

STORAGE QUALITY OF BELL PEPPERS PRETREATED WITH HOT WATER AND POLYETHYLENE PACKAGING

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ABSTRACT

*Treatments of bell peppers (*Capsicum annuum*, L.) with hot water at 45C for 15 min or 53C for 4 min prior to storage at 8C markedly reduced the incidence of fungal infections. However, the hot water treatment induced shriveling during storage. When hot water treated pepper fruits were subsequently placed in low density polyethylene bags, storage quality of these peppers improved tremendously including retention of firmness, reduction of water loss, retardation of color change, and alleviation of chilling injury. Total soluble solids, titratable acidity, and pH values in the pepper fruit were generally not affected by these treatment. A 4 min dip at 53C followed by packaging with 0.065 mm low density polyethylene film was very effective in maintaining pepper quality. This treatment inhibited respiration rate, reduced decay, retained turgidity and green color, and maintained excellent overall quality after 28 days of storage at 8C. Hot water treatment combined with polyethylene film packaging is a promising technique for improving the storage quality of bell peppers.*

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INTRODUCTION

Bell peppers are an important crop in the U.S., Mexico, and many other countries; however, peppers are highly perishable. They are susceptible to fungal infections caused by *Botrytis cinerea* and *Alternaria alternata* (Barkai-Golan 1981). Because of their large surface to weight ratio, peppers are also prone to water loss and shriveling. The most effective method of maintaining quality and controlling decay of peppers is by a rapid cooling after harvest followed by storage at low temperature with a high relative humidity (Hardenburg *et al.* 1986). However, peppers are very sensitive to chilling injury which limits storage temperature to above 10C (Hardenburg *et al.* 1986). On the other hand, without refrigeration, peppers turn color and deteriorate in a few days as a result of rapid aging and parasitic infections. Packaging of bell peppers in polymeric films has been reported to inhibit fruit respiration, delay ripening, decrease ethylene production, reduce chilling injury, retard softening, slow down compositional changes associated with ripening, maintain color and extend shelf-life (Ben-Yehoshua *et al.* 1983; Miller *et al.* 1986; González and Tiznado 1993). These beneficial effects can be explained by the modified atmosphere created inside the package as well as the reduction in water loss. High CO₂ and/or low O₂ atmospheres have been reported to improve the quality retention of bell peppers during storage (Luo and Mikitzel 1996; Mercado *et al.* 1995; Wang 1977). Although packaging also reduces water loss, postharvest diseases could be enhanced by the high humidity created in the bags.

Hot water dips are one of the techniques that have been successfully used to prevent decay in various crops (Couey 1989). Beneficial effects have been reported in different horticultural crops dipped in hot water prior to cold storage (Lurie 1998). Postharvest heat treatments are nonpolluting physical procedures for insect disinfestation and disease control in fresh horticultural products (Klein and Lurie 1991; Paull 1990). Hot water dips in conjunction with film packaging could be an alternative to reduce quality losses during postharvest handling of bell peppers. Very little attention has been paid to study the combined effects of these two physical treatments on postharvest fruit behavior. Our study was undertaken to determine the effectiveness of hot water dips and film packaging, individually or in combination, in maintaining or improving the quality of bell peppers during cold storage.

MATERIALS AND METHODS

Plant Materials

Freshly harvested green bell peppers (*Capsicum annuum* L.) were obtained

from packing houses in Guaymas, Mexico. Fruits were delivered to the laboratory immediately after harvest and uniform sized peppers free of blemishes or defects were selected for this study. Initially, a random sample of 20 fruits were used to measure respiration rate (CO_2 mL /Kg.h), and 30 fruits for skin color, weight, firmness, total soluble solids (SS), pH, and titratable acidity (TA).

