UNDER PEER REVIEW

Original Research Article

Postharvest quality of banana 'Prata Anã' treated with microalgae coating

ABSTRACT

Biodegradable technologies that maintain the quality of food without causing harm to the health of the consumer or the environment will be an innovative tool applied in post-harvesting of fruits. The objective of this study was to test the efficiency of microalgae in the coating of bananas, of the variety: 'Prata Anã' stored under ambient temperature. The treatments were 0%, without coating; 2% Chlorella sp .; 2% of Scenedesmus sp .; 2% Spirulina platensis. After application of the treatments, the fruits were stored at 25 ± 2 °C and 65 ± 5% RH and analyzed periodically every two days for 10 days. The microalgae Spirulina platensis, Chlorella sp. and Scenedesmus sp., used at 2% in the coating of 'Prata Anã' bananas, offer reduction of ripening, maintenance of pulp firmness and fresh mass loss, potentiating fruit conservation for up to eight days, stored at room temperature (25 ± 2 ° C and 65 ± 5% RH). Untreated fruits had accelerated ripening, high fresh weight loss and low pulp firmness, limiting post-harvest shelf life within six days of storage.

Keywords: Musa acuminata; conservation; edible films; alimentary safety.

1. INTRODUCTION

The banana (*Mussa spp*.) it constitutes one of the main ones fruitful produced in all the continents, being one of the more important tropical fruits commercially, due to special flavor and nutritional properties, as well as world readiness along the year (Alali et al., 2018). The bananas are considered the second more important fruit in Brazil, just the oranges overcame production. The year of 2016, in agreement with [10], the total Brazilian production was of 6,7 million tons. In Brazil it prevails to cultivate Prata an evidence of good acceptance for the consumer.

Recently, a form quite studied to try to increase the life powder-crop of the fruits is the use of eatable coverings capable to delay the metabolism of the fruit and consequently to increase his/her useful life. The eatable coverings are being studied thoroughly in function of potential in increasing the useful life of the vegetables, they can be used to inhibit the migration of the humidity, oxygen and carbon dioxide, improving like this the characteristics of the covered products [5].

To improve the results of the coatings, the choice of the matter type excels to be used is of extreme importance. Among the several researched materials they stand out the microalgae, that can be an alternative for the coatings elaboration with the objective of prolonging the useful life of fruits and others vegetate.

Among the species of microalgae that they can be used for the fruit coating, stands out the use of the *Spirulina platensis*, which is interesting, because it presents in constitution great amount of proteins (64 to 74%), vitamins (A, B, B2, B6, B12, E and D), minerals, carbohydrates, carotenoids, beta-carotene, xanthophyll, γ-linolenic acid, antioxidant activity, among other properties [14, 2, 22]. Onias et al. [17] it detaches positive results when used as matter excels for the making of eatable coatings in the concentration of 3% associated to 3% of corn starch, it was what provided increase in the soluble solids around 30%, pulp firmness 15 N and loss of inferior fresh mass to 4%, and the largest vitamin content C to the 11 days of storage in mangos 'Tommy Atkins' stored 10 °C and 63% UR, shelf life of one day to 21,2 °C and 51% UR, being considered by the authors as better coating among tested them in the study.

UNDER PEER REVIEW

Besides to *S. platensis*, the *Chlorella sp.* it also presents a rich constitution in proteins, substances as fatty acids, starch, mineral salts, phycocyanin, chlorophyll, beta-carotene, astaxanthin, vitamins, lipids, enzymes and essential amino acids [24].

Ursu et al. [23], they affirm that the proteins of the *Chlorella sp*. they possess a high emulsifying capacity compared with other ingredients overcoming them in this requirement. Besides rich composition that brings several benefits the human and animal health, the Chlorella sp. proved to have higher preservative activity than obtained them synthetically, such as, the compositions butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) [20]. Its rich composition does a promising matter of her excels for the use in fruits as a bio-organic coating, could join value to the products for their numerous nutritional properties.

The *Scenedesmus sp*. is one of the microalgae more thoroughly used in many studies for industrial application, such as for the production of biodiesel, bioethanol, polymeric and addictive alimentary because it is relatively easy to cultivate in culture and has the capacity to survive in extreme atmospheres. The microalgae of the gender *Scenedesmus* depending on cultivation possesses in constitution lipids (up to 60%), proteins (up to 60%), polysaccharides (up to 50%) and composed of high value, including, for instance, astaxanthin and lutein, besides containing all of the essential amino acids and good amounts of macro and microelements [1, 7].

In this sense, the objective of this work was to study the potential of the microalgae *Spirulina platensis*, *Chlorella sp*. and *Scenedesmus sp*., for the use as coating in bananas 'Prata Anã' analyzed periodically under storage conditions in room temperature.

