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Postharvest of 'Tommy Atkins' Mango Submitted to Coating of *Chlorella* sp.

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Abstract

The use of natural products as coatings to preserve the fruit quality during storage is an important step to maintain food safety for consumer health. The use of microalgae in coatings, therefore, may be promising in the preservation of mango. The present work had the objective to evaluate the effect of coatings based on *Chlorella* sp. on the postharvest preservation of 'Tommy Atkins' mango during storage at room temperature (23 °C). We carried out a completely randomized design experiment consisting of 0%, 1%, 2%, 3% and 4% of *Chlorella* sp., using 10 fruits per treatment (n = 10). Analyzing the L*, a* and, b* indices, in the peel and the pulp of the mango fruit, we observed a delay in the ripening with the increase of the biofilm concentration. The firmness of the pulp and maintenance of the organic acids of the fruits were higher in the treatments with a large amount of *Chlorella* sp. The use of biofilm with *Chlorella* sp. at 2% preserved the quality of 'Tommy Atkins' mango until ten days of storage, at 23 °C and 42% RH.

Keywords: coating, *Mangifera indica* L., microalgae, storage

1. Introduction

Brazil is the seventh main mango fruit producer and the sixth world exporter. According to the Brazilian Fruit Culture Yearbook (2017), the Brazilian Institute of Geography and Statistics (IBGE) reported, in 2015, the mango cultivation in 64,305 hectares with the harvesting of 976,815 tons and mean productivity of 15,190 Kg per hectare. The exportation reached 156,337 tons in 2015, generating US$ 184,342,375 million, and in 2016, Brazil exported 154,211 tons (-1.36%), moving US$ 179,932,100 million (-2.39%). Besides the loss, Brazil remained as the sixth world exporter of mango.

Tommy Atkins mango (*Mangifera indica* L.) is the leading cultivated variety in Brazil, corresponding to 80% of the cultivated area and 90% of mango exportation in Brazil (IBGE, 2013).

Aware of the relationship among diet, health and diseases prevention, human populations are increasing the search for healthy food. Therefore, they choose products with a lower addition of chemical substances, preferably organic products that are expanding the market potential.

Microalgae have a high nutritive value, composed of proteins, minerals, phosphorous, iron, manganese, copper, zinc, magnesium and, calcium (Bertoldi, Anna, & Oliveira, 2008), being an alternative for the use in fruit coatings. Besides, microalgae like *Chorella vulgaris* and *Spirulina platensis* may be used as food supplement and other products, such as dyes, pharmaceuticals and, cosmetics (Safi, Zebib, Merah, Pontalier, & Vaca-Garcia, 2014) consisting in an alternative for edible coatings. Research of coatings based on biological products, such as polysaccharides, proteins, lipids and, derivatives are increasing to attend the population needs for natural products since they act as a barrier against external elements, prolonging the shelf life and decreasing the risk for health (Onias, Rocha, Lima, Onias, & Furtunato, 2016).

Proteins consist of 42 to 58% of the dry weight of *Chlorella* sp., besides the presence of essential and non-essential amino acids, being within the nutritional patterns proposed by the World Health Organization (WHO) and Food and Agriculture Organization (FAO) (Safi, Charton, Pignolet, Pontalier, & Vaca-Garcia, 2013). The biomass may be composed of 40% of lipids, having amid and cellulose as well (Lordan, Ross, & Stanton, 2011). One of the main polysaccharides is the o β1→3 glucan that is rich in pigments as chlorophyll and

beta-carotene, and beneficial to the health (Lordan et al., 2011). *Chlorella* sp. is also a source of vitamin A, E and, C, which are essential for cellular growth and differentiation and have antioxidant activity (Safi et al., 2014).

Researchers using the microalgae *Spirulina platensis* in the coatings of mango fruit (Onias et al., 2016) and pomegranate (Moreira & Rocha, 2015) have shown positive results to maintain the organic acids during storage. Due to the rich constitution of *Chlorella* sp., this work aimed to evaluate the effect of different concentration of coatings with Chlorella sp. on the storage of 'Tommy Atkins' mango fruit.

