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Use of pectin in the postharvest conservation of tangerine

[1]Plácido, G. R.*, [2]Silva, R. M., [3]Silva, M.A.P., [2]Furtado, D. C., [4]Santos, M. G., [5]Caliari, M. and [6]Oliveira, D. E. C.

[1]Department of Food Science and Technology, Federal Institute Goiás - Rio Verde Campus, CP 66, 75901-970, Rio Verde, GO, Brazil.
[2]Department of Food Engineering, Federal Goiás Institute - Campus Rio Verde, CP 66, 75901-970, Rio Verde, GO, Brazil.
[3]Department of Animal Science, Federal Institute Goiás - Rio Verde Campus, CP 66, 75901-970, Rio Verde, GO, Brazil.
[4]Department of Food Science and Technology, Federal University of Goiás, CP 131, 74690-900, Goiânia - GO, Brazil.
[5]Department of Food Science and Technology, Federal University of Goiás, CP 131, 74690-900, Goiânia - GO, Brazil,
[6]Department of Agrarian Sciences - Agronomy, Federal Institute Goiás - Rio Verde Campus, CP 66, 75901-970, Rio Verde, GO, Brazil.

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The aim of the present study was to evaluate the postharvest behavior of tangerine coated with different pectin concentrations during storage under controlled temperature (22°C ± 0.1). Fruits with green color (± 90% of the surface) were divided into four groups: fruits without any coating (T1) and fruits coated with pectin solution at 4 g / 100 g (T2), 6 ml / 100 ml (T3) and 8 g / 100 ml (T4). Tangerines were evaluated during the storage period (0, 3, 6, 9, 12 and 15 days) for the following parameters: vitamin C, soluble solids (SS), total titratable acidity (TTA), mass loss, turgidity pressure and external appearance through colorimetric analysis. In general, coated fruits showed lower mass loss over the storage period. The polynomial model was the model that best suited the experimental data. Regarding to the physico-chemical characteristics, the citrus fruits and non-climacteric, showed little variation in the treatments and changes that have occurred and which can be explained by the variability of the fruits used. In general, the fruit treated with different concentrations of pectin kept green for longer period and with this feature of the fruits, is better accepted by the consumer.

Key words: *Citrus deliciosa* Tenore, pectin, coatings, coloring, mathematical models.

INTRODUCTION

Tangerine belonging to genus *Citrus deliciosa* Tenore is a citrus fruit originated from Asia. Trees that produce tangerines adapt to tropical and sub-tropical climates, have intermediate size and are thorny, with full and rounded crown formed by small leaves of dark green color.

It is considered a mid-season fruit, which is harvested primarily from May to June and due to seasonality, there is a need to extend its offer to other periods of the year (Nascimento et al., 2010). About 960 tons of tangerines are harvested annually in the country (IBGE, 2012). The quality characteristics of citrus fruit are of paramount importance for marketing, whether for fresh consumption or for juice processing. Attributes that are of relevance in postharvest quality as include appearance, flavor, odor, texture and nutritional value. Chitarra and Chitarra (2005) report that postharvest fruit quality is related to the minimization of the respiration rate, firmness, color, appearance, aiming at keeping them attractive to consumer for a longer period of time.

According to Miguel et al. (2009), fruits of strong and bright coloring are preferred by consumers, although it is not a factor that contributes to their nutritional value. Many storage techniques have been developed over the years to increase the shelf life of fresh fruits, which can be extended by the use of controlled and modified atmosphere and use of edible coatings (Togrul and Arslan, 2004). Despite the wide availability of synthetic packaging and functionality, there is difficulty in recycling, and this has encouraged investigators to develop biodegradable materials with functional characteristics that allow its use as packaging (Souza et al., 2012).

Edible coatings are biofilms prepared from biological materials that act as barriers to external elements by protecting the packaged product from physical and biological damage and increasing its shelf life (Henrique et al., 2008). Coatings have excellent barrier properties, especially against the transport of gases and water vapor, and other factors that contribute to maintaining the postharvest quality of fruits. Edible films can help providing firmness and shine to coated fruits (Valencia-Chamorro et al., 2011).

