EFFECT OF DIFFERENT PRE-PACKAGING TREATMENTS ON THE PHYSICAL/CHEMICAL QUALITY OF MARGARITEÑO TOMATOES DURING POST-HARVEST STORAGE AT ROOM TEMPERATURE

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ABSTRACT

A study was made of the effect of different pre-packaging treatments on the physical/chemical quality (*L**, *a**, *b**, *C**, *h**, titratable acidity, pH, soluble solids content, maximum shear force, and weight loss) of Margariteño tomatoes (*Lycopersicum esculentum* cv. “España”) during post-harvest storage at room temperature. A total of 160 green-ripe tomatoes showing no signs of deterioration were divided into four groups of 40, to each of which one of the following pre-packaging treatments was applied: (1) blanching in hot water (60ºC) for 30 s; (2) washing in chlorinated water (150 mg/L sodium hypochlorite (NaOCl) solution) for 5 min at 2ºC, pH 7.5; (3) covering of the peduncle area with commercial paraffin wax; and (4) untreated controls. All tomatoes were placed in 0.5 mm PET containers and stored at room temperature (30ºC; 90% RH). The results obtained confirmed that waxing, blanching and washing in chlorinated water all delayed the onset of the physical/chemical changes characteristic of ripening and the appearance of signs of deterioration. Waxing was found to be the most effective treatment for extending the postharvest shelf life of commercial samples from 11 days to 19 days.

Keywords: *tomato, physical/chemical quality, pre-packaging treatments, postharvest life*

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PRACTICAL APPLICATIONS

The study evaluated the effect of three treatments applied prior to commercial packaging (blanching in hot water, washing in chlorinated water, and waxing) on the physical/chemical quality of Margariteño tomatoes kept at room temperature, with a view to identifying low-cost technological alternatives for extending their shelf life without impairing quality attributes, in developing countries where refrigerated storage of horticultural products is not always feasible, since the equipment required may not be available; little or no refrigeration is used during storage and transport to market, and fruit and vegetables are often kept at room temperature prior to processing. The results suggested that waxing was the most effective treatment for extending postharvest shelf life from 11 d to 19 d at 30°C and 90% RH, satisfying in a constantly-increasing consumer demand for high quality produce in those countries.

INTRODUCTION

Fruit and vegetable producers seek to ensure a high-quality product with a long shelf-life, which can be transported over long distances. Effective post-harvest management requires a thorough knowledge of the product's characteristics, and of the storage environment, since the quality and conservation of horticultural products depend on the interaction of these factors with a range of pre-harvest factors (Kader 2002a).

The Margariteño tomato is a highly profitable crop in eastern Venezuela, due to high yields and a strong demand in the States of Anzoátegui, Bolívar, Sucre, Monagas and Nueva Esparta (Núñez 1996, Quijada 2002). It can be consumed fresh but also used in making sauces, stews and soups.

The most commonly-used method of prolonging the post-harvest shelf life of fruits and vegetables is refrigerated storage, since low temperatures prompt a decrease in respiration rate and thus slow both ripening and senescence (Barreiro and Sandoval 2006). However, refrigerated storage of horticultural products is not always feasible, since the equipment required may not be available; in most developing countries, little or no refrigeration is used during storage and transport to market, and fruit and vegetables are often kept at room temperature prior to processing (Lamúa 2000). Green-ripe tomatoes, moreover, are particularly susceptible to cold damage, and thus undergo rapid deterioration during low-temperature storage (Hakim *et al*. 2004).

Post-harvest heating is a non-contaminating physical treatment which delays ripening processes, reduces cold damage and controls pathogen activity; for that reason, it is often used commercially for the quality control of fresh produce (Akbudak *et al.* 2007). The main purpose of blanching is to deactivate the enzymes responsible for quality impairment during storage. Pectin methylesterase (PME) belongs to the group of enzymes that degrade pectin, a heteropolysaccharide responsible for preserving the integrity of plant tissues. Many fruits and vegetables contain substantial amounts of this enzyme, which causes the deterioration of plant texture.

Blanching reduces texture loss in fruit and vegetables by inhibiting the activity of PME and other enzymes causing deterioration (Begun and Brewer 2001).

Tomatoes are commonly blanched by conventional immersion in hot water, but this can cause changes in the color of the final product, since lycopene – the main pigment in tomatoes – is affected not only by exposure to oxygen in the air but also by heat treatment during processing, leading to the isomerization of the double *trans* bonds in the pigment to their *cis* form; this change in structure can prompt a reduction in color intensity (Begum and Brewer 2001).