2. MATERIAL AND METHODS

The bananas 'Prata Anã' they were obtained in Petrolina-PE, the bunches were picked at stadium of maturation 2 (green peel with yellow lines), according to Norms of Classification of Banana [19]. They were conditioned in only layer, in containers previously covered with paper pricked to minimize the impact and the attrition among them and transported to the Postharvest Technology Laboratory of Fruits of the Federal University of Campina Grande (UFCG), Pombal-PB campus. In the laboratory selection was accomplished as for the size uniformity and color, discarding those with defects or offenses due to the transport. The fruits were washed with solution of neutral detergent to 1% and, after rinsing, sanitized with sodium hypochlorite solution to 100 mg L-1 of chlorine, for 15 minutes and dry outdoors.

The experimental design was the completely randomized (DIC), in the outline of portions subdivided in the time, is tended in the portions the treatments (T), and in the subplots, the samplings along the time, with four repetitions and three fruits for portion. The samplings in the time happened periodically every other day, during 10 days of storage in atmosphere temperature (25 °C and 65% UR). The treatments (T) they were the following ones: T1: 0% control, without coating; T2: 2% of *Chlorella sp*.; T3: 2% of *Scenedesmus sp*.; T4: 2% *Spirulina platensis*, whose concentration was established previously with base in results of researches obtained for [15, 16].

The microalgae used in this study were produced according to [11], in tanks of organic production, in Fazenda Tamanduá, located in the city of Patos-PB. After the obtaining of the biomasses, the same ones were diluted in 2 L of distilled water, under constant agitation until the complete homogenization of the solution. The treatments were applied through the immersion of the fruits in referred them solutions. The analyzed variables were: Coloration of the peel through two readings in the equatorial area of the fruit and of the pulp through traverse cut and two readings for fruit, being used colorimeter (Konica Minolta, model Chroma to put CR-400), color space L * a * b *, for reflectance, whose calibration was accomplished with plate white pattern, following the manufacturer's instructions. The measured color parameters regarding to plate-pattern they were: Starting from the values L*, a*, b*, the angle hue was made calculations (h°=arctang(a*/b*) (-1)+90), for a* negative and (h°=90-arctang(a*/b *)), for a* positive, and the saturation index or chromaticity, C * (C*=[(a *)2+(b *)2]1/2); Firmness of the pulp (N): certain with aid of digital penetrometer, (Instrutherm, model PTR-300), being made measurements in two opposed points, in the equatorial area of the fruit with peel, accomplished with ferrule of 6 mm, according to [4]; Fresh mass loss (%): obtained by difference among the mass of the fruits checked in electronic scale, in the day of the installation of the experiment and every other day of the beginning of the storage. The homogenized pulp used in the evaluations was obtained after

UNDER PEER REVIEW

it peels of the fruits and processing in domestic blender, being analyzed the following variables later: Titratable acidity (AT,% malic acid): certain through the titrating of 5 g of pulp of the banana diluted to 50 mL of distilled water and increasing 2 drops of phenolphthalein to 1%, proceeding the titration, under constant agitation, with solution of hydroxide of sodium NaOH to 0,1 M, according to [9]; pH: certain for direct reading in the pulp homogenized through digital peg of bench (Digimed DM-22), [9]; soluble Solids (SS,%): certain in the pulp through direct reading in digital refractometer (Instrutherm) [4]; SS/AT ratio: made calculations by the quotient among the two variables; Total soluble sugars (%): certain for the anthrone method, second procedure described by [26] with modifications. 0,5 g of the sample was diluted for 100 mL of distilled water, soon later it was taken brackets of 0,5 µL for fruits up to four days also adding 0,5 µL of distilled water totaling 1 mL, and brackets of 0,3 µL for fruits starting from six days also adding 0,7 µL of distilled water totaling 1 mL, to which 2 m L of anthrone was added in one tube under agitation, being put in bath Maria to 100 ºC for 5 minutes, after cooling, the samples were taken to the spectrophotometer for reading, the a wavelength of 620 nm.

The results were submitted to variance analyses and polynomial regression starting from the obtained averages of the samples of each treatment, compared by the significance of R^2 of the equation and for the test t of Student, to 5% of probability being used the software SISVAR version 5.6 [8].

3. RESULTS AND DISCUSSION

In the day of the installation of the experiment, analyses were accomplished in the bananas for the characterization of the fruits in the moment of the crop, presenting the following values, according to the Table 1.

