International Food Research Journal 23(4): 1629-1634 (2016)
Journal homepage: *http://www.ifrj.upm.edu.my*

Conservation of physalis by edible coating of gelatin and calcium chloride

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Article history

Received: 17 June 2015
Received in revised form: 10 November 2015
Accepted: 2 December 2015

Keywords

Weight loss
Browning index
Texture
Fungal deterioration
Physalis peruviana.

Abstract

The removal of the calyx from physalis for the commercialization of the fresh cut fruit reduces its shelf life. In this context, gelatin is a protein polymer produced on large scale at relatively low cost that may be employed as edible coating increasing the shelf life of this fruit. The objective of this study was to evaluate the effect of gelatin application associated to calcium chloride in the conservation of *Physalis peruviana* without calyx, stored either at room temperature or under refrigeration. The fruits were selected, sanitized, centrifuged, dried under forced ventilation, coated, packed in trays with a polyethylene terephthalate cover and stored at 5±1°C for 21 days and 20±1°C for 14 days. Analyses of weight loss, texture, browning index, total soluble solids and pH were performed. Although gelatin-based coatings were efficient in controlling fungal deterioration regardless of storage temperature, refrigeration extended the conservation of the fruits. The coatings provided reduction of weight loss in the storage at 5ºC, but did not affect firmness, browning index and total soluble solids. The addition of calcium chloride in gelatin coating avoided fungal deterioration of the fruit.

Introduction

Among the more than 120 species of the Solanaceae family, *Physalis peruviana* is the most well-known and shows high commercial prospection. It may be found in temperate climate regions in South and North America (Gutierrez *et al*., 2008; Licodiedoff *et al*., 2013b). Physalis is a small and round berry-like climacteric fruit involved by a dark orange-colored calyx composed of 150 to 300 seeds which presents acid taste and is a source of vitamins and flavonols (Bolzan, 2011; Licodiedoff *et al*., 2013a). The calyx extends the fruit's post-harvest life in approximately 67% when compared to the calyx-less fruit due to a decrease in respiration intensity, weight loss and color loss, the latter as a consequence of chlorophyll, carotenoid and anthocyanin degradation (Galvis *et al*., 2005). On the other hand, commercialization currently requires calyx-less physalis without its natural oil because of phytosanitary problems (Alvarado *et al*., 2004). Consequently, fruit disinfection prior to commercialization is a market requirement.

According to Bolzan *et al*. (2011), the fruit *Physalis peruviana* L. may be stored without calyx at 2±1ºC and relative humidity of 90±5% for up to 58 days, even though such conditions are difficult to achieve on the retail market. The same authors report that changes to the fruit, which depend on storage temperature and on presence or absence of the calyx, may lead to weight loss, color change, decreased firmness and altered relationship between total soluble solids and total titratable acidity, which impairs flavor. Edible coatings, defined as a fine layer of eatable matter which is applied and formed on the product's surface, may be an alternative to reduce changes in physalis during storage (Krochta, Mulder-Johnston, 1997).

Among the substances used as edible coatings, gelatin has been focused by researchers for it is a protein polymer produced on a large scale at low costs. However, the use of gelatin as a film-like edible coating is still at its early stages (Oliveira *et al*., 2012). In fact, gelatin forms a barrier against the loss of moisture, oxygen, carbon dioxide and other compounds. It also provides protection against the natural deterioration of fruits that are perishable regarding to their sensorial and physicochemical characteristics (Fakhouri, Grosso, 2003; Cortez-Vega *et al*., 2014).

By its turn, calcium improves the nutritional quality of fruits and vegetables in the post-harvest period and increases shelf-life due to firmness given to the fruit and to the reduction of respiration rate and

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ethylene production (Paula *et al.*, 2007). The above results may be ascribed to the formation of bridges between pectic and polysaccharide acids. These acids provide resistance to the bridges so that they may function as anti-senescence sites that stabilize the structure of the cell wall and membrane, which hinders the hydrolytic activities of enzymes such as pectin methylesterase (Lara *et al*., 2004; Atress *et al.*, 2010; Aghdam *et al*., 2013).

Data on physalis conservation are currently very rare and even non extant when coating is involved. The objective of this study was to evaluate the effect of gelatin application associated with calcium chloride in the conservation of physalis *(Physalis peruviana)* stored at room temperature or under refrigeration.

Materials and Methods

Material

Physalis *(Physalis peruviana)* harvested on the Fazenda Coxilha Rica in Lages, SC, Brazil were used as raw material. The fruit was immediately conditioned under refrigeration (7.0±0.5°C) for 3 days and then transported to the Laboratory of Food Physical Properties of the Federal University of Santa Catarina, Brazil, where they were processed. The fruits were selected according to size, maturation degree (4 and 5) and absence of any physiological blemish (ICONTEC, 1999).

Preparation of samples

The calyx of the fruits was removed for hygienization by immersion in ozonated water (0.5 $\mu g.mL^{-1}.min^{-1}$) and the excess water was removed by manual centrifugation. The fruit were handled at approximately 15ºC. Commercial gelatin was acquired in the local market and its solubilization was undertaken slowly in distilled water at 60ºC under constant stirring for 30 minutes until total dissolution. Glycerol and calcium chloride were then added to the solution, according to the conditions of each treatment, under heavy stirring for approximately 10 min.

Coatings were prepared in water solution under the following conditions: Treatment 1 - Control (fruit without any coating); Treatment 2 - $CaCl_2$ (1.0% w/v); Treatment 3 - gelatin (7.0% w/v) and glycerol (1.0% v/v); Treatment 4 - gelatin (7.0% w/v), $CaCl_2$ (1.0% w/v) and glycerol (1.0% v/v). The fruits were immersed in the solutions for 1 min and then taken to a ventilated refrigerated place for drying for approximately 1h. They were then packed in trays covered with PET lids. The number of fruits (11 units) per package was standardized, and the packaged physalis were stored at 5±1ºC or 20±1ºC during 21 and 14 days, respectively. Physical and physico-chemical analyses were performed on the day of sample processing and after 3, 7, 10, 14, 17 and 21 days of storage. All experiments were conducted in triplicate, with the exception of color and tissue analyses, which were undertaken at least with 5 replications.

Fungal decay

Fungal decay was assessed visually and fruits detected with any mycelium development on the surface were considered deteriorated. Results were expressed as a percentage of infected physalis.

Weight loss

The weight loss was calculated by the difference between initial weight of the physalis and the weight at the end of each storage time using Equation 1, giving results on percentage of weight loss.

$$\text{Weight loss (\%)} = \left[\frac{(\text{initial weight} - \text{final weight})}{(\text{initial weight})}\right] \times 100 \quad (1)$$

Texture analysis

Tissue firmness was measured by a texture analyzer (TAXT2i, Stable Micro Systems) with a 50 kg charge cell. A 2 mm-diameter cylinder pointer was used to analyze perforation. Speeds during pre-test, post-test and test were respectively 3 $mm.s^{-1}$, 5 $mm.s^{-1}$ and 3.3 $mm.s^{-1}$, with a 5 mm penetration depth for 30s. Results were given in Newton (N).

Color

Color was evaluated by a spectrophotometer (HunterLab MiniScan EZ, Hunter Associates Laboratory) calibrated and equipped with D65/10° illumination. The color coordinates a^*, b^* and L^* were used to calculate the browning index (BI) by Equation 2, according to Palou *et al*. (1999):

$$BI = \frac{[100(X-0.31)]}{0.172}, \text{ where } X = \frac{(a^*+1.75L)}{(5.645L+a^*-3.02b^*)} \quad (2)$$

Total soluble solids

The contents of total soluble solids were determined from the liquid extract obtained after grounding the sample by a refractometer (AR 200, Reichert Analytical Instruments). Results were given in Brix degrees (AOAC, 2000).

pH

Fruit's pH was measured using samples of 5 g ground in 50 mL of distilled water with subsequent direct reading in a digital pHmeter (Q400MT, Quimis) (AOAC, 2000).

Statistical analysis

All results underwent analysis of variance and means were compared by Tukey's test at 5% significance using the software Statistica 7.0 (StatSoft, Tulsa, USA). Polynomial regression analyses were conducted to describe the behavior of the variables according to the storage period.