2. Material and Methods

We obtained the fruits in the orchard of organic mango of the Tamanduá Farm, located at the municipality of Santa Terezinha, close to Patos city, Paraíba, Brazil. The mangos were harvested at the beginning of the morning, by hand, with the peduncle, at the ripening stage II (Protrade, 1992), which is characterized by a green pulp with yellow traces. A previous selection excluded the fruits that present anthracnose, scab and, cochineal, or burned by latex run-out and deformed. The fruits were packed in a single layer in containers previously coated with cut paper to minimize the impact and friction between them.

At the laboratory of Food Analysis of the Federal University of Campina Grande, in Pombal-PB, Brazil, a second selection was made to standardize the color and size, excluding the mango fruits that had injuries during transportation. We washed the fruits with neutral detergent at 1%; we rinsed and sanitized with Sodium hypochlorite solution at 100 pp of chlorite during 15 minutes. The fruits were dried outdoor.

Before the start of the experiment, a sample of 10 mango fruits was analyzed to characterize the initial condition of the fruit. The initial characteristics were: 3.32 of pH, 1.05% of titratable acidity (TA), 7.88% of soluble solids (SS), 8.22 of SS/TA ratio and, 23.09% of Vitamin C.

We used a completely randomized design (CRD) with five replicates of each treatment and two fruits per plot. We prepared solutions of 1%, 2%, 3% and 4% of Chlorella sp. biomass diluting in 1L of distilled water under constant shaking, until complete homogenization. *Chlorella* sp. biomass was obtained in ponds of organic production at Tamanduá Farm, following the procedure described by Lima (2016). The characterization of the *Chlorella* sp. used in the experiment is described in the Table 1. We applied 500 ml of the solutions in each treatment with a manual micro sprinkler from Flowers American Pets brand, covering all external surface of the fruit with the solution. After, the fruits dried outdoor and were stored in an acclimatized room at 23 °C and 42% of RH during ten days.

The variables analyzed were: peel and pulp color, pulp firmness (N), pH, titratable acidity (TA), soluble solids (SS), SS/TA ratio and, Vitamin C. The color space L*, a* and b* were measured using a colorimeter from brand Konica Minolta (model Chroma meter CR-400). Calibration followed the manufacturer's instructions (Pinheiro, 2009). Pulp firmness was measured in two opposite points of the fruit without peel, at the equatorial region, using a digital penetrometer (Brand Instrutherm, model PTR-300) with 8mm of ferrule size (AOAC, 2006).

The pulp was processed in a domestic centrifuge to obtain a homogenized sample for the analyses of pH, titratable acidity (TA), soluble solids (SS), SS/TA ratio and, Vitamin C. Titratable acidity (% citric acid) was determined by titrating 1 ml of mango juice diluted to 50 ml of distilled water and adding 2 drops of 1% phenolphthalein, titrate under constant stirring with hydroxide solution of sodium 0.1M NaOH (IAL, 2008). Vitamin C (% ascorbic acid) was determined by titration of 1 ml of mango juice diluted to 49 ml of oxalic acid, and titrated under constant stirring with dfi solution according to Tillman method (AOAC, 2006). Soluble solids (SS, %) was measured by direct reading in an Instrutherm digital refractometer (AOAC, 2006). SS/AT ratio was calculated by the quotient between the two variables. pH, determined by direct reading in the homogenized pulp using a digital pH meter from brand Digimed DM-22 (IAL, 2008).

The treatments were compared using an analysis of variance and polynomial regression. The regression was compared using the significance of de R^2 and the Student's t-test, at 5% probability using the software SISVAR version 5.3 (Ferreira, 2011).

