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SUGARS AND ORGANIC ACIDS CONTENTS OF EUROPEAN (*PYRUS COMMUNIS* L.) AND ASIAN (*PYRUS SEROTINA* REHD.) PEAR CULTIVARS

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The content of sugars (glucose, fructose, sucrose, sorbitol) and organic acids (citric, malic, fumaric, tartaric) was analysed with HPLC (High Performance Liquid Chromatography) in pear fruits of 18 European (*Pyrus communis* L.) and 4 Asian (*Pyrus serotina* Rehd.) cultivars. The cultivars differed in the content of different sugars and organic acids. Fructose varied in the European pear cultivars from 23.7 g kg^{-1} in cv. 'Conference' to 66.1 g kg^{-1} in cv. 'Clapp Favorite' and in the Asian cultivars from 27.9 g kg^{-1} in cv. 'Shinseiki' to 45.7 g kg^{-1} in cv. 'Koshui'. Sorbitol varied in the European pear cultivars from 12.5 g kg^{-1} in cv. 'Conference' to 24.9 g kg^{-1} in cv. 'Beurré Bosc' and in the Asian cultivars from 5.0 g kg^{-1} in cv 'Shinseiki' to 19.0 g kg^{-1} in cv. 'Kumoi'. The Asian pear cultivars contained more total sugars than the European ones. The early cultivars of pears contained more than 1.0 g kg^{-1} of citric acid and the late ones less than 1.0 g kg^{-1}. The cvs. 'Williams Bon Chrétien', 'Early Morettini', 'Princess Mariane', 'Koshui' and 'Hoshui' contained more citric than malic acid. In the cvs. 'Concorde', 'Conference' and 'Beurré Alexandre Lucas' no citric acid was traced. The content of tartaric acid was traced only in cv. 'Hardy'.

Keywords: pear, *Pyrus communis*, *Pyrus serotina*, sugars, organic acids, HPLC

In man's diet fruit is appreciated for the good taste, aroma, appearance and content of nutritive substances, especially vitamins. It has nutritious, hygienic and dietetic-therapeutical values. Carbohydrates, organic acids, pectins, vitamins, mineral substances and other fruit components play an important role in fruits. Not many consumers are aware that sugars, which are present in fresh fruit, are the main source of energy (TRUSWELL, 1998). The value of consumed fruit certainly depends on the fruit quality – the internal quality (contents of sugars, organic acids, vitamins, minerals, pectins, etc.) and the pomological characteristics (shape, size, fruit colour).

The fruit quality depends on fruit texture, sweetness, acidity, taste and on the colour of a fruit. The fruit texture is the cultivar's property which can be influenced by sufficient water supply and is the most important element of pear quality. It depends on chemical and physical nature of the cell wall, especially on the quantity and the quality of the polysaccharides in the cell wall (YAMAKI, 1983). Sweetness, acidity and taste of fruits are dependent on the contents of sugars, organic acids and aromatic components which can change considerably during the fruit development (DOYON et al., 1991). From the beginning of June till picking time the glucose and sorbitol contents in the pear fruits decreae, whereas the contents of fructose and sucrose increase (HUDINA & ŠTAMPAR, 1998). The changes of the taste, firmness and appearance of fruits can be the consequence of changes in content and ratio of the organic acids, sugars and alcohols. Sugar and organic acid contents depend on the plant's genotype and environmental circumstances which can also be influenced by technological measures such as irrigation, nutrition, assimilation area and training system. The content of sugars in fruits depends directly on the assimilant's supply, that is the efficiency of the photosynthesis and transport of assimilates from the place of origin to the fruit (GENARD et al., 1996). In the majority of fruit cultivars of the *Rosaceae* family, especially in the genera *Malus* and *Pyrus* the main product of the photosynthesis is the alcohol sugar sorbitol, which is also the translocating substance. It represents 60–90% of all carbohydrates, which are transported from the leaves to the other parts of the plants.

RICHMOND and co-workers (1981) studied sugar contents in fruits of various families and inside the family *Rosaceae*. The content of individual sugars in 24 strawberry cultivars was determined by ROEMER (1989). The most common sugars were glucose and fructose. That was confirmed by PÉREZ and co-workers (1997). The sugar contents in stone fruits were determined in various apricot cultivars (VOI et al., 1995 and DOLENC-ŠTURM et al., 1999), in peaches (BROOKS et al., 1993), cherries (DOLENC & ŠTAMPAR, 1998), plums (NERGIZ & YILDIZ, 1997) and nectarines (SELLI & SANSAVINI, 1995). MEHERIUK and co-workers (1987) studied the influence of a cultivar on nectar sugar content in several species of apricot, cherry, pear, apple and peach. Little is known about the individual sugar content in various cultivars of pears. FOURIE and co-workers (1991) reported on individual sugar contents in various pear cultivars in South Africa, BOSETTO and ARFAIOLI (1992) in 7 pear cultivars (*Pyrus communis*) in Italy and BEHBUDIAN and LAWES (1994) in several pear cultivars (*Pyrus serotina*) in New Zealand.

