Article Journal-General Economics
June, 2022 Vol.6 No.10 29-34

Soursop fruit storage: Edible coating based on Hibiscus sabdariffa mucilage

Almacenamiento de frutos de guanábana: Recubrimiento comestible a base de mucílago de Hibiscus sabdariffa

DE LOS SANTOS-SANTOS, Miguel Angel, BALOIS-MORALES, Rosendo, JIMÉNEZ-ZURITA, José Orlando and LÓPEZ-GUZMÁN, Graciela Guadalupe

ID 1st Author: *Miguel Angel*, *De los Santos-Santos* / **ORC ID**: 0000-0002-4997-5592

ID 1st Co-author: *Rosendo, Balois-Morales* / **ORC ID**: 0000-0002-4835-5631

ID 2nd Co-author: *José Orlando, Jiménez-Zurita* / **ORC ID**: 0000-0001-9561-0052

ID 3rd Co-author: *Graciela Guadalupe, López-Guzmán* / **ORC ID**: 0000-0003-2594-2275

DOI: 10.35429/JGE.2022.10.6.29.34 Received March 21, 2022; Accepted June 22, 2022

Abstract

Soursop fruit (Annona muricata L.) is a crop of important economic value for the state of Nayarit, however, it has a fast ripening that causes a short shelf life. Several post-harvest handling techniques have been applied to reduce its metabolic processes, such as refrigeration, the use of 1-methylcyclopropene (1-MCP) and controlled and modified atmospheres. In recent years, polysaccharide-based coatings have been applied to fruits. The aim of this research was to evaluate the physicochemical changes of soursop fruits coated with hibiscus calyx mucilage (2%), stored at 22 °C and 15 °C. Weight loss, firmness, pH, total soluble solids, acidity and colour were evaluated. Results for coated fruits stored at 15 °C showed lower weight loss (6.4%), lower firmness (29.7 N), higher TSS concentration (10.4 °Bx) and lower acidity (0.38%) compared to uncoated fruits. Coating with hibiscus mucilage and storage at 15 °C for four days decreased fruit weight loss. It was also observed that storage under these conditions allows a lower concentration of total soluble solids and organic acids. The coatings did not intervene in the decrease of fruit peel colour. Key words: coating, mucilage, soursop, postharvest. Introduction Mexico is the world's leading producer of soursop, with a national production of 30, 790 T in 2019. In this sense, the state of Nayarit was the largest producer of soursop with 23,230 T (Servicio de Información Agroalimentaria y Pesquera [SIAP], 2020). Soursop production contributes to the economic growth of Nayarit; however, there is a problem in the handling of the fruit due to the high respiration rate and ethylene production leading to softening of the fruit, resulting in a short post-harvest shelf life (Balois-Morales et al., 2019). Nayarit does not have an adequate postharvest system, which leads to inadequate fruit handling during handling (Jiménez-Zurita et al., 2016), causing production losses (Tovar-Gómez et al., 2011). Therefore, there is interest in investigating postharvest technologies that allow prolonging shelf life while maintaining the nutritional quality of the fruit (Moreno-Hernández et al., 2014). As an alternative to improve postharvest handling and maintain the quality of fruit and vegetable products, the use of edible coatings has been implemented (Park et al., 2014). Edible coatings based on polysaccharides have gained importance because they create a modified atmosphere through a semi-permeable layer in the fruit that allows gas exchange, reducing metabolic processes and prolonging the postharvest life of the fruit (Solano-Doblado et al., 2018). Among the polysaccharides of interest, mucilages have been used due to their highly branched structure, complex polymeric and hydrocarbon nature that allows modifying the rheology of a solution (Dugarte et al., 2019). Coatings made from mucilage allow a decrease in weight loss, delay in the concentration of total soluble solids, as well as colour improvement (Zambrano et al., 2017). In the above context, hibiscus mucilage could be used as a material for the preparation of an edible coating to prolong the shelf life of fruits. With this in mind, the effect of hibiscus mucilage-based coating (2%) on physicochemical changes during postharvest storage was evaluated in this study.

