Suitability of Asian plums for the production of traditional Czech plum spread

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Summary

The paper deals with experimental findings on the use of Asian plums for processing into the traditional Czech plum spread called povidla. Physico-chemical and sensory properties of the fruits were evaluated. Derived from the botanical species *Prunus salicina* Lindley, Asian plums are at the forefront of commercial stone fruit production on various continents. Apart from China, where they are clearly dominant, their cultivation has also spread to America and the countries of southern Europe. Nowadays, Japanese plum seedlings are offered by growers in the Czech Republic as well. In the present paper, we evaluated the processing of fruit of four Asian plum varieties (Black Amber, Shiro, Ozark Premier and Kleopatra) in comparison with fruits of the European variety Toptaste and plum spread (povidla) as a commercial product. The top-rated plum spread without added saccharose was made from fruit of the European Toptaste variety. Sweetened plum spread variants made from Asian plum varieties were always rated higher than variants without added saccharose. For the Asian Ozark Premier variety, higher levels of L-ascorbic acid and antioxidant activity were determined in fresh fruit and manufactured plum spread.

Keywords

Asian plum; European plum; plum spread; sensory; antioxidant

Fruits are an important source of water, simple sugars, vitamins, minerals, fibre and other bioactive compounds in human nutrition [1–3]. From the nutritional aspect, stone fruits, which include plums, are an indispensable source of dietary fibre, potassium, vitamin C and other antioxidants, especially plant phenolics [4–6]. In EU, plums are the second most cultivated stone fruit after peaches, with an annual production of approximately one million tonnes. In the Czech Republic, 35–40 thousand tonnes of plums are harvested annually [7, 8].

The genus *Prunus*, which includes both European and Asian plums, has a rather complicated botanical classification. Both species, *P. domestica* L. (plums) and *P. salicina* Lindley (Japanese plums), belong to the family of *Rosaceae*, subfamily *Prunoideae*, subgenus *Prunophora* Focke and section *Euprunus* Koehne (which also includes *P. cerasifera* – cherry plums, *P. insititia* – mirabelle plums and *P. simonii* – apricot plums). Varieties belonging to *P. domestica* are hexaploid ($6n = 48$), while *P. cerasifera* (cherry plum) and *P. salicina* (Japanese plums) are diploid ($2n = 16$). Tetraploid species and varieties (*P. spinosa* $4n = 32$) also occur [9].

The plum (*P. domestica*) comes from Caucasus from where it probably arrived in Central Europe with the Slavic population. In South Moravia and Bohemia, cultivated plums were identified in archaeological finds from 9th–10th century. The plum has also been taken to North America, where it has spread through the targeted activities of breeders and farmers [6].

The origin of Asian plum trees (sometimes referred to as Japanese plum trees, *P. salicina*) or their wild forms is unknown. In China, the Zhui Li variety was cultivated more than 2000 years ago. From China, these plum trees were eventually

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imported to Japan, where the first archaeological finds were confirmed from 200 BC. The first written references to the cultivation of these plums in culture were then dated by the Japanese to 500 AD. These plums were introduced from Japan to USA in 1870. In 1875, Luther Burbank used them in his plum selection breeding activities and later as part of interspecific crossing with apricots, which gave rise to the first plumcots [6, 10].

Commercial plantings of plum trees are dominated by both European plum trees (*P. domestica*), grown mainly in Europe and North America, and Japanese plum trees (*P. salicina*), grown mainly in China, America and southern Europe. The main European producers of plums (*P. domestica* and *P. salicina* as minor plum species) are Romania, France, Italy and Spain. Asian plums are grown mainly in China, where European varieties are not popular, and also in Japan, Oceania and America [4, 7, 11]. The introduction of genetic resources and cultivars from regions with high genetic diversity can have a positive effect on fruits growing, especially in the context of the changing climate. In the Czech Republic, growers have become aware of the Asian varieties of plum trees very recently. While in this country fruits of Asian plums do not reach as high sugar content as that observed for European varieties, they are attractive due to their appealing aroma and a higher content of antioxidants [12, 13].

In the Czech Republic, the produced plums are consumed fresh, preserved or dried, and as a fruit distillate. Up to 25 % is used for industrial and domestic production of plum spread (povidla) [14, 15]. Plum spread has been produced in the Czech Republic historically. It was one of the few ways to preserve fruits for a long time. Traditional fruit spreads are also produced in Germany (Pflaumenmus, Zwetschgenmus), Austria (Powidl), Poland (Powidla) and Slovakia (Lekvár). Plum spread is used both directly as a sweet spread on bread or other pastries and as a sweet filling for pastries, like in Germknödel.

Originally, plum spread was made without the addition of saccharose by cooking the de-stoned fruits including skins in open kettles over a prolonged period of time. By evaporating the water, the fruit fraction and refractory solids were concentrated and, after cooling, the product acquired the desired semi-solid consistency and resistance to the growth of microorganisms. Czech legislation [16] defines traditional Czech plum spread called povidla as a food of semi-solid to solid consistency with fine to coarse particles of fruit pulp, made with or without added saccharose from plums or pears.