Other post-harvest treatments such as waxing can also prolong tomato shelf life (Akbudak *et al.* 2007). Waxing lubricates tomatoes, thus improving handling and protecting them from damage (Hall 1989, Mejía *et al.* 2009). Today, tomatoes are also waxed to make them more shiny, as well as to avoid cold damage, reduce weight loss during storage and maintain product quality (Mejía *et al.* 2009).

Another post-harvest treatment widely used in the fruit and vegetable industry to extend shelf life is washing with chlorinated water, generally at concentrations ranging between 50 and 200 mg/L, for between 1 and 5 min (Oluwatosin *et al.* 2011).

This study sought to evaluate the effect of three treatments applied prior to commercial packaging (blanching in hot water, washing in chlorinated water, and waxing) on the physical/chemical quality of Margariteño tomatoes kept at room temperature, with a view to identifying low-cost technological alternatives for extending their shelf life without impairing quality attributes.

MATERIAL AND METHODS

Plant material

A total of 160 tomatoes (*Lycopersicum esculentum* cv. “España”) grown at Municipio Antolín del Campo, Nueva Esparta State, Venezuela, were harvested at the green-ripe stage. Tomatoes were similar in size, shape and appearance, and displayed no visible signs of bruising or other damage.

Pre-packaging treatments and post-harvest storage

Tomatoes were transferred to the Food Technology Research Laboratory at the Universidad de Oriente, where they were divided into four groups of 40, to each of which one of the following pre-packaging treatments was applied: (1) blanching in hot water (60ºC) for 30 s; (2) washing in chlorinated water (150 mg/L sodium hypochlorite (NaOCl) solution) for 5 min at 2ºC, pH 7.5, followed by rinsing and absorption of excess surface water using clean paper towels; (3) waxing of the peduncle area with commercial paraffin wax (Rebain Internacional®, Caracas, Venezuela); and (4) untreated controls.

Individual tomatoes were then weighed on an electronic balance (0–210±0.001 g; model C-600-SX, Cobos, Barcelona, Spain) and placed in individual 0.5 mm-thick colorless PET containers measuring 15 x 10 x 8 cm; three 5 mm holes were made in each side of the container (including lid and bottom) for ventilation purposes. Once packaged and coded, tomatoes were stored at room temperature (30°C, 90% RH), in order to simulate the post-harvest storage conditions prevailing in Venezuela. The product was kept under these conditions throughout the trial period; three samples for each of the four treatments were drawn every 72 h (until day 9) and thereafter every 48 h (until the product showed evident signs of deterioration) for physical and chemical analysis.

Physical and chemical analysis

Skin or external color values (L^*, a^* y b^*) were individually measured at the equator of each fruit, turning it 90º between measurements, using a Minolta Chroma Meter CR-400 (Minolta Corporation, Ramsay, NJ, USA). Chroma (C^*) and hue angle (h^*) were calculated as (a^*^2 + b^*^2)^(1/2) and $\tan^{-1}$ (b^*/a^*), respectively. Illuminant C and 2-degree standard observer measurements were made in all cases. The four measurements obtained per fruit for each color parameter tested were averaged.

Titratable acidity, pH and soluble solids content were determined following Flores *et al.* (2009). All measurements were made in triplicate.

To determine maximum shear force, tomatoes were cut longitudinally into 3 equal parts. Samples were then assayed using a Warner-Bratzler shearer (Salter, Manhattan, Kansas, USA) following Ferreira *et al.* (2006); head speed was 200 mm/min. Values for each of the three samples were averaged to provide the maximum shear force (N).

Weight losses during post-harvest storage were determined by measuring changes in weight using the same electronic balance (Nasrin *et al.* 2008, Mejía *et al.* 2009).

Statistical analysis

A multifactorial analysis of variance was performed for quality-related parameters, using post-harvest storage time (0-11 days) and treatments as factors. Means were compared using Duncan's multiple range test at $p = 0.05$. All data were analyzed using the Statgraphics Centurion XV software package (StatPoint Inc., Warrenton, Northern Virginia, USA).

RESULTS AND DISCUSSION

Due to evident signs of deterioration in all groups, analysis of control-group tomatoes continued until day 11 of post-harvest storage, while for tomatoes blanched in hot water and those washed in chlorinated water, tests continued until day 13 of storage (data not shown), and waxed tomatoes were tested until day 19 (data not shown).