Results and Discussion

Fungal decay and weight loss

Tables 1 and 2 present the results of fungal decay and weight loss for physalis coated with gelatin and $CaCl_2$ under several treatments and stored at 5±1°C for 21 days or at 20±1°C for 14 days. During storage, there was a significant increase in fungal growth, regardless of temperature and type of coating. However, a significant decrease in fungal deterioration of coated fruits occurred at the end of storage when compared to the control sample, regardless of temperature. The addition of $CaCl_2$ to the gelatin coating (T4) provided the lowest percentage of fungal deterioration.

These results suggest that calcium, being a divalent cation, caused a reduction of electrostatic repulsion among the protein molecules, increasing their interaction and leading, consequently, to a lower permeability to oxygen, which impaired fungal growth. The results also indicate influence of temperature on fungal deterioration. The highest temperature (20±1°C) favored the growth of fungus and reduced the shelf life of physalis stored at this specific temperature. The lowest temperature (5±1°C) allied to coating provided favorable conditions for the shelf life of physalis up to 21 days of storage.

Table 2 shows that, regardless of storage treatment and temperature, there was a significant weight loss ($p<0.05$) along storage. Refrigerated storage decreased approximately 60% of weight loss for coated fruits and 37% for fruit without any coating (control) when compared to the product stored at 20±1°C for 14 days.

There was a significant decrease ($p<0.05$) of weight loss of fruits added of gelatin when compared to the control sample in storage at 5±1°C. The same decrease was not detected in the storage at 20±1°C. The non-coated fruit (control) had the highest weight loss when compared to those added of $CaCl_2$, which had the lowest percentage of weight loss. Among the substances used to coat and prolong the shelf life of fruits, gelatin is a feasible alternative to avoid the product's weight loss after harvest, alone or combined with polysaccharides or lipids, with an approximate

Table 1. Fungal decay (%) of physalis coated with gelatin and $CaCl_2$ under different treatments and stored at 5±1°C for 21 days and at 20±°C for 14 days[1]

Fungal decay 5±1 °C				
Days	T1	T2	T3	T4
3	0.00^a	0.00^a	0.00^a	0.00^a
7	0.00^a	0.00^a	0.00^a	0.00^a
10	0.77^a	0.77^a	0.00^b	0.00^b
14	0.88^c	1.31^b	1.52^a	0.00^d
17	2.54^a	1.53^b	1.55^b	1.49^b
21	6.70^a	6.00^b	4.80^c	2.95^d
Equation	$y=0.029x^2-0.346x+0.668$	$y=0.024x^2-0.285x+0.565$	$y=0.020x^2-0.233x+0.405$	$y=0.015x^2-0.203x+0.381$
R^2	0.951	0.908	0.948	0.943
Fungal decay 20±1 °C				
3	1.54^a	1.23^b	0.93^c	0.63^d
7	5.07^a	4.73^b	3.73^c	2.03^d
10	10.66^a	9.49^b	6.44^c	5.68^d
14	24.68^a	15.17^b	10.40^c	8.25^d
Equation	$y=0.158x^2-0.546x+0.946$	$y=0.044x^2+0.519x-0.673$	$y=0.024x^2+0.446x-0.536$	$y=0.026x^2+0.260x-0.406$
R^2	0.996	0.997	0.999	0.975

[1]Means followed by the same letter on the same line do not differ according to Tukey's test ($p<0.05$). *Treatments: (T1) control; (T2) $CaCl_2$ (1.0% w/v); (T3) gelatin (7.0% w/v) and glycerol (1.0% v/v); (T4) gelatin (7.0% w/v), $CaCl_2$ (1.0% w/v) and glycerol (1.0% v/v).

Table 2. Weight loss (%) of physalis coated with gelatin and $CaCl_2$ under different treatments, stored at 5±1°C for 21 days and at 20±1°C for 14 days(1)

