



Environmentally Friendly and  
Safe Technologies for Quality  
of Fruits and Vegetables

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Authors are responsible for content and accuracy of their papers.

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SECTION 3. QUALITY MANAGEMENT  
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# 21. EFFECT OF POSTHARVEST ELICITORS ON 'FUYU' PERSIMMON QUALITY DURING COLD STORAGE

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## Abstract

To induce resveratrol synthesis and reduce skin browning in 'Fuyu' persimmons, fruit were treated directly after harvest with the following elicitors: UV irradiation, ozone, phosphonate, or acibenzolar-S-methyl and then kept for three months at -0.5 °C in air storage at around 95% relative humidity. Traces of trans-resveratrol were detected in the skin of the persimmons at harvest, but after treatment and cold storage this compound was not found. After shelf-life (storage plus 5 d at 20 °C), the soluble solids content (SSC), reducing and non-reducing sugars and total polyphenols were not significantly influenced by any of the elicitor treatments. Fruit treated with ozone showed a higher reducing sugar content but developed skin damage, flesh browning and small internal cavities. These results were correlated with the skin colour. Fruit treated with acibenzolar-S-methyl had the highest flesh firmness and total polyphenol content. However, this treatment had a higher skin browning index after shelf-life.

**Keywords:** acibenzolar-S-methyl, irradiation, ozone, phosphonate, UV

## Introduction

'Fuyu' persimmon is the main non-astringent cultivar grown in Brazil. Most of Brazil's persimmon production is consumed directly in the domestic market, but recently a part is also being exported. Increased export opportunities have created a need for extended storage life, to allow for the long distance sea transport required to supply 'out of season' fruit to the northern hemisphere. However, improved postharvest practices and storage techniques are required in order to meet these increased export demands. Furthermore, fruit quality requirements are changing as consumer acceptance is now linked not only to the fruit's visual appearance and sugar content but also to its functional or nutraceutical properties. Resveratrol (*trans*-3,5,4'-trihydroxystilbene) is a biologically active phenolic compound and phytoalexin, and is produced *de novo* or formed in response to abiotic stress or pathogen attack (Grimmig *et al.* 2002). Resveratrol effectively acts as a free radical scavenger, and as been shown to inhibit low-density lipoprotein (LDL) oxidation (Pinto *et al.* 1999), to provide cardio-protection and induce vasorelaxation (Wallerath *et al.* 2005), to protect neurons (Zhuang *et al.* 2003) and to inhibit platelet aggregation and cancer activity (Fremont 2000).

This study investigates the effect of postharvest elicitors on nutraceutical properties, skin browning and general fruit quality of 'Fuyu' persimmon.

## Material & Methods

'Fuyu' persimmon fruit were harvested in 2005 at commercial maturity stage from an orchard located at Farroupilha, Rio Grande do Sul, Brazil, and immediately transported to the storage facilities at the University of Santa Maria where they were sorted to remove damaged, blemished and unripe fruit. After grading, samples were dipped for 3 min in water (control) or treated with solutions containing phosphonate (P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O at 1.27 g L<sup>-1</sup> and 1.18 g L<sup>-1</sup> respectively) or acibenzolar-S-methyl at 50 mg L<sup>-1</sup>. The UV-C (2.4 kJ m<sup>-2</sup>) treatment was applied with 25 cm between the source and the fruit surface using a wavelength of 254 nm at

30 °C. For the ozone treatment, fruit were exposed to 0.03  $\mu\text{L L}^{-1}$  ozone during storage and as an untreated control, fruit were cold stored in air. After the experiment treatments were applied, the persimmons were kept at -0.5°C for three months and then 5 d shelf-life at 20 °C.

After shelf-life (storage plus 5 d at 20 °C) fruit were analyzed for: skin color using a Minolta CR-300 colorimeter and expressed in  $L^*a^*b^*$  values. Skin browning was scored in four categories: (1 = no symptoms; 2 = < 20%; 3 = 20-50%; and 4 = > 50%). A browning index was calculated as the average browning score (Neuwald 2008) and the percentage of decayed fruit based on a visual evaluation. A small portion of the skin was removed from two opposite sides of the equatorial region of the fruit for phenolic compound analysis. Flesh firmness was measured on two opposite sides of each individual fruit after peel removal using a penetrometer (11 mm diameter tip). Soluble Solids content (SSC) was determined with a hand-held refractometer from a juice sample. Reducing and non-reducing sugars were determined by the method of Somogyi & Nelson (Nelson 1944). The analysis of trans-resveratrol was carried out in a HPLC and expressed in  $\mu\text{g } 100\text{g}^{-1}$  following the method as described by Sautter et al. (2008). Total polyphenol concentration was determined by the colorimetric method of Folin–Ciocalteu and expressed in mg gallic acid equivalents  $\text{L}^{-1}$  (Sautter et al. 2008).

The skin browning index data were normalized using an arc sine transformation. ANOVA was performed and means were compared using the Tukey test at a 5% significance level.

## Results & Discussion

Traces of trans-resveratrol were detected at-harvest in the skin of ‘Fuyu’ persimmon (data not shown) but none was detected after cold storage in all treatments (Table 1).

**Table 1.** Contents of trans-resveratrol and polyphenol in the skin and reducing and non reducing sugars in flesh of ‘Fuyu’ persimmons after 3 months of cold storage at -0.5°C plus 5 d shelf-life at 20 °C.

Treatments	Resveratrol ( $\mu\text{g } 100 \text{ g}^{-1}$ )	Polyphenols ( $\text{mg L}^{-1}$ ) <sup>(2)</sup>	Reducing sugars ( $\text{g } 100 \text{ mL}^{-1}$ )	Non reducing sugars ( $\text{g } 100 \text{ mL}^{-1}$ )
Air control	Nd <sup>(1)</sup>	3495.3 ab <sup>(3)</sup>	15.0 a	0.0 b
Irradiation UV-C	Nd	3373.6 b	16.1 a	0.6 ab
Ozone	Nd	3511.0 ab	14.9 a	1.3 a
Phosphonate	Nd	3633.8 ab	16.9 a	0.0 b
Acibenzolar-S-methyl	Nd	4069.2 a	14.3 a	0.1 b

<sup>(1)</sup> Nd = Resveratrol was not detected after shelf-life; <sup>(2)</sup> Values for total polyphenols in mg of gallic acid; <sup>(3)</sup> Values followed by the same letter vertically do not differ by the Tukey test at 5%

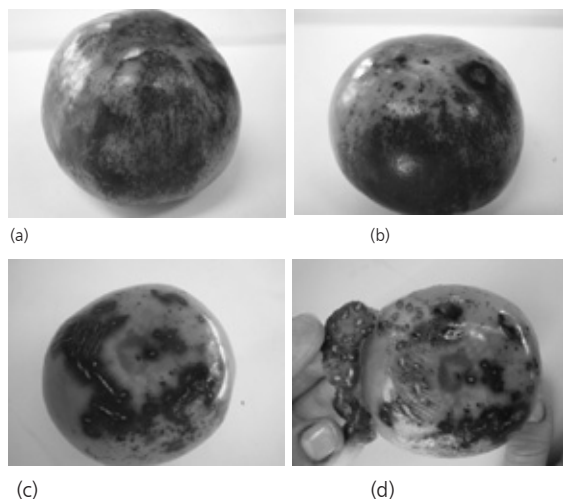
**Table 2.** Quality parameters of ‘Fuyu’ persimmons after 3 months of cold storage at -0.5°C followed by 5 d shelf-life at 20 °C.

Treatments	Skin browning		Colour		Firmness	SSC <sup>(1)</sup>
	(0 - 3)	L*	a*	b*	(N)	(°Brix)
Air control	1.6 b <sup>(2)</sup>	37.5 ab	19.9 ab	16.8 ab	26.2 bc <sup>(2)</sup>	15.7 a
Irradiation UV-C	2.1 a	36.6 ab	17.6 b	15.0 bc	26.5 bc	15.8 a
Ozone	2.2 a	35.2 b	16.4 ab	13.2 c	18.1 c	14.7 a
Phosphonate	1.6 b	38.8 a	20.0 b	17.3 ab	36.8 ab	15.9 a
Acibenzolar-S-methyl	2.3 a	38.8 a	22.5 a	18.8 a	54.5 a	15.3 a

<sup>(1)</sup> SSC = Soluble solids content; <sup>(2)</sup> Values followed by the same letter vertically do not differ by Tukey test at 5%

These results agree with Neuwald *et al.* (2008) who found no differences in the SSC of 'Fuyu' persimmon after various storage treatments. Sautter *et al.* (2008) evaluated 'Gala' apples after postharvest elicitor treatments and also found no differences in reducing sugars.

