Combined effects of postharvest heat treatment and chitosan coating on quality of fresh-cut mangoes (Mangifera indica L.)

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Summary The influence of heat treatment combined with coating on sensory quality, physico-chemicals characteristics (firmness, colour, pH, titratable acidity, total soluble solids and total carotenoids content) and microbiological quality of fresh-cut mangoes were studied. Whole mangoes (Mangifera indica cv ‘Tommy Atkins’) were subjected to hot water dipping (HWD) at 50 °C for 30 min and cooled for 15 min. Heated and unheated fruits were minimally processed and mango cubes were coated with chitosan solution (0.25% w/v) dissolved in 0.5% (w/v) citric acid, and stored for 9 days at 6 °C under ambient atmosphere. This study showed that both HWD 50 °C for 30 min and chitosan coating, either alone or combined, did not affect the taste and the flavour of mangoes slices. The chitosan coating combined with HWD or not inhibited the microbial growth for 9 days at 6 °C. Indeed chitosan coating was used for his antimicrobial proprieties. HWD 50 °C for 30 min was the beneficial treatment to maintain firmness and colour during 9 days at 6 °C.

Keywords Chitosan coating, fresh-cut mangoes, heat treatment, shelf-life.

Introduction With a global production exceeding 33 million tons in 2007, mango fruit (Mangifera indica L., Anacardiaceae) is one of the most important tropical fruit (FAOSTAT, 2009). Mango is a climacteric tropical fruit with a high nutritional value by its wealth of antioxidants (total carotenoids and vitamin C). Fresh-cut mango is a very interesting product to attend the increasing demand for fresh-cut fruits which led to a dynamic growth in sales and new market opportunities for the fresh produce sector.

However, fresh-cut fruits and vegetables are highly perishable due to cut-damaged surface, exposed tissues and availability of cell nutrients to pathogenic organisms (Soliva-Fortunay & Martínez-Belloso, 2003; Charles et al., 2008). The typical response of mango fruit to the process is softening and decrease in overall appearance by browning of the cut surface (Plotto et al., 2004). That is why several methods have been applied to improve the storability of this fruit.

Heat treatment is one of the postharvest treatments used to extend the shelf-life of whole and fresh-cut fruits and vegetables (Lurie, 1998). Several researchers reported that heat treatment improved the firmness and avoided the browning of fresh-cut apples (Kim et al., 1993; Barrancos et al., 2003) and reduced the respiration rate of fresh-cut melon (Lamikanra et al., 2005). Our previous work have shown that a hot water dipping (HWD) of 50 °C for 30 min applied on whole ‘Keitt’ mangoes before the process maintained the firmness and the colour of the fresh-cut product (Djioua et al., 2009).

Edible coatings are also promising to improve the quality and extend the shelf-life of fresh-cut products. They act as barriers to water loss and gas exchange by creating a micro-modified atmosphere around the product (Baldwin et al., 1995; Li & Barth, 1998). Edible coating was investigated as a mechanism to apply a thin layer of protective material to the surface of the fruit (or vegetable) with the objective of replacing the natural protective tissue. Dipping into the coating solution is the commonly used method for fruits and vegetables. Commodities are directly dipped into the coating formulations, drained and dried, whereby a thin membranous film is formed over the commodity surface.
Heat and chitosan effects on fresh-cut mangoes T. Djoua et al.

Chitosan is a natural polymer, nontoxic and biodegradable, derived by deacetylation of chitin [poly-\(\beta-(1 \rightarrow 4)\)-N-acetyl-D-glucosamine] which is the second most abundant natural biopolymer after cellulose (Shahidi et al., 1999). It has been documented to possess a film-forming property for use as edible films or coating (No et al., 2007). Chitosan has attracted attention as a potential food preservative of natural origin due to its antimicrobial activity against fungi, yeast and bacteria (Sagoo et al., 2002) and can improve the storability of perishable foods by modifying the internal atmosphere as well as decreasing the transpiration losses (El Ghaouth et al., 1991; Zhang & Quantick, 1997). Chitosan has been used to maintain the quality of postharvest whole fruits such as kiwifruit (Du et al., 1997), apples (Ippolito et al., 2000), litchi fruit (Zhang & Quantick, 1997), citrus (Chien et al., 2007a) and mango (Jitareerat, 2007; Wang et al., 2007). Additionally, the advantageous effects of chitosan were investigated on fresh-cut fruits such as strawberries (Devlieghere et al., 2004), litchi (Dong et al., 2004) and mango (Plotto et al., 2004; Freire et al., 2005; Chien et al., 2007b).

