

Preservation of minimally processed papaya by using chitosan coatings with turmeric hydroalcoholic extract

Conservación de papaya mínimamente procesada mediante recubrimientos de quitosano con extracto hidroalcohólico de cúrcuma

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Abstract

The influence of chitosan coatings (1.5 and 2% w/v) with turmeric hydroalcoholic extract (*Curcuma longa*) (THE) (5.5 µg/µL of total polyphenols; 0.2 and 0.4% v/v) was evaluated, at laboratory scale, during storage between 2 and 4 °C of minimally processed papaya (*Carica papaya*) var. Maradol Roja. Fresh papayas were selected and pretreated, guaranteeing homogeneity in size, absence of defects and uniform ripening degree. For the application of the coatings by immersion, the papayas were peeled and cut into cubes. Physical and chemical determinations were carried out that included penetration degree, acidity, pH, moisture content, soluble solids and ripening index. Over a period of 11 days, changes in physical, chemical and microbiological attributes were observed. The chitosan coating with THE did not influence the physical and chemical characteristics of the minimally processed papaya, although in general, the samples treated with coatings showed greater firmness and a lower ripening index. Chitosan coating at 1.5% (w/v) with an addition of 0.2% (v/v) of THE was the most effective in inhibiting the contaminating microbiota of the product.

Keywords: Minimally processed papaya; chitosan coatings; turmeric hydroalcoholic extract; preservation.

Resumen

Se evaluó, a escala de laboratorio, la influencia de los recubrimientos de quitosano (1,5 y 2% p/v) con extracto hidroalcohólico de cúrcuma (*Curcuma longa*) (THE) (5,5 µg/µL de polifenoles totales; 0,2 y 0,4% v/v), durante almacenamiento entre 2 y 4 °C de papaya (*Carica papaya*) var. Maradol Roja. Las papayas frescas fueron seleccionadas y pretratadas, garantizando homogeneidad en tamaño, ausencia de defectos y grado uniforme de maduración. Para la aplicación de los recubrimientos por inmersión, las papayas fueron peladas y cortadas en cubos. Se realizaron determinaciones físicas y químicas que incluyeron grado de penetración, acidez, pH, contenido de humedad, sólidos solubles e índice de maduración. Durante un período de 11 días se observaron cambios en atributos físicos, químicos y microbiológicos. El recubrimiento de quitosano con THE no influyó en las características físicas y químicas de la papaya mínimamente procesada, aunque en general, las muestras tratadas con recubrimientos mostraron mayor firmeza y menor índice de maduración. El recubrimiento de quitosano al 1,5% (p/v) con una adición de 0,2% (v/v) de THE fue el más eficaz para inhibir la microbiota contaminante del producto.

Palabras clave: Papaya mínimamente procesada; recubrimientos de quitosano; extracto hidroalcohólico de cúrcuma; preservación.

Introduction

Currently, there is a marked tendency to acquire foods with sensory characteristics that reflect a minimum intervention of industrial processes, especially when it comes to fruit and vegetable products.¹ The accelerated pace of today's life and the lack of time for food preparation have increased consumer interest in minimally processed fruits and vegetables.² The damage caused during peeling and cutting favors the occurrence of reactions that cause deterioration, which is why it is necessary to develop conservation techniques that delay these processes and maintain their microbiological safety.

Among these methods is the use of edible films and coatings. One of the materials used in the production of edible films and coatings is chitosan. Some properties of chitosan, such as its biocompatibility, biodegradability, and antimicrobial properties, make it a good candidate for food preservation.^{3,4}

Many studies have clearly shown low or no antioxidant capacity of native chitosan.⁵⁻⁸ The incorporation of turmeric hydroalcoholic extract (THE) into chitosan films and coatings enhances its antioxidant and antimicrobial character. THE has a high content of phenolic compounds, above other aromatic plants such as peppermint, mint, parsley, common basil, and French oregano.⁹ For this reason, the use of chitosan and natural extracts in the preservation of fruits¹⁰ such as mango¹¹ and

papaya^{12,13} have been investigated, as well as the effects of the addition of turmeric extracts on the properties of the films and coatings have been evaluated in minimally processed pineapple.¹⁴

