Comparison of sensory and compositions of five selected persimmon cultivars (*Diospyros kaki* L.) and correlations between chemical components and processing characteristics

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Abstract Persimmon is one of the most popular and valuable fruits in markets because of its distinguished flavor as well as its significant benefits to health. The present study systematically compared the sensory characteristics and chemical compositions of five commercial persimmon fruits, and the correlations between chemical components and processing characteristics were also included. Our results showed that obvious differences in aroma and taste were found among the cultivars. Likewise, the contents of chemical components including sugar, total phenol, β -carotene and ascorbic acid, varied significantly ($p < 0.05$) across different persimmon cultivars. The processing characteristics of persimmon fruit closely correlated with the chemical compositions. Pectin ($r = 0.76$, $p < 0.01$) and total phenol ($r = 0.576$, $p < 0.05$) were found to enhance the viscosity of persimmon pulp, and the colour of persimmon powder was greatly influenced by β -carotene, ascorbic acid and sugar contents ($r = 0.823$, -0.729 and -0.685 , $p < 0.01$, respectively). Powder recovery of persimmon was positively correlated with pectin content ($r = 0.503$, $p < 0.05$) and negatively related to total sugar content ($r = -0.668$, $p < 0.01$). Pectin content exerted positive effect ($r = 0.719$, $p < 0.01$) on

hygroscopicity of persimmon powder, and the powder solubility showed a positive correlation to sugar and a negative relationship to pectin contents ($r = 0.662$ and -0.716 , $p < 0.01$, respectively). In addition, a positive correlation ($r = 0.642$, $p < 0.01$) of the content of ascorbic acid to phenolic retention was also observed.

Keywords Persimmon · Sensory · Chemical compositions · Processing characteristics · Correlation

Introduction

Persimmon (*Diospyros kaki* L.), belonging to the Ebenaceae family, is cultivated widely in China, Japan and Korea. It has become a popular fruit in China due to the unique flavour and taste, as well as its significant benefits to health. Currently, persimmon is consumed as fresh or in processed forms, such as dried fruit and wine.

Persimmon fruits are broadly classified into two main groups (the non-astringent and astringent). Each group includes many local cultivars based on different producing regions, shapes, colours or maturity period. It is reported that there are over 400 local cultivars of persimmon in China (Nicoletti et al. 2005). The contents of primary and secondary metabolites such as sugars, organic acids, carotenoids and polyphenols vary significantly in different cultivars of persimmon fruit growing in Slovenia (Veberic et al. 2010). These chemical compositions in persimmon fruit are closely related not only to its flavour and sensory quality, but also to the nutritional properties and beneficial health effects of the fruit. It is commonly known that the contents of individual sugars as well as the sugar/organic acid ratio directly correlate with the sweetness of persimmon fruit (Schwieterman et al. 2014). The colour of persimmon fruit in different cultivars varies from

Highlights Five persimmon cultivars showed different aroma and taste. Chemical compositions in persimmon fruit varied greatly ($p < 0.05$) amongst cultivars. Processing characteristics were closely correlated to chemical components of persimmons.

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yellow and orange to deep red, which results from the different contents of carotenoids (Zhou et al. 2011). Persimmon fruits with high concentrations of carotenoids and polyphenols also exert greatly potential effects on preventing cardiovascular diseases (George and Redpath 2008).

In addition, the compositions and concentrations of primary and secondary compounds of persimmon fruit may also closely correlate with its processing characteristics. For instance, persimmon pulp with high content of pectin may have great viscosity, thus hard to be dried and resulting in a low juice yield, and fruits with high content of sugar turn brown easily during processing (Wojdyło et al. 2014; Jaeger et al. 2010). Therefore, it is necessary to obtain more detailed information on the correlations between chemical compositions and processing properties of persimmon fruit in different cultivars. However, up till now, very limited information on the compositions and contents of primary and secondary metabolites in different cultivars of Chinese persimmon fruit is available, and reports concerning the correlations between chemical compositions and processing properties of persimmon fruit are unavailable. The present study aimed to systematically compare the sensory qualities and chemical compositions of five different cultivars of Chinese persimmon fruit, and the correlations between chemical components and processing properties of persimmon fruit were also included. We believe that detailed information on the relationship between chemical compositions and processing characteristics of persimmon fruit will provide a good guide for the industry processing.

Materials and methods

Samples

One non-astringent cultivar ('ChanSiWan') and four astringent cultivars ('TaiLiHong', 'RaoTianHong', 'YongJiQingShi' and 'YueShi') of persimmon fruit were collected in September to October (2012) from the National Persimmon Germplasm Repository of Northwest Agriculture and Forestry University, located in Yangling, Shanxi Province, China, at their physiological maturity and allowed to ripen (full-ripeness, consumption maturity) at room temperature prior to analysis. For each cultivar, fruits from five trees were collected, i.e. three fruits per tree ($n = 15$). All of the reagents used were of analytical grade.