The quality of fruits, being a subjective and complex parameter, is very difficult to define. It depends on a combination of several factors: flavour, acidity, sweetness, aroma and astringency. In this research work the contents of individual and total sugars and organic acids in fruits of various cultivars of European and Asian pears grown in Slovenia are presented. The pomological characteristics as well as the content of sugars and organic acids in fruits are very important for the popularity of an individual cultivar among the consumers. Based on the results we will be able to evaluate pear cultivars according to their contents of sugars and organic acids.

1. Materials and methods

1.1. Materials and reagents

1.1.1. Reagents. When analysing sugars (glucose, fructose, sucrose and sorbitol) and organic acids (citric, fumaric) we used chemicals which are the products of Fluka Chemical (New York, USA), except for malic acid, where products of Merck Chemicals (Darmstad, Germany) were used.

1.1.2. Fruit samples. Fruit samples of 18 European pear cultivars *Pyrus communis*: 'Williams Bon Chrétien', 'Passe Crassane', 'Clapp Favorite', 'Abatte Fettel', 'Packham's Triumph', 'Conference', 'Red Williams', 'Beurré Bosc', 'Princess Mariane', 'Rosired', 'Concorde', 'Clairgeau', 'Vicar of Winkfield' ('Poire de Curé'), 'Beurré Alexandre Lucas', 'Early Morettini', 'Beurré d'Avranches', 'Santa Maria', 'Hardy' ('Beurré Hardy') and 4 Asian pear cultivars *Pyrus serotina*: 'Hoshui', 'Koshui', 'Shinseiki' and 'Kumoi' grown in Slovenia were analysed in the season of 1998. All pear cultivars *Pyrus communis* were grafted on Quince MA except for cv. 'Concorde', which was grafted on Quince BA 29. The Asian pear cultivars *Pyrus serotina* were grafted on Quince C7. Fruit samples were picked at stage called "commercial maturity" time. The dates of individual cultivar pickings are stated in Table 1.

1.1.3. Standard solution. For each sugar and organic acid the calibration curve of known concentration standards with the use of bidistilled water was formed. The number of samples of different concentrations differed with regard to their response to the detectors (UV and RI). The concentrations of individual standards were similar to the concentrations of these substances in pear samples.

1.2. Preparation of fruit samples

1.2.1. Macroscopic analysis. The diameter and length of each fruit was measured, as well as the mass of the fruit (accuracy: 0.01 g). Soluble solids were determined in the juice with a refractometer (Kübler, Germany) at 20 °C. From each fruit juice was squeezed and the proportion of soluble solids was determined.

1.2.2. HPLC analysis of suspended sugar and organic acid contents. For each cultivar, 12 fruits (=12 samples) analyses were performed. Samples for HPLC analysis were prepared firstly by homogenisation with a manual blender (Braun), then with Ultra-Turrax T-25 (Ika – Labortechnik). Ten g of mashed fruit were in bidistilled water up to 40 ml and centrifuged at 6000 rotation/min for 15 min. The extract was filtered through 0.45 μm Minisart filtre (RC-25, Sartorious). For each HPLC analysis of sugars and organic acids 20 μl of sample was used.

Table 1

Average diameter, length, weight, date of harvest and soluble solids of fruits of different pear cultivars; 1998

