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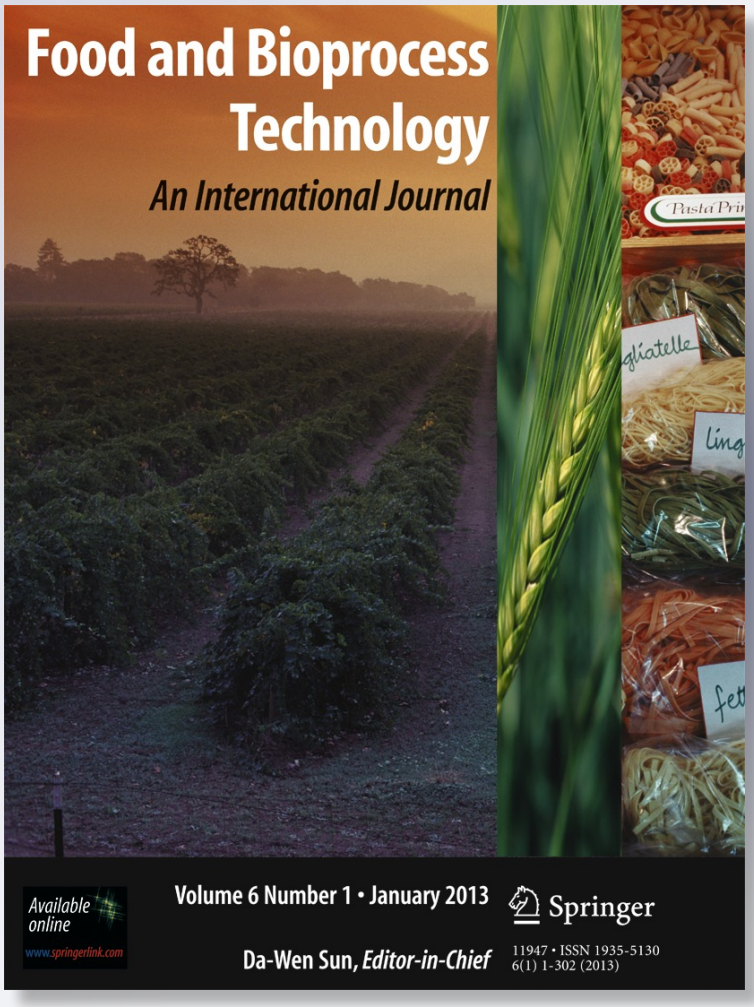

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ORIGINAL PAPER

Effect of Osmotic Dehydration and Pectin Edible Coatings on Quality and Shelf Life of Fresh-Cut Melon

Cristhiane C. Ferrari · Claire I. G. L. Sarantópoulos · Sandra M. Carmello-Guerreiro · Miriam D. Hubinger

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Abstract The aim of this work was to investigate the influence of osmotic dehydration and pectin edible coating on quality parameters of fresh-cut melon. Fruits were osmodehydrated in 40°Bx sucrose solution containing 0.5% calcium lactate or dipped in 0.5% calcium lactate solutions. Then, samples were coated with 1% pectin. Melon pieces dipped in sanitizing solution (nontreated sample) were used as control. Weight loss, respiration rate, firmness, color parameters (lightness, chroma, and whiteness index), sensory acceptance, microbial growth, and structural changes of fruits were evaluated during storage at 5 °C for 14 days. The shelf life of the control sample was limited to 9 days due to microbial growth and sensory rejection, while treated samples showed a shelf life of 14 days. Higher preservation of firmness in coated samples was attributed to the action of calcium salt on melon structure, causing a strengthening of the cell wall. Calcium lactate also inhibited microbial growth along storage, improving microbiological stability of fresh-cut melon. The use of calcium lactate dips and pectin edible coatings hindered weight loss and maintained fruit color characteristics during the storage time. However, these pretreatments probably masked melon taste, reducing the sensory acceptance scores at the end of shelf life study. The combination of osmotic dehydration and pectin coatings was a good preservation alternative for fresh-cut melon, since it improved fruit sensory acceptance, promoting the reduction of product respiration rate, as well as the maintenance of quality parameters during 14 days.

Keywords Melon · Calcium lactate · Polysaccharide-based coatings · Shelf life · Quality · Osmotic dehydration

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Introduction

Changes in the consumers' lifestyle have increased the consumption of tropical fresh-cut products in the world market due to their convenience, quality, freshness, low caloric content, and health benefits, answering the demand for healthy food (Martín-Belloso 2007). Despite their advantages, minimally processed products are more perishable due to tissue injuries during peeling, slicing, and cutting operations. Wounding of fruit tissue induces a number of physiological disorders that need to be minimized in order to obtain fresh-cut products with high quality and nutritional value. The intensification of metabolic activity results in the increase of respiration rate and ethylene production, which accelerates the senescence process, promoting changes in fruit quality parameters and reducing product shelf life (Soliva-Fortuny and Martín-Belloso 2003).

Melon is appreciated due to its sensory characteristics, showing a high commercial value. Fruit production has been increasing, as a result of a very good market in Brazil and abroad. As melons do not show an increase of their

sugar content after harvest, they should be commercialized with a minimum soluble solids content of 11°Bx. However, in an attempt to extend the post-harvest shelf life, melon is frequently harvested before its complete maturation (Alves 2000). Thus, osmotic dehydration can be used in order to improve final fruit solids content. The slight water activity reduction observed during the process, combined with other mild techniques and refrigerated storage, prolongs product shelf life, improving its microbiological stability and maintaining the fresh fruit characteristics (Torreggiani and Bertolo 2001; Rodrigues et al. 2006).

Edible coatings have been employed to reduce the undesirable effects of minimal processing. These coatings create a semipermeable barrier to external elements, promoting a similar effect to the storage under modified atmosphere. Thus, edible coatings may decrease moisture loss, gas exchange, respiration, and oxidative reactions, improving food quality and extending the shelf life of fresh-cut products (Vargas et al. 2008). Pectin is a purified carbohydrate product obtained by aqueous extraction of appropriate edible plant material—usually citrus fruits or apples. Due to their hydrophilic nature, pectin edible coatings exhibit low water vapor barrier, but good oxygen and carbon dioxide barrier properties. Low methoxy (LM) pectins are often used as edible coatings because of their ability to form strong gels upon reactions with multivalent metal cations, like calcium. The incorporation of calcium in the polysaccharide edible coatings reduces their water vapor permeability, making the coatings water-insoluble (Lacroix and Le Tien 2005; Olivas et al. 2007). Furthermore, calcium salts have been employed as a tissue structural preservative, since this ion acts as a cross-linking agent, forming complexes with the cell wall and middle lamella pectin, improving structural integrity and promoting greater tissue firmness (Martín-Diana et al. 2007).

In this context, the purpose of this work was to investigate the effect of osmotic dehydration using calcium lactate as a cross-linking agent and pectin edible coating on quality parameters of fresh-cut melon cubes during storage at 5 °C for 14 days. Weight loss, respiration rate, firmness, color parameters (lightness, chroma, and whiteness index [WI]), sensory acceptance, microbial growth, and structural changes of fruits were evaluated along storage, as well as the gas composition inside the packages.

Material and Methods

Material

Ripe melons (*Cucumis melo* cv. *inodorus*) were used in the experiments. A set of around 25 melons (5 boxes of 13 kg each one) was purchased at a local market (CEASA, Campinas, Brazil). Fruits of uniform size (2,193.2± 157.4 g), with no physical damage were selected, according to the standards for melon, described by the Brazilian Program for Horticulture Modernization (CEAGESP 2004). Ripe fruits from the "yellow" group, "extra" category were chosen, based on their soluble solids content (7–9°Bx), skin color (intense yellow), and flesh color (cream).