Table 1 - Initial Characterization of bananas 'Prata Anã', for occasion of the crop. Pombal-PB, 2018. (n=12)

Characteristics Initials	Averages ± DP
Fresh mass loss (g)	140,00 ± 11,05
Brightness in the peel (L*)	57,07 ± 2,45
Chromaticity in the peel (C*)	40,79 ± 1,08
Hue angle (h°) in the peel	116,58 ± 0,52
Brightness in the pulp (L*)	86,4 ± 0,34
Chromaticity in the pulp (C*)	21,43 ± 1,35
Hue angle (h°) in the pulp	92,08 ± 0,77
Pulp firmness (N)	63,65 ± 5,82
Titratable acidity (% malic acid)	0,33 ± 0,65
pH	5,73 ± 0,07
Soluble solids (%)	4,55 ± 0,63
SS/TA ratio	14,66 ± 0,52
Total soluble sugars (%)	3,80 ± 0,29

The isolated effect of the factor was verified time of storage for the characteristics of brightness and chromaticity of the peel, and interaction between the coatings and the time of storage, for the other studied characteristics. Quadratic behavior is observed along the storage period, evidencing that the coatings didn't interfere in a negative way in the process of evolution of the coloration of the bananas, that happened slowly when compared the values of the fruits in the moment of the installation of the experiment, with the following values: for brightness and chromaticity of the peel, 57,07 and 40,79, respectively, and after 10 days of storage, they presented average of 57,27 for brightness and 41,09 for chromaticity, Figure 1(A and B). During ripening, the banana presents a change of coloration of green peel for yellow, resulting in increase in the values of the parameters of color of the brightness and of the it chromes, reflecting the yellowing of the peel [25]. [13] evaluating the effect of films formed by pectin, egg albumen, carrageenan, gelatin, potato starch, xanthan and corn starch in the conservation of banana cv. Caturra (Musa paradisíaca L.) it observed a yellowish coloration in all of the treatments, during every storage period.

UNDER PEER REVIEW

The color angle (h°) of the peel it presented tendency to decrease along the time of storage, the fruits began with average of 116,58 ° characterizing a green coloration with yellow lines, and the fruits control presented the smallest values, fact that it can be observed to the 6 days in that the fruits without coating presented values of (h°) of 103,30 ° and the largest value among the coatings was verified in 2% of *Scenedesmus* sp. of 111,43 °, the other coatings stayed same. Already to the 8 days the largest value of (h°) it was verified for 2% of S. platensis of 105,88 °, and again the smallest value was verified for the fruits control of 95,21 °. This reduction in the color angle coincides with the ripening of the fruit, in which happens the change of green coloration in the peel of the bananas for yellow, indicating that the fruits no covered to the 8 days of storage they presented coloration of the yellowish peel and the covered fruits presented peel with coloration yellow greenish (Figure 1C).

It is verified for the brightness of the pulp tendency to decrease along the storage period, us which the fruits with coatings didn't present great variations, presenting same behavior until the 6 of storage, and differing to the 8 days in that the fruits control presented the smallest value 75,09. The coating to 2% of S. platensis was the second smallest value, 80,24, characterizing a darker pulp, indicating retard in the process of ripening of the pulp of the bananas (Figure 1D).

For the pulp the (h°) there was little variation along the time, already among the coatings it happened larger variation to the 8 days of storage, in that the control presented the largest value of 91,56 ° and the smallest value for 2% of S. platensis (87,95 °). The fruits of the control presented characteristic pulp of banana ripens with coloration of cream-colored color. The covered fruits presented pulp of yellow coloration, with greenish lines, indicating retard in the ripening (Figure 1E).

Oliveira et al. [15] they also verified that with the increase in the concentrations of the coating of *Chlorella sp*. it happens larger pulp firmness and smaller transformations in the color of the peel of the mangos "Tommy Atkins". And that the use of the coating of *Chlorella sp*. in the concentration of 1% and 2%, it provides ripening without damage in the attributes of quality of the fruits analyzed to the 28 days of storage (21 days to 10 ºC and 42% UR, more seven days to 25ºC).