No.	Cultivars	Diameter (mm)	Length (mm)	Weight g	Date of harvest	Soluble solids %
1	'Williams Bon Chrétien'	68.1	92.4	205.59	18 August	11.5
2	'Red Williams'	66.5	84.3	171.61	19 August	11.3
3	'Rosired'	67.6	81.6	173.44	19 August	11.8
4	'Clapp Favorite'	72.5	94.0	223.39	11 August	11.9
5	'Early Morettini'	64.1	89.8	161.38	30 July	11.6
6	'Conference'	74.8	113.3	259.09	7 September	12.6
7	'Concord'	77.3	108.4	268.15	7 September	13.7
8	'Packham's Triumph'	79.9	96.7	283.39	7 September	11.6
9	'Abatte Fettel'	76.3	140.9	316.77	8 September	13.3
10	'Beurré Bosc'	80.5	114.9	293.30	7 September	12.8
11	'Passe Crassame'	87.2	83.5	354.51	12 October	11.1
12	'Clairgeau'	83.8	100.2	316.49	7 September	11.7
13	'Vicar of Winkfield'	87.1	127.5	402.55	4 October	11.7
14	'Hardy'	63.9	77.7	155.96	10 September	10.4
15	'Beurré d'Avranches'	65.6	91.4	181.79	8 September	12.5
16	'Princess Mariane'	66.3	102.2	199.50	7 September	10.7
17	'Santa Maria'	64.6	97.4	180.66	18 August	10.3
18	'Beurré Alexandre Lucas'	83.2	92.9	326.03	8 September	12.3
19	'Kumoi'	73.5	57.5	180.57	17 September	11.2
20	'Koshui'	59.7	49.9	102.40	7 September	10.6
21	'Hoshui'	59.7	51.5	107.28	7 September	10.1
22	'Shinseiki'	51.2	44.8	67.91	7 September	8.6
	$HSD_{0.05}$					0.9

1.3. HPLC of sugars and organic acids

1.3.1. Instrumentation. HPLC method was used for separation, identification and quantification of individual compounds in pear puree. The HPLC system consisted of Thermo Separation Products (TSP), USA, equipment with model P1000 pump, autosampler model AS1000, column heater and OS/2 Warp IBM Operating system (1994)-workstation. Solute elution was monitored using a variable wavelength UV detector (Knauer, Germany) set at 210 nm and differential refractive index RI (model Shodex-71RI, Japan).

1.3.2. Separation procedures

1.3.2.1. HPLC separation of sugars. Sugars (glucose, fructose, sucrose and sorbitol) were analysed isocratically on the Aminex – HPX 87C (300×7.8 mm) cartrige (Bio-Rad, USA) with an eluent flow rate of 0.6 ml min^{-1} and at 85 °C with bidistilled and on-line degassed water used as eluent. Attenuation of the refractive index detector was set at 16x. Sugars present in each sample were identified by comparison of the retention time of each peak with those of standard sugars. The concentration of each sample was calculated by comparison of peak areas to the area of calibrated sugar solutions of known concentrations (method of external standard). The reproducibility of the chromatographic separation of the components was determined by making six injections of the standard solutions and pear sample. The results expressed as relative standard deviation (RSD%) are as follows: 0.27 for glucose, 0.28 for fructose, 0.29 for sucrose and 0.26 for sorbitol. Figure 1 shows the chromatogram of sugars in pear puree.

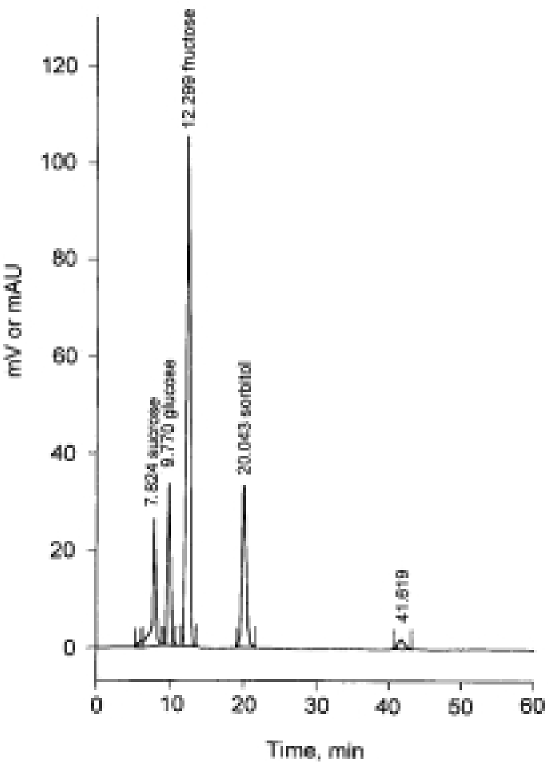

Fig. 1. Chromatographic separation of sugars in pear puree

1.3.2.2. HPLC separation of organic acids. Organic acids (malic, citric and fumaric) were analysed on the Aminex – HPX 87H (300×7.8 mm) cartrige (Bio-Rad, USA) with the flow of 0.6 ml min^{-1} and at 65 °C. For mobile phase 4 mM sulphuric acid was used. Organic acids were identified and quantified by using UV detector with wavelength set at 210 nm and by comparison of retention times and peak areas with standard solution of known organic acids. Results of reproducibility study of chromatographic separation for organic acids expressed as relative standard deviation (RSD%) are as follows: 0.30 for malic acid, 0.31 for citric acid and 0.13 for fumaric acid. Figure 2 shows the chromatogram of organic acids in pear purce.

