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ORIGINAL RESEARCH ARTICLE

Effect on the preservation of minimally processed Rambutan (*Nephelium Lappaceum* L.) by cactus (*Opuntia ficus-indica*) mucilage coating

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ABSTRACT

Rambutan (*Nephelium lappaceum* L.) was introduced to Mexico in 1959. Currently there is an estimated planted area of 835.96 ha and a production of 8,730.27 tons. The fruit is mainly consumed fresh, but quickly loses its external appearance due to dehydration and browning, which limits its commercialization, an alternative may be minimal processing and adjuvant treatments that extend the shelf life. The objective of this work was to evaluate the effect of coating with cactus mucilage (*Opuntia ficus-indica*), in the preservation of minimally processed rambutan stored at 5 °C, in two types of packaging. The rambutan was sanitized with chlorinated water (80 ppm), the epicarp was removed and batches were formed for each treatment. The factors were type of container (polyethylene bag and polystyrene container), coating (with and without coating) and time (0, 3, 6, 6, 10 and 12 d). The coating consisted of mucilage obtained from developing cladodes (15–21 cm), applied by dipping. All treatments were stored at 5 °C. Total soluble solids (TSS), firmness (N) and color (L*, a*, b*, chroma and hue angle) were evaluated at each storage period. Also, 40 untrained judges (47% male and 53% female) evaluated sensory acceptability, consumption intention and acceptance/rejection. The results showed significant effect ($p \leq 0.05$) of package type on firmness, chroma and hue angle. Coating had an effect on L* value and product acceptability. Consumption intention was higher, and was maintained for 10 days, in fruits with coating and packaged in polyethylene bags, stored at 5 °C.

Keywords: Cactus Mucilage; Minimal Processing; Sensory Quality; Rambutan

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1. Introduction

Rambutan (*Nephelium lappaceum* L.), of the Sapindaceae family, has its origins in Malaysia and Indonesia. It was introduced to Mexico in 1959 by the Soconusco region in Chiapas, with seeds from Malaysia. In the Americas, it is cultivated in tropical countries such as Colombia, Ecuador, Honduras, Costa Rica, Trinidad and Tobago, Cuba and Mexico[1].

In Mexico, production is obtained mainly in Chiapas, followed by Tabasco and Nayarit. Nationally, it is estimated that 835.96 ha are planted and a pro-duction of 8,730.27 tons, with a value of more than 10 million pesos. Likewise, it is considered that there are about 50,000 backyard plants and unregistered orchards[2]. Production in Tabasco is mainly located in the municipality of Teapa, where clones from Chiapas have been introduced.

According to the Asociación Hondