Inhibition of Astringency Removal in Semidried Japanese Persimmon Fruit by 1-methylcyclopropene Treatment

Toshikazu Matsumoto, Hajime Matsuzaki, Kou Takata,
Yoko Tsurunaga, Hiroyasu Takahashi, and Takao Kurahashi

Shimane Agricultural Technology Center, Ashiwata 2440, Izumo, Shimane,
693-0035, Japan

Shinya Maki¹ and Kazushi Fujiwara

Niihama National College of Technology, Yagumo 7-1, Niihama, Ehime,
792-8580, Japan

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Abstract. The inhibition of astringency removal on semidried persimmon fruit treated with 1-methylcyclopropene (1-MCP) was investigated. The rate at which soluble tannin decreased in 1-MCP-treated semidried fruit was less than control fruit, the soluble tannin concentration in dried flesh of 1-MCP-treated fruit was more than 150 mg·100 g⁻¹ on a fresh weight (FW) basis and, with sulfur treatment, reached 270 mg·100g⁻¹ FW [which exceeds the concentration of tannins required to detect astringency (Inari and Takeuchi, 2001)], and the degree of inhibition for astringency removal in semidried fruit was different among cultivars. It is suggested that these phenomena occur by the inhibition of ethylene action for fruit softening by 1-MCP treatment.

Semidried persimmon (*Diospyros kaki* Thunb.) is becoming a popular new type of processed fruit (Fig. 1) in Japan that is highly sought after and exported to Taipei, China. However, the procedure used for processing has some inherent problems, which include long work hours for processing and a decreased market value resulting from overproduction and the lack of efficient long-term storage (Kurahashi et al., 2005). By evenly distributing production and providing longer storage conditions for material fruit (at least 1 to 2 months), these products can yield much higher market prices. However, ‘Saijo’ persimmon fruit softens easily and is difficult to preserve by refrigeration more than 2 weeks after harvesting. A more effective method for material fruit storage of semidried fruit of ‘Saijo’ persimmon using this approach is needed. Recently, a new technology based on 1-methylcyclopropene (1-MCP), an inhibitor of ethylene perception, has become available to horticultural industries around the world. 1-MCP can delay ripening and senescence processes in many fruit and vegetables (Watkins, 2006). The effect of 1-MCP treatment for prolonging the shelf life for many types of fruits and vegetables was reported (Blankenship and Dole, 2003; Watkins, 2006). In persimmon fruit, an effect of 1-MCP was reported by Nakano et al. (2001) and Kurahashi et al. (2005). Although 1-MCP may appear advantageous for preservation of horticultural crops, no research on the effects of 1-MCP on

subsequent drying processing of fruit has been reported. In this study, the inhibition of astringency removal during the processing of semidried fruit treated by 1-MCP is reported.

Materials and Methods

Mature ‘Saijo’ fruits were harvested in the orchard of Shimane Agricultural Exper-

iment Station on 15 Oct. 2005. The fruit were preclimacteric with ethylene production of $\approx 0.01 \mu\text{L}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$ and average firmness of $2.03 \text{ kg}\cdot\text{cm}^{-2}$ (Fruit hardness tester KM type; Fujiwara Scientific Co., Ltd., Tokyo, Japan). The harvested fruit was prepared for following three kinds of processing materials: 1) 20 fruits ($\approx 2 \text{ kg}$) were treated $1 \text{ mg}\cdot\text{L}^{-1}$ 1-MCP in an airtight container (117 L) at room temperature (6 to 10 °C, average 7.8 °C) for 20 h and stored for 5 d at 5 °C (1-MCP treatment); 2) 20 fruits were treated dry ice (1.2% of fruit fresh weight) to remove astringency in fruit for 5 d at room temperature (6 to 13 °C, average 8.0 °C) in a sealed polyethylene bag after 1-MCP treatment (1-MCP + DI treatment); and 3) 20 fruits were stored at 5 °C for 6 d (control). Semidried persimmon fruit were processed as follows: 1) the removal of the pericarp by a drying period of 2 d (temperature 6 to 15 °C, average 9.7 °C, humidity 69%); 2) a sulfur treatment in a sealed box ($10 \text{ g}\cdot\text{m}^{-3}$ for 1 h at 10 °C) to sterilize the surface and prevent color change of the product; and 3) machine drying started 2 d after peeling and continued for 7 d. This drying machine was made with wood panels with a heat blower (Fig. 2) and the heat blower worked the interval of on (for 2 h, temperature; up to 35 °C, humidity; up to 60%)/off (for 1 h, 15 to 35 °C, 15% to 60%). The average water content of semidried fruit was $38.1 \pm 0.4\%$ (data not shown).

Soluble tannin content in semidried fruit during the drying procedure was detected according to Taira (1996). At each stage, the calyx and seeds were removed, cut finely, and mixed evenly. Samples (5 mg) were

Fig. 1. Product of (A) semidried and (B) dried persimmon fruit. Bar: 10 mm. (A) Peeled fruit was dried for 2 d of air drying and after 7 d of machine drying (water content $\approx 34\%$). (B) Peeled fruit was dried for ≈ 2 months of air drying to 5 to 15 °C (water content $\approx 15\%$).

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¹To whom reprint requests should be addressed; e-mail maki@chem.niihama-nct.ac.jp.

extracted and then treated with 10 mL of 80% ethanol with a homogenizer (Polytron Model KR; Kineatica AG, Lucerne, Switzerland) for ≈ 10 s. The resultant paste was then filtered and brought to 100 mL using an 80% ethanol solution. Ninety microliters of the solution was added to 90 μ L of 50% Folin-Ciocalteu Reagent (Wako Pure Chemical Industries, Ltd., Osaka, Japan) and 90 μ L of 10% Na_2CO_3 solution for analysis sample. Total soluble tannin content was then detected by a microplate absorbance reader at 690 nm (Sunrise Thermo, TECAN, Salzburg, Austria). Standard solutions of 2, 4, 6, 8, and 10 $\text{mg}\cdot\text{L}^{-1}$ were made from (+)-catechin hydrate (Sigma, Steinheim, Germany) for the analysis. At least three fruits were used for each analysis.

Results and Discussion

1-MCP increases the shelf life of harvested fruit and vegetables by acting as an

Fig. 2. A drying machine for semidried persimmon.

inhibitor toward the ethylene receptors in plant tissues (Watkins, 2006).

Soluble tannin concentrations in semidried persimmon fruit treated with 1-MCP during the drying procedure were similar to that of the untreated control by day 2 (Fig. 3), but the rate of loss in 1-MCP was subsequently much. A soluble tannin concentration of 100 $\text{mg}\cdot 100\text{ g}^{-1}$ FW has been reported as a threshold value to detect astringency (Inari and Takeuchi, 2001). The inhibition of astringency removal in semidried fruit treated with 1-MCP was also confirmed by a sensory test (unpublished data).

The effects of sulfur treatment before machine drying on the soluble tannin concentration in semidried fruit were tested. It was observed that a sulfur treatment tended to increase the amount of soluble tannin, especially when semidried fruit were treated with 1-MCP treated (Table 1).

The concentration of soluble tannin in semidried fruit was compared with two other cultivars of pollination-constant and non-astringent-type persimmons, 'Atago' and 'Yokono' (Table 2). The concentration of soluble tannin in 'Atago' dried fruit remained three times higher than that of 'Saijo', and a strong inhibition of astringency removal was also observed by 1-MCP treatment. On the other hand, semidried 'Yokono' fruit contained the same levels of soluble tannin between 1-MCP-treated and control samples. Inhibition of astringency removal in semidried fruit was not observed by 1-MCP treatment (Table 2), but there was a large

difference among the three cultivars in semidried fruit treated with 1-MCP.

Morphological observation on sections of 1-MCP-treated semidried fruit indicated that the flesh of 'Yokono' samples (which did not inhibit astringency) softened to the same extent as the control. However, the central flesh area of 'Saijo' samples, in which inhibition of astringency removal in semidried fruit was observed, appeared to melt, whereas most of the flesh in the 'Atago' samples (which was strongly inhibited) did not soften (Fig. 4). Electron microscopy was used to further observe the structural detail of 'Saijo' semidried fruit. Nearly all the cell walls inside the semidried fruit controls were dissolved, whereas most of the cell walls of 1-MCP-treated samples had not changed (Fig. 4).