Table 1. Physical characterization, granulometry, mineral composition and aminogram of *Chlorella* sp. used in the coating composition for 'Tommy Atkins' mango fruit

Granulometry (mm)	0.252	Aspartic acid (g/100 g)	1.33
Moisture and volatile (g/100 g)	6.81	Glutamic acid (g/100 g)	3.37
Ash (g/100 g)	24.15	Serine (g/100 g)	1.36
Total lipid (g/100 g)	11.48	Glicine (g/100 g)	1.26
Total nitrogen (g/100 g)	4.61	Histidine (g/100 g)	0.60
Protein (Nx6.25) (g/100 g)	28.82	Arginine (g/100 g)	2.42
Calories (g/100 g)	28.74	Threonine (g/100 g)	1.58
Total carbohydrates (kcal/100g)	334	Alanine (g/100 g)	1.44
pH (solution 10%)	8.15	Proline (g/100 g)	1.62
Calcium (mg/kg)	55689	Tyrosine (g/100 g)	0.97
Cobalt (mg/kg)	0.49	Valine (g/100 g)	1.43
Copper (mg/kg)	142	Methionine (g/100 g)	0.39
Sulfur (mg/kg)	4298	Cysteine (g/100 g)	0.13
Iron (mg/kg)	355	Isoleucine (g/100 g)	1.38
Phosporous (mg/kg)	14541	Leucine (g/100 g)	1.83
Magnesium (mg/kg)	22547	Phenylalanine (g/100 g)	1.24
Manganese (mg/kg)	131	Lysine (g/100 g)	1.49
Nickeul (mg/kg)	0.76	Tryptophan (g/100 g)	0.16
Potassium (mg/kg)	10042		
Sodium (mg/kg)	4879		
Zinc (mg/kg)	11.83		

Note. Analyzes conducted by the Institute of Food Technology, Center for Science and Food Quality, SP.

3. Results and Discussion

We found average of 49.39 for the brightness index L*. Thus, there was no adjustment of this variable to the regression. It can indicated that there was no influence of *Chlorella* sp. in relation to the brightness of the fruits (Figure 1A). The index a* decreased with *Chlorella* sp. concentration from 16.78 at 0% of the coating to 4.78 and 1.22 at 3 and 4% of *Chlorella* sp, respectively (Figure 1B). This reduction means that the fruits with coating showed a greater trend of green coloration. The b * index decreased with the increase in the concentration of the coating, indicating a lower ripening of the fruits after the storage period (Figure 1C).