Sucrose (Copersucar União, Piracicaba, Brazil) was used as dehydrating agent and calcium lactate (LabSynth, São Paulo, Brazil) was used to preserve melon texture. Peracetic acid (Tsunami 100®, ECOLAB, São Paulo, Brazil) was used as sanitizing agent and low (methyl) ester or LM pectin (GENU® L21102AS-FS) obtained from CPKelco (Limeira, Brazil) was employed in the coating formulations.

Expanded polystyrene (EPS) trays (110×110×30 mm) wrapped with polyvinyl chloride (PVC) stretch film with 20 μm thickness (Goodyear, São Paulo, Brazil), oxygen permeability rate of 8,200 $cm^3\ m^{-2}\ day^{-1}$ (at 25 °C and 101.3 kPa), and water vapor permeability rate of 262 $g\ m^{-2}\ day^{-1}$ (at 25 °C and 90% RH) were used as packaging systems. Approximately 50 g of product (corresponding to nine melon cubes of 20 mm) were placed in each tray.

Methods

Samples Preparation and Processing

Only one independent storage trial was done, which is in agreement with some studies performed with different fresh-cut fruits, such as apple (Qi et al. 2011), mango (Chiumarelli et al. 2011), banana (Bico et al. 2009), peach (Maftoonazad et al. 2008), melon (Oms-Oliu et al. 2008a; Raybaudi-Massilia et al. 2008), pear (Oms-Oliu et al. 2008b), pineapple (Bierhals et al. 2011), and plum (Eum et al. 2009). Experimental treatments were named (1) nontreated fresh-cut melon only dipped in sanitizing solution (control); (2) fresh-cut melon osmodehydrated in 40°Bx sucrose solution containing 0.5% calcium lactate and coated with 1% pectin (OD+coating); and (3) fresh-cut melon dipped in 0.5% calcium lactate solution and coated with 1% pectin (CaDIP+coating).

Minimal processing was carried out at 15 °C, using appropriate personal protection equipment, such as gloves, caps, masks, aprons, and boots. Fruits were washed with tap water and immersed in 80 ppm solution of peracetic acid for 3 min. Melons were then manually peeled and cut into 20-mm cubes with a sharp knife. Samples were dipped again in peracetic acid solution for 3 min more. All the utensils used in the processing were previously sanitized with peracetic acid.

Samples were osmodehydrated in 40°Bx sucrose solution containing 0.5% calcium lactate. These concentrations

were optimized in a previous work (Ferrari et al. 2010). The product/solution mass ratio was 1:10 to avoid significant dilution of the medium and subsequent decrease of the driving force during the process. Fruits and solution (five pieces per flask) were placed in a thermostatic shaker (Model TE 420, Tecnal, Piracicaba, Brazil) and the process was carried out for 30 min under controlled temperature (30 °C) and agitation (120 rpm). These process conditions were established according to some preliminary tests.

Fruits not subjected to the osmotic treatment were dipped in 0.5% calcium lactate solution for 15 min at 15 °C to allow cross-linking between calcium and pectin (Martín-Diana et al. 2007). Pectin solutions (1%) were prepared at 60 °C under magnetic agitation until complete dissolution and then cooled to room temperature.

After the osmotic process or calcium dip treatment, melon pieces were drained to remove excess solution in order to guarantee a better adhesion of coating material to the fruit surface. Osmodehydrated or calcium-dipped samples were immersed in 1% pectin solution for 2 min and drained again at room temperature (15 °C and 80% RH) for 3 h. All the samples were packaged in EPS trays with PVC stretch film and stored in a chamber (BOD TE 391 with temperature control, Tecnal Equipments Ltda., Piracicaba, Brazil) at 5 °C and 80% RH for 14 days. For each treatment, 360 cubes were obtained from approximately 8 fruits, which were randomly distributed in 40 trays containing 9 melon cubes in each one.

Storage Quality Evaluation

Weight Loss Three trays were weighed after the processing (day 1) and along storage (at days 5, 9, and 14). The results were expressed as percentage loss of initial weight.

Respiration Rate Respiration rate was measured by static method in a closed system using an O_2/CO_2 Dual Head Space Analyzer (Model PAC CHECK 325, Mocon, Minneapolis, MN, USA). Nine melon pieces (approximately 50 g) were placed in a 200-ml hermetically sealed glass jar with a silicon septum. They were maintained in a controlled temperature chamber at 5 °C and gas sampling was performed 1 h after closing the jars (Chiumarelli et al. 2010). Respiration rate of the fruits subjected to different treatments were determined in triplicate after 1, 4, 8, 11, and 14 days of storage and expressed in milliliters of CO_2 per kilogram per hour.

Gas Composition The concentrations of O_2 and CO_2 in the headspaces of packages were analyzed using an O_2/CO_2 Dual Head Space Analyzer (Model PAC CHECK 325, Mocon, Minneapolis, MN, USA) in order to verify if the packaging system modified the atmosphere around the product. The gas concentration was measured by inserting the equipment needle through a silicon septum attached to the package surface, as described by Chiumarelli et al. (2010). Three trays per treatment were analyzed after 1, 4, 8, 11, and 14 days of storage.

Firmness Melon firmness was evaluated by puncture tests using a Universal Testing Machine (TA.TX Plus Texture Analyzer, Stable Micro Systems, Surrey, England), according to previous studies carried out with fresh-cut fruits coated with polysaccharides (Oms-Oliu et al. 2008a; Rojas-Graü et al. 2008; Bico et al. 2009). A 3-mm-diameter stainless steel cylindrical probe with a flat end was used. The maximum penetration force (in newtons), defined as the maximum force required to push the probe into the melon sample of 20 mm height to a depth of 8 mm at a speed of 2 mm s^{-1} (Garcia et al. 2010), was employed to determine fruit firmness. Five fruit pieces of each treatment were analyzed after 1, 5, 9, and 14 days of storage and the mean results were reported.

Color The surface color of melon pieces was measured using a Hunter Lab colorimeter (Hunter Associates Laboratory, Inc., Reston, VA, USA), Model Color Quest II, with CIELab scale (L^*, a^*, and b^*), illuminant D65, and 10° observer angle as a reference system. Reflectance-specular included (RSIN) mode, which measures total reflectance, including diffuse reflectance and specular reflectance, was used. Color measurements were expressed in terms of lightness L^* ($L^*=0$ for black and $L^*=100$ for white) and the chromaticity parameters a^* (green [−] to red [+]) and b^* (blue [−] to yellow [+]). Numerical values of L^*, a^*, and b^* parameters were employed to calculate chroma (C^*) and WI, using Eqs. 1 and 2, respectively, according to Raybaudi-Massilia et al. (2008) and Aguayo et al. (2004):

$$C^* = \left(a^{*2} + b^{*2}\right)^{1/2} \tag{1}$$

$$\mathrm{WI} = 100 - \left[(100 - L^*)^2 + (a^*)^2 + (b^*)^2\right]^{1/2} \tag{2}$$

Five cubes per treatment were taken at each sampling time (days 1, 5, 9, and 14) and three readings were made in each sample.

Microbiological Analysis Samples were analyzed in respect to yeast and mold growth, coliforms, and *Salmonella* spp., which were considered the main spoilage microorganisms able to develop in melon. Coliform group and *Salmonella* spp. were only determined at the beginning of storage time in order to evaluate the hygienic conditions of raw material and processing, while yeast and mold counts were evaluated at days 1, 5, 9, and 14. Viable counts were expressed as colony-forming units (CFU) per gram of fruit.

All the analyses were performed in triplicate, according to the methodology of Downes and Ito (2001).

