Quality comparison of dried slices processed from whole persimmons treated with different destringency methods

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Abstract The effects of different destringency treatments (untreated, carbon dioxide, warm water, or ethanol), before drying on the quality characteristics of dried fruit slices prepared from whole “Cheongdobansi” persimmons were evaluated. L* (lightness) and a* (redness) values of dried slices from warm water- and ethanol-treated groups were higher, respectively, compared to that of dried slices from other groups. Hardness was lower in dried slices from ethanol-treated fruits. Moisture, water activity, soluble solids, titratable acidity, and sensory properties (color, aroma, texture, sweetness, and overall acceptability) of the dried slices from astringency-removed fruits were higher when compared to those of the dried slices from non-treated persimmons. In particular, the dried slices from ethanol-treated fruits showed the highest values for these parameters. Moreover, soluble tannin and DPPH radical scavenging activity decreased by destringency treatment. Results suggest that ethanol destringency treatment before drying could be a useful method to improve most quality characteristics, except antioxidative activity, of dried persimmon slices.

Keywords: *Diospyros kaki*, destringency, drying, ethanol, quality

Introduction

Diospyros kaki is mainly cultivated in East Asia. The fruits of *D. kaki* are traditionally considered as healthy foods and divided into two categories, astringent and sweet persimmon, according to the astringency at harvest (1). Astringent persimmons should be treated by destringency methods before consumption; they are commonly processed into dried, soft, and fresh astringency-removed types based on their variety (2). These processed persimmons have a characteristic quality, which is affected by the processing methods. The dried type has a hard texture, high sweetness, and long shelf life, unlike fresh persimmons. Recently, it was shown that consumers prefer the dried type with a softer texture and non-brown color, similar to fresh persimmons (3). Dried persimmons are generally prepared from the peel and/or slices of whole astringent fruits, followed by SO₂ fumigation and drying of the cut fruit (4). SO₂ fumigation treatment, before drying, has been used to prevent browning and has an antimicrobial effect on the cut treated-fruit during processing of dried persimmons (5,6). However, residual amounts of SO₂ in dried fruits are restricted by law owing to the

occurrence of allergies (6). When processing dried persimmons, drying techniques with low drying velocity should be used because of the required periods for astringency removal (4,7). The development of alternatives to chemicals such as SO₂ and improvement of the drying procedure are required for processing dried persimmons. To address this, we assumed that a pretreatment before drying could be applied to persimmons.

Pretreatment before drying is generally required to suppress and minimize chemical reactions and decreases in quality induced by drying. Blanching treatment with boiling water, steam or microwaves, osmotic dehydration, dipping in organic acids such as ascorbic acid or citric acid, sodium chloride solutions, and oleate emulsions have been used as pretreatment methods for various fruits and vegetables (8,9). However, regarding dried persimmons, we have found no reports where drying has been used in combination with these destringency pretreatments.

The physicochemical and physiological changes induced by destringency treatment on intact persimmons depend on the variety of persimmon and destringency methods, which include warm water (10), ethanol (11), and high CO₂ treatments (12). It is

known that the main cause of astringency removal via deastringency treatments is a result of direct reactions between acetaldehydes produced during anaerobic respiration caused by deastringency treatment and soluble tannins, forming insoluble, astringency-removed products (13,14). Ethanol and high CO₂ treatments are commercially used since they are practical and provide better fruit quality when compared with other methods (15). Ethanol-treated astringency-removed persimmons have good flavor and texture; however, they also have characteristics that promote softening and low storability (16). In contrast, astringency-removal by CO₂ treatment results in persimmons with high storability owing to harder flesh but low juice content (16). The effects of deastringency methods on the quality of astringency-removed persimmons have been revealed as mentioned above. However, it is expected that deastringency methods have different effects on the quality of dried products and that the optimum deastringency method will be selected after further research.

This study aimed to develop a pretreatment method for processing high-quality dried products from astringent persimmon fruits and investigate the effects of different deastringency pretreatments (on the whole persimmon) on the drying and quality characteristics of dried persimmon slices.