In this context, the objective of this work was to evaluate the influence of chitosan coatings with THE as an alternative method for the conservation of minimally processed papaya during refrigerated storage. This work contributes to the understanding of conservation strategies for minimally processed fruits and their practical application in the food industry. The combined application of chitosan and turmeric extract offers a promising eco-friendly alternative to synthetic preservatives. The study's findings align with previous research on natural coatings for food preservation. Future studies could explore optimal formulations and application methods for scaling up this technology in the food industry.

Materials and methods

Selection and pretreatment of fresh papayas

Fresh papayas (*Carica papaya* L.) var. Maradol Roja with an average mass of 2.5 kg, was purchased from a state market in Havana. The fruits were selected taking into account that they all generally presented the same characteristics of size, absence of bumps, spots, cracks, and uniform ripening degree (Stage 4)¹⁵, according to Fig. 1. The characterization of the selected fruits was carried out, for which the percentage of acidity, moisture content, percentage of soluble solids, and ripening index were determined. The selected fruits were washed with drinking water and disinfected with an 80 mg/L sodium hypochlorite solution,¹⁶ peeled, and cut into cubes with approximately 2 cm edges.

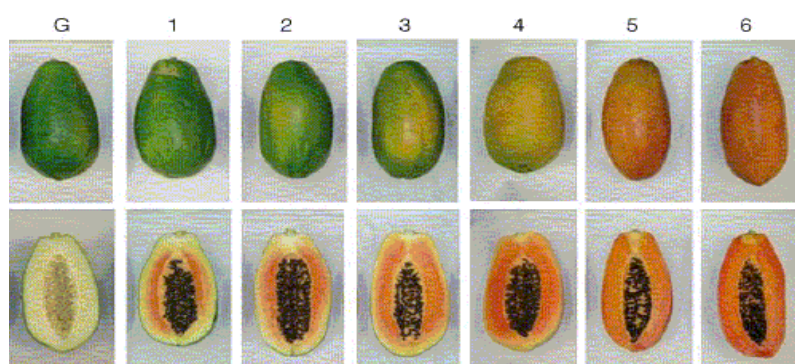


Fig. 1. Visual aspect of representative Maradol papaya fruit at each maturity stage. G: green skin without yellow stripe; 1: green skin with light yellow stripe; 2: green skin with well-defined yellow stripe; 3: one or more orange-colored striped in skin; 4: clearly orange-colored skin with some light green areas; 5: characteristic orange-colored skin of Maradol papaya; 6: fruit color similar to stage 5, but more intense.¹⁵

Materials and chemical reagents

The materials used to prepare the edible coating-forming solutions were chitosan, supplied by the Center for Research and Development of Medicines (CIDEM), obtained by the heterogeneous thermoalkaline N-deacetylation method of the chitin of the Caribbean or common lobster (*Panulirus argus*),¹⁷ with a molecular mass of 275 kDa and a degree of distillation of 75%, Tween 80 as a surfactant (Acros Organics, Belgium), 90% lactic acid (Merck, Germany), THE (*Curcuma longa*) (EHC) with a concentration of total polyphenols of 5.5 µg/µl supplied by the Research Institute for the Food Industry and distilled water.

Coatings application

The application of the coatings was carried out by simply immersing the 8 cm³ cubes in the chitosan solution with THE for 2 min and drying on stainless steel grills subjected to a forced air flow at ambient temperature and relative humidity (30 °C and 81% RH) for 30 min. The treatments are presented in Table 1.

The papaya pieces (80 g) were packed in polystyrene trays and coated with a 10 µm thick low-density polyethylene shrink film and stored in refrigeration (4 to 6 °C and ~90% RH) with forced air circulation. There was a control batch (without chitosan coating or THE that was only immersed in a 1% (v/v) lactic acid solution) that was maintained under the same storage conditions (4 to 6 °C) to compare the changes during it. The evaluations of the physical-chemical quality attributes were carried out every three days for 11 days. During the procedure, the necessary hygienic conditions were maintained to avoid excessive contamination of the product with microorganisms from handlers, utensils, and surfaces.