Hot Water Treatment and Film Packaging

Peppers were grouped into lots of 50 fruits and subjected to the following six treatments: (1) control (C); (2) dipped in water at 53C for 4 min (D1); (3) dipped at 45C for 15 min (D2); (4) D1 plus film packaging; (5) D2 plus film packaging; (6) control plus film packaging (control). The packaging film used was a low density polyethylene film (20 × 30 cm). In previous work (González and Tiznado 1993) this film proved effective in maintaining the quality of peppers. Thickness, O_2 , CO_2 and water permeability rates of the film were 0.065 mm, 223 and 125 $\text{cm}^3/(\text{m}^2 \cdot \text{h} \cdot \text{atm})$, and 0.168 $\text{g}/(\text{m}^2 \cdot \text{h} \cdot \text{atm})$, respectively (González and Tiznado 1993). The baths contained 200 PPM chlorinated water. Water temperature was continuously monitored to keep the fluctuation within $\pm 1\text{C}$. The temperature and duration of hot water dips were selected after preliminary tests. After dip treatments, fruits were air dried and then stored either directly at 8C or packaged in groups of two fruits in a low density polyethylene film before storage for 28 days. Each group of peppers selected for continuous cold storage were placed in a clean plastic box with the fruits touching. The batches of peppers treated and packaged were placed in the same cold room chamber and maintained at $8 \pm 1\text{C}$ with 80-85% relative humidity (RH). Measurements for color intensity, pH, percent TA, SS, chilling injury (CI) symptoms, and firmness were taken on days 14 and 28. Respiration rate, fruit weight, decay, and quality was taken on days 4, 8, 12, 16, 20, 24, and 28 of storage.

Quality Attributes

Respiration rate was evaluated immediately after hot water treatments and throughout the storage period. Individual fruits were placed in a plastic container and connected to a flow-board through which an 80-85% RH air stream was passed. CO_2 flow rates were maintained below 0.3% to prevent physiological disorders caused by accumulation of CO_2 inside the containers. CO_2 concentrations were analyzed by collecting 1 mL gaseous sample from the head space of each container and then injected the 1 mL into an infrared gas analyzer (Model PIR-2000, Horiba Instruments, Inc., Irvine, Calif.). Peppers were inspected for signs of decay every 4 days. Those peppers that showed decay were recorded, removed

from the bags, and discarded. At each interval, peppers were assessed for percentage of weight loss, color, firmness, quality, decay, and CI. Peppers were weighed before and after the storage intervals to calculate percentage of fresh weight loss. Skin color was assessed with a tri-stimulus color difference meter (Minolta CR 300) and expressed as "a", "b", L and hue angle values. Three locations around the equator of the fruit were evaluated. Firmness was determined by scoring (1-5) the degree of tissue yield by applying finger pressure; 1=flaccid, 2= slightly firm, 3= moderately firm, 4=firm, and 5=very firm (Miller *et al.* 1983). Quality was evaluated subjectively according the following scale: 1= unusable, 3= poor, 5= fair, 7=good, 9= excellent. Extent of decay was assessed based on the area of decay and amount of microorganisms growing on it. Decay was rated on a scale of 1-5 where; 1=none, 2=slight, 3=moderate, 4=severe, 5=extreme. The score of CI was based on the percentage of total surface areas affected by sheet pitting; 0=no injury, 1=slightly, 2=moderate, 3=severe. Total SS, TA, and pH were measured according the AOAC (1990) procedures.

Analysis of variance (ANOVA) and Tukey multiple range test for comparison of means were performed using the SAS system (1990). Percent data (subjective measurements) were analyzed after arcsin transformation, then back transformed for presentation.

RESULTS AND DISCUSSION

Effects of hot water dips (HWD) on respiration of bell pepper fruits during storage at 8C and 80-85% RH are shown in Fig. 1. Respiration rate was initially increased by HWD. However, it decreased considerably in D1 treated fruits after 4 days at 8C, remaining lower than those of the control and D2 treatment. Fruits treated with D2, showed a higher respiration rate and more senescent symptoms than the control and D1 treated fruits. The respiration rate of D2 treated fruit increased slightly but not significantly on day 12. In fact, no bell peppers showed significant changes in CO₂ production rates with time. This supports previous reports where peppers followed a typical non climacteric respiratory pattern (Salveit 1977).

Table 1 shows weight loss percentage, firmness, and CI symptoms of peppers, after 14 and 28 days of storage at 8C. HWD slightly increased ($p < 0.05$) weight loss of peppers compared with the control. Increase in fruit weight loss following HWD (Schirra and D'hallewin 1997; González-Aguilar *et al.* 1997) or hot air treatment (McGuire and Reeder 1992) have been reported on 'Fortune' and 'Marsh' grapefruits, while studies on kumquats showed the opposite trend (Rodov *et al.* 1995). However, the cause of increase or decrease in fruit water loss following heat treatment remains to be elucidated. After 28 days of storage HWD plus packaging significantly ($p < 0.05$) reduced weight loss of pods while unpackaged peppers lost

