Agrovoc deskriptors: Prunus persica, Prunus persica nucipersica, varieties, sugars, organic acids, quality, qualitative analysis, chemicophysical properties, HPLC

Agris category code: F60

COBISS Code 1.01

Contents of sugars and organic acids in the cultivars of peach (*Prunus persica* L.) and nectarine (*Prunus persica* var. *nucipersica* Schneid.)

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Received October 1, 2003; accepted May 20, 2004.
Delo je prispelo 1. oktobra 2003; sprejeto 20. maja 2004.

ABSTRACT

The contents of sugars and organic acids in fruits were studied among 19 different peach and nectarine cultivars. The fruits were obtained from the Fruit Growing Centre Bilje near Nova Gorica in the time of technological maturity. Sugars (glucose, fructose, sucrose and sorbitol) and organic acids (citric, malic, shikimic and fumaric acid) in fruits were identified and measured by high performance liquid chromatography (HPLC). Sucrose was the major sugar and malic and citric acids were the predominant organic acids in all cultivars. The content of fructose ranged from 6.76 to 12.97 g/kg, glucose from 5.43 to 11.11 g/kg, sucrose from 46.14 to 70.7 g/kg and sorbitol from 0.40 to 2.80 g/kg of fruits. The content of citric acid was from 1.71 to 8.34 g/kg, malic acid from 3.2 to 8.05 g/kg, shikimic acid from 127 to 809 mg/kg and fumaric acid from 1.56 to 6.09 mg/kg of fruits. The content of total sugars was from 61.53 to 93.70 g/kg and the content of total organic acids was from 7.06 to 14.69 g/kg of fruits. We recommend cultivars 'Françoise', 'Orion', 'Venus', 'Roza' and '325 x A/8' from the point of the content of sugars and organic acids and the optimal ratio between them.

Key words: fruit growing / peaches / *Prunus persica* / nectarines / *Prunus persica* var. n*ucipersica* / sugars / organic acids / internal quality

IZVLEČEK

VSEBNOST SLADKORJEV IN ORGANSKIH KISLIN V KULTIVARJIH BRESKEV (*Prunus persica* L.) IN NEKTARIN (*Prunus persica* var. *nucipersica* Schneid.)

Proučevali smo vsebnost sladkorjev in organskih kislin v plodovih 19 kultivarjev breskev in nektarin, ki so bili nabrani leta 2000 v času tehnološke zrelosti v Sadjarskem centru Bilje pri Novi Gorici. Posamezne sladkorje (fruktozo, glukozo, saharozo in sorbitol) in organske kisline (citronsko, jabolčno, šikiminsko in fumarno kislino) smo analizirali z metodo tekočinske kromatografije visoke ločljivosti (HPLC). Glavni sladkor v plodovih je bil saharoza, med

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organskimi kislinami pa sta prevladovali jabolčna in citronska kislina. Vrednosti fruktoze so bile od 6,76 do 12,97 g/kg, glukoze od 5,43 do 11,11 g/kg, saharoze od 46,14 do 70,07 g/kg in sorbitola od 0,40 do 2,80 g/kg plodov. Vrednosti citronske kisline so bile od 1,71 do 8,34 g/kg, jabolčne od 3,82 do 8,05 g/kg, šikiminske od 127 do 809 mg/kg in fumarne kisline od 1,56 do 6,09 mg/kg plodov. Vsebnost skupnih sladkorjev je bila od 61,53 do 93,70 g/kg in skupnih organskih kislin od 7,06 do 14,69 g/kg plodov. Z vidika vsebnosti sladkorjev in organskih kislin ter njunega optimalnega razmerja priporočamo od preizkušanih kultivarjev kultivarje 'Françoise', 'Orion', 'Venus', 'Roza' in '325 x A/8'.