The aim of the study was to evaluate the usability of Asian plum fruits for processing into the traditional Czech plum spread, as well as to analyse their physico-chemical and sensory properties.

MATERIALS AND METHODS

Fruits

The plums of four Asian varieties, namely, Black Amber, Shiro, Ozark Premier and Kleopatra, one European variety (Toptaste) and one commercial sweetened plum product (Lidl Česká republika, Prague, Czech Republic) were compared.

Black Amber is a medium-fast growing, upright variety native to USA. It is self-sterile. The fruits are large, broadly flat, weighing approximately 60 g, ripening during September. The skin is dark blue-purple, the flesh is light yellow. The flesh is well separated from the stone.

Shiro is a fast growing, self-sterile variety native to USA. The fruits are medium-sized, heart-shaped, weighing approximately 35 g, ripening during August. The skin and flesh are yellow; the flesh is partially detachable from the stone.

Ozark Premier is a medium-fast growing variety native to USA, self-sterile. The fruits are large, spherical, weighing approximately 60 g, ripening in early August. The skin is orange with a red cheek. The flesh is yellow, well separated from the stone.

Kleopatra is a weakly growing variety of unknown origin, self-sterile. The fruits are medium-sized, spherical and flattened, weighing approximately 35 g. They ripen in early August. The skin is blue-black, the flesh is red, partially separable from the stone.

Toptaste is a medium-fast growing semi-plum tree of German origin, partly self-fertile. The fruits are large, elongated, weighing approximately 50 g, ripening during September. The skin is purple, the flesh is yellow-green, well separated from the stone [12, 13].

The fruits originated from the orchards of the Faculty of Horticulture of Mendel University in Lednice (N 48.79°, E 16.80°), which guaranteed the same growing and climatic conditions. Depending on the variety and maturity, the fruits were harvested during August and early September; the quantity was 15 kg per variety.

Making plum spread

Fruits of each variety were used to make plum spread without or with added saccharose; three replicates were prepared for each option ($n = 3$).

De-stoned plum fruits (approximately 2.75 kg) for the production of plum spread without added saccharose and approximately 0.85 kg for the production of plum spread with added saccharose were heated in a Thermomix apparatus (Vorwerk, Wuppertal, Germany) at 98 °C. The fruits were stirred vigorously throughout until the mixture reached the soluble solids content (*SSC*) of 60 %. To achieve microbiological stability, the fruit spread was immediately filled into jars while hot and sealed with a lid. The material balances converted to 1 kg of product are presented in tables with results.

In the production of the saccharose-containing plum spread, a calculated amount of saccharose was added to the fruits and the subsequent procedure was the same as for the production of the unsweetened plum spread. The saccharose addition by weight was calculated based on the determined *SSC* of the raw material as the maximum possible saccharose addition, taking into account the legal regulation, which requires a minimum fruit weight content of 1 700 g per 1 kg of plum spread [16].

Soluble solids content

The collected fruits were homogenized and the juice was obtained by forcing the homogenate through a fine nylon sieve (pore size 40 μm). For fruits, the determination was carried out immediately after harvesting. For plum spread, the *SSC* was measured after the completion of the production. The juice was analysed using an Abbe refractometer (Carl Zeiss, Jena, Germany). The *SSC* was expressed as percentage.

Glucose, fructose and saccharose

An amount of 2 g of the homogenate obtained from fresh fruits was diluted 5-fold with distilled water. The mixture was stirred for 15 min on a shaker PSU-20i (Biosan, Riga, Latvia) and then filtered through a syringe nylon filter (diameter 25 mm, pore size 0.45 μm). An amount of 2 g of the plum spread was diluted with distilled water in a porcelain grinding mortar and then the homogenate was quantitatively transferred into a 50 ml tube. Distilled water was then added to the sample to weigh 50 g. The sample was shaken on a shaker PSU-20i and filtered through a syringe nylon filter (diameter 25 mm, pore size 0.45 μm). The samples prepared in this way were analysed using an high-performance liquid chromatography (HPLC) apparatus (Watrex, Prague, Czech Republic) with an injection volume of 20 μl and a column Polymer IEX Ca SN8422 (250 mm × 8 mm, particle size 8 μm; Watrex). The mobile phase was deionized water at a flow rate of 0.5 $ml{\cdot}min^{-1}$, pressure 1.9 MPa and temperature 80 °C. A refractometric detector (Watrex) was used for detection. The glucose, fructose, and saccharose contents were calculated using calibration curves and expressed in grams of the respective sugar per kilogram of sample.

Titratable acidity

The juice obtained as described above was diluted with distilled water to approximately 40 ml and then pH was measured using a combined electrode SenTix 81 (WTW, Weilheim, Germany) and a pH meter inoLab pH 7310 (WTW, Weilheim, Germany). The mixture was titrated with 0.1 $mol{\cdot}l^{-1}$ NaOH solution to pH 8.1. For plum spread; 5 g of plum spread was weighed and mixed with distilled water. Titratable acidity (*TA*) was expressed in grams of citric acid per kilogram of sample.