Sensory analysis

Sample preparation

Three hundred grams of persimmons were crushed into pulp with a blender (HJE880 beater, Hauswirt, Germany). The persimmon pulp was divided into two parts, one for the analysis

of electronic nose and the other mixed with water at a ratio of 1:1 (w/v) and then hydrolyzed by 0.02 % pectinase (v/v) for 2 h at 50 °C. The enzymatic hydrolysate was filtered with a 200 mesh gauze and centrifuged at 10,000 rpm for 5 min (Eppendorf centrifuge 5804R, Germany), and the supernatant was obtained for the analysis of electronic tongue.

Analysis of electronic nose and electronic tongue

A FOX 4000 from Alpha MOS (Toulouse, France) was used for electronic nose analysis. A volume of 5 mL of sample was taken into a 20 mL vial and heated at 50 °C for 2 min. The sample headspace was pumped over the sensor surfaces at a flow rate of 150 mL/min, and during this time the sensor signals were recorded. An electronic tongue system (α -AstreeII, Alpha M.O.S, France) was employed. A total volume of 80 mL of sample was filled into a 100 mL vessel, and the time of data collection was 120 s.

Analytical methods of chemical compositions in persimmon pulp

Extractions of the chemical compositions of persimmon pulp were conducted at consumption maturity, which was determined by the colour parameters obtained with a Minolta CR400 Chroma portable colourimeter (Minolta Co., Osaka, Japan) with a CIELAB scale (L^* , a^* and b^*) (Veberic et al. 2010). Chroma (C) was used to determine the saturation of colourfulness, which was calculated by the formula: $C = (a^{*2} + b^{*2})^{1/2}$. Hue angle (h°) was calculated from parameters a^* and b^* and used as a reference, where 0° represents red colour, 90° yellow, 180° green and 360° blue (Veberic et al. 2010). The parameter h° was reported as an important maturity indicator for persimmon fruit (Candir et al. 2009). In this study, the parameter h° of persimmon fruit of five cultivars was between 45° and 55°, which indicated that the selected fruits were considered to be at consumption maturity.

Moisture content of persimmon fruit was determined using the method described by Tonon et al. (2009). The total sugar and reducing sugar of persimmon fruit were measured according to the phenol-sulfuric acid and Fehling's methods (Li et al. 2009), respectively. Determination of organic acids (tartaric acid, citric acid, fumaric acid and malic acid) was performed on a SHIMADZU liquid chromatograph system (Shimadzu Co., Kyoto, Japan) with a Hypersil ODS2 column (4.6 mm $\times$ 200 mm, 5 μ m, Elite, China). Separation was accomplished with methanol-phosphate (v/v = 19:1) as mobile phase at 0.8 mL/min in an isocratic elution program. Column temperature was set at 25 °C and the eluate was monitored at 210 nm. The contents of total phenol, ascorbic acid and pectin in persimmon fruit were determined by Folin–Denis, 2, 6-dichloroindophenol titration and carbazole colourimetry methods (Gu et al. 2008; Iqbal and Bhanger 2006; Wang

et al. 2012), respectively. The measurement of β -carotene was based on the method by Barba et al. (2006). The activities of polyphenol oxidase (PPO) and peroxidase (POD) were tested according to the methods described previously (Aquino-Bolaños and Mercado-Silva 2004; Alikhani-Koupaei et al. 2014).

Determination of pulp and powder characteristics of persimmon fruit

Viscosity measurement

Persimmon fruit was crushed into pulp (persimmon/water at a ratio of 1:1 (w/w)) using a blender (HJE880 beater, Hauswirt, Germany). The viscosity of persimmon pulp was measured with a DV-II + PRO viscometer (Brookfield Viscometers Ltd., Harlow, UK). Analysis was performed at 25 °C with the rotary velocity at 1.5 r/min for 30 s.

Spray drying

Samples for spray drying were prepared according to our previous work (Du et al. 2014). A special laboratory scale spray dryer (YC-1000, Yacheng, Shanghai, China) was used for spray drying. The technological parameters of spray drying were as follows: the feed flow rate 25 rpm, fan frequency 35 Hz, compressor air pressure 0.2 MPa, inlet temperature 110 ± 1 °C, and outlet temperature 85 ± 1 °C. The spray dried powders were collected immediately and sealed for further analysis.

Measurement of powder characteristics

The powder yield (powder recovery) after spray drying was expressed as the percentage of the amount of solids collected with respect to the total solids mass in feed solution (Jayasundera et al. 2011). The measurement of moisture content, colour and total phenol of spray dried powder was according to the methods described above. The determination of hygroscopicity and solubility was based on the methods described previously (Tonon et al. 2009; Cortes-Rojas and Oliveira 2012). Total phenolic retention was expressed as the ratio of the total phenolic content present in the spray dried powder to that in feed solution.

Statistical analysis

All of the determinations were performed at least in triplicate. Data were expressed as the mean $\pm$ standard deviation (SD) and evaluated by one-way Analysis of Variance (ANOVA) with Duncan's multiple range test. Correlation analysis was accomplished by Pearson correlation coefficient with two-tailed test. *p* Values less than 0.05 were considered as

significant. All statistical analyses were carried out using SPSS 19.0 (SPSS, Inc., Chicago, IL).

