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Research Article

Biodegradable Films with *Spirulina platensis* as Coating for Cambuci Peppers (*Capsicum* sp.)

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Abstract

Objective: The main objective of this study was to extend shelf life of Cambuci peppers stored under refrigeration or at room temperature by using biodegradable films with *Spirulina platensis* as coating. **Materials and Methods:** Peppers were washed, sanitized and separated into four groups. Two groups were coated with biodegradable films and the other two groups were used as control ones. Storage occurred at both room and refrigeration temperatures. All groups were analyzed regarding their general appearance, pH, titratable acidity, soluble solids, loss of mass, color and instrumental texture at the beginning of the experiment and on the 3rd, 6th, 8th and 14th days of storage. Data were analyzed by the analysis of variance and Fisher's LSD test ($p<0.05$). **Results:** There was no significant difference ($p>0.05$) in luminosity among samples at room temperature. Peppers showed less accelerated maturation at refrigeration temperature. The sample with coating application, stored at room temperature, had less mass loss by comparison with its control. Reduction in soluble solid values was significant ($p<0.05$) for all samples under analysis. **Conclusion:** The combination of low temperature and application of coating was beneficial for extension of shelf life of Cambuci peppers.

Key words: Postharvest technology, refrigerated storage, luminosity, shelf life, edible coating

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Biodegradable films, whose composition may vary according to the needs of their application, have been studied as an innovative proposal for coatings and active food packaging. Several biomolecules, such as proteins, lipids and polysaccharides, have the ability to form films in isolation and in combination. However, the use of these components has some limitation due to their high absorption of moisture which leads to consequent changes in properties. Processing conditions of biodegradable coating, besides its composition and storage temperature, are factors that influence the performance of compounds with antimicrobial potential[1].

Spirulina sp., is a filamentous microalgae that has anti-inflammatory, immunomodulatory and anti-allergic properties[2]. Its antioxidant power has been attributed to some of its constituents, such as fatty acids, phenolic compounds, chlorophyll, phycobilins, phycoerythrin, allophycocyanin and phycocyanin[3,4].

Fruits and vegetables undergo rapid deterioration, due to their high metabolic activity, which can be delayed by means of layers of edible coatings[5]. Among methods of food preservation, temperature lowering is important since it slows down various enzymatic and chemical reactions, as well as microbial growth[6,7].

The application of coating and reduction in temperature can be effective to maintain the quality of the products, since they act in synergy. The cold chain reduces respiration and perspiration, thus, slowing senescence[8]. Therefore, studies that take into account the inherent particularity of plants and the specific composition of coatings are necessary to determine the feasibility of coating application. This study aimed at evaluating biofilm application to Cambuci (*Capsicum* sp.) peppers by immersion, so as to extend their shelf life at both room and refrigeration temperatures.

MATERIALS AND METHODS

Materials: The experiment was conducted at the State University of Ponta Grossa, located in Ponta Grossa, Paraná (PR), Brazil, in the second half of 2016. Peppers (*Capsicum* sp.) were bought in a local market. Commercial cassava starch and cassava bagasse from the Lorenz® cassava processing industry in Umuarama, PR, Brazil, besides dehydrated, colorless commercial gelatin (Apti®), commercial *Spirulina platensis* biomass (Tamanduá®), with application to Cambuci peppers, were used for producing the coatings. Reagents were glycerol P.A (Reactif®), NaOH (0.01 N) and phenolphthalein.

Methods

Preparation of peppers: Cambuci (*Capsicum* sp.) peppers were selected for the experiment. They were firm and homogeneous in relation to their color and average size (6°Brix and 5 cm in diameter). They were washed in running water, immersed in chlorinated solution (200 ppm) for 3 min, rinsed and dried at room temperature.

Elaboration of filmogenic solutions: Coverage was obtained by hydrating the raw materials (starch (4%), cassava bagasse (0.66%), *Spirulina platensis* (0.66%), gelatin (0.66%) and glycerol (1%)) in distilled water (93%). The solution was then heated on an asbestos plate, stirred until it reached boiling point and kept in this condition for 15 min.

Coating: After the filmogen solution was cooled at room temperature, fruits were immersed in it for 2 min. The solution was then drained by suspending the fruits through the stalk. Fruits were left drying at room temperature for 3 h. Afterwards, both treatment and control groups were conditioned on trays at 5±2°C (Prosdócimo 340 L refrigerator, Brazil). Follow-up examinations were carried out for 14 days, i.e., at the beginning of the experiment and on the 3rd, 6th, 8th and 14th days of storage. Samples were denominated as follows: R (A): With coating at room temperature, R (R): With coating at refrigeration temperature, C (A): Control at room temperature and C (R): Control at refrigeration temperature.

Color: Color was measured by a portable spectrophotometer (Hunterlab, Miniscan EZ, USA), which operated in the CIELab system (L*a*b*). Absolute values of coordinates L* (lightness), a* (green to red) and b* (blue to yellow) were obtained. Coordinates a* and b* were used for calculating chromaticity (the higher the value, the more intense the color) and the Hue angle[9,10]. Equation 1 calculates the chroma whereas Eq. 2 determines the Hue angle.

$$\text{Chroma} = \sqrt{(a^*)^2 + (b^*)^2} \quad (1)$$

$$\text{Hue} = \text{arc tan}\left(\frac{b^*}{a^*}\right) \quad (2)$$

General appearance: During the storage period (14 days), samples were photographed so that their general appearance could be compared at different stages of maturation.

