EXTENDING SHELF LIFE OF FRESH-CUT PERSIMMON BY HONEY SOLUTION DIPS

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Accepted for Publication March 28, 2008

ABSTRACT

*Ripe persimmon fruit (*Diospyros kaki *L) cv. "Hachiya" were diced, then treated with 10–20% w/v diluted honey solution or water as the control, followed by cold storage at 4C until loss of acceptable quality. The persimmon cubes were subject to assessments during the storage of organoleptic and visual quality, softness and exuding juice, soluble solids content (SSC), and absorbance at 436, 440, 675 and 760 nm, respectively. Honey treatments prevented off-aroma development and delayed jelling. Softness and exuding juice of the fresh-cut persimmon cubes increased with time, with the increase in both parameters being significantly suppressed by honey solution dips. Changes in SSC, pH and the absorbance at 436, 440, 675 and 760 nm, respectively, during storage were minor and there was little effect of the honey treatments on these parameters. Overall, the shelf life of fresh-cut persimmon cubes was extended by honey solution dips, which delayed off-aroma development, firmness loss and jelling.*

PRACTICAL APPLICATIONS

New products and changing trends make today's food marketplace alive, and fresh-cut fruits and vegetables seem to be on top of list of these products. Although fresh-cut produce has been on the market for a long time, preserving their quality attributes has not been completely successful especially in the case of fruit. This study focuses on a new alternative fresh-cut produce, fresh-cut persimmon, with adapting a potentially safe organic method, use of

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Journal of Food Processing and Preservation **34** (2010) 2–14.
DOI: 10.1111/j.1745-4549.2008.00243.x

honey dips. The present study demonstrated that honey solution dip treatments could preserve the fresh-like quality of typical flavor or aroma of persimmon fruit by causing no changes in aroma and taste attributes and extending shelf life. Therefore, honey dip treatment may be used, depending on commodity, to preserve and extend shelf life of fresh-cut produce in fresh-cut processing industry.

INTRODUCTION

The persimmon (*Diospyros kaki*) is a member of the Ebenaceae family and believed to be native to China. Persimmon has been grown in China since the prehistoric period (Yonemori *et al.* 2000). The plant is now also widely cultivated in Italy, Brazil, Israel, Spain, U.S.A., Australia and New Zealand. Persimmons are broadly classified into two groups, nonastringent and astringent varieties. Astringency is caused by soluble tannins that decrease in the course of ripening. Persimmon fruit has a tough, glossy, orange-reddish skin, and a sweet, juicy and yellow-orange flesh when ripe. The persimmon fruit is rich in nutrients like vitamin C (0.7 mg/g of pulp) and pro-vitamin A (0.65 mg/g of pulp), and a good source of calcium (0.09 mg/g of pulp) and iron (0.002 mg/g of pulp) (Tous and Ferguson 1996). Furthermore, the fruit is a good source of carotenoids, which may have a role in cancer prevention by acting as free radical scavengers or antioxidants (Tee 1992), in preventing cardiovascular diseases (Gaziona and Hennekens 1993), and in treating chronic diseases, such as photosensitivity diseases (Matthews-Roth 1993). The persimmon fruit is mainly consumed fresh but it can also be frozen, canned or dried.

Convenience foods like cut fruits and premixed salads also known as lightly processed or fresh-cut are growing in popularity (Garret 2002). Fresh-cut produce has relatively short shelf life compared to their intact counterparts, and the fresh-cut persimmon fruit is no exception. The persimmon fruit reaches its best quality at the end of the preclimacteric stage, where the fruit has maximum sugar content and an appealing orange color (Harima *et al.* 2003). However, as soon as the climacteric stage starts, the fruit softens rapidly within a couple of days (Harima *et al.* 2003). Consequently, the shelf life of ripe persimmon fruit is limited to a few days. Few studies have been carried out to date on the fresh-cut persimmon fruit (controlled atmosphere storage; Wright and Kader 1997a,b). Wright and Kader (1997b) found that gas treatments containing 12% CO_2 increased the shelf life of sliced persimmon fruit by delaying appearance of black areas on the cut surfaces.