UNDER PEER REVIEW

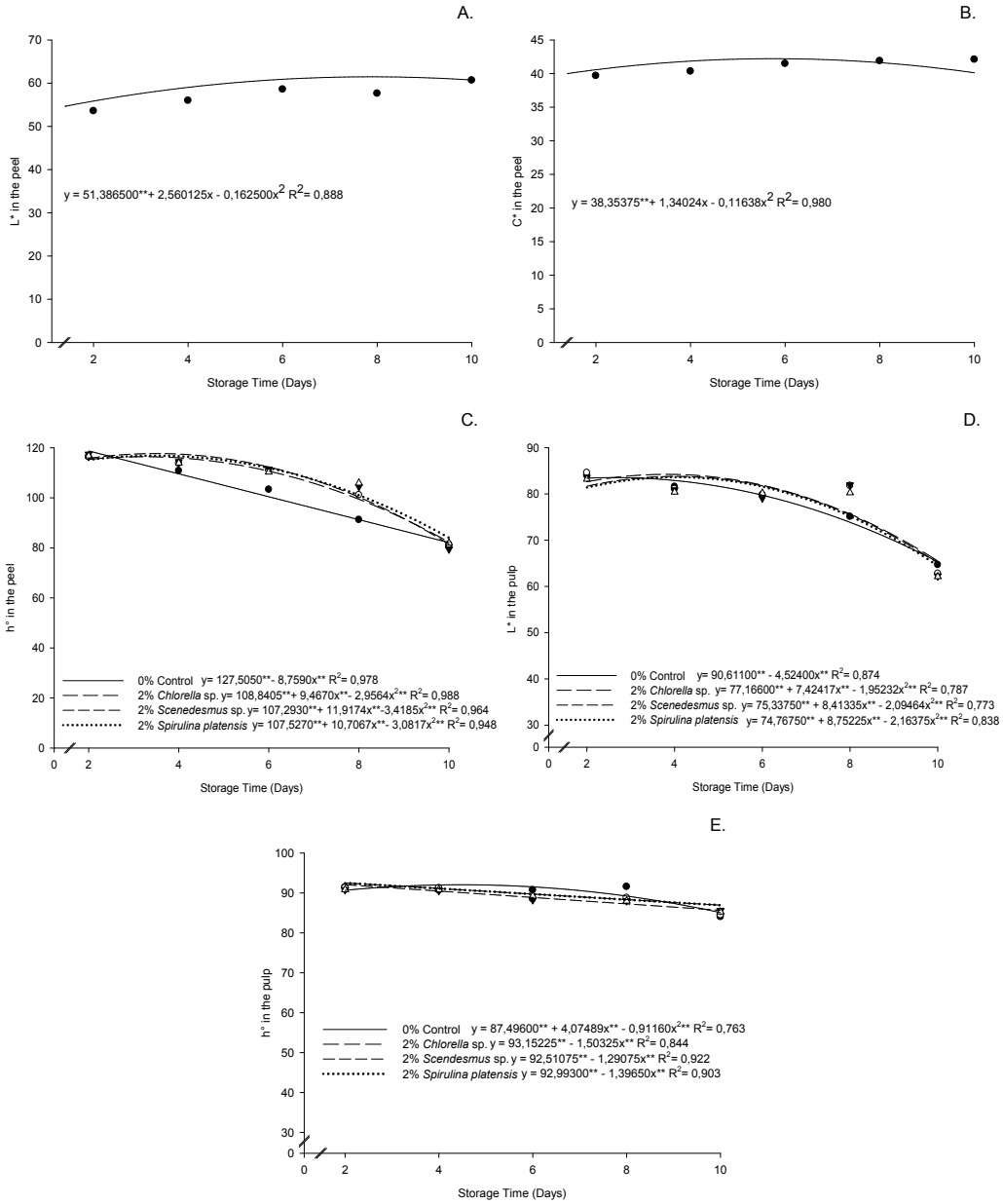

Figure 1. Brightness of the peel (L *), hue angle in the peel (h°), chromaticity in the peel (C *), brightness in the pulp (L *), hue angle in the pulp (h°), respectively (A, B, C, D and E) in bananas 'Prata Anã' submitted the different coatings the microalgae base during the storage under 25 ± 2 ºC and 65 ± 5% UR, after 10 days.

The fresh mass loss of the bananas increased for all of the treatments studied along the storage, and the fruits of the control presented larger mass loss. To the 6 days of storage, the fruits control lost 10,12% of mass, following for the concentration 2% of *Chlorella sp*. with 5,89%, being this to smallest mass loss. In this way, the fruits covered with 2% of *Chlorella sp*. they maintained turgidity until the 8 days of packaging. At the end of the experiment larger mass loss was verified for the fruits controls of 18,82%, following by 2% of *Spirulina platensis* and 2% of *Scenedesmus sp*. 17,02 and 16,85%, respectively, and smaller mass loss for the bananas covered with 2% of *Chlorella sp*. 14,81% (Figure 2).

Oliveira et al. [16] they verified that the best indicative physical-chemical of maintenance of the quality mango 'Tomy Atkins' they were observed in the fruits that received the coating to the 1% of *Chlorella*

UNDER PEER REVIEW

sp., as reflex in the good appearance, loss of inferior fresh mass to 5,5% and total sugars above 12%, in storage conditions refrigerated to 10 °C and atmosphere to 23 °C.

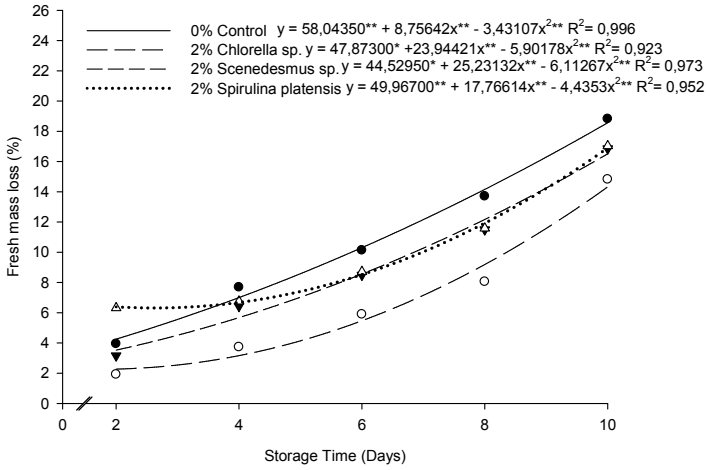

Figure 2. Fresh mass loss (%) in bananas 'Prata Anã' submitted the different coatings the microalgae base during the storage under 25 ± 2 ºC and 65 ± 5% UR, after 10 days.