Mass loss: Fruit mass loss was determined in agreement with a methodology adapted from Mohebbi *et al.*[11], by an analytical balance with precision of 0.0001 g. Five fruits per test were weighed during 14 days of storage.

Texture profile: Texture evaluation was performed by a texturometer, the TA-XT plus Texture Analyzer (Stable Micro Systems, Godalming, U.K.), which operated at 25°C. In the compression test, a 2 mm diameter probe and a 25 kg load cell, at 1.5 mm sec^{-1}, were used in the central part of the fruit. Compression distance was 40 mm and contact force was 5.0 g. The parameter in Newton's (N) was evaluated five times during 14 days of storage. Tests were done in six replicates. Firmness was stipulated as the value obtained at the peak of the analysis.

Titratable acidity: Titratable acidity was determined with small adaptations[12] (g citric acid/100 g sample). One gram sample was added in 100 mL distilled water and three drops phenolphthalein, was put into Erlenmeyer flasks. Samples were titrated with 0.01 N NaOH solution until they reached pink staining.

pH: One gram sample diluted in 100 mL distilled water was weighed in an Erlenmeyer flask. Reading was performed by a calibrated digital bench top pH meter (pHmeter-PHS-3B).

Determination of total soluble solids: The sample was added drop wise (2) to the prism of the ATAGO portable refractometer (N-1α Brix 0-32%) for direct reading, in agreement with the manufacturer's instructions. Reading was done in degrees Brix.

Statistical analysis: Data were analyzed by the one way analysis of variance (ANOVA) and Fisher's LSD test[13] in order to verify the existence of significant differences among the conditions under study at 90 or 95% confidence level ($p<0.10$ or 0.05, respectively). The statistical treatment of the data was done by the Excel Action 2.8 supplement (Microsoft, São Paulo, Brazil).

RESULTS

Color: Color is an important attribute of quality since it influences consumer's acceptability and indicates deterioration due to senescence, chemical and enzymatic reactions and microbial growth[14]. As a result, several synthetic dyes have been added to food, even though there is consumer's appeal for the use of natural compounds[15].

The use of low temperatures slows enzymatic activity whereas coatings protect against excessive exposure to oxygen, thus, helping to reduce the loss of the green color which is typical of Cambuci peppers[16]. Data obtained by the analysis of the color of peppers are shown in Table 1.

Table 1: Color analysis of peppers with and without coating, stored at room and refrigeration temperatures

	Chroma				
Storage (days)	R (A)	R (R)	C (A)	C (R)	p-value
0	28.54±2.47^{Aab}	27.74±2.57^{Aa}	25.02±4.82^{Aab}	26.30±9.07^{Aa}	0.747
3	37.40±4.89^{Aa}	29.94±2.44^{BCa}	25.46±7.08^{Cab}	34.28±3.09^{ABa}	0.006
6	25.51±9.79^{Ab}	30.04±8.09^{Aa}	28.11±2.84^{Aa}	28.52±1.53^{Aa}	0.933
8	29.90±10.35^{Aab}	29.77±5.25^{Aa}	17.97±7.09^{Bb}	23.01±7.38^{ABa}	0.075
14	28.08±8.48^{Aab}	31.35±4.97^{Aa}	30.66±2.17^{Aa}	34.55±5.04^{Aa}	0.371
p-value	0.100	0.860	0.075	0.225	
Hue (°)					
0	286.26±2.52^{Aab}	284.54±1.40^{Aab}	284.35±3.54^{Ab}	285.93±2.48^{Aa}	0.573
3	288.66±4.24^{ABa}	283.68±1.64^{Bb}	289.79±6.52^{Ab}	286.56±0.86^{ABa}	0.021
6	284.96±2.97^{Aab}	286.24±1.63^{Aa}	285.05±4.88^{Ab}	298.47±27.91^{Aa}	0.934
8	283.92±5.54^{Aab}	284.07±2.05^{Aab}	290.02±10.77^{Ab}	285.63±2.25^{Aa}	0.403
14	281.80±4.57^{Cb}	283.45±2.49^{BCb}	273.46±0.88^{Aa}	285.84±1.14^{Ba}	<0.001
p-value	0.102	0.072	0.034	0.434	
L*					
0	27.55±3.64^{Aa}	24.36±3.96^{Ac}	24.71±3.17^{Aa}	26.02±1.86^{Abc}	0.424
3	22.13±4.35^{BCa}	26.27±3.91^{ABabc}	18.03±8.36^{Ca}	32.20±2.01^{Aa}	0.004
6	24.83±7.48^{Aa}	24.83±4.86^{Abc}	22.76±9.26^{Aa}	25.41±3.64^{Ac}	0.927
8	29.09±6.40^{Aa}	31.53±5.77^{Aa}	20.63±5.01^{Ca}	23.69±4.39^{BCc}	0.023
14	24.41±6.16^{Aa}	30.22±2.03^{Aab}	25.04±5.58^{Aa}	29.53±1.56^{Aab}	0.108
p-value	0.373	0.050	0.444	0.001	

