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The Effect of Hot Water and Calcium Solution Dipping on Quality in Kiwifruit During Storage

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Abstract: This study investigated the effects of mild heating combined with calcium dips on quality in kiwifruit (*Actinidia deliciosa* cv. Hayward). Whole fruits were treated with heat treatment for 5, 10 and 15 min at 47°C and then dipped in $CaCl_2$ solutions (2% (w/v)). Fruits were stored at 0°C for 120 days. Heat-treated combined with calcium solution resulted in higher total antioxidant activity than control, which was correlated to the high levels of ascorbic acid content. Additionally, the levels of soluble sugars remained also at higher concentrations in treated fruits. According to these results and sensory analyses, treated kiwifruits quality increased due to physicochemical changes during storage period. Improvement of fruit quality increased with prolongation of exposure time to heat. Our results showed that with this simple and non-contaminant technology, after long periods of storage, quality of kiwifruit could be even greater than in recently harvested fruits.

Key words: Total antioxidant activity · Sensory analyses · Heat treatment · Kiwifruit · Postharvest

INTRODUCTION

The kiwifruit was introduced to the world market from New Zealand in 1950s. The export of fresh fruit led to rapid expansion [1]. Production is almost exclusively of the cultivar 'Hayward' because of its longer storage life and its larger fruit size [2]. In recent years, there has been increasing interest in the production of kiwifruit due to its vitamin C content and high antioxidant capacity [3, 4].

During cold storage and ripening, kiwifruits undergo biochemical changes including conversion of starch to sugar, changes in cell wall constituents and production of characteristic volatiles which lead to the taste, texture and aroma desired by consumers. Such fruit lack the quality characteristics of consumers' demand and if eaten, may discourage consumers from purchasing kiwifruit until later in the season. The increasing market demand for this fruit has challenged post-harvest and food technologists to develop procedures to lengthen storage life.

The calcium plays a significant role in maintaining quality in a number of different fruits [5]. The pre and postharvest application of calcium salts has been used successfully in many fresh fruits to slow down the ripening process [6]. Calcium alters intracellular and extracellular processes which retard ripening exemplified by lower rates of color change, softening, CO_2 and ethylene production, increase in sugar and a reduction in total acid content [7]. Pre and postharvest calcium application has been demonstrated to produce beneficial effects on whole fruit quality, decreasing the incidence of physiological disorders [8] and delaying softening [9].

To extend storability and marketing of several fruits, good results were obtained with heat treatments. Heat treatments have already been used to control post-harvest decay and to improve the storage quality in intact fruits, due to changes it induces in physiological and physicochemical characteristics and post-processing quality [10]. This was observed in the case of whole fruit, with apples [11], strawberries [12], citrus fruit [13] and mangoes [14].

Studies on temperature effects of Ca solutions have been limited to application in conjunction with heat treatments. A combination of heat treatments followed by Ca dips has also been applied for the primary purpose of controlling postharvest pests and/or diseases and has been found to have very good results in maintaining or

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improving the texture of several products. In this sense, Ca application, combined or not with heat treatments, maintained firmness in a wide variety of fruit and vegetables including lettuce [15] and cantaloupe [15].

The objective of this study was to determine the effects of mild heating combined with calcium dips on 'Hayward' kiwifruit storage capability, functional properties and quality attributes.

MATERIALS AND METHODS

Plant Material: Mature, unripe kiwifruit (*Actinidia deliciosa* cv. Hayward) of medium sized (80-120 g) fruits, free from visible defects or decay, were harvested from a commercial kiwifruit orchard in Gorgan, Iran with average firmness of 9.8 (kg/cm^2) and 7%°Brix. Fruits were immediately transferred to the postharvest laboratory.