The results for the firmness of the pulp had quadratic behavior, with significant reduction at the end of the storage. To the 6 days; the behavior was similar to it of loss of fresh mass, with prominence for the fruits covered with 2% of *Chlorella sp*., which presented the largest pulp firmness, 65,24 N, while the control obtained the value of 53,61 N. To the 10 days, to smallest pulp firmness it continued in the fruits no covered of 15,35 N, following for 2% of Scenedesmus sp. and 2% of Chlorella sp. with 15,49 and 16,01 N, respectively. The largest firmness was observed for 2% of *S. platensis* presenting 25,46 N (Figure 3). [13] evaluating effects of films of polymeric natural in the conservation of banana cv. 'Caturra', it also observed reductions of the firmness in all of the treatments along the storage, the same indicates that were proportionate for the reactions so much of syntheses, as degradations of the components of the cellular wall and to the loss of turgidity of the cells in the fabric with the progress of the ripening of the fruit.

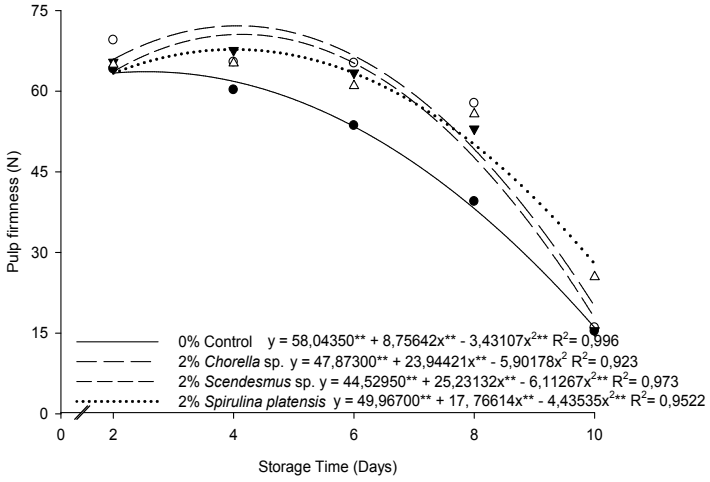

Figure 3. Pulp firmness (N) in bananas 'Prata Anã' submitted the different coatings the microalgae base during the storage under 25 ± 2 ºC and 65 ± 5% UR, after 10 days.

UNDER PEER REVIEW

The titratable acidity presented increase tendency in all of the studied treatments, along the storage period, among the coatings there was not significant difference until the 6 days of storage, in which the smallest values were observed to 2% of *Spirulina platensis* (0,45% of malic acid), following for 2% of *Chlorella sp*. (0,60% of malic acid), control and 2% of *Scenedesmus sp*. with medium values of 0,65% of malic acid. In the end of the storage, the control had the smallest values (0,72% of malic acid) and 2% of *S. platensis* with 1,33% of malic acid; however, all the results obtained starting from the 8 days of storage were superior to the moderated by other studies with banana of same variety (Figure 4A).[12] they obtained 0,22% to 0,36% of malic acid in study with study with bananas 'Prata Anã' stored by 35 days, under cooling. Sarmento et al. (2015) for banana Silver they told values among 0,2% to 0,5% of malic acid.

Due to the increase tendency in the acidity, reduction was verified accentuated in the pH values for all of the treatments tested along the time of storage, presenting significant difference to the 6 days and 8 days of storage, being the smallest values of the fruits control, 4,41 and 4,14, respectively, among the coatings it was not verified differentiates amongst themselves, being the largest values moderated by 2% of *S. platensis* of 5,13 in keeping with the results of acidity at the end of the storage (Figure 4B).