Structural Changes The structural changes of melon tissue were evaluated through light microscopy analysis at days 1, 8, and 14. Samples (~5×3×3 mm) from the fleshy tissue of melons were fixed in 40 $g kg^{-1}$ glutaraldehyde in phosphate buffer (pH 7.0) with 40 $g kg^{-1}$ of added sucrose and dehydrated in a graded ethanol series. The dehydrated samples were embedded in hydroxyethyl methacrylate historesin (Leica Microsystems, Heidelberg, Germany) and sectioned using a rotary microtome (820 Spencer Microtome, American Optical Corporation, New York, NY, USA). Sample sections measuring 10 μm were stained with toluidine blue O (0.5 $g kg^{-1}$) in acetate buffer (pH 4.7) and examined using an Olympus BX 51 light microscope (Olympus Optical Co., Tokyo, Japan) in accordance with Ferrari et al. (2010). For each treatment, two samples from different fruits were used for the microscopic evaluation.

Sensory Analysis Sensory acceptance tests were carried out in a standardized test room after 1, 5, 9, and 14 days of storage. Control and treated samples were presented in completely balanced blocks, in a monadic form, using white plates labeled with three-digit random number codes. Appearance, aroma, flavor, texture, and overall impression of fruit samples were evaluated by 35 melon consumers, representative of the target public, using a 9-cm unstructured hedonic linear scale anchored with "I dislike very much" on the left side and "I like very much" on the right side. An average score of 4.5 was considered the acceptability limit and the consumers' purchase intention was also evaluated (Meilgaard et al. 1999). Sensory analysis was in agreement with the standards established by the Research Ethics Committee of the Faculty of Medical Sciences of the State University of Campinas—UNICAMP.

Statistical Analysis

The results were statistically evaluated by analysis of variance, using the software Statistica® 8.0 (StatSoft, Inc., Tulsa, OK, USA), in order to determine significant differences among the samples (control, OD+coating, and CaDIP+coating). Mean separation was performed with the Tukey procedure at $p \leq 0.05$.

Results and Discussion

Weight Loss

Weight loss of melon cubes throughout storage is presented in Fig. 1. A significant increase of weight loss was observed during shelf life study, which can be related to water loss that resulted from surface water evaporation respiration and transpiration and also to the wounding stress during minimal processing operations.

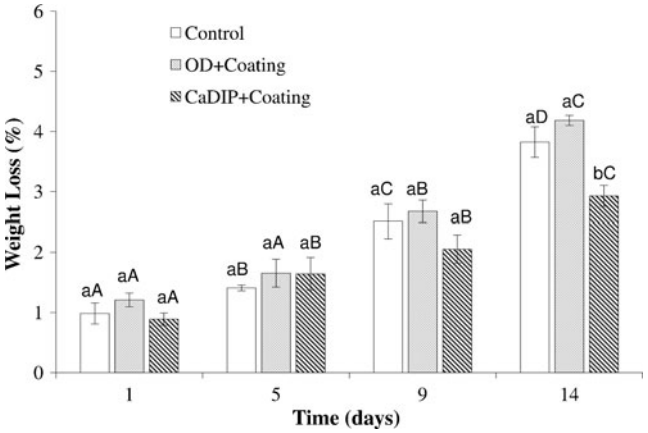

Fig. 1 Weight loss of fresh-cut melon during storage at 5 °C. *Control* nontreated fresh-cut melon, *OD+coating* fresh-cut melon osmodehydrated in 40°Bx sucrose solution containing 0.5% calcium lactate and coated with 1% pectin, *CaDIP+coating* fresh-cut melon treated with 0.5% calcium lactate solution and coated with 1% pectin. *Different letters* indicate significant differences at $p \leq 0.05$ (*small letters* among different treatments for the same time, *capital letters* among different times for the same treatment). *Bars* represent the mean standard error

No statistical differences were verified among the samples up to ninth day. However, at the end of storage, pretreated fruits with calcium lactate (CaDIP+coating) showed lower weight loss values (<3%), indicating that the use of calcium lactate prior to the application of pectin edible coating was effective in reducing weight loss along storage. According to Lamikanra and Watson (2004), calcium salts are efficient in the maintenance of cell integrity due to the cross-linking of calcium ions and pectin molecules of the fruit cell wall, showing a great influence on the reduction of weight loss of minimally processed fruits. Moreover, at lower temperatures (4 °C), these intermolecular interactions are stronger, forming a protective layer that remains intact during storage. Therefore, the possible formation of a moisture barrier around the melon surface due to the combined action of calcium lactate, pectin edible coating, and refrigerated storage probably hindered sample dehydration throughout time. In a similar study, Olivas et al. (2007) verified a significant decrease of weight loss in fresh-cut apple coated with alginate, in comparison to uncoated fruit. The authors attributed this behavior to the ability of calcium to cross-link alginate, making the coating insoluble and improving its moisture barrier properties.

Weight loss of control and OD+coating samples were higher at the 14th day (around 4%), meaning that the beneficial effect of calcium on the reduction of fruit weight loss was not observed in the OD+coating sample at the end

of storage time (Fig. 1). In this case, it is possible that the sugar layer on the fruit surface of osmodehydrated samples may have intensified the dehydrating effect along the storage time, contributing to the partial dissolution of pectin coating, which is a hydrophilic material, at the end of shelf life study.

During the osmotic dehydration of apples using glucose solutions (50%) and calcium lactate (0–2%), Castelló et al. (2009) observed higher weight loss in osmodehydrated samples after 6 days of storage at 10 °C. In this case, the use of calcium salts in the osmotic solution did not provide a considerable influence on weight loss during storage. All the osmodehydrated samples showed remarkable weight loss at the end of storage (>7%) due to the structural changes, such as turgor loss, plasmolysis, cellular collapse, and tissue shrinkage during the osmotic process. According to the authors, the negative effect of the osmotic process on cell integrity prevailed over calcium action, resulting in an increase of water loss along the time.

Respiration Rate

Figure 2 shows the respiration rates of melon pieces subjected to different treatments. The control sample had higher CO_2 production at the beginning of storage time (around 16 ml $CO_2 kg^{-1} h^{-1}$), which can be related to tissue stress caused by minimal processing operations, such as trimming, peeling, and cutting. Similar behavior was verified in other works with minimally processed apple (Lee et al. 2003) and papaya (Tapia et al. 2008).

The use of pectin coatings promoted a significant decrease of respiration rate in fresh-cut melon, indicating that the interaction of calcium ions with pectin hindered gas exchange. Olivas et al. (2007) observed a similar behavior in fresh-cut apple coated with alginate solution. According to Serrano et al. (2004) and Moraga et al. (2009), cell wall strengthening due to calcium salt addition during processing allows the formation of a homogenous film around the fruit surface, reducing fruit respiration rate. Furthermore, calcium plays a role in intracellular osmotic stress defense by restraining water transport through the plasmalemma membrane, since this ion acts in the regulation of some proteins, such as aquaporins. These proteins are involved in the active water transport, which occurs with ATP consumption. The blockage of aquaporins by Ca^{2+} decreases water flow through the cells, increasing ATP concentration. Thus, ATP accumulation inside the cells results in the respiration reduction of coated melon samples.