Resumen

El fruto de guanábana (Annona muricata L.) es un cultivo de importante valor económico para el estado de Nayarit, sin embargo, presenta una maduración rápida que ocasiona una corta vida de anaquel. Para reducir sus procesos metabólicos se han aplicado diversas técnicas de manejo postcosecha, como la refrigeración, el uso de 1-metilciclopropeno (1-MCP) y atmósferas controladas y modificadas. En los últimos años se han aplicado a las frutas recubrimientos a base de polisacáridos. El objetivo de esta investigación fue evaluar los cambios fisicoquímicos de frutos de guanábana recubiertos con mucílago de cáliz de hibisco (2%), almacenados a 22 °C y 15 °C. Se evaluó la pérdida de peso, firmeza, pH, sólidos solubles totales, acidez y color. Los resultados de los frutos recubiertos almacenados a 15 °C mostraron menor pérdida de peso (6,4%), menor firmeza (29,7 N), mayor concentración de SST (10,4 °Bx) y menor acidez (0,38%) en comparación con los frutos sin recubrir. El recubrimiento con mucílago de hibisco y el almacenamiento a 15 °C durante cuatro días redujeron la pérdida de peso de los frutos. También se observó que el almacenamiento en estas condiciones permite una menor concentración de sólidos solubles totales y ácidos orgánicos. Los recubrimientos no intervinieron en la disminución del color de la cáscara de los frutos. Palabras clave: recubrimiento, mucílago, guanábana, poscosecha. Introducción México es el primer productor mundial de guanábana, con una producción nacional de 30, 790 T en 2019. En este sentido, el estado de Nayarit fue el mayor productor de guanábana con 23, 230 T (Servicio de Información Agroalimentaria y Pesquera [SIAP], 2020). La producción de guanábana contribuye al crecimiento económico de Nayarit; sin embargo, existe un problema en el manejo de la fruta debido a la alta tasa de respiración y producción de etileno que conduce al ablandamiento de la fruta, lo que resulta en una corta vida de anaquel postcosecha (Balois-Morales et al., 2019). Nayarit no cuenta con un sistema de poscosecha adecuado, lo que conlleva a un manejo inadecuado de la fruta durante su manipulación (Jiménez-Zurita et al., 2016), ocasionando pérdidas en la producción (Tovar-Gómez et al., 2011). Por ello, existe interés en investigar tecnologías poscosecha que permitan prolongar la vida útil manteniendo la calidad nutricional del fruto (Moreno-Hernández et al., 2014). Como alternativa para mejorar el manejo poscosecha y mantener la calidad de los productos hortofrutícolas, se ha implementado el uso de recubrimientos comestibles (Park et al., 2014). Los recubrimientos comestibles a base de polisacáridos han cobrado importancia debido a que crean una atmósfera modificada a través de una capa semipermeable en el fruto que permite el intercambio gaseoso, reduciendo los procesos metabólicos y prolongando la vida poscosecha del fruto (Solano-Doblado et al., 2018). Entre los polisacáridos de interés, se han utilizado los mucílagos debido a su estructura altamente ramificada, naturaleza polimérica compleja e hidrocarbonada que permite modificar la reología de una solución (Dugarte et al., 2019). Los recubrimientos elaborados a partir de mucílagos permiten disminuir la pérdida de peso, retrasar la concentración de sólidos solubles totales, así como mejorar el color (Zambrano

Citation: DE LOS SANTOS-SANTOS, Miguel Angel, BALOIS-MORALES, Rosendo, JIMÉNEZ-ZURITA, José Orlando and LÓPEZ-GUZMÁN, Graciela Guadalupe. Soursop fruit storage: Edible coating based on Hibiscus sabdariffa mucilage. Particular case of sector suppliers. Journal-General Economics. 2022. 6-10: 29-34

* Correspondence to Author (email: ejardon@utleon.edu.mx)
† Researcher contributing first author.

Bibliographic Review

Polysaccharides and their use as coatings Films obtained from biopolymers are of great interest in the industry because they present the property of being biodegradable; in addition, if certain bioactive substances are added, the properties can be improved, as well as the controlled release of bioactive compounds that would allow prolonging the post-harvest life of the coated product (Raspo *et al*., 2018).