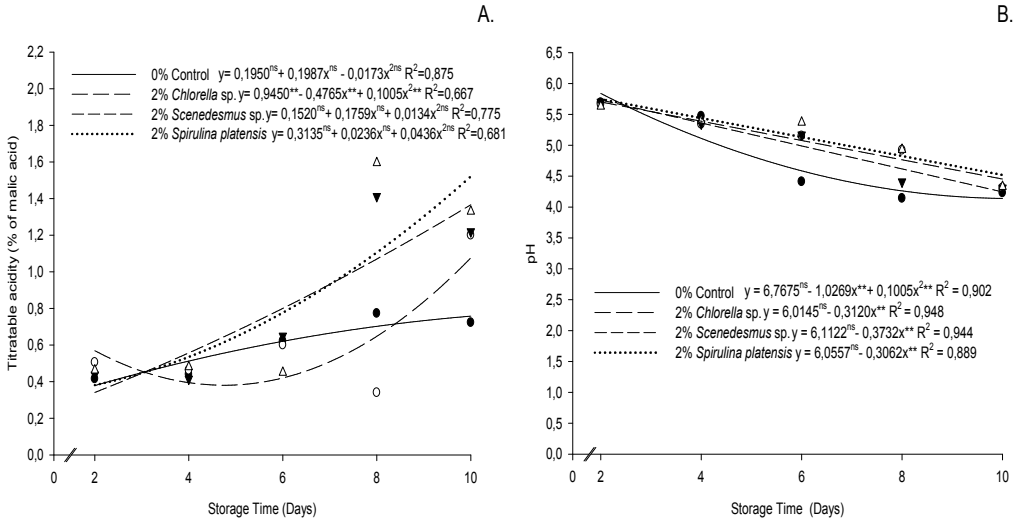

Figure 4. Titratable acidity (% of malic acid) (A), and pH (B), in bananas 'Prata Anã' submitted the different coatings the microalgae base during the storage under 25 ± 2 ºC and 65 ± 5% UR, after 10 days.

The soluble solids increased along the storage period, until the 8 days of storage the treatments that presented the largest values of soluble solids were the control with 20,95 following by 2% of *Scenedesmus sp*., however to the 10 days of storage the coating 2% of *Chlorella sp*. it presents the largest values with 25,50 and the fruits control presented the smallest values of 22,70 (Figure 5A). That behavior of SST indicates that the starch is hydrolyzed in sugars, through primary metabolism to supply breathing substrate for biological activities of the fruit, with consequent increase of the sweetness [18].

In agreement with the increase of the acidity and soluble solids along the storage, the ratio also presented tendency to growth along the packaging period, presenting variation among treatments, to the 10 days. The control had the largest value for the ratio of (32,30), following for 2% of *Chlorella sp*., 2% *Scenedesmus* sp. and 2% *S. platensis*, respectively, 21,73, 21,58 and 17,66 (Figure 5B). According to [6], the high ratio is very important and desirable in the fruits, being one in the ways more used for the evaluation of the flavor.

UNDER PEER REVIEW

The total soluble sugars presented variations for all of the treatments along the storage period, beginning with value of 3,80%, and occurrence of the first variation to the 6 days of storage, in which the control presented the pick of synthesis of 11,70%, following for 2% of Chlorella sp. (8,27) and the other coatings Scenedesmus sp., S. platensis, with 4,04% and 4,10%, respectively. At the end of the storage it is observed that the fruits covered with S. platensis presented the largest values (9,08), following for Chlorella sp. (8,52), values inferior were certain in the fruits no covered (6,82), close values to the obtained with 2% of Scenedesmus sp. (6,63). In agreement with [6], (2005) the increases of total sugars are associated with the the elevation of the tenors of soluble solids, (Figure 5C), although the measurement of these, don't represent the exact tenors of the produced sugars, therefore other substances also one find dissolved in the vacuolar sap: (vitamins, phenolics, pectins, organic acids, etc.); however, the sugars are the most representative, getting to constitute up to 85 - 90% of the soluble solids.