Honey has been used as a sweetening agent in food since ancient times due to its distinctive flavor. Beyond its unique flavor and high sugar content, honey contains a number of components that act as preservatives. These

compounds include α-tocopherol, ascorbic acid, flavonoids, other phenolics, and enzymes (Crane 1975; Ferreres *et al.* 1993). Many of these substances have antioxidant activity that make them preservatives (Chen *et al.* 2000). Honey has been investigated as an antibrowning agent in raisins (10% and 20% honey solution; McLellan *et al.* 1995), grape juice (Lee 1996) and fresh-cut apple (10% honey solution; Jeon and Zhao 2005). Furthermore, honey prevents enzymatic browning of fruit and vegetable homogenates (Chen *et al.* 2000), and of fresh-cut apples (Jeon and Zhao 2005).

Honey treatment may, therefore, be a method of extending the shelf life of fresh-cut persimmon fruit. Fresh-cut persimmon fruit with longer shelf life could appeal to more customers and increase fresh consumption of persimmon fruits. The objective of this study was, therefore, to characterize the shelf life of the fresh-cut persimmon fruit cubes pretreated with honey and held at the temperature for minimally processed products of 4C.

MATERIALS AND METHODS

Fruit Material and Handling

"Hachiya" – an astringent variety persimmon fruit – was obtained from a farmer market, at Kahramanmaras, Turkey. Fruit with glossy skin, and dark-yellow, and soft flesh, typical characteristics of ripe "Hachiya" persimmon, were used in the present experiment. After selection of defect-free fruit and rejection of overripe and unripe fruit, they were washed with tap water, dipped in household bleach solution (200 ppm) for 2 min and then dried. All tools and equipment were sanitized with household bleach solution (150 ppm) prior to fresh-cut processing. Both blossom and pedicel ends including the calyx of each fruit were removed with a sharp knife and then cut longitudinally to make two slices of 2–2.5 cm in thickness. The slices were cut into cubes, with approximate dimension of 2–2.5 × 2–2.5 × 2–2.5 cm^3 and weight of 10–15 g (Fig. 1). During the cutting process, fruit with internal defects were discarded. The excised cubes were divided into three uniform batches for treatments.

Treatments

Honey (Balkasik®, Istanbul) was obtained from a local market. The desired concentration of honey was attained by using sterilized tap water (121C for 15 min) with stirring for 20 min at room temperature. The first batch of cubes was dipped into 10% diluted honey solution, the second batch into 20% diluted honey solution, and the third batch into water (the control), each for 5 min. The 10% diluted solution was chosen due to a previous honey dip related work (McLellan *et al.* 1995) and the 20% diluted solution due to

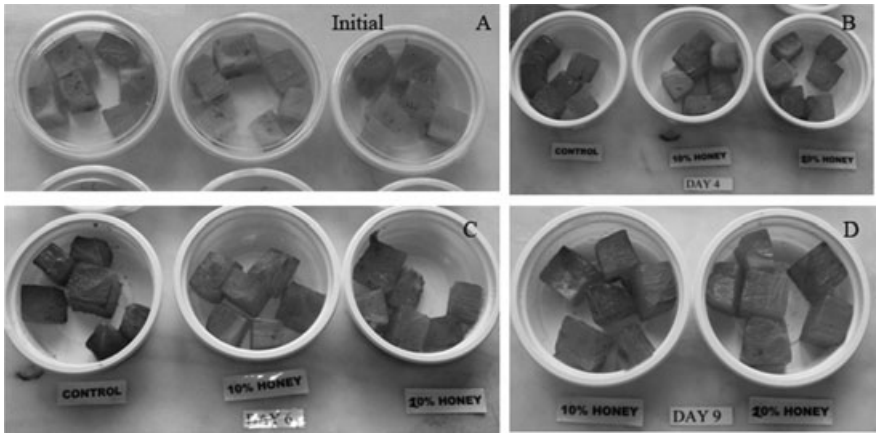

FIG. 1. IMAGES OF PERSIMMON CUBES TREATED WITH 10%, 20% DILUTED HONEY SOLUTION OR WATER AS CONTROL AND THEN STORED AT 4C FOR (A) 0, (B) 4, (C) 6 and (D) 9 days.

similarity with soluble solids content (SSC) of persimmons used the present study. The cubes were removed from the water or diluted honey solution using a plastic strainer and then drained by shaking the strainer that was half-filled with cubes. Afterwards, six cubes per replication were placed in non-airtight plastic containers and stored in a 4C room. The volume of each plastic container (102–130, Huhtamaki Istanbul, Ambalaj San. A.Ş.) with white colored and noncolored lid was 130 mL (Fig. 1).