Malic acid, citric acid and L-ascorbic acid

The procedure for preparing the samples for acid determination was the same as for sugars. The prepared samples were analysed by HPLC with an injection volume of 20 μl and a column Prevail Organic Acid 110A (250 mm × 4.6 mm, particle size 5 μm; Hichrom, Reading, United Kingdom). The mobile phase was 25 $mmol{\cdot}l^{-1}$ KH_2PO_4 at a flow rate of 1 $ml{\cdot}min^{-1}$, pressure 9 MPa and temperature 30 °C. A UV-Vis detector (Ecom, Prague, Czech Republic) was used for detection at a wavelength of 210 nm. The malic, citric and L-ascorbic acid contents were evaluated using calibration curves and expressed in grams of the respective acid per kilogram of sample.

Total antioxidant activity by DPPH method

An amount of 2 g of the blended fresh fruit or 2 g of plum spread were, together with 70% methanol, homogenized in a grinding mortar and then the homogenate was quantitatively transferred into a 15ml tube. The tube was sealed and the mixture was stirred on a shaker PSU-20i for 15 min. Then, the solid and clear contents were separated in a centrifuge Eppendorf 5702R (Eppendorf, Hamburg, Germany) at 1 400 ×*g*. The clear supernatant was poured into a 50ml volumetric flask. The solid portion in the tube was again supplemented with 70% methanol and the subsequent procedure was repeated twice more. Finally, the volumetric flask was filled to the mark with 70% methanol and its contents was shaken. A volume of 2 500 μl of methanolic 2,2-diphenyl-1-picrylhydrazyl (DPPH) solution and 100 μl of the prepared sample were added to a cuvette by dispensing. To generate the calibration curve, 100 μl of 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) standard at concentrations of 0.1 mmol·l^{-1}, 0.2 mmol·l^{-1}, 0.3 mmol·l^{-1}, 0.4 mmol·l^{-1} and 0.5 mmol·l^{-1} were used instead of the sample. The content was mixed, incubated for 30 min and its absorbance was measured at the wavelength of 515 nm in a spectrophotometer Specord 50 Plus (Analytik Jena, Jena, Germany). The results were expressed in millimoles of Trolox equivalents (TE) per kilogram of sample.

Total antioxidant activity by FRAP method

Samples of fresh fruits and plum spread were prepared in the same way as for the determination of antioxidant activity by the DPPH method. The cuvette was charged with 1 900 μl of the reagent (produced by mixing ferric chloride, 2,4,6-tris(2-pyridyl)-s-triazine (TPTZ), 35% hydrochloric acid, sodium acetate and acetic acid) and 25 μl of sample. To generate the calibration curve, 25 μl of Trolox standard at concentrations of 0.1 mmol·l^{-1}, 0.2 mmol·l^{-1}, 0.3 mmol·l^{-1}, 0.4 mmol·l^{-1} and 0.5 mmol·l^{-1} were used instead of the sample. The content was mixed, incubated for 10 min and its absorbance was measured at the wavelength of 593 nm in a spectrophotometer in a spectrophotometer Specord 50 Plus. The ferric reducing antioxidant power (FRAP) was expressed in millimoles of TE per kilogram of sample.

Chromaticity

The colour of the plum spread was determined by measuring transmittance using Lovibond RT850i (Tintometer, Dortmund, Germany). The resulting colour was defined as the colour space $L^*a^*b^*$ (CIELAB). The values of L^*, a^*, b^* were calculated and the software application Lovibond OnColor Premium (Tintometer) was used for evaluation.

Sensory evaluation of plum spread

The sensory evaluation of plum spread samples was performed by 10 sensory assessors selected according to ISO 8586 [17] using a categorical ordinal scoring scale for plum spread (max. of 100 points). Five organoleptic parameters were evaluated with different scoring weights (appearance up to 15 points, smell up to 20 points, texture up to 25 points, taste up to 35 points, overall impression up to 5 points).

Statistical methods

After harvesting, the fruit of each variety was divided into three portions for the determination of analytical parameters and the production of two variants of plum spread (with and without added saccharose). The results were expressed as mean and standard deviation ($n = 3$). Statistica 12 (Stat-Soft, Tulsa, Oklahoma, USA) was used for further statistical analysis of the data. Cochran's, Hartley's and Bartlett's tests were used to confirm the variance homogenity. The method of multiple analysis was selected to confirm a conclusive difference between values with subsequent use of Tukey's honestly significant difference (*HSD*) test at a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

Fruits

To achieve the aim of the study, four Asian va-

Tab. 1. Results of analytical evaluation of fruits for making plum spread.