Ključne besede: sadjarstvo / breskev / *Prunus persica* / nektarina / *Prunus persica* var. *nucipersica* / sladkorji / organske kisline / notranja kakovost

INTRODUCTION

Peach is the fruit variety whose cultivars change frequently, therefore a continuous observation in this area is regarded as a very important and demanding task (Fajt and Komel, 2000). The properties of new cultivars must suit various factors: weaker growth, resistance to diseases, pests and low temperatures, maturity in appropriate time, good quality of fruits (excellent flavour, high content of sugars, balanced ratio between sugars and acids). The properties of new cultivars are researched into during several successive years to enable our good judgement whether the examined properties are genetically determined or influenced by the environment (Smole, 1988; Smole, 1990).

The property of peach which has a high impact on the satisfaction of growers and consumers is the internal quality of fruits. It is determined by chemical components, nutritional value, firmness, juiciness, texture, freshness, sweetness, sourness, aroma, flavour. The internal quality of fruits can be evaluated in various ways using different methods: chemical analyses (chromatographic evaluations of chemical components in fruits); tasting or sensory evaluations including analyses of flesh colour, firmness, texture, juiciness and organoleptic traits of flesh; physical measurements (firmness) (Robertson *et al*., 1989).

Chemical analyses of fruits show that the peach fruits contain the highest amount of water (87-91 %), low contents of sugars (4.6-9.6 %), less organic acids (0.5-1.3 %) and proteins (0.8-1.7 %) (Wills *et al*., 1983). Important sugars are fructose, glucose, fructose, sucrose and sorbitol), worth mentioning are also xylitol, xylose, inositol. Sucrose, which is present in ripe fruits in highest amounts, gives better flavour to the fruit, has anti-oxidative effects, and is an important source of energy (Huberlant and Anderson, 1993). Alcohol sugar sorbitol is, beside sucrose, the main transport sugar which is a product of photosynthesis in leaves but is not produced in fruits, it is translocated from other parts of the tree through phloem (Lo Bianco *et al*., 2000). The peach fruits with higher contents of fructose are more firm and of better flavour. Fruits of lower quality contain more sucrose and sorbitol and seven-fold amount of phenolic compounds compared to the fruits of higher quality. Such peach fruits are more bitter with tart aftertaste. The flavour depends on acidity, soluble solids, individual sugars and organic acids (non-volatile substances) as well as on polyphenolic substances (Robertson and Meredith, 1988; Robertson *et al*., 1989; Senter and Callahan, 1990).

The content of organic acids is eight-fold lower than the content of sugars. Most frequent acids are malic, citric and quinic; less frequent are shikimic, fumaric, oxalic, succinic and ascorbic. Although these acids are weak, they have a significant influence on the flavour of fruits (Wills *et al*., 1983).

The major volatile substance is benzaldehyd which provides almond aroma and the aroma of stone fruit in their mesocarp (Narain *et al*., 1990). Peach aroma is achieved by lactones (very expressed in the cultivars 'Glohaven' and 'Redhaven') and flower aroma is given by terpens and esters (in the cultivar 'Maria Laura') (Rizzolo *et al*., 1995).

Biological and genetic markers attributing to the quality of peach fruits with regard to their contents of sugars and organic acids are still little investigated. Peach cultivars which originate in south China are less sour. This property is very important in breeding processes, especially when introducing early cultivars which are often too acid (Dirlewanger *et al*., 1998). To achieve better aroma and flavour of fruits the breeders tend to increase the content of soluble solids by more than 15 % and to stabilize the content of titrable acids expressed as malic acid at 6-8 milliequivalents in milliliter of juice. This would cause a desired ratio between sugars and acids and the fruits would be harvested firm and not too sour (Souza *et al*., 2000).

White-fleshed nectarines are of lower quality than yellow-fleshed ones. Therefore the latter are more favoured by the consumers as they are more delicious and bigger. To improve the organoleptic quality of white-fleshed nectarines the breeders cross-breed them with yellow-fleshed cultivars (Bellini *et al*., 1996). Robertson *et al*. (1990) discovered that the white-fleshed nectarines had a little higher contents of sucrose, glucose and fructose and a statistically significantly higher content of volatile substances which add to aroma. The ratio between soluble solids and titrable acids was higher as well. The texture and juiciness were better in yellow-fleshed nectarines.