Many studies with biofilms have been aimed at evaluating the physical and chemical quality of fruits and vegetables, among them: cassava starch in the conservation of sweet pepper; (Lemos et al., 2007) tomatoes coated with different pectin concentrations (Oliveira et al., 2012.); postharvest conservation of guavira coated with carboxy methyl cellulose, pectin and calcium chloride and pectin alone (Scalon et al., 2012.); tomatoes coated with FruitWax H2 carnauba wax, FruitWax M-AC emulsion resins and Meghwax carnauba wax (Chiumarelli and Ferreira, 2006); carnauba wax in the conservation of persimmon (Blum et al., 2008.); blackberry coated with cassava starch and water kefir grains (Oliveira et al., 2013). Despite the great diversity of biofilms used on fruits and vegetables, there is little information on the application of pectin-based biofilm on tangerines.

Pectin is of utmost importance in food technology and processing as it is associated with the function of providing firmness, flavor and aroma retention, as well to its role as hydrocolloid in the dispersion and stabilization of various emulsions (Gancz et al., 2006). Although, pectin extraction varies according to the raw material used, in general, the process comprises extraction of original vegetable in acid aqueous medium, purification of the liquid extracted and pectin isolation by precipitation (Christensen, 1984). The content of pectic substances varies according to the botanical origin of the plant material, four byproducts from agricultural and food industries rich in pectic substances (content above 15 g / 100 g dry basis): apple bagasse, citrus albedo, beet pulp and sunflower petals (Thibault, 1980). Above, the research aimed to evaluate the influence of coating the base of pectin in physical and chemical characteristics of mandarins (*C. deliciosa Tenore*) during storage.

MATERIALS AND METHODS

The study was conducted at the Laboratory of Fruits and Vegetables - Food Engineering sector, Federal Institute of Goiás - Rio Verde Campus, and the colorimetric evaluation was performed at the Food Engineering sector, School of Agronomy, Federal University of Goiás (Goiânia).

Materials

The fruits were harvested at its full physiological development (± 90% of the surface), being obtained by manual harvesting in a farm in the region of Rio Verde - GO (17° 37'38.26 "S; 50° 45'18.94"W; Altitude: 704 m). Fruits were washed in running water, sanitized with sodium hypochlorite solution at 100 mg.kg^{-1} solution for 15 min and dried with paper towel. Fruits were then randomly divided into four groups: tangerine with no coating, composing the control treatment (T1) and fruits coated with pectin solution at 4 g / 100 ml (T2), 6 g / 100 ml (T3) and 8 g / 100 ml (T4).

Preparation and addition of coatings

Preparation of proposals for concentrations of the biofilm, we used the following amounts of commercial citrus pectin maker Dinâmica - Química Contemporrânea Ltda (formulation 1 L): 40 g (solution at 4 g / 100 ml); 60 g (solution at 6 g / 100 ml) and 80 g (solution at 8 g / 100 ml). Formulations were homogenized in a semi-industrial blender (Skymsen 15V-04) for 30 s until pectin gelation. After preparation, tangerines were immersed in different solutions (± 1 min) and placed in metal racks to dry naturally. Subsequently, they were placed on polystyrene trays for BOD storage with controlled temperature (22 ± 0.1°C) for 0, 3, 6, 9, 12 and 15 days.

Physical and chemical analyses

Every three days of storage, whole fruits were submitted to turgidity pressure, by flattening technique using a horizontal leveler (Calbo and Nery, 1995) and to determine the mass loss of tangerines in each treatment three replicates were formed, and each repetition contained five fruits. The weight of the fruits was performed on an analytical balance CELTC FA 2104M, with results expressed in grams. We used the same fruits to evaluate the evolution of the mass loss during storage (AOAC, 2005), and after manual pulping,

*Corresponding author. E-mail: geovanarochaplacido@yahoo.com.br. Tel: +055 (64) 8124-9504.

