Packaging Technology and Science
An International Journal

PACKAGING TECHNOLOGY AND SCIENCE
Packag. Technol. Sci. 2012; **25**: 413–425
Published online 22 November 2011 in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/pts.987

Effect of Antimicrobial Starch Edible Coating on Shelf-Life of Fresh Strawberries

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Strawberry is a very sensitive fruit and presents a short post-harvest shelf-life. Among the factors responsible for strawberries' quality loss are high metabolic activities and mold decay. To increase product shelf-life, cassava starch–based edible coatings (3%), added or not with potassium sorbate (0.05%), were applied on minimally processed strawberries. Uncoated minimally processed strawberries were used as control samples. Physical and chemical properties, respiration rate and sensorial acceptance of uncoated and coated strawberries stored up to 15 days at 5°C were monitored. The results showed that coatings had no significant effect on soluble solids, titrable acidity, pH and colour of strawberries. Besides reducing the respiration rate of samples, cassava starch edible coatings were efficient in delaying weight and firmness loss of strawberries during storage. In the studied conditions, potassium sorbate was not efficient in controlling microbial growth. Strawberries coated with cassava starch without the antimicrobial agent showed good conditions for consumption and good sensorial acceptance up to 12 days of storage, whereas the control samples and the samples treated with the coating containing potassium sorbate achieved a shelf-life of 9 days because of microbial spoilage. Copyright © 2011 John Wiley & Sons, Ltd.

Received 20 April 2011; Revised 15 July 2011; Accepted 14 October 2011

KEY WORDS: strawberry; edible coating; cassava starch; potassium sorbate; minimally processed

INTRODUCTION

The consumption of fruit and vegetables has increased continuously in recent years. Minimally processed fruit and vegetables can be considered to be an alternative to fast food and other ready-to-eat products, attending the demand for healthy and convenient food, and also permitting better utilization of raw material, besides the possibility of increasing the product value.[1]

Strawberries are highly perishable non-climacteric fruit with a short post-harvest life. Strawberry spoilage after harvest can occur by factors as mechanical injury and dehydration, but it mainly occurs because of the high incidence of yeast and mold.[2,3] One common tool used to reduce mold growth and retard fruit senescence is the fruit storage under cold condition and modified or controlled atmosphere.[4–6] However, prolonged exposure of berries to high CO_2 concentrations can cause off-flavour development.[7]

The application of edible coatings on fruit surface to increase this product storage time is a technique that has been extensively studied.[2,3,8–12] Besides controlling the O_2 and CO_2 transport in the product surface, edible coatings can modify fruit tissue metabolism by affecting respiration rate; decreasing moisture and texture loss; transporting antimicrobials, antioxidants and others preservatives; controlling microbial growth; and maintaining fruit quality for a longer period.[3,9,10,13–17]

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Depending on the desired characteristics, coatings can be produced using one type of material or a mixture of them. Lipids, resins, polysaccharides and proteins are the commonly used materials in the production of edible coatings, and among the polysaccharides, starch is the natural biopolymer most commonly used.[13] Cassava is produced throughout the Brazilian territory and other tropical countries and is popularly used as meal, as animal fodder, or cooked and eaten as a vegetable. Besides being abundantly produced, cassava starch is used in a much lesser extent than other starches in food industry, and because of that, it has low price when compared with other starch sources.[18,19]

Films developed from starches are isotropic, odourless, tasteless, colourless, non-toxic and biologically degradable. Preferred properties of cassava starch include high transparency, high resistance to acidity and high viscosity when in solution.[20,21] The use of cassava starch to develop edible films and coatings has been considered in some researches found in the literature.[8,21–23]

Sorbic acid and its potassium salt (sorbate) are considered Generally Recognized As Safe (GRAS) additives and are active against yeast, molds and bacteria.[24] Addition of sorbate to edible films and coatings has been proposed as a way of retarding microbial growth.[14,25–27] Starches can interact with antimicrobial agent such as sorbic, benzoic and *p*-benzoic acids, and the nature of this interaction depends on the type of starch as well as on the concentration and the chemical characteristics of the preservative.[28] As a consequence, some properties of the preservative such as its solubility, diffusivity, partition coefficient and the ability to penetrate into a biological membrane can be modified affecting the antimicrobial activity. Ofman *et al*.[29] showed that preservatives such as potassium sorbate and sodium benzoate have a great influence on sorption and mechanical properties of starch systems, affecting starch functionality. Also, a starch–preservative interaction was proven to occur, and this interaction might affect microbiological stability of the systems.