Table 1. Treatments carried out on papaya cubes

Treatment	Chitosan (% m/v)	Turmeric extract (% v/v)	hydroalcoholic Tween 80 (% v/v)
TC1	0.0	0.0	0.0
TQ1	1.5	0.0	0.1
TQ1-C1	1.5	0.2	0.1
TQ1-C2	1.5	0.4	0.1
TC2	0.0	0.0	0.0
TQ2	2.0	0.0	0.1
TQ2-C1	2.0	0.2	0.1
TQ2-C2	2.0	0.4	0.1

Microbiological, physical and chemical determinations

The content of soluble solids¹⁸, pH¹⁹ and titratable acidity²⁰ were determined. The moisture content was determined by indirect gravimetry by volatilization, by separating the water from the product by drying on a Sartorius thermobalance (Mod. MA-40, Germany) at 105 °C until constant mass. The degree of penetration was determined using a 30° angle cone penetrometer (A. H. Thomas, Co. USA) of 150 g, which was applied to the papaya cubes for 5 s in free fall.

The counts of aerobic microorganisms at 30 °C²¹ and of total coliforms,²² were carried out after the coating application (time 0) and at the end of the period of observation. Deterioration due to fungi and yeasts was visually inspected on the days on which physical and chemical analyses of the products were carried out.

Statistical analysis

The values of the measured indicators were subjected to factorial variance analysis, using the STATISTICA program (version 7, 2004, StatSoft. Inc., Tulsa, USA). Duncan's multiple range test ($p \leq 0.05$) was used to determine the statistical difference between the samples.

Results and discussion

The physical and chemical characteristics of fresh papayas play a crucial role in their quality and suitability for preservation techniques such as chitosan coatings. The values of the physical-chemical parameters of the fresh papaya cubes are reported in Table 2. The penetration distance measurement indicates the firmness of papaya flesh. A study by Oliveira Filho et al.²³ found that different treatments influenced fruit firmness, affecting penetration distance. Soluble solids content is a key indicator of fruit sweetness and maturity.

Table 2. Physical and chemical evaluation of fresh papayas

Parameter	Mean $\pm$ Standard deviation
Penetration distance (1/10 mm)	70.64 $\pm$ 14
Soluble solids (°Brix)	4.20 $\pm$ 2
Moisture (% m/m)	91.23 $\pm$ 1
Titratable acidity (% m/m citric acid)	0.62 $\pm$ 0.01
pH	5.48 $\pm$ 0.2

Alam et al.²⁴ demonstrated significant variations in soluble solids among different portions of ripe and unripe papaya fruit. The high humidity content observed aligns with typical moisture levels in fresh papaya. Muñoz-Tebar et al.²⁵ informed similar moisture levels in fruits coated with edible films containing bioactive compounds. Titratable acidity influences fruit flavor and preservation. Also, the combined effect of ascorbic acid and chitosan on acidity levels in papaya was investigated.²⁶ The pH value is vital for determining fruit ripeness and storage conditions.

García et al.²⁷ reported values of pH and moisture for the Maradol papaya, similar to those presented. The parameters penetration distance and soluble solids were greater than those reported in Table 2, thus evidencing that the state of maturity of the fruits used by the author was greater than that of those in the present study.

In Fig. 2, it is observed that the firmness decreased, following a similar pattern during the storage period in all treatments, but with differences in the magnitude of the changes. The results shown suggest that a loss of firmness of the samples occurs with increasing storage time and that this loss is greater in the control sample.