Weight loss 5±1 °C				
Days	T1	T2	T3	T4
3	0.59 ± 0.11^a	0.25 ± 0.04^b	0.17 ± 0.06^b	0.13 ± 0.04^b
7	0.76 ± 0.13^a	0.46 ± 0.04^b	0.34 ± 0.07^b	0.32 ± 0.06^b
10	0.84 ± 0.12^a	0.58 ± 0.04^b	0.45 ± 0.08^b	0.46 ± 0.07^b
14	1.06 ± 0.13^a	0.81 ± 0.04^b	0.67 ± 0.08^b	0.69 ± 0.10^b
17	1.13 ± 0.12^a	0.91 ± 0.06^{ab}	0.81 ± 0.08^b	0.79 ± 0.12^b
21	1.30 ± 0.10^a	1.17 ± 0.09^{ab}	1.02 ± 0.07^b	0.99 ± 0.16^b
Equation	$y=-0.000007x^2+0.039x+0.471$	$y=0.0003x^2+0.043x+0.128$	$y=0.0004x^2+0.037x+0.051$	$y=-0.0002x^2-0.052x-0.026$
R^2	0.992	0.996	0.998	0.998
Weight loss 20±1 °C				
3	0.36 ± 0.06^a	0.42 ± 0.08^a	0.36 ± 0.04^a	0.39 ± 0.02^a
7	0.82 ± 0.10^b	1.06 ± 0.04^a	0.89 ± 0.10^{ab}	0.92 ± 0.08^{ab}
10	1.23 ± 0.16^b	1.64 ± 0.13^a	1.38 ± 0.15^{ab}	1.38 ± 0.21^{ab}
14	1.69 ± 0.23^b	2.16 ± 0.11^a	1.91 ± 0.23^{ab}	1.78 ± 0.17^{ab}
Equation	$y=0.00002x^2+0.122x-0.013$	$y=-0.002x^2+0.195x-0.156$	$y=-0.00007x^2+0.144x-0.082$	$y=-0.002x^2+0.171x-0.112$
R^2	0.998	0.997	0.999	0.997

[1]Means followed by the same letter on the same line do not differ according to Tukey's test ($p<0.05$). *Treatments: (T1) control; (T2) $CaCl_2$ (1.0% w/v); (T3) gelatin (7.0% w/v) and glycerol (1.0% v/v); (T4) gelatin (7.0% w/v), $CaCl_2$ (1.0% w/v) and glycerol (1.0% v/v).

reduction of 10% in weight loss (Oshiro *et al*., 2012; Poverenov *et al*., 2014). The literature reports that coating with gelatin alone is extremely fragile and thus the addition of glycerol and $CaCl_2$ in the coating provides more plasticity, flexibility, firmness and other benefits (Lara *et al.*, 2004; Luvielmo, Lamas, 2012). These compounds indeed reduce weight loss since Treatment 4 showed the lowest weight loss percentage (0.99%) at the end of 21 days of storage at 5±1°C.

Firmness and browning index

Tables 3 and 4 give results on the firmness and

Table 3. Firmness (N) of physalis coated with gelatin and $CaCl_2$ under different treatments, stored at 5±1°C for 21 days and at 20±1°C for 14 days[1]

Firmness 5±1 °C				
Days	T1	T2	T3	T4
3	2.49 ± 0.62^a	2.28 ± 0.46^a	2.51 ± 0.48^a	2.63 ± 0.76^a
7	2.33 ± 0.20^b	2.47 ± 0.32^{ab}	3.15 ± 0.49^a	2.75 ± 0.24^{ab}
10	2.41 ± 0.48^a	2.23 ± 0.46^a	2.48 ± 0.41^a	2.33 ± 0.70^a
14	2.68 ± 0.39^a	2.36 ± 0.32^a	2.51 ± 0.24^a	2.58 ± 0.18^a
17	3.04 ± 0.52^{ab}	2.51 ± 0.32^b	3.27 ± 0.45^a	2.68 ± 0.25^{ab}
21	2.75 ± 0.77^a	2.60 ± 0.19^a	2.51 ± 0.56^a	2.58 ± 0.30^a
Equation	$y = -0.00003x^2 + 0.031x + 2.235$	$y = 0.001x^2 - 0.023x + 2.403$	$y = -0.002x^2 + 0.062x + 2.419$	$y = 0.001x^2 - 0.036x + 2.776$
R^2	0.573	0.617	0.044	0.095
Firmness 20±1 °C				
3	2.97 ± 0.40^a	2.57 ± 0.55^a	3.00 ± 0.80^a	2.84 ± 0.20^a
7	2.40 ± 0.54^{ab}	3.28 ± 0.79^a	3.25 ± 0.74^a	2.11 ± 0.43^b
10	1.93 ± 0.52^a	2.07 ± 0.49^a	2.04 ± 0.54^a	2.79 ± 0.89^a
14	2.34 ± 0.43^a	2.32 ± 0.46^a	2.46 ± 0.51^a	2.43 ± 0.13^a
Equation	$y = 0.024x^2 - 0.499x + 4.618$	$y = -0.006x^2 + 0.047x + 2.670$	$y = 0.008x^2 - 0.234x + 3.976$	$y = 0.006x^2 - 0.132x + 3.129$
R^2	0.963	0.247	0.453	0.105