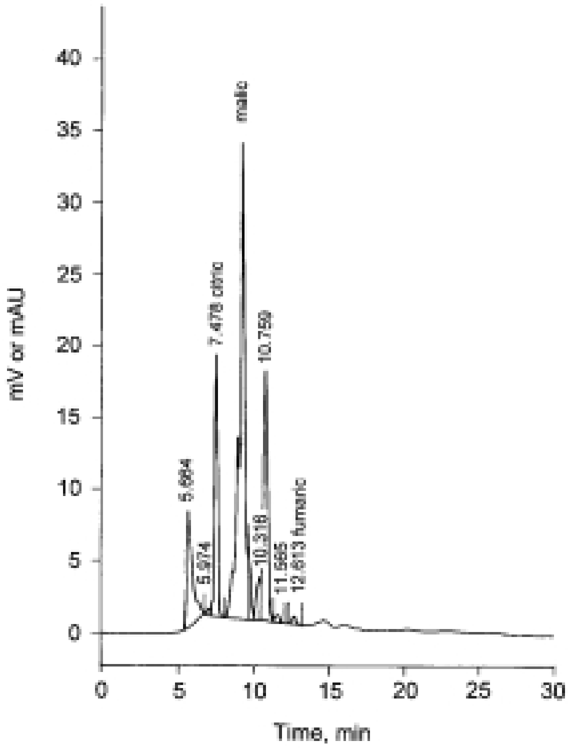

Fig. 2. Chromatographic separation of organic acids in pear puree

1.3.3. Statistical analysis. The data were analysed by using a completely randomised design as described by SNEDEKOR and COCHRAN (1971). For testing the differences of individual cultivars a One-Way ANOVA and Tukey test (HSD) at $P = 0.05$ were used.

2. Results and discussion

2.1. Size and soluble solids of pear fruits

The pear cultivars differ in their diameter, length and weight of fruit (Table 1). The average fruit diameter of the European pear cultivars was from 63.9 mm (cv. 'Hardy') to 87.2 mm (cv. 'Passe Crassane') and of the Asian pear cultivars from 51.2 mm (cv. 'Shinseiki') to 73.5 mm (cv. 'Kumoi'). The average length of the European pear cultivars varied between 77.7 mm (cv. 'Hardy') and 140.9 mm (cv. 'Abatte Fettel') and of the Asian pear cultivars from 51.5 mm (cv. 'Hoshui') to 57.5 mm (cv. 'Kumoi'). The average fruit weight of the European pear cultivars varied from 155.96 g (cv. 'Hardy') to 402.55 g (cv. 'Vicar of Winkfield'). The Asian fruits were less substantial as their average fruit weight amounted from 67.91 g (cv. 'Shinseiki') to 180.57 g (cv. 'Kumoi').

The cultivars varied also in the content of soluble solids (Table 1). The soluble solids content in the Asian pears was lower than in the European ones, in the Asian pears it varied from 8.6% (cv. 'Shinseiki') to 11.2% (cv. 'Kumoi') and in the European pears from 10.3% in cv. 'Santa Maria' to 13.7% in cv. 'Concorde'. The cultivars grown in Slovenia contained more soluble solids than the same cultivars in South Africa (FOURIE et al., 1991).

2.2. Sugar contents in pear fruits

The analytical data on the carbohydrate fraction of pear cultivars are presented in Table 2. The fructose content among the European pears was the highest in cv. 'Clapp Favorite' (66.1 g kg^{-1}) and the lowest in cv. 'Conference' (23.7 g kg^{-1}). In comparison to other cultivars cv. 'Passe Crassane' contained small amount of fructose, which reflects also in the high glucose/fructose ratio value. In the Asian pears fructose contents ranged from 27.9 g kg^{-1} in cv. 'Shinseiki' to 45.7 g kg^{-1} in cv. 'Koshui'. In European pears the fructose representation ranged from 42.9% of total sugars in cv. 'Beurré Bosc' to 68.4% of total sugars in cv. 'Clapp Favorite' and in the Asian pears from 40.4% of total sugars in cv. 'Kumoi' to 58.9% of total sugars in cv. 'Koshui'.

Fructose is the most represented sugar in all pear cultivars (*Pyrus communis* and *Pyrus serotina*) as reported by FOURIE and co-workers (1991), MORVAI and MOLNÁR-PERL (1992), CASPARI and co-workers (1996) and BOSETTO and ARFAIOLI (1992).