Color changes

Average values for L^*, a^*, b^*, C^* and h^* in tomatoes subjected to the different pre-packaging treatments throughout storage at room temperature are shown in Table 1. In all groups, a significant (p < 0.05) decrease in L^* was recorded over the storage period, tomatoes becoming darker during storage at room temperature. At 3, 6, 9 and 11 days' storage, statistically-significant (p < 0.05) inter-group differences were noted for average L^* values, which were highest in waxed tomatoes, followed by tomatoes washed in chlorinated water, blanched tomatoes, and finally untreated controls. The latter displayed the lowest values for luminosity throughout storage.

Similar results have been reported by Núñez (1996) and Cantwell (2004), who note that luminosity decreases during ripening and post-harvest storage, and tomatoes acquire an intense red color. According to Kantola and Helén (2001), these changes in color during ripening are due mainly to the conversion of chloroplasts to chromoplasts. During the early stages of ripening, chloroplast thylakoid membranes, starch granules and chlorophyll are degraded, and new carotenoid pigments accumulate in plastidia, including β-carotene and lycopene, which are responsible for the orange and red coloring, respectively, of tomatoes.

Values for a^* increased in all groups during storage, i.e. tomatoes tended to become less green and more red during storage at room temperature, a finding also reported by Kantola and Helén (2001), who noted an increase in a^* from the start of ripening. After 3 days' storage, waxed tomatoes displayed significantly (p < 0.05) lower a^* values than tomatoes washed in chlorinated water, and both groups had significantly (p < 0.05) lower a^* values than controls and tomatoes blanched in hot water; values for the latter groups did not differ significantly ($p > 0.05$). At 6, 9 and 11 days, inter-group differences were in all cases significant ($p < 0.05$), the lowest value being found for waxed tomatoes followed by those washed in chlorinated water, blanched tomatoes, and finally untreated controls, the latter displaying the highest a^* values throughout storage.

Mejía *et al.* (2009) evaluated color changes in waxed "Charleston" tomatoes during post-harvest storage, first at temperatures of between 5 and 12°C, sampling at 5, 10, 15 and 20 days, and then at 22°C, sampling at 3, 6, 9 and 12 days. They found that a^* values increased during ripening, both in waxed and untreated tomatoes, the increase being more marked during the first 6 days of storage at 22°C; this is directly related to the change in skin color from green to red, attributable to chlorophyll loss and lycopene synthesis, the latter taking place more slowly in waxed than in untreated tomatoes. These results agree with those of the present study, except that here the speed of increase in a^* values remained virtually constant throughout storage.

Control tomatoes and blanched tomatoes displayed a decrease in b^* values, i.e. a progressive loss of yellow coloring, during storage; by contrast, waxed tomatoes and those washed in chlorinated water recorded an increase in b^* values until 6 days' storage, indicating a yellower coloring, while after 9 days' storage, values fell as in other groups. At 9 and 11 days, b^* values for waxed tomatoes were significantly higher ($p < 0.05$) than those for other groups, followed by tomatoes washed in chlorinated water, blanched tomatoes, and finally controls, which always displayed the lowest values.

Begun and Brewer (2001) report that the immersion of "Bell Roma" tomatoes in water at 100ºC for 4 min prompts a fall in L^* and an increase in a^* and b^*, i.e. that blanching gives rise to redder and yellower tomatoes. A similar trend was observed here for

*L** and *a** in blanched tomatoes, although not for *b**, perhaps because in the former study tomatoes were treated at the early-ripening stage, rather than the green-ripe stage.

Dilmaçünal *et al.* (2011) found that waxing of "Bandita" tomatoes using a mineral-oil spray, followed by 20 days' storage at 20°C, had no significant effect on final *L**, *a** and *b** values with respect to controls. However, color changes associated with ripening took place more quickly in untreated controls, as they did here.

Values for *C** at the start of the experiment (time 0) displayed no significant ($p <$ 0.05) inter-group differences. However, at 3 and 6 days' storage, *C** values were significantly lower in controls than in blanched tomatoes, whilst values for waxed tomatoes and those washed in chlorinated water were significantly higher; no significant difference was recorded between these two groups. By 9 and 11 days' storage, significant differences were observed for all groups, the lowest values for *C** being recorded in waxed tomatoes, followed by those washed in chlorinated water, blanched tomatoes, and finally untreated controls, which displayed the highest values.