11 times more weight than packaged ones. Packaged fruit lost only between 1.3-1.4% of its weight after 28 days. These fruits remained more hydrated than control ones. Also they were free from wilting and shriveling, while the others showed moderate to severe wilting and shriveling. In general, treated fruits were firmer than control fruits. However, the highest values were scored for D1 and D2 treated peppers packaged in low density polyethylene bags. This is in agreement with several other authors (Ben-Yehoshua *et al.* 1983; Watada *et al.* 1987; González and Tiznado 1993) who found that the main benefit of film packaging of peppers was a reduction in fruit water loss and firmness. Lerdthanangkul and Krochta (1996) found that a mineral-oil-based coating could be used to reduce moisture loss and maintain fruit firmness and freshness of peppers during storage at 10C.

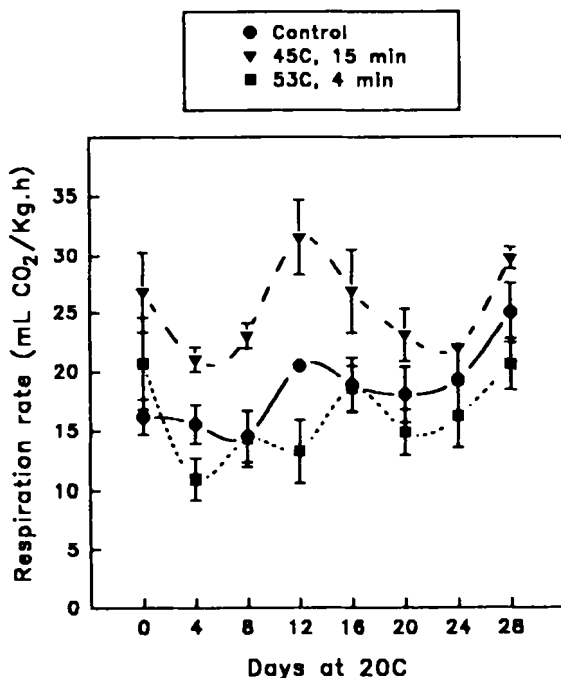


FIG. 1. RESPIRATION RATE (ML CO₂/KG.H) OF CONTROL AND HOT WATER TREATED PEPPERS

Peppers were stored at 8C, however, the respiration rates were measured 2 h after transfer of samples to 20C. Data are means of 20 replicates \pm standard errors

Hot water treatments alone did not prevent firmness loss, however, we observed that fruits treated and packaged with polyethylene bags maintained firmness and good visual characteristics. Flesh firmness decreased continuously

with cold storage, being more noticeable in unpackaged fruits. After 28 days of storage, these fruits were scored with low values (< 2.1) which correspond to flaccid and soft fruits, whereas packaged fruits got higher scores (3.8-4.2) which correspond to firmer fruits. Control fruits presented major CI symptoms, followed by D1 and D2 treated fruits directly stored at 8C (Table 1). Severity of CI symptoms was reduced by combination of HWD and film packaging. Forney and Lipton (1990) reported that pepper fruit packed in a plastic bag created a modified atmosphere within the package, thus reducing its susceptibility to CI. It is possible that CI was further alleviated by enhancement of the humidity within the package. Gorini *et al.* (1976) studied the effect of 5- 6C storage on 19 different pepper cultivars, and found in some cultivars that CI was eliminated by placing pods in polyethylene bags, whereas for other cultivars CI was only reduced in wrapped vs nonwrapped pods. On the other hand, Miller and Rise (1986) found that film wrapping did not reduce the incidence of visible CI symptoms on either pericarp or seeds during prolonged exposure to cold stress.

TABLE 1.
WEIGHT LOSS, FIRMNESS, AND CHILLING INJURY (CI) OF BELL PEPPERS UNDER THE TREATMENTS APPLIED, AFTER 14 DAY AND 28 DAYS AT 8C

Days at 8C	Weight loss (%)		Firmness ¹		CI ²	
	14	28	14	28	14	28
Control	9.2 ^{b,s}	15.4 ^b	1.2 ^c	1.0 ^c	1.2 ^a	2.5 ^a
45C, 15 min	11.5 ^a	17.2 ^a	3.2 ^b	1.6 ^{bc}	1.0 ^a	1.4 ^b
53C, 4 min	11.7 ^a	17.1 ^a	4.1 ^{ab}	2.1 ^b	0.5 ^b	0.8 ^c
45C, 15 min + Film	1.2 ^c	1.3 ^c	4.8 ^a	4.0 ^a	0.3 ^b	0.5 ^c
53C, 15 min + Film	1.1 ^c	1.3 ^c	5.0 ^a	4.2 ^a	0.2 ^b	0.4 ^c
Control + Film	1.3 ^c	1.4 ^c	4.7 ^a	3.8 ^a	0.4 ^b	0.8 ^c