*Mean±Standard Deviation, different upper case letters represent significant differences in the row and different lowercase letters represent significant differences in the column, according to Fisher's LSD test ($p<0.05$), R (A): With coating at room temperature, R (R): With coating at refrigeration temperature, C (A): Control at room temperature and C (R): Control at refrigeration temperature

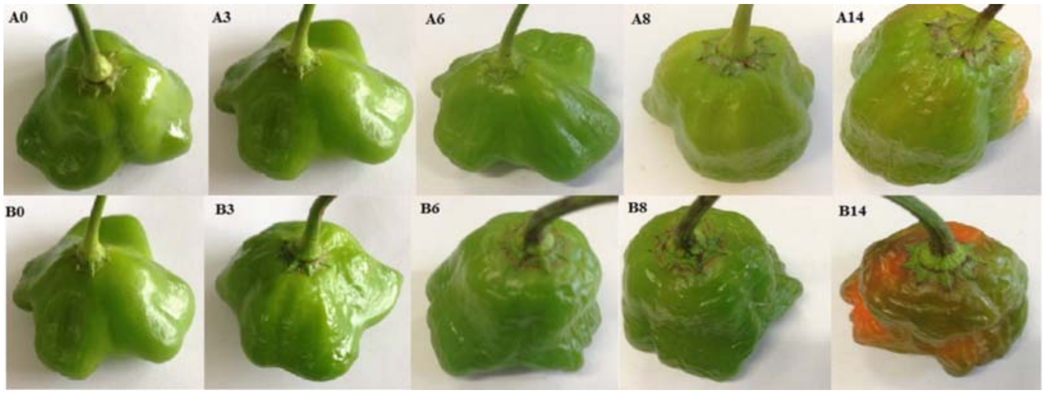

Fig. 1: General appearance of peppers stored at room temperature
A: Coated samples, B: Control samples (uncoated), 0, 3, 6, 8 and 14 days of storage

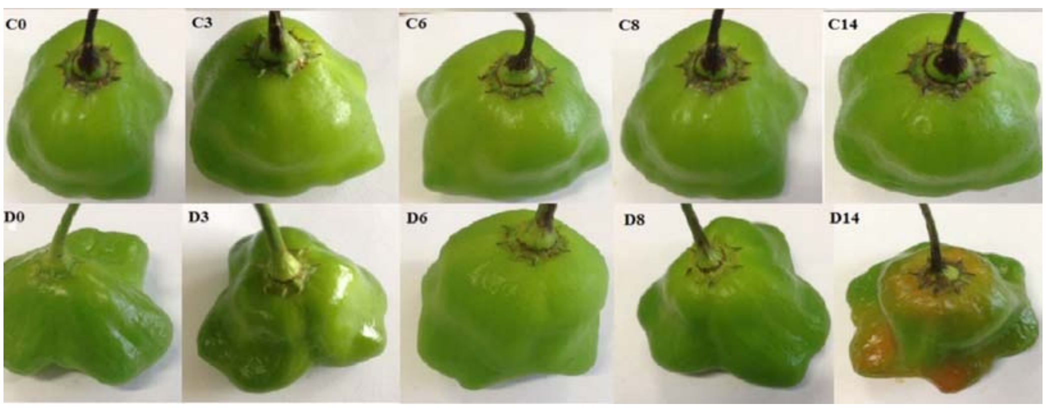

Fig. 2: General appearance of peppers stored at refrigeration temperature
C: Coated samples, D: Control samples (uncoated), 0, 3, 6, 8 and 14 days of storage

General appearance: During the follow-up period, peppers matured and the application of the coating aimed at decelerating this process. The visual analysis showed that coated samples had a satisfactory appearance until the 8th day while control samples, which began to lose turgidity on the 3rd and 6th days, had an inadequate appearance for consumption at room temperature (19.8±2.8°C). The apparent deterioration is consistent with the loss of mass during storage. Images of uncoated and coated samples at room temperature are shown in Fig. 1 whereas the ones at refrigeration temperature are depicted in Fig. 2.

Mass loss: Reduction in mass loss of samples under analysis occurred at refrigeration temperatures during 14 days of storage as shown in Fig. 3. Results of samples kept at room temperature (coated and control) and at refrigeration temperature (coated and control) were similar. Samples with coating application had lower mass loss than their respective controls. Loss of mass among samples and throughout the days of the analyses ($p<0.10$) was significant.

Texture profile: Determination of the texture of fresh and processed fruits and vegetables is a parameter which has been used for establishing product quality and consumers' acceptability[17]. In general, plant tissues have higher values of firmness at pH below 4; however, firmness decreases with increasing pH[18]. Metabolic processes can cause starch degradation and conversion of acids to sugars, leading to changes in firmness[19] (Table 2).