Begun and Brewer (2001) found that blanching of "Bell Roma" tomatoes in water at 100ºC for 4 min prompted an increase in *C** from 19.79 to 44.04. This trend was also noted here in blanched tomatoes, though only from day 3 of storage onwards. Cantwell (2004) found that *C** values fluctuated during ripening: an initial decrease as the color changed from green-ripe to pink-orange was followed by an increase as tomatoes took on an orange-red coloring; values then fell again as the color changed to dark red. Here, the initial drop and subsequent rise in *C** values was recorded for controls and blanched tomatoes, whereas the behavior of tomatoes washed in chlorinated water and waxed tomatoes might be better described as rise-fall-rise (data not shown), reflecting the yellowish tone at the start of storage, which prompted a certain lack of color uniformity. No final decrease in C^* values was recorded here, perhaps due to the initial ripeness of the tomatoes.

Controls and blanched tomatoes displayed a significant ($p < 0.05$) increase in h^* values from day 0 to day 3, thenceforth decreasing. In tomatoes washed in chlorinated water and waxed tomatoes, values dropped over the first 3 and 6 days of storage, respectively; thereafter, values rose and fell again, matching the trends observed for b^*.

Cantwell (2004) has reported that h^* values decline during ripening and also during post-harvest storage, as tomato color changes from yellowish-green to reddish-orange. Here, h^* values fluctuated in all groups, tending to decline towards the end of storage.

According to Artés and Artés (2007), ripening during the climacteric is accompanied by rapid development of green coloring, subsequent degradation of chlorophyll and the appearance of orange and red hues. They note, moreover, that the tomato's red color is due to the replacement of chlorophyll by carotenoid pigments, and particularly to an increase both in lycopene, the most abundant specific carotene in red, yellow and orange varieties, and in xanthophylls as chloroplasts are converted into chromoplasts. The synthesis of yellowish pigments is subsequently masked by massive accumulation of reddish pigments.

The formation of yellow and red compounds during the tomato climacteric accounts for fluctuations in h^* values in the course of post-harvest storage, which were greater in waxed tomatoes and those washed with chlorinated water than in the other groups.

Behavior of physical/chemical quality parameters

Mean values for titratable acidity, pH, soluble solids content, maximum shear force, and weight loss in Margariteño tomatoes subjected to different pre-packaging treatments during storage at room temperature are shown in Table 2.

In all groups, there was a significant ($p < 0.05$) decline in titratable acidity over the storage period. However, all three pre-packaging treatments delayed the decline, which is characteristic of ripening reactions during storage; waxing was found to be the most effective treatment for this purpose.

The fall in titratable acidity is due to the metabolic activity of horticultural products during ripening, when intense enzyme activity prompts a complex series of overlapping, feedback-driven metabolic changes, leading to the conversion of stored organic acids into sugars, which will be consumed during cell respiration (Badui 2006).

Akbudak *et al.* (2007), in an investigation of the effects of blanching at 54ºC for 5 min on titratable acidity in “Alona” and “Naomi” tomatoes during refrigerated storage, also found that acidity values fell more rapidly in untreated controls than in the blanched group. They noted that the decline in titratable acidity during storage is due to the utilization of acids in respiration and other physiological processes.

In all groups except waxed tomatoes, pH values increased during storage at room temperature, as titratable acidity values fell. Similar findings are reported by Babitha and Kiranmayi (2010), who noted that the pH of tomatoes stored at room temperature rose from 3.61 (day 1) to 6.0 (day 24). In the present study, pH values in waxed tomatoes decreased over the first 6 days of storage, despite the fall in titratable acidity, thereafter, values rose as in other groups.

Berbesí *et al.* (2006) suggest that the rise in pH may be due to the transformation of stored organic acids in cell vacuoles into sugars which are used for respiration; this prompts a decline in the acidity of the medium and therefore an increase in pH. Yet here pH values initially fell in waxed tomatoes despite that decline in acidity.

Barco *et al.* (2009) have reported a drop in pH in waxed bananas over the first two days of storage, followed by the increase characteristic of ripening. This initial drop in values was not recorded either in controls or in bananas treated with a starch solution. This would suggest that waxing may lead to the accumulation of gases affecting pH but not titratable acidity (acids are neither synthesized nor degraded), since the latter displayed the constant decrease associated with ripening.