¹ Firmness was evaluated according the following scale; 1 = flaccid; 3 = moderately firm; 5 = very firm

² Chilling injury was evaluated according the following scale: 0 = no injury; 3 = severe

³ Means within a column followed by the same letter are not significantly different according to turkey multiple range test ($p < 0.05$).

Hot water treatments significantly ($p < 0.05$) reduced CI, to varying extents. Decay symptoms were considerably reduced by combining HWD and film packaging (Fig. 2). Immersion of bell peppers at 53C for 4 min or 45C for 15 min, followed by packaging, resulted in a clear delay in the onset of decay. Fruit in these treatments did not show appreciable incidence of chilling symptoms during the first 20 days of storage, while unpackaged D1 and D2 treated and control fruits showed moderate and severe decay symptoms. In these fruits, it took 8 days to detect

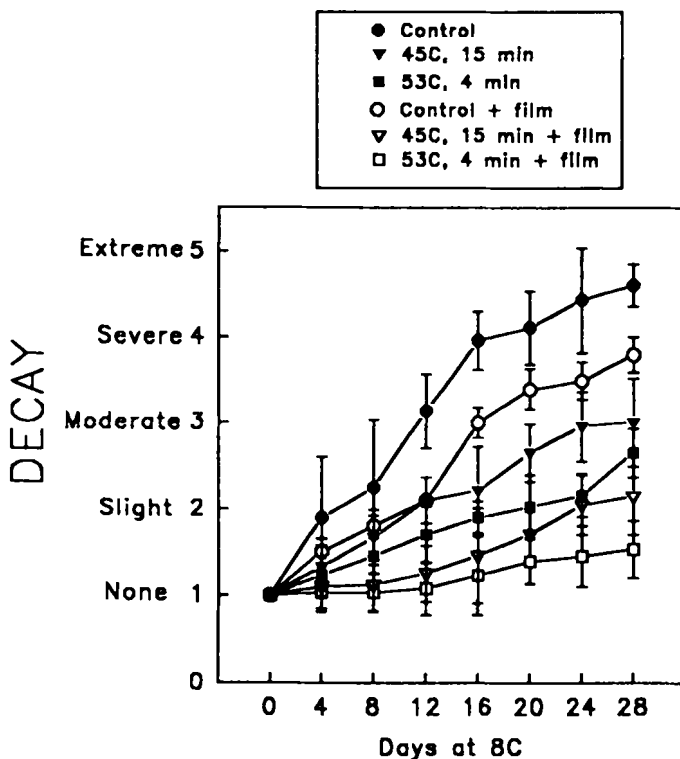


FIG. 2. DECAY OF PEPPER FRUITS UNDER DIFFERENT TREATMENTS EVALUATED ACCORDING TO THE FOLLOWING SCALE, 5 = EXTREME, 1 = NONE
Data are means of 15 replicates \pm standard errors.

growth of microorganism whereas for the other treatments minor decay was detected at 20 days. In general, HWD's did not damage the fruits. However, control fruits degraded rapidly during storage, and a high percentage of them had to be discarded. HWD by itself reduced the incidence of decay but it was more effective when fruits were packaged. Only minor decay incidences were observed in fruits treated with D1 and film packaging after 28 days at 8°C. HWD's alone were effective up to 14 days, however, the efficacy of D1 and D2 treatments was reduced afterwards. These fruits were scored with slight and moderate symptoms of decay, whereas control fruits showed severe decay symptoms. However, no significant benefit was observed in HWD treated fruits compared with control ones, because both presented high percentage of water loss during storage that reduced quality of peppers (Table 1 and Fig. 3). The reduction of decay symptoms by HWD's has been observed in many fruits, however the mechanisms involved in this reduction still remain unclear. Miller *et al.* (1984) and Govindarajan (1985)

observed no effect on decay development while others have reported that bulk or individual film packaging enhance decay development because water condensation inside the package induces secondary infection (Bussel and Kenigsberger 1975; Ben-Yehoshua 1985; Brackett 1990). Disadvantages of film packaging include the possibility of condensation inside packages, the growth of pathogens, and the potential for anaerobic states to occur. In this study, the use of low temperature was critical for maintaining quality of peppers. The most prevalent decay pathogens were *Alternaria alternata* (fr.) Keissler followed to a lesser extent by *Botrytis* and *Geotrichum candidum* Link:Leman species.