Considering economical issue and functional advantages, fruits with high economical value and short post-harvest life, like strawberries, are the main products benefitting from coating application. To increase strawberries' shelf-life, some studies considered the use of different coating materials such as corn and potato starch,[14] wheat gluten,[30] cactus mucilage,[31] chitosan[3,32] and amaranth flour.[33]

The purpose of this study was to evaluate the effect of cassava starch edible coatings, with or without potassium sorbate, on shelf-life of minimally processed strawberries, stored at 5°C. Physical and chemical properties, respiration rate and sensorial acceptance were the evaluated parameters.

MATERIALS AND METHODS

Raw materials

Strawberries (*Fragaria ananassa* cv Oso Grande) were harvested in a local farm and transported to University of Campinas, where they were maintained in a refrigerated room until processing on the next day. Strawberries were selected based on commercial ripening stage (75% red surface), uniform size, and absence of fungal infection and physical damage. The strawberry composition, determined according to the Association of Official Agricultural Chemists,[34] is shown on Table 1. Cassava

Table 1. Strawberry (*Fragaria ananassa* cv Oso Grande) composition.

Component	Mean values (g/kg)
Moisture (wet basis)	892.9 ± 23.8
Ash	3.3 ± 0.6
Total sugar	64.7 ± 5.1
Fat	2.7 ± 0.4
Total acidity	8.0 ± 0.3
Protein	7.3 ± 0.2
Fibre (by difference)	21.1

All data were obtained using triplicate analyses and expressed as mean ± standard deviation.

DOI: 10.1002/pts

starch (CS), with 17%–19% of amylose content, and food grade potassium sorbate (PS) used in the coating formulations were obtained from Pilão Amidos Ltda (Guaíra/PR, Brazil) and Doce Aroma (São Paulo/SP, Brazil), respectively.

Preparation of the edible coating solution

The coatings studied in this work were aqueous solutions prepared with cassava starch–based edible coatings (3%), added or not with potassium sorbate (0.05%). These conditions were determined based on a previous work.[35] The solutions were heated under constant agitation until they reached 70°C, which is the gelatinization temperature of cassava starch. After that, the coatings were allowed to cool down to room temperature (23°C).

Fruit coating

Selected strawberries were washed in tap water, had the stems removed, were sanitized in an 80-ppm peracetic acid solution for 3 min and drained. Strawberries were randomly distributed into one of the three treatments: control samples, coating containing only CS (3%) and coating containing CS (3%) + PS (0.05%). Samples without coating were used as control samples. For the coating treatments, fruits were immersed in the coatings solutions for 3 min and then allowed to drain during 3 h. Strawberries were packed in polypropylene trays ($125 \times 80 \times 40$ mm) and wrapped with polyvinyl chloride (PVC) stretch film with 20 μm of thickness, oxygen transmission rate of 341.7 $cm^3\,m^{-2}\,h^{-1}$ (25°C and 1.01×10^5 N m^{-2}) and water vapour transmission rate of 10.9 g $m^{-2}\,h^{-1}$ (38°C and 90% relative humidity). The PVC stretch film was perforated (five 0.45-mm diameter holes per package) to maintain the atmospheric composition of air inside the package. All treatments were stored at 5°C until evaluation, which was carried out 1, 5, 9, 12 and 15 days after the treatment. The samples evaluation was done at least in triplicate.

Physical and chemical properties of strawberries

Weight loss of minimally processed strawberries was measured by monitoring the weight changes of 30 fruits (five packages with six strawberries in each) during cold storage. Weight loss was calculated as a percentage of initial weight.

Soluble solids (SS) content was determined using a refractometer (Zeiss, Oberkochen, West Germany) and expressed as °Brix. For pH and titrable acidity (TA) analysis, strawberries were cut into small pieces and homogenized with a mixer until puree formation. The pH value was obtained from direct measurement of the puree with a pH meter. TA was determined by titrating a mixture of 10 g of strawberry puree and 90 ml of distilled water with 0.1M NaOH to an end point of pH 8.1. Measurements were accomplished in an automatic titrator (T50; Mettler Toledo, Schwerzenbac, Switzerland), and results were expressed as percentage of citric acid.

Colourimetric measurements of strawberry surface were carried out in a Hunterlab spectrocolorimeter (ScanVis; Hunter Associates Laboratory, Fairfax, VA, USA). CIELAB (L^*, a^*, b^*) coordinates were obtained using D65 illuminant and a 10° observer angle as a reference system. L^* represents the overall brightness (0) or darkness (100), a^* represents the green (−) or red (+) component and b^*, the blue (−) or yellow (+) component.[36] a^* and b^* values were converted into chroma (C^*) and hue angle (H^*), according to Equations 1 and 2, respectively. L^* value was taken from direct measurement. Two readings were taken in different regions of each strawberry, and seven fruits were analysed per treatment.