Contreras *et al.* (2008) coated oranges with chitosan, stored them at 20°C and measured internal CO_2 and O_2 by gas chromatography; they found an increase in CO_2 and a decrease in O_2 levels with respect to untreated controls. This would confirm the earlier assumption that the waxing of tomatoes prompts an initial drop in pH due to CO_2 accumulation, which does not affect titratable acidity.

An initial increase in soluble solids content was observed in all groups, until 6 days (controls), 9 days (blanching and washing in chlorinated water) and 13 days (waxing); thereafter, values fell (data not shown for waxed tomatoes). In waxed tomatoes, there was no significant differences in average soluble solids content between days 0 and 3 or between days 3 and 6.

According to the Organization for Economic Cooperation and Development (OECD) (1998), during the ripening of horticultural crops, nutrients in the form of starch are converted into sugars, thus prompting an increase in soluble solids content. However, Cordeiro *et al.* (2007) report that this post-harvest increase is not always observed, since the product may no longer contain starch reserves because they were consumed during on-plant ripening. Indeed, as Damasceno *et al.* (2005) have indicated, there may even be a decline in soluble solids content during post-harvest storage due to microbial action, since fungi and bacteria use fruit sugars as a metabolic substrate.

Akbudak *et al.* (2007) report a slower fluctuation in soluble solids content in blanched "Alona" and "Naomi" tomatoes with respect to controls, suggesting that blanching slows down product ripening, a finding also observed in the present study.

Mejía *et al.* (2009) observed an increase in soluble solids content in both waxed and untreated "Charleston" tomatoes during the first 6 days of storage at 22°C; values subsequently fell, as they did here. They note that hydrolysis of starch at the start of ripening would prompt an initial increase, while the subsequent decline could result from an increased respiration rate once the product is fully ripe. These authors found that waxing had no significant impact on soluble solids content, whereas here a significant improvement was observed. This disparity in findings may reflect the differing degree of ripeness at treatment application.

Dilmaçünal *et al.* (2011) report that waxed "Bandita" tomatoes displayed a soluble solids content of 4.58% after 16 days' storage, compared to 4.88% for untreated controls, confirming that waxing is an effective technique for slowing down the decline in soluble solids content during ripening. These authors suggest that a lower respiration rate prompts a reduction in the synthesis and use of metabolites, giving rise to a lower soluble solids content.

Tomatoes in all groups displayed a statistically-significant ($p < 0.05$) reduction in maximum shear force (N) during storage at room temperature, indicating a deterioration in texture. Values at day 0 ranged between 11.5 and 12.3 N. Significant inter-group differences in maximum shear force values were observed at 6, 9 and 11 days of storage; the highest values were displayed throughout the study by waxed tomatoes, followed by blanched tomatoes, tomatoes washed in chlorinated water, and finally controls.

A number of studies report a decrease in tomato firmness during post-harvest storage. Kantola and Helén (2001), in a study of “Espero-I class” organic tomatoes packed in biodegradable plastic film and stored at 11ºC, found that firmness dropped from an initial 4.3 to 2.6 N/mm after 22 days’ storage.

During ripening, softening is caused by changes in the structure of cellulose, hemicellulose and pectin, the main constituents of plant cell walls (Kantola and Helén 2001). Artés and Artés (2007) suggest that softening in tomatoes during ripening is due to the depolymerization of cell-wall pectins and of the parenchymal middle lamella, prompted largely by the action of a number of polysaccharide hydrolase enzymes; the most abundant of these, polygalacturonase, is the main cause of depolymerization.

Akbudak *et al.* (2007) evaluated the efficacy of blanching as a means of slowing down the decrease in firmness of “Alona” and “Naomi” tomatoes during storage, noting that blanching either directly inhibits pectinesterase and polygalacturonase activity, which commonly cause post-harvest softening of fruits, or blocks the synthesis ethylene, which regulates the activity of these enzymes.

Dilmaçünal *et al.* (2011) reported that waxing reduced the loss of firmness in “Bandita” tomatoes during storage with respect to untreated controls. Their results, similar to those obtained here, suggest that waxing is an effective way of limiting loss of tomato firmness during storage.

Tomatoes in all groups exhibited a significant increase in weight loss during post-harvest storage. After 11 days’ storage at room temperature, control-group tomatoes weighed 5.90% less that at the start; weight loss over that period in tomatoes washed in chlorinated water was 4.27%, compared with 4.09% in blanched tomatoes and 2.95% in waxed tomatoes. Significant inter-group differences were apparent from 3 days’ storage onwards, the greatest weight loss being displayed by control tomatoes, followed by those washed in chlorinated water, blanched tomatoes and, finally, waxed tomatoes.