Beside fructose there is also a lot of sorbitol in the pears. The European pears contained from 12.5 g kg^{-1} of sorbitol in cv. 'Conference' to 25.8 g kg^{-1} in cv. 'Concorde'. The ripe pear fruits contain more than 2% sorbitol (fresh fruit weight), it was stated by BIELESKI (1982) and KAWAMATA (1977) (we came to the same conclusion with certain cultivars) and more than 50% total sugars. We stated that sorbitol represented from 15.0% of total sugars in cv. 'Clapp Favorite' to 29.1% of total sugars in cv. 'Concorde'. The Asian pear cv. 'Hoshui' contained the highest amount of sorbitol (17.6 g kg^{-1}) and the cv. 'Shinseiki' contained the lowest amount, only 5.0 g kg^{-1}.

The glucose content appeared in the European pears in two groups, from 4.8 g kg^{-1} (cv. 'Williams Bon Chrétien') to 7.4 g kg^{-1} (cv. 'Vicar of Winkfield') and from 10.5 g kg^{-1} (cv. 'Beurré Bosc') to 15.3 g kg^{-1} in (cv. 'Beurré d'Avranches'). The glucose content in the Asian pears varied from 13.7 g kg^{-1} in cv. 'Kumoi' to 21.8 g kg^{-1} in cv. 'Hoshui'.

Table 2

Average contents of glucose, fructose, sucrose and sorbitol in g kg^{-1} of fresh fruits and standard deviations (SD) in different pear cultivars; 1998

Cultivars	Glucose		Fructose		Sucrose		Sorbitol	
	g kg^{-1}	±SD	g kg^{-1}	±SD	g kg^{-1}	±SD	g kg^{-1}	±SD
'Williams Bon Chrétien'	4.8	0.5	39.9	11.7	3.4	0.9	17.5	1.4
'Red Williams'	5.8	0.8	32.8	3.5	2.8	0.8	16.7	2.0
'Rosired'	5.3	0.8	38.0	4.1	4.2	0.7	17.8	2.1
'Clapp Favorite'	11.6	2.0	66.1	10.1	4.3	1.9	14.5	2.2
'Early Morettini'	6.3	0.9	41.8	3.5	3.3	0.3	14.4	1.8
'Conference'	4.9	1.9	23.7	5.0	11.3	4.0	12.5	2.9
'Concord'	11.9	1.2	45.8	2.8	5.1	0.7	25.8	2.2
'Packham's Triumph'	11.6	1.9	34.7	7.7	5.3	1.2	19.8	3.3
'Abatte Fettel'	16.3	1.4	43.6	4.4	6.6	1.0	21.0	2.3
'Beaurré Bosc'	10.5	2.2	42.5	4.4	21.1	6.1	24.9	3.2
'Passe Crassane'	13.1	2.2	25.1	4.2	5.5	1.1	13.4	2.2
'Clairgeau'	13.0	1.2	36.5	3.6	4.3	0.8	22.1	2.4
'Vicar of Wingfield'	7.4	1.0	40.0	4.7	13.4	2.8	13.7	1.4
'Hardy'	13.5	1.8	37.6	3.0	5.9	1.8	16.1	2.1
'Beurré d'Avranches'	15.3	1.7	44.6	4.1	10.1	1.8	14.6	2.5
'Princess Mariane'	14.9	2.5	47.7	10.2	2.2	0.8	16.0	4.0
'Santa Maria'	6.5	1.1	46.7	3.1	8.2	1.3	12.9	1.7
'Beurré Alexandre Lucas'	6.9	1.9	34.9	6.7	13.2	3.6	17.6	1.9
'Kumoi'	13.7	2.2	32.6	5.4	15.4	8.6	19.0	3.3
'Koshui'	18.0	0.9	45.7	2.4	2.6	0.9	11.2	1.2
'Hoshui'	21.8	0.6	37.3	3.4	2.9	0.7	17.6	1.4
'Shinseiki'	14.8	1.2	27.9	1.8	10.8	4.1	5.0	0.7
$HSD_{0.05}$	2.3		8.4		4.3		3.5	

The sucrose amount was the highest in the European pears (21.1 g kg^{-1}) in cv. 'Beurré Bosc' and the lowest in cv. 'Princess Mariane' (2.2 g kg^{-1}). The Asian pears cvs 'Koshui' and 'Hoshui' contained only 2.6 g kg^{-1} or 2.9 g kg^{-1}, cvs 'Kumoi' and 'Shinseiki' on the other hand, contained significantly more sucrose (15.4 g kg^{-1} or 10.8 g kg^{-1}). Cv. 'Beurré Bosc' contained significantly more sucrose than other cultivars, that was also quoted by FOURIE and coworkers (1991).