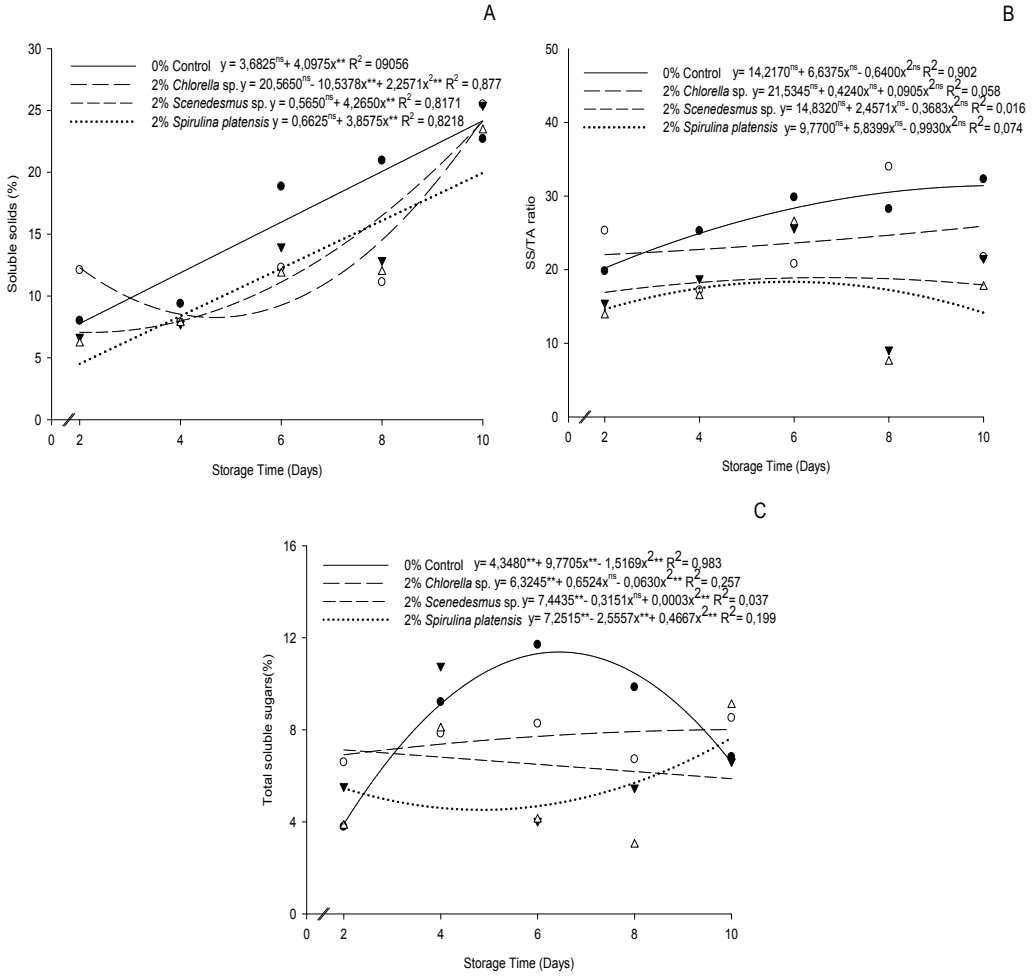

Figure 5. Soluble solids (%) (A), SS/TA ratio (B) and total soluble sugars (%) (C), in bananas 'Prata Anã' submitted the different coatings the microalgae base during the storage under 25 ± 2 ºC and 65 ± 5% UR, after 10 days.

UNDER PEER REVIEW

4. CONCLUSION

The microalgae *Spirulina platensis*, *Chlorella sp*. and *Scenedesmus sp*., used to 2% in the coating of bananas 'Prata Anã' they reduce the ripening, the loss of pulp firmness and the mass loss, potentiating the conservation of the fruits for to eight days under storage in atmosphere conditions (25 ± 2 ºC and 65 ± 5% UR).

REFERENCES

1. Abdulsamad JK, Varghese SA (2017) Effects of fish silage on growth and biochemical characteristics of fresh water microalga Scenedesmus sp. Mb 23. Agriculture and natural resources 51(4):235-242. https://doi.org/10.1016/j.anres.2017.10.002

2. Adel M, Yeganeh S, Dadar M, Sakai M, Dawood MAO (2016) Effects of dietary Spirulina platensis on growth performance, humoral and mucosal immune responses and disease resistance in juvenile great sturgeon (Huso huso Linnaeus, 1754). Fish & shellfish immunology 56:436-444. https://doi.org/10.1016/j.fsi.2016.08.003

3. Alali AA, Awad MA, Al-Qurashi AD, Mohamed SA (2018) Postharvest gum Arabic and salicylic acid dipping affect quality and biochemical changes of 'Grand Nain' bananas during shelf life. Scientia Horticulturae 237:51-58.

4. Aoac, Association of Official Analytical Chemists (2006) Official methods of analysis of the Association of official analytical chemists. Gaithersburg: AOAC .18th ed.

5. Botrel DA, Fátima Ferreira Soares ND, Camilloto GP, Barros Fernandes RVD (2010) Revestimento ativo de amido na conservação pós-colheita de pera 'Williams' minimamente processada. Ciência Rural 40(8):1814-1820.

6. Chitarra MIF, Chitarra AB (2005) Pós-colheita de frutas e hortaliças: fisiologia e manuseio. 2ª ed. Lavras, UFLA, 785p

7. Di Caprio F, Altimari P, Pagnanelli F (2018) Effect of ca2+ concentration on Scenedesmus sp. growth in heterotrophic and photoautotrophic cultivation. New biotechnology 40:228-235. https://doi.org/10.1016/j.nbt.2017.09.003

8. Ferreira DF (2011) Sisvar: um sistema computacional de análise estatística. Ciência e Agrotecnologia 35(6):1039-1042. www.scielo.br/pdf/cagro/v35n6/a01v35n6

9. Ial (2008) Normas analíticas do Instituto Adolfo Lutz: métodos físico-químicos para análise de alimentos. 4.ed.; 1.ed. digital. 4.ed. São Paulo: Instituto Adolfo Lutz 1020p. <http://www.crq4.org.br/sms/files/file/ analisedealimentosial_2008.pdf>. Acesso: 20 jan. 2018.