Results and discussion

Sensory characteristics

The sensory characteristics of five cultivars of persimmon fruit were analyzed by electronic nose and electronic tongue. In order to make a better data visualization, principal component analysis (PCA) and discriminant factor analysis (DFA) were carried out on all analyzed cultivars. Figure 1a showed the PCA scores plot defined by the first two principal components (99.75 % of the total variance), from which a clear separation of five clusters was observed. Moving from left to right along the first component (explained variance 99.30 %), cultivar 'YongJiQingShi' was clearly separated from the rest persimmon samples, but there was no evident discrimination among cultivars 'YueShi' and 'ChanSiWan'. Likewise, moving along the vertical axis, cultivars 'RaoTianHong' and 'TaiLiHong' showed close odor.

DFA was used to further discriminate these persimmon cultivars. A DFA scores plot with approximately 95.48 % of the total variance was presented in Fig. 1b. The first two principal components showed the values of 87.23 and 8.28 % data variance, separately. Cultivar 'YongJiQingShi' was located on the left of the DFA plot, and the rest cultivars were mainly grouped on the right of the scores plot, indicating that cultivar 'YongJiQingShi' can be easily discriminated from the other four cultivars. The plot also demonstrated that cultivars 'YueShi' and 'ChanSiWan' may have similar aroma profiles, which was in accordance with the result of PCA. Moving along the vertical axis, cultivars 'YueShi', 'ChanSiWan' and 'TaiLiHong' were clustered in the upper, central and lower right quadrant respectively, indicating that the three samples can be distinguished properly. Compared to the PCA results, the DFA plot exhibited a more precise discrimination among the five cultivars.

A PCA scores plot of electronic tongue was shown in Fig. 2a. It was seen that the first two principal components explained 99.87 % of the total variance and all persimmon samples were differentiated into two main groups in the plot. Cultivars 'RaoTianHong', 'TaiLiHong' and 'YongJiQingShi' were closely located on the left of the plot, while cultivars 'YueShi' and 'ChanSiWan' were grouped on the right of the plot, indicating different tastes of the two groups. In addition, cultivars 'RaoTianHong' and 'TaiLiHong' partially overlapped with each other, suggesting that the two cultivars showed similar taste. The discriminations in taste among different cultivars were also observed in the DFA plot (Fig. 2b). Cultivars 'YueShi' and 'ChanSiWan' were clustered in the upper and lower right quadrant respectively, indicating that

Fig. 1 Electronic nose evaluation of five cultivars of persimmon. **a** Principal component analysis scores plot. **b** Discriminant factorial analysis scores plot. *CSW* cultivar ‘ChanSiWan’, *RTH* cultivar ‘RaoTianHong’, *TLH* cultivar ‘TaiLiHong’, *YJQS* cultivar ‘YongJiQingShi’, *YS* cultivar ‘YueShi’

the tastes of the two cultivars were quite different. Cultivars ‘RaoTianHong’, ‘TaiLiHong’ and ‘YongJiQingShi’ were located on the left of the plot, with cultivars ‘RaoTianHong’ and ‘TaiLiHong’ mostly overlapping each other, suggesting similar taste of the two cultivars. DFA results showed that the flavour of the two groups was of great difference, which was in line with the PCA results described above.

Taken together, the results of electronic nose and electronic tongue showed obvious distinctions of flavour between group 1 (cultivars ‘RaoTianHong’, ‘TaiLiHong’ and ‘YongJiQingShi’) and group 2 (cultivars ‘YueShi’ and ‘ChanSiWan’). Cultivars ‘YueShi’ and ‘ChanSiWan’ in group 2 exerted the highest similarity in sensory characteristics among the five persimmon cultivars.

Comparison of chemical compositions in five cultivars of persimmon fruit

Moisture

Moisture content in five cultivars of persimmon fruit ranged from 76.34 ± 0.52 to 81.10 ± 0.05 % (Table 1), which was in accordance with the report of Isabelle et al. (2010). The highest content of moisture (81.10 ± 0.05 %) was measured in cultivar ‘YongJiQingShi’, followed by cultivars ‘YueShi’, ‘ChanSiWan’ and ‘RaoTianHong’ (80.28 ± 0.03 , 79.97 ± 0.06 and 78.83 ± 0.07 %, respectively), while cultivar ‘TaiLiHong’

had the lowest content of moisture (76.34 ± 0.52 %). The significant differences ($p < 0.05$) of moisture content in five persimmon cultivars were mainly due to varietal differences. Moisture content in persimmon fruit is comparable to that in kiwifruit (82.12 %), mango (78.54 %) and pineapple (81.65 %), but higher than durian (61.09 %) and lower than starfruit (89.34 %), strawberry (89.89 %) and watermelon (91.90 %) (Gao et al. 2012; Isabelle et al. 2010).