In comparison with the sugar content results in cvs 'Beurré Bosc', 'Hardy', 'Packham's Triumph', 'Clapp Favorite' and 'Williams Bon Chrétien' from South Africa (FOURIE et al., 1991), we determined that our cultivars contained less glucose, less than half, the same was also stated by MORVAI and MOLNÁR-PERL (1992). The only exception was cv. 'Clapp Favorite' containing more glucose (plus 1.63 g kg^{-1}) than according to FOURIE and co-workers (1991). The fructose content was also a little lower with the exception of cv. 'Clapp Favorite' which contained more fructose (plus 12.95g kg^{-1}) than the same cultivars in South Africa. The sucrose content was lower by a third in cv. 'Beurré Bosc', by a half in cvs 'Hardy' and 'Clapp Favorite' and by two thirds in cv. 'Williams Bon Chrétien' according to FOURIE and co-workers (1991). According to MORVAI and MOLNÁR-PERL (1992) the sucrose content was in cv. 'Beurré Bosc' similar to the value we measured in the same cultivar. FOURIE and co-workers (1991) stated that cv. 'Beurré Bosc' in South Africa contained a six-fold amount of sucrose of cv. 'Packham's Triumph', but we found that cv. 'Beurré Bosc' contained a four-fold amount of sucrose in cv. 'Packham's Triumph'. The sorbitol contents, according to FOURIE and co-workers (1991), in cvs 'Beurré Bosc', 'Hardy', 'Packham's Triumph', 'Clapp Favorite' and 'Williams Bon Chrétien' were similar to the contents we traced in cultivars grown in Slovenia.

BOSETTO and ARFAIOLI (1992) reported on sugar contents in pear cultivars in Italy. Comparing their values to ours we can state that in Italy the cv. 'Williams Bon Chrétien' contained less sorbitol by one third in total sugars and 3-times more sucrose, cv. 'Beurré Bosc' contained 20% more fructose and 2-times more sucrose, cv. 'Conference' contained 50% more sorbitol and even 6-times less sucrose, the cv. 'Passe Crassane' contained also in Italy the same amount of glucose, fructose, sucrose and sorbitol as in Slovenia. With the Asian pears cv. 'Hoshui' we found out that in Slovenia this cultivar contains the same sucrose, fructose and sorbitol values and 2-times more glucose than quoted by CASPARI and co-workers (1996).

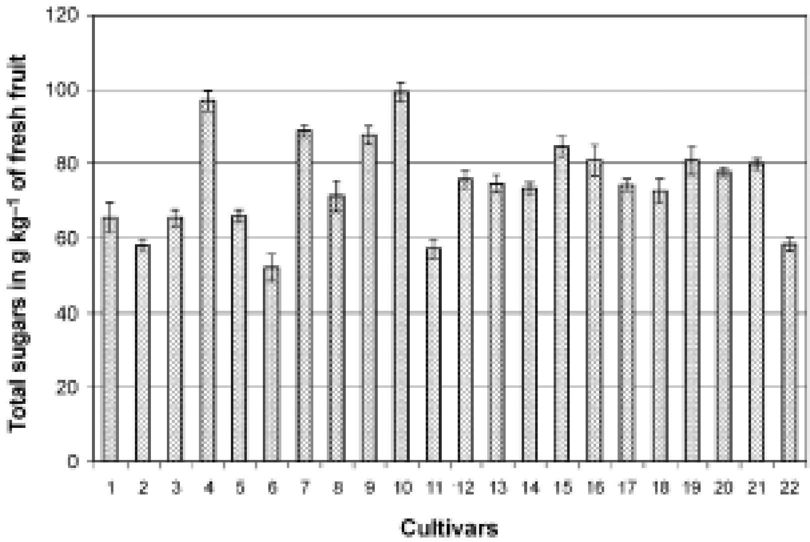

Fig. 3. Average contents of total sugars in g kg^{-1} of fresh fruits and standard error in different pear cultivars; 1998. The name of cultivars indicated in numbers here can be found in Table 1

The total sugar content (Fig. 3) in the European pears was from 52.3 g kg^{-1} in cv. 'Conference' to 99.0 g kg^{-1} in cv.'Beurré Bosc' and in the Asian pears from 58.5 g kg^{-1} in cv. 'Shinseiki' to 80.7 g kg^{-1} in cv.'Kumoi'. According to the content of total sugars, the European cultivars can be divided into three groups. The first group comprises the cultivars with less than 60 g kg^{-1} total sugars ('Passe Crassane', 'Conference' and 'Red Williams'). The second group consists of the cultivars with the total sugar contents of 60 to 80 g kg^{-1} total sugars ('Williams Bon Chrétien', 'Packham's Triumph', 'Rosired', 'Clairgeau', 'Vicar of Winkfield', 'Beurré Alexandre Lucas', 'Early Morettini', 'Santa Maria' and 'Hardy'). The cultivars in the third group contain more than 80 g kg^{-1} total sugars ('Clapp Favorite', 'Abatte Fettel', 'Beurré Bosc', 'Princess Mariane', 'Concorde' and 'Beurré d'Avranches').