Experimental Design

There were three treatments in the experiment: control, 10% and 20% diluted honey solution. The experiment was Randomized Complete Block Design with six replications and each container (total 180 containers) with six cubes (subsample) represented a replication. The containers were kept at 4C until cubes from each treatment lost their firmness. Six containers (three for organoleptic and visual quality, and three for softness, exuding juice, SSC and pH) for each treatment were removed daily for analysis. Additionally, 50 intact fruits were stored at the same temperature and five of them were removed daily to compare to the cubes after dicing.

Organoleptic and Visual Quality

Jelling on the upper surface of fresh-cut cubes was rated by the same person under a fluorescent light according to the following hedonic scale

(MacRae 1987): 0 = none; 1 = slight (less than 25%); 2 = moderate (around 50%); 3 = severe (around 75%); 4 = all over and 5 = dark. Afterwards, descriptive analyses were performed for off-aroma and off-flavor at room temperature by laboratory personnel and students who had received some basic training before evaluations. The evaluations were made of at least three cubes in each container by a different panelist using a quantitative descriptive analysis: first off-aroma and next taste evaluation. In each treatment (total of three treatments), 18 total (3×6) cubes were available for the member panel for each session. When a panelist rated more than one for the same sample, the mean was taken to reduce complexity of analyses. Ratings for both off-aroma and off-flavor were based on a hedonic scale described by Taira *et al.* (1997) with a slight modification: 0 = none, 1 = little, 2 = some, 3 = moderate and 4 = very.

Softness and Exuding Juice

Softness and exuding juice were measured by the same person using his index finger and thumb to gently squeeze as described by Woolf *et al.* (1997). Ratings were based on a hedonic scale, where 0 = none, 1 = little, 2 = some, 3 = moderate, and 4 = very.

SSC and pH

The juice used for SSC and pH was extracted from cubes with a fruit juice extractor (Premier, PR-603, Hong Kong). SSC was measured using a hand-held refractometer (Atago NI, Japan) and pH using a pH meter (WTW 526, Germany). The remaining juice was frozen at −20C for further analysis.

Juice Absorbance

The frozen juice was thawed at room temperatures and then diluted with water (1:4) followed by a centrifugation (Hettich, Universal 16A) at 2,500 g for 5 min. Color differences in supernatants were recorded using on a spectrophotometer (Spectramax Plus 384) at 436 nm (carotene; Schwartz and Maria Patroni-Killam 1985), 440 nm (browning metabolites; Brandelli and Lopes 2005), and 675 (total phenol content; Parka *et al.* 2006) or 760 nm (total phenol content; Suzuki *et al.* 2005).

Statistical Analysis

SAS (version 8.1, SAS Institute Inc., Cary, NC) software was used to perform analyses of variance (general linear model) and Duncan Mean Comparison Tests. The mean of cubes per container was taken to reduce the complexity of analyses.

RESULTS

Organoleptic Evaluation and Jelling

The sensory off-aroma score among treatments did not differ statistically by day 5, ranging from 0 to 1. Thereafter, the control scored higher values (2–3) than the honey treatments (0–1; Table 1). The highest off-aroma value recorded for honey treatments was 1, which was rated only on days 8 and 9. The off-aroma was a sharp rot-like scent. No panelist recorded any off-flavor for any treatments at any time during the storage (data not shown). Jelling did not differ significantly among the treatments by day 5, with changing progressively from 0 to 4 (Table 1). Thereafter, the control showed a higher degree of jelling (4–5) than the honey treatments (Fig. 1). The honey treatments eventually reached the highest score (degree) of jelling (5) on days 8 and 9. However, the control reached these levels 2 days earlier (on day 6) than the honey treatments did.