Titratable acidity, pH and total soluble solids (°Brix): Reduction in acidity is associated with the natural process of fruit and vegetable ripening, since in respiration, organic acids

Table 2: Texture of Cambuci pepper samples with and without coating at room and refrigeration temperatures during storage

	Texture (N)				
Storage (days)	R (A)	R (R)	C (A)	C (R)	p-value
0	9.19±0.59^{Ba}	8.50±0.47^{Bd}	9.64±0.50^{Aa}	9.78±0.88^{Aa}	0.004
3	9.60±1.45^{Ba}	10.68±0.91^{Aa}	8.85±0.30^{Bb}	5.54±1.08^{Cc}	<0.001
6	9.04±0.93^{Ba}	10.41±0.60^{Aab}	9.60±0.70^{Ba}	7.70±0.42^{Cb}	<0.001
8	8.68±0.50^{Ba}	9.25±0.65^{Ac}	7.61±0.27^{Cc}	9.14±0.36^{ABa}	<0.001
14	9.19±0.46^{Ba}	9.92±0.46^{Abc}	7.61±0.74^{Dc}	8.26±0.42^{Cb}	<0.001
p-value	0.413	<0.001	<0.001	<0.001	

Mean±Standard Deviation, different upper case letters represent significant differences in the row and different lowercase letters represent significant differences in the column, according to Fisher's LSD test (p<0.05), R (A): With coating at room temperature, R (R): With coating at refrigeration temperature, C (A): Control at room temperature and C (R): Control at refrigeration temperature

Table 3: Monitoring of acidity, pH and soluble solids of Cambuci pepper samples with and without coating stored at room and refrigeration temperatures

	Titratable acidity (mg citric acid/100 g)				
Storage (days)	R (A)	R (R)	C (A)	C (R)	p-value
0	1.54±0.18^{Aa}	1.58±0.12^{Aa}	1.79±0.14^{Aa}	1.20±0.08^{Bab}	0.005
3	1.96±0.13^{Aa}	1.79±0.06^{Aab}	1.79±0.16^{Ab}	1.54±0.12^{Bab}	0.025
6	1.59±0.15^{Abc}	1.48±0.21^{ABbc}	1.29±0.06^{Bc}	1.30±0.17^{Bab}	0.071
8	1.46±0.11^{Aab}	1.36±0.32^{Aab}	0.91±0.01^{Bc}	1.20±0.29^{Aaa}	0.072
14	0.95±0.22^{Ac}	1.02±0.03^{Ac}	0.88±0.03^{Ac}	0.96±0.06^{Aab}	0.584
p-value	0.006	0.013	<0.001	0.143	
pH					
0	6.06±0.01^{Bab}	6.15±0.11^{ABba}	6.17±0.11^{ABa}	6.2±0.03^{Aa}	0.0986
3	5.95±0.18^{ABab}	5.96±0.06^{ABba}	5.89±0.12^{Bbc}	6.12±0.03^{Aa}	0.1085
6	6.17±0.16^{Aab}	5.92±0.08^{Aba}	5.78±0.24^{Bc}	5.97±0.06^{ABb}	0.075
8	6.10±0.14^{Aab}	6.00±0.03^{ABa}	6.02±0.04^{Aabc}	6.05±0.01^{Bb}	0.1098
14	6.21±0.12^{Aab}	5.40±0.58^{Bb}	6.18±0.06^{Aab}	5.46±0.07^{Aa}	0.038
p-value	0.2219	0.0526	0.0404	<0.001	
Soluble solids (°Brix)					
0	5.93±0.25^{Aa}	4.80±0.2^{Ba}	6±0.3^{Aa}	4.17±0.15^{Ca}	<0.001
3	6.00±0.2^{Aa}	5.00±0.1^{Ba}	4.50±0.2^{Cb}	3.87±0.30^{Da}	<0.001
6	3.13±0.15^{Ab}	2.13±0.15^{Bb}	2.37±0.16^{Bc}	2.20±0.20^{Bc}	<0.001
8	2.00±0.1^{Bc}	1.92±0.18^{BCbc}	1.71±0.11^{Ce}	2.57±0.06^{Ab}	<0.001
14	2.97±0.25^{Ab}	1.80±0.09^{Cc}	1.90±0.1^{Cd}	2.20±0.05^{Bc}	<0.001
p-value	<0.001	<0.001	<0.001	<0.001	

*Mean±Standard Deviation, different upper case letters represent significant differences in the row and different lowercase letters represent significant differences in the column, according to Fisher's LSD test (p<0.05), R (A): With coating at room temperature, R (R): With coating at refrigeration temperature, C (A): Control at room temperature and C (R): Control at refrigeration temperature

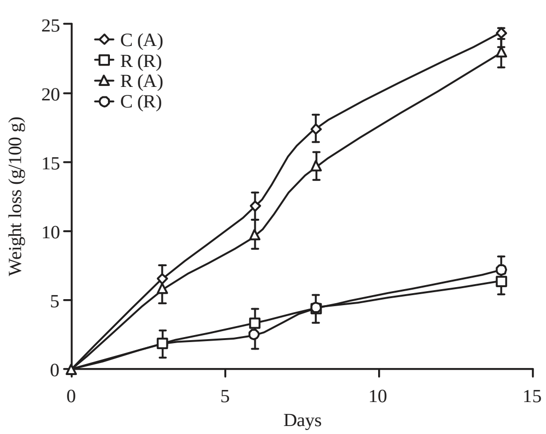

Fig. 3: Mass loss of Cambuci pepper samples
R (A): With coating at room temperature, R (R): With coating at refrigeration temperature, C (A): Control at room temperature, C (R): Control at refrigeration temperature

are metabolized in other non-acidic compounds[20]. In this study, acid contents of all samples reduced during storage.