Sugar

As the main nutritional ingredient in fruit, sugar content highly correlates with the sweet aroma and taste of persimmon fruit. Significant differences ($p < 0.05$) in the contents of reducing sugar and total sugar were observed among five persimmon cultivars. As shown in Table 1, reducing sugar and total sugar levels (g/100 g) ranged from 10.26 ± 0.41 to 15.06 ± 0.21 and 11.55 ± 0.45 to 15.67 ± 0.52 , respectively. Cultivar ‘YueShi’ showed the highest content of reducing sugar (15.06 ± 0.21 g/100 g) and total sugar (15.67 ± 0.52 g/100 g), followed by cultivars ‘ChanSiWan’ (14.13 ± 0.30 and 15.38 ± 0.27 g/100 g, respectively), ‘RaoTianHong’ (12.78 ± 0.38 and 14.33 ± 0.21 g/100 g, respectively) and ‘YongJiQingShi’ (10.44 ± 0.15 and 12.56 ± 0.38 g/100 g, respectively). The lowest contents of reducing sugar and total sugar were observed in cultivar ‘TaiLiHong’ with the values of 10.26 ± 0.41 and 11.55 ± 0.45 g/100 g, respectively. As

Fig. 2 Electronic tongue evaluation of five cultivars of persimmon. **a** Principal component analysis scores plot. **b** Discriminant factorial analysis scores plot. *CSW* cultivar ‘ChanSiWan’, *RTH* cultivar ‘RaoTianHong’, *TLH* cultivar ‘TaiLiHong’, *YJQS* cultivar ‘YongJiQingShi’, *YS* cultivar ‘YueShi’

Table 1 Chemical compositions of five cultivars of persimmon fruit

Chemical compositions	Persimmon cultivars				
	TLH	RTH	CSW	YJQS	YS
Moisture content (%)	76.34 ± 0.52d	78.83 ± 0.07c	79.97 ± 0.06b	81.10 ± 0.05a	80.28 ± 0.03b
Reducing sugar (g/100 g)	10.26 ± 0.41d	12.78 ± 0.38c	14.13 ± 0.30b	10.44 ± 0.15d	15.06 ± 0.21a
Total sugars (g/100 g)	11.55 ± 0.45c	14.33 ± 0.21b	15.38 ± 0.27a	12.56 ± 0.38c	15.67 ± 0.52a
Tartaric acid (mg/kg)	799.03	209.13	227.48	515.57	323.73
Citric acid (mg/kg)	182.37	3.24	109.29	2.25	11.28
Fumaric acid (mg/kg)	1.03	1.54	9.92	0.93	0.41
Malic acid (mg/kg)	197.36	94.60	175.21	66.95	69.65
Total acids (mg/kg)	1179.79	308.51	521.91	585.69	405.07
Sugar/acid ratio	97.90	464.49	294.69	214.45	386.85
Total phenols (mg/g)	18.44 ± 0.28b	8.98 ± 0.16d	6.74 ± 0.26e	11.04 ± 0.12c	19.16 ± 0.17a
β-Carotene (μg/100 g)	214.05 ± 6.5a	163.82 ± 2.9c	116.21 ± 3.0d	173.79 ± 3.5b	110.20 ± 0.2d
Ascorbic acid (mg/100 g)	27.00 ± 0.43b	9.43 ± 0.44e	25.59 ± 0.11c	17.68 ± 0.14d	43.17 ± 0.12a
Pectin (g/100 g)	2.39 ± 0.09a	2.24 ± 0.04b	0.69 ± 0.05d	1.65 ± 0.06c	2.14 ± 0.09b
PPO (U/g/min)	6.83 ± 0.5a	1.19 ± 0.0d	2.23 ± 0.17c	4.77 ± 0.4b	1.90 ± 0.1c
POD (U/g/min)	99.7 ± 3.12	30.67 ± 0.49	0	0	466.5 ± 2.26

The data are given as the mean ± SD ($n = 3$). Mean values in each variable with unlike letters are significantly different among cultivars ($p < 0.05$) CSW cultivar ‘ChanSiWan’, RTH cultivar ‘RaoTianHong’, TLH cultivar ‘TaiLiHong’, YJQS cultivar ‘YongJiQingShi’, YS cultivar ‘YueShi’

sweetness is a key factor contributing to the processing quality of persimmon fruit, cultivars with high sugar levels should be promoted. Similar findings have been reported in 11 persimmon cultivars growing in Slovenia, with total sugar values between 10.6 to 17.8 g/100 g (Veberic et al. 2010). However, the sugar contents of astringent persimmons in our study were higher than that in some other astringent cultivars, such as cultivars ‘Kikuhira’, ‘Hyozaemon’ and ‘Gionbo’ (9.9, 10.1 and 10.5 g/100 g, respectively) (Giordani et al. 2011). Persimmon cultivars possessed higher content of total sugar than medlar (Glew et al. 2003), but lower than jujube (Gao et al. 2012).

Sweet flavour is a primary factor contributing to the consumption of persimmon fruit, and sweetness is the main component of taste perception related to the content of sugars. Soluble solid content has been regarded as an effective indicator of sweetness in fruit, with a total measurement of sucrose, glucose and fructose as the predominant soluble solids (Basson et al. 2010). Previous reports also showed that the variation in sweetness intensity was well explained by sugar content (Schwieterman et al. 2014). An approximately equal content ($p > 0.05$) of total sugar was observed in cultivars ‘YueShi’ and ‘ChanSiWan’ (Table 1), which explained their high similarity of taste (Fig. 2). Likewise, there were non-significant differences ($p > 0.05$) in sugar content between cultivars ‘TaiLiHong’ and ‘YongJiQingShi’, which was in line with the PCA results of electronic tongue. The two groups were found to have significant differences ($p < 0.05$) in sugar content, contributing to the different sensory characteristics.