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

$$H^* = \arctan\left(\frac{b^*}{a^*}\right) \tag{2}$$

Changes in total anthocyanin content were calculated according to Francis.[37] Aliquots of 2 g of homogenized strawberry were dissolved in 50 ml of an ethanol–HCl solution (ethanol 95% acidified

DOI: 10.1002/pts

with HCl 1.5M) in the proportion of 85 : 15 (v/v). The solution was manually agitated and kept 1 hour at 7°C to extract the pigments. The flocculate was filtered off, and the absorbance of the resulting clear liquid containing the pigments was measured in a spectrophotometer (DU-70; Beckman Instruments, Fullerton, CA, USA) with a light wave of 520 nm. Anthocyanin concentration was calculated according to Equation 3:

$$A = \frac{(\text{Abs} * V)}{(E * M)} \tag{3}$$

where Abs is the absorbance read, V is the measured volume, E is the molar extinction coefficient of pelargonidin-3-glucoside at 1% (67.13) and M is the sample weight. Results were expressed as milligram of pelargonidin-3-glucoside per 100 g of strawberry.

The strawberries' mechanical properties were analysed by puncture and compression tests using a TA-XT plus Universal Testing Machine (Stable Micro Systems, Godalming, Surrey, UK). For the puncture tests, a 3-mm diameter stainless steel cylindrical probe with a flat end was used. The maximum penetration force (N) was defined as the maximum force required to pushing the probe into the strawberries to a depth of 8 mm at a speed of 2 mm s^{-1}. Seven whole strawberries of each treatment were analysed, with the mean value of each treatment being reported. For the compression tests, the maximum compression force (N) was measured using a cylindrical acrylic 60-mm diameter probe, a cross-head speed of 1 mm s^{-1} and 80% deformation. Seven whole strawberries of each treatment were analysed, with the mean value of each treatment being reported.

Respiration rate

Initial respiration rate of the strawberries, expressed in millilitre of CO_2 kg^{-1} h^{-1} was measured using static method in a closed system using an O_2/CO_2 Dual Head Space Analyzer (Model PAC CHECK 325; Mocon, Minneapolis, MN, USA). Approximately 50 g of strawberry were placed in 200-ml hermetically sealed glass jars with a silicon septum in the lid for sampling the gas of the headspace. They were maintained in a controlled temperature chamber at 5°C, and gas sampling was carried out 1 h after closing the jars.[38]

Sensory acceptance

Sensory acceptance tests were carried out in a standardized test room. Samples were presented for each panellist in a completely randomized order, in a monadic form and using white saucers labelled with three-digit random numbers. The sensorial attributes of the samples (appearance, aroma, flavour, texture and overall impression) were evaluated by 30 panellists, strawberry consumers and representative of target public. A 9-cm unstructured hedonic scale anchored with 'I dislike very much' on the left side and 'I like very much' on the right side was used.[39] An average score of 4.5 was considered the limit for acceptability.[40] The purchase intention was also evaluated.

Statistical analysis

Variance analysis, using the software STATISTICA 5.5 (StatSoft, Inc., Tulsa, OK, USA), was used to determine statistically significant differences between the different treatments studied. The analysis of means was performed using the Tukey procedure at $p < 0.05$.

RESULTS AND DISCUSSION

Physical and chemical properties of strawberries

Weight loss. A continuous weight loss was observed in all treatments during storage. However, the edible coatings were efficient in reducing strawberries' weight loss during cold storage (Figure 1). This reduction can be explained by the higher difficulty of water permeation from the fruit to the environment because of the coating barrier on strawberries' surface. Although, the observed reduction was

DOI: 10.1002/pts

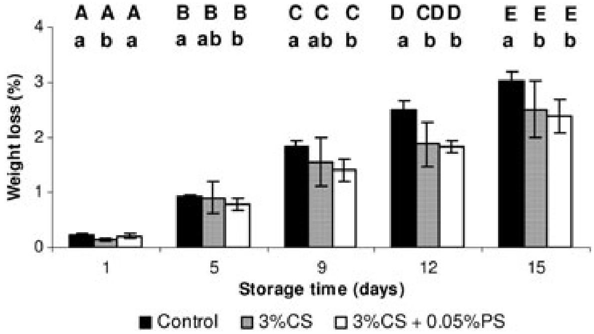

Figure 1. Weight loss of minimally processed strawberries subjected to different treatments. Mean separation by the Tukey test at $p < 0.05$. Means with the same small letter, in the same storage time, did not differ significantly. Means with the same capital letter, for the same treatment during storage, did not differ significantly. CS, cassava starch; PS, potassium sorbate.

statistically significant ($p < 0.05$) only for the coatings containing potassium sorbate. According to Garcia,[35] the antimicrobial agent can increase the water vapour resistance and, consequently, reduce the strawberries' weight loss.