Refrigerated samples (coated and control) showed significant reduction in pH in the 14 day period (p<0.05). Values of pH found for samples at room temperature were consistent with their acidity and had significant difference (p<0.10) in the 14 day analysis, except coated samples maintained at room temperature, which maintained their pH throughout this period. Samples maintained at room temperature showed increase in the pH value during storage.

Reduction in soluble solids (°Brix) was significant (p<0.05) for all samples under analysis. The highest reduction in these values occurred for control samples stored at room temperature (Table 3).

DISCUSSION

Regarding the luminosity parameter (L), refrigerated samples were observed to have higher values by comparison with those stored at room temperature, although there was no significant difference between them, neither at the beginning of the experiment nor on the 6th and 8th days. Luminosity did not show any significant difference among samples with and without coating stored at room temperature from the beginning of the experiment to the 14th day ($p>0.10$). It shows that color was maintained by the presence of the film in this condition. The maturation process occurred at different speeds, a fact evidenced by the luminosity on the pepper surfaces on the 3rd and 8th days.

A study by Carvalho *et al.*[21] of *Physalis peruviana* L., coated with alginate films found no significant difference among the fruits regarding the staining parameter during refrigerated storage (21 days). On the other hand, L* values and the Hue angle were low in all samples with polysaccharide films enriched with dietary fibers and applied to apples[22].

The control sample stored at refrigeration temperature did not have any statistical difference ($p>0.10$) concerning the Hue angle during 14 days of storage. On the last day of the analysis (14th), a significant difference ($p>0.10$) regarding the Hue angle was established among all samples under analysis. In a study of the application of emulsion-based films in apples[23], showed that coated apples had a higher color parameter L* than uncoated apples during the storage period.

High values represent bright or intense colors[24]. There was no significant difference ($p>0.10$) among the 4 samples under analysis on the days of the analyses. Control sample C (A) had increased staining intensity at the end of the 14 days of storage. The other samples remained constant.

Control samples stored at refrigeration temperature had high color intensity after the 14 day follow-up period while samples kept at room temperature had the lowest chroma values. In the case of coatings produced with fruit and vegetable residues, chroma values ranged from 59-6[25]. In general, refrigerated storage time had a significant influence on the fruit color ($p<0.10$) and the treatments with coatings did not affect the color parameters in a remarkable way. This fact can be explained by the decrease in reaction rates due to the effect of temperature, thus inhibiting post-harvest metabolism[26].

Mechanical damage and cuts during transport and storage of quality fruits and vegetables decrease their quality and commercialization generating large losses in the production chain[27]. In order to store these products for a longer period of time, post-harvest refrigeration is fundamental, in addition to proper handling practices[28]. The quality of the marketed product depends on the maintenance of some parameters, such as appearance, color and firmness, which are affected by deterioration caused by ripening and microorganisms[21].

The use of coating visually interfered in the samples from the 6th day on. Changes were not as noticeable as in samples at room temperature due to reduction in surface wrinkling. Changes were observed in peppers from the control group from the 6th day on, whereas alterations in the coated samples were only observed on the 14th day.

Loss of water from coated fruits occurs due to an accelerated evaporation of surface water caused by low relative humidity (between 40 and 50%)[16]. In this study, samples were stored at $50\pm12\%$ relative humidity. Even though mass loss occurred in peppers, moisture was maintained due to the formation of water from the respiratory process[29]. After 17 days of storage, as ripening proceeded, the weight loss increased by 8.3-9.7% in melatonin-treated tomato fruits[30]. At refrigeration temperature ($3.6\pm1.6°C$), peppers showed less accelerated maturation than samples kept at room temperature ($19.8\pm2.8°C$). It confirms that the combination of preservation methods (coating and low temperature) is positive for fruits and vegetables.

The result of the physiological processes may correspond to the tissue sensitivity to ethylene, rather than exclusively to the increase in its production. Fruit and pepper seeds show uniformity in their development but indeterminate growth[31]. Therefore, fruits in different stages of maturation may be found in the same plant, a fact which makes harvest difficult[32].

Perspiration and respiration of fruits can be reduced by applying coatings, which act as a cover on the food, thus filling stomata and lenticels[33]. CO_2 produced as a result of O_2 consumption in the respiratory process, is maintained even at low rates and modifies the storage atmosphere[19]. The atmosphere formed and retained by the film may not be tolerated by peppers and cause physiological disorders, such as weight loss. Since films can extend shelf life due to protection of the food against the external environment, there may be condensation of water from the respiration, a fact that enables microbial development and reduction in product preservation[33].

Mass loss is one of the limiting factors of the use of biodegradable coatings, since they have low barriers to moisture and water vapor, besides problems related to mechanical properties[34]. Weight loss and aroma in fruit is related to respiration, which is a physiological process that results in the consumption of sugars and starch[35]. If it is a non-climacteric fruit, respiration decreases gradually during maturation. Weight reduction implies loss of quality for consumption, related to texture[36,37]. Higher losses make fruits and vegetables unfit for consumption.