	Black Amber	Shiro	Ozark Premier	Kleopatra	Toptaste
Soluble solids content [%]	12.1 ± 0.5^{b}	10.1 ± 0.3^{a}	13.2 ± 0.9^{b}	10.2 ± 0.4^{a}	22.4 ± 0.6^{c}
Glucose [g·kg^{-1}]	49.91 ± 6.94^{ab}	30.83 ± 5.14^{a}	51.75 ± 9.19^{b}	37.12 ± 3.03^{ab}	108.71 ± 9.97^{c}
Fructose [g·kg^{-1}]	29.46 ± 4.82^{a}	13.64 ± 2.81^{b}	32.85 ± 3.42^{a}	14.70 ± 1.10^{b}	30.83 ± 5.67^{a}
Saccharose [g·kg^{-1}]	13.97 ± 2.58^{a}	31.74 ± 6.03^{b}	19.85 ± 2.83^{ab}	26.39 ± 4.16^{ab}	63.77 ± 6.98^{c}
Titratable acidity [g·kg^{-1}]	12.4 ± 3.6^{a}	14.8 ± 2.5^{ab}	15.0 ± 2.9^{ab}	21.3 ± 2.8^{b}	8.9 ± 1.1^{a}
Malic acid [g·kg^{-1}]	14.09 ± 1.46^{ab}	15.93 ± 2.83^{ab}	13.39 ± 4.66^{a}	21.86 ± 2.79^{b}	9.62 ± 2.22^{a}
Citric acid [g·kg^{-1}]	0.19 ± 0.08^{a}	0.35 ± 0.06^{a}	0.36 ± 0.09^{a}	0.31 ± 0.10^{a}	0.58 ± 0.07^{b}
L-Ascorbic acid [g·kg^{-1}]	0.14 ± 0.05^{ab}	0.12 ± 0.03^{ab}	0.23 ± 0.07^{b}	0.07 ± 0.02^{a}	0.16 ± 0.04^{ab}
AC_{FRAP} [mmol·kg^{-1}]	2.98 ± 0.02^{b}	1.64 ± 0.12^{a}	3.76 ± 0.15^{c}	2.87 ± 0.26^{b}	2.95 ± 0.22^{b}
AC_{DPPH} [mmol·kg^{-1}]	3.36 ± 0.03^{b}	2.03 ± 0.06^{a}	4.26 ± 0.03^{c}	3.25 ± 0.19^{b}	3.15 ± 0.06^{b}

Values represent mean ± standard deviation. The small letters in superscript indicate statistically significant differences between the values in each row, at a significance level of $p = 0.05$. Antioxidant activity is expressed as millimoles of Trolox equivalents. AC_{FRAP} – antioxidant activity determined by FRAP assay, AC_{DPPH} – antioxidant activity determined by DPPH assay.

rieties, Black Amber, Shiro, Ozark Premier and Kleopatra, were selected, which were introduced in recent years and positively evaluated in the cultivating settings of the Faculty of Horticulture (Mendel University, Lednice, Czech Republic) [13, 18]. Results of analytical evaluation of fruits for making plum spread are given in Tab. 1.

The achieved *SSC* of ripe fruits of the Asian varieties ranged from 10.1 % (Shiro) to 13.2 % (Ozark Premier). Ripe fruits of the European variety Toptaste reached significantly higher values with an average of 22.4 %. The same trend was observed for individual sugars. The content of glucose was from 30.83 $g \cdot kg^{-1}$ (Shiro) to 51.75 $g \cdot kg^{-1}$ (Ozark Premier) for the Asian varieties, while for Toptaste the value was almost 108.71 $g \cdot kg^{-1}$. The fructose content of Shiro and Kleopatra was very similar, 13.64 $g \cdot kg^{-1}$ and 14.70 $g \cdot kg^{-1}$, respectively. Roughly double the values were measured for Black Amber, Toptaste and Ozark Premier, where the values were approximately 30 $g \cdot kg^{-1}$. The saccharose content of the Asian varieties ranged from 13.97 $g \cdot kg^{-1}$ to 31.74 $g \cdot kg^{-1}$, with a value of 63.77 $g \cdot kg^{-1}$ determined for the Toptaste variety. Fig. 1 documents the percentages of the selected sugars determined in the fruits. The content of glucose was very high in all the fruits studied, ranging from 40 % to 54 %. The fructose level differed much between varieties, ranging from 15 % (Toptaste) to 32 % (Black Amber). The highest saccharose share (42 %) was determined for the Shiro variety. The total sugar content expressed as *SSC*, as well as the fruit size attained, is strongly influenced by the harvest year and significantly also by the rootstock type [12, 19, 20]. DUGALIČ et al. [21] found in the European plum varieties that glucose was always the dominant sugar and the ratio between fructose and saccharose was dependent on the variety.