In accordance, Chiumarelli *et al*.[8] observed a reduction on weight loss of fresh-cut mangos treated with cassava starch coating. Garcia *et al*.[14] also observed a reduction on weight loss of strawberries, coated with a 2% corn starch coating, during cold storage. A weight loss reduction of strawberries treated with chitosan-based and amaranth flour–based edible coatings was reported by Han *et al*.[41] and Colla *et al*.,[33] respectively. According to these authors, strawberries' dehydration was minimized by the coating on the fruit surface, reducing the fruit weight loss.

pH, soluble solids and titrable acidity. Some statistically significant ($p < 0.05$) changes on the SS and pH values of minimally processed strawberries treated with different coatings were observed (Table 2). The observed differences could be related to variations in the strawberries analysed in each storage time because it is not possible to remark any tendency on the variations. The coating pH is higher than the strawberry pH, which can be an explanation for the higher coated samples pH when compared with the control sample pH.

The SS presented in fruits contain important components, especially sugars and organics acids, that are responsible for the taste and consequent consumers' acceptance of the product. Non-climacteric fruits, like strawberries, normally exhibit a reduction on SS content during storage. The reason is that at harvest time, these fruits present low or no energy source (starch), because necessary, the use of the sugars present in the fruit as an energy source for respiration, which results in a reduction of the fruits SS content. However, Tanada-Palmu and Grosso[30] and Hernández-Muñoz *et al*.[42] observed an increase, during storage, in the SS content of strawberries that were covered with gluten-based and chitosan-based edible coating, respectively. This increase can be explained considering the high water loss observed in these two works, which resulted in SS concentration.

No significant changes ($p > 0.05$) were observed on the TA of uncoated and coated strawberries throughout the storage period (Table 2). Also, significant changes were not remarked between the different treatments in each storage time. Hernández-Muñoz *et al*.[42], who studied the application of chitosan-based edible coating on strawberries, did not observe significant changes on the TA of coated samples during the storage time. However, according to the authors, because TA is given as a percentage of citric acid per strawberry wet weight, small differences can be found in TA as a consequence of the difference in the water loss of uncoated and coated samples.

Colour. Changes of strawberries' surface colour, stored for 15 days at 5°C, given by L^*, chroma and hue angle are shown in Figure 2.

Fruit darkening can be analysed using the L^* coordinate. Coated samples presented statistically similar L^* values when compared with uncoated samples, right after the coating treatment and during the cold storage. So, it can be concluded that cassava starch–based coating had no influence on strawberry lightness.

DOI: 10.1002/pts

Table 2. pH, soluble solid and titrable acidity of minimally processed strawberries subjected to different treatments.

		Storage time (days)				
		1	5	9	12	15
pH	Control	3.67 ± 0.04^{aAC}	3.57 ± 0.02^{aB}	3.70 ± 0.02^{aA}	3.63 ± 0.01^{aC}	3.69 ± 0.18^{aAC}
	CS	3.64 ± 0.05^{aA}	3.75 ± 0.01^{bB}	3.68 ± 0.05^{aAB}	3.83 ± 0.03^{bC}	3.71 ± 0.08^{aAB}
	CS + PS	3.72 ± 0.04^{aA}	3.76 ± 0.01^{bA}	3.78 ± 0.07^{aA}	3.76 ± 0.02^{cA}	3.72 ± 0.07^{aA}
Soluble solid (°Brix)	Control	8.3 ± 0.3^{aA}	8.3 ± 0.3^{aA}	7.5 ± 1.3^{aAB}	7.0 ± 0.5^{abB}	7.8 ± 0.3^{aAB}
	CS	8.2 ± 0.8^{aAB}	8.3 ± 0.3^{aA}	7.0 ± 0.7^{aAB}	6.8 ± 0.4^{aB}	7.3 ± 0.8^{aB}
	CS + PS	8.3 ± 0.3^{aA}	8.3 ± 1.3^{aAB}	7.5 ± 0.5^{aB}	7.8 ± 0.4^{bAB}	7.7 ± 0.3^{aB}
Titrable acidity (% citric acid)	Control	0.877 ± 0.11^{aA}	0.843 ± 0.08^{aA}	0.875 ± 0.08^{aA}	0.927 ± 0.07^{aA}	0.887 ± 0.07^{aA}
	CS	0.849 ± 0.05^{aA}	0.811 ± 0.09^{aA}	0.870 ± 0.13^{aA}	0.883 ± 0.07^{aA}	0.860 ± 0.08^{aA}
	CS + PS	0.808 ± 0.07^{aA}	0.822 ± 0.06^{aA}	0.877 ± 0.11^{aA}	0.877 ± 0.11^{aA}	0.877 ± 0.11^{aA}
Anthocyanin (mg of pelargonidin-3-glucoside per 100 g of fruit)	Control	14.06 ± 2.33^{aA}	16.71 ± 1.76^{aAB}	17.63 ± 2.21^{aAB}	16.07 ± 3.35^{aAB}	20.09 ± 1.04^{aB}
	CS	16.21 ± 1.23^{aA}	15.15 ± 1.29^{abA}	$16.,82 \pm 1.23^{aA}$	17.04 ± 3.23^{aA}	14.01 ± 1.92^{bA}
	CS + PS	17.71 ± 0.14^{aA}	11.69 ± 0.51^{bB}	16.30 ± 1.26^{aA}	17.70 ± 0.70^{aA}	15.70 ± 2.82^{abAB}