In some products, color changes are related to surface dehydration, which occurs due to moisture losses in the form of vapor[38]. In this study, as well as in the study by Xing *et al.*[27], storage temperature influenced the weight loss of peppers, showing that the use of refrigeration is able to control this parameter. Coated peppers stored at refrigeration temperature showed decrease in transpiration by comparison with control samples in the same conditions. Likewise, a study of green chillies showed that they were benefited by the use of refrigeration and high relative humidity[16].

High concentrations of chitosan and gum arabic in films applied to carambolas caused great loss of mass during the storage period, a fact that may be explained by increase in anaerobic respiration[39]. Alginate films applied to minimally processed watermelon gave good results in relation to mass loss during the storage period, by comparison with the control sample[40].

Minimally processed products must go through the sanitation stage-to reduce pathogenic microorganisms-use of packaging and refrigeration system[41]. Plastic films (PVC), modified atmosphere and low temperatures have been commonly used in fruits for export[42]. These factors interfere in the mass loss of marketed products.

Regarding the nano-laminate coating applied to fresh-cut pear, the coating avoided mass loss, proving the efficiency as barrier[43]. Since cell membranes act as barriers to solute movements, loss of mass can be attributed to their degradation due to the senescence of the fruit which leads to disintegration and impairment of the control of biochemical and physiological processes of the cells. The purpose of the coatings is to reduce mass losses, but it has not always been observed.

In this study, controls at both temperatures showed decrease in firmness during 14 days of storage. All samples significantly differed among them ($p<0.05$). Samples with coating application maintained at room temperature ($19.8\pm2.8°C$) kept their firmness characteristics with no changes whereas coated peppers kept at refrigeration temperature ($3.6\pm1.6°C$) became firmer with the passage of time. At the end of the analysis period, the highest and lowest results of firmness were found for coated and refrigerated samples ($3.6\pm1.6°C$) and for control ones at room temperature ($19.8\pm2.8°C$), respectively. The use of coating was efficient in maintaining the firmness of the samples under analysis by comparison with control ones.

A study of fresh melon samples showed that they required mean compression force of 35 N to get 50% deformation while chitosan coated samples required strength between 45 and 54 N, thus, indicating that the coating was efficient in reducing fruit softening[7]. A similar result was obtained by Poverenov *et al.*[20], who's study of untreated samples of red peppers (*Capsicum annuum* L. cv. *vergasa*) showed considerable degradation in texture, whereas samples coated with chitosan and gelatin remained unchanged during storage.

Control samples stored at room temperature showed the highest acidity reduction at the end of the period under study, it was an expected result due to maturation caused by temperature. Reduction in organic acid contents was significant ($p<0.05$) for all samples, except for the control samples stored at refrigeration temperature, i.e., they maintained organic acids for 14 days. This result indicates that the control sample stored at low temperature, in relation to the acidity parameter, was better preserved. On the last day of the analysis, samples showed no significant difference in titratable acidity.

Total Titratable Acidity (TTA) of minimally processed papaya (climacteric fruit) coated with chitosan film and pectin remained constant during storage by comparison with control samples[5]. A similar result was found by a study of film coating applied to carrots based on residues of fruits and vegetables. It showed the tendency to increase TTA contents, followed by reduction during storage. At the end of the experiment, there was a significant difference ($p<0.05$) between both groups (coated and control)[25].

Determination of pH or hydrogen ions in solution deals with interferents, such as temperature, pressure and viscosity[18]. Carrots coated with films from fruit and vegetable residues showed an initial acidic pH by comparison with control ones, during storage, values suffered small variations[28]. The use of chitosan and pectin coatings applied to papaya did not influence fruit pH, which remained stable during the analysis[5].

Reduction in soluble solids (°Brix) demonstrate that the metabolic process followed its natural course, although it was influenced by temperature and coating. Data from the literature showed that coatings applied to carrots had initial 1.8 °Brix while control samples had 2.4 °Brix. These values were linearly reduced during storage[28]. Different results were also obtained, i.e., total soluble solid contents were higher in the coated samples than in the control ones[5]. These data enables the peculiarity of maturation among different fruits to be observed.

CONCLUSION

The overall appearance of coated Cambuci peppers was kept close to the fresh fruits at both temperatures (4 and 20°C). At refrigeration temperature the peppers presented less accelerated maturation when compared to the samples kept at room temperature. Coatings aided in the maintenance of color and texture, besides preventing surface wrinkling. It was possible to confirm that the combination of preservation techniques, i.e., application of coating and low temperatures were beneficial for extension of shelf life of Cambuci peppers.

SIGNIFICANCE STATEMENTS

Biodegradable coatings are packaging applied to food for the purpose of preserving the product. In the present study a biodegradable coating containing *Spirulina platensis* was evaluated for improving the post harvest behavior of *Cambuci* peppers, contributing to decrease losses of this vegetable.