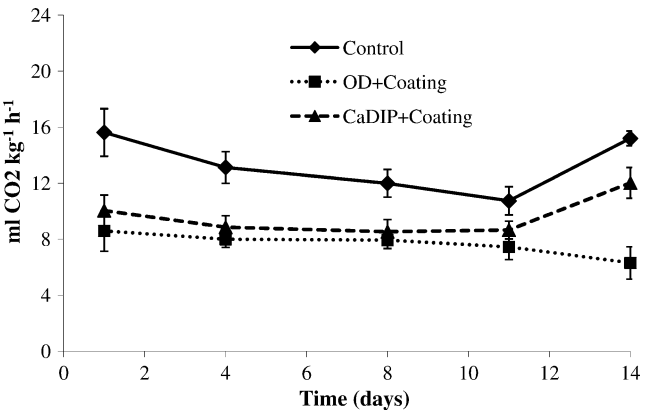

Fig. 2 Respiration rates (in milliliters of CO_2 per kilogram per hour) of fresh-cut melon during storage at 5 °C. *Control* nontreated fresh-cut melon, *OD+coating* fresh-cut melon osmodehydrated in 40°Bx sucrose solution containing 0.5% calcium lactate and coated with 1% pectin, *CaDIP+coating* fresh-cut melon treated with 0.5% calcium lactate solution and coated with 1% pectin

Control and CaDIP+coating samples presented a respiration reduction up to the 11th day, followed by an increase of CO_2 production, reaching approximately 15 and 12 ml CO_2 kg^{-1} h^{-1}, respectively, at the 14th day. This respiration increase at the end of shelf life study can be correlated to the senescence process and/or microbial growth, which is in agreement with the results obtained by Aguayo et al. (2008). The authors verified an increase of CO_2 concentration in minimally processed melon after 8 days of storage, but this behavior was not detected in fruits dipped with 0.9% calcium propionate, suggesting an antimicrobial effect of this salt.

The combination of osmotic treatment and pectin coating delayed the respiration rate all along the shelf life study (Fig. 2), showing values around 6 ml CO_2 kg^{-1} h^{-1} at the end of storage time. Castelló et al. (2009) stated that osmotic dehydration may improve the shelf life of minimally processed products due to the respiration reduction throughout storage, inhibiting the metabolic processes associated with ripening and senescence. External and collapsed cells act as a barrier, limiting O_2 diffusion into the tissue. Lewicki et al. (2001) reported that, at the beginning of osmotic treatment, sugar diffusion into the tissue increases the substrates for respiration process, increasing CO_2 production. On the other hand, high sugar uptake along the process may cause structural changes in the cell wall and plasmalemma, as well as the reduction of water availability for biological reactions, decreasing respiration rates.

Although CaDIP+coating sample showed an increase in respiration rate at the end of the storage period, the respiratory activity of calcium-dipped samples and osmodehydrated fruits showed a similar behavior up to the 11th day, as seen in Fig. 2. This confirms the influence of calcium lactate on the respiration rate reduction of minimally processed melon.

Gas Composition

According to Rojas-Graü et al. (2008), edible coatings may create a modification of internal atmosphere due to the

semipermeable film formed on the product surface, reducing the oxygen available for vegetal tissue. In the present work, modifications of the atmosphere around the product were not significant for either treated or nontreated samples (Fig. 3), indicating that the packaging system (EPS tray wrapped with PVC stretch film) does not create a passive modified atmosphere. The packaging system exhibited an internal atmosphere close to that of air, with O_2 concentrations around 20% and CO_2 concentrations lower than 2% in all trays along the storage time. Samples subjected to the osmotic dehydration pretreatment (OD+coating) showed lower CO_2 concentrations during the storage period (<0.5%) due to its lower respirations rates, as previously discussed.

Firmness

Figure 4 shows the firmness of fresh-cut melon subjected to different treatments. No statistical differences ($p \leq 0.05$) were verified between control and OD+coating samples at the beginning of storage. Firmness significantly decreased throughout storage time, but this reduction was more pronounced for uncoated melon sample from the fifth day onwards, meaning that the pretreatments were able to maintain melon texture.

According to Maftoonazad et al. (2008), firmness loss can be associated with the degradation of components responsible for structural rigidity of the fruit, mainly insoluble pectin and protopectin. During ripening, pectinesterase and polygalacturonase activities increase, causing the solubilization of pectic substances. Low oxygen and high carbon dioxide concentrations reduce the activity of these enzymes, implying better maintenance of fruit texture. This fact was observed in CaDIP+coating and OD+coating samples, which presented lower respiration rates in comparison to the control sample (Fig. 2), retarding the metabolic reactions and preserving melon texture. Similar behavior was also pointed out by Chiumarelli et al. (2011) in fresh-cut mangoes coated with cassava starch or sodium alginate.

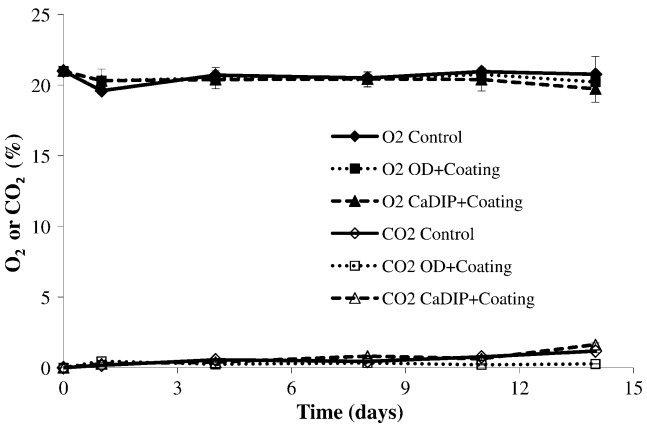

Fig. 3 O_2 and CO_2 concentrations inside the packages during storage at 5 °C. *Control* nontreated fresh-cut melon, *OD+coating* fresh-cut melon osmodehydrated in 40°Bx sucrose solution containing 0.5% calcium lactate and coated with 1% pectin, *CaDIP+coating* fresh-cut melon treated with 0.5% calcium lactate solution and coated with 1% pectin

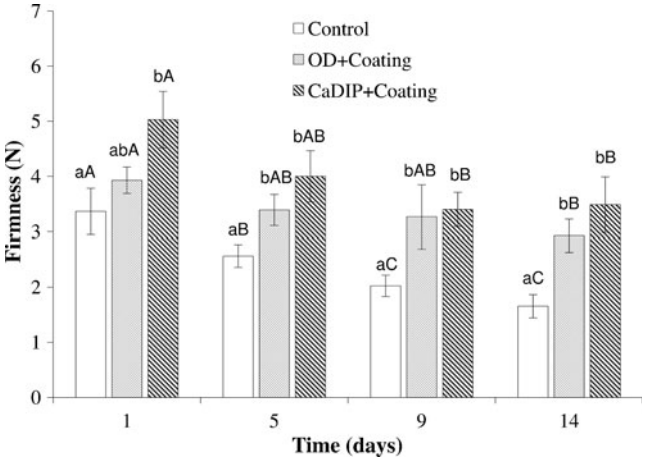

Fig. 4 Firmness of fresh-cut melon during storage at 5 °C. *Control* nontreated fresh-cut melon, *OD+coating* fresh-cut melon osmodehydrated in 40°Bx sucrose solution containing 0.5% calcium lactate and coated with 1% pectin, *CaDIP+coating* fresh-cut melon treated with 0.5% calcium lactate solution and coated with 1% pectin. *Different letters* indicate significant differences at $p \leq 0.05$ (*small letters* among different treatments for the same time, *capital letters* among different times for the same treatment). *Bars* represent the mean standard error

Higher firmness preservation in pretreated samples along the storage time can be also attributed to the addition of calcium lactate in the osmotic dehydration or before the coating application. Calcium ions react with cell wall pectin in order to form calcium pectate, which strengths molecular bonding between cell wall constituents, reinforcing the fruit cellular structure. This firming effect provided by calcium salts has been observed in several coated fresh-cut fruits, such as banana (Bico et al. 2009), apple (Qi et al. 2011), and papaya (Tapia et al. 2008). Olivas et al. (2007) reported that the use of calcium salts kept the texture of apple slices coated with alginate solutions, avoiding the solubilization and depolymerization of pectin substances responsible for tissue softening. Bierhals et al. (2011), working with fresh-cut pineapple coated with cassava starch, verified that the pretreatment with calcium lactate (2%) enhanced the stress at failure values, denoting that the presence of calcium increased the pineapples resistance to deformation.