Treatments: Some kiwifruits were subjected to a previously optimized heat treatment with warm water at 47°C for 5, 10, 15 min and also some dipped in 2% (w/v) calcium chloride solution. For combined treatments, fruits were treated for 5, 10 and 15 min at 47°C and then dipped in $CaCl_2$ solution (2% (w/v)). Non-heat and non- calcium chloride treated fruits were used as control samples. Fruits were divided into eight batches of 160 fruits. The first, second and third batches were treated with heat treatment at 47°C for 5, 10 and 15 min combined with 2% (w/v) calcium chloride solution, the fourth batch was treated with 2% (w/v) calcium chloride solution, the fifth, sixth and seventh batches were treated with warm water treatment at 47°C for 5, 10 and 15 min with warm water, the eighth batch had no treatment as control. Kiwifruits individually labeled and packaged into ventilated bags, then stored at 0±1°C and 90 ± 5% relative humidity (RH) for 4 months. Samples were taken every month interval during storage for quality evaluation and following analyses.

Physical and Physicochemical Assays

Ascorbic Acid (AA): Ascorbic acid was measured by the oxidation of ascorbic acid with 2,6-dichlorophenol endophenol and the results were expressed as mg/100 g fresh weight [16].

DPPH Radical Scavenging Activity (RSA): The free radical scavenging activity was measured by 2,2-diphenyl-2- picrylhydrazil (DPPH) on the basis of the method of Brand-Williams *et al*. [17] with minor modifications. For this determination, aliquots (0.1 mL) of the extract were mixed with 1 mL of a DPPH solution (500 µM) in 80% ethanol. The mixture was incubated at room temperature for 30 min. Solution absorbance was determined at λ =515 nm. The DPPH radical concentration was calculated using the following equation: scavenging effect (TAA%) = (1 - Af/Ao) □ 100; Ao stands for the absorbance of the control sample and Af for the absorbance in the presence of the sample. L-ascorbic acid was used for calibration curve and the results were expressed as mg L-ascorbic acid equivalent. 100 g^{-1} fw (fresh weight).

Soluble Sugars and Starch Content: Soluble sugars were extracted with the phenol - sulfuric acid and measured. 1 ml phenol solution (5%) was added to one ml of extract and immediately 5 ml of concentrated sulfuric acid was added. The resulting solution was shaken for 30 seconds and then the tubes were transferred into ice water until cooled. Then the absorption was read by spectrophotometer at 490 nm [18].

In order to measure the starch content, 2.5 ml of the supernatant extract was added into the test tube, then 10 ml of anthron (2 g L^{-1}) solution was added into the test tube and was put into a warm bath for 7.5 min. Test tubes containing the solution was transferred into the ice to be cooled then the absorbance was read at 630 nm with a WVP model spectrophotometer [19].

Sensory Evaluation: Sensory analyses to compare the quality of kiwifruits were carried out by 10 trained adults, aged 25-40 years (5 females and 5 males). Each judge evaluated four kiwifruits for the following characteristics: crunchiness (amount of noise generated when the fruit was chewed at a fast rate with the back teeth), juiciness (amount of free fluid released from the fruit during chewing), sweetness, sourness, texture preference and visual appearance on a scale of 1-5 (ranked), where 1) very low, 2) low, 3) medium, 4) high and 5) very high. The sensorial analyses were made initial and after 2 and 4 months.

Statistical Analyses: Data were subjected to analyses of variance (GLM). Sources of variation were time of storage and treatments and the interaction of treatment × storage time. Mean comparisons were performed using the LSD test to examine if differences between treatments and storage time were significant at $P < 0.05$. All analyses were performed with SAS software package v. 9.1 for windows.