The present study investigated a possible combined effect of a hot water treatment (50 °C for 30 min) applied to the whole fruit and a chitosan coating applied after the fresh-cut process on the quality and the shelf-life of fresh-cut mangoes.

Materials and methods

Plant material

This experiment was carried in Embrapa Food Technology (Rio de Janeiro State, Brazil). Mango fruits (Mangifera indica L cv. ‘Tommy Atkins’) were bought at the local wholesale fruit market and immediately brought to the laboratory. Fruits were selected for their uniformity, weight (~0.5 kg per mango) and absence of damage or infection. Before the experiment, fruits were ripened at 25 ± 1 °C for 7 days to an average of firmness and colour parameters of about 0.6 N, \(L^* = 57\) and \(b^* = 37\), respectively.

Fresh-cut process and treatments

Ninety fruits were washed in chlorinated water (100 ppm sodium hypochlorite) for 10 min and were divided on two groups. The first one was immersed in hot water bath for 30 min at 50 °C (HWD) and the other one was used as a control (Control). Heated fruits were then cooled in water at 17 °C for 15 min. Then, all fruits were hand peeled, diced into cubes, washed in 10 ppm sodium hypochlorite for 1 min and strained. Cubes of mango from heated and unheated fruits were dipped for 2 min into either distilled water (Control and HWD) or a solution of 0.25% Chitosan (Dip, HWD + Dip). Then, samples were placed in a 0.5 L polyethylene terephthalate plastic tray (~100 g per tray). Thirty-two trays per treatment were stored under air at 6 °C for 9 days.

Chitosan solution (0.25%, w/v) was prepared by dissolving 0.25 g of chitosan powder (deacetylation degree of 85–90%; MW: 340 kDa; Viscosity < 200 mPa s, Polymar Ind., Brazil) in 100 mL of 0.5% anhydrous citric acid (Isofar) in distilled water with continuous agitation and under heating (70 °C for 15 min).

Quality analysis

For quality analysis, five trays from each treatment were removed for sensory evaluation, two trays for physical analysis (firmness and colour), three trays for biochemical analysis (total soluble solids, pH, titratable acidity, total carotenoids) and one tray for microbiological analysis at every sample interval.

Sensory evaluation and intent of purchase estimation of minimally processed mangoes

The sensory analysis was carried out as defined by the Brazilian Association of Technical Standards (ABNT, 1993). The sensory quality was evaluated by visual appearance, odour/aroma, texture and flavour (aromatic, taste). Samples of fresh-cut mangoes were presented at random to sixty panellists for sensory evaluations. They were rated on a nine-point hedonic scale and the acceptability increased with the numerical value (9, like extremely; 7, like moderately; 5, neither liked; 3, moderately liked and 1, poor). The same panellist indicated their intend to purchase the product using a seven point scale (7, definitely buy; 6, certainly buy 5, probably buy; 4, may/may not be buy; 3, probably would not buy; 2, certainly not buy; 1, definitely not buy). These analysis was carried out after 1 and 7 days of storage.

Firmness measurements

Instrumental analysis of firmness was carried out with TA-TX 2 equipment; model TA-Hdi with a probe of 2 mm diameter. The penetration depth was about 5 mm and the applied force used was 0.25 N. For each condition, firmness measurements were taken for five samples per tray and the results were expressed as force in Newton (N) and were carried out at 0, 3, 6 and 9 days.

Colour

The colour characteristics were assessed using a computer S & M model SM-4-CH in the Hunter system to determine \(L^*\) value (lightness), \(a^*\) value (greenness or redness) and \(b^*\) value (blueness or yellowness) of mango cubes. The instrument was calibrated with a white
standard tile: \( L^* = 90.21, a^* = -2.36 \) and \( b^* = 1.39 \). 
\( \Delta E^* \) (Euclidean distance between two colour points) was calculated as the root mean square of the differences in individual \( L^*, a^* \) and \( b^* \) value [i.e. \( \Delta E^* = (\Delta L^*^2 + \Delta a^*^2 + \Delta b^*^2)^{1/2} \)]. \( \Delta L^*, \Delta a^* \) and \( \Delta b^* \) were obtained as differences in \( L^*, a^* \) and \( b^* \) values of samples on any given day from those measured on the first day (values are the mean of five samples per tray at each time). For each condition, colour measurements were carried out at days 0, 3, 6 and 9.