[1]Means followed by the same letter on the same line do not differ according to Tukey's test (p<0.05). *Treatments: (T1) control; (T2) $CaCl_2$ (1.0% w/v); (T3) gelatin (7.0% w/v) and glycerol (1.0% v/v); (T4) gelatin (7.0% w/v), $CaCl_2$ (1.0% w/v) and glycerol (1.0% v/v).

Table 4. Browning index of physalis coated with gelatin and $CaCl_2$ under different treatments, stored at 5±1°C for 21 days and at 20±1°C for 14 days[1]

Browning index 5±1 °C				
Days	T1	T2	T3	T4
3	253.49 ± 1.74^a	236.31 ± 4.98^a	241.28 ± 3.74^a	226.30 ± 4.13^a
7	245.25 ± 4.24^a	213.95 ± 1.59^a	225.17 ± 2.10^a	250.67 ± 2.11^a
10	273.76 ± 2.10^a	228.42 ± 1.53^a	258.76 ± 2.04^a	258.13 ± 1.41^a
14	247.79 ± 1.37^a	252.56 ± 2.18^a	258.75 ± 1.79^a	258.12 ± 2.55^a
17	244.07 ± 1.91^a	230.91 ± 1.94^a	255.07 ± 1.89^a	268.76 ± 3.37^a
21	241.76 ± 3.58^a	224.65 ± 1.62^a	238.46 ± 3.28^a	248.89 ± 1.45^a
Equation	$y = -0.1246x^2 + 2.2486x + 246.55$	$y = -0.0736x^2 + 1.8933x + 221.7$	$y = -0.2162x^2 + 5.7888x + 216.5$	$y = -0.2343x^2 + 6.8551x + 209.98$
R^2	0.313	0.045	0.363	0.686
Browning index 20±1 °C				
3	218.11 ± 1.45^a	231.93 ± 1.22^a	225.93 ± 3.03^a	248.70 ± 2.65^a
7	270.28 ± 3.65^a	249.83 ± 1.79^a	246.81 ± 1.96^a	267.02 ± 2.38^a
10	233.67 ± 2.12^a	233.71 ± 2.69^a	257.90 ± 2.39^a	200.43 ± 2.24^b
14	242.64 ± 3.62^{ab}	242.94 ± 3.12^{ab}	252.25 ± 2.21^a	222.46 ± 3.80^b
Equation	$y = -0.7714x^2 + 14.345x + 187.51$	$y = -0.1548x^2 + 3.1916x + 226.18$	$y = -0.4755x^2 + 10.565x + 198.03$	$y = 0.0663x^2 - 4.8833x + 270.3$
R^2	0.393	0.187	0.988	0.359

[1]Means followed by the same small on the same line do not differ according to Tukey's test (p<0.05). *Treatments: (T1) control; (T2) $CaCl_2$ (1.0% w/v); (T3) gelatin (7.0% w/v) and glycerol (1.0% v/v); (T4) gelatin (7.0% w/v), $CaCl_2$ (1.0% w/v) and glycerol (1.0% v/v).

browning index of physalis with different edible coatings stored at 5±1°C and 20±1°C for respectively 21 and 14 days. Results showed that firmness was maintained during storage, except for fruits subjected to Treatment 1 (control) stored at 20±1°C, which showed significant decrease in firmness. No significant influence was detected when $CaCl_2$ and coating were added, regardless of temperature. A similar behavior was reported by Poverenov *et al.* (2014) in whose studies the firmness of red bell peppers was maintained by using chitosan (2%)/ gelatin (1%) coating when the fruits were stored under refrigeration at 7ºC for 21 days.

Depending on the storage temperature and regardless of the physalis species under analysis, Bolzan *et al.* (2011) reported that the firmness of fruits with or without calyx decreased during storage. The above differed from the current results, where the influence of storage temperature was not significant.