Table 1. Mathematical model applied for mass loss.

Model	Model designation
Page	$PM = \exp(-k \cdot t^n)$
Linear	$PM = k \cdot t$
Modified Page	$PM = \exp((k \cdot t)^n)$
Logarithm	$PM = a \cdot \exp(-k \cdot t) + c$
Handerson and Pabis	$PM = a \cdot \exp(-k \cdot t)$
Two Terms	$PM = a \cdot \exp(k_0 \cdot t) + b \cdot \exp(k_1 \cdot t)$
Polynomial	$PM = k_0 + k_1 \cdot t + k_2 \cdot t^2 + k_3 \cdot t^3$

t: Storage time, days; k, k_o, k_1, k_2, k_3: model constants, $days^{-1}$; and a, b, c, n: model coefficients.

the following chemical analyses were performed: the vitamin C content was determined according to the methodology described by Lutz Institute Adolf (1985) by titration with potassium iodide and the results expressed as mg vitamin C / 100 mL of juice, soluble solids based on direct reading refractometer Atago N-2E (ITB, 2005), the results being expressed in brix and the total acidity according to the methodology described by AOAC No. 942.15 (1997), by titration with NaOH 0.1 M was determined, and the results expressed as g total acid / 100 mL. For mass loss, fruits were numerically marked and weighed during storage.

Color

Tangerines were evaluated in terms of instrumental color parameters according to the CIELab system L *, a * and b * in colorimeter (ColorQuest II, Hunter Associates Laboratory Inc, Virginia), where three distinct points were analyzed, totaling 24 points in each fruit. The results were expressed in L *, a * and b * values, where L * values (luminosity or brightness) ranged from black (0) to white (100), a * values from green (-60) to red (60), and b * values from blue (-60) to yellow (60).

Mass loss

From the experimental data obtained by the weight loss, they were adjusted to different equations shown in Table 1 commonly used to represent the rate of mass loss of agricultural products during storage. The use of different equations for mass loss study is relevant to have a higher precision.

Statistical analyses

Experiments were conducted in a completely randomized design (CRD) in 4 x 6 factorial scheme consisting of four treatments (control, 4, 6 and 8 g / 100 ml pectin) and six storage times (0, 3, 6, 9, 12 and 15 days) using software R (2014), where the analyzes were conducted in three replicates for each treatment, and each replicate consisted of 5 fruits, and each analysis was performed in triplicate for each repetition. The results were submitted to analysis of variance by F test and the comparison of means by the Tukey test at 5% probability. For statistical analysis of mass loss, mathematical models were fitted by nonlinear regression using the Gauss-Newton method and statistical software. The models were selected considering the magnitude of the determination coefficient (R^2), Chi-square test ($\chi 2$) and standard deviation of the estimate (SE).

$$SE = \sqrt{\frac{\sum \left(Y - \hat{Y}\right)^2}{GLR}}$$

$$\chi^2 = \frac{\sum \left(Y - \hat{Y}\right)^2}{GLR}$$

Where, Y: value experimentally observed; $\hat{Y}$: value estimated by the model; GLR: degrees of freedom (number of experimental observations minus the number of model coefficients).

The criteria used for selecting the model were the magnitude of the determination coefficient (R^2), the lowest standard deviation of the estimate (SE) and the $\chi 2$ value (chi-square).

RESULTS AND DISCUSSION

Chemical characterization

During storage, acids present in fruits are used as substrates for respiration, reducing their content. The titratable acidity values (Figure 1) showed small variations ($p \leq 0.05$) as a function of treatments and storage time. In general, the vitamin C content (Figure 2) decreased as a function of the storage time all treatments. The applied coatings were used in an attempt to prevent the transfer of gases between atmosphere and fruit. Accordingly, coatings should help prevent the oxidation of vitamin C by preventing fruit exposure to oxygen and changing enzyme activity. However, samples showed statistically equal losses, with little or no variation. Azeredo et al. (2012) reported that acerola fruit coated with mixtures of nano-reinforced polymeric materials showed lower levels of ascorbic acid when compared to a single coating. Alleoni et al. (2006) also observed a slight change in TS and SS values in juice from orange coated with films based on milk whey protein concentrate. Arnon et al. (2014) reported that the TS and SS levels in juice are important parameters of internal quality in citrus and did not observe any significant effects

Table 2. Mean determination coefficient (R^2), standard deviation of the estimate and χ2 values for mathematical models of mass loss for coated tangerines.