Mean separation by the Tukey test at $p < 0.05$. Means with the same small letter in a column, for the same parameter, did not differ significantly. Means with the same capital letter in the same line did not differ significantly.

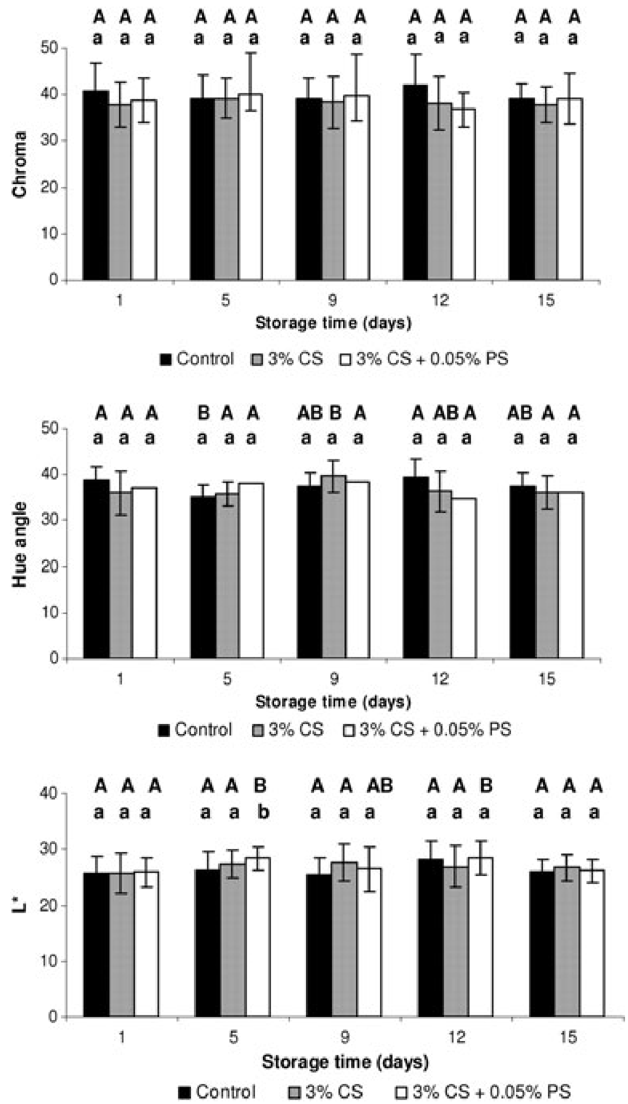

Figure 2. Chroma, hue angle and luminosity of minimally processed strawberries subjected to different treatments. Mean separation by the Tukey test at $p < 0.05$. Means with the same small letter, in the same storage time, did not differ significantly. Means with the same capital letter, for the same treatment during storage, did not differ significantly. CS, cassava starch; PS, potassium sorbate.

On chroma evaluation, no statistically significant changes ($p > 0.05$) were observed on minimally processed strawberries subjected to the different treatments during storage, indicating that coatings maintained the samples' superficial colour intensity. Also, no differences were observed between the different treatments at each storage time.

Isolated changes in the hue angle of uncoated strawberries and those treated with CS coating were observed during the cold storage. Although, it can be noted that the observed changes are punctual, and for this reason, they might be related with the strawberries variation (because different fruits were evaluated during the storage time) rather than with the coating treatment. No significant changes ($p > 0.05$) were observed on the hue angle of strawberries treated with the coating containing CS + PS during storage.