The concept of quality of fruits is complex and may be quite subjective – as proved by the outcomes of the research into internal quality of fruits which have been performed so far. The research that we conducted and is presented in the report is just a part of a huge mosaic as we examine the internal quality of fruits by evaluating chemical components of fruits – contents of individual sugars and organic acids in fruits of various peach and nectarine cultivars which are subject to sensory evaluations in Slovene pedoclimatic conditions.

MATERIAL AND METHODS

The experiment was conducted in the year 2000 in Fruit Growing Centre near Nova Gorica. To research chemical compounds of fruits we harvested fruits of yellow-fleshed peach cultivars 'Maria Marta', 'Romestar', 'Simphonie', 'Roza', 'Redhaven', 'Françoise', 'Quenncrest', '325 x A/8', '224 x A/13', 'B x S/4', 'V x S/4'; fruits of white-fleshed cultivars 'Bea' and 'Anita', and fruits of yellow-fleshed nectarine cultivars 'Orion', 'Maria Aurelia', 'Venus', 'Maria Laura', 'Weinberger' and 'Spring Red'. To evaluate internal quality of fruits (contents of sugars and organic acids) we gathered ten fruits of each cultivar. The samples were homogenized with a manual blender (Braun). 10 g of the sample was dissolved in bidistillated water to 60 ml and extracted for 2 hours. Following the extraction the samples were centrifugated for 10 minutes at 4200 rotation/min. The supernatant was used for chemical analyses and filtrated through 0.45 µm Minisart filter (RC-25, Sartorious). The chemical

evaluation included qualitative and quantitative determination of individual sugars (fructose, glucose, sucrose and sorbitol) and organic acids (citric, malic, shikimic and fumaric) in the peach fruits. The HPLC was used according to Dolenc and Štampar method (1997).

RESULTS AND DISCUSSION

In the analysed cultivars the following values were determined: contents of sugars (fructose, glucose, sucrose and sorbitol) and contents of organic acids (citric, malic, shikimic and fumaric).

Table 1: The contents of sugars in fruits of analysed peach and nectarine cultivars

Cultivar	Sugars (g/kg)				
	Fructose	Glucose	Sucrose	Sorbitol	Total sugars
'Maria Marta'	8.86	7.54	62.51	0.94	79.85
'Romestar'	11.70	9.07	62.88	2.80	86.45
'Simphonie'	8.58	7.38	60.90	0.97	77.82
'Roza'	8.80	7.43	64.54	1.03	81.79
'Redhaven'	8.62	7.08	51.67	0.53	67.90
'Françoise'	8.31	7.17	52.04	0.40	67.93
'Quenncrest'	8.37	7.49	64.02	1.80	81.68
'325 x A/8'	8.28	6.71	46.14	0.41	61.53
'224 x A/13'	12.97	10.33	50.31	0.92	74.53
'B x S/4'	10.35	8.30	49.43	1.39	69.47
'V x S/4'	9.14	8.17	48.23	0.45	66.00
'Bea'	6.76	5.43	66.33	1.06	79.58
'Anita'	10.00	8.76	69.83	1.77	90.36
'Orion'	11.08	9.80	70.07	2.75	93.70
'Maria Aurelia'	10.44	8.59	66.05	2.71	87.79
'Venus'	12.10	10.65	66.92	2.29	91.96
'Maria Laura'	10.35	8.93	68.07	0.75	88.11
'Weinberger'	12.74	11.11	60.83	1.55	86.23
'Spring Red'	8.32	7.02	51.34	0.82	67.50

The cultivar 'Bea' had the lowest contents of fructose (6.76 g/kg) and glucose (5.43 g/kg). The highest value of fructose was 12.97 and of glucose 11.11 g/kg. The content of fructose higher than 12 g/kg was observed in the cultivars '224 x A/13', 'Venus' and 'Weinberger'; the same cultivars exhibited the content of glucose higher than 10 g/kg. According to the reports by Wills *et al*. (1983) the content of fructose in fruits was from 7 to 16 g/kg and similarly the content of glucose. Bassi and Selli (1990) stated higher contents of glucose in fruits – up to 19 g/kg.