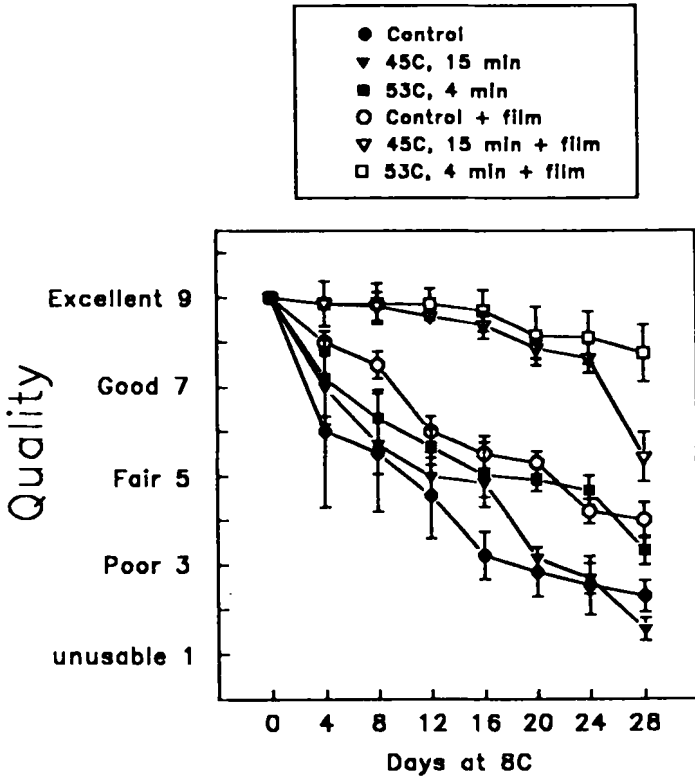


FIG. 3. OVERALL QUALITY OF PEPPER FRUITS UNDER DIFFERENT TREATMENTS EVALUATED ACCORDING TO THE FOLLOWING SCALE, 9 = EXCELLENT, 1 = UNUSABLE
Data are the means of 15 replicates ± standard errors.

TABLE 2.
 COLOR CHANGES (L, a, b AND HUE ANGLE) OF BELL PEPPERS UNDER THE TREATMENTS APPLIED, AFTER 14 AND 28 DAYS AT 8C.
 INITIAL COLOR WAS (L = 37.4, A = -9.54, B = 10.15, °H = 133.22)

		Color Value							
		L		a		b		Hue angle	
Days at 8C		14	28	14	28	14	28	14	28
Control		29.69 ¹	24.22 ^a	-4.49 ^a	-3.23 ^d	14.73 ^a	15.16 ^a	106.95 ^d	102.03 ^a
53C, 4 min		34.34 ^a	30.13 ^b	-8.25 ^{ab}	-1.21 ^c	8.86 ^c	9.52 ^c	132.96 ^c	97.25 ^b
45C, 15 min		30.36 ^b	30.16 ^b	-4.89 ^b	0.55 ^c	9.06 ^c	9.55 ^c	118.31 ^{bc}	93.30 ^c
53C, 4 min	+ film	37.52 ^a	36.45 ^a	-9.52 ^a	-9.27 ^a	8.25 ^c	8.74 ^d	139.09 ^a	136.69 ^a
45C, 15 min	+ film	36.42 ^a	34.84 ^a	-8.86 ^{ab}	-7.99 ^b	11.05 ^b	12.86 ^b	125.87 ^b	122.26 ^b
Control +film		33.54 ^a	32.45 ^{ab}	-7.96 ^b	-5.43 ^c	10.12 ^b	10.11 ^c	118.22 ^{bc}	118.24 ^b

¹ Means within a column followed by the same letter are not significantly different according to tukey multiple range test (p<0.05).