Colour is an important factor of perception of strawberry quality. Vargas *et al.*[3] observed reduction on the chroma and hue angle of uncoated strawberries stored for 10 days at 5°C, and the higher superficial dehydration can be the reason for these changes. Still, Hernández-Muñoz *et al.*[32] observed a significant reduction ($p < 0.05$) on chroma and hue angle of uncoated and coated strawberries stored

DOI: 10.1002/pts

at 20°C. Nevertheless, minor changes were noticed in coated samples because coating presence on fruit surface reduces its respiration rate, retarding the senescence and, consequently, colour change. Colour changes in strawberries are greatly influenced by storage temperature, and therefore, more accentuated colour differences were expected between control and coated strawberries that are stored at higher temperatures.

Anthocyanins. During storage, a significant increase ($p < 0.05$) was observed in the anthocyanin content of uncoated strawberries, whereas no significant changes were observed in the anthocyanin content of coated samples (Table 2). For samples treated with CS + PS, a significant reduction ($p < 0.05$) on the anthocyanin content was observed on the fifth storage day, probably as a result of sample variation. No significant differences ($p > 0.05$) were observed between the treatments in each storage time, except on the last storage day, when uncoated samples presented a significant higher ($p < 0.05$) anthocyanin content. The colour of strawberries, expressed in terms of L^*, chroma and hue angle, did not reproduce this pigment concentration increase.

The greater anthocyanin content presented by uncoated samples can be explained by the higher respiration rate, especially on the last storage days. The higher the respiration rate, the higher is the metabolism rate resulting in a greater pigment production. Anthocyanins are water-soluble pigments and confer a range of attractive colours in fruits, flowers and leaves. The amount of anthocyanin is important for the maturity evaluation of strawberries because the index of ripeness used for harvesting is the redness resulting from the anthocyanin synthesis.[43,44] According to Shin *et al.*,[45] the anthocyanin content of strawberries increased significantly after 4 days of storage at 20°C; however, no changes on pigment concentration were observed when samples were stored at 0.5°C and 10°C. Yet, Garcia *et al.*[14] reported that uncoated samples presented higher pigment concentration, when compared with coated samples at each storage time.

Mechanical properties. Mechanical properties of uncoated and coated strawberries were evaluated by maximum penetration force and maximum compression force obtained from puncture and compression tests, respectively. However, in both tests, mechanical properties will be discussed in terms of '*firmness*' to make possible associations with other works found in the literature.

Puncture test. During storage, a reduction on the maximum penetration force was observed for all treatments (Figure 3). However, this reduction was significant ($p < 0.05$) only after the ninth day for uncoated samples. It can be concluded that cassava starch–based edible coatings were effective on retarding the strawberries' firmness loss. No statistical differences ($p > 0.05$) on the maximum penetration force were observed between the coated samples during storage. Uncoated strawberries showed a more severe softening than coated ones. The use of edible coatings on fruits surface can retard the fruit senescence process as there is a reduction on respiration rate and on product metabolic activities. Besides that, they can act as a barrier to water transfer, retarding dehydration and therefore, maintaining the firmness of coated fruits.

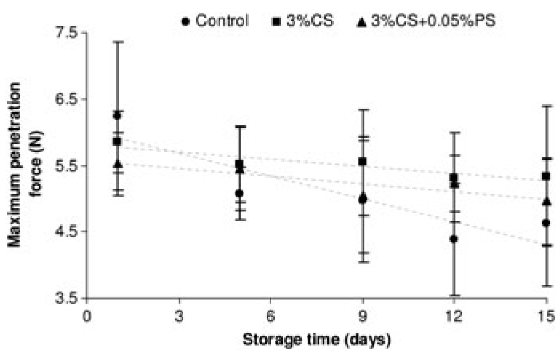

Figure 3. Maximum penetration force (N) of minimally processed strawberries subjected to different treatments. CS, cassava starch; PS, potassium sorbate.

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Firmness loss is one of the most noticeable changes occurring in fruits and vegetables during prolonged storage and is related to metabolic changes and water content. The rate and extension of firmness loss during ripening of soft fruits, such as strawberries, is one of the main factors to determine fruit quality and post-harvest shelf-life.[14]

The results obtained in the present work are in agreement with those reported by Del-Valle *et al*.[31] who observed a firmness loss reduction using a cactus mucilage edible coating. Vargas *et al*.[3] also observed less firmness loss in coated strawberries, and according to them, the lower metabolic activity of samples, the antimicrobial protective effects and the higher water vapour resistance caused by coating application can explain the observed results.