**Extraction and analysis of total carotenoids**

Total carotenoid content was measured using the method described by Rodriguez-Amaya (2001) with some modifications. Four grams of mixed mango sample (from each tray used for biochemical analysis) were homogenised in mortar with the same amount of Celite\textsuperscript{TM} and ground with cold pure acetone (extractor of pigment) until the residue becomes colourless. Then, the homogenate was filtered under suction through filter. The mortar, pestle and the residue were rinsed with acetone and the extract was transferred to a separator funnel. Petroleum ether (30 mL) was added to the extract and rinsed with distilled water about six times to remove acetone. Carotenoids were collected from ether-real extract and then passed through a glass funnel containing anhydrous sodium sulphate. The quantification was carried out by spectrophotometry at 453 nm and petroleum ether was used as a blank sample. Total carotenoids concentration was expressed as mg per 100 g fresh weight.

**Total soluble solids, titratable acidity and pH**

From each tray, juice samples were prepared by thoroughly mixing mango cubes in a blender. Total soluble solids (TSS) were carried out using an electronic refractometer Pr-101 (Atago, Japan) and expressed as percentage. pH was analysed on the juice by a pH meter. Acidity was determined by titration of mango juice with 0.1 \( \text{NaOH} \) to pH 8.1 using an automatic titrator (794 Basic Titrinon, Metrohm) and expressed as g of citric acid per 100 g of fresh mango.

**Microbiological quality**

Analysis of aerobic psychrotrophic bacteria and yeast and moulds were carried out according Downes & Ito (2001). About 25 g of mango cubes were diluted with 225 mL of sterile aqueous peptone solution (0.1%, \( \text{w/v} \)) and blended for 1 min in a stomacher. The serial dilutions of this solution were made in sterile saline solution. The media and the conditions used were as follows: Plate Count Agar (PCA) incubated at 7 °C for 10 days for aerobic psychrotrophic bacteria and Dichlor- oran-Rose Bengal-Chloramphenical Agar (DRBC) incubated at 25 °C for 5 days for yeast and mould populations. The microbial population on the fresh-cut mangoes was determined after 1 and 9 days of storage. Results were expressed in colony forming unit per gram (CFU g\(^{-1}\)) and one replicate was used for each treatment and each time of analysis.

**Statistical analysis**

Standard error of mean values was determined from SD and sample size. XLSTAT version 2008.6.08 was used to calculate analysis of variance (ANOVA) with the least significance difference (LSD) test at \( P < 0.05 \).

**Results and discussion**

**Effect of treatments on sensory quality**

Sensory evaluation was planned to be carried out after 1 and 7 days of storage. However, after 7 days, all the samples became unacceptable for consumption and the analysis was not performed.

After 1 day of storage, the results for sensory analysis showed the scores was from 6 to 8 (likely product) without a significant difference between treatments (\( P < 0.05 \), Fig. 1a). This result indicated that the majority of panel (more than 75%) appreciated the samples. Moreover, more than 71% of the

![Image](https://example.com/image1.png)  
**Figure 1** Effect of heat treatment and chitosan coating on sensory quality (a) and the intent to purchase (b) of treated and untreated fresh-cut mangoes after 1 day of storage at 6 °C. Data are mean (\( n = 60 \)) ± SE with mean separation by LSD (\( P < 0.05 \)).
panel (data not shown) intended to purchase all the products by scoring samples from 5 to 6 (probably buy) (Fig. 1b). This result highlighted that HWD 50 °C for 30 min and 0.25% chitosan coating did not change the taste and the flavour of the fresh-cut mangoes as compared to the control. Chien et al. (2007b) have also reported that several compositions of chitosan coating (0.5%, 1%, 2%) did not change the natural taste of ‘Irwin’ sliced mango and delayed the drop in sensory quality during the storage at 6 °C for 7 days. In contrast, other studies have reported that chitosan coating with 0.5% and 0.75% induced an off-flavour to the fresh-cut mangoes (Plotto et al., 2004). All these results suggested the necessity to consider source, purity and interaction of chitosan with the fruit on which is applied as a factor in the coating formulation.