The average glucose/fructose ratio of the cultivars are shown in Fig. 4.

The cultivars with a lower glucose/fructose ratio produce sweeter flavour in pears. Therefore, the European cultivars can be divided into very sweet ones ('Williams Bon Chrétien', 'Clapp Favorite', 'Red Williams', 'Rosired', 'Vicar of Winkfield', 'Early Morettini' and 'Santa Maria'), sweet ones ('Abatte Fettel', 'Packham's Triumph', 'Conference', 'Beurré Bosc', 'Princess Mariane', 'Concorde', 'Clairgeau', 'Beurré Alexandre Lucas', 'Beurré d'Avranches' and 'Hardy') and less sweet ones ('Passe Crassane').

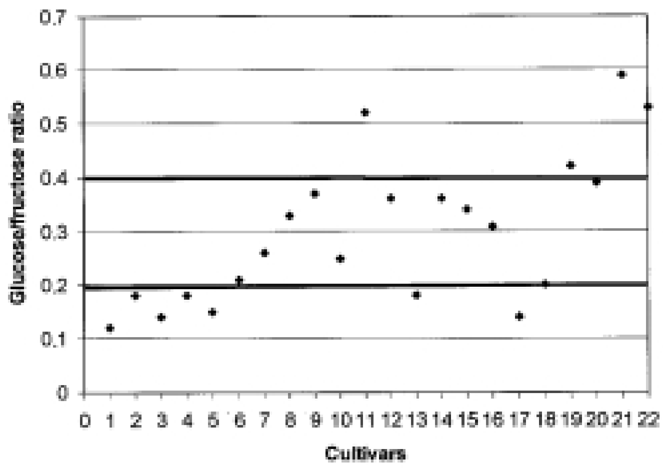

Fig. 4. Average glucose/fructose ratio in different pear cultivars; 1998. The name of the cultivars indicated in numbers here can be found in Table 1

The glucose/fructose ratio in early pear cultivars (‘Williams Bon Chrétien’, ‘Red Williams’, ‘Rosired’, ‘Clapp Favorite’, ‘Early Morettini’ and ‘Santa Maria’) varied from 0.12 to 0.18. In the cultivars that ripen later the glucose/fructose ratio was higher – from 0.20 in cv. ‘Beurré Alexandre Lucas’ to 0.52 in cv. ‘Passe Crassane’, which ripens as last of the observed European cultivars. The only exception was cv. ‘Vicar of Winkfield’ with a low glucose/fructose ratio (0.18). The Asian cultivars had glucose/fructose ratio values from 0.39 to 0.59, which was much higher than that of the European cultivars, which ripen at the same time as the examined Asian cultivars.

The sweet flavour of pears is the result of the highest amount of fructose and sorbitol which are very useful nutrition sugars in a diet of a diabetic. The Asian pear cultivars, in average, contained more total sugars, especially glucose, compared to the European ones.

2.3. Organic acid content in pear fruits

The results for the individual organic acids and the malic/citric acid ratio in the pear cultivars are presented in Table 3.

It is known that pears contain the highest amount of malic acid, and that citric acid comes in the second place. However, in some cultivars the contents are equal or there is even more citric than malic acid present (ARFAIOLI & BOSETTO, 1993).

Table 3

Average contents of malic, citric and fumaric acids, standard deviations (SD) and malic/citric acid ratio in different pear cultivars; 1998