Materials and Methods

Materials Astringent persimmons (*Diospyros kaki* T. cv. Cheongdobansi) were harvested at commercial maturity from a farm in the Cheongdo region of Korea and graded according to size and defects. Healthy and uniform-sized fruits (120±5 g) were used for the following experiments. Folin-Ciocalteu reagent was from Junsei Chemical Co. (Tokyo, Japan), and catechin and 2,2-diphenyl-1-picrylhydrazyl (DPPH) were from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA). All other chemicals used for analyses were of high purity grade.

Deastringency treatment Astringent persimmons were subjected to deastringency via three different methods. The conditions used for deastringency treatments were obtained from previous studies to achieve effective results (10-12). First, astringent persimmons were treated for 2 days at 20°C in an 80% CO₂ atmosphere in an air-tight glass jar. Second, astringent persimmons were treated for 2 days at 35°C in a water bath. Finally, astringent persimmons were treated for 6 days at 20°C in 35% ethanol vapor in an air-tight glass jar. Untreated astringent persimmons were used as controls.

Preparation of dried slices Astringency-removed persimmons and astringent persimmons were peeled and sliced into four wedges using a sharp stainless steel knife. Fifteen 300-g lots of slices, from each deastringency method, were put into a cabinet-type dryer at 30°C air temperature with a constant airflow rate and dried for 4 days. These drying conditions reflect the conditions commonly used

Fig. 1. Photographs of dried persimmon slices prepared from whole persimmon fruits treated with different deastringency methods. Con, untreated; CD, treated with 80% CO₂ gas for 2 days at 20°C; WW, treated with warm water for 2 days at 35°C; and ET, treated with 35% ethanol for 6 days at 20°C.

for conventional drying of persimmon (7). After drying, the product was immediately packaged in a 0.08-mm thick nylon/polyethylene bag and used for quality analysis. Photographs of dried persimmon slices are shown in Fig. 1.

Measurement of surface color The color properties were measured using a colorimeter (CR-200; Minolta Co., Osaka, Japan) fitted with a CIE illuminant C and 8-mm-diameter measuring aperture, which was calibrated with a standard white plate ($L^*=97.79$, $a^*=0.38$, $b^*=2.05$). The L^* value represents lightness, whereas a^* and b^* values represent redness and yellowness, respectively. The h° value represents the color tone. It is defined as reddish purple: 0°, yellow: 90°, bluish green: 180°, and blue: 270° and calculated as $h^\circ = \tan^{-1}(b/a)$. The C^* value is a measure of color purity or saturation and is calculated as $(a^{*2}+b^{*2})^{1/2}$.

Measurement of hardness The persimmon samples (10 mm in height) were prepared from the equatorial region of the dried products using a sharp stainless steel knife. The hardness of 10 samples from each deastringency method was determined using a rheometer (Compac-100 II; Sun Scientific Co., Ltd., Tokyo, Japan) equipped with a 20-mm-diameter tip. Penetration depth and table speed were 4 mm and 60 mm/min, respectively.

Measurements of moisture and water activity Moisture content of dried persimmon slices was determined by drying at 105°C until insignificant consecutive weight changes were measured. Water activity of the dried persimmon slices was determined at 25°C using a water activity meter (Thermoconstanter, TH200; Novasina, Lachen, Switzerland).

Measurements of soluble solids and titratable acidity The dried persimmon slices (5 g) were homogenized in 10 volumes of deionized water. The homogenate was extracted for 4 h in a shaking water bath and centrifuged, and the supernatant was used for the measurements of soluble solid content and titratable acidity. Soluble solid content was measured using a hand refractometer (Master- α ; ATAGO Co., Ltd., Tokyo, Japan) and expressed in °Bx. Titratable acidity was measured by titrating the diluted supernatant with 0.1 mol/L NaOH to pH 8.2 and expressed as mg equivalent citric acid per 100-g slices.