UV-C resulted in typical fruit damage (Fig 1A, B) but there was less severe skin browning compared with the ozone treatment, probably because the mechanism that triggered the injury occurred just before storage. The abiotic stress, caused by UV irradiation, disturbs the cellular homeostasis to increase hydrogen peroxide ( $H_2O_2$ ) levels (Mittler 2002) which stimulates FAL and increases the permeability of plasma membranes to  $Ca^{2+}$  (Cassells & Doyle 2003), to trigger the phenylpropanoid pathway. Ultraviolet irradiation at low doses can trigger repair mechanisms in the cell, and induce the biosynthesis of phytoalexins that are active for periods ranging from hours to days (Shama 2007). UV-C and UV-B are elicitors of stilbenes, in particular the phytoalexin resveratrol in grapes, (Adrian *et al.* 2000). However, in this work UV-C did not stimulate the synthesis of resveratrol in persimmon (Table 1). Skin browning may be a consequence of a too higher UV-C dose (Fig 1A, B) when polyphenols condense or oxidize to form browning compounds, but not changing the total polyphenol content (Table 1). Similar skin browning symptoms were also found in grapes following UV-C (Nigro *et al.* 1998). In our results, UV-C light was correlated with skin colour (Table 2) and skin browning (Table 1). There is evidence that the UV-C treatment increased fruit metabolism as shown in the subtle elevation of the reducing sugars content (Table 1).



**Fig 1.** Skin damage caused by irradiation treatment (A, B), ozone showed typical skin damage (C) flesh browning and small internal cavities (D).

The fruit treated with ozone showed typical skin damage with flesh browning and small internal cavities (Fig 1C, D). Oxidative stress stimulates phenylalanine ammonia-lyase (FAL), to trigger the formation of polyphenols and subsequent oxidation can occur enzymatically by polyphenoloxidase to give a brown colour (Cassells & Doyle 2003). Sensitivity to ozone differs among different plant species and even cultivars. When ozone enters the plant tissue through stomata, the first contact is with the apoplastic fluid. In an aqueous media,  $O_3$  produces  $H_2O_2$ , and subsequently  $OH^\cdot$ , by the Haber-Weiss reaction (Mano 2002). The guard-cells have a number of stress indicator proteins such as G proteins and these are involved with oxidative stress response signalling. This stress signal response is complex and unknown, but it is mediated by abscisic acid (Joo *et al.* 2005). Without this first defence, ozone can breakdown the cell wall and plasma membrane by active free radicals (oxygen species) generally leading to the hypersensitive response and cell death (Langebartles *et al.* 2002). The damage observed in our experiment may have occurred by the effect of ozone on the cell wall and plasma membrane, causing cells to collapse and form cavities. In this case there is evidence of increased metabolism as shown by the higher reducing sugars content (Table 1).

Fruit treated with phosphonate showed no significant differences in any of the parameters (Table 1, 2). However, fruit treated with acibenzolar-S-methyl had the highest flesh firmness (Table 2), although this is contrary to results found in apples where it accelerated fruit softening (Sautter *et al.* 2008). The acibenzolar-S-methyl treatment had the highest total polyphenol content (Table 1) but also the highest skin browning index after storage plus 5 d shelf-life at 20 °C.

## Conclusions

The elicitors acibenzolar-S-methyl, UV-C irradiation, ozone and phosphonate did not stimulate the synthesis of trans-resveratrol in persimmon. The combination of acibenzolar-S-methyl postharvest dips maintained higher flesh firmness and total polyphenol content during air storage, but resulted in skin browning after shelf-life. Future work should explore the use of postharvest elicitors under CA conditions, to try to reduce the amount of skin browning and also to evaluate the effect on decay control.

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