Kader (2002b) and Barreiro and Sandoval (2006) note that a tomato may lose up to 10% of its weight due to water loss. Other studies (Kantola and Helén 2001, Hakim *et al.* 2004, Akbudak *et al.* 2007) report a tendency towards weight loss of around 5%-6% during post-harvest storage at low temperatures. They have also found that application of treatments similar to those tested here reduced weight loss to around 4%-5%, as well as delaying the onset of weight loss with respect to untreated controls. Kantola and Helén (2001) reported weight loss of between 1.7% and 2.7% for waxed "Espero-I class" tomatoes stored at 11ºC and 80% RH.

Hakim *et al.* (2004), in a study of sliced tomato stored in refrigerated conditions (1°C; 90% RH) observed weight loss of between 1.0% and 1.8% after 10 days' storage. Akbudak *et al.* (2007) found that blanching "Alona" and "Naomi" tomatoes reduced weight loss during refrigerated storage (6°C; 90% RH) to 8.19% after 28 days, whilst weight loss in untreated controls over the same period was 12.40%. Nasrin *et al.* (2008) washed "Lalima" tomatoes for 5 min in water containing 200 ppm chlorine and stored them in ambient conditions (20º-25°C; 70%-90% RH); after 20 days' storage, control tomatoes exhibited a weight loss of 7.49%, compared with 4.90% for those washed in chlorinated water. Mejía *et al.* (2009) found that waxing reduced weight loss in "Charleston" tomatoes by reducing respiration rates, while Dilmaçünal *et al.* (2011) have reported that by 20 days' storage at 20°C; 90% RH, waxed "Bandita" tomatoes had lost around 5% of their weight, compared with 8% for untreated controls.

CONCLUSIONS

Control tomatoes displayed evident signs of deterioration (softening, exudation and wrinkled surface) by 13 days' storage; these signs were observed in blanched tomatoes and tomatoes washed in chlorinated water at 15 days, and in waxed tomatoes at 21 days. In all cases, skin color darkened during post-harvest storage, although in waxed and chlorine-treated tomatoes an increase in yellow coloring was observed over the first 6 days of storage. Titratable acidity and maximum shear force declined, while weight loss and pH increased, during post-harvest storage at room temperature; however, the extent of these changes varied significantly between treatment groups. Waxed tomatoes displayed a decline in pH over the first 6 days of storage. Soluble solids content for all groups increased during the first part of storage, falling thereafter. The results obtained here suggest that waxing, blanching and washing in chlorinated water slowed down the physical/chemical changes associated with ripening, and also delayed the appearance of signs of deterioration. Waxing proved to be the most effective treatment for extending postharvest shelf life from 11 d to 19 d at 30°C and 90% RH.

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TABLE 1.

AVERAGE VALUES FOR L*, a*, b*, C* AND h* IN MARGARITEÑO TOMATOES (*LYCOPERSICUM ESCULENTUM* CV. ESPAÑA) SUBJECTED TO DIFFERENT PRE-PACKAGING TREATMENTS AND POSTHARVEST STORAGE AT ROOM TEMPERATURE.