The mechanism of inhibition for astringency removal of 1-MCP-treated material fruit appears to differ in dried and fresh fruit. Astringency occurs as a result of acetaldehyde accumulation (Pesis et al., 1988; Taira, 1996). On the other hand, Taira and Ono (1997) suggested that the reduction of astringency in dried fruit mainly occurred by two alternate factors that do not cause acetaldehyde accumulation. They are 1) by adhesion of soluble tannin to cell wall fragments produced during fruit softening (Taira and Ono, 1997), and 2) a complex formation between the soluble tannin and water-soluble pectin that increases during fruit softening (Taira et al., 1997). These mechanisms are regulated by ethylene in the flesh of the fruit (Watkins, 2006). The disassembly

Fig. 3. Concentration of soluble tannin in semidried 'Saijo' persimmon fruit treated with 1-MCP. 1-MCP: Fruit treated with 1-MCP at 1 $\text{mg}\cdot\text{L}^{-1}$ for 20 h at 10 °C. Vertical bars represent SE. 1-MCP = 1-methylcyclopropene.

Table 1. Effect of sulfur treatment on soluble tannin concentrations in 1-MCP-treated semidried persimmon Saijo.

	Conc. of soluble tannin ($\text{mg}\cdot 100\text{ g}^{-1}$ FW)	
	Nontreatment	Treatment ²
Treatments for the material		
Control	60.5 $\pm$ 20.8 (–)	138.4 $\pm$ 2.7 (–)
1-MCP	154.4 $\pm$ 18.6 ($\pm$)	272.1 $\pm$ 105.6 ($++$)

²Sulfur (10 $\text{g}\cdot\text{m}^{-3}$) for 1 h after 2 d of peeling and air drying.

³Degree to feel bitterness (– = non; $\pm$ = a little; + = bitter).

Soluble tannin contents were determined after 2 d of air drying and 7 d of machine drying.

1-MCP = 1-methylcyclopropene.

Table 2. Effect of 1-MCP treatment for materials on soluble tannin concentrations in three cultivars.

Cultivar	Conc. of soluble tannin ($\text{mg}\cdot 100\text{ g}^{-1}$ FW $\pm$ SE)	
	Control	1-MCP treatment
Atago	95.7 $\pm$ 19.8	530.0 $\pm$ 199.0
Yokono	95.0 $\pm$ 18.5	95.0 $\pm$ 8.0
Saijo	60.5 $\pm$ 20.8	154.4 $\pm$ 18.8

Soluble tannin conc. were determined after 2 d of air drying and 7 d of machine drying without sulfur treatment.

1-MCP = 1-methylcyclopropene.

Fig. 4. Flesh of three kinds of semidried persimmon fruit treated with 1-MCP. Each fruit was peeled and then dried for 2 d of air drying and after 7 d of machine drying. Control: stored for 6 d at 5 °C before peeling and drying. 1-MCP treatment: treated with 1 mg·L⁻¹ of 1-MCP for 20 h and stored for 5 d at 5 °C before peeling and drying. 1-MCP = 1-methylcyclopropene.

Fig. 5. Electron micrograph of semidried 'Saijo' persimmon fruit flesh treated with 1-MCP (left) and control (right). Each peeled fruit was dried for 2 d of air drying and after 7 d of machine drying. Control: stored for 6 d at 5 °C before peeling and drying. 1-MCP treatment: treated with 1 mg·L⁻¹ of 1-MCP for 20 h and stored for 5 d at 5 °C before peeling and drying. Bar = 0.5 mm. 1-MCP = 1-methylcyclopropene.

and disintegration of the cell wall in 1-MCP-treated fruit during the drying procedure (Fig. 5) might be suppressed by the inhibition of the ethylene found in the fruit. In addition, the texture in 1-MCP-treated semidried fruit also decreased as a result of the inhibition of cell wall disassembly, possibly as a result of a decrease in ethylene production of the fruit. Furthermore, the different degrees of astringency removal in 1-MCP-treated semidried fruit among cultivars might depend on different sensitivity levels for these mechanisms.

In conclusion, the inhibition of astringency removal for semidried fruit was observed in some persimmon cultivars during the procedure using 1-MCP-treated material. Thus, 1-MCP treatment should be further investigated for commercial needs.

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