Model	R^2 (%)	SE (decimal)	χ^2
T1			
Page	98.94	1.20	1.45
Linear	98.93	1.08	1.17
Modified Page	98.94	1.20	1.45
Logarithm	99.15	1.25	1.55
Handerson & Pabis	90.31	3.64	13.28
Two Terms	90.31	5.15	26.56
Polynomial	99.63	1.01	1.02
T2			
Page	98.61	0.96	0.93
Linear	96.01	1.46	2.12
Modified Page	98.61	0.96	0.93
Logarithm	97.42	1.51	2.29
Handerson & Pabis	87.05	2.93	8.61
Two Terms	92.85	3.08	9.51
Polynomial	99.62	0.71	0.50
T3			
Page	98.68	0.97	0.94
Linear	98.88	0.80	0.64
Modified Page	98.68	0.97	0.94
Logarithm	99.73	0.51	0.26
Handerson & Pabis	94.33	2.00	4.01
Two Terms	97.88	1.73	3.00
Polynomial	99.76	0.58	0.34
T4			
Page	97.98	1.27	1.62
Linear	96.70	1.46	2.12
Modified Page	97.98	1.27	1.62
Logarithm	99.15	0.96	0.92
Handerson and Pabis	94.59	2.08	4.35
Two Terms	94.59	2.95	8.69
Polynomial	99.41	0.98	0.95

either using commercial waxes or coating mixtures on the TS and SS levels of juices from any of the varieties tested in the study.

The SS content of control and coated fruits showed an increasing trend, which may be related to the mass loss of fruits. The behavior of soluble solids observed in this study corroborates with the results obtained by Nascimento et al. (2011) and Obenland et al. (2011).

Turgidity pressure and mass loss evaluation

Firmness is a critical quality attribute for consumer acceptability. Coated fruits showed significant turgor values compared to control fruits during the study period. Pectin coatings had a beneficial effect on fruit firmness so that at the end of the storage period, all treatments led to higher fruit firmness values compared to control fruits ($p = 0.05$) (Table 2).

In general, coated fruits showed higher firmness values over the storage time, and treatments T3 and T4 were the most efficient; however, at the end of the storage period, treatment T2 showed peel stiffness, which is not related to turgidity pressure, but rather to a physiological disorder by CO_2 accumulation promoted by atmosphere modification, water loss and high variability of fruits used.