Organic acid

In the present study, four kinds of organic acids were determined in five persimmon cultivars, with tartaric acid being the predominant one, followed by malic acid, citric acid and fumaric acid (Table 1). The total content of organic acid was 2–4 times higher in cultivar ‘TaiLiHong’ than in the other four cultivars. Among the individual organic acids, the highest content of tartaric acid (799.03 mg/kg) was observed in cultivar ‘TaiLiHong’, and the lowest content (209.13 mg/kg) was in cultivar ‘RaoTianHong’. Cultivar ‘TaiLiHong’ was also found to contain the most abundant malic acid (197.36 mg/kg) and citric acid (182.37 mg/kg). Our results were in accordance with a previous study of Veberic et al. (2010). While the content of citric acid in our study (2.25–182.37 mg/kg) was lower than the value (657 mg/kg) obtained by Daood et al. (1992). The diversity of organic acid among the five persimmon cultivars may be mainly due to the genetic factor. Compared to other common fruits, the total organic acid in persimmon was lower than that in apple (8300–17,850 mg/kg) and *Lycium chinense* Mill. (8410 mg/kg) (Glew et al. 2003).

Sugar/acid ratio

The sugar/acid ratio in matured persimmon is regarded to be a good indicator of internal fruit quality. Optimal sugar/acid ratio is crucial for a harmonious flavour of fruit. High sugar/acid ratio is related to the sweetness of fruits, on the contrary, the lower the ratio, the sourer are the fruits. As shown in

Table 1, the sugar/acid ratios differed among cultivars. Cultivar ‘RaoTianHong’ had the highest sugar/organic acid ratio, followed by cultivars ‘YueShi’, ‘ChanSiWan’ and ‘YongJiQingShi’. Cultivar ‘TaiLiHong’ had the lowest content of sugar and a considerably high content of organic acid, and thus a minimum sugar/acid ratio was obtained.

Total phenolic content (TPC)

The high polyphenol content is one of the unique characteristics of persimmon fruit and polyphenols are responsible for the health benefits (Du et al. 2014). TPC of the five cultivars varied widely from 6.74 ± 0.26 to 19.16 ± 0.17 mg/g ($p < 0.05$). Cultivar ‘YueShi’ contained the most abundant TPC (19.16 ± 0.17 mg/g), together with the lower contents of cultivars ‘TaiLiHong’ (18.44 ± 0.28 mg/g) and ‘YongJiQingShi’ (11.04 ± 0.12 mg/g), while the lowest TPC was found in cultivar ‘ChanSiWan’ with a value of 6.74 ± 0.26 mg/g. Generally, astringent persimmons had higher concentrations of total phenol than did non-astringent fruits, for both pulp and peel. Cultivar ‘ChanSiWan’ belonged to the non-astringent, thus containing the lowest TPC when compared to the other four astringent cultivars. Much lower concentrations (0.13 – 0.29 mg/g) of total phenol have been reported by Veberic et al. (2010) in some other persimmon cultivars growing in Slovenia. Persimmons growing in Israel were reported to have an average TPC of 1.16 mg/g (Isabelle et al. 2010). Our data showed higher TPC of the five analyzed persimmon cultivars than reported cultivars. The difference might be due to the genetic and environmental factors. In addition, most of these studies used ethanol or acetone to extract total phenol from persimmon fruit. Because the highly polymerized tannins accounted for the main component of persimmon polyphenols, it could not be extracted sufficiently from the fruit by ethanol or acetone. In the present study, we used methanol acidified with 1 % hydrochloric acid as the extracting solvent, which might also contribute to the higher TPC. TPC in persimmon fruit is higher than many other fruits, such as juicy peach (2.4 mg/g), pear (2.1 mg/g), litchi (3.35 mg/100 g), guava (4.95 mg/100 g), mango (6.25 mg/100 g) and wax apple (1.39 mg/100 g) (Gorinstein et al. 1999). High levels of polyphenols in persimmon should allow us to exploit it as a beneficial phytonutrient source.

β-Carotene

The yellow to red colour of persimmon fruit is closely related to its carotenoid contents. β-Carotene was reported to be the predominant carotenoid in persimmon, which accounted for 65 to 72 % of the total carotenoids (Veberic et al. 2010). The contents of β-carotene of the five persimmon cultivars are shown in Table 1. The highest amount of β-carotene was found in cultivar ‘TaiLiHong’ (214.05 ± 6.5 μg/100 g) and

the lowest content was in cultivars ‘ChanSiWan’ and ‘YueShi’ with the values of 116.21 ± 3.0 and 110.20 ± 0.2 μg/100 g, separately. Different levels of β-carotene were also observed in other persimmon cultivars. For instance, higher concentrations of β-carotene were measured in cultivars ‘Tone Wase’ (494 μg/100 g) and ‘Hana Fuyu’ (875 μg/100 g) growing in Slovenia (Veberic et al. 2010). While, Giordani et al. (2011) reported that the contents of β-carotene in cultivars ‘Fuji’, ‘Triumph’ and ‘Jiro’ were 31, 45 and 93 μg/100 g, respectively, which were much lower than our results, probably due to cultivar differences and environmental effects. Zhou et al. (2011) demonstrated that the content of β-carotene in cultivar ‘YueShi’ rapidly increased from green to mature, indicating that the maturity of persimmon fruit also had an important impact on the carotenoid content. The β-carotene content in persimmon was lower than that in mango, apricot and papaya, but higher than that in apple, pear and orange (Giordani et al. 2011).

Ascorbic acid

Ascorbic acid, an important water soluble vitamin, is widely distributed in fruits and vegetables (Del Bubba et al. 2009). It is also commonly used in food industry acting as a nutritional antioxidant supplement. Due to its characteristic of easy degradation, which could lead to browning of the products, ascorbic acid is generally regarded as an indicator of the internal quality of fruits during processing. Wide variation (9.43 ± 0.44 to 43.17 ± 0.12 mg/100 g, $p < 0.05$) was observed in ascorbic acid content of the five persimmon cultivars, indicating considerable levels of genetic diversity. The highest amount of ascorbic acid was observed in astringent cultivar ‘YueShi’ (43.17 ± 0.12 mg/100 g), which was four times more than that in cultivar ‘RaoTianHong’ (Table 1).

The contents of ascorbic acid ranged from 100 mg/100 g in cultivar ‘Kaki Tipo’ (Del Bubba et al. 2009) to 218 mg/100 g in cultivar ‘Fuyu’ (Homnava et al. 1990), which were much higher than our results. In persimmon fruit, the content of ascorbic acid was comparable to that in mango and lemon, higher than medlar (Glew et al. 2003), and lower than cherry and jujube (Gao et al. 2012).

Pectin

Pectin, a mixture of high molecular weight polysaccharide in cell wall, was closely related to processing quality of fruit. Pectin content ranged from 0.69 ± 0.05 g/100 g in cultivar ‘ChanSiWan’ to 2.39 ± 0.09 g/100 g in cultivar ‘TaiLiHong’ (Table 1). There was little difference ($p > 0.05$) between the cultivars ‘YueShi’ and ‘RaoTianHong’, with an average value of 1 – 2 g/100 g. Asgar et al. (2003) reported a similar pectin content in Japanese persimmon (1.6 g/100 g), while the total pectin in cultivar ‘Hiratanenashi’ reported by Taira et al.

(1997) was much lower (0.3 g/100 g). Previous reports revealed that the protopectin content decreased from 5 to 2 g/100 g and the soluble pectin increased from 0.2 to 2.5 g/100 g of persimmon fruit, which might be attributed to the converting of protopectins to soluble pectin substances by enzymes in the period of fruit ripening (Kashyap et al. 2001). In comparison with cherry (0.24–0.54 g/100 g), litchi (0.42 g/100 g) and passion fruit (0.5 g/100 g) (Prasanna et al. 2007), persimmon fruit had significantly higher pectin content. While, the pectin content of persimmon was a little lower than that of lemon (2.5–4.0 g/100 g) (Prasanna et al. 2007).

Polyphenol oxidase (PPO) and peroxidase (POD)

PPO and POD are very important enzymes in food industry because they are involved in the change of food quality during processing. Currently, studies on PPO and POD in persimmon are limited. The activity of PPO ranged from 1.19 ± 0.0 U/g/min in cultivar ‘RaoTianHong’ to 6.83 ± 0.5 U/g/min in cultivar ‘TaiLiHong’. On the other hand, the highest POD activity was found in cultivar ‘YueShi’ with a value of 466.5 ± 2.26 U/g/min, while cultivars ‘YongJiQingShi’ and ‘ChanSiWan’ had the lowest activities of POD which were hardly detectable. Our results also showed that the activity of POD was much higher than that of PPO in most cultivars. The difference between cultivars was also reported in apple, with the PPO activity ranging from 270 U/g (‘Shampion’) to 3120 U/g (‘Warta’) (Podsędek et al. 2000). The diminished quality of fruit occurs mainly due to the oxidation of phenolic compounds catalyzed by enzymes, contributing to a change of the contents of bioactive compounds.

Correlation of pulp and powder characteristics with chemical components of persimmon fruit

Correlation of pulp viscosity with pectin and total phenolic contents

Viscosity is an important quality index of most fluid and semi-fluid food products. Pulp viscosity is also highly correlated with the efficiency of spray drying. Generally, materials with low-viscosity concentrates are effortless to dry and yield stable powders. While high viscosity of pulp is sometimes troublesome for spraying, which may lead to inhomogeneities in the sprayed droplets size and shape. An appropriate pulp viscosity for spray drying is needed. Significant differences ($p < 0.05$) were observed among the five persimmon cultivars (Table 2). The peak viscosity was observed in cultivar ‘TaiLiHong’, with an average value of more than 30,000 mPa·s, while the lowest was observed in cultivar ‘ChanSiWan’, with the pulp viscosity of 8238 ± 416 mPa·s. It was shown that the pectin content in pulp had a great correlation to viscosity ($r = 0.76, p < 0.01$) (Fig. 3). Wojdyło et al.