There was no significant difference of storage time on the browning index (Table 4) in stored physalis fruits, except for those subjected to Treatment 3 and stored at 20±1°C, for which an increase of the index was reported. The presence of coating did not interfere in the fruit's browning index when compared to fruits subjected to Treatment 1 (control). It seems that temperature did not affect the results, as observed by Barbosa *et al.* (2012) when they evaluated color parameters for carrots with and without gelatin-based edible coating. Differently from the results of the current analysis, Oliveira *et al.* (2012) evaluated the color of okra coated with gelatin (10%), cocoa oil and $CaCl_2$ and reported a significant influence of storage time on color changes.

Total soluble solids and pH

Table 5 presents the total soluble solids and pH for physalis stored at 5±1°C for 21 days and at 20±1°C for 14 days for different edible coatings. The soluble solids content during storage at 5±1°C was maintained due to the fact that most metabolic and enzymatic processes decrease at low temperatures, as reported by Chitarra and Chitarra (2005). In the case of storage at 20±1°C there was a significant influence of time on the values of soluble solids of fruits subjected to treatments T1 to T3, indicating that the presence of gelatin alone was not effective for decreasing the fruit's maturation rate.

Ávila *et al.* (2006) and Pizato *et al*. (2013) reported that the soluble solids content oscillated during storage due to an increase in the fruit's respiratory intensity for a percentage of sugar may be consumed by respiration. Such phenomena - respiration and variation of soluble solids content - occur simultaneously, at different intensity, according to the maturation stage. However, Oshiro *et al.* (2012) stated that the soluble solids content increased in guavas coated with 3% gelatin, regardless of the temperature evaluated. According to these authors, low efficiency of gelatin in the coating of guavas enhanced the concentration of sugar in the tissues and impaired the fruit's conservation.

Although there was no significant influence of time on pH of fruits stored at 5±1°C, a significant increase in pH occurred during storage at 20±1°C for treatments T1, T2 and T3. It may be suggested that an

Table 5. Total soluble solids (ºBrix) and pH of physalis coated with gelatin and $CaCl_2$ under different treatments, stored at 5±1°C for 21 days and at 20±1°C for 14 days [1]