Effect of treatments on firmness

Firmness of fresh-cut mangoes decreased during storage for all conditions except for HWD (Fig. 2). HWD allowed a significant retention of firmness for up to 9 days (P < 0.05). We have previously reported the beneficial effect of HWD 50 °C for 30 min on the firmness of fresh-cut ‘Keitt’ mangoes (Djioua et al., 2009). This study confirms this effect on ‘Tommy Atkins’ mangoes.

Firmness was also influenced by coating. After 3 days, Dip fresh-cut mangoes softened faster than the others with 40% of firmness loss as compared to 9% for control and no loss for HWD and HWD + Dip (Fig. 2). This result suggested that the chitosan coating alone was not enough to maintain the firmness of fresh-cut mangoes during the storage. Thommohaway et al. (2007) have reported that chitosan coating in lower concentration (0.05%, 0.1% and 0.2%) had no effects on firmness of fresh-cut guava. In contrast, Wang et al. (2007) and Zhu et al. (2008) reported that 2% chitosan coating decreased the firmness loss of mango fruit stored at 15 °C. The advantageous effect of the higher chitosan concentration on fruit firmness has also been reported for peach, kiwifruit (Du et al., 1997), ‘Muscott’ tangor (Chien et al., 2007) and strawberry (Hernandez-Munoz et al., 2008). In our experiment, chitosan concentration at 0.25% did not influence the firmness of fresh-cut mangoes. These results underlined again the effect of the concentration of chitosan and indicated that the chitosan concentration about 0.25% did not maintain the firmness of fresh-cut mangoes.

Influence of treatment on colour and carotenoids content

The colour of fresh-cut mangoes strongly influences consumer acceptance. Colour, as evaluated by lightness (L* value) and blue/yellow components (b* value) is displayed in Fig. 3a and b.

Decreasing in L* and b* values during the storage were noticed in all samples. A decrease in L* value, which is evident by the loss of brightness, is an indicator of

Figure 2 Effect of heat treatment and chitosan coating on firmness of fresh-cut mangoes during storage at 6 °C. Data are mean (n = 10) ± SE with mean separation by LSD (P < 0.05). Numbers in parentheses represent the percentage of loss compared to the initial value (day 0) for each condition.

Figure 3 Changes in L* values (a) and b* value (b) in treated and untreated fresh-cut mangoes during storage at 6 °C. Data are mean (n = 10) ± SE with mean separation by LSD (P < 0.05). Numbers in parentheses represent the percentage of loss compared to the initial value (day 0) for each condition.

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browning in fresh-cut fruits (Ganzalez-Aguilar et al., 2008). However, it was observed that HWD allowed to maintain colour during 3 days. This result has been already observed on fresh-cut ‘Keitt’ mangoes (Djioua et al., 2009). Moreover, in Fig. 3, the percentage of colour loss showed that coating decreased the loss on \( L^* \) and \( b^* \) values as compared to control after 6 and 9 days, respectively. Similar results of the effect of chitosan on \( L^* \) values have been reported on strawberries (Hernandez-Munoz et al., 2008) and on fresh-cut rose apple (Worakeeratikal et al., 2007). This result could be explained by the chitosan inhibiton of polyphenol oxidase (PPO) and the peroxidase activity as reported on litchi fruit (Zhang & Quantick, 1997; Ducamp-Collin et al., 2008). At the end of the storage, \( L^* \) decreased by around 35% for control and by around 23%, 16% and 26% for Dip, HWD and HWD + Dip, respectively, as compared to day 0. This result means that the association of Dip with HWD did not exert any additional effect on delaying mango browning and that HWD alone was the most efficient treatment to maintain colour.

An increase in total colour difference \( \Delta E^* \) was observed with storage time indicating the colour change of samples (Table 1). After 3 days, HWD and Dip reduced the overall change in colour when compared to Control and HWD + Dip. After this time, \( \Delta E^* \) increase was higher in control as compared to the other treatments and between day 6 and day 9, \( \Delta E^* \) values were significantly lower with HWD. These results demonstrated the beneficial effect on the colour of each treatment. Freire et al. (2005) reported that chitosan coating allowed a best appearance with a clear yellow colour of fresh-cut ‘Kent’ mangoes stored at 4 \(^{\circ}\)C for 9 days. Moreover, Vargas et al. (2009) have reported that total colour differences (\( \Delta E^* \)) of carrots caused by chitosan coating were relatively lower.

Colour was also determined by pigments composition. In mangoes, carotenoids are responsible for yellow and orange colour and are important lipophilic radical scavengers found in many fruits and vegetables. After 1 day of storage, total carotenoids ranged from 2.9 to 3.3 mg 100 g \(^{-1}\) FW without significant differences between control and treated samples (Table 2). Then, total carotenoid content remained stable during 9 days whatever the treatment. The initial stage of maturity of mangoes could explain this result. To conclude, heat treatments of 50 \(^{\circ}\)C for 30 min and chitosan coating have no effect on the total carotenoids evolution during storage but they induced a significant change on colour parameters (\( L^* \), \( b^* \) and \( \Delta E^* \)).

### Effect of treatment on physico-chemical parameters

Total soluble solids (TSS), pH and TA were analysed. As shown in Table 2 and after 1 day of storage, treatments had no effect on these parameters except for HWD + Dip which resulted in higher TSS level than in control. Then, during the storage and for all treatments, TSS level remained stable for every condition, demonstrating that neither HWD nor chitosan coating have an effect on TSS of fresh-cut mangoes. Similar results for fresh-cut mangoes were reported by Djioua et al. (2009) for heat treatment and by Freire et al. (2005) for chitosan coating. Concerning TA and pH, they remained unchanged for all conditions until day 9. At that time, TA values increased for Control and Dip and pH values decreased only for Dip. As the same, Chien et al. (2007b) found that fresh-cut ‘Irwin’ mangoes have a higher amount of TA after 7 days of storage at 6 \(^{\circ}\)C. Moreover, Campaniello et al. (2008) reported that pH of fresh-cut strawberries seemed to be not influenced by chitosan treatment (1%).

### Microbiological quality

Fresh-cut fruits have their natural microbial flora about \( 10^4-10^5 \) CFU g \(^{-1}\) and typically, products become spoiled once these levels increase to \( 10^7-10^9 \) CFU g \(^{-1}\) (Martinez-Ferrer et al., 2002). The lower pH of fruits is the major factor that influences the composition of their microflora and mould and yeast are the main contaminant that induces visual degradation (Jay, 1996). In fresh-cut products, the cut damaged surface and the availability of cell nutrients provide good conditions for microbes growing and the low temperature of storage (4–6 \(^{\circ}\)C) increase the psychrotrophic bacteria growth. That is why we have analysed the change of mould, yeast and psychrotrophic bacteria and not enterobacteria. Moreover, because logistics parameters, analysis have been performed only after 1 and 9 days of storage.

After 1 day of storage, HWD samples had lower mould and yeast populations than the others. This result could be explained by the results of Ngarmsak et al. (2006) which indicated that mild heat treatments applied at 50 \(^{\circ}\)C for 5 min on mango fruit reduced the risk of contamination of the flesh during processing. After 9 days of storage, all samples remained safe with an average of \( 10^3 \) CFU g \(^{-1}\) for aerobic psychrotrophic bacteria and an average of \( 10^3 \) CFU g \(^{-1}\) for mould and yeast (Table 3). Compared to control, HWD + Dip decreased significantly the proliferation of psychrotrophic

<table>
<thead>
<tr>
<th>( \Delta E^* )</th>
<th>Day 3</th>
<th>Day 6</th>
<th>Day 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>7.9</td>
<td>18.4</td>
<td>25.3</td>
</tr>
<tr>
<td>Dip</td>
<td>5.5</td>
<td>12.6</td>
<td>16.7</td>
</tr>
<tr>
<td>HWD</td>
<td>3.0</td>
<td>8.1</td>
<td>11.4</td>
</tr>
<tr>
<td>HWD + Dip</td>
<td>10.9</td>
<td>6.9</td>
<td>17.1</td>
</tr>
</tbody>
</table>

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bacteria during 9 days (Table 4). These results showed that the antibacterial action of chitosan coating of 0.25% was more effective when applied with heat treatment 50°C for 30 min. On the other hand, results showed that none of the two treatments had an influence on mould and yeast proliferation.

**Conclusion**

Comparing the two treatments, HWD 50°C for 30 min was more effective than chitosan coating (0.25%, w/v) to maintain the firmness and the colour of fresh-cut mangoes during 9 days of storage at 6°C. Chitosan coating (Dip) also avoided the colour change during storage. When combining treatments, the only parameter which was improved is the antimicrobial effect.