Compression test

During 15 days of storage at 5°C, significant differences ($p < 0.05$) on maximum compression force were found between uncoated and coated strawberries (Figure 4). Samples treated with cassava starch coatings maintained their compression force during the entire refrigerated storage. Although in uncoated samples, the maximum compression force declined gradually from the beginning of storage. No significant differences were observed between the coated samples during the storage time.

Whey protein concentrate–based edible coatings also maintained the firmness of minimally processed apples, stored for 14 days at 3°C.[16] Garcia *et al*.[14] observed a firmness reduction in uncoated strawberries and in the ones treated with corn and potato starch coating. However, a more severe firmness reduction was observed in uncoated strawberries, indicating that the coatings were able to reduce the firmness loss.

Observing the results of puncture and compression tests, we can conclude that the cassava starch coating, with or without potassium sorbate, had a beneficial result on lowering the firmness loss of minimally processed strawberries, stored at 5°C for 15 days.

Respiration rate

For all the studied treatments, a high strawberry respiration rate was observed on the first storage day, followed by a significant reduction ($p < 0.05$) from day 1 to day 5 (Figure 5). From the fifth day, successive increases on the respiration rate were noticed for all treatments, the highest respiration rate being achieved on the last storage day.

The stress caused on vegetable tissue by processing operations, such as handling, cutting, and packaging, among others, favours the increase on respiration rate, explaining the high values observed for the strawberries on the first day of storage. However, the metabolic activity of fruits (and consequently the respiration rate) decreases when these products are stored at low temperatures. The metabolic activity reduction occurs gradually, and so, a contact time between the fruit and the cold environment is needed for the reduction to take place. Thus, in this study, the thermo equilibrium among the strawberries and the cold environment was achieved between day 1 and day 5, explaining the strawberry respiration rate reduction. On the other side, the increase in strawberry respiration rate between days 5 and 15 can be explained by the fruit senescence and the microbial growth.

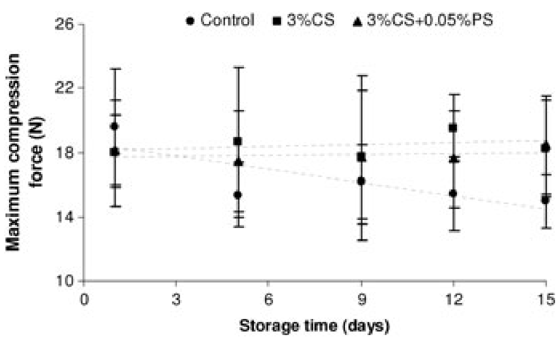

Figure 4. Maximum compression force (N) of minimally processed strawberries subjected to different treatments. CS, cassava starch; PS, potassium sorbate.

DOI: 10.1002/pts

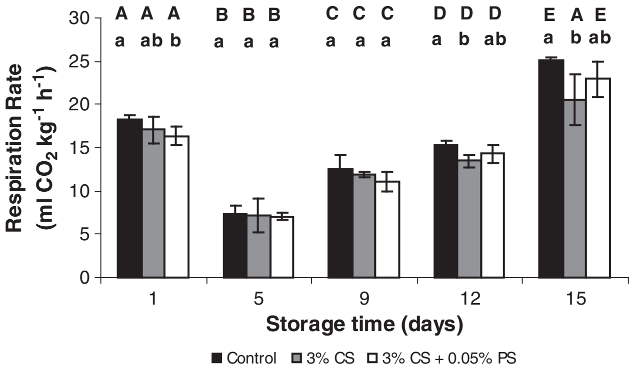

Figure 5. Respiration rate (ml CO_2 kg^{-1} h^{-1}) of minimally processed strawberries subjected to different treatments. Mean separation by the Tukey test at $p < 0.05$. Means with the same small letter, in the same storage time, did not differ significantly. Means with the same capital letter, for the same treatment during storage, did not differ significantly. CS, cassava starch; PS, potassium sorbate.

With respect to the treatments applied on minimally processed strawberries, the control samples presented higher respiration rate during storage time when compared with coated ones, and no significant differences ($p > 0.05$) were observed between samples treated with the two different coatings. The explanation for the observed results is the gas barrier between the strawberry tissue and the environment, promoted by edible coatings, that modifies the atmosphere around the fruit and so reduces its respiration rate.

A respiration rate behaviour similar to the observed in the present work was reported by Vargas *et al.*[3] who studied the quality of cold-stored coated and uncoated strawberries. The authors also observed a reduction on strawberry respiration rate because of the use of chitosan-based edible coatings. In agreement, Lee *et al.*[16] reported that the use of carrageenan and whey protein concentrate edible coatings reduced the respiration rate of minimally processed apples, stored at 25°C.