Softness and Exuding Juice

The softness score for all three treatments increased with time. The increase was higher in the control, starting from day 2 (Table 2). The control

TABLE 1.
SENSORY OFF-AROMA SCORES AND JELLING OF FRESH-CUT PERSIMMON CUBES TREATED WITH 10%, 20% DILUTED HONEY SOLUTION OR WATER AS CONTROL AND THEN STORED AT 4C

Day	Off-aroma*			Jelling†		
	Control	Honey (10%)	Honey (20%)	Control	Honey (10%)	Honey (20%)
1	0.33a‡	0.33a	0.33a	0.00a	0.00a	0.00a
2	0.33a	0.33a	0.33a	1.67a	0.67a	0.67a
3	0.67a	0.00a	0.00a	3.67a	3.67a	2.33a
4	1.00a	0.00a	0.33a	3.33a	3.33a	3.00a
5	0.66a	0.00a	0.33a	3.33a	3.33a	3.00a
6	2.50a§	0.00b	0.67b	5.00a§	3.00b	3.67b
7	2.00a	0.00b	0.67b	4.67a	3.33b	3.67b
8	–	0.67a	1.00a	–	4.33a	5.00a
9	–	0.67a	0.67a	–	4.67a	4.67a

* Off-aroma was evaluated based on a 5-point hedonic scale: 0 = none, 1 = little, 2 = some, 3 = moderate and 4 = very.

† Jelling was evaluated based on a 6-point scale: 0 = none, 1 = slight (less than 25%), 2 = moderate (around 50%), 3 = severe (around 75%), 4 = all over and 5 = dark.

‡ Means with different letters within rows are significantly different according to Duncan's multiple range test ($P < 0.05$).

§ The dash horizontal lines indicate the end of shelf life.

TABLE 2.
SCORES FOR SOFTNESS AND EXUDING JUICE OF FRESH-CUT PERSIMMON CUBES TREATED WITH 10%, 20% DILUTED HONEY SOLUTION OR WATER AS CONTROL AND THEN STORED AT 4C

Day	Softness*			Exuding juice*		
	Control	Honey (10%)	Honey (20%)	Control	Honey (10%)	Honey (20%)
1	0.67a†	0.33a	0.33a	0.00a	0.00a	0.00a
2	2.33a	0.33b	0.33b	1.00a	0.00b	0.00b
3	2.33a	0.33b	0.33b	1.33a	0.00b	0.00b
4	2.33a	0.67b	1.00b	1.00a	0.33a	0.33a
5	2.67a	0.67b	1.00b	1.00a	0.33a	0.33a
6	3.33a‡	1.67b	1.67b	2.00a‡	0.33b	0.67b
7	4.00a	2.67b	3.00b	2.00a	1.00b	1.00b
8	–	2.67a‡	3.33a‡	–	1.33a‡	1.67a‡
9	–	4.00a	4.00a	–	1.67a	1.33a

* Softness and exuding juice were evaluated based on a 5-point hedonic scale: 0 = none, 1 = little, 2 = some, 3 = moderate and 4 = very.

† Means with the different letters within rows are significantly different according to Duncan's multiple range test ($P < 0.05$).

‡ The dash horizontal lines indicate the end of shelf life.

cubes showed a none (0) to moderate (3) softening levels during first 6 days of the storage whereas the honey treated cubes showed the same levels during first 8 days of the storage, indicating the time range of the same softening levels in the honey treated cubes was 2 days more than in the control cubes. The control cubes reached the very softening stage by day 7 while the honey treated cubes by day 9. The control cubes on day 7 and the honey treated cubes on day 9 were unacceptable to the panelists regardless of their taste and aroma. Thus, the shelf life of the control cubes was limited to 6 days and of honey treated cubes to 8 days. Exuding juice measured by the gentle squeeze technique increased with time in parallel to the increase softness (Table 2). The increase of exuding juice in the control started on day 2 while in the honey treatments on day 4. The control showed a statistically higher degree of exuding juice compared to the honey treatments during most of the storage period. When the honey treated cubes started to become juicy on day 4, the statistical differences among the treatments disappeared until day 5 and then reappeared.