Color

Table 1 shows lightness, chroma, and WI of control and treated samples during storage. Lightness (L^*) of treated samples remained practically unchanged throughout 14 days of storage, while control fruit had a significant reduction of

Table 1 Lightness (L^*), chroma (C^*), and whiteness index (WI) of fresh-cut melon subjected to different treatments during storage at 5 °C

Color parameter	Time (days)	Control	OD+coating	CaDIP+coating
L^*	1	72.29±3.10aA	69.91±3.01aA	70.46±2.47aA
	5	71.39±2.13aA	69.12±2.97aA	69.71±2.59aA
	9	65.32±2.93aB	70.05±2.15bA	72.51±0.84cA
	14	64.60±2.10aB	68.03±3.11abA	69.26±4.21bA
C^*	1	16.16±1.86aA	19.86±1.83bA	16.46±1.43aA
	5	14.93±2.29aAB	19.84±2.39bA	18.70±2.74bA
	9	13.37±1.77aBC	17.05±2.17bB	16.47±2.30bA
	14	12.67±1.29aC	17.57±1.98bAB	16.48±2.67bA
WI	1	70.56±2.47aA	63.76±3.27bA	67.27±1.89cA
	5	68.30±2.70aA	64.01±2.00bA	65.91±1.54bA
	9	60.88±2.10aB	66.84±1.96bA	67.74±1.32bA
	14	59.87±3.87aB	65.69±2.91bA	63.38±2.65abB

Different letters indicate significant differences at $p \leq 0.05$ (*small letters* among different treatments for the same time, *capital letters* among different times for the same treatment)

Control nontreated fresh-cut melon, *OD+coating* fresh-cut melon osmodehydrated in 40°Bx sucrose solution containing 0.5% calcium lactate and coated with 1% pectin, *CaDIP+coating* fresh-cut melon treated with 0.5% calcium lactate solution and coated with 1% pectin

lightness along storage (Table 1). This behavior could be related to the use of calcium lactate, since calcium salts work as an antibrowning agent, inhibiting polyphenol oxidase, due to the calcium ion interaction with cooper at the polyphenol oxidase active site (Olivas et al. 2007). Bico et al. (2009) verified that calcium chloride combined with the use of carrageenan coatings caused small changes in L^* and C^* parameters of fresh-cut banana, while the uncoated sample showed the highest browning rate. In a similar study, Qi et al. (2011) observed that chitosan coatings formulated with calcium chloride (0.5%) and ascorbic acid (1%) were effective in the maintenance of lightness in apple slices stored at 5 °C for 8 days, avoiding fruit browning along the storage time.

Pectin coatings are a good barrier to oxygen and carbon dioxide, decreasing respiration rates and delaying browning in fresh-cut products. Besides, color changes of vegetable tissue are also associated with the metabolic processes that occur during ripening and senescence. Then, it is possible that higher respiration rates verified in uncoated fruit (Fig. 2) may have contributed to the decrease of lightness values along the storage time.

Regarding chroma, the pretreatments did not affect the color intensity of melon cubes. A significant influence of storage time was only observed for the control sample that showed a decrease of C^* parameter during the storage period. At day 1, osmodehydrated samples presented higher chroma values when compared to other samples, indicating greater color intensification, as a consequence of pigments concentration during the osmotic treatment. The superficial sugar layer formed around the fruit surface results in a drop of sample water activity, reducing enzymatic browning reactions. Rodrigues et al. (2006) observed a stability of color parameters in osmodehydrated papaya pieces stored under modified atmosphere packaging. According to the researchers, the redness of papaya was retained along 15 days of refrigerated storage due to the protective effect of sugars on color characteristics.

The control sample showed a significant decrease ($p \leq 0.05$) of WI along storage, as seen in Table 1, which could be associated with an increase in translucency injury. This visual deterioration is a common physiological disorder, characterized by dark and glassy flesh and also related to senescence (Raybaudi-Massilia et al. 2008). Aguayo et al. (2004) reported that higher respiration rates accelerate the development of translucency in fresh-cut melon, a behavior also observed in the present work, since control samples showed higher CO_2 production (Fig. 2).

At the beginning of shelf life study, WI values of OD+coating fruit were significantly lower than those obtained for control and CaDIP+pectin samples. According to Castelló et al. (2010), osmotic dehydration causes a loss of intracellular liquid and tissue collapse, implying in an increase of product translucency. WI values of the OD+coating sample did not show statistical differences ($p \leq 0.05$) throughout storage. On the other hand, a significant decrease of this color parameter was only observed at the 14th day for the CaDIP+pectin sample, probably due to the increase of respiration rates from the 11th day onwards (Fig. 2).

Microbiological Analysis

Melon samples were in accordance with the microbiological standards established by the National Health

Surveillance Agency—ANVISA (Brazil RDC Resolution No. 12 of 2 January 2001), not threatening consumers' health. *Salmonella* ssp. was not found in both treated and nontreated samples, while total coliform and *Escherichia coli* were below the detection limit of the method (<10 CFU g^{-1}). These results indicate that the hygienic practices and the sanitization process were effective.

In respect to yeast and mold counts, ANVISA does not specify limits for fruit products. Nevertheless, the development of these microorganisms is undesirable because they affect the appearance, flavor, and aroma of fruit products, impairing their sensory characteristics. Moreover, Lee et al. (2003) reported that toxic substances may be produced when yeast and mold counts exceed 10^6 CFU g^{-1} and this value is considered the limit of acceptance during shelf life study of fruit products.

At the beginning of storage, yeast and mold counts of all samples were lower than the detection limit of the method (<5.0×10^2 CFU g^{-1}), as can be observed in Table 2. From the fifth day onwards, the control sample presented higher microbial count, reaching values around 10^6 CFU g^{-1} at the end of shelf life study. OD+coating and CaDIP+coating samples had lower microorganism growth along the storage period, showing yeast and mold counts about 10^5 CFU g^{-1} after 14 days of storage, meaning that the use of pretreatments combined with the application of pectin coatings promoted higher microbiological stability on fresh-cut melon. This behavior can be attributed to the antimicrobial effect of calcium lactate, as previously pointed out by Alandes et al. (2006), Moraga et al. (2009), and Pereira et al. (2010) in their works with minimally processed apple, grapefruit, and guava, respectively.

Polysaccharide edible coatings also have an inhibitory effect on microbial growth. Bico et al. (2009), Rojas-Graü et al. (2008), and Oms-Oliu et al. (2008b) verified that edible coatings retarded the microbiological deterioration of fresh-cut banana, apple, and pear, respectively. However, in another study with fresh-cut pineapple, Bierhals et al. (2011) observed that the use of cassava starch coatings did not prevent microorganisms' proliferation and that the yeast and mold counts obtained for the pineapple slices had an increase of 3 to 4 log cycles during storage. According to the researchers, the accumulation of exuded juice in the packaging along the storage possibly contributed to speed up the product deterioration. Although higher weight loss was verified in the OD+coating sample at the end of storage time (Fig. 1), yeast and mold counts were significantly lower ($p\leq0.05$) in comparison to the control sample, indicating that osmotic process and pectin coatings delayed microbial spoilage.

Light Microscopy

Figure 5 shows the cellular structure of melon samples subjected to different treatments along the storage time. At day 1, all the samples showed similar characteristics, that is, turgid and round-shaped cells with a well-defined and thin cell wall (Fig. 5a, d, g).

At the eighth day, the control fruit showed cytoplasm plasmolysis and alterations in cell shape, evidenced by dashed arrows in Fig. 5b, as well as cell wall damage (solid arrows). After 14 days of storage, structural damage was more intense, with more deformed, contracted, and collapsed cells (Fig. 5c), probably due to the higher weight loss throughout storage (Fig. 1), causing extensive cellular plasmolysis and loss of cell turgor pressure. An increase in intercellular spaces and a reduction in cell-to-cell contact were also observed, resulting in separation of some cells and loss of adhesion between adjacent cell walls. According to Rico et al. (2007), the intercellular spaces increase during the senescence process, facilitating the penetration of microorganisms into the cells and their development, which is related to the higher yeast and mold counts verified in the control sample at the end of shelf life (Table 2).