Sucrose in peach fruits was a predominant sugar (from 46.14 to 70.07 g/kg). The content of sucrose lower than 50 g/kg was exhibited in cultivars '325 x A/8', 'B x S/4' and 'V x S/4'. Cv. 'Orion' had the highest content of sucrose. Wills *et al*. (1983)

reported the contents of sucrose ranging from 31 g/kg in cv. 'Redhaven' to 67 g/kg. The same span of sucrose content was observed in our cultivars.

The content of sorbitol in fruits was the lowest among the sugars (from 0.40 to 2.80 g/kg), less than 0.50 g/kg had the cultivars 'Françoise', '325 x A/8' and 'V x S/4', more than 2.5 g/kg is observed in 'Romestar', 'Orion' and 'Maria Aurelia'. Bassi and Selli (1990) reported similar values. Later, Selli and Sansavini (1995) stated that the contents of sorbitol were higher – up to 19 g/kg of fruits.

The content of total sugars ranged from 61.53 do 93.70 g/kg, the lowest amount of total sugars was measured in the cultivar '325 x A/8'. The cultivars 'Romestar', 'Anita', 'Orion', 'Venus', 'Maria Laura' and 'Weinberger' exhibited higher contents of total sugars – more than 85 g/kg of fruits. According to Bassi and Selli (1990) these cultivars may be accepted as delicious and aromatic with regard to the content of total sugars. The researched early cultivars did not exhibit 100 g of total sugars per kilo of fruits, neither do the late cultivars exhibit 110 g of total sugars per kilo of fruits, what was considered by Crochon (1985) to be the measure for desirable flavour of peaches.

Table 2: The contents of organic acids in fruits of analysed peach and nectarine cultivars

Cultivar	Organic acids				
	Citric (g/kg)	Malic (g/kg)	Shikimic (mg/kg)	Fumaric (mg/kg)	Titrable acids (g/kg)
'Maria Marta'	3.17	5.23	191	3.11	8.59
'Romestar'	3.35	4.47	234	1.56	8.05
'Simphonie'	2.20	6.12	197	3.40	8.52
'Roza'	3.60	6.25	288	3.30	10.14
'Redhaven'	4.16	4.93	281	4.57	9.37
'Françoise'	2.54	5.92	127	3.36	8.59
'Quenncrest'	1.94	7.05	206	3.68	9.20
'325 x A/8'	3.82	3.82	253	4.96	7.90
'224 x A/13'	3.06	4.64	200	1.73	7.90
'B x S/4'	5.64	4.48	267	3.24	10.39
'V x S/4'	2.99	3.88	191	4.21	7.06
'Bea'	1.71	6.86	198	4.36	8.77
'Anita'	4.94	7.09	327	5.15	12.36
'Orion'	3.86	7.45	253	4.22	11.57
'Maria Aurelia'	4.23	8.05	271	6.09	12.55
'Venus'	3.96	7.27	265	3.77	11.50
'Maria Laura'	4.83	7.91	809	4.50	13.55
'Weinberger'	8.34	5.95	392	3.86	14.69
'Spring Red'	5.55	6.74	257	5.68	12.55

Despite its lower share in peaches, citric acid adds to the sourness of fruits more than malic acid does. The cultivars 'Bea' and 'Quencrest' had less than 2 g of citric acid per kilo, while cv. 'Weinberger' had more than 8 g of citric acid per kilo of fruits.

Wang *et al*. (1993) reported even lower contents of citric acid – from 2 to 4 g/kg. Closer to our results were the measurements by Selli and Sansavini (1995) where the contents of citric acid ranged from 3.2 to 7.7 g/kg .

Malic acid is generally present in highest quantities. Exceptions in the experiment were the cultivars 'Weinberger' and 'B x S/4' which exhibited the highest contents of citric acid. Malic acid tastes better than citric acid. The cultivars '325 x A/8' and 'V x S/4' had less citric acid than 4 g/kg and more than 8 g/kg was measured in the cultivar 'Maria Aurelia'. Wang *et al*. (1993) reported the contents of malic acid ranging from 3.5 to 6.0 g/kg, while Wills *et al*. (1983) discovered slightly higher contents, up to 8.1 g/kg.

