Organic ‘Tommy Atkins’ mango postharvest quality when treated with biofilms enriched by Spirulina platensis

Abstract
The use of edible coatings has been extensively explored for coating fruits and vegetables to minimize moisture loss and reduce respiration rates, and giving bright and attractive appearance. The objective of this study was to evaluate the mango postharvest quality of ‘Tommy Atkins’ organic, coated with cassava starch and corn starch enriched with Spirulina platensis. The experiment was conducted in a completely randomized design in split plot in time, having in the plots biofilms (B), and the subplots, the sampling throughout the storage time. Biofilms (B) were: B1 (without coating); B2 (3% of cassava starch); B3 (3% corn starch); B4 (3% Spirulina powder); B5 (3% starch plus 3% Spirulina powder cassava) and B6 (3% cornstarch plus 3% Spirulina powder). The fruits were stored at 10 °C and 63% RH, where they remained for 0, 3, 6, 9 and 12 days, each range, plus a day to 21.2 °C and 51% RH. The B5 coating showed an increase in soluble solids (SS) until the eighth day and subsequent reduction with storage breakthrough. The fresh weight loss variables (PMF) and flesh firmness decreased their values with storage advancement in all treatments. However, it was concluded through research that the treatment was more efficient was the B6, which provided an increase in soluble solids at around 30%, 15 N flesh firmness and loss of weight less than 4% at the end storage and a higher content of vitamin C (25 mg 100 g⁻¹) to 11 days of storage.

Additional keywords: edible films; Mangifera indica L.; microalgae; storage.

Resumo
O uso de películas comestíveis tem sido bastante explorado para revestimento de frutas e hortaliças, visando a minimizar a perda de umidade e a reduzir as taxas de respiração, além de conferir aparência brilhante e atraente. O objetivo do trabalho foi avaliar a qualidade pós-colheita de manga ‘Tommy Atkins’ orgânica, recoberta com fécula de mandioca e amido de milho, enriquecidos com Spirulina platensis marca Tamanduá®. O experimento foi instalado em delineamento inteiramente ao acaso, em esquema de parcelas subdivididas no tempo, tendo-se nas parcelas os biofilmes (B), e nas subparcelas, as amostragens ao longo do tempo de armazenamento. Os biofilmes (B) foram: B1 (sem recobrimento); B2 (3% de fécula de mandioca); B3 (3% de amido de milho); B4 (3% de Spirulina em pó); B5 (3% de fécula de mandioca mais 3% de Spirulina em pó), e B6 (3% de amido de milho mais 3% de Spirulina em pó). Os frutos foram armazenados a 10 °C e 63% de UR, permanecendo nestas condições durante 0; 3; 6; 9 e 12 dias, sendo cada intervalo acrescido de um dia a 21,2 °C e 51% de UR. O recobrimento B5 (3% de fécula de mandioca mais 3% de Spirulina platensis em pó) proporcionou aumento nos teores de sólidos solúveis (SS) até o oitavo dia e posterior redução com o avanço do armazenamento. As variáveis de perda de massa fresca (PMF) e firmeza de polpa reduziram seus valores com o avanço do armazenamento, em todos os tratamentos. O biofilme B6 (3% de amido de milho mais 3% de Spirulina platensis em pó) proporcionou aumento nos sólidos solúveis em torno de 30%, firmeza de polpa 15N e perda de massa fresca inferior a 4% e maior conteúdo de vitamina C, aos 11 dias de armazenamento, sendo considerado o melhor dos recobrimentos testados.

Palavras-chave adicionais: armazenamento; Mangifera indica L.; microalgas; películas comestíveis.
Introduction

The mango tree (Mangifera indica L.) belongs to the Anacardiaceae family. Originally from India, it produces one of the most economically important tropical fruits in national and international markets, especially for its pleasant taste and aroma. In addition, mango has high nutritional value and is characterized as a pulpy fruit with variable size (Souza et al., 2010).

In Paraíba (PB), Brazil, organic mango production was introduced in the Santa Terezinha region, PB, in orchards certified by the Biodynamic Institute Association Certification (IBD). Production is conducted by small and medium farmers, where 80% of ‘Tommy Atkins’ cultivar production is intended for the European market. Unlike conventional mango culture, no synthetic chemical is applied in the organic system, minimizing risks to the environment and consumers (Pinto et al., 2008). However, products from organic systems require the use of Good Agricultural Practices (GAP) and post-harvest technologies with bioorganic alternatives, as these products are more susceptible to deterioration (Feygenberg et al., 2005).

Thus, research using films and coatings that show potential to delay degradation and/or substance synthesis reactions in fruits has been conducted, providing longer shelf life for mango (Amariz et al., 2010; Plotto et al., 2010), guava (Cerqueira et al., 2011) and tomato (Damasceno et al., 2003).