The OD+coating sample showed a more structured cell arrangement at day 8, despite the elliptical and flat shape of some cells (Fig. 5e). Nevertheless, cellular plasmolysis was verified at the end of the storage period (dashed arrows),

Table 2 Yeast and mold counts (10^3 CFU g^{-1}) of fresh-cut melon subjected to different treatments during storage at 5 °C

Treatments	Time (days)			
	1	5	9	14
Control	0.40±0.05aA	4.20±0.60aB	400±30aC	2500±220aD
OD+coating	0.40±0.05aA	2.80±0.40bB	82±10bC	650±80bD
CaDIP+coating	0.10±0.03bA	2.40±0.40bB	18±1cC	650±60bD

Different letters indicate significant differences at $p\leq0.05$ (*small letters* among different treatments for the same time, *capital letters* among different times for the same treatment)

Control nontreated fresh-cut melon, *OD+coating* fresh-cut melon osmodehydrated in 40°Bx sucrose solution containing 0.5% calcium lactate and coated with 1% pectin, *CaDIP+coating* fresh-cut melon treated with 0.5% calcium lactate solution and coated with 1% pectin

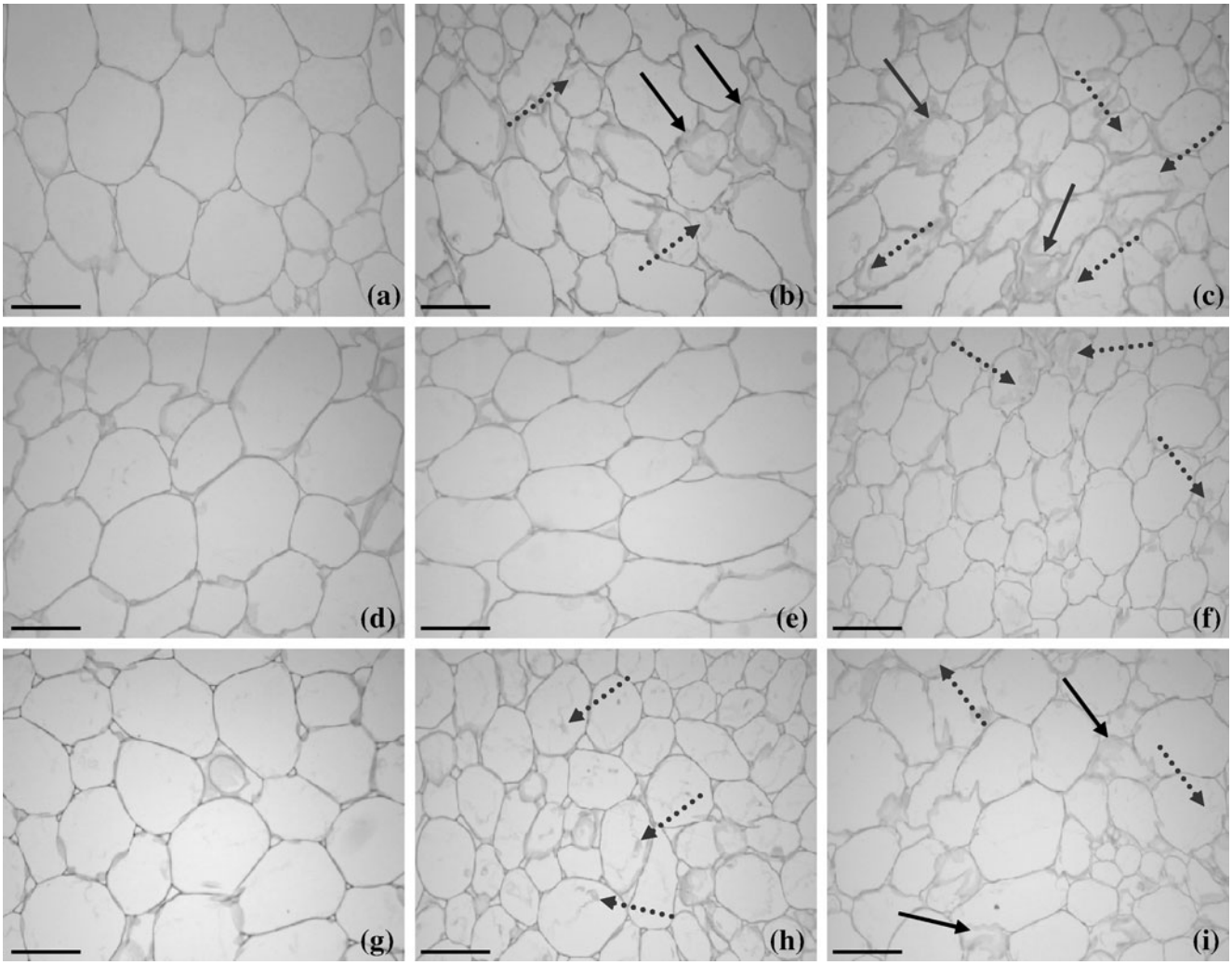

Fig. 5 Micrographs of melon parenchyma tissue during storage at 5 °C. **a**–**c** Nontreated (control) fresh-cut melon, **d**–**f** fresh-cut melon osmodehydrated in 40°Bx sucrose solution containing 0.5% calcium lactate and coated with 1% pectin, **g**–**i** fresh-cut melon treated with 0.5% calcium lactate solution and coated with 1% pectin. **a**, **d**, **g** After 1 day; **b**, **e**, **h** after 8 days; **c**, **f**, **i** after 14 days of storage. Scale bar=140 μm. *Solid arrows* cell wall damage, *dashed arrows* cellular plasmolysis

while the cell wall kept its structure due to the presence of calcium lactate (Fig. 5f). The CaDIP+coating sample presented cytoplasm plasmolysis at the eighth day and some cell wall damage was evident after 14 days of storage (Fig. 5h–i), without affecting the firmness values, as shown in Fig. 4. Therefore, calcium lactate preserved melon structure, causing a strengthening of the cell wall along storage, but the salt was unable to avoid cellular plasmolysis. Similar behavior was pointed out by Pereira et al. (2010) in their study with osmodehydrated guavas, using sucrose or maltose solutions containing calcium lactate.

Sensory Analysis

The sensory acceptance scores of melon samples are presented in Fig. 6. At the beginning of storage time, no statistical differences ($p \leq 0.05$) were verified among the treatments. Uncoated and coated fruits had good sensory acceptance, showing scores around 6 for all the attributes evaluated (Fig. 6a).

After 9 days of storage, the control fruit showed lower scores for flavor, below the acceptability limit (4.5), leading to sample rejection (Fig. 6c). The poor sensory acceptance of this sample can be correlated to its higher respiration rate (Fig. 2) and microbial growth (Table 2), resulting in an undesirable taste, not allowing the sensory analysis at the end of storage time. The control fruit also presented lower scores for appearance at the ninth day, but above the acceptability limit, probably due to the higher translucency aspect of this sample, as previously discussed (Table 1). Besides, pectin coatings promoted an attractive brightness on the fruit surface, which probably contributed to the higher appearance scores obtained for coated samples.