Measurement of water-soluble tannins Soluble tannin content was measured according to the Folin-Ciocalteu procedure (17). Dried persimmon slices (5 g) were homogenized in 10 volumes of deionized water. The homogenate was extracted for 4 h in a shaking water bath and centrifuged. A portion (1 mL) of the supernatant was then transferred into a test tube. Folin-Ciocalteu reagent (2 mL) was added, and the test-tube contents mixed thoroughly. After 5 min, 2 mL of 10% Na₂CO₃ solution was added and the mixture was incubated for 1 h. The absorbance of the resulting solution was measured using a spectrophotometer (Evolution 201; Thermo Fisher Scientific, Madison, WI, USA) at 640 nm. The soluble tannin content was measured by comparing its absorbance values to those of catechin used at different concentrations as the standard.

Measurement of radical scavenging activity Radical scavenging activity was determined using the DPPH radical (18). A 0.2-mL sample of persimmon slice extract was added to 0.8 mL of 0.4 mmol/L DPPH radical in ethanol. The mixture was shaken vigorously and incubated for 10 min. The absorbance of the resulting solution was measured at 525 nm with a spectrophotometer (Evolution 201; Thermo Fisher Scientific). The radical scavenging activity was calculated using the following formula: DPPH radical scavenging activity (%) = $[1 - (\text{absorbance of sample} / \text{absorbance of DPPH})] \times 100$.

Sensory analysis A sensory test using 20 panels comprising university students was conducted in a room illuminated with a fluorescent lamp. The dried persimmon slices were served to the panels in a random order as three slice samples (based on deastringency methods) on white dishes, each labeled with a 3-digit code. The panels were instructed to cleanse their mouths between samples

using distilled water. The panels evaluated the sensory qualities of the persimmon slices, such as color, aroma, texture, sweetness, and overall acceptability, using a 9-point scale (1=extremely dislike and 9= extremely like).

Statistical analysis All experiments were performed in triplicate, and the data were presented as the mean $\pm$ standard deviation. Differences in effects of deastringency treatments on the quality of the dried fruit slices were assessed using analysis of variance, and mean values were compared using Duncan's multiple range test ($p < 0.05$). All statistical analyses were performed using IBM SPSS statistics software (ver. 20; IBM Corp., Armonk, NY, USA).

Results and Discussion

Comparison of surface color Surface color is the major quality index of dried persimmons and influences consumers' choices (3). Surface color, L*, a*, b*, h°, and C* values of the dried persimmon slices prepared from whole persimmons treated with different deastringency methods are shown in Table 1. Color values were significantly affected ($p < 0.05$) by the specific deastringency treatments. There were significant differences in L* values among deastringency methods. That is, the L* value was significantly higher in the dried slices from intact astringency-removed persimmons treated by warm water compared to that of the other treatment groups. It is well known that the L* value can be used as a suitable index for the evaluation of browning in fruits and vegetables (19). In general, the L* value of dried persimmons tended to decrease during the drying process (20). The L* value might be decreased by enzymatic browning. Enzymatic browning of fruits is known to be a result of oxidation by polyphenol oxidase and peroxidase (21). These L* value results could be explained by the inactivity of polyphenol oxidase and peroxidase induced by warm water treatment (13). From the above results, the browning susceptibility of dried persimmon was found to correlate with the method of pre-drying deastringency treatment. Deastringency treatment using warm water had a significant effect on browning control of dried persimmon slices. There were significant differences in the a* values among dried persimmon slices based on the deastringency method. The a* value

Table 1. Color values of dried slices prepared from persimmon fruits treated with different deastringency methods

Color	Deastringency method ¹⁾			
	Con	CD	WW	ET
L*	53.74 $\pm$ 5.02 ^{b2)}	55.29 $\pm$ 2.78 ^b	63.17 $\pm$ 4.34 ^a	47.97 $\pm$ 4.35 ^c
a*	6.50 $\pm$ 1.38 ^{bc}	5.01 $\pm$ 1.44 ^c	6.73 $\pm$ 1.96 ^b	10.47 $\pm$ 1.23 ^a
b*	24.84 $\pm$ 6.47 ^b	28.43 $\pm$ 3.41 ^b	40.31 $\pm$ 3.55 ^a	24.76 $\pm$ 6.92 ^b
h°	74.47 $\pm$ 5.14 ^b	80.07 $\pm$ 2.49 ^a	80.42 $\pm$ 2.91 ^a	66.27 $\pm$ 4.75 ^c
C*	25.75 $\pm$ 6.27 ^b	28.89 $\pm$ 3.49 ^b	40.92 $\pm$ 3.45 ^a	26.97 $\pm$ 6.66 ^b