TSS 5±1 °C				
Days	**T1**	**T2**	**T3**	**T4**
3	13,10 ± 0,10^{a}	13,90 ± 0,10^{a}	13,77 ± 0,10^{a}	14,00 ± 0,29^{a}
7	13,63 ± 0,57^{a}	13,27 ± 0,23^{a}	13,83 ± 0,12^{a}	13,83 ± 0,06^{a}
10	12,99 ± 0,13^{c}	13,32 ± 0,08^{a}	13,08 ± 0,06^{c}	13,65 ± 0,10^{a}
14	13,28 ± 0,13^{ac}	13,73 ± 0,03^{a}	13,43 ± 0,03^{b}	13,03 ± 0,16^{c}
17	12,98 ± 0,36^{b}	13,43 ± 0,10^{ab}	13,73 ± 0,06^{a}	13,60 ± 0,05^{a}
21	13,10 ± 0,09^{b}	13,32 ± 0,08^{a}	13,20 ± 0,05^{ab}	13,20 ± 0,10^{ab}
Equation	$y = -0,001x^2 + 0,015x + 13,20$	$y = 0,001x^2 - 0,059x + 13,88$	$y = 0,001x^2 - 0,051x + 13,90$	$y = 0,002x^2 - 0,097x + 14,31$
R^2	0,135	0,232	0,235	0,658
TSS 20±1 °C				
3	12,50 ± 0,10^{b}	13,17 ± 0,06^{a}	12,53 ± 0,15^{c}	12,83 ± 0,15^{a}
7	13,27 ± 0,12^{ab}	13,60 ± 0,10^{a}	13,00 ± 0,10^{ab}	12,70 ± 0,53^{a}
10	13,23 ± 0,03^{a}	13,22 ± 0,08^{a}	13,23 ± 0,12^{a}	13,27 ± 0,06^{a}
14	13,23 ± 0,06^{a}	12,90± 0,10^{a}	13,31 ± 0,22^{a}	13,03 ± 0,28^{a}
Equation	$y = -0,013x^2 + 0,294x + 11,77$	$y = -0,013x^2 + 0,196x + 12,73$	$y = -0,007x^2 + 0,189x + 12,02$	$y = -0,001x^2 + 0,060x + 12,60$
R^2	0,939	0,820	0,999	0,333
pH 5±1 °C				
Days	**T1**	**T2**	**T3**	**T4**
3	3,30 ± 0,07^{a}	3,46 ± 0,01^{a}	3,33 ± 0,02^{a}	3,45 ± 0,01^{a}
7	3,42 ± 0,01^{b}	3,54 ± 0,08^{a}	3,48± 0,02^{ab}	3,45 ± 0,01^{ab}
10	3,44 ± 0,02^{b}	3,53 ± 0,05^{a}	3,45 ± 0, 02^{b}	3,39 ± 0,02^{b}
14	3,36 ± 0,01^{c}	3,52 ± 0,01^{a}	3,42 ± 0, 02^{ab}	3,45 ± 0,05^{b}
17	3,40 ± 0,04^{b}	3,51 ± 0,02^{a}	3,44 ± 0,02^{b}	3,44 ± 0,01^{b}
21	3,48 ± 0,01^{c}	3,59 ± 0,04^{ab}	3,53 ± 0,02^{bc}	3,61 ± 0,02^{a}
Equation	$y = -0,000x^2 + 0,009x + 3,308$	$y = 3E\text{-}05x^2 + 0,004x + 3,472$	$y = -0,000x^2 + 0,010x + 3,342$	$y = 0,001x^2 - 0,027x + 3,533$
R^2	0,426	0,510	0,490	0,841
pH 20±1 °C				
3	3,44 ± 0,02^{ab}	3,43 ± 0,03^{ab}	3,47 ± 0,02^{a}	3,37 ± 0,06^{c}
7	3,57 ± 0,01^{a}	3,62 ± 0,01^{a}	3,54 ± 0,01^{a}	3,34 ± 0,03^{c}
10	3,63 ± 0,01^{ab}	3,64 ± 0,03^{a}	3,55 ± 0,03^{bc}	3,49 ± 0,07^{c}
14	3,59 ± 0,02^{a}	3,60 ± 0,02^{a}	3,72 ± 0,03^{a}	3,51 ± 0,02^{c}
Equation	$y = -0,003x^2 + 0,064x + 3,275$	$y = -0,004x^2 + 0,084x + 3,220$	$y = 0,001x^2 - 0,009x + 3,488$	$y = 0,001x^2 - 0,001x + 3,347$
R^2	0,996	0,990	0,948	0,753

[1]Means followed by the same letter on the same line do not differ according to Tukey's test ($p<0.05$).
*Treatments: (T1) control; (T2) $CaCl_2$ (1.0% w/v); (T3) gelatin (7.0% w/v) and glycerol (1.0% v/v); (T4) gelatin (7.0% w/v), $CaCl_2$ (1.0% w/v) and glycerol (1.0% v/v).

increasing trend in pH values may be associated with the maturation process, inasmuch as fruits are inclined to be less acid during storage due to the transformation of organic acids into sugars. According to Chitarra and Chitarra (2005), respiration corresponds to the oxidative reactions of organic compounds (organic acids and carbohydrates), which are transformed into water and carbon dioxide, producing chemical energy. This transformation may be ascribed to high storage temperatures as reported by Novoa *et al.* (2006) and Agostini *et al*. (2009). T4 was the only treatment characterized by the maintenance of either pH or soluble solids during storage at 20°C. The combination between gelatin and calcium chloride probably provided the formation of a barrier that altered the fruit's respiration rate.

Conclusions

The current study showed that it is possible to improve the conservation of physalis through the application of a low cost coating of gelatin and calcium chloride, helping to expand the market potential of this fruit, which is a rich source of vitamins and flavonols. The gelatin-based coating was efficient in controlling fungal growth regardless of storage temperature, although refrigerated storage extended fruit conservation regarding to the physicochemical conditions for a 21 day period. Storage under refrigeration at 5°C associated with gelatin coatings significantly reduced weight loss and did not influence on firmness, browning index and total soluble solid values of physalis. The addition of calcium chloride to the gelatin coating contributed to the decrease of fungal deterioration regardless of storage temperature.

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