SSC and pH

The initial SSC ranged from 20 to 22.8%. After the treatments were imposed, SSC was 18.7% in the control, 19.7% in the 10% honey treatment

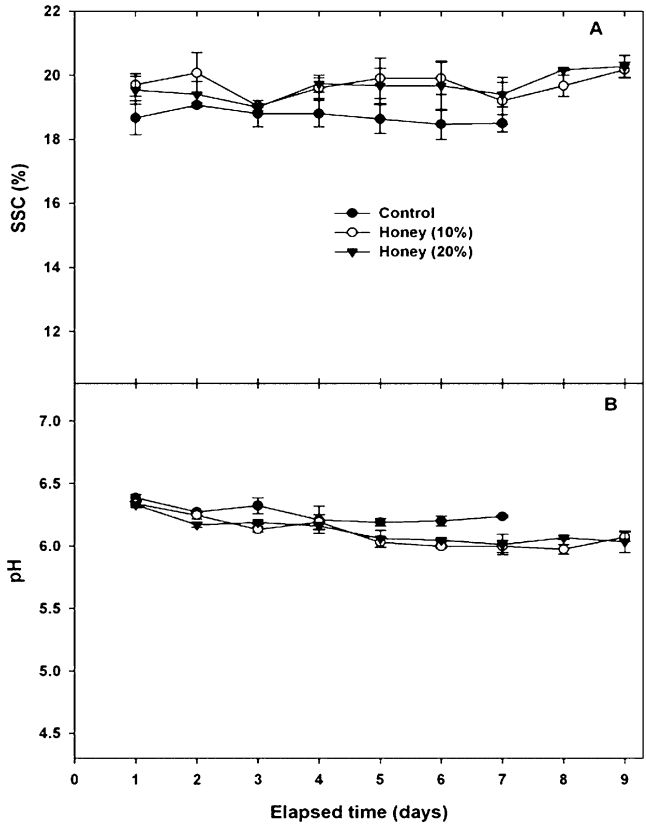

FIG. 2. JUICE FROM PERSIMMON CUBES TREATED WITH 10%, 20% DILUTED HONEY SOLUTION OR WATER AS CONTROL AND THEN STORED AT 4C
(A) Soluble solids content and (B) pH values of juice. Error bars indicate the standard error.

and 19.6% in the 20% honey treatment. SSC values of all three treatments seemed to fluctuate slightly during storage. However, SSC values were very close to the day 2 values when the experiment was terminated (Fig. 2A). No statistical differences were recorded among the treatments.

Before execution of treatments, pH values of persimmon fruit ranged from 6.04 to 6.11. Thereafter, they changed to approximately 6.33 in all three treatments by the first day of the experiment. Thereafter, pH values decreased slightly by the end of the storage period compared to the day 2 values (Fig. 2B). The decrease for the control was, however, lower compared to the honey treatments, resulting in a significant difference between the control and the two honey treatments from day 5 through 7.

TABLE 3.
ABSORBANCE OF JUICE FROM THE PERSIMMON CUBES TREATED WITH 10%, 20% DILUTED HONEY SOLUTION OR WATER AS CONTROL AT 436 NM (CAROTENE), 440 NM (BROWNING METABOLITES), AND 675 OR 760 NM (TOTAL PHENOL CONTENT)

Day	436 nm			440 nm		
	Control	Honey (10%)	Honey (20%)	Control	Honey (10%)	Honey (20%)
3	0.21a*	0.19a	0.17a	0.21a	0.19a	0.17a
5	0.13a	0.11a	0.22a	0.13a	0.11a	0.22a
7	0.17a	0.14a	0.21a	0.17a	0.14a	0.20a
9	–	0.21a	0.22a	–	0.21a	0.22a
	675 nm			760 nm		
3	0.06a	0.06a	0.06a	0.05a	0.05a	0.06a
5	0.04a	0.04a	0.07a	0.04a	0.04a	0.06a
7	0.05a	0.04a	0.06a	0.04a	0.04a	0.05a
9	–	0.07a	0.07a	–	0.06a	0.06a

* Means with different letters within rows are significantly different according to Duncan's multiple range test ($P < 0.05$).

Juice Absorbance

The absorbance of juice of the control and of the 10% honey treatment at 436 and 440 decreased through day 5, and then increased. In contrast, absorbance of the 20% honey treatment increased through day 5, then they were almost stable (Table 3). The control showed slight declines in the absorbance at 675 and 760 nm with time. However, the 10% honey treatment absorbance increased at the end of the storage period compared to the day 3 values. Also, absorbance for the 20% honey treatment almost remained unchanged in the course of the storage. However, none of the treatments showed any significant differences in wavelength due to these diminutive changes.