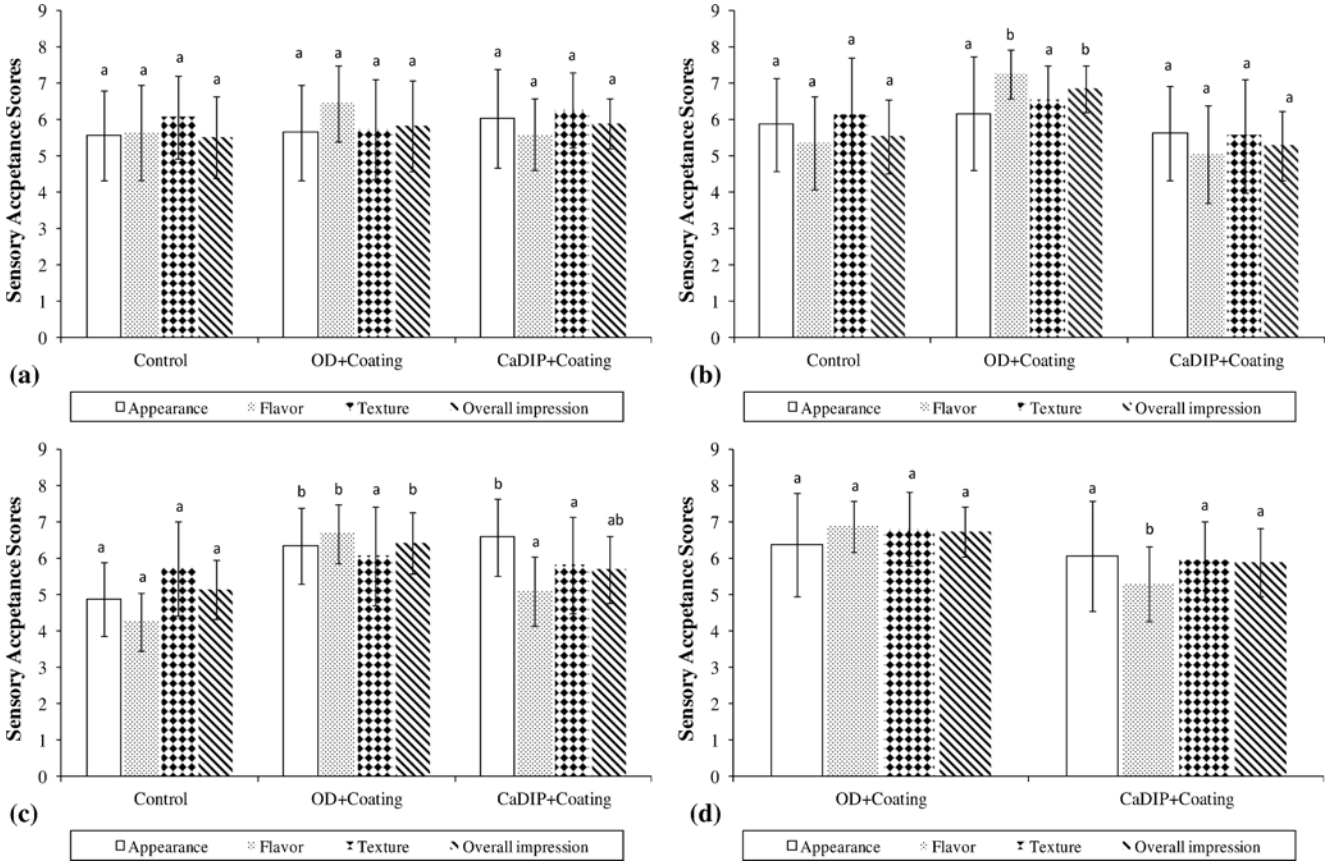

Fig. 6 Sensory acceptance scores of fresh-cut melon during storage at 5 °C. **a** After 1 day, **b** 5 days, **c** 9 days, and **d** 14 days of storage. *Control* nontreated fresh-cut melon, *OD+coating* fresh-cut melon osmodehydrated in 40°Bx sucrose solution containing 0.5% calcium lactate and coated with 1% pectin, *CaDIP+coating* fresh-cut melon treated with 0.5% calcium lactate solution and coated with 1% pectin. *Different letters* indicate significant differences among the treatments at $p \leq 0.05$. *Bars* represent the mean standard error

The use of osmotic dehydration or pectin edible coatings did not affect melon aroma throughout shelf life study (data not shown). Similar behavior was observed for texture, despite the differences between firmness results of coated and uncoated samples along the storage (Fig. 4).

After 5 days of storage, the OD+coating sample showed the best sensory acceptance. Flavor and overall impression scores were significantly higher ($p \leq 0.05$) in comparison to other treatments (Fig. 6b–d). This consumer preference is probably related to the higher sugar content of osmodehydrated fruits, since melon is often harvested before its complete maturation, not reaching the suitable soluble solids content for commercialization. The CaDIP+coating sample presented lower scores for flavor until the end of storage, indicating that the combination of calcium lactate and pectin coating may have masked melon taste, affecting flavor scores. Consumers' purchase intention also confirmed a clear preference for the OD+coating sample, showing values around 80% over the storage period, while the purchase intention for control and CaDIP+coating samples was about 45% and 50%, respectively, at the end of storage time.

According to the results of sensory analysis, the shelf life of the nontreated melon sample was limited to 9 days due to microbial growth and sensory rejection, while both OD+coating and CaDIP+coating samples showed a shelf life of 14 days. However, the use of osmotic dehydration and pectin edible coatings best maintained melon sensory attributes along the storage time.

Conclusions

The shelf life of the control sample was limited to 9 days, while pretreated samples showed a shelf life of 14 days. Calcium lactate showed a beneficial effect on firmness results and also preserved the cellular structure of melon tissue, reducing the mechanical damage along storage. Furthermore, this salt inhibited microbial growth, improving the microbiological stability of coated samples throughout storage.

The combination of calcium lactate dips and pectin coating was able to reduce weight loss and maintain firmness and color characteristics of fresh-cut melon along

storage. However, these pretreatments probably masked melon taste, reducing the sensory acceptance scores at the end of shelf life. Osmotic dehydration increased product soluble solids content, improving the sensory acceptance of coated melon. In general, the association of osmotic dehydration and pectin coatings was a good preservation alternative for fresh-cut melon, promoting the reduction of fruit respiration rate, as well as the maintenance of sensory characteristics and quality parameters of minimally processed melon during 14 days of storage.

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References

Aguayo, E., Escalona, V. H., & Artés, F. (2004). Metabolic behavior and quality changes of whole and fresh processed melon. *Journal of Food Science, 69*(4), 148–155.

Aguayo, E., Escalona, V. H., & Artés, F. (2008). Effect of hot water treatment and various calcium salts on quality of fresh-cut "amarillo" melon. *Postharvest Biology and Technology, 47*(3), 397–406.

Alandes, L., Hernando, I., Quiles, A., Pérez-Munuera, I., & Lluch, M. A. (2006). Cell wall stability of fresh-cut 'Fuji' apples treated with calcium lactate. *Journal of Food Science, 71*(9), 615–620.

Alves, R.E. (2000). Melon: post-harvest (pp. 1–43). Brasília: Embrapa Comunicação para Transferência de Tecnologia. (In Portuguese).

Bico, S. L. S., Raposo, M. F. J., Morais, R. M. S. C., & Morais, A. M. M. B. (2009). Combined effects of chemical dip and/or carrageenan coating and/or controlled atmosphere on quality of fresh-cut banana. *Food Control, 20*(5), 508–514.

Bierhals, V. S., Chiumarelli, M., & Hubinger, M. D. (2011). Effect of cassava starch coating on quality and shelf life of fresh-cut pineapple (*Ananas comosus* L. Merril cv "Pérola"). *Journal of Food Science, 76*(1), 62–72.

Brazil RDC Resolution No. 12 of 2 January (2001). *Technical regulation on microbiological standards for foodstuffs.* Brasilia: National Health Surveillance Agency (Ministry of Health/ ANVISA). http://www.anvisa.gov.br/legis/resol/12_01rdc.htm/. Accessed 25 Jan 2010.

Castelló, M. L., Igual, M., Fito, P. J., & Chiralt, A. (2009). Influence of osmotic dehydration on texture, respiration and microbial stability of apple slices (var. Granny Smith). *Journal of Food Engineering, 91*(1), 1–9.