Table 2 The colour C value and viscosity of five cultivars of persimmon pulp

Cultivars	C value	Viscosity (mPa·s)
TLH	$44.87 \pm 1.00a$	$31,634 \pm 380a$
RTH	$45.88 \pm 0.30a$	$20,342 \pm 1131c$
CSW	$24.53 \pm 0.33d$	$8238 \pm 416d$
YJQS	$42.38 \pm 0.59b$	$25,435 \pm 1415b$
YS	$33.31 \pm 0.48c$	$18,139 \pm 547c$

The data are given as the mean $\pm$ SD ($n = 3$). Mean values in each column with unlike letters are significantly different among cultivars ($p < 0.05$)

CSW cultivar ‘ChanSiWan’, RTH cultivar ‘RaoTianHong’, TLH cultivar ‘TaiLiHong’, YJQS cultivar ‘YongJiQingShi’, YS cultivar ‘YueShi’

(2014) also suggested that the viscosity of juice was mainly determined by the content of pectin substances. During fruit ripening, protopectins are transformed into soluble pectins which easily penetrate to the juice, thus causing an increase in viscosity. Total phenolic content was also found to have a significant effect on the viscosity of persimmon pulp ($r = 0.576, p < 0.05$), which was consistent with the research on wheat starch, indicating that phenolic compounds could increase the peak viscosity effectively. Hydrophobic phenolic moieties exist in persimmon fruit could form gel network junctions, contributing to the increase in viscosity (Peshkova and Li 2003).

Correlation of powder recovery of spray drying with sugar and pectin contents

Converting fresh fruits to solid powders by spray drying is a widely used economical technique for easy storage, transporting and processing. Powder recovery is the most important indicator of spray drying and directly related to the economic efficiency. Due to the high content of sugar in persimmon fruit, in the preliminary study, persimmon fruit powders could hardly be obtained under conventional spray drying conditions even if a large amount of drying carriers were added. Fortunately, we overcame the stickiness problem and obtained high yield powders by adjusting the drying technology (Du et al. 2014). The highest powder recovery was found in cultivar ‘TaiLiHong’ (76.62 ± 0.42 %), while cultivars ‘RaoTianHong’ and ‘ChanSiWan’ showed the lowest powder recovery (about 68 %). As presented in Fig. 3, powder recovery was positively correlated with pectin ($r = 0.503, p < 0.05$) and negatively related to total sugar ($r = -0.668, p < 0.01$). High levels of sugar would go against drying as a result of reducing glass transition temperature in the process of spray drying. Generally, pulp with high content of pectin was not beneficial for spray drying due to the high viscosity, which would be difficult to feed-in during processing. However, previous studies demonstrated that pectin was effective to aid

◀ **Fig. 3** Correction analysis of chemical compositions to processing properties of persimmon fruit. Coefficient of determination (r) and p -value of fit is listed above individual scatterplots. Solid line represents linear fit, an asterisk denotes significant fit ($p < 0.05$) and two asterisks denote highly significant fit ($p < 0.01$)

drying and improve the stability of powders (Sansone et al. 2011), which was in agreement with our results.

Correlation of powder colour with β -carotene, ascorbic acid and sugar

Colour is an important indicator in the visual appearance of spray dried powders and it directly influences the acceptance of the products by consumers. Significant differences of C values (ranging from 21.26 ± 0.21 to 39.43 ± 0.35 , $p < 0.05$) were found in the five persimmon powders (Table 3). The highest and lowest C values were measured in cultivars ‘RaoTianHong’ and ‘YueShi’, separately. Compared to the C values of persimmon pulp (Table 2), an obvious decrease in C values was observed in spray dried powder, except for cultivar ‘ChanSiWan’, which showed a little increase. Furthermore, there was a significant correlation of powder colour to pulp colour ($r = 0.943$, $p < 0.01$) of persimmon fruits (Fig. 3). Our study also suggested that β -carotene was the most important contributor to the C value of persimmon pulp ($r = 0.819$, $p < 0.01$). Besides, the change of colour during spray drying was also associated with the alteration in sugar and ascorbic acid contents. As shown in Fig. 3, β -carotene had a significantly positive correlation to the colour of persimmon powder ($r = 0.832$, $p < 0.01$), which was consistent with the result in persimmon pulp. On the contrary, ascorbic acid and total sugar showed negative correlations with the colour of persimmon powder ($r = -0.729$ and -0.685 , $p < 0.01$, respectively). Ascorbic acid was found to reduce the redness (a^*) and the yellowness (b^*) colour values of strawberry, peach, and apple puree (Rababah et al. 2005), which was in line with our results. The impact of ascorbic acid on colour loss has been reported intensively, however, the corresponding mechanism still remained unclear. Jurd (1972) demonstrated that the interaction between ascorbic acid and anthocyanin in fruit may

contribute to the pigment degradation and colour fading. Sugar (particularly glucose and fructose), was actively involved in the formation of brown pigmented substances caused by non-enzymatic browning such as Maillard reaction, thus causing the change of colour.