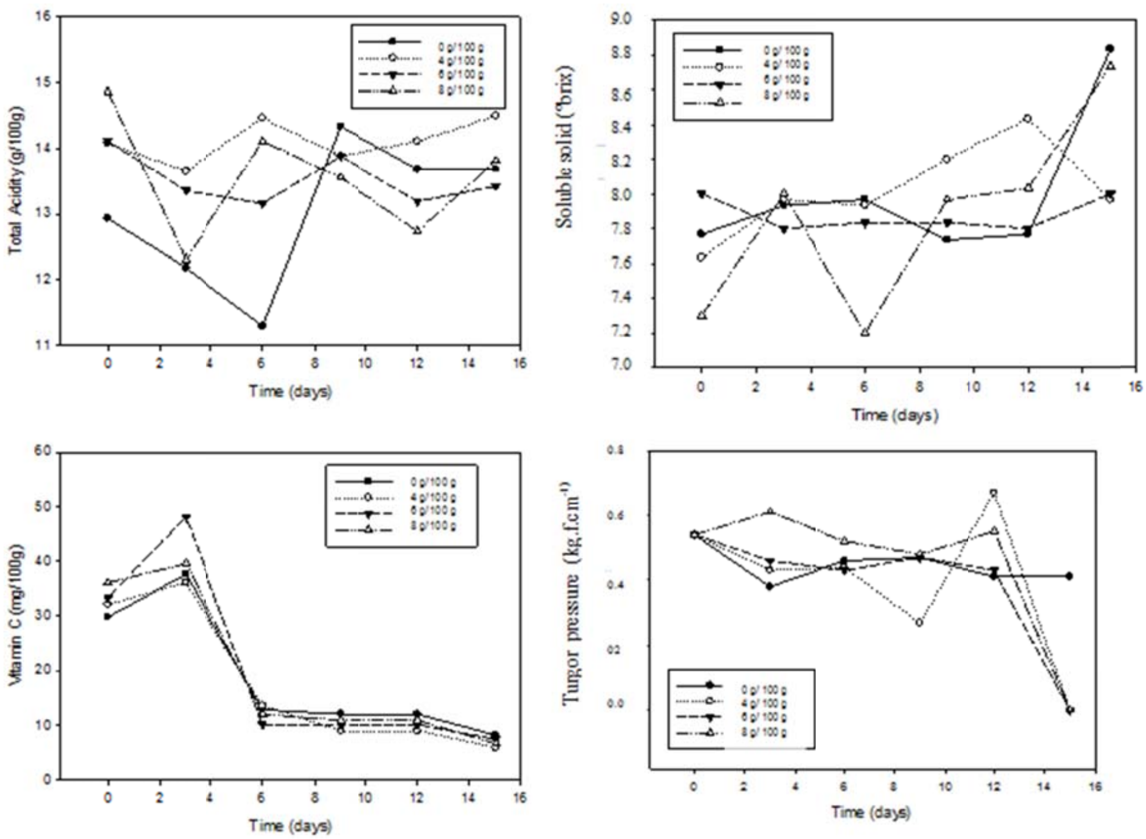

Figure 1. Titratable acidity (g/100 g), solubles solids, vitamin C and turgor pressure of tangerine coated with pectin -based biofilm stored at 22°C.

Arnon et al. (2014) reported on studies with different citrus that the modification of the internal atmosphere of fruits causes CO_2 accumulation and can stimulate anaerobic respiration. Table 2 shows the R^2, χ2 and SE values. By analyzing the determination coefficient, it turns out that the polynomial model obtained the highest values for all treatments and Two Terms and Henderson and Pabis models showed the lowest values. According to Doymaz (2012), the determination coefficient is one of the main criteria for the selection of the model that best fits the drying process; however, in addition to R^2, parameters SE and χ^2 are used to determine the fitness quality. Analyzing the average deviation of the estimate (SE), all models showed low values; however, the polynomial model ($PM = k_0 + k_1 \cdot t + k_2 \cdot t^2 + k_3 \cdot t^3$) showed the lowest values for all treatments. According to Draper and Smith (1981), the ability of a model to adequately represent a given physical process is inversely proportional to the mean deviation of the estimate. Table 2 also showed that through the chi-square test, it appears that only Two Terms and Henderson and Pabis models for the control treatment (T1) showed calculated chi-square values higher than tabulated values ($\chi^2_{tabulated}$ = 11.070), which discards the use of these models for the representation of this phenomenon. The polynomial model showed the lowest chi-square values for all treatments. Günhan et al. (2005) point out that the lower the chi-square value, the better the model fits the study phenomenon.