¹⁾Con, untreated; CD, treated with 80% CO₂ gas for 2 days at 20°C; WW, treated with warm water for 2 days at 35°C; and ET, treated with 35% ethanol for 6 days at 20°C.

^{2)a-c}Values represent the mean $\pm$ standard deviation (SD) ($n=3$). Means within each row followed by different letters are significantly different at $p < 0.05$.

of dried persimmon slices prepared by ethanol treatment was significantly higher than that of the other groups. This result might be explained by enhanced ripening, including carotenoid biosynthesis, in ethanol-treated fruit (20,22). It was reported that the b^* value of dried persimmons decreased during drying (20). The dried persimmon slices from astringency-removed fruits prepared using warm water had a higher b^* value compared to that of other groups. There were no significant differences in the b^* values among dried fruit treated with other deastringency methods compared to that of the untreated control. The C^* value of the dried persimmon slices was affected by the deastringency method in a similar manner to that of the b^* value. The h^o value of dried persimmon slices from astringency-removed fruits prepared by ethanol was significantly lower than those values of dried persimmon slices prepared by other methods. These results suggest that decreases in lightness, yellowness, and chroma in dried persimmon slices were retarded by pre-drying deastringency with warm water, and an increase in redness level was accelerated by pre-drying deastringency with ethanol.

Comparison of hardness Hardness was suggested as an index for quality grading in dried persimmon (3). The hardness of dried persimmon slices prepared from astringency-removed and untreated fruits is presented in Fig. 2. The hardness of the dried persimmon slices was significantly affected ($p<0.05$) by the deastringency method. The hardness of dried persimmon slices from ethanol-treated fruit was significantly lower than that of other groups. The hardness of dried persimmon slices from untreated fruits was significantly higher than that of other groups. This difference in hardness as affected by deastringency treatment was similar to the differences in moisture content (Table 2). It was also reported that hardness decreased and then increased owing to softening and moisture loss during drying (23,24). The results suggest that the hardness of dried persimmon slices was affected by deastringency treatment before drying and that ethanol treatment could be used as a method to obtain soft texture of dried persimmon slices.

Comparison of moisture content and water activity The moisture content and water activity are considered indices of quality control for dried food processing and preservation. Moisture content and water activity of dried persimmon slices processed from astringency-

Fig. 2. Hardness of dried slices prepared from persimmon fruits treated with different deastringency methods. Values represent the mean $\pm$ standard deviation (SD) ($n=3$). Means with different letters above the bar are significantly different at $p<0.05$. Con, untreated; CD, treated with 80% CO₂ gas for 2 days at 20°C; WW, treated with warm water for 2 days at 35°C; and ET, treated with 35% ethanol for 6 days at 20°C.

removed and untreated fruits are presented in Table 2. Both characteristics were significantly affected ($p<0.05$) by the deastringency method used before drying. Moisture content and water activity of dried persimmon slices from the astringency-removed fruits were significantly higher than those of dried slices from astringent fruit. Both characteristics were highest in ethanol-treated dried persimmon slices, followed by CO₂- and warm water-treated fruit. There were no significant differences in the moisture content and water activity between CO₂- and warm water-treated fruits. In persimmons, it is well known that moisture content and water activity are decreased by drying treatments, and the rate at which these parameters decrease, referred to as the drying rate, depends on various drying conditions (4,23). In this study, it was determined that deastringency treatment before drying caused a decrease in the drying rate of persimmons. In particular, this effect was highest with ethanol treatment. These results may be related to structural changes induced by deastringency treatments in persimmon tissue.

Table 2. Moisture content, water activity, soluble solids, and titratable acidity of dried slices prepared from persimmon fruits treated with different deastringency methods

Characteristics	Deastringency method ¹⁾			
	Con	CD	WW	ET
Moisture (g/100 g)	20.61 $\pm$ 0.61 ²⁾	23.2 $\pm$ 0.72 ^b	23.19 $\pm$ 0.14 ^b	26.08 $\pm$ 1.37 ^a
Water activity	0.611 $\pm$ 0.01 ^c	0.632 $\pm$ 0.01 ^b	0.627 $\pm$ 0.01 ^b	0.653 $\pm$ 0.02 ^a
Soluble solids ($^{\circ}$ Bx)	54.00 $\pm$ 2.00 ^b	59.33 $\pm$ 3.05 ^{ab}	59.33 $\pm$ 3.05 ^{ab}	64.00 $\pm$ 4.00 ^a
Titratable acidity (mg/100 g)	314.00 $\pm$ 13.00 ^c	507.00 $\pm$ 58.00 ^{ab}	477.00 $\pm$ 59.00 ^b	594.00 $\pm$ 49.00 ^a

¹⁾Con, untreated; CD, treated with 80% CO₂ gas for 2 days at 20°C; WW, treated with warm water for 2 days at 35°C; ET, treated with 35% ethanol for 6 days at 20°C.

^{2)a-c}Values represent the mean $\pm$ standard deviation (SD) ($n=3$). Means within each row followed by different letters are significantly different at $p<0.05$.

Comparison of soluble solids and titratable acidity Soluble solid content is an approximate measure of sugar content in fruit. Titratable acidity is a quantitative measure of organic acids present in fruit. Soluble solid content and titratable acidity of the dried slices processed from astringency-removed and untreated persimmons are presented in Table 2. Soluble solid content and titratable acidity were significantly affected ($p<0.05$) by the deastringency method. Soluble solid content of dried persimmon slices from the astringency-removed fruit was significantly higher than that of dried slices from astringent fruit. Among the treatment groups of dried persimmon slices from astringency-removed fruits, soluble solids were significantly higher in ethanol-treated slices compared to CO₂- or warm water-treated slices. It has been found that the soluble solid content of persimmons is decreased by deastringency treatment (15,25) and increased by drying treatment (4,23). The decrease in soluble solids by deastringency treatment could be due to the decrease in soluble tannin content (1). The increase in soluble solids by drying might be due to decrease in moisture content (7). In this study, higher soluble solids in dried persimmon slices from astringency-removed fruits processed by ethanol treatment could be related to an increase in ripening. Titratable acidity in dried persimmon slices prepared from ethanol-treated fruits was highest, followed by that prepared from CO₂-treated, warm water-treated, and untreated fruits. In general, the titratable acidity of persimmons was decreased by deastringency treatment (15,25). These results suggest that soluble solids and titratable acidity of dried persimmon slices can be increased by deastringency treatment with ethanol before drying.

Comparison of soluble tannins and DPPH Tannins are closely associated with astringency and enzymatic browning of persimmons (26,27). Water-soluble tannins of dried persimmon slices processed from astringency-removed and untreated fruits are shown in Fig. 3. The content of soluble tannin in the dried slices was significantly affected ($p<0.05$) by deastringency treatment. The soluble tannin content of dried persimmon slices from untreated fruit was significantly higher than that of dried slices prepared from astringency-removed persimmons. However, there were no significant differences in soluble tannins among the three deastringency methods. It is well known that soluble tannins was decreased by deastringency and drying treatments (4,10-12). These results suggest that the decrease in soluble tannins in dried persimmon slices by deastringency and drying was not affected by deastringency methods used in this study. DPPH radical scavenging activity was investigated to measure the antioxidant ability of dried persimmon slices. DPPH radical scavenging activities of dried persimmon slices processed from the astringency-removed and untreated fruits are shown in Fig. 3. The level of DPPH radical scavenging activity in dried slices was significantly affected ($p<0.05$) by the deastringency treatments. DPPH radical scavenging activity of dried persimmon slices from untreated fruits was significantly higher than that of dried slices from astringency-removed fruits. This difference was similar to what was