Films and coatings are generally prepared from biological materials, such as polysaccharides, proteins, lipids and derivatives, which act as a barrier to external elements, protecting the product and increasing its shelf life without risks to consumers’ health. Such biological materials are not metabolized by the organism, and their passage through the gastrointestinal tract is innocuous (Costa, 2008).

In recent years, increasing interest in microalgae shown by studies and biotechnological processes is observed due to economic, ecological and nutritional applicability. Substances synthesized by these organisms may have commercial applicability in nutrition, human and animal health. In addition, compounds of interest for food, chemical, cosmetic and pharmaceutical industries, among others, may be obtained from microalgae (Chu et al., 2010).

Spirulina platensis use has been studied due to its multiple benefits to human health. Spirulina platensis is a microalgae with suitable composition for use as a food supplement, as it was classified as GRAS (Generally Recognized as Safe) by the FDA (Food and Drug Administration), ensuring its use as food without health risks (Morais et al., 2006). Its composition on a dry basis has high protein (64 to 74%), polysaturated fatty acid, vitamin and antioxidant compound contents (Colla et al., 2007).

Various studies have been developed from biofilms formulated with concentrations ranging from 2% to 4% tapioca starch and corn starch (Damasceno et al., 2003; Pereira et al., 2006; Vieira et al., 2009; Santos et al., 2011). More recently, microalgae use in fruit coating has been tested, such as Spirulina platensis use in pomegranate fruits (Moreira, Rocha, 2015) and Chlorella sp. use in ‘Tommy Atkins’ mango, with maximum concentrations of 4% (Rocha et al., 2015). In pomegranate, coating with 3% cassava starch plus 3% Spirulina platensis associated with cooling showed better biometric, visual and physicochemical quality in the fruit during storage (Moreira, Rocha, 2015).

Organic mango coating with cassava starch or corn starch and Spirulina platensis may enhance storage quality maintenance, besides nutritionally enriching the product. Therefore, the objective of this study was to assess organic ‘Tommy Atkins’ mango post-harvest conservation when coated with cassava and corn starch enriched with Spirulina platensis, by Tamanduá®.

Material and methods

Fruits were obtained from an organic mango orchard located in the Tamanduá Farm, municipality of Santa Terezinha, northeast Brazil, near the municipality of Patos, state of Paraíba. Harvest took place between 6 and 8 a.m., and priority was given to fruits that were in maturity stage II (PROTRADE, 1992). Fruits were harvested manually, along with peduncle. Randomly, previous selection was carried out in the field, avoiding fruit with symptoms of anthracnose, scab or cochineal, burned by latex dripping and/or deformed. Subsequently, fruits were placed in a single layer in containers previously coated with shredded paper, in order to minimize impact and friction. Afterwards, fruits were transported to the Food Analysis Laboratory of Federal University of Campina Grande, Agrifood Science and Technology Center.

After transport to the laboratory, careful selection regarding size and color uniformity was conducted, discarding fruits with defects or mechanical injuries. Thereafter, fruits were washed with 1% neutral detergent solution. After rinsing, fruits were sanitized with sodium hypochlorite at 100 ppm free chlorine for fifteen minutes.

After drying, fruits were randomly separated in lots for treatment application, which consisted of different suspensions based on cassava starch, corn starch and Spirulina. For suspension preparation and coating application, 300g cassava starch, corn starch (both purchased at the local supermarket) and Spirulina powder (acquired directly from the producer in commercial form) were weighed in a semi-analytical balance, heated to 70 °C under constant stirring and dissolved in 10L distilled water without heating. Thus, each formulation was made.

The experiment was conducted in a completely randomized design with split-plot arrangement consisting of biofilms (B) in the plots and samples over
time in the subplots, with 3 replications, 2 fruits per plot and 5 periodic analysis intervals. Biofilms (B) were, as follows: B1 (control), without coating; B2 (3% cassava starch); B3 (3% corn starch); B4 (3% Spirulina powder); B5 (3% cassava starch plus 3% Spirulina powder); and B6 (3% corn starch plus 3% Spirulina powder). Plots were applied after suspension cooling by immersing fruits in the suspension for five minutes. Excess suspension was drained by putting fruits in hollow plastic containers.

After coating, fruits were stored in a BOD incubator at 10 ± 0.5 °C and 63 ± 2% RH for 12 days, where they remained for 0, 3, 6, 9 and 12 days. One day under ambient conditions was added to each interval (21.2 ± 0.5 °C and 51 ± 2% RH). For physicochemical analyzes in the pulp, peeling, stone removal and centrifuge processing were conducted.