Finally, this study underlined the beneficial effect of HWD 50°C for 30 min on fresh-cut ‘Tommy Atkins’ mangoes quality. This result was correlated to previous data obtained on another variety: ‘Keitt mangoes’.

**Acknowledgments**

The authors would like to thank all the staff of the sensory, physical and biochemical, and microbiological laboratories of EMBRAPA Food Technology (Rio de Janeiro, Brazil) for their participation in this study.

**References**


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**Table 2** Effect of HWD and chitosan coating on changes in TSS, TA, pH and total carotenoids content of fresh-cut mangoes during storage at 6°C for 9 days

<table>
<thead>
<tr>
<th>TSS (%)</th>
<th>TA (g 100 g⁻¹ citric acid)</th>
<th>pH</th>
<th>Total Carotenoids (mg 100 g⁻¹ FW)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1-day storage</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>11.87 ± 0.40 Ab</td>
<td>0.19 ± 0.01 Ba</td>
<td>4.65 ± 0.11 Aa</td>
</tr>
<tr>
<td>Dip</td>
<td>12.20 ± 0.69 Aab</td>
<td>0.20 ± 0.04 Ba</td>
<td>4.46 ± 0.13 Aa</td>
</tr>
<tr>
<td>HWD</td>
<td>12.50 ± 0.26 Aab</td>
<td>0.18 ± 0.02 ABA</td>
<td>4.62 ± 0.12 Aa</td>
</tr>
<tr>
<td>HWD + Dip</td>
<td>12.77 ± 0.15 Ba</td>
<td>0.22 ± 0.02 Aa</td>
<td>4.46 ± 0.04 Aa</td>
</tr>
<tr>
<td><strong>3-day storage</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>12.33 ± 0.25 Ab</td>
<td>0.20 ± 0.04 Bab</td>
<td>4.55 ± 0.23 Abc</td>
</tr>
<tr>
<td>Dip</td>
<td>11.93 ± 0.25 AaB</td>
<td>0.23 ± 0.04 ABA</td>
<td>4.38 ± 0.13 Ac</td>
</tr>
<tr>
<td>HWD</td>
<td>13.10 ± 0.17 Aa</td>
<td>0.14 ± 0.02 Bb</td>
<td>4.84 ± 0.08 Aa</td>
</tr>
<tr>
<td>HWD + Dip</td>
<td>13.23 ± 0.38 Aa</td>
<td>0.19 ± 0.00 Aab</td>
<td>4.66 ± 0.07 Aab</td>
</tr>
<tr>
<td><strong>6-day storage</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>11.83 ± 0.64 Ab</td>
<td>0.16 ± 0.06 Ba</td>
<td>4.61 ± 0.29 Aa</td>
</tr>
<tr>
<td>Dip</td>
<td>12.33 ± 0.38 Aab</td>
<td>0.20 ± 0.01 Ba</td>
<td>4.48 ± 0.03 Aa</td>
</tr>
<tr>
<td>HWD</td>
<td>13.13 ± 0.49 Aa</td>
<td>0.17 ± 0.05 ABA</td>
<td>4.66 ± 0.25 Aa</td>
</tr>
<tr>
<td>HWD + Dip</td>
<td>12.63 ± 0.06 Bab</td>
<td>0.22 ± 0.06 Aa</td>
<td>4.38 ± 0.24 Aa</td>
</tr>
<tr>
<td><strong>9-day storage</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>12.30 ± 0.17 Aa</td>
<td>0.30 ± 0.08 Aa</td>
<td>4.30 ± 0.25 Aab</td>
</tr>
<tr>
<td>Dip</td>
<td>12.33 ± 0.21 Aa</td>
<td>0.30 ± 0.07 Aa</td>
<td>4.12 ± 0.16 Bb</td>
</tr>
<tr>
<td>HWD</td>
<td>12.77 ± 0.50 Aa</td>
<td>0.21 ± 0.05 Aa</td>
<td>4.65 ± 0.04 Aa</td>
</tr>
<tr>
<td>HWD + Dip</td>
<td>12.77 ± 0.15 Ba</td>
<td>0.30 ± 0.15 Aa</td>
<td>4.32 ± 0.44 Aab</td>
</tr>
</tbody>
</table>

The results were expressed as means (n = 3) ± SD. Lower case letters in each column: comparison of different treatments at each storage time; upper case letters: evolution of each treatment during storage.