Sensory acceptance

Minimally processed strawberries subjected to different treatments showed good sensory acceptance for all the evaluated attributes, receiving scores above the acceptability limit (4.5) for appearance, aroma, flavour, texture and overall impression during the storage (Table 3). Up to the ninth day, the

Table 3. Sensory evaluation of minimally processed strawberries subjected to different treatments.

		Storage time (days)			
		1	5	9	12
Appearance	Control	7.1^{aA}	7.2^{aA}	6.7^{aA}	–
	CS	6.1^{aA}	7.1^{aA}	6.6^{aA}	6.8^{A}
	CS + PS	6.6^{aA}	7.0^{aA}	6.6^{aA}	–
Aroma	Control	6.6^{aA}	7.5^{aA}	6.6^{abA}	–
	CS	6.1^{aA}	7.1^{abAB}	7.5^{aAB}	7.9^{B}
	CS + PS	6.8^{aA}	6.4^{bA}	6.5^{bA}	–
Flavour	Control	6.5^{aA}	6.8^{aA}	5.5^{aB}	–
	CS	6.1^{aA}	6.6^{aA}	5.8^{aA}	6.4^{A}
	CS + PS	5.8^{aA}	5.1^{bA}	6.1^{aA}	–
Texture	Control	7.1^{aA}	7.4^{aA}	6.9^{aA}	–
	CS	7.1^{aA}	7.4^{aA}	6.9^{aA}	7.5^{A}
	CS + PS	6.8^{aA}	5.2^{bB}	6.8^{aA}	–
Overall impression	Control	6.6^{aA}	7.1^{aA}	6.3^{aA}	–
	CS	6.5^{aA}	6.9^{aA}	6.5^{aA}	6.7^{A}
	CS + PS	6.2^{aA}	5.8^{bA}	6.4^{aA}	–

Mean separation by the Tukey test at $p < 0.05$. Means with the same small letter in a column, for the same parameter, did not differ significantly. Means with the same capital letter in the same line did not differ significantly.

strawberries subjected to all treatments were sensorially evaluated. However, a visual microbial spoilage observed in some packages of uncoated strawberry (control) and the ones treated with CS + PS impeded the sensory evaluation of these samples on the 12th day. For strawberries treated with CS, the visual microbial spoilage was observed on 15th day, and the sensory analysis was also interrupted. The flavour of minimally processed strawberries, added or not with edible coatings, obtained good scores during the whole storage time, with no significant differences between the treatments. However, the uncoated strawberry (control samples) presented a significant reduction on this attribute during storage. The overall impression reproduces in one score the consumers insight in relation to the parameters individually evaluated. During storage, no significant changes ($p > 0.05$) were observed in overall impression, in all the studied treatments.

It can be concluded that the edible coatings, with or without potassium sorbate, did not affect the sensory characteristics of strawberries. However, some edible coating materials, like chitosan, may diminish the overall sensory quality of coated strawberries because of the astringent characteristic of the material.[3] The addition of some antimicrobials in edible coatings, such as cinnamon, oregano and lemongrass essential oils, was also associated with changes in aroma and flavour of some fruits, like melons and apples.[46,47]

The statistically significant differences observed on CS + PS–treated samples in relation to aroma, flavour, texture and overall impression on the 5th day can be attributed to the strawberry heterogeneity because it was not observed any behaviour tendency during storage.

On the beginning of storage, all treatments showed a purchase intention higher than 60%. However, for control and samples treated with CS + PS, a reduction in the purchase intention was observed at the end of storage, whereas for samples treated with CS coating, around 70% of consumers still would buy the product.

CONCLUSIONS

Cassava starch edible coatings, with or without potassium sorbate, were efficient in reducing weight loss, mechanical property loss and respiration rate of minimally processed strawberries, stored for 15 days at 5°C. Samples of all treatments received good sensorial scores (higher than the limit of acceptability), and these results were reproduced in the purchase intention evaluation.

A shelf-life of 9 days was established for minimally processed strawberries uncoated and coated with cassava starch added with potassium sorbate. The potassium sorbate did not inhibit the microbial growth and did not promote the increase on the shelf-life of strawberries, and for this reason, the antimicrobial on the concentration and conditions used in this work is not recommended.

Strawberries treated with cassava starch edible coating achieved a shelf-life of 12 days. Among the studied coatings, this was the only one that favoured the increase of strawberries shelf-life.

ACKNOWLEDGEMENTS

The authors would like to thank CNPq and FAPESP for the financial support.

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DOI: 10.1002/pts

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DOI: 10.1002/pts