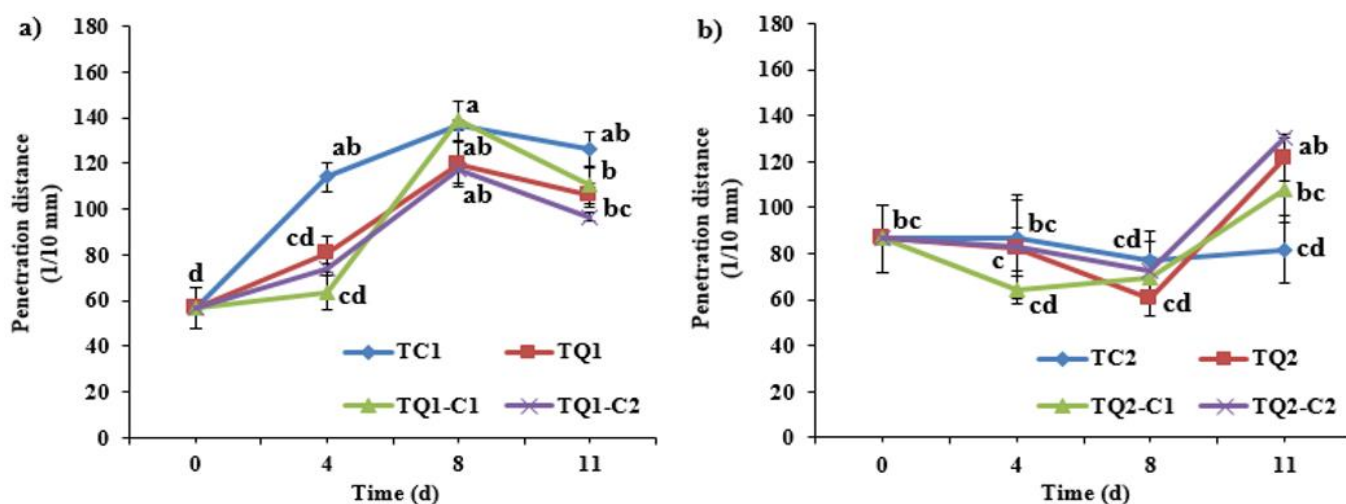


Fig. 2. Behavior of the penetration distance in minimally processed papaya during storage according to the treatments: a) chitosan coatings at 1.5% (m/v); b) chitosan coatings at 2.0% (m/v) with the addition of turmeric hydroalcoholic extract at 0.2 and 0.4% (v/v). Error bars indicate standard deviation (n= 4). Different letters indicate a significant difference ($p \leq 0.05$) according to Duncan's multiple range test.

Fig. 2 shows that there are significant differences between the control treatments (TC 1 and TC 2) and the treatments with chitosan at 1.5 and 2.0% (m/v) (TQ1 and TQ2) and chitosan at 1.5 and 2.0% (m/v) with EHC at 0.2% (v/v) (TQ1-C1 and TQ2-C1) evidencing the effectiveness of the application

of these coatings on papaya cubes; Therefore, it can be hypothesized that the control sample matured to a greater degree than the control samples treated with chitosan and EHC. Similar results were obtained by Díaz et al.²⁸ when applying chitosan coating at 1 and 2% (m/v) on fresh papaya cubes. A study conducted by El-Ghaouth et al.²⁹ compared chitosan coatings with a commercial fungicide on strawberry quality, and found that strawberries treated with chitosan were firmer than those treated with fungicide and than control strawberries (without treatment). These authors suggest that these results obtained are due to the reduction of metabolic processes and consequently a delay in fruit ripening.

Recent studies have shown the influence of packaging conditions on the retention of firmness of cut fruits. Soliva-Fortuny et al.³⁰ reported that the composition of the atmosphere in the packaging of pre-cut “Golden Delicious” apples and “Conference” pears has a very important influence on the retention of the firmness of the products. The microstructural studies showed the formation of a large amount of exudate on the surface of the cells after prolonged storage, a fact that is related to the loss of tissue firmness.³¹ The severity of this softening could be reduced by packaging under conditions with low oxygen concentrations.