Correlation of hygroscopicity and solubility of powder with pectin and sugar content

As presented in Table 3, the hygroscopicity of persimmon powders varied from 25.00 ± 0.92 to 29.92 ± 0.24 g/100 g. Cultivar ‘YongJiQingShi’ had the highest hygroscopicity, followed by cultivars ‘TaiLiHong’, ‘YueShi’ and ‘RaoTianHong’, while cultivar ‘ChanSiWan’ showed the lowest hygroscopicity. The hygroscopicity of persimmon powder was comparable to that of spray-dried propolis powder (27.4 – 29.3 g/100 g) (Da Silva et al. 2013). Pectin content was found to have a significant enhancing effect on the hygroscopicity of persimmon powder ($r = 0.719$, $p < 0.01$) (Fig. 3). Similar results were obtained in the powder of mango peel which was rich in pectin (Malviya and Kulkarni 2012), indicating that powders with high pectin content were hygroscopic in nature and needed to be stored in air-tight containers.

Besides hygroscopicity, solubility is another important factor to assess the hydration properties of powder. Powder solubility varied from 63.94 ± 1.51 to 71.58 ± 0.78 g/100 mL and cultivars ‘ChanSiWan’ and ‘TaiLiHong’ were found to have the highest and lowest solubility, separately. The difference could be attributed to the components of raw materials. For instance, cultivar ‘ChanSiWan’ had high content of soluble substances (such as sugar) and relatively low content of insoluble substances (such as pectin), while cultivar ‘TaiLiHong’ possessed the lowest level of sugar and the most abundant pectin. High correlations of sugar and pectin to the solubility of persimmon powder ($r = 0.662$ and -0.716 , $p < 0.01$, respectively) were observed (Fig. 3). Cocoa powder was reported to have favorable dispersible capacity in water mainly due to its high content of sugars (Abdelaziz et al. 2014). As the most abundant sugars in persimmon fruit, glucose and fructose were found to have favorable hydrophilic properties,

Table 3 Processing characteristics of spray dried persimmon powders of five persimmon cultivars

Cultivar	Powder recovery (%)	Moisture (%)	Hygroscopicity (g/100 g)	Solubility (g/100 mL)	C value	Phenolic retention (%)
TLH	$76.62 \pm 0.42a$	$4.52 \pm 0.22a$	$28.89 \pm 0.39ab$	$63.94 \pm 1.51d$	$36.95 \pm 0.70b$	$66.24 \pm 0.37b$
RTH	$68.42 \pm 2.30ab$	$4.89 \pm 0.68a$	$27.92 \pm 0.19b$	$65.75 \pm 0.43c$	$39.43 \pm 0.35a$	$60.31 \pm 1.25c$
CSW	$68.40 \pm 3.75b$	$4.02 \pm 0.40ab$	$25.00 \pm 0.92c$	$71.58 \pm 0.78a$	$27.31 \pm 0.75d$	$69.75 \pm 0.25a$
YJQS	$73.14 \pm 2.80ab$	$3.37 \pm 0.13b$	$29.92 \pm 0.24a$	$69.48 \pm 0.83b$	$35.74 \pm 0.42c$	$70.60 \pm 0.18a$
YS	$72.74 \pm 1.23ab$	$3.27 \pm 0.26b$	$28.82 \pm 0.26ab$	$70.45 \pm 0.31ab$	$21.26 \pm 0.21e$	$70.49 \pm 0.46a$

The data are given as the mean $\pm$ SD ($n = 3$). Mean values in each column with unlike letters are significantly different among cultivars ($p < 0.05$) CSW cultivar ‘ChanSiWan’, RTH cultivar ‘RaoTianHong’, TLH cultivar ‘TaiLiHong’, YJQS cultivar ‘YongJiQingShi’, YS cultivar ‘YueShi’

indicating that the two monosaccharides were the main contributors to the powder solubility of persimmon.

Correlation of total phenolic retention with ascorbic acid

It is well known that persimmon is characterized by rich in polyphenols, which were confirmed to be one of the main phytochemicals for health benefits in consuming persimmon fruit. Therefore, phenolic retention is an important index to evaluate the nutrient retention in fruit processing. Total phenolic retention of the spray dried powders of five cultivars was in range of 60.31 ± 1.25 to 70.60 ± 0.18 % (Table 3). The lowest value was measured in cultivar ‘RaoTianHong’ and the highest was found in cultivar ‘YongJiQingShi’. The loss of phenols is mainly due to the oxidation reaction during the pretreatment (blend or homogenize). Obviously, there was a significant correlation ($r = 0.642$, $p < 0.01$) of the amount of ascorbic acid to phenolic retention (Fig. 3). The presence of ascorbic acid could protect phenolic compounds from oxidation in the process of spray drying, mainly attributed to its potent antioxidant activity (Scartezzini et al. 2006).

Conclusion

The present study indicated that significant differences existed in aroma and taste of selected persimmon cultivars in China. The contents of chemical components such as sugar, total phenol, β -carotene and ascorbic acid in persimmon fruit varied greatly amongst cultivars. In addition, close correlation was found between the chemical components and the processing properties of persimmon fruit. Pectin and total phenol were positively correlated to the viscosity of persimmon pulp, and the colour of persimmon powder was mostly dependent of β -carotene, ascorbic acid and sugar. Pectin and sugar had significant effects on powder recovery, as well as the hygroscopicity and solubility of persimmon powder. A positive correlation of the content of ascorbic acid to phenolic retention was also observed. These findings revealed the chemical compositions affected the processing properties of persimmon fruit greatly. Our results would provide a good guide for the industry processing of persimmon fruit.

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