Soluble solids (SS) were determined in a digital refractometer (by Digital Refractometer) using three drops of pulp homogenized and filtered through qualitative filter paper (AOAC, 2006); Titratable acidity (TA) was determined by titration of 1g homogenized pulp and dilution with 50 mL distilled water. Three drops of 1% phenolphthalein indicator were added to the sample. Afterwards, titration under constant stirring with 0.1 N NaOH solution was conducted, and results were expressed as citric acid % (IAL, 2008); SS/TA ratio was calculated by the ratio between the two variables; The pH was determined by homogenized pulp direct reading through digital benchtop pH meter with glass electrode (DIGIMED DM-22) (IAL, 2008); 5) Fresh mass loss (FML) was determined by fruit mass, which was obtained individually by gravimetry using the ratio between initial mass in the day of collection and the mass obtained in each day of evaluation. Results expressed as percentage; Pulp firmness was determined after skin removal, which was conducted with a 3 mm blade. A digital penetrometer coupled to a ferrule measuring 8 mm diameter was used. Two evaluations were carried out per fruit on opposite sides in the equatorial region (AOAC, 2006); Vitamin C was determined by Tillman method. 1g sample was weighed on an analytical balance and transferred to Erlenmeyer, where the volume was completed to 50 mL with 0.5% oxalic acid. Titration was conducted with Tillman solution until the turning point (AOAC, 2006). Statistical analysis was conducted using the SISVAR (Ferreira, 2011) computer program, through analysis of variance and regression.

Results and discussions

SS variable had linear behavior in most treatments, except for the coating in B5, in which there was quadratic effect, with SS increase until the eighth day and subsequent reduction with storage advance. Mangoes treated with B6 had about 30% soluble solids increase at the end of storage (Figure 1). Mango tree fruits increased pulp carbohydrates during ripening as a result of long-chain polysaccharide degradation in simple carbohydrates. Subsequently, due to senescence, those levels decreased. Spirulina platensis use at 3% with 3% corn starch possibly provided higher mineral and carbohydrate absorption due to microalga mineral and chemical constitution (Manrich et al., 2014), resulting in higher pulp carbohydrate content by the end of storage.

On average, TA was of 1.0 mg 100g⁻¹ citric acid, except for B2 and B3 treatments, which had quadratic effect, indicating TA increase along storage (Figure 2). Cassava starch or corn starch use provided higher acidity in ‘Tommy Atkins’ mangoes compared to mangoes that were not treated with biofilms (Santos et al., 2011). Generally, acidity is reduced with fruit ripening in mangoes, and organic acid intake during breathing is the main responsible for this behavior. Thus, the short shelf life (a day at 21.2 ± 0.5 °C) used in this study may have not been enough to metabolize organic acids in the fruit.

SS/TA ratio oscillated in most treatments, except for the B5 treatment, in which there was no regression adjustment, and B6 treatment, in which quadratic effect was observed (Figure 3). In all treatments, SS/TA ratio stood in the range from 8 to 16. Lima et al. (2012) reported that SS/TA ratio in ‘Tommy Atkins’ mangoes differed during storage but was not affected by coatings. According to the authors, ratio variation occurred from 14.70 to 19.62, which was similar to the range reported by Pinto et al. (2008). These values were higher than those reported in this study.

There was little variation in pulp pH in all treatments. Variations occurred between values above 3.0 and below 4.0, and there was quadratic effect in this range for most treatments (Figure 4). Lima et al. (2012), while studying organic ‘Tommy Atkins’ mango post-harvest conservation, which was harvested under good agricultural practices (GAP) and coated with fennel extract and tapioca starch, found that pH varied during storage in relation to the coatings. Control pH peaked in the 3rd day of storage, although pH ranged between 3.4 and 3.9, corroborating with the results of this study.

Fresh mass loss (FML) was linear along storage in all treatments. There were around 5% higher mass losses for fruits that were not coated. In the other treatments, mass loss was lower (Figure 5), being lower than 3.5% in the B5 at the end of storage. Santos et al. (2011), while analyzing tapioca starch and corn starch biofilm on ‘Tommy Atkins’ mango postharvest quality, found that mass loss increased in all treatments during storage. However, fruit treated with cassava starch and corn starch film had the lowest mass losses during storage, indicating that the film protected the fruit against excessive water loss to the atmosphere. Spirulina platensis use along with tapioca starch may have enhanced biofilm efficiency, what can be attributed to its composition, rich in proteins and lipids (Manrich et al., 2014).
Figure 1 - Soluble solids (SS) in 'Tommy Atkins' mango treated with different edible biofilms during storage at 10 ± 0.5 °C and 63 ± 2% RH, shelf life of a day at 21.2 ± 0.5 °C and 51 ± 2% RH. FM: cassava starch; AM: corn starch; SP: *Spirulina platensis*.