Table 3 shows how the soluble solids increase in the papaya cubes, evidencing significant differences in the treatments at the beginning and the end of storage. These results are similar to those obtained by Díaz et al.²⁸ and González-Aguilar et al.³¹, which coated papaya cubes (Maradol variety) with chitosan coatings at different concentrations, of which the most efficient in delaying ripening was 2% (m/v) chitosan. In the days of storage in which there was a decrease in soluble solids, it may be a product of the variety of ripeness that the papaya cubes presented or due to the metabolism of microorganisms that use the sugars present in the fruits as a substrate in their reactions. metabolic. Similar results were obtained by Cruaños et al.³² where fresh blueberries were coated with 1% (m/v) chitosan coating and stored for 15 days.

Table 3. Variation in soluble solids content of MP papayas during storage

Treatment	Time (d)			
	0	4	8	11
TC1	6.1 ± 0.4 ab	5.8 ± 0.5 b	6.2 ± 0.0 ab	6.5 ± 2.0 ab
TQ1	6.1 ± 0.4 b	6.0 ± 0.8 b	5.9 ± 0.8 b	4.1 ± 0.6 c
TQ1-C1	6.1 ± 0.4 b	6.5 ± 1.0 ab	7.4 ± 0.4 ab	7.5 ± 0.0 a
TQ1-C2	6.1 ± 0.4 b	5.7 ± 0.5 bc	5.6 ± 0.7 bc	3.5 ± 0.4 cd

TC2	2.3 ± 0.4 d	3.2 ± 1.0 cd	3.0 ± 1.0 cd	3.2 ± 0.6 cd
TQ2	2.3 ± 0.4 d	3.1 ± 1.0 cs	3.4 ± 0.2 cd	3.4 ± 0.6 cd
TQ2-C1	2.3 ± 0.4 d	4.0 ± 0.4 c	3.1 ± 0.4 cd	4.1 ± 0.4 c
TQ2-C2	2.3 ± 0.4 d	4.3 ± 0.6 c	4.7 ± 0.2 bc	4.7 ± 0.3 bc

Mean ± Standard deviation; n= 3.

Different letters indicate significant differences ($p \leq 0.05$), according to

Duncan's multiple range test.

Sugars and organic acids are the main components of soluble compounds. During ripening, the sugar content increases until it reaches a maximum and then usually remains unchanged. García et al.¹⁶ agree with the aforementioned explanation about the behavior of treatments TQ2 and TQ2-C2. Based on the results of soluble solids content, TQ1-C1 emerges as the most effective treatment for maintaining or enhancing soluble solids content in MP papayas over an 11-day storage period. This treatment could be further explored for its potential in extending the shelf life and quality of minimally processed papayas.

Table 4 shows the decrease in moisture content in the papaya cubes, which reflects that in the different treatments, there were no significant differences between the moisture values at the beginning and the end of storage, so the same pattern of behavior was evident with a slight decrease in moisture content, caused by the transpiration process of the fruit.

Table 4. Variation in moisture content of MP papayas during storage

Treatment	Time (d)			
	0	4	8	11
TC1	89.56 ± 0.09 bc	87.6 ± 0.2 cd	88.4 ± 0.9 c	89.1 ± 0.5 bc
TQ1	89.56 ± 0.09 bc	87.38 ± 0.01 cd	87.52 ± 0.03 cd	84.3 ± 0.2 d
TQ1-C1	89.56 ± 0.09 bc	85.7 ± 0.2 d	88.0 ± 0.5 c	88.3 ± 0.9 c
TQ1-C2	89.56 ± 0.09 bc	88.2 ± 0.3 c	86.3 ± 0.6 cd	88.8 ± 0.1 bc
TC2	92.89 ± 0.07 a	91.5 ± 0.6 ab	92.0 ± 0.1 ab	91.4 ± 0.7 ab
TQ2	92.89 ± 0.07 a	89.8 ± 0.1 bc	91.9 ± 0.8 ab	91.2 ± 0.1 ab
TQ2-C1	92.89 ± 0.07 a	89.2 ± 0.1 bc	90.75 ± 0.07 b	92.4 ± 0.4 ab
TQ2-C2	92.89 ± 0.07 a	88.0 ± 0.6 c	90.6 ± 0.3 bc	90.9 ± 0.1 ab

Mean ± Standard deviation; n= 3.