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REFERENCES

1. Martinez-Camacho, A.P., M.O. Cortez-Rocha, J.M. Ezquerra-Brauer, A.Z. Graciano-Verdugo and F. Rodriguez-Felix *et al*., 2010. Chitosan composite films: Thermal, structural, mechanical and antifungal properties. Carbohydr. Polym., 82: 305-315.
2. Moraes, I.D.O., R.D.O.M. Arruda, N.R. Maresca, A.D.O. Antunes and R.D.O. Moraes, 2013. *Spirulina platensis*: Process optimization to obtain biomass. Food Sci. Technol., 33: 179-183.
3. Shaieb, F.A., A.A. Issa and A. Meragaa, 2014. Antimicrobial activity of crude extracts of cyanobacteria *Nostoc commune* and *Spirulina platensis*. Arch. Biomed. Sci., 2: 34-41.
4. Vaz, B.D.S., J.B. Moreira, M.G. de Morais and J.A.V. Costa, 2016. Microalgae as a new source of bioactive compounds in food supplements. Cur. Opin. Food Sci., 7: 73-77.
5. Brasil, I.M., C. Gomes, A. Puerta-Gomez, M.E. Castell-Perez and R.G. Moreira, 2012. Polysaccharide-based multilayered antimicrobial edible coating enhances quality of fresh-cut papaya. LWT-Food Sci. Technol., 47: 39-45.
6. Mantilla, N., M.E. Castell-Perez, C. Gomes and R.G. Moreira, 2013. Multilayered antimicrobial edible coating and its effect on quality and shelf-life of fresh-cut pineapple (*Ananas comosus*). LWT-Food Sci. Technol., 51: 37-43.
7. Martinon, M.E., R.G. Moreira, M.E. Castell-Perez and C. Gomes, 2014. Development of a multilayered antimicrobial edible coating for shelf-life extension of fresh-cut cantaloupe (*Cucumis melo* L.) stored at 4°C. LWT-Food Sci. Technol., 56: 341-350.
8. El-Beltagy, A., A.H.A. Eissa and S. El-Sayed, 2013. Development of chitosan-glucose and chitosan-citric complexes edible coating to improve tomatoes post-harvest quality. Agric. Eng. Int.: CIGR J., 15: 208-216.
9. Veiga-Santos, P., C. Ditchfield and C.C. Tadini, 2011. Development and evaluation of a novel pH indicator biodegradable film based on cassava starch. J. Applied Polym. Sci., 120: 1069-1079.
10. Azarakhsh, N., A. Osman, H.M. Ghazali, C.P. Tan and N.M. Adzahanb, 2014. Lemongrass essential oil incorporated into alginate-based edible coating for shelf-life extension and quality retention of fresh-cut pineapple. Postharvest Biol. Technol., 88: 1-7.
11. Mohebbi, M., N. Hasanpour, E. Ansarifar and M.R. Amiryousefi, 2014. Physicochemical properties of bell pepper and kinetics of its color change influenced by *Aloe vera* and gum tragacanth coatings during storage at different temperatures. J. Food Process. Preserv., 38: 684-693.
12. AOAC., 2005. Official Methods of Analysis of the Association of Analytical Chemists. 18th Edn., AOAC, Washington, DC., USA.
13. Stahle, L. and S. Wold, 1989. Analysis of variance (ANOVA). Chemom. Intell. Lab. Syst., 6: 259-272.
14. Marin, A., F. Ferreres, G.G. Barbera and M.I. Gil, 2015. Weather variability influences color and phenolic content of pigmented baby leaf lettuces throughout the season. J. Agric. Food Chem., 63: 1673-1681.
15. Carocho, M., M.F. Barreiro, P. Morales and I.C.F.R. Ferreira, 2014. Adding molecules to food, pros and cons: A review on synthetic and natural food additives. Compr. Rev. Food Sci. Food Saf., 13: 377-399.
16. Hedayati, S. and M. Niakousari, 2015. Effect of coatings of silver nanoparticles and gum arabic on physicochemical and microbial properties of green bell pepper (*Capsicum annuum*). J. Food Process. Preserv., 39: 2001-2007.
17. Chen, L. and U.L. Opara, 2013. Texture measurement approaches in fresh and processed foods-A review. Food Res. Int., 51: 823-835.
18. Andres-Bello, A., V. Barreto-Palacios, P. Garcia-Segovia, J. Mir-Bel and J. Martinez-Monzo, 2013. Effect of pH on color and texture of food products. Food Eng. Rev., 5: 158-170.
19. Mahajan, P.V., O.J. Caleb, Z. Singh, C.B. Watkins and M. Geyer, 2014. Postharvest treatments of fresh produce. Philosophical Trans. Royal Soc. Lon. A: Math. Phys. Eng. Sci., Vol. 372. 10.1098/rsta.2013.0309.