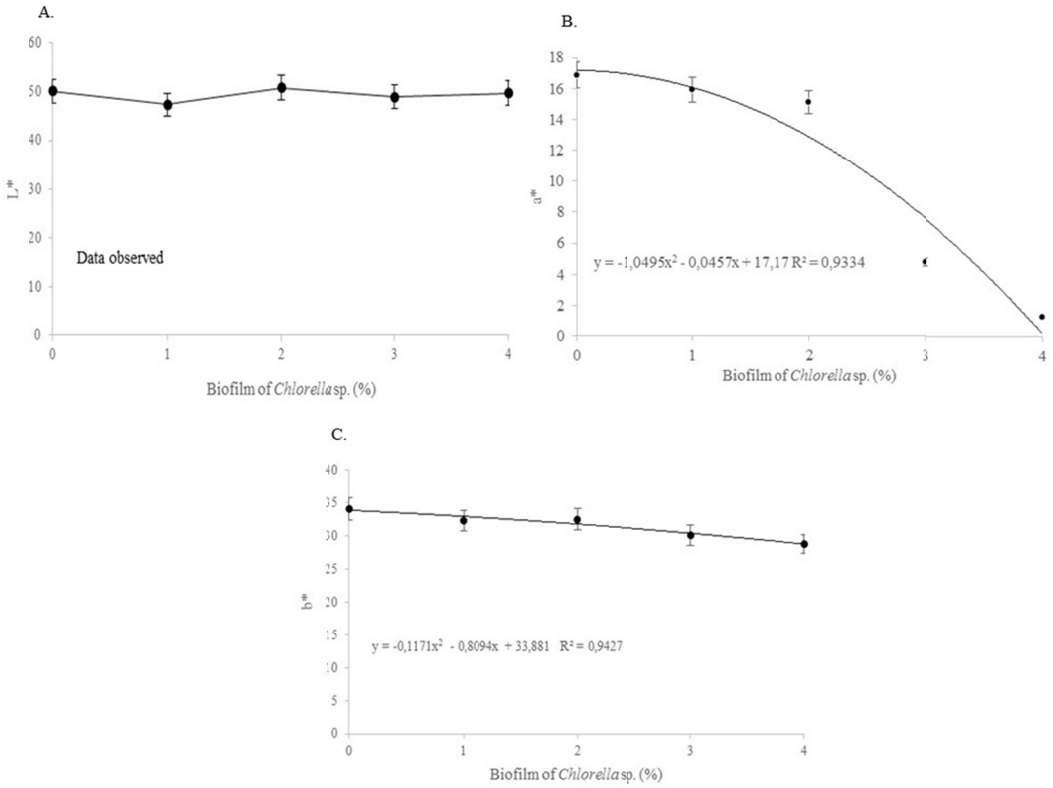

Figure 1. Color coordinates L*, a*, b* of the peel (A, B and C, respectively) of 'Tommy Atkins' mango according to the concentration of *Chlorella* sp. in the coating, after ten days of storage at 23 °C and 42% RH

The results of the color index a* showed that there was a tendency for smaller changes in the pigmentation of the peel of treated fruits with concentrations above 2% of the coating when compared to untreated fruits (T1). Cissé, Polidori, Montet, Loisean, and Ducamp-Collin (2015), observed a similar behavior of maintenance of the coloration in the peel of 'Palmer' mangoes using a coating of chitosan.

The luminosity L* of the pulp was 71.25 on average, with small variations between the treatments, and there was no adjustment to the regression Figure 2A. The color index a* and b* of the pulp decreased with coating concentration (Figures 2B and 2C). Index a* decreased from 8.91 to 6.8 and b* from 66.44 to 57.17, respectively for the fruits without the coating and the fruits with 4% of the coating.