Different letters indicate significant differences ($p \leq 0.05$), according to Duncan's multiple range test.

This behavior can be attributed to the fact that the product was packaged in polystyrene trays, coated with a polyethylene shrink film, all of which slows the migration of moisture. This indicates that under these conditions the plastic packaging materials used were the ones that controlled moisture migration and not the chitosan coatings. Results similar to those in Table 4 were obtained by García et al.¹⁶ and Díaz et al.²⁸ when they coated papaya cubes with chitosan coating at 1 and 2% (m/v). TC1 and TQ1-C1 appear to be among the better treatments for maintaining moisture levels in MP papayas during storage. These treatments show relatively stable moisture profiles over time, which is crucial for preserving the quality and shelf life of MP papayas.

The acidity of the papaya cubes remained constant during the first three days for all treatments and then presented an increasing trend throughout storage and in the end, it decreased because organic acids are used as a source of energy for the activity. cell phone; although there were no significant differences between the control sample and the treatments with chitosan coatings with THE (Figure 3a).

The tendency to increase acidity values is associated with the fact that the papaya cubes in the trays did not have the same stage of maturity. The results of the determination of acidity in papaya cubes coated with chitosan coatings by Díaz et al.²⁸ and González-Aguilar et al.³¹ are different from those presented in Fig. 3, since the initial acidity values were high and decreased during the storage, where there were significant differences in the decrease in acidity of the control treatment. Concerning the other treatments, the 2% (m/v) chitosan coating was the one that delayed this decrease the most. Similar results were reported in the control batch of papaya cubes by García et al.¹⁶

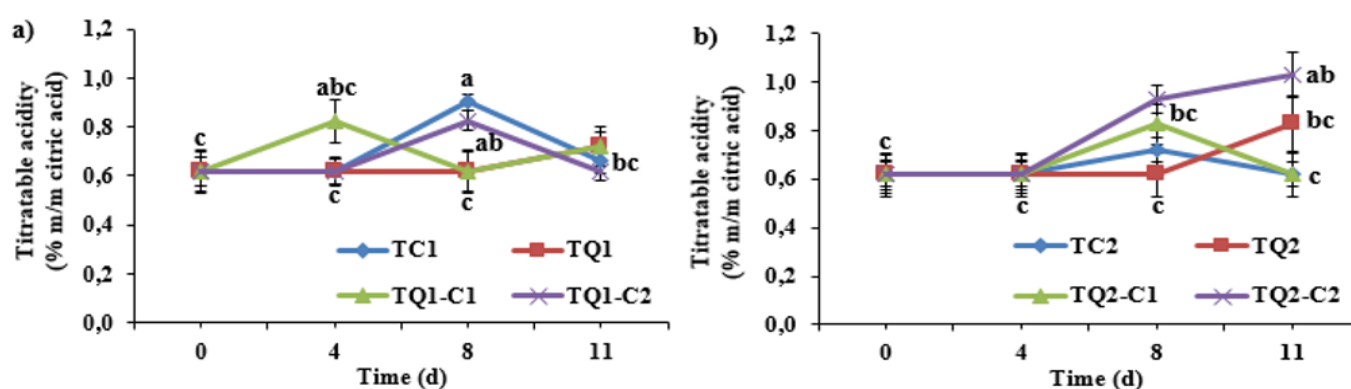


Fig. 3. Behavior of minimally processed papaya acidity during storage according to the treatments: a) chitosan coatings at 1.5% (m/v); b) chitosan coatings at 2.0% (m/v) with the addition of turmeric

hydroalcoholic extract at 0.2 and 0.4% (v/v). Error bars indicate standard deviation ($n=3$). Different letters indicate a significant difference ($p \leq 0.05$) according to the Duncan multiple range test.

