجواک، م. جوسیپویک، و ت. کاپیک

چکیده

هدف این پژوهش ارزیابی مقدار سوربیتول ، گلوکز،فروکتوز، سوکروز، و قند کل میوه آلو و تغییرات آنها در سال های مختلف با آب وهوای متفاوت (ازنظر دمای هوا و بارندگی) بود. کالتیوارهای مطالعه شده شامل بود بر:Topstar، Toptaste،Jojo، Haganta ، Tophit و Top 2000 . برداشت میوه ها در بهترین مرحله رسیدن در باغ تحقیقاتی موسسه کشاورزی Osijek انجام شد. مقدار سوربیتول ، گلوکز،فروکتوز، سوکروز در میوه ها شناسایی و با دستگاه اچ.پی.ال.سی. اندازه گیری شد. تفاوت های معنی داری بین سوربیتول ، گلوکز،فروکتوز، سوکروز مشاهده شد که به شرایط آب وهوایی و نوع کالتیوار بستگی داشت. تقریبا در تمام سال ها سوکروز بیشترین مقدار را داشت. در کالتیوارهای Jojo و Top 2000 گلوکز فراوان ترین قند بود. مقدار فروکتوز و سوربیتول از سوکروز و گلوکز کمتر بود. میانگین محتوی قند میوه ها در دوره ۱۲–۲۰۰۸ با شرایط آب و هوایی در این دوره مقایسه شد و آشکار شد که اثر سال روی سوکروز، سوربیتول، قند کل، و ماده خشک معنی دار بود ولی تاثیری روی فروکتوز وگلوکز مشاهده نشد. هر یک از قندها با دیگرقندها به طور معنی داری وابستگی داشت. تجزیه مولفه های اصلی نشان داد که کالتیوارهای آلو بر پایه تغییرات مقدار قند میوه در اثر شرایط آب وهوایی به روشنی از یکدیگر متمایز بودند. نتایج به دست آمده آشکار ساخت که شرایط آب و هوایی ممکن است اثرات معنی داری روی کیفیت میوه آلو داشته باشد وبه همین دلیل انجام آزمون های کافی قبل از توصیه کاشت هر کالتیوار اهمیت دارد.