Fig. 3. Water-soluble tannins and DPPH radical scavenging activity of dried slices prepared from persimmon fruits treated with different deastringency methods. Values represent the mean $\pm$ standard deviation (SD) ($n=3$). Means with different letters above the bar are significantly different at $p<0.05$. Con, untreated; CD, treated with 80% CO₂ gas for 2 days at 20°C; WW, treated with warm water for 2 days at 35°C; and ET, treated with 35% ethanol for 6 days at 20°C.

observed for the soluble tannin content (Fig. 3). It was previously reported that DPPH radical scavenging activity and the content of total polyphenols were highly correlated in persimmons during drying and this activity was decreased by deastringency and drying treatments (28). Results herein suggest that the DPPH radical scavenging activity of dried persimmon slices prepared from astringency-removed fruits was not affected by the deastringency method.

Comparison of sensory characteristics The quality-related sensory characteristics, such as color, aroma, texture, sweetness, and overall acceptability, of dried persimmon slices processed from the astringency-removed and untreated fruits are shown in Table 3. All sensory characteristics of dried persimmon slices were significantly affected ($p<0.05$) by the deastringency methods. Sensory color was significantly better in dried persimmon slices pre-treated with ethanol and was significantly worse with CO₂ pre-treatment as compared to that with other methods. The high color score in ethanol-treated persimmon slices may be explained by the redness

Table 3. Sensory characteristics of dried slices prepared from persimmon fruits treated with different deastringency methods

Sensory characteristics	Deastringency method ¹⁾			
	Con	CD	WW	ET
Color	5.73±1.19 ^{b2)}	2.91±1.04 ^c	5.36±1.69 ^b	7.36±1.43 ^a
Aroma	4.91±2.11 ^{ab}	4.18±1.54 ^b	5.72±1.62 ^{ab}	6.00±1.84 ^a
Texture	3.18±1.94 ^b	4.36±1.74 ^b	4.00±1.48 ^b	6.82±1.40 ^a
Sweetness	4.36±1.50 ^b	5.45±1.37 ^b	4.45±1.37 ^b	7.27±1.10 ^a
Overall acceptability	3.64±1.86 ^c	5.00±1.26 ^b	5.18±1.25 ^b	7.64±1.03 ^a

¹⁾Con, untreated; CD, treated with 80% CO₂ gas for 2 days at 20°C; WW, treated with warm water for 2 days at 35°C; and ET, treated with 35% ethanol for 6 days at 20°C.

^{2)a-c}Values represent the mean±standard deviation (SD) (n=20). Means within each row followed by different letters are significantly different at *p*<0.05.

of these slices (Table 1). The lowest color score of CO₂-treated persimmon slices could be explained by black spots that developed in the flesh of persimmons (Fig. 1). The aroma, texture, and sweetness scores of ethanol-treated persimmon slices were significantly higher in comparison with those of persimmons treated with other methods. The persimmon slices from fruit treated with ethanol showed a significantly higher score in terms of overall acceptability. This result might be explained by the high color, aroma, texture, and sweetness scores in ethanol-treated persimmon slices. Therefore, the results suggest that overall sensory acceptability of dried persimmons could increase by deastringency treatment using ethanol.

In conclusion, deastringency treatments before drying affected the drying rate and quality characteristics of dried persimmon slices. Lightness of the dried persimmon slices was higher in warm water-treated samples than in other groups. Hardness of dried persimmon slices decreased by deastringency treatment using ethanol. Surface redness, moisture content, water activity, soluble solids, titratable acidity, and sensory acceptability (color, aroma, texture, and sweetness) of dried persimmon slices were all increased by the deastringency treatment using ethanol. It was also shown that warm water treatment for deastringency could retard the browning of persimmon slices. The use of ethanol treatment could decrease the drying rate of persimmon slices; however, it was also shown to enhance the red color, soft texture, and sweet taste of dried persimmon slices from astringency-removed fruit. Therefore, deastringency pre-treatments, such as those investigated in this study, could be an interesting alternative to the use of chemicals.

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