20. Poverenov, E., Y. Zaitsev, H. Arnon, R. Granit and S. Alkalai-Tuvia *et al*., 2014. Effects of a composite chitosan-gelatin edible coating on postharvest quality and storability of red bell peppers. Postharvest Biol. Technol., 96: 106-109.
21. Carvalho, C.P., D. Villano, D.A. Moreno, M. Serrano and D. Valero, 2015. Alginate edible coating and cold storage for improving the physicochemical quality of cape gooseberry (*Physalis peruviana* L.). J. Food Sci. Nutr., Vol. 1.
22. Moreira, M.R., L. Cassani, O. Martin-Belloso and R. Soliva-Fortuny, 2015. Effects of polysaccharide-based edible coatings enriched with dietary fiber on quality attributes of fresh-cut apples. J. Food Sci. Technol., 52: 7795-7805.
23. Galus, S.S. and J. Kadzinska, 2015. Food applications of emulsion-based edible films and coatings. Trends Food Sci. Technol., 45: 273-283.
24. Goyeneche, R., M.V. Aguero, S. Roura and K. Di Scala, 2014. Application of citric acid and mild heat shock to minimally processed sliced radish: Color evaluation. Postharvest Biol. Technol., 93: 106-113.
25. Fai, A.E.C., M.R.A. de Souza, N.V. Bruno and E.C.B.D.A. Goncalves, 2015. [Production of edible coating based on fruit and vegetable residues: Application on minimally processed carrot (*Daucus carota* L.)]. Sci. Agrop., 6: 59-68.
26. Vicente, A.R., G.A. Martinez, A.R. Chaves and P.M. Civello, 2006. Effect of heat treatment on strawberry fruit damage and oxidative metabolism during storage. Postharvest Biol. Technol., 40: 116-122.
27. Xing, Y., X. Li, Q. Xu, J. Yun, Y. Lu and Y. Tang, 2011. Effects of chitosan coating enriched with cinnamon oil on qualitative properties of sweet pepper (*Capsicum annuum* L.). Food Chem., 124: 1443-1450.
28. Lai, T.Y., C.H. Chen and L.S. Lai, 2013. Effects of tapioca starch/decolorized hsian-tsao leaf gum-based active coatings on the quality of minimally processed carrots. Food Bioprocess Technol., 6: 249-258.
29. Goncalves, V.D., D.H. Mueller, C.L.F. Fava and E.C. Camili, 2015. Physiological ripeness of pepper bode vermelha seeds. Revista Caatinga, 28: 137-146.
30. Sun, Q., N. Zhang, J. Wang, H. Zhang and D. Li *et al*., 2014. Melatonin promotes ripening and improves quality of tomato fruit during postharvest life. J. Exp. Bot., 66: 657-668.
31. Lisboa, C.F., D.D.A. Silva, I.R. Teixeira, A.J. de Campos, I.A. Devilla and A.G. da Silva, 2016. Physiological quality of sesame seed harvested at different plant positions and maturity stages. Afr. J. Agric. Res., 11: 2825-2832.
32. Nguyen, C.V., J.T. Vrebalov, N.E. Gapper, Y. Zheng, S. Zhong, Z. Fei and J.J. Giovannoni, 2014. Tomato GOLDEN2-LIKE transcription factors reveal molecular gradients that function during fruit development and ripening. Plant Cell, 26: 585-601.
33. Maqbool, M., A. Ali, P.G. Alderson, N. Zahid and Y. Siddiqui, 2011. Effect of a novel edible composite coating based on gum arabic and chitosan on biochemical and physiological responses of banana fruits during cold storage. J. Agric. Food Chem., 59: 5474-5482.
34. Azeredo, H., L.H.C. Mattoso, D. Wood, T.G. Williams, R.J. Avena Bustillos and T.H. McHugh, 2009. Nanocomposite edible films from mango puree reinforced with cellulose nanofibers. J. Food Sci., 74: N31-N35.
35. Missio, J.C., R.M. Renau, F.C. Artigas and J.C. Cornejo, 2015. Sugar-and-acid profile of Penjar tomatoes and its evolution during storage. Sci. Agric., 72: 314-321.
36. Mahfoudhi, N., M. Chouaibi and S. Hamdi, 2014. Effectiveness of almond gum trees exudate as a novel edible coating for improving postharvest quality of tomato (*Solanum lycopersicum* L.) fruits. Revista de Agroquimica y Tecnologia de Alimentos, 20: 33-43.
37. Yadav, A.K. and S.V. Singh, 2014. Osmotic dehydration of fruits and vegetables: A review. J. Food Sci. Technol., 51: 1654-1673.
38. Assis, O.B.G. and D.D. Britto, 2014. Review: Edible protective coatings for fruits: Fundamentals and applications. Braz. J. Food Technol., 17: 87-97.
39. Gol, N.B., M.L. Chaudhari and T.V.R. Rao, 2015. Effect of edible coatings on quality and shelf life of carambola (*Averrhoa carambola* L.) fruit during storage. J. Food Sci. Technol., 52: 78-91.
40. Sipahi, R.E., M.E. Castell-Perez, R.G. Moreira, C. Gomes and A. Castillo, 2013. Improved multilayered antimicrobial alginate-based edible coating extends the shelf life of fresh-cut watermelon (*Citrullus lanatus*). LWT-Food Sci. Technol., 51: 9-15.
41. Pasha, I., F. Saeed, M.T. Sultan, M.R. Khan and M. Rohi, 2014. Recent developments in minimal processing: A tool to retain nutritional quality of food. Crit. Rev. Food Sci. Nutr., 54: 340-351.
42. De Oliveira, T.A., E.M.M. Aroucha, R.H. de Lima Leite, R.M. de Araujo Ferreira and F.K.G.D. Santos, 2015. Postharvest conservation Star fruit refrigerated with biofilm coating gelatin and PVC. Rev. Verde Agroec. Desenv. Sust., 10: 59-66.
43. Flores-Lopez, M.L., M.A. Cerqueira, D.J. de Rodriguez and A.A. Vicente, 2016. Perspectives on utilization of edible coatings and nano-laminate coatings for extension of postharvest storage of fruits and vegetables. Food Eng. Rev., 8: 292-305.