According to the criteria adopted, the polynomial model was chosen to represent the mass loss process of stored coated fruits because this model was the one that best suited to all treatments. Togrul and Aslan (2004) worked with tangerines coated with carboxy methyl cellulose and concluded that the polynomial model was the most suitable to represent the fruit mass loss. Figure 3 shows the mass loss *versus* storage time of fruits coated with different pectin concentrations adjusted by the polynomial model. The mass loss analysis allowed verifying the effectiveness of coatings in delaying the loss of water from fruits. The beneficial effects of fruit coatings included improved appearance and reduced mass loss. Machado et al. (2012) reported that there is a highly significant interaction between coatings and shelf life of fruits, reducing their mass loss. Shi et al. (2013) evaluated the effect of coatings on postharvest longan fruits and concluded that coatings significantly reduced the mass loss of fruits. Mathematical models describe mass loss as a function of storage time. Experimental data are closely linked to data estimated by the polynomial model, which

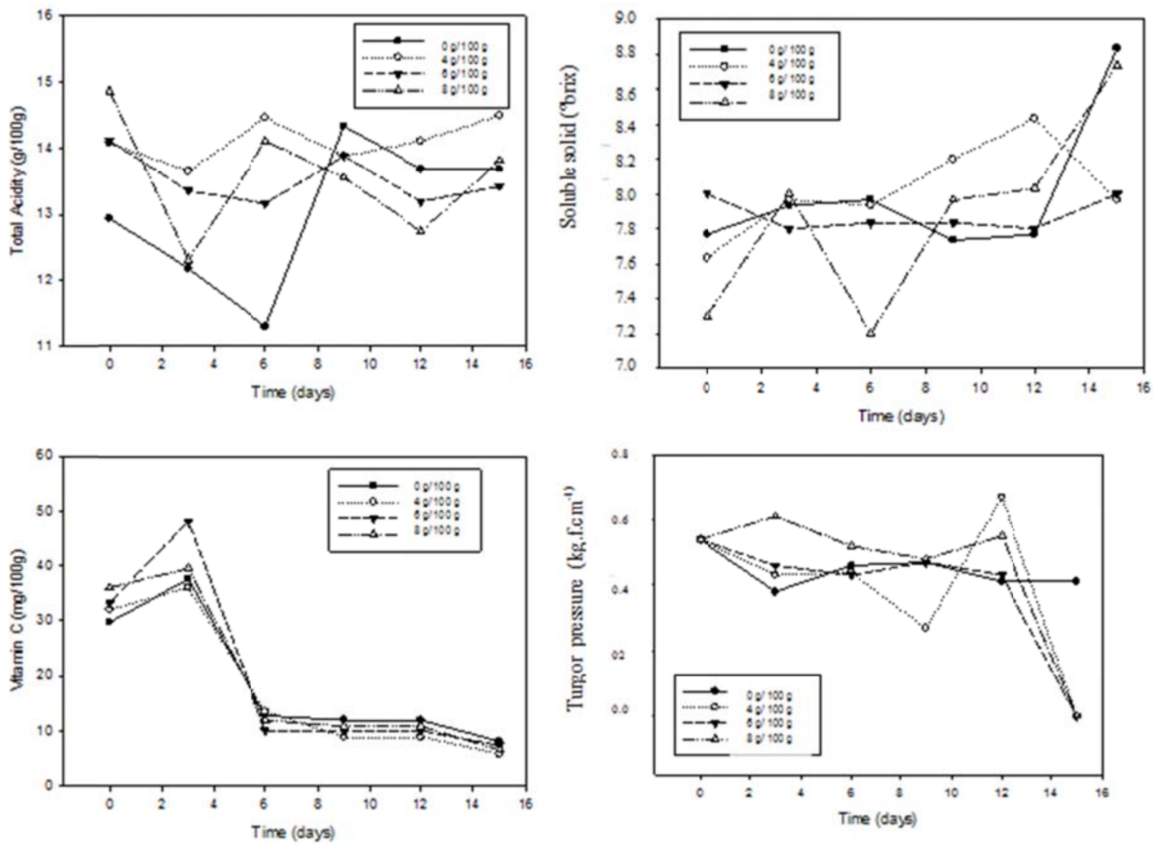

Figure 2. Titratable acidity (g/100 g), solubles solids, vitamin C and turgor pressure of tangerine coated with pectin - based biofilm stored at 22°C.

Table 3. Polynomial model fitted to experimental data of mass loss during storage.