TA of the fruits of the selected Asian varieties ranged from 12.4 $g \cdot kg^{-1}$ (Black Amber) to 21.3 $g \cdot kg^{-1}$ (Kleopatra), with the Toptaste variety having approximately half that value, 8.9 $g \cdot kg^{-1}$ (Tab. 1). Malic acid was the most abundant acid. Among the Asian varieties, the lowest content of this acid was 13.39 $g \cdot kg^{-1}$ in Ozark Premier and the highest (almost 22 $g \cdot kg^{-1}$) in Kleopatra, while the quantity determined for Toptaste was less than 10 $g \cdot kg^{-1}$. The citric acid content of all varieties was significantly lower, ranging from 0.19 $g \cdot kg^{-1}$ to 0.58 g·kg-1. The lowest content of vitamin C as L-ascorbic acid was determined for the Kleopatra variety (almost 0.1 $g \cdot kg^{-1}$), and more than three times the value was recorded for the Ozark Premier variety, over 0.2 $g \cdot kg^{-1}$, which was also reflected by the high antioxidant activity of the fruits. Similar conclusions in terms of relations between substances were reached by WOLF et al. [18]. In contrast, the highest L-ascorbic acid content was found by CUEVAS et al. [22] in the Black Amber variety and their research showed a significant effect of harvest year and cultivation method on the production of phytochemicals in plums.

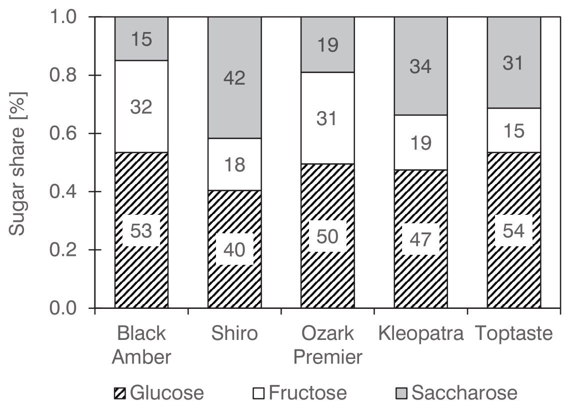

Fig. 1. Proportion of the individual sugars in fruits for the production of plum spread.

The values of antioxidant activity of the fruits determined by the FRAP method correlated with the values obtained using the DPPH method. Using both methods, the highest value of antioxidant activity was determined for the Ozark Premier variety (3.76 $mmol \cdot kg^{-1}$ determined by FRAP assay and 4.26 $mmol \cdot kg^{-1}$ determined by DPPH assay) and the lowest in the Shiro variety (1.64 $mmol \cdot kg^{-1}$ determined by FRAP assay and 2.03 $mmol \cdot kg^{-1}$ determined by DPPH assay). In both cases, the antioxidant activity of the Ozark Premier variety was more than double compared to the Shiro variety. The Black Amber, Kleopatra and Toptaste varieties had very similar values of antioxidant activity. When measured by the FRAP method, they were approximately 3 $mmol \cdot kg^{-1}$, measured by the DPPH method they were determined to be approximately 3.3 $mmol \cdot kg^{-1}$ (Tab. 1). The value of antioxidant activity of fruits may be influenced not only by the actual L-ascorbic acid content but also by the content of anthocyanin pigments in the skin and flesh of the fruits [5, 13, 23].

Plum spreads

The production of plum spread from selected plum varieties was based on Czech legislation [16], according to which plum spread must contain at least 1 700 g of fruit in 1 kg of food, the *SSC* value must be at least 60 % and acidity (as citric acid) must be between 6 $g \cdot kg^{-1}$ and 26 $g \cdot kg^{-1}$.

Tab. 2. Results of analytical evaluation of the produced plum spread without added saccharose.

	Black Amber	Shiro	Ozark Premier	Kleopatra	Toptaste
Fruit part [g·kg-1]	5 100	5 850	4 550	5 850	2 600
Added saccharose [g·kg-1]	0	0	0	0	0
Soluble solids content [%]	61.3 ± 1.3 a	60.3 ± 0.5 a	60.7 ± 0.5 a	60.7 ± 0.9 a	60.3 ± 0.9 a
Glucose [g·kg-1]	301.84 ± 24.88 a	308.57 ± 11.56 a	310.73 ± 23.92 a	341.53 ± 6.67 ab	361.76 ± 17.19 b
Fructose [g·kg-1]	200.34 ± 7.13 b	176.61 ± 3.61 a	197.52 ± 6.36 b	164.50 ± 3.24 a	164.26 ± 12.61 a
Saccharose [g·kg-1]	nd	nd	nd	nd	nd
Titratable acidity [g·kg-1]	62.0 ± 4.1 b	85.1 ± 5.3 c	68.7 ± 1.9 b	125.2 ± 6.0 d	20.8 ± 3.2 a
Malic acid [g·kg-1]	77.12 ± 7.3 bc	89.47 ± 5.10 c	58.17 ± 4.52 b	131.78 ± 12.86 d	22.08 ± 1.9 a
Citric acid [g·kg-1]	1.27 ± 0.44 a	2.17 ± 0.38 a	1.82 ± 0.40 a	2.21 ± 0.54 a	1.36 ± 0.18 a
L-Ascorbic acid [g·kg-1]	0.96 ± 0.26 ab	0.95 ± 0.10 ab	1.21 ± 0.05 b	0.52 ± 0.11 a	0.47 ± 0.33 a
AC_{FRAP} [mmol·kg-1]	14.21 ± 0.21 b	11.89 ± 0.25 a	17.18 ± 0.13 c	21.47 ± 0.03 d	18.59 ± 0.60 d
AC_{DPPH} [mmol·kg-1]	10.30 ± 0.35 b	7.87 ± 0.42 a	13.12 ± 0.10 d	11.74 ± 0.02 c	12.70 ± 0.87 cd
L^*	23.34 ± 0.82 ab	25.69 ± 1.36 bc	27.35 ± 0.41 c	21.54 ± 0.82 a	24.82 ± 0.68 bc
a^*	3.98 ± 0.54 ab	5.39 ± 0.58 ab	9.55 ± 1.15 c	2.70 ± 1.07 a	6.61 ± 1.05 b
b^*	3.89 ± 0.16 b	4.16 ± 0.65 b	7.74 ± 0.49 d	1.25 ± 0.45 a	5.91 ± 0.47 c