DISCUSSION

Honey treatments suppressed off-aroma development in fresh-cut persimmon cubes at 4C. Panelists gave the highest off-aroma values (2 = some to 3 = moderate) to the control on days 6 and 7 while they never rated the honey treatments over 1 (none) during the storage period of 9 days. Deterring off-aroma development by honey could be due to some compounds acting as preservatives, such as α-tocopherol, ascorbic acid, flavonoids, other phenolics and enzymes (Crane 1975; Ferreres *et al.* 1993). Neither persimmon cubes

treated with nor those without honey treatments showed signs of off-flavor development. This absence of differences might be attributed to termination of assessments when cubes softened completely.

Jelling is an accepted indication of overripening and/or chilling injury (MacRae 1987). In the present study, jelling increased with time irrespective of the treatments. However, the increase in control cubes was faster compared to honey treatments, indicating that honey might delay overripening and/or development of chilling injury symptoms. The control showed the highest degree of jelling (5, dark) on day 6 whereas the honey treatments only reached such high score on days 8 and 9. Grant *et al.* (1992) reported that the development of the chilling injury involves solubilization of cell wall materials and the release of large molecular mass polyuronides from the cell wall without degradation. Besides delaying jelling, honey treatments also delayed the firmness loss. Thus, honey solution dip may deter further cell wall modifications in persimmon.

Wright and Kader (1997b) working with sliced persimmon fruit (Fuyu) reported black areas on cut surfaces as causing a decrease in shelf life. They partially overcome this problem by applying 12% CO_2. This type of discoloration was not observed in the present study and might be due to cultivar differences.

Intact persimmon fruit soften very quickly once the climacteric phase starts, resulting in poor quality fruit with jelly like flesh within a few days (Harima *et al.* 2003). In the present experiment, softness of the persimmon cubes in all three treatments increased with time. However, honey treatment retarded firmness loss compared to the control. Compounds in honey acting as preservatives (e.g., antioxidants) might be responsible for the delay of the softening process in the persimmon cubes.

SSC of the persimmon cubes fluctuated with time but showed no differences among the treatments. Thus, neither the honey treatments nor the 4C storage affected soluble solids. The persimmon cubes showed a slight decline in the pH values irrespective of treatments. The attenuation was slightly lower in the control cubes relative to the honey treated cubes but the magnitude was very small. The largest differences between the control and the honey treatments was under 4% recorded at day 7 when the control was pH 6.24 and the 20% honey treatment was pH 6.01.

The absorbance of the juice extracted from the persimmon cubes at 436 (carotenes) and 440 nm (browning metabolites) showed similar patterns. The control and 10% honey treatment values first decreased and then increased. In contrast, the 20% treatment values first increased and then stabilized at around 0.21. The control cubes showed a slight decline in absorbance of 675 and 760 nm (total phenol content) with time as well. The corresponding 10% honey treatment values increased at the end of the storage period compared to

the day 3 values, which the 20% honey treatment values were almost steady. Since changes in absorbance at 440 nm paralleled those at 436, the small changes in carotene content which were not affected by the honey treatments. Wavelengths for total phenol content did not show either significant change over time or variations among treatments. The 4C storage condition may prevent accumulation of phenolic compounds irrespective of honey treatments.

Fresh-cut processing requiring steps such as peeling, scrubbing, slicing, etc., causes produce to bruise, desiccate and wilt. These steps expose internal tissues to microorganisms and harmful enzymes, which are reasons for increase in respiration and ethylene production, accelerated senescence, enzymatic browning, etc. (Rosen and Kader 1989). Conventional types of fruit and vegetable processing, such as canning, prevent and/or control many of these problems by heating, packaging or through the application of various additives (Garcia and Barrett 2002). In the fresh-cut processing, such applications are avoided to preserve the fresh-like quality. In the present study, honey solution dip treatments preserved the fresh-like quality of typical flavor or aroma of persimmon fruit by causing no changes in aroma and taste attributes and extending shelf life. Therefore, honey dip treatment may be used, depending on commodity, to preserve and extend shelf life of fresh-cut produce.

In conclusion, honey solution dip can extend the shelf life of fresh-cut persimmon fruit by delaying off-aroma development, firmness loss and jelling. Thus, it is concluded that 10 or 20% honey solution dips can be used as a postharvest application to fresh-cut persimmon fruit at approximately 20% SSC.

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