Storage time (d)	Parameter	Treatment			
		Control	Hot water	Chlorinated water	Wax
0	L^*	$74.53^{n}\pm0.69$	$73.34^{m}\pm0.81$	$75.04^{n}\pm1.49$	$77.30^{p}\pm0.64$
	a^*	$-5.61\ ^{bc}\pm0.42$	$-5.39^{c}\pm0.35$	$-6.06^{a}\pm0.30$	$-5.86^{ab}\pm0.22$
	b^*	$28.48^{k}\pm0.42$	$28.47^{k}\pm0.41$	$28.44^{k}\pm0.35$	$28.43^{k}\pm0.28$
	C^*	$29.03^{hi}\pm0.40$	$28.97^{h}\pm0.43$	$29.08^{hi}\pm0.35$	$29.03^{hi}\pm0.26$
	h^*	$-78.86^{cd}\pm0.88$	$-79.27^{c}\pm0.64$	$-77.97^{e}\pm0.61$	$-78.34^{de}\pm0.48$
3	L^*	$68.37^{i}\pm0.50$	$70.60^{k}\pm0.69$	$72.28^{l}\pm0.43$	$76.25^{o}\pm0.78$
	a^*	$1.06^{f}\pm0.06$	$0.98^{f}\pm0.18$	$-0.98^{e}\pm0.15$	$-3.01^{d}\pm0.09$
	b^*	$23.24^{g}\pm0.41$	$24.49^{h}\pm0.21$	$29.44^{l}\pm0.50$	$29.53^{l}\pm0.38$
	C^*	$23.27^{b}\pm0.40$	$24.51^{d}\pm0.20$	$29.46^{ij}\pm0.50$	$29.68^{j}\pm0.37$
	h^*	$87.38^{q}\pm0.18$	$87.72^{q}\pm0.43$	$-88.10^{a}\pm0.30$	$-84.18^{b}\pm0.20$
6	L^*	$61.62^{g}\pm0.47$	$66.14^{h}\pm0.89$	$69.50^{j}\pm0.77$	$74.60^{n}\pm0.77$
	a^*	$12.50^{k}\pm0.68$	$10.31^{j}\pm0.70$	$7.13^{h}\pm0.56$	$-0.90^{e}\pm0.10$
	b^*	$20.43^{d}\pm0.64$	$22.44^{f}\pm1.13$	$30.41^{m}\pm0.77$	$31.33^{n}\pm0.41$
	C^*	$23.96^{c}\pm0.67$	$24.71^{d}\pm1.04$	$31.24^{l}\pm0.82$	$31.34^{l}\pm0.41$
	h^*	$58.55^{k}\pm1.55$	$65.30^{m}\pm1.90$	$76.82^{o}\pm0.88$	$-88.37^{a}\pm0.17$
9	L^*	$53.44^{d}\pm0.95$	$57.55^{e}\pm0.62$	$58.45^{f}\pm0.85$	$68.53^{i}\pm1.00$
	a^*	$23.39^{n}\pm0.85$	$20.65^{m}\pm0.29$	$12.58^{k}\pm0.50$	$2.13^{g}\pm0.20$
	b^*	$19.37^{c}\pm0.77$	$21.43^{e}\pm0.47$	$25.30^{i}\pm0.66$	$27.43^{j}\pm0.86$
	C^*	$30.37^{k}\pm0.93$	$29.76^{j}\pm0.34$	$28.26^{g}\pm0.63$	$27.52^{f}\pm0.85$
	h^*	$39.63^{h}\pm1.29$	$46.05^{i}\pm0.84$	$63.56^{l}\pm1.10$	$85.55^{p}\pm0.52$
11	L^*	$42.52^{a}\pm0.46$	$48.47^{b}\pm0.61$	$49.29^{c}\pm0.98$	$61.30^{g}\pm0.75$
	a^*	$34.29^{p}\pm0.42$	$27.53^{o}\pm0.67$	$17.50^{l}\pm0.33$	$7.64^{i}\pm0.44$
	b^*	$14.43^{a}\pm1.07$	$16.22^{b}\pm0.47$	$19.44^{c}\pm0.32$	$20.45^{d}\pm0.40$
	C^*	$37.21^{n}\pm0.69$	$31.96^{m}\pm0.57$	$26.16^{e}\pm0.31$	$21.83^{a}\pm0.45$
	h^*	$22.80^{f}\pm1.43$	$30.52^{g}\pm1.05$	$48.00^{j}\pm0.74$	$69.51^{n}\pm1.06$

Arithmetical means of 12 measurements. Different letters for the same parameter indicate significant differences ($p < 0.05$).

TABLE 2.

AVERAGE TITRATABLE ACIDITY (TA), pH, SOLUBLE SOLIDS CONTENT (SSC), MAXIMUM SHEAR FORCE (MSF) AND WATER LOSS (WL) IN MARGARITEÑO TOMATOES (*LYCOPERSICUM ESCULENTUM* CV. ESPAÑA) SUBJECTED TO DIFFERENT PRE-PACKAGING TREATMENTS AND POSTHARVEST STORAGE AT ROOM TEMPERATURE.