The pH of MP papaya during storage plays a crucial role in maintaining its quality and shelf life. Research indicates that pH affects enzymatic activity and microbial growth in papaya, influencing its texture, flavor, and color.³³ Monitoring pH levels is essential for controlling microbial stability, as suitable pH conditions can inhibit spoilage and pathogenic bacteria.³⁴ Furthermore, pH directly influences enzymatic processes that impact fruit ripening and softening, which are critical factors affecting papaya's shelf life. Optimal pH levels also contribute to desirable taste perception, ensuring a pleasant eating experience for consumers.³⁵ Understanding and managing pH levels during storage are imperative for preserving the quality, safety, and marketability of MP papaya.

Table 5 shows the trend of treatments with chitosan coating at 1.5% (m/v) with EHC; the pH increases due to the ripening of the papaya cubes and then decreases as the stage of maturity of the papaya cubes varies. papaya cubes or by fermentative metabolism of the fruit microbiota and decomposition of sugars.¹⁶ TQ1-C1 and TQ1-C2 maintained relatively stable pH values over time, although the variation in pH in all cases, with values between 5 and 5.7 in general, does not influence, in the practice, the stability of MP papaya.

Table 5. Variation in the pH of MP papayas during storage

Treatment	Time (d)			
	0	4	8	11
TC1	5.35 $\pm$ 0.05 cd	5.28 $\pm$ 0.06 d	5.21 $\pm$ 0.1 de	5.03 $\pm$ 0.05 de
TQ1	5.35 $\pm$ 0.05 cd	5.8 $\pm$ 0.1 b	5.95 $\pm$ 0.09 a	5.34 $\pm$ 0.02 cd
TQ1-C1	5.35 $\pm$ 0.05 cd	5.70 $\pm$ 0.08 bc	5.6 $\pm$ 0.1 bc	5.5 $\pm$ 0.1 cd
TQ1-C2	5.35 $\pm$ 0.05 cd	5.74 $\pm$ 0.16 bc	5.75 $\pm$ 0.02 bc	5.5 $\pm$ 0.1 cd
TC2	5.60 $\pm$ 0.24 bc	4.95 $\pm$ 0.27 e	5.17 $\pm$ 0.06 de	5.2 $\pm$ 0.1 de
TQ2	5.60 $\pm$ 0.24 bc	5.3 $\pm$ 0.1 cd	5.23 $\pm$ 0.05 de	5.25 $\pm$ 0.1 d
TQ2-C1	5.60 $\pm$ 0.24 bc	5.34 $\pm$ 0.24 cd	5.4 $\pm$ 0.2 cd	5.2 $\pm$ 0.2 de
TQ2-C2	5.60 $\pm$ 0.24 bc	5.46 $\pm$ 0.07 cd	5.2 $\pm$ 0.2 de	5.20 $\pm$ 0.09 de

Mean $\pm$ Standard deviation; $n=3$.

Different letters indicate significant differences ($p \leq 0.05$), according to Duncan's multiple range test.

The significant differences presented by the treatment with chitosan coatings at 2.0% (m/v), so these coatings delayed the increase in pH and thus the ripening of the papaya cubes during storage. Similar results were obtained by García et al.¹⁶ when minimally processing papayas and coating them with chitosan at 1.5% (m/v); with the difference that after 10 days of storage, there were no significant differences between the samples of their treatments, but after 15 days all their treatments presented significant differences.

Table 6 shows the behavior of aerobic microorganisms at 30 °C total for both treatments (chitosan coating at 1.5 and 2.0% (m/v) at the beginning and at the end of storage. It shows an increase in the microbial load in both treatments at the end of storage. Table 6 shows that there are no significant differences between the 1.5% (m/v) chitosan coating treatments at the beginning of storage, this shows that the application of the treatments was carried out hygienically, avoiding contamination of the samples. The same happened for the treatments with 2.0% (m/v) chitosan coating, although the initial microbial load registered was slightly lower.