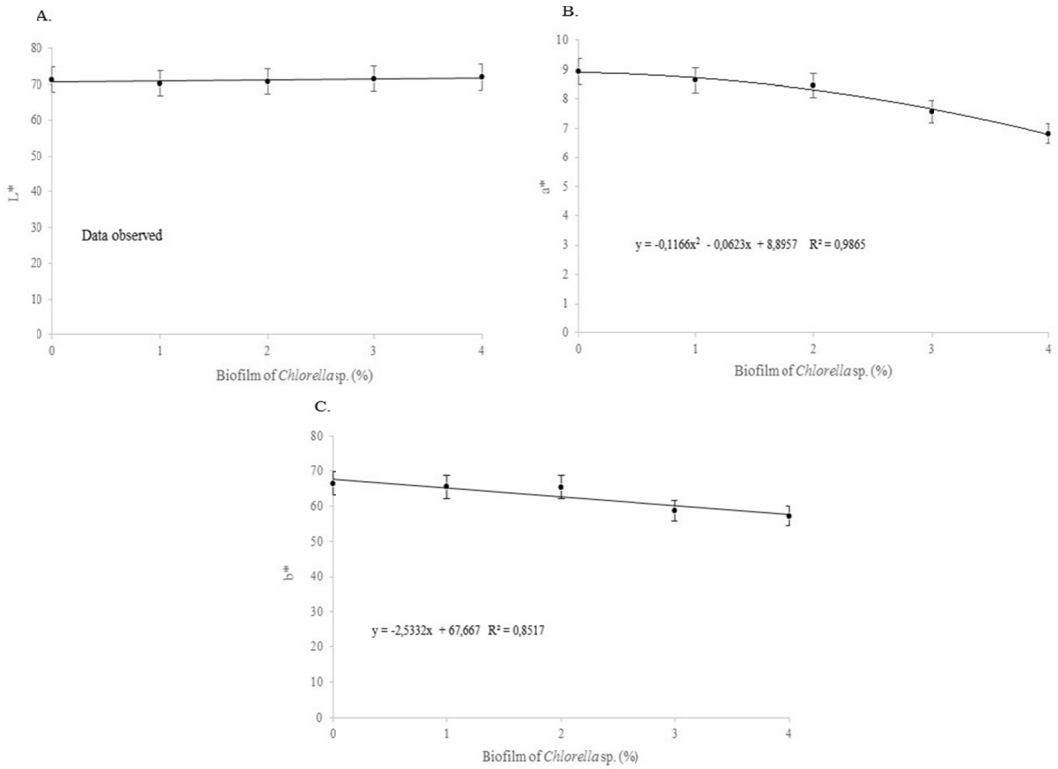

Figure 2. Color coordinates L*, a*, b* of the pulp (A, B and C, respectively) of 'Tommy Atkins' mango according to the concentration of *Chlorella* sp. in the coating, after ten days of storage at 23 °C and 42% RH

The indices L*, a* and b* found for the peel and the pulp of the mango with *Chlorella* sp. indicated lower ripening of the fruits, observed by the lower evolution in coloration after the storage period with the increase of the coating concentration. The results show that it is possible to use up to 2% concentration of *Chlorella* sp. without any damage in the color of the peel or fruit pulp when stored at 23 °C.

'Tommy Atkins' mango treated with *Chlorella* sp. had a linear increase in pulp firmness, with the increase in concentrations of *Chlorella* sp. The concentration of 4% provided the highest firmness of the pulp (16.94 N), showing fruits 63.3% firmer than fruits without coating (6.22 N). These results indicate that the use of the microalgae delayed the fruit ripening keeping them firmer (Figure 3).

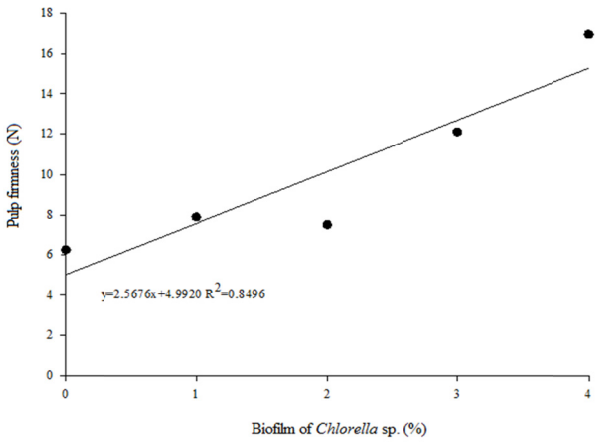

Figure 3. Firmness of 'Tommy Atkins' mango pulp treated with different concentrations of *Chlorella* sp. in the coating, after ten days of storage at 23 °C and 42% RH

Other studies reported a reduction of the firmness of mango cv. 'Tommy Atkins' (Vieira, Pereira, Santos, & Lima, 2009), 'Palmer' (Souza, Morgado, Marques, C. F. M. Mattiuz, & B. Mattiuz, 2011; Serpa et al., 2014) and Kent (Cissé et al., 2015), independently of the coating used, which shows the efficiency of *Chlorella* sp. in delay the fruit ripening.

With the increase of climacteric respiration and ethylene production during fruit maturation, there is the induction of cell wall degrading enzymes, making the fruits softened, with less firmness and consequently more fragile to transport and with a shorter shelf life (Serpa et al., 2014). The use of the *Chlorella* sp. on coating may have reduced the water loss and degradation of the cell wall that occurs during maturation.

There was little variation in vitamin C with the increase in the concentration of the algae on the coating, from 16.27% to 18.13% of ascorbic acid (maximum value), at 0% and 3% concentrations, respectively (Figure 4).

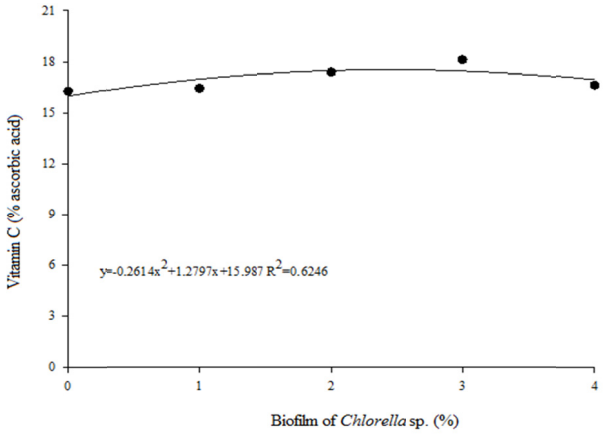

Figure 4. Vitamin C in 'Tommy Atkins' mango treated with different concentrations of *Chlorella* sp. in the coating, after ten days of storage at 23 °C and 42% RH

Serpa et al. (2014) reported a reduction of ascorbic acid levels in 'Palmer' mangoes coated with manioc starch prepared with clove water and cinnamon stored for ten days. Ascorbic acid usually decreases during the fruit ripening process due to the ascorbic acid oxidase (ascorbinase) activity, as well as the oxidation and consequent transformation of ascorbic acid into 2,3-diketogulonic acid (M. I. F. Chitarra & A. B. Chitarra, 2005). The absence of a reduction in Vitamin C shows that the treatments were able to maintain the ascorbic acid values.

There was an increase in the titratable acidity (TA), and the highest value was recorded at the concentration of 4% of coating, corresponding to the rise of 48.3% when compared to fruits without coating (Figure 5A). In contrast to TA, pH had a slight decrease with increasing concentrations of *Chlorella* sp., from 4.44 to 3.83, at 0% and 4% concentrations of the algae, respectively (Figure 5B). Differently, Cissé et al. (2015) reported a reduction in acidity and pH increase in 'Palmer' mangoes coated with chitosan.

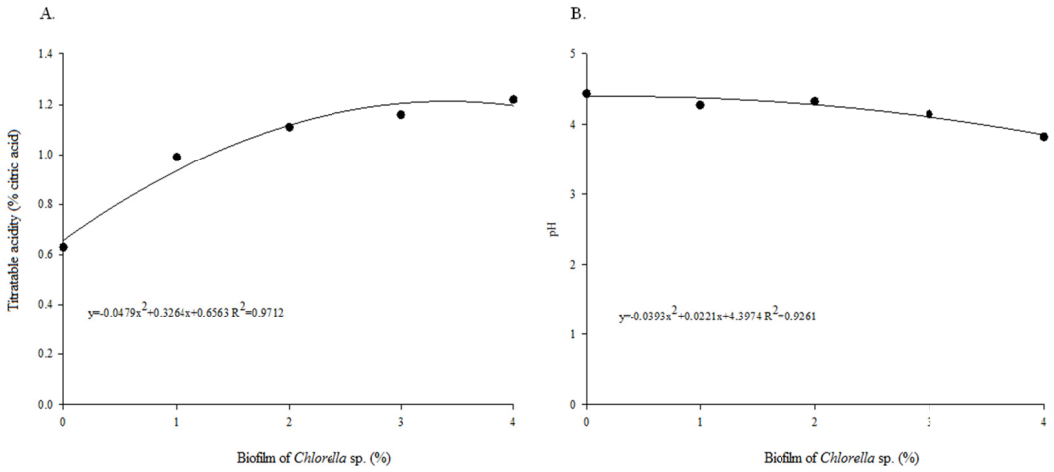

Figure 5. Titratable acidity (A) and pH (B) in 'Tommy Atkins' mango with different concentrations of *Chlorella* sp. in the coating, after ten days of storage at 23 °C and 42% RH

Climacteric fruits, such as the mango, tend to increase the pH and decrease the acidity during the process of ripening. The opposite behavior, found here, that is, the retention of the acidity with the use of *Chlorella* sp. is another indication of the efficiency of the use of the coating in delaying the ripening of the fruit.

Fruits without coating showed higher soluble solids (SS) (18.3%) (Figure 6). Although the variations in SS were small between the concentrations, there was a reduction with the increase in the concentration of *Chlorella* sp. Serpa et al. (2014) found similar behavior for SS showing little variation with a small reduction in 'Palmer' mangoes.

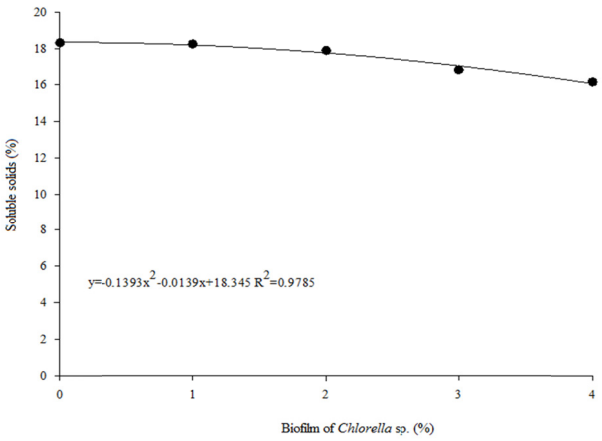

Figure 6. Concentration of soluble solids in 'Tommy Atkins' mango with different concentrations of *Chlorella* sp. in the coating, after ten days of storage at 23 °C and 42% RH

There was a linear reduction of SS/TA ratio with the increase in the coating concentrations, which is a consequence of the decline of the SS and the increase in the TA. The reduction of SS/TA ratio indicates more acidic fruits with the increase in the concentrations of coatings (Figure 7). Similar results of a decrease in SS/TA ratio were observed by Vieira et al. (2009) in 'Tommy Atkins' mangoes coated with manioc or corn starch with sunflower oil.

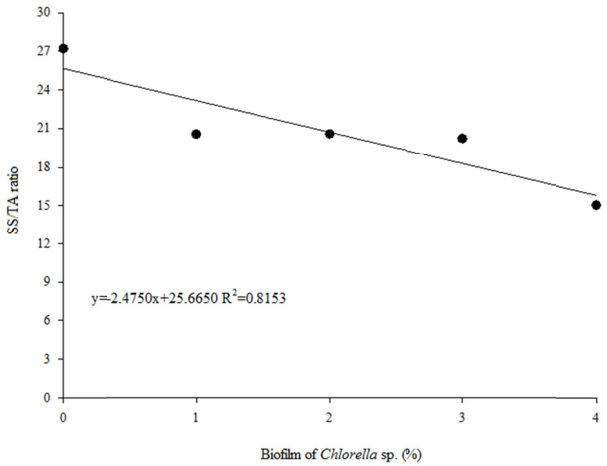

Figure 7. SS/TA ration in 'Tommy Atkins' mango with different concentrations of *Chlorella* sp. in the coating, after ten days of storage at 23 °C and 42% RH

The use of *Chlorella* sp. for coating presents characteristics that indicate that it may be a semipermeable coating, acting as a barrier to gas exchange and loss of moisture, prolonging the useful life of fruits after harvest, with the potential to become a new class of biofilm.

4. Conclusions

The use of biofilm of *Chlorella* sp. at 2% maintained the good characteristics of the 'Tommy Atkins' mango, keeping the quality of the fruit after ten days of storage at 23 °C and 42% RH.

The indices L *, a * and b * analyzed in the peel, and the pulp of the mango treated with the biofilm of *Chlorella* sp. indicated lower ripening of fruits with increasing biofilm concentration.

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