The shikimic acid content was lower than the contents of the organic acids mentioned above. The content ranged from 127 (cv. 'Françoise') to 809 mg/kg (cv. 'Maria Laura'). Somewhat lower contents are mentioned by Wills *et al*. (1983) - to 50 mg/kg of fruits. Less than 200 mg/kg were observed in the cultivars 'Françoise', 'Maria Marta', 'Simphonie', 'V x S/4' and 'Bea'.

The content of fumaric acid was the lowest of all organic acids analysed in the peach fruits. It ranged from 1.56 to 6.09 mg/kg. The effect of fumaric acid on the flavour of fruits is, despite its scarcity, stronger than the effect of citric acid. The content of fumaric acid lower than 2 mg/kg was found in the cultivars 'Romestar' and '224 x A/13', higher than 5 mg/kg was found in the cultivars 'Maria Aurelia', 'Spring Red' and 'Anita'. Wang *et al*. (1993) reported the values of fumaric acid even lower than 38 mg/kg.

The contents of titrable acids were from 7.06 to 14.69 g/kg. Lower contents than 8 g/kg were measured in the cultivars 'V x S/4', '325 x A/8' and '224 x A/13'. The cultivars 'Weinberger', 'Maria Laura', 'Spring Red', 'Maria Aurelia', 'Anita', 'Orion', 'Venus', 'B x S/4' and 'Roza' exhibited more than 10 g of titrable acids per kilo of fruits. According to Bassi and Selli (1990) the cultivars which contain from 10 to 16 g of organic acids per kilo of fruits may be regarded as acceptable and delicious with regard to their aroma and flavour.

The ratio between the analysed total sugars and organic acids is a good indicator of internal quality of fruits as it indicates their flavour. Optimal ratio differs between cultivars and it is significant that the fruits within the ratio have harmonious flavour. The higher the ratio is, the sweeter the fruits are. The lower the ratio is, the bitter the fruits are.

The lowest ratio was measured in the cultivar 'Spring Red', namely 5.4, with a low content of sugars and a rather high content of organic acids. Cv. 'Romestar' had a high content of sugars and a very low content of organic acids and thus the highest ratio – 10.7. The cultivars Maria Aurelia' (ratio 7.0) and 'Venus' (ratio 8.0) had rather high contents of both organic acids and sugars. In cv. 'Weinberger' (ratio 5.9) predominant were sugars although the content of organic acids are high as well. Cv. '325 x A/8' had low contents of both sugars and organic acids (ratio 7.8).