Table 6. Total count of aerobic microorganisms at 30 °C (log ufc/g) during storage of MP papayas

Treatment	Time (d)	
	0	11
TC1	1.98 ± 0.02 cd	2.19 ± 0.15 abc
TQ1	1.98 ± 0.02 cd	1.9 ± 0.1 d
TQ1-C1	1.98 ± 0.02 cd	2.0 ± 0.06 cd
TQ1-C2	1.98 ± 0.02 cd	2.04 ± 0.06 bcd
TC2	1.9 ± 0.1 d	2.3 ± 0.1 a
TQ2	1.9 ± 0.1 d	2.29 ± 0.01 a
TQ2-C1	1.9 ± 0.1 d	2.0 ± 0.06 cd
TQ2-C2	1.9 ± 0.1 d	2.24 ± 0.04 ab

Mean ± Standard deviation; n= 3.

Different letters indicate significant differences ($p \leq 0.05$), according to Duncan's multiple range test.

The results of the statistical processing of the total count of aerobic microorganisms at 30 °C indicate that there are significant differences between the values at the beginning and the end of the treatments with chitosan coating at 1.5% (m/v) except for treatments TQ1-C1 and TQ1-C2 (chitosan coatings at 1.5% and THE at 0.2 and 0.4% (v/v)) that their microbiological values at the beginning and the end

of storage did not show significant differences between them. The same thing happens for the treatments with 2% chitosan coatings, which showed significant differences in all treatments between the values at the beginning and at the end of storage, except for treatment TQ2-C1 (2% chitosan coatings (m/v). and 0.2% (v/v) THE). This behavior agrees with the studies carried out by García et al.¹⁵, where the effectiveness of 1.5% (m/v) chitosan coatings applied to pineapple slices was demonstrated, slowing microbial growth during 15 days of refrigerated storage. According to studies carried out by Díaz et al.²⁸ and Gonzales-Aguilar et al.³⁰, who applied chitosan coatings at different concentrations (1 and 2% m/v) on papaya cubes and demonstrated that the 2% chitosan coating was the best for preserving the physical properties. chemicals and microbial growth retardation. Therefore, when comparing these results with those presented in Table 6, it can be stated that the turmeric concentration of 0.4% (v/v), in the 2.0% (m/v) chitosan coating, negatively affects the antimicrobial activity of chitosan coating-forming solutions, causing an antagonistic interaction.

Papaya is a fruit susceptible to fungal and yeast infection, since it has a high water content and an optimal pH for the growth of these microorganisms, this being one of the main causes of its deterioration. Taking into account that NC 585³⁶ recommends the investigation of certain microbial groups for each category of food, that the product is considered a ready-to-eat food, total mesophiles and total and thermotolerant coliforms are established as parameters to evaluate. However, the fungal and yeast count was evaluated at the beginning and end of the application of the different treatments, observing a slight increase in fungal contamination, although it was not qualitatively important.

The presence of fungi was greater in the control treatment, undoubtedly attributed to possible contamination of the sample during its handling, since in general it was observed that the presence of the chitosan coatings retarded the growth of the rest of the microorganisms during storage time, which corresponds to González-Aguilar et al.³¹, who evaluated the effectiveness of the application of chitosan coatings at 1 and 2% (m/v) on cut papaya stored at 5 °C for 15 days. Similar results were obtained by García et al.¹⁶ when applying chitosan coatings at 1.5% (m/v) on pineapple slices stored between 4 and 6 °C for 15 days.

In the treatments carried out at the beginning and end, no growth of total coliforms was observed in any of the samples; which indicates that the handling was correct throughout the process and that the sanitary standards for food handling were met. Similar results were obtained by Díaz et al.²⁸ in the detection of these microorganisms in papaya cubes coated with 1 and 2% (m/v) chitosan coatings.

Conclusions

The application of chitosan and EHC coatings did not influence the physical-chemical characteristics of the minimally processed papayas, although in general, the samples treated with coatings presented greater firmness and a lower maturity index. The 1.5% (m/v) chitosan coating with the addition of 0.2% (v/v) EHC was more effective in inhibiting the development of the product's contaminating microbiota.

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