Cultivars	Malic acid		Citric acid		Fumaric acid		Malic/citric acid
	g kg^{-1}	±SD	g kg^{-1}	±SD	g kg^{-1}	±SD	ratio
'Williams Bon Chrétien'	1.1	0.2	1.7	0.3	1.8	0.9	0.7
'Red Williams'	1.5	0.4	2.1	0.5	0.8	0.3	0.7
'Rosired'	1.7	0.3	2.4	0.6	1.0	0.3	0.7
'Clapp Favorite'	3.2	1.3	2.7	1.0	2.5	1.9	1.2
'Early Morettini'	1.9	0.3	1.4	0.4	1.6	1.1	1.4
'Conference'	2.3	0.5	0.0	0.1	20.3	8.3	/
'Concord'	2.3	0.4	0.0	0.0	2.7	2.1	/
'Packham's Triumph'	3.2	0.9	0.4	0.2	2.8	1.2	8.8
'Abatte Fettel'	3.3	0.4	0.3	0.2	2.1	0.7	12.4
'Beurré Bosc'	4.1	0.5	0.1	0.1	16.9	10.3	27.5
'Passe Crassane'	2.4	0.6	0.1	0.1	0.5	0.2	47.8
'Clairgeau'	2.2	0.3	0.1	0.2	1.0	0.4	21.6
'Vicar of Winkfield'	3.9	0.3	0.1	0.1	0.4	0.3	26.2
'Hardy'	3.6	0.9	0.2	0.2	1.6	1.3	16.3
'Beurré d'Avranches'	3.7	0.6	0.1	0.2	0.6	0.1	40.8
'Princess Mariane'	0.5	0.5	0.9	0.3	2.1	2.0	0.6
'Santa Maria'	3.7	0.4	0.1	0.1	0.7	0.2	41.2
'Beurré Alexandre Lucas'	4.1	0.5	0.0	0.0	0.6	0.3	/
'Kumoi'	1.4	0.6	0.8	0.2	3.5	1.6	1.8
'Koshui'	0.0	0.0	0.4	0.2	17.3	5.4	0.0
'Hoshui'	1.1	0.2	1.0	0.2	3.3	0.8	1.1
'Shinseiki'	0.2	0.4	0.8	0.2	0.6	0.2	0.2
$HSD_{0.05}$	0.8		0.5		4.8		

We stated that cvs 'Williams Bon Chrétien', 'Early Morettini', 'Princess Mariane', 'Koshui' and 'Hoshui' contained more citric than malic acid. In cvs 'Concorde', 'Conference' and 'Beurré Alexandre Lucas' we traced no citric acid. In cv. 'Koshui' malic acid was not present. Tartaric acid content was traced only in cv. 'Hardy', namely 59 g kg^{-1} of fresh pears.

The early cultivars contained more than 1.00 g kg^{-1} citric acid and the late pear cultivars less than 1.00 g kg^{-1} citric acid. The European pears contained up to 2.4 g kg^{-1} citric acid in cv. 'Rosired' and the Asian pear cultivars contained from 0.4 g kg^{-1} citric acid in cv. 'Koshui' to 1.0 g kg^{-1} citric acid in cv. 'Hoshui'.

The malic acid content in the European pears was from 0.5 g kg^{-1} in cv. 'Princess Mariane' to 4.1 g kg^{-1} in cvs 'Beurré Alexandre Lucas' and 'Beurré Bosc', in the Asian pears the content was from 0.2 g kg^{-1} in cv. 'Shinseiki' to 1.4 g kg^{-1} in cv. 'Kumoi'. Cv. 'Koshui' contained no malic acid. The Asian pear cultivars contained less malic acid than the European ones.

The fumaric acid content was in various pear cultivars much lower than malic and citric acid contents. The fumaric acid content was from 0.4 mg kg^{-1} in cv. 'Vicar of Winkfield' to 20.3 mg kg^{-1} in cv. 'Conference' in the European pears and from 0.6 mg kg^{-1} in cv. 'Shinseiki' to 17.3 mg kg^{-1} in cv. 'Koshui' in the Asian pears.

Based on the malic/citric acid ratio the European pear cultivars can be divided into two groups. In the first one there are the cultivars with higher acidity ('Williams Bon Chrétien', 'Clapp Favorite', 'Abatte Fettel', 'Packham's Triumph', 'Red Williams', 'Princess Mariane', 'Rosired', 'Early Morettini' and 'Hardy'), in the second one there are the cultivars with lower acidity ('Passe Crassane', 'Beurré Bosc', 'Clairgeau', 'Vicar of Winkfield', 'Beurré d'Avranches' and 'Santa Maria').

The malic/citric acid ratio in the Asian pear cultivars was on average lower than in the European cultivars. The early cultivars of the European pears had lower malic/citric acid ratios than the later ones, the same is true for the glucose/fructose ratio. In the early cultivars of the European pears malic/citric acid ratio was from 0.6 (cv. 'Santa Maria') to 1.3 (cv. 'Early Morettini').

3. Conclusion

The quality of fruits is an important factor, which needs more attention. One of the parameters of the fruit quality is certainly the sugar and organic acid content, which can be connected to other quality parameters such as the shape or form, the color and the taste of fruits. Not only is the content of individual sugars and organic acids very important for the consumer, popularity of a particular cultivar, screening of new cultivars and breeding selection for their potential acceptability, but it also plays an essential role in food industry.

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