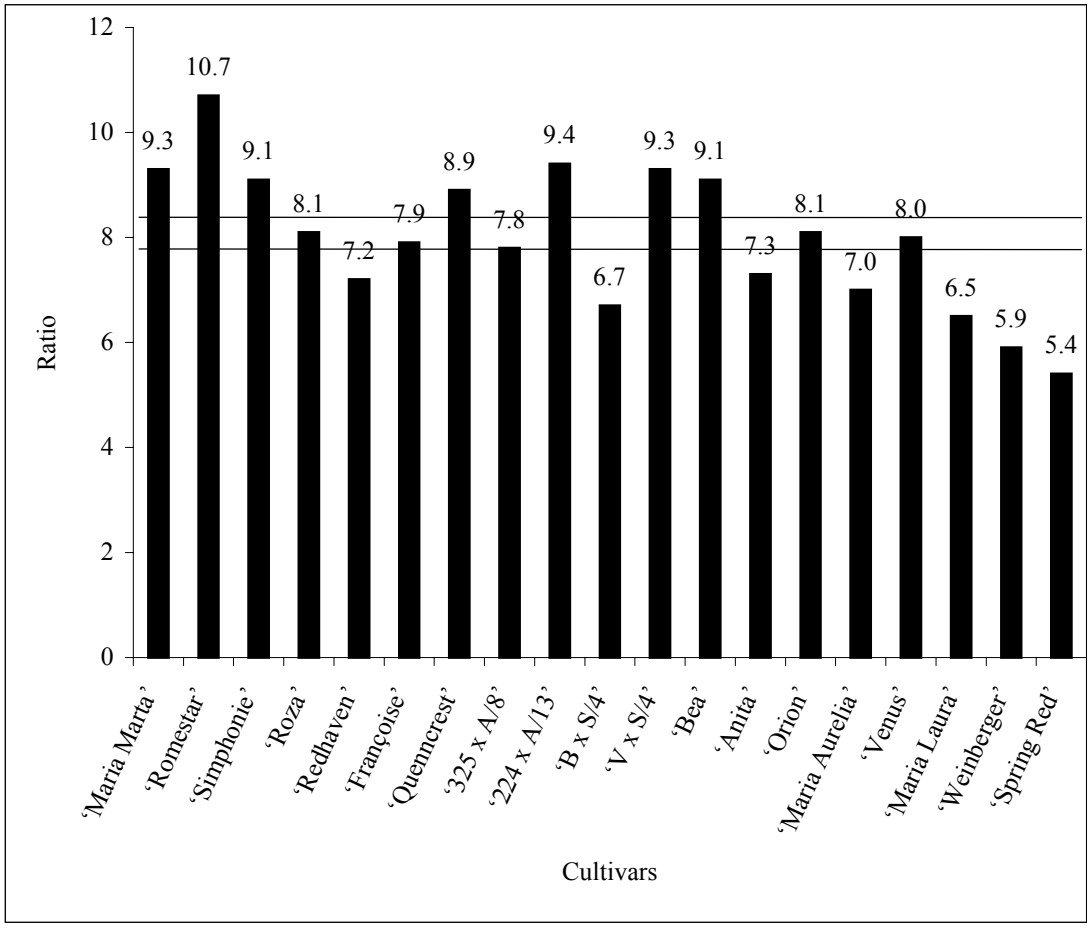

Figure 1: The ratio between total sugars and organic acids in fruits of analysed peach and nectarine cultivars

In the research performed by Bassi and Selli (1990) the ratio between the sugars and organic acids of examined cultivars ranged from 6.5 in cv. 'Suncrest' to 19.4 in cv. 'Rubiette'. They discovered optimal ratio between sugars and organic acids to be between 7.8 and 8.5. Considering this conclusion we found the following cultivars to have optimal ratio and thus harmonious flavour: 'Roza', 'Françoise', '325 x A/8', 'Orion' and 'Venus'.

CONCLUSIONS

The cultivars of peach and nectarine evaluated in the research exhibit various contents of individual and total sugars and organic acids in their fruits.

Sucrose was, in all the cultivars evaluated in the research, the most abundant sugar. Among organic acids the highest contents were attributed to malic acid, with the exception of two cultivars 'Weinberger' and 'B x S/4', which exhibited higher contents of citric acid. The lowest content among sugars went to sorbitol, and among organic acids to fumaric acid.

The highest contents of glucose, citric acid and titrable acids were measured in the cultivar 'Weinberger', the highest content of malic and fumaric acids were observed in the cultivar 'Maria Aurelia', the highest contents of sucrose and total sugars were found in the cultivar 'Orion', the highest content of shikimic acid was measured in the cultivar 'Maria Laura', the highest content of fructose was observed in the cultivar '224 x A/13' and the highest content of sorbitol was detected in the cultivar 'Romestar'. The lowest contents were measured as follows: glucose, fructose and citric acid in cv. 'Bea'; sucrose, total sugars and malic acid in cv. '325 x A/8'; sorbitol and shikimic acid in cv. 'Françoise'; fumaric acid in cv. 'Romestar'; and titrable acids in cv. 'V x S/4'.

Based on the results of chemical evaluations of fruits and the ratios between the sugars and organic acids we concluded that cv. 'Romestar' bears sweet fruits, while cv. 'Spring Red' bears sour fruits, the latter may be less delicious. Optimal ratio between the sugars and organic acids were exhibited the following cultivars: 'Roza', 'Françoise', '325 x A/8', 'Orion' and 'Venus'. The contents of sugars and organic acids and the ratio between them are important indicators of internal quality of fruits; therefore we recommend the cultivars 'Françoise', 'Orion', 'Venus', 'Roza' and '325 x A/8'. Considering the outcomes of the research and pomological evaluations of the cultivars we will select peaches and nectarines for national fruit variety list.

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