Polysaccharides such as cellulose derivatives, chitosan, starches, pectins and mucilages have been reported as raw materials for preparing edible films and coatings that can be used as packaging material for food preservation (Cazón *et al*., 2017). Edible coatings, based on polysaccharides, are an alternative for food packaging due to their biodegradability and low production cost, however, their hygroscopic nature and physical instability are important limitations (Rafieian et al., 2014).

Mucilage

Mucilages are complex carbohydrates made up of chains of L-arabinose, Dgalactose, L-rhamnose, D-xylose and galacturonic acid, the proportion of these monomers varies according to various factors such as variety, age, environmental conditions, extraction method, part of the plant, among other factors (Molina *et al*., 2019). Research reports the use of mucilage from Nopal (*Opuntia ficus-indica*) and cactus (*Opuntia elatior Mill*) indicating that coatings made from this polysaccharide decrease weight loss, total soluble solids concentration, transpiration rate and respiration (Molina *et al*., 2019; Zambrano *et al*., 2017).

Hibiscus mucilage (*Hibiscus sabdariffa L*)

Among the main plant sources from which polysaccharides can be extracted, hibiscus calyx (*Hibiscus sabdariffa* L.) is an excellent source of mucilage, hibiscus has been reported to have a high content of this polysaccharide, therefore, it can be used to make edible coatings applied to fruits and vegetables (Castañeda and Cáceres, 2014). However, hibiscus calyx mucilage has not been extensively studied, therefore, little is known about its effect as a coating on fruit and vegetable products.

Method and tols

Plant material

Soursop fruits harvested at physiological maturity were used. The harvest was carried out in a commercial orchard located in the ejido Venustiano Carranza in the municipality of Tepic, Nayarit (21° 32' 2.77" N, 104° 58' 37.73" W, 893 masl) (Jiménez-Zurita *et al*., 2016) (Jiménez-Zurita et al., 2016). The fruits were transported to the special analysis laboratory of the Food Technology Unit of the Autonomous University of Nayarit.

A selection of fruits was made by visually discarding those with physical, mechanical and phytopathological damage; subsequently, they were washed by immersion for 1 min with a solution of water with sodium hypochlorite at a concentration of 1 % (v/v) to avoid proliferation of harmful microorganisms, the fruits were left to dry at room temperature (25 °C) to apply the mucilage coating respectively.

Preparation and application of the coating

A 2% solution of hibiscus calyx mucilage and water (w/v) was prepared. The solution was then heated at 50 ± 2 °C for 30 min with constant stirring. The coating was applied to the fruits by dipping for one minute. After the fruits were coated and left in the open air at 25 °C to solidify the hibiscus calyx mucilage (2%), they were stored in climate chambers (ClimaCell®, CLC-B2V-M 404). Sample collection 1 g of pulp was mixed with 10 mL of distilled water using ULTRA-TURRAX T-25 IKA®.

This mixture was used for the quantification of pH, total soluble solids (TSS) concentration and titratable acidity. Variables evaluated Weight loss was determined by gravimetry using a digital balance (Scout Pro, OHAUS®). Colour was measured in the soursop peel using the parameters brightness (L), hue angle (°Hue) and chromaticity (C) with a colourimeter (Konica Minolta®). Loss of firmness was measured in two equatorial zones of the fruit using a penetrometer (Force Gauge model GY-4) with an 8 mm diameter probe. Pulp pH was measured with a potentiometer (Hanna Instruments HI22).

ISSN-On line: 2524-2008

Total soluble solids (TSS) concentration was determined by placing an aliquot in a refractometer (Hanna HI 96801). Titratable acidity was determined according to the official method (AOAC, 2005) by volumetric titration.

Experimental design

Treatments were established under a completely randomised design, with a 2 × 2 factorial arrangement (two temperatures and two coating conditions). The fruits were grouped in four batches. The treatments (T) were: uncoated fruits (T1 and T3), coated fruits (T2 and T4). The fruits of T1 and T2 were stored for 6 days at 22 °C and 90% RH. T3 and T4 fruits were stored for 8 days (4 days at 15 °C, then 4 days at 22 °C and 90% RH).

Results and discussion

Weight loss

Fruits stored at 22 °C showed an average daily mass loss of 3.9% (T1) and 4.2% (T2). At the end of eating maturity, the cumulative mass loss was 11.8% (T1) and 12.8% (T2), respectively. Soursop fruits stored at 15 °C showed a daily mass loss of 2.4% (T3) and 2.8% (T4). At the end of storage the cumulative mass loss was 9.8 (T3) and 11.4% (T4) (Figure 1 (a)). No significant statistical difference was found between treatments ($P \geq 0.05$) (Figure 1 (a)). Valero and Serrano (2010) reported that fruit weight loss during postharvest handling is mainly due to transpiration and respiration.

Tovar-Gómez et al. (2011), reported that the use of coating and low temperatures decrease weight loss between 2.5 and 2.4% of soursop fruits coated with wax emulsions and 1-MCP. On the other hand, Jiménez-Zurita et al. (2017), observed that uncoated soursop fruits stored for seven days (four days at 15 °C and then three days at 22 °C), present a cumulative weight loss of 2.3% and 2.7%, respectively. The same authors reported cumulative mass losses of 6.7 and 7.1% in uncoated soursop fruits stored for six days at 22 °C. The results obtained in the present investigation showed a lower mass loss in T4 compared to T1 and T2 fruits.

Firmness

A gradual decrease in firmness was observed in fruit stored at 22 °C during storage, where values of 27.1 N (T1) and 22 N (T2) were recorded after six days of storage (Figure 1 (b)). The same behaviour was observed for fruit stored at 15 °C for 4 days, where firmness decreased to 24.8 N (T3) and 22.7 N (T4). According to the statistical analysis, significant differences ($P \leq 0.05$) were observed in the treatments, where T1 and T3 showed higher firmness during storage (51.7 and 35.1 N) (Figure 1 (b)).

Loss of firmness in climacteric fruits such as soursop has been reported to be attributed to cell wall degradation due to the effects of enzymatic solubilisation and depolymerisation (Márquez et al., 2012). Montalvo-González et al. (2014), observed that the application of candelilla wax and beeswax to fruits stored at 25 °C reduced firmness by up to 9.4 N in soursop fruits.

The results obtained in this research were also higher than those reported by Márquez et al. (2012), who reported firmness values of 7.5 N at seven days after harvest. pH The pH of soursop pulp in fruits stored at 22 °C decreased during ripening from 5.7 (T1) and 5.4 (T2) to values of 4.3 and 4.2, respectively (Figure 1(c)).

Similar results were obtained for fruit stored at 15 °C for 4 days and subsequently transferred to 22 °C, where initial values were from 5.7 (T3) and 5.8 (T4) to 4.7(T3) and 4.5(T4), respectively. Statistically significant differences ($P \leq 0.05$) were observed (Figure 1 (c)). The decrease in pH is related to the increase in acidity characteristic of soursop fruits (Jiménez-Zurita et al. 2016).

These results are in the range established by the Colombian Technical Standard for Commercialisation (NTCC) at physiological or commercial maturity, "soursop fruits must have a minimum pH of 3.38" (Instituto Colombiano de Normas Técnicas y Certificación [ICONTEC], 2003). Jiménez-Zurita et al. (2016) conducted a characterisation of soursop fruits in Tepic, Nayarit, at 26 °C, obtaining a pH of 3.6 at consumption maturity.

ISSN-On line: 2524-2008

Villalba et al., (2006) conducted an investigation with soursop fruits from Colombia at eating maturity, reporting pH values of 3. Total soluble solids (TSS) The final TSS concentration in soursop fruits stored at 22 °C was 13.7 (T1) and 14.4 °Bx (T2), respectively (Figure 1 (d)). On the other hand, the final TSS concentration of fruits stored at 15 °C for four days was 10.75 and 11.95 °Bx (T3 and T4), respectively, showing significant differences in the treatments (P≤0.05) (Figure 1 (d)). Yashoda et al. (2006), mention that the increase in TSS is attributed to the reduction of total sugars, starch and cellulose during ripening to monosaccharides that confer the texture and flavour characteristics of the fruit.

The reduction of these sugars is due to the high enzymatic activity of amylase and polygalacturonase, which results in an increase in total soluble solids during ripening (Nolasco-González et al., 2019). Montalvo-González et al. (2014), reported 18.6 °Bx 10 days after harvest using combinations of 1-MCP and wax emulsions in the preservation of soursop stored at 25 °C. These results are within the range of the NTCC, which states that "soursop fruits should be above 13 °Bx", which is the maturity indicator used for soursop fruits (ICONTEC, 2003) Days of storage 0 2 2 4 6 8 10 Total soluble solids (°Brix) 0 5 10 15 20 Days of storage 0 2 2 4 6 8 10 pH 2 3 4 5 6 7 Firmness (N) 20 40 60 80 100 Weight loss (%) 0 5 10 15 20 T1 22 °C T2 22 °C T3 15 °C + 4 D at 22 °C T4 15 °C + 4 D at 22 °C A B C D Figure 1. Loss of mass (A), firmness (B), pH (C) and total soluble solids (D) in soursop fruit stored at 22 °C and 15 °C.

Each point represents the mean of six observations and its standard error. The dotted line indicates the end of refrigerated storage. Titratable acidity The concentration of organic acids increased during the storage period from 0.12 and 0.09% to 0.8 (T1) and 1.0% (T2) (Figure 2 (a)).

As for fruits stored for four days at 15 °C and transferred to 22 °C, lower concentration of organic acids was observed, where the initial concentration ranged from 0.1 and 0.17 % (T3 and T4) to 0.42 and 0.5 % (T3 and T4) at eating maturity, respectively. Statistically significant difference was observed between treatments (P≤0.05) (Figure 2 (a)).

The increase in the concentration of organic acids has been reported by Tovar-Gómez et al. (2011), where they observed that titratable acidity in soursop fruits increases during the ripening process by decreasing pH levels and acidifying the pulp.

It has been reported that the acidity of soursop fruits decreases at the end of storage, so it can be inferred that organic acids are used as substrates in the respiration process (Etienne et al., 2013). Jiménez-Zurita et al. (2017) reported values of 0.88 and 0.96% in soursop fruits stored at 22 °C after eight days of storage, while Do Sacramento et al. (2003), in selections of soursop fruits ("Lisa", "Morada" and "Comum"), obtained values between 0.92 and 1.0% of titratable acidity at eating maturity. Colour (L ∗ C ∗ h) The fruits stored at 22 °C (T1 and T2) showed a decrease in the colour parameters, where the average values at physiological maturity were characteristic of an opaque green with low luminosity (Luminosity= 44. 2 and 44, chromaticity= 16.3 and hue angle=109.5°), these values decreased to a very opaque green with a low lightness index at consumption maturity (lightness= 40.5 and 41.2, chromaticity= 9.2 and hue angle=80.89°) (Figure 2 (d)) (Figure 2 (d)).

This behaviour was similar in fruits stored for 4 days at 15 °C and then transferred to 22 °C, where a dull green colour was recorded in soursop fruits (Luminosity= 47.5 and 43, Chromaticity= 18. 5 and 15.1, hue angle=105 and 113.7°) which decreased to a less intense green at low light (Brightness= 40 and 34.8, Chromaticity= 11.3 and 5.9, hue angle=81.4 and 78.5) (Figure 2 (b)). Significant differences were observed in the evaluated treatments (P≤0.05). T3 fruits showed higher lightness (L = 44.4) and chromaticity (C = 15.8); however, hue angle was higher in coated fruits (hue = 102.7). Nolasco-González et al. (2019), observed a decrease in the green colour of soursop fruits and suggest that annonaceae during the ripening process manifest variations in colour and brightness, as well as decrease in the green colour angle, the peel colouring transforms from dark green to a light yellowish green indicating that the chlorophyll has lost carotenoids which are the main contributors to the peel colouring. Lima et al. (2003) reported values of L = 50, hue = 118 and C = 24 in uncoated soursop fruits stored at 23 °C.

Tovar-Gómez et al. (2011) reported brightness values of 43 and 45 in soursop fruits coated with wax and 1-MCP emulsions stored at 13 ± 2 °C, observing from day 10 a dark skin that caused a decrease in brightness values (43.5).