Fruit quality declined to varying degrees during storage depending on treatments. Quality of all fruits were rated fair or better on day 12 (Fig. 3). Subsequently, the quality of the control fruits decreased continuously until it reached very low levels of acceptability (1 to 3). Fruits from treatments D1 plus film packaging and D2 plus film packaging were rated excellent the first 16 days, with slight decreases afterwards, being more severe for D2 treated fruits after 28 days of storage (Fig. 3). In general, treated fruits showed better appearance and quality than nontreated ones. The best results as regards to quality attributes was shown by low density polyethylene bags plus D1 treatments. Those fruit remained hydrated and green after 4 weeks in storage and were significantly different from nonpacked and control fruits. These results agree with reports where film packaging was effective in reducing quality loss of bell peppers (González and Tiznado 1993; Meir *et al.* 1995; Wall and Berghage 1996).

TABLE 3.
QUALITY CHANGES OF BELL PEPPERS UNDER THE DIFFERENT TREATMENTS,
AFTER 14 AND 28 DAYS AT 8C

Days	%TA ¹		pH		TSS ²	
	14	28	14	28	14	28
Control	0.089 ^{bc,3}	0.019 ^a	6.24 ^a	6.17 ^a	3.6 ^b	4.8 ^a
53C, 4 min	0.100 ^{ab}	0.028 ^a	6.28 ^a	6.35 ^a	4.2 ^a	3.6 ^b
45C, 15 min	0.110 ^a	0.022 ^a	6.32 ^a	6.23 ^a	4.1 ^a	3.7 ^b
53C + film	0.087 ^{bc}	0.024 ^a	5.99 ^a	6.50 ^a	3.0 ^c	3.6 ^b
45C + film	0.082 ^c	0.021 ^a	6.15 ^a	6.42 ^a	3.3 ^{bc}	3.9 ^b
Control +film	0.082 ^{bc}	0.022 ^a	6.15 ^a	6.20 ^a	3.4 ^{bc}	3.8 ^b

¹ % TA = Percent titratable acidity

² TSS = Total soluble solids

³ Means within a column followed by the same letter are not significantly different according to turkey multiple range test ($p < 0.05$).

The initial color of peppers were: $L = 37.4 \pm 3.23$, $a = -9.54 \pm 2.25$, $b = 14.15 \pm 3.45$ and hue angle = 133.22 ± 12.5 . Progressive color changes in "L", "a", "b" and hue angle values were observed in the peppers over time (Table 2). "a" represents the axis from green to red. A positive value indicates a red color and a negative value indicates a green color. A rapid increase in "a" values were

observed on treated unpackaged peppers followed by control ones. Fruits from treatment D1 plus film packaging and D2 plus film packaging showed the smallest changes in color. A decrease in "b" representing the blue-yellow axis, was found in unpackaged peppers while packaged fruits had no significant changes in "b" values after 28 days at 8C. Peppers treated at 45C during 15 or 53C during 4 min and packed maintained the fresh "L" value "L" represents lightness and darkness while the "L" value of all other peppers decreased considerably (Table 2). Hue angle represents best the changes in fruit ripening. None of the hot water treatment used plus packaging, substantially influenced color changes during the storage period. Hue angle, as represented by average ($\tan^{-1} b/a$), of these pepper fruits remained in the range 118 to 136 degrees after 28 days at 8C. However, lower values (<102 degrees) in hue angle were found in control and treated (D1 and D2) fruits, in the same period (Table 2). In general, a significant reduction in color changes was observed by film packaging. We found that HWD plus packaging reduced considerably color change. HWD's alone did not prevent maturation and ripening of peppers. In these fruits color changes were more pronounced. Packaged fruits remained green after 28 days of storage whereas nontreated fruit were greenish-yellow. Packaged peppers had values comparable in color with the initial ones whereas nonpackaged ones showed, in general, lower values (Table 2). Color change, disease incidence, and dehydration, became the limiting factors to shelf-life for control and nonpackaged fruits.

There were no significant ($p < 0.05$) differences for pH and TA among treatments, after 28 days at 8C (Table 3). Only minor differences were observed after 14 days of storage. However, SS were higher in control fruits than in hot water treated fruits after 28 days at 8C.

Taking overall quality into consideration, the best treatment was treatment of 53C for 4 min plus film packaging. That treatment appears to be an effective method for improving the postharvest quality of peppers. Fruits treated at 53C for 4 min and packed maintained quality attributes similar to their initial ones. These fruits remained hydrated, green and had good visual appearance after storage. The low rate of respiration of these fruits may also account for the retention of pepper quality. Further studies are needed to optimize packaging and dipping treatments of fruit harvested at different maturity stages in order to improve ripening and fruit quality after cold storage.

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