Treatment	Polynomial model
T1	PM = - 0.2350 + 2.6209t - 0.0922t^2 + 0.0029t^3
T2	PM = - 0.1780 + 2.4570t +0.8916t^2 + 0.4155t^3
T3	PM = - 0.1359 +0.8916t +0.0473t^2 - 0.0012t^3
T4	PM = - 0.0505 + 0.4155t + 0.1183t^2 - 0.0036t^3

indicates the suitability of the model to describe the mass loss of fruits with and without coating. Table 3 presents the polynomial equations with constants obtained for the mass loss process. Constant "k" is related to water loss rate during storage processes and coatings, as barriers against water loss, influence the "k" values. By analyzing data, it was observed that constant "k" decreases in absolute values with increasing pectin concentrations in fruits, a fact expected, since higher coating concentrations lead to less transfer of water to the environment.

Colorimetric analysis

Luminosity or L * represents the brightness of the fruit surface. Increase in L * value is related to fruit ripening, and coatings, as barriers to gas exchange, slow biochemical reactions of chlorophyll degradation, reducing ripening and therefore increasing the L * values. Significant difference (p = 0.05) between treatments was observed for all parameters.

By analyzing the luminosity values of fruits during the storage period (Figure 3), it was observed that pectin coatings influenced gradually with concentrations used. Fruits coated with 8 g / 100 mL of pectin showed smaller L * values, a fact related to chlorophyll preservation. Importantly, fruits with more attractive features are better marketed. Asgar et al. (2010) worked with tomatoes coated with gum Arabic and concluded that fruits kept luminosity values stable during storage. Asgar et al. (2011) reported that papaya fruits coated with higher chitosan concentrations obtained slower changes in