UNDER PEER REVIEW

10. IBGE Instituto Brasileiro de Geografia e Estatísticas (2017) Censo Agropecuário. Banco de dados agregados. www.sidra.ibge.gov.br. Acesso em: 08 jul. 2018.

11. Lima JF (2016) Cultivo e secagem da microalga Chlorella sp. em diferentes concentrações de nutrientes. UFCG (Tese de doutorado em engenharia de processos).

12. Martins RN, Dias MSC, Boas EVB, Santos LO (2007) Armazenamento refrigerado de banana 'Prata Anã' proveniente de cachos com 16, 18 e 20 semanas. Ciência e Agrotecnologia 1423-1429. http://dx.doi.org/10.1590/S1413-70542007000500023

13. Montibeller MJ, Zaparolli FB, Oliveira BG, Pietrowski GAM, Almeida DM (2016) Efeito de filmes de polímeros naturais na conservação de banana cv. 'Caturra' (Musa paradisiaca L.). Revista Brasileira de Produtos Agroindustriais 18(1):11-19.

14. Moreira IS, Rocha RHC (2015) Estudo da qualidade da romã 'Molar': Romã 'Molar' submetida a temperaturas de armazenamento e revestimento comestível. Ed. Novas Edições Acadêmicas 76p.

15. Oliveira AMF, Rocha RHC, Guedes WA, Dias GA, Lima JF (2018b) Use of Chlorella sp. for coating 'Tommy Atkins' mango fruits stored under refrigeration. Semina: Ciências Agrárias 39(2):565-572.a http://dx.doi.org/10.5433/1679-0359.2018v39n2p565

16. Oliveira AMF, Rocha RHC, Guedes WA, Furtunato TCS, Lima JF (2018a) Postharvest conservation of 'Tommy Atkins' mango with bio-organic coating of Chlorella sp. Científica, 46(1):08-16.b http://dx.doi.org/10.15361/1984-5529.2018v46n1p8-16

17. Onias EA, Rocha RHC, Lima JF, Onias EA, Furtunato TCS (2016) Organic 'Tommy Atkins' mango postharvest quality whentreated with biofilms enriched by Spirulina platensis. Científica 44(3):286-293. http://dx.doi.org/10.15361/1984-5529.2016v44n3p286-293

18. Passos FR, Mendes FQ, Cunha MC, Pigozzi MT, Carvalho AMX (2016) Propolis extract in postharvest conservation banana 'Prata'. Revista Brasileira de Fruticultura 38(2):(e-931). http://dx.doi.org/10.1590/0100-29452016931

19. Pbmh, Pif. Programa Brasileiro para a modernização da horticultura e Produção integrada de frutos (2006) Normas de classificação de banana. São paulo: ceagesp 2p. (documentos, 29).

UNDER PEER REVIEW

20. Safi C, Zebib B, Merah O, Pontalier PY, Vaca-Garcia C (2014) Morphology, composition, production, processing and applications of Chlorella vulgaris: a review. Renewable and sustainable energy reviews 35:265-278. http://dx.doi.org/10.1016/j.rser.2014.04.007

21. Sarmento DHA, Souza AP, Sarmento JDA, Freitas RVSF, Salgado Filho M (2015) Armazenamento de banana 'Prata Catarina' sob temperatura ambiente recobertas com fécula de mandioca e PVC. Revista Caatinga 28(2):235-241.

22. Shabana EF, Mahmoud Ali Gabr MAG, Moussa HR, El-Shaer EA, Ismaiel MMS (2017) Biochemical composition and antioxidant activities of arthrospira (Spirulina) platensis in response to gamma irradiation. Food Chemistry 214:550-555. https://doi.org/10.1016/j.foodchem.2016.07.109

23. Ursu AV, Marcati A, Sayd T, Sante-Lhoutellier V, Djelveh G, Michaud P (2014) Extraction, fractionation and functional properties of proteins from the microalgae Chlorella vulgaris. Bioresource technology 157:134-139. https://doi.org/10.1016/j.biortech.2014.01.071

24. Viegas CV, Hachemi I, Maki-Arvela P, Smeds A, Aho A, Freitas SP, Gregônio CMS, Carbonetti G, Peurla M, Paranko J, Kumar N, Donato AGA, Murzin DY (2015) Algal products beyond lipids: Comprehensive characterization of different products in direct saponification of green alga Chlorella sp. Algal research 11:156-164. https://doi.org/10.1016/j.algal.2015.06.014

25. Yang XT, Zhang ZQ, Joyce D, Huang XM, Xu LY, Pang XQ (2009) Characterization of chlorophyll degradation in banana and plantain during ripening at high temperature. Food Chemistry 114(2):383–390. https://doi.org/10.1016/j.foodchem.2008.06.006

26. Yemn EW, Wills AJ (1954) The estimation of carbohydrate in plant extracts by antrone. The Biochemical Journal 57(3):504–514.