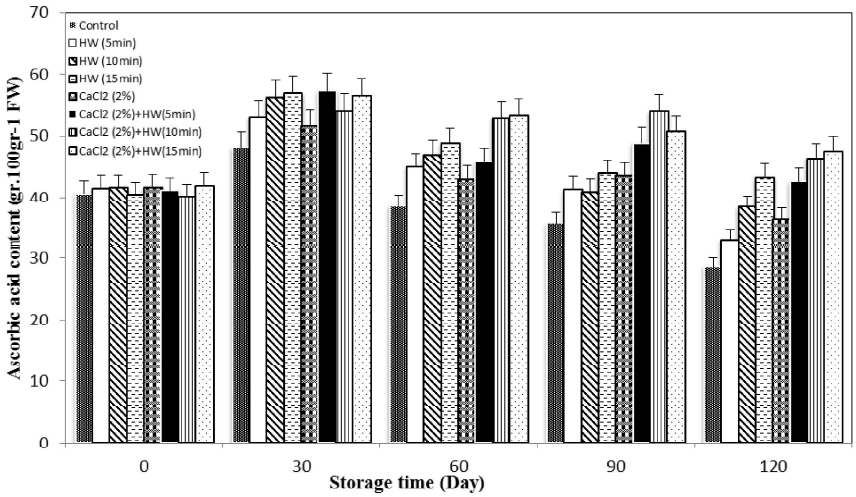

Fig. 1: Change in ascorbic acid content of kiwifruit during 120 days storage at 0°C storage. Whole fruits were non-treated (control), dipped in 2% $CaCl_2$, heat treated at 48°C for 5 min(H5), 10 min (H10), 15 min (H15) and $CaCl_2$(2%) + HW (at 48°C for 5 min, 10 min, 15 min). Least significant difference is 3.84 at level of 5% of significance. Vertical bars represent standard deviations of the means.

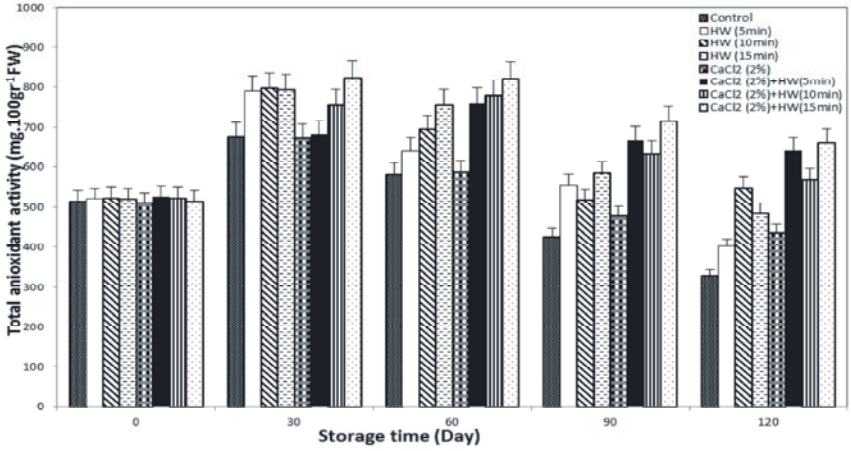

Fig. 2: Change in total antioxidant activity of kiwifruit during 120 days storage at 0°C storage. Whole fruits were non-treated (control), dipped in 2% $CaCl_2$, heat treated at 48°C for 5 min(H5), 10 min (H10), 15 min (H15) and $CaCl_2$(2%) + HW (at 48°C for 5 min, 10 min, 15 min). Least significant difference is 39.74 at level of 5% of significance. Vertical bars represent standard deviations of the means.

RESULTS AND DISCUSSION

Ascorbic Acid: Throughout the storage period, maximum ascorbic acid content was maintained by Ca+HW treatment, while it was least in control (Fig. 1). During storage, the levels of ascorbic acid remained also significantly higher ($P < 0.05$) in HW treated than in control fruits. That is reinforced by the fact that blanching and other heat treatments favor the stability of AA, presumably as a consequence of inactivation of enzymes, including ascorbate oxidase [20].

Total Antioxidant Activity: During storage periods, TAA was significantly higher ($P < 0.001$) in HW15, HW10 and HW5 than in control fruits (329.18), with final levels of 485.56, 549.8 and 402.04 mg. $100g^{-1}$, respectively, after 120 days of cold storage (Fig. 2). After 120 days of low-temperature storage and fruit ripening, TAA level of treated fruit pulp tissues was significantly higher as compared with control. Similar result was observed by Mirdehghan *et al*. [21-23].