Storage time (d)	Parameter	Treatment			
		Control	Hot water	Chlorinated water	Wax
0	TA* (% citric acid)	$0.8^{m}\pm0.01$	$0.80^{lm}\pm0.02$	$0.79^{jkl}\pm0.02$	$0.80^{klm}\pm0.02$
	pH*	$3.94^{bc}\pm0.04$	$3.94^{bc}\pm0.06$	$3.96^{cd}\pm0.03$	$3.94^{bc}\pm0.03$
	SSC* (°Brix)	$5.4^{bc}\pm0.1$	$5.3^{ab}\pm0.1$	$5.4^{bc}\pm0.1$	$5.4^{bc}\pm0.1$
	MSF* (N)	$12.3^{g}\pm0.7$	$11.5^{f}\pm0.7$	$12.3^{g}\pm0.7$	$11.6^{f}\pm0.5$
	WL** (%)	$0.00^{a}\pm0.00$	$0.00^{a}\pm0.00$	$0.00^{a}\pm0.00$	$0.00^{a}\pm0.00$
3	TA* (% citric acid)	$0.74^{f}\pm0.01$	$0.77^{hi}\pm0.02$	$0.78^{ijk}\pm0.01$	$0.78^{hij}\pm0.02$
	pH*	$4.04^{ef}\pm0.10$	$4.02^{ef}\pm0.02$	$3.99^{de}\pm0.02$	$3.88^{a}\pm0.10$
	SSC* (°Brix)	$5.9^{gh}\pm0.2$	$5.7^{f}\pm0.1$	$5.6^{de}\pm0.2$	$5.4^{bc}\pm0.3$
	MSF* (N)	$10.6^{e}\pm0.7$	$10.5^{e}\pm0.3$	$10.6^{e}\pm0.7$	$11.3^{f}\pm0.9$
	WL** (%)	$1.66^{e}\pm0.06$	$1.13^{c}\pm0.02$	$1.47^{d}\pm0.01$	$0.95^{b}\pm0.02$
6	TA* (% citric acid)	$0.69^{e}\pm0.01$	$0.75^{fg}\pm0.01$	$0.76^{gh}\pm0.01$	$0.75^{fg}\pm0.01$
	pH*	$4.04^{ef}\pm0.06$	$4.06^{f}\pm0.03$	$4.02^{ef}\pm0.01$	$3.87^{a}\pm0.01$
	SSC* (°Brix)	$6.3^{k}\pm0.1$	$5.9^{gh}\pm0.2$	$6.0^{hi}\pm0.0$	$5.5^{cd}\pm0.3$
	MSF* (N)	$7.5^{c}\pm0.4$	$10.5^{e}\pm0.4$	$9.0^{d}\pm0.7$	$11.4^{f}\pm0.4$
	WL** (%)	$2.81^{i}\pm0.11$	$2.22^{g}\pm0.03$	$2.65^{h}\pm0.04$	$1.83^{f}\pm0.04$
9	TA* (% citric acid)	$0.65^{d}\pm0.01$	$0.70^{e}\pm0.03$	$0.69^{e}\pm0.02$	$0.70^{e}\pm0.02$
	pH*	$4.21^{h}\pm0.08$	$4.11^{g}\pm0.01$	$4.13^{g}\pm0.05$	$3.91^{ab}\pm0.03$
	SSC* (°Brix)	$6.0^{hi}\pm0.2$	$6.2^{jk}\pm0.1$	$6.2^{jk}\pm0.1$	$5.9^{gh}\pm0.1$
	MSF* (N)	$6.0^{b}\pm0.4$	$9.4^{d}\pm0.5$	$7.0^{c}\pm0.0$	$10.5^{e}\pm0.4$
	WL** (%)	$4.02^{m}\pm0.01$	$3.08^{k}\pm0.03$	$3.47^{l}\pm0.03$	$2.23^{g}\pm0.03$
11	TA* (% citric acid)	$0.55^{a}\pm0.03$	$0.62^{b}\pm0.01$	$0.64^{c}\pm0.01$	$0.63^{c}\pm0.02$
	pH*	$4.29^{i}\pm0.01$	$4.14^{g}\pm0.03$	$4.19^{h}\pm0.01$	$3.96^{cd}\pm0.03$
	SSC* (°Brix)	$5.2^{a}\pm0.1$	$5.7^{ef}\pm0.0$	$5.8^{fg}\pm0.1$	$6.1^{ij}\pm0.2$
	MSF* (N)	$5.0^{a}\pm0.4$	$7.0^{c}\pm0.0$	$6.1^{b}\pm0.4$	$9.0^{d}\pm0.4$
	WL** (%)	$5.90^{p}\pm0.03$	$4.09^{n}\pm0.04$	$4.27^{o}\pm0.01$	$2.95^{j}\pm0.06$

*: Arithmetical mean of 9 measurements. **: Arithmetical mean of 3 measurements. Different letters for the same parameter indicate significant differences ($p < 0.05$).