Values represent mean ± standard deviation. The small letters in superscript indicate statistically significant differences between the values in each row, at a significance level of $p = 0.05$. The fruit part is converted to 1 kg of product. Antioxidant activity is expressed as millimoles of Trolox equivalents.
nd – no detected, AC_{FRAP} – antioxidant activity determined by FRAP assay, AC_{DPPH} – antioxidant activity determined by DPPH assay.

Tab. 3. Results of analytical evaluation of the produced plum spread with added saccharose.

	Black Amber	Shiro	Ozark Premier	Kleopatra	Commercial plum spread
Fruit part [g·kg-1]	1 700	1 700	1 700	1 700	Min. 1 700
Added saccharose [g·kg-1]	394	430	374	428	Max. 300
Soluble solids content [%]	60.3 ± 1.3 a	62.0 ± 0.8 a	60.7 ± 0.7 a	61.3 ± 0.8 a	65.0 ± 0.6 b
Glucose [g·kg-1]	301.75 ± 9.25 c	301.58 ± 12.59 c	275.05 ± 1.71 ab	296.81 ± 3.78 bc	267.08 ± 13.67 a
Fructose [g·kg-1]	261.09 ± 10.03 b	280.65 ± 11.05 b	256.26 ± 5.10 ab	273.90 ± 3.14 b	227.57 ± 18.10 a
Saccharose [g·kg-1]	28.41 ± 0.84 a	33.01 ± 2.35 a	27.57 ± 0.59 a	25.77 ± 0.45 a	86.66 ± 9.39 b
Titratable acidity [g·kg-1]	22.5 ± 3.5 b	22.8 ± 2.5 b	22.3 ± 3.6 b	37.3 ± 3.1 c	13.5 ± 2.5 a
Malic acid [g·kg-1]	23.17 ± 0.89 b	25.03 ± 1.84 b	22.16 ± 4.21 b	36.46 ± 2.15 c	9.22 ± 1.36 a
Citric acid [g·kg-1]	0.36 ± 0.09 a	0.50 ± 0.35 a	0.58 ± 0.18 a	0.72 ± 1.02 a	0.57 ± 0.45 a
L-Ascorbic acid [g·kg-1]	0.26 ± 0.01 ab	0.22 ± 0.02 ab	0.41 ± 0.12 b	0.11 ± 0.02 a	0.33 ± 0.12 b
AC_{FRAP} [mmol·kg-1]	11.48 ± 0.50 c	5.38 ± 0.26 a	14.12 ± 0.37 d	9.33 ± 0.19 b	11.14 ± 0.37 c
AC_{DPPH} [mmol·kg-1]	8.21 ± 0.23 c	4.98 ± 0.19 a	10.14 ± 0.27 d	7.20 ± 0.15 b	8.18 ± 0.12 c
L^*	31.57 ± 0.82 b	36.13 ± 0.14 c	29.36 ± 1.36 b	25.67 ± 1.09 a	23.16 ± 0.68 a
a^*	15.77 ± 0.93 c	11.11 ± 0.69 b	10.78 ± 0.35 b	10.07 ± 0.23 b	2.24 ± 0.35 a
b^*	8.97 ± 0.33 c	20.66 ± 0.32 d	10.06 ± 0.73 c	5.03 ± 0.57 b	1.57 ± 0.16 a

Values represent mean ± standard deviation. The small letters in superscript indicate statistically significant differences between the values in each row, at a significance level of $p = 0.05$. The fruit part is converted to 1 kg of product. Antioxidant activity is expressed as millimoles of Trolox equivalents.
AC_{FRAP} – antioxidant capacity determined by FRAP assay, AC_{DPPH} – antioxidant capacity determined by DPPH assay.

The production of both plum spread options was stopped after reaching a *SSC* of 60–62 %. Results of analytical evaluation of the produced plum spread are given in Tab. 2 (products without added saccharose) and Tab. 3 (products with added saccharose).