The bright green colour of the fruits evaluated in this research decreased during ripening to a dull green with low lightness index due to darkening of the epidermis. Days of storage 0 2 4 6 8 10 Chromaticity (C) 0 5 10 15 20 25 Days of storage 0 2 4 6 8 10 Hue (°) 40 60 80 100 120 Titratable acidity (%) 0.0 0 0.2 0.4 0.6 0.8 0.8 1.0 1.2 1.4 1.6 1.6 1. 8 T1 22 °C T2 22 °C T3 15 °C + 4 D at 22 °C T4 15 °C + 4 D at 22 °C Luminosity (L) 20 30 40 A 50 B C D Figure 2. Titratable acidity (A), Luminosity (B), Chromaticity (C) and °Hue (D) in soursop fruits stored at 22 °C and 15 °C. Each point represents the mean of six observations and its standard error.

The dotted line indicates the end of refrigerated storage. Conclusions Hibiscus mucilage coating and storage at 15 °C for four days decreased fruit weight loss. It was also observed that storage under these conditions allows a lower concentration of total soluble solids and organic acids. The coatings did not intervene in the decrease of the fruit peel colour.

References

Balois-Morales, R., Jiménez-Zurita J. O., Alia-Tejacal, I., López-Guzmán, G. G., Palomino-Hermosillo, Y. A. y Sánchez-Herrera, L. M. (2019). Antioxidant enzymes and antioxidant activity in two soursop selections (Annona muricata L.) from Nayarit, Mexico stored at 15°C. Revista Brasileira de Fruticultura, 41(1), e-083. doi.org/10.1590/0100-29452019083

Castañeda, R. y Cáceres, A. (2014). Compuestos bioactivos y propiedades terapéuticas de los cálices de rosa de Jamaica (Hibiscus sabdariffa L.). Revista científica, 24(1), 7–24. Cazón, P., Velazquez, G., Ramírez, J. A., y Vázquez, M. (2017). Polysaccharide-based films and coatings for food packaging: A review. Food Hydrocolloids, 68, 136-148. doi:10.1016/j.foodhyd.2016.09.009.

Do-Sacramento, C. K., Faria, J. C., Lopes-Da Cruz, F., De Sousa-Barretto, W., WalterGaspar, J. y Vieira Leite, J. B. (2003). Caracterização física e química de frutos de três tipos de gravioleira (Annona muricata L.). Revista Brasileira de Fruticultura, Jaboticabal, 25(2), 329-331. doi.org/10.1590/S0100-29452003000200037

Dugarte, N., Molina, F., y García, A. (2019). Aplicaciones de los mucílagos en el sector agro-alimentario. Ciencia y Tecnología de Alimentos, 30(1), 70-76. Etienne, A., Génard, M., Lobit, P., Mbeguié-A-Mbéguié, D., y Bugaud, C. (2013). What controls fleshy fruit acidity? a review of malate and citrate accumulation in fruit cells. Journal of Experimental Botany, 64(6), 1451–1469. doi: 10.1093 / jxb / ert035.

González, E. M., León-Fernández, A. E. Paez, H. R., De Oca, M. M. y Gómez, B. T. (2014). Uso combinado de 1-Meticiclopropeno y emulsiones de cera en la conservación de guanábana (Annona muricata). Revista Brasileira de Fruticultura, 36(1), 296-304. doi.org/10.1590/S0100-29452014000500035

ICONTEC [Instituto Colombiano de Normas Técnicas y Certificación] (2003). Frutas frescas: guanábana. Especificaciones (Norma Técnica Colombiana No. 5208), Instituto Colombiano de Normas Técnicas y Certificación, Bogotá, Colombia, pp. 3-7.

Jiménez-Zurita, J. O. Balois-Morales, R., Alia-Tejacal I., … (2017). Cold storage of two selections of soursop (Annona muricata L.) in Nayarit, Mexico. Journal of Food Quality, 2017, 4517469, 9. doi.org/10.1155/2017/4517469

Jiménez-Zurita, J. O. Balois-Morales, R., Alia-Tejacal, I., Juárez-López, P., SumayaMartínez, M. T. y Bello-Lara, J. E. (2016). Caracterización de frutos de guanábana (Annona muricata L.) en Tepic, Nayarit, México. Revista Mexicana de Ciencias Agrícolas, 7(6), 1261–1270. Lima.