Castelló, M. L., Fito, P. J., & Chiralt, A. (2010). Changes in respiration rate and physical properties of strawberries due to osmotic dehydration and storage. *Journal of Food Engineering, 97*(1), 64–71.

CEAGESP (2004). *Normas de Classificação de Melão* (*Cucumis melo* L.). São Paulo: Programa Brasileiro para Modernização da Horticultura. http://www.ceagesp.gov.br/produtor/classific/fc_melao. Accessed 9 Feb 2009.

Chiumarelli, M., Pereira, L. M., Ferrari, C. C., Sarantópoulos, C. I. G. L., & Hubinger, M. D. (2010). Cassava starch coating and citric acid to preserve quality parameters of fresh-cut 'Tommy Atkins' mango. *Journal of Food Science, 75*(5), 297–304.

Chiumarelli, M., Ferrari, C. C., Sarantópoulos, C. I. G. L., & Hubinger, M. D. (2011). Fresh cut 'Tommy Atkins' mango pretreated with citric acid and coated with cassava (*Manihot esculenta* Crantz) starch or sodium alginate. *Innovative Food Science and Emerging Technologies, 12*(3), 381–387.

Downes, F. P., & Ito, K. (2001). *Compendium of methods for the microbiological examination of foods*. Washington: American Public Health Association.

Eum, H. L., Hwang, D. K., Linke, M., Lee, S. K., & Zude, M. (2009). Influence of edible coatings on quality of plum (*Prunus salicina* Lindl. cv. 'Sapphire'). *European Food Research and Technology, 229*(3), 427–434.

Ferrari, C. C., Carmello-Guerreiro, S. M., Bolini, H. M. A., & Hubinger, M. D. (2010). Structural changes, mechanical properties and sensory preference of osmodehydrated melon pieces with sucrose and calcium lactate solutions. *International Journal of Food Properties, 13*(1), 112–130.

Garcia, L. C., Pereira, L. M., Sarantópoulos, C. I. G. L., & Hubinger, M. D. (2010). Selection of an edible starch coating for minimally processed strawberry. *Food and Bioprocess Technology, 3*(6), 834–842.

Lacroix, M., & Le Tien, C. (2005). Edible films and coatings from non-starch polysaccharides. In J. H. Han (Ed.), *Innovations in food packaging* (pp. 338–361). San Diego: Elsevier Academic.

Lamikanra, O., & Watson, M. A. (2004). Effect of calcium treatment temperature on fresh-cut cantaloupe melon during storage. *Journal of Food Science, 69*(6), 468–472.

Lee, J. Y., Park, H. J., Lee, C. Y., & Choi, W. Y. (2003). Extending shelf life of minimally processed apples with edible coatings and antibrowning agents. *LWT—Food Science and Technology, 36* (3), 323–329.

Lewicki, P. P., Gondek, E., Witrowa-Rajchert, A. D., & Nowak, N. (2001). Effect of drying on respiration of apple slices. *Journal of Food Engineering, 49*(4), 333–337.

Maftoonazad, N., Ramaswamy, H. S., & Marcotte, M. (2008). Shelf-life extension of peaches through sodium alginate and methyl cellulose edible coatings. *International Journal of Food Science and Technology, 43*(6), 951–957.

Martín-Belloso, O. (2007). Pros and cons of minimally processed foods. *Trends in Food Science & Technology, 18*(11), 582.

Martín-Diana, A. B., Rico, D., Frías, J. M., Barat, J. M., Henehan, G. T. M., & Barry-Ryan, C. (2007). Calcium for extending the shelf life of fresh whole and minimally processed fruits and vegetables: a review. *Trends in Food Science & Technology, 18*(4), 210–218.

Meilgaard, M., Civille, G. V., & Carr, B. T. (1999). *Sensory evaluation techniques*. Boca Raton: CRC.

Moraga, M. J., Moraga, G., Fito, P. J., & Martínez-Navarrete, N. (2009). Effect of vacuum impregnation with calcium lactate on the osmotic dehydration kinetics and quality of osmodehydrated grapefruit. *Journal of Food Engineering, 90*(3), 372–379.

Olivas, G. I., Mattinson, D. S., & Barbosa-Cánovas, G. V. (2007). Alginate coatings for preservation of minimally processed 'Gala' apples. *Postharvest Biology and Technology, 45*(1), 89–96.

Oms-Oliu, G., Soliva-Fortuny, R., & Martín-Belloso, O. (2008a). Using polysaccharide-based edible coatings to enhance quality and antioxidant properties of fresh-cut melon. *LWT—Food Science and Technology, 41*(10), 1862–1870.

Oms-Oliu, G., Soliva-Fortuny, R., & Martín-Belloso, O. (2008b). Edible coatings with antibrowning agents to maintain sensory quality and antioxidant properties of fresh-cut pears. *Postharvest Biology and Technology, 50*(1), 87–94.

Pereira, L. M., Carmello-Guerreiro, S. M., Junqueira, V. C. A., Ferrari, C. C., & Hubinger, M. D. (2010). Calcium lactate effect on the shelf life of osmotically dehydrated guavas. *Journal of Food Science, 75*(9), 612–619.

Qi, H., Hu, W., Jiang, A., Tian, M., & Li, Y. (2011). Extending shelf-life of fresh-cut 'Fuji' apples with chitosan-coatings. *Innovative Food Science and Emerging Technologies, 12*(1), 62–66.

Raybaudi-Massilia, R. M., Mosqueda-Melgar, J., & Martín-Bellloso, O. (2008). Edible alginate-based coating as carrier of antimicrobials to improve shelf-life and safety of fresh-cut melon. *International Journal of Food Microbiology, 121*(3), 313–327.

Rico, D., Martín-Diana, A. B., Frías, J. M., Barat, J. M., Henehan, G. T. M., & Barry-Ryan, C. (2007). Improvement in texture using calcium lactate and heat-shock treatments for stored ready-to-eat carrots. *Journal of Food Engineering, 79*(4), 1196–1206.

Rodrigues, A. C. C., Pereira, L. M., Sarantópoulos, C. I. G. L., Bolini, H. M. A., Cunha, R. L., Junqueira, V. C. A., et al. (2006). Impact of modified atmosphere packaging on the osmodehydrated papaya stability. *Journal of Food Processing and Preservation, 30*(5), 563–581.

Rojas-Graü, M. A., Tapia, M. S., & Martín-Belloso, O. (2008). Using polysaccharide-based edible coatings to maintain quality of fresh-cut Fuji apples. *LWT—Food Science and Technology, 41*(1), 139–147.

Serrano, M., Martínez-Romero, D., Castillo, S., Guillén, F., & Valero, D. (2004). Role of calcium and heat treatments in alleviating physiological changes induced by mechanical damage in plum. *Postharvest Biology and Technology, 34*(2), 155–167.

Soliva-Fortuny, R. C., & Martín-Belloso, O. (2003). New advances in extending the shelf-life of fresh-cut fruits: a review. *Trends in Food Science & Technology, 14*(9), 341–353.

Tapia, M. S., Rojas-Grau, M. A., Carmona, A., Rodriguez, F. J., Soliva-Fortuny, R., & Martin-Belloso, O. (2008). Use of alginate- and gellan-based coatings for improving barrier, texture and nutritional properties of fresh-cut papaya. *Food Hydrocolloids, 22*(8), 1493–1503.

Torreggiani, D., & Bertolo, G. (2001). Osmotic pre-treatments in fruit processing: chemical, physical and structural effects. *Journal of Food Engineering, 49*(2–3), 247–253.

Vargas, M., Pastor, C., Chiralt, A., McClements, D. J., & González-Martínez, C. (2008). Recent advances in edible coatings for fresh and minimally processed fruits. *Critical Reviews in Food Science and Nutrition, 48*(6), 496–511.