Table 1: Change in soluble sugar content of kiwifruit during 120 days storage at 0°C storage. Whole fruits were non- treated (control), dipped in 2% $CaCl_2$, heat treated at 48°C for 5 min(H5), 10 min (H10), 15 min (H15) and $CaCl_2$ (2%) + HW (at 48°C for 5 min, 10 min, 15 min).

	Storage time (Day)				
Treatment	0	30	60	90	120
Control	27.43	38.33	44.61	34.57	33.96
HW (5 min)	25.93	35.38	39.13	42.53	41.55
HW (10 min)	25.18	32.72	41.92	39.11	46.50
HW (15 min)	28.18	32.89	39.93	41.08	49.44
$CaCl_2$ (2%)	27.93	34.67	41.52	40.78	37.10
$CaCl_2$ (2%) + HW(5 min)	24.43	38.92	42.26	41.49	45.32
$CaCl_2$ (2%) + HW(10 min)	26.68	38.36	39.79	43.07	49.65
$CaCl_2$ (2%) + HW(15 min)	26.93	37.61	37.38	42.09	52.85
Time	(0.97)[a]				
Treatment	(1.23)[b]				
Time × Treatment	(2.76)[a]				

LSD values are in brackets.
[a] $P < 0.05$.
[b] $P < 0.01$.

Table 2: Change in starch content of kiwifruit during 120 days storage at 0°C storage. Whole fruits were non- treated (control), dipped in 2% $CaCl_2$, heat treated at 48°C for 5 min(H5), 10 min (H10), 15 min (H15) and $CaCl_2$ (2%) + HW (at 48°C for 5 min, 10 min, 15 min).

	Storage time (Day)				
Treatment	0	30	60	90	120
Control	6.72	4.23	3.08	2.85	2.39
HW (5 min)	6.60	4.96	3.70	3.45	2.02
HW (10 min)	6.52	4.86	4.01	3.33	1.88
HW (15 min)	6.75	5.25	4.25	3.86	1.38
$CaCl_2$ (2%)	6.77	4.86	3.44	3.11	2.10
$CaCl_2$ (2%) + HW(5 min)	6.677	6.46	5.41	3.96	1.00
$CaCl_2$ (2%) + HW(10 min)	6.70	5.86	4.75	4.30	1.16
$CaCl_2$ (2%) + HW(15 min)	6.52	6.70	5.23	3.36	1.01
Time	(0.18)[a]				
Treatment	(0.23)[b]				
Time × Treatment	(0.53)[b]				

LSD values are in brackets.
[a] $P < 0.05$.
[b] $P < 0.01$.

Sugar and Starch Content: Fruits treated with HW and Ca tended to maintain higher levels of sugars compared with the control fruits (Table. 1). The lowest levels of sugars were probably related to the breakdown of tissues in the control. Results of total sugars in fruit were significant and maximum total sugars (39.51 g. 100g $^{-1}$) were presented in HW+Ca10 min, while minimum total sugars (35.78 g. 100g $^{-1}$) were recorded in control. Treatment effect on total sugars was statistically non-significant for HW+Ca treatment in different periods. This might be due to hydrolysis of starch and accumulation of sugars [24] and conversion of starch through the process of glucogenesis [25]. In general, kiwifruit treated with HW+Ca, maintained higher levels of starch than control ($P < 0.05$) (Table 2) during storage, but