The saccharose-free plum spread complying with the requirements of the above-mentioned legislation were produced only from the European variety Toptaste with *TA* of 20.8 $g \cdot kg^{-1}$. The other saccharose-free plum spreads made from Asian plums had *TA* from 62.0 $g \cdot kg^{-1}$ to 125.2 $g \cdot kg^{-1}$, which was well above the legal limit. In the case of sweetened plum spread, products prepared from the Asian varieties Black Amber (*TA* of 22.5 $g \cdot kg^{-1}$), Shiro (*TA* of 22.8 $g \cdot kg^{-1}$) and Ozark Premier (*TA* of 22.3 $g \cdot kg^{-1}$) met the legislative requirements as well.

Glucose was the most abundant sugar in all products. For plum spread produced without saccharose, the glucose content ranged from 301.84 $g \cdot kg^{-1}$ (Black Amber variety) to 361.76 $g \cdot kg^{-1}$ (European Toptaste variety). The glucose content of the sweetened plum spread ranged from 267.08 $g \cdot kg^{-1}$ (commercial plum spread) to approximately 302 $g \cdot kg^{-1}$ (Shiro and Black Amber products). Saccharose was not detected in any of the plum spreads made without added saccharose. During prolonged heating, all the saccharose initially contained in the fruits was hydrolytically broken down into glucose and fructose in an acidic environment. This decomposition occurred in the saccharose-added option as well, but the heating was not long enough to decompose all the initial and added saccharose [24]. The highest saccharose content was determined for the commercial plum spread, approximately 87 $g \cdot kg^{-1}$. The content of saccharose did not differ much in plum spread made from the Asian varieties, with values of approximately 30 $g \cdot kg^{-1}$.

Malic acid was the most abundant acid in the products. A statistically significantly higher content of this acid was measured in plum spread without added saccharose, specifically in the Kleopatra variety (131.78 $g \cdot kg^{-1}$), while the lowest content for this variant of plum spread was found in plum spread made from the European Toptaste variety (22.08 $g \cdot kg^{-1}$). Among the sweetened plum spreads, the highest malic acid content was again found in the Kleopatra variety (36.46 $g \cdot kg^{-1}$). Other sweetened plum spreads made from Asian varieties differed only slightly in malic acid content (Ozark Premier, 22.16 $g \cdot kg^{-1}$, Black Amber, 23.17 $g \cdot kg^{-1}$, Shiro 25.03 $g \cdot kg^{-1}$). The L-ascorbic acid content was higher in products without added saccharose, especially in plum spreads made from Asian plum varieties. The content ranged from 0.47 $g \cdot kg^{-1}$ (Toptaste) to 1.21 $g \cdot kg^{-1}$ (Ozark Premier). In the sweetened plum spread option, the addition of saccharose resulted in a significant dilution of the original L-ascorbic acid content, the reduced value ranged from 0.11 $g \cdot kg^{-1}$ (Kleopatra) to 0.41 $g \cdot kg^{-1}$ (Ozark Premier). The resulting sugar and acid contents of the plums can be significantly modified by the plum variety used and the production technology, in particular the degree of concentration, the addition of sugars and possibly gelling agents [25].

The antioxidant activity values were higher in the plum spread produced without added saccharose. The highest value was determined by the FRAP method for plum spread made from the Kleopatra variety (21.47 $mmol \cdot kg^{-1}$) and by the DPPH method for plum spread made from the Ozark Premier variety (13.12 $mmol \cdot kg^{-1}$). The lowest values of antioxidant activity were measured for the Shiro variety (11.89 $mmol \cdot kg^{-1}$ measured by FRAP method and 7.87 $mmol \cdot kg^{-1}$ measured by DPPH method). In the option with added saccharose, the highest antioxidant activity was determined for the Ozark Premier variety, both by FRAP method (14.12 $mmol \cdot kg^{-1}$) and DPPH method (10.14 $mmol \cdot kg^{-1}$). In this plum spread option, too, the lowest value of antioxidant activity was determined for the Shiro variety (5.38 $mmol \cdot kg^{-1}$ by FRAP assay and 4.98 $mmol \cdot kg^{-1}$ by DPPH assay). The higher content of initial mass of fresh fruits to reach the set point (*SSC*) was the reason for the determination of higher antioxidant activity for plum spread without added saccharose [4, 26].

Chromaticity

For the latter reason, the chromaticity of the products was also evaluated by an instrumental method (Tab. 2 and Tab. 3), which provides the possibility of objectifying the results [27]. The L^* values represented the intensity of lightness (0 = black to 100 = white). The chromaticity dimension a^* measures the intensity of red colour at a positive value and green colour at a negative value, whereas b^* signifies the intensity of yellow colour at a positive value and blue colour at a negative value. The darkening in plum spreads without saccharose addition was probably due to the Maillard reactions [28]. Commercial plum spreads were also typically dark in hue ($L^* = 23.16$). In the case of the saccharose-added option, the colour of the original fruits was partially preserved. The Black Amber variety plum spread with a statistically significantly higher a^* value was burgundy red, while the same option

Tab. 4. Results of sensory evaluation of produced plum spreads without added saccharose.