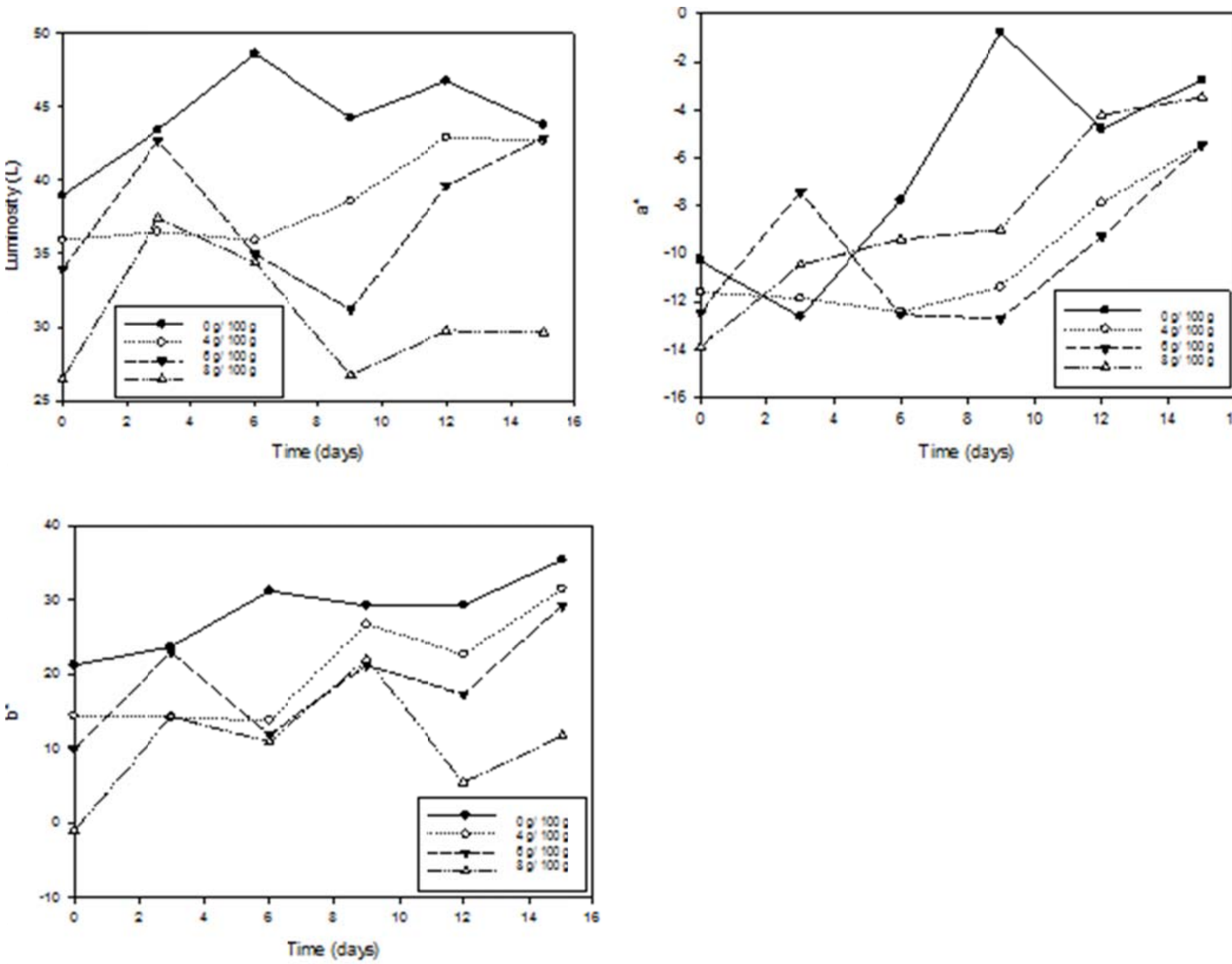

Figure 3. Luminosity (L *), green intensity (-a *) and yellow intensity (+ b *) of tangerine peels coated with pectin-based biofilm stored at room temperature.

the L * variable, corroborating the present work. Rojas-Grau et al. (2009) observed that chitosan-based coatings decreased the browning of pears during storage because the biofilm forms a barrier against gas exchange. In general, pectin-based treatments influence variable a * up to the fifteenth day, being therefore effective to keep the green color of fruits. During ripening, tangerine peel goes from green to yellow, which is related to chlorophyll degradation and revelation of carotenoids (Jacomino et al., 2008). Alvares et al. (2003) found a variation of coordinate -a *, which defines the green color in bananas (Ribeiro, 2006). The yellow intensity (+ b *) of fruit peel presented in Figure 3 showed great variance throughout the storage period for Control fruits and for treatments T2 and T3, and revealed a significant increase in the yellow color of fruits. The advancement in the b * values is the sign of maturation of fruits, with great influence for marketing. For fruits with higher pectin concentration (8 g / 100 mL), the advancement in b * values was less expressive and it could be inferred that the pectin concentration was enough to prevent the "yellowing" of fruits. Chroma is the relationship between a * and b * values, in which the real color of the object being analyzed is obtained. The results of the chroma parameter corroborate the b * results, in which control and treated fruits had 4 g / 100 ml and 6 g / 100 mL pectin, with significant values for yellow color and fruits with 8 g / 100 mL pectin, keeping color green. Statistically, at the beginning of the storage period, treatments can be considered equal, with variability occurring from the third day. The statistical difference for fruits with 8 g / 100 mL pectin over time is much less pronounced when compared to other treatments, and it could be concluded that fruits maintained green color over the storage period. Maftoonazad and Ramaswamy (2005) studied postharvest avocados and reported that coated fruits showed a slower rate of change in peel color. Ali et al. (2010) reported that coated tomatoes were greener even after 20 days of storage compared to control.

Conclusion

Mathematical models are suited to fruit mass loss, being useful tools to describe the mass loss during storage. The polynomial model best fitted to experimental data. The use of pectin-based coatings reduced the fruit mass loss. Fruits coated with 8 g / 100 ml pectin can be stored for 15 days at 22°C. The results presented confirm the beneficial effect of pectin films in postharvest conversation of tangerine fruits. Coatings are a simple, environmentally friendly and relatively inexpensive way to extend the shelf life of tangerine fruits.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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