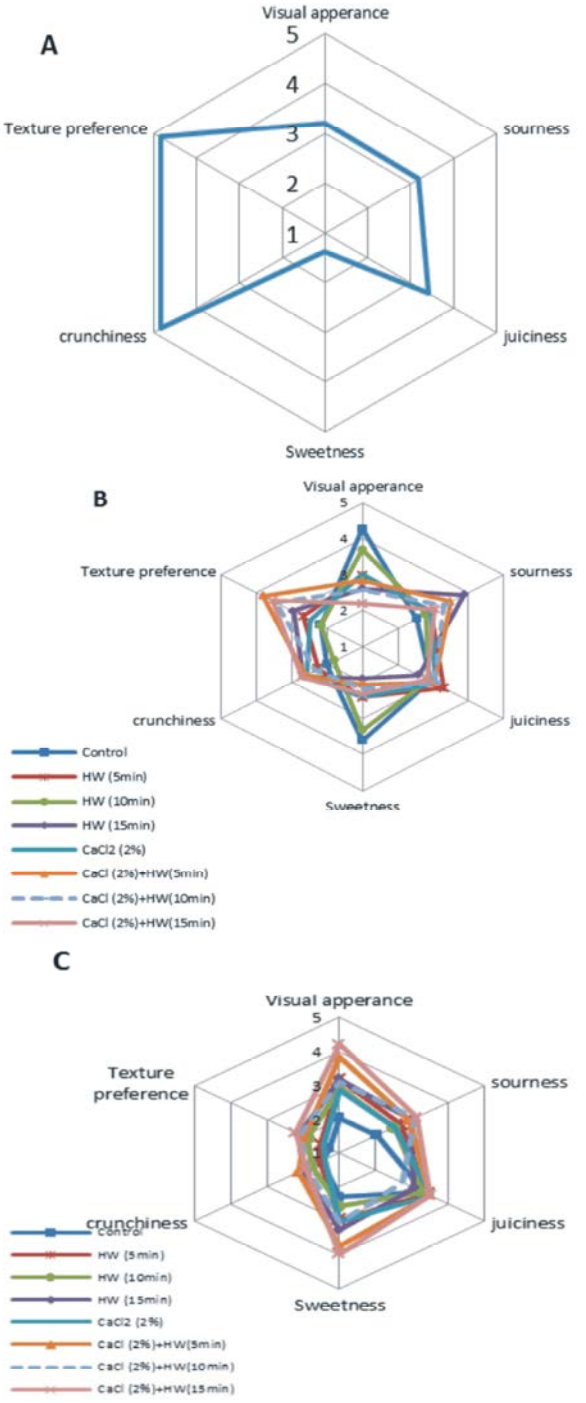

Fig. 3: Radial graph of the sensory analysis of kiwifruit at 0 day (**A**), 60 days (**B**) and after 120 days (**C**) of the storage. Whole fruits were non- treated (control), dipped in 2% $CaCl_2$, heat treated at 48°C for 5 min(H5), 10 min (H10), 15 min (H15) and $CaCl_2$ (2%) + HW (at 48°C for 5 min, 10 min, 15 min). Vertical bars represent standard deviations of the means.

the application of heat and Ca treatment did not modify the total sugar content individual and no significant differences between control and treated fruits were found after storage at 0°C. Sugar content of untreated fruit tissue decreased after 60 days storage, while in those fruits treated with HW and Ca treatment decreased after 90 days but HW5 and HW15 treatments increased sugar content until the end of storage (Table 1). Therefore, it is possible to hypothesize that the increase in total sugars observed in heat-treated fruits is due to an increased activity of the invertase enzymes caused by heat treatment. Calcium may influence structure and function of the cell walls and membranes and certain aspects of cell metabolism [26].

Sensory Analyses: Following 120 d storage, eating quality diminished, but all treated fruits were considered to be of good eating quality more than control (Fig. 3). As a general conclusion related to kiwifruit sensory quality, treatments did not adversely affect the sensorial attributes of kiwifruit and longer dipping times induced higher scores in the appearance. Similar result was observed by other researchers [27]. The score of sourness for treated fruits were significantly higher during storage. Texture and crunchiness decreased during the storage period showing a similar trend to appearance values. Fruits showed significantly higher scores for texture and crunchiness of HW+ Ca treatment during storage. There was no signification difference in sourness and juiciness between control and HW treatment at 120 days of storage (Fig. 3). The results of Aguayo*et al*. [28], Manganaris *et al*. [29] and Luna-Guzmán, *et al*. [30], maintaining firmness by the use of Ca salts, were confirmed by the sensory panel. Throughout the storage time, all the fruits showed a loss of visual acceptance. The greatest visual acceptance for treated fruit by consumers correlates with the lower levels of dehydration and darkening experienced by them during storage. Sweetness was the primary factor used in determining preference among treated samples. Most of the consumers had comments that appeared unrelated to the treatments.

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