Parameters	Black Amber	Shiro	Ozark Premier	Kleopatra	Toptaste	Maximum points possible
Appearance	12 ± 3	12 ± 2	7 ± 2	12 ± 2	12 ± 2	15
Smell	15 ± 4	14 ± 4	13 ± 3	14 ± 4	17 ± 5	20
Texture	21 ± 4	21 ± 3	13 ± 5	16 ± 6	22 ± 4	25
Taste	17 ± 5	17 ± 5	19 ± 6	18 ± 6	29 ± 5	35
Overall impression	3 ± 1	3 ± 1	3 ± 1	3 ± 1	4 ± 1	5
Total rating	67 ± 11	66 ± 7	54 ± 12	64 ± 9	83 ± 13	100

Values represent mean ± standard deviation.

Tab. 5. Results of sensory evaluation of the produced plum spreads with added saccharose.

Parameters	Black Amber	Shiro	Ozark Premier	Kleopatra	Commercial plum spread	Maximum points possible
Appearance	10 ± 3	9 ± 2	11 ± 1	12 ± 2	15 ± 0	15
Smell	14 ± 2	13 ± 4	14 ± 4	13 ± 4	15 ± 3	20
Texture	18 ± 3	17 ± 3	19 ± 2	18 ± 5	22 ± 5	25
Taste	24 ± 5	28 ± 4	27 ± 5	24 ± 4	31 ± 4	35
Overall impression	3 ± 1	3 ± 1	4 ± 1	3 ± 1	4 ± 1	5
Total rating	69 ± 8	71 ± 7	75 ± 9	70 ± 10	88 ± 10	100

Values represent mean ± standard deviation.

of Shiro variety plum spread had a significantly higher b^* value than the option without saccharose, resulting in a yellow-brown colour.

Sensory evaluation

In order to evaluate the acceptability of the produced plum spread, sensory analysis of the products without added saccharose and the sweetened options was carried out (Tab. 4 and Tab. 5). Among the saccharose-free plum spreads, the European Toptaste variety was the best (83 ± 13), scoring high in the taste parameter (29 ± 5). The highest score among the saccharose-free plum spreads made from Asian plums was obtained by the Black Amber variety (67 ± 11). For plum spread with added saccharose, the best rating was for the commercial plum spread (88 ± 10). Among the saccharose-added plum spreads made from Asian varieties, Ozark Premier (75 ± 9) and Shiro (71 ± 7) were the highest scoring varieties. The addition of saccharose resulted in a statistically significant improvement in the scoring of Ozark Premier (Fig. 2). Appearance was rated higher for all plum spreads without added saccharose. For the saccharose-free option, a longer heating time of the raw material was used, which resulted in the formation of a brown colour typical for plum spread [29].

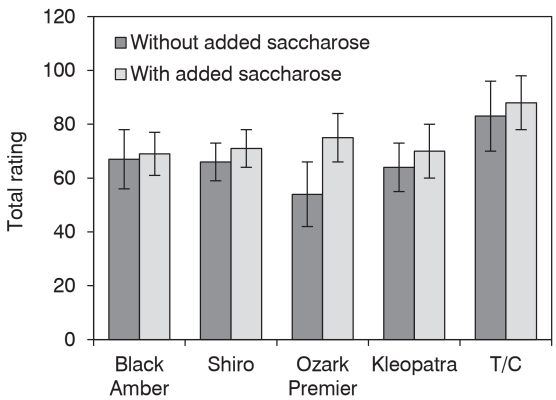

Fig. 2. Comparison of the overall sensory evaluation of plum spreads made without and with added saccharose.

T – Toptaste (without added saccharose), C – commercial plum spread (with added saccharose).

CONCLUSIONS

The four Asian plum varieties evaluated (Black Amber, Shiro, Ozark Premier and Kleopatra) were not suitable for the production of traditional Czech plum spread in the saccharose-free version. Ripe fruits of Asian varieties contained higher amounts of acids compared to fruits of the European Toptaste variety. Statistically significantly higher L-ascorbic acid content and antioxidant activity was found in Asian plums of the Ozark Premier variety. During the processing of plums of Asian varieties without added saccharose, it was necessary to concentrate the raw material to a higher degree by evaporating water (*SSC* minimum of 60 %). This increased the acid content of the finished product, which then did not meet the legal requirements for traditional Czech plum spread (*TA* of maximum 26 $g \cdot kg^{-1}$) and the product was inharmoniously acidic. The addition of saccharose in the processing of Asian varieties of fruit ranging from 374 $g \cdot kg^{-1}$ to 430 $g \cdot kg^{-1}$ of product was an appropriate technological solution. The sweetened options of plum spread made from Asian plum varieties were always rated higher than the options without added saccharose. They retained the colour of fresh fruits better and the products made from Black Amber, Shiro and Ozark Premier met then the legal requirements for traditional Czech plum spread.

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