M. A. C. D., Alves, R. E., Filgueiras, H. A. C., y Enéas-Filho, J. (2003). Comportamento respiratório e qualidade pós-colheita de graviola (Annona muricata L.) “morada” sob temperatura ambiente. Revista Brasileira de Fruticultura, 25(1), 49–52, 2003. doi.org/10.1590/S0100-29452003000100015

ISSN-On line: 2524-2008

Márquez, C., Villacorta, D., Yepes, D., Ciro, H., y Cartagena, J. (2012). Physiological and physico chemical characterization of the soursop fruit (Annona muricata L. Cv. elita). Revista Facultad Nacional de Agronomía-Medellín, 65(1), 6477–6486.

Molina, F., Osorio, N., Yáñez, M., Rojas, J., y García, M. (2019). Recubrimientosdemucílagodenopal (Opuntiaficus-indica) y pectina con aceite esencial de romero (Rosmarinus officinalis) en la conservación de naranjas. Ciencia y Tecnología de Alimentos, 29(2), 53-58.

Nolasco-González, Y., Hernández-Fuentes, L. M., y Montalvo González, E. (2019). Caracterización morfológica y fisicoquímica de frutos de accesiones de guanábanas seleccionadas en Nayarit. Revista mexicana de ciencias agrícolas, 10(23), 223-237. doi.org/10.29312/remexca.v0i23.2023

Official Method of Analysis of AOAC [AOAC] (2005). Acidity (titrable) of fruit products, International, (18)37, p. 10. Park H. J., Byun, Y. J., Kim, Y. T., Whiteside, W. S. y Bae, H. J. (2014). Processes and applications for edible coating and film materials from agropolymers. In: Innovations in Food Packaging. Second edition. J. H. Han (ed.). Academic Press. London, UK. pp:257- 275, https://doi.org/10.1016/B978-0-12-394601-0.00010-2

Rafieian, F., Shahedi, M., Keramat, J., y Simonsen, J. (2014). Thermomechanical and morphological properties of nanocomposite films from wheat gluten matrix and cellulose nanofibrils. Journal of Food Science, 79(1), 100-107. doi:10.1111 / 1750- 3841.12231.

Raspo, M., Gómez, C. y Andreatta, A. (2018). Optimization of antioxidant, mechanical and chemical physical properties of chitosan-sorbitol-gallic acid films by response surface methodology. Polymer Testing, 70, 180-187. doi:10.1016/j.polymertesting.2018.07.003.

Servicio de Información Agroalimentaria y Pesquera [SIAP] (2020). Anuario Estadístico de la Producción Agrícola. Secretaría de Agricultura, México City, México.

Solano-Doblado, L. G., Alamilla-Beltrán, L., y Jiménez-Martínez, C. (2018). Películas y recubrimientos comestibles funcionalizados. Revista Especializada en Ciencias Químico-Biológicas, 21(2),30-42. doi.org/10.22201/fesz.23958723e.2018.0.153

Tovar-Gómez, B., Mata-Montes de Oca, M., García-Galindo, H., y Montalvo-González, E. (2011). Efecto de emulsiones de cera y 1-metilciclopropeno en la conservación poscosecha de guanábana. Revista Chapingo Serie Horticultura, 17(1), 53-61.

Valero, D. y Serrano, M. (2010). Postharvest Biology and Technology for Preserving Fruit Quality. CRC, Boca Raton, FL, United of America.

Villalba, M., Yepes, I., y Arrázola-Paternina, G. S. (2006). Caracterización fisicoquímica de frutas de la zona del Sinú para su agroindustrialización. Temas Agrarios, 11(1), 15-23. 10.21897/rta.v11i1.636

Yashoda, H. M., Prabha, T. N. y Tharanathan, R. N. (2006). Mango ripening: changes in cell wall constituents in relation to textural softening. Journal of the Science of Food and Agriculture, 86(5), 713-721. doi.org/10.1002/jsfa.2404

Zambrano, J., Valera, A., Maffei, M., Materano, W., Quintero, I. y Graterol, K. (2017). Efecto de un recubrimiento comestible formulado con mucílago del cactus (opuntia elatior mill.) Sobre la calidad de frutos de piña mínimamente procesados. Bioagro, 29(2), 129-136

ISSN-On line: 2524-2008