* *1% and *5% significance.

\[ Y = 8.323094 + 0.264505x, R^2 = 0.7235 \]
\[ Y = 8.149033 + 0.261092x, R^2 = 0.9079 \]
\[ Y = 8.391354 + 0.167804x, R^2 = 0.8736 \]
\[ Y = 8.367466 + 0.245165x, R^2 = 0.7441 \]
\[ Y = 8.349781 + 0.431522x - 0.022529x^2, R^2 = 0.9978 \]
\[ Y = 8.374289 + 0.275313x, R^2 = 0.9846 \]

Figure 2 - Titratable acidity (TA) in 'Tommy Atkins' mango treated with different edible biofilms during storage at 10 ± 0.5 °C and 63 ± 2% RH, shelf life of a day at 21.2 ± 0.5 °C and 51 ± 2% RH. FM: cassava starch; AM: corn starch; SP: *Spirulina platensis*.

* *1% and *5% significance.
**Figure 3** - SS/TA ratio in 'Tommy Atkins' mango treated with different edible biofilms during storage at 10 ± 0.5 °C and 63 ± 2% RH, shelf life of a day at 21.2 ± 0.5 °C and 51 ± 2% RH. FM: cassava starch; AM: corn starch; SP: *Spirulina platensis*. * *1% and *5% significance.

**Figure 4** - pH in 'Tommy Atkins' mango treated with different edible biofilms during storage at 10 ± 0.5 °C and 63 ± 2% RH, shelf life of a day at 21.2 ± 0.5 °C and 51 ± 2% RH. FM: cassava starch; AM: corn starch; SP: *Spirulina platensis*. * *1% and *5% significance.
**Figure 5** - Fresh mass loss (FML) in ‘Tommy Atkins’ mango treated with different edible biofilms during storage at 10 ± 0.5 °C and 63 ± 2% RH, shelf life of a day at 21.2 ± 0.5 °C and 51 ± 2% RH. FM: cassava starch; AM: corn starch; SP: *Spirulina platensis*.

* **1% and *5% significance

**Figure 6** - Pulp firmness in ‘Tommy Atkins’ mango treated with different edible biofilms during storage at 10 ± 0.5 °C and 63 ± 2% RH, shelf life of a day at 21.2 ± 0.5 °C and 51 ± 2% RH. FM: cassava starch; AM: corn starch; SP: *Spirulina platensis*.

* **1% and *5% significance
Firmness decreased linearly along with storage in all treatments. Reduction was more significant in the B4 treatment, where there was a reduction from 80 N to values close to 5 N from the beginning to the end of storage (Figure 6). This behavior indicates that *Spirulina platensis* use alone is not effective as a biofilm. Other components are required in the formulation, such as those tested in this study, which provide more contact with the plant tissue, allowing for chemical compound retention, such as proteins, peptides, carbohydrates, minerals and oil.

There were vitamin C content variations in all treatments tested, except for the treatment without coating, where there was no adjustment. There was a tendency to increase vitamin C from the 5th to the 11th day of storage, with subsequent reduction. The highest vitamin C content, about 25 mg 100 g\(^{-1}\), was observed in the B6 treatment after 11 days of storage (Figure 7). In pomegranate, coating with *Spirulina platensis*, with or without cassava starch, preserved vitamin C content, having the highest rates if compared to other coatings during storage for six days at 25 °C (Moreira; Rocha, 2015). Similar behavior was observed for ‘Tommy Atkins’ mango, in which higher vitamin C content (22.17%) was observed in fruits treated with 3% *Chlorella sp.* biofilm (Rocha et al., 2015).

![Figure 7 - Vitamin C in ‘Tommy Atkins’ mango treated with different edible biofilms during storage at 10 ± 0.5 °C and 63 ± 2% RH, shelf life of a day at 21.2 ± 0.5 °C and 51 ± 2% RH. FM: cassava starch; AM: corn starch; SP: *Spirulina platensis*. * *1% and *5% significance.](image)

### Conclusion

B5 coating (3% cassava starch plus 3% *Spirulina platensis* powder) provided soluble solids (SS) increase until the eighth day, with subsequent reduction along storage. Fresh mass loss (FML) and pulp firmness variables reduced their values along storage in all treatments.

B6 biofilm (3% corn starch plus 3% *Spirulina platensis* powder) provided around 30% soluble solids increase, 15N pulp firmness, mass loss lower than 4% and higher vitamin C content after 11 days of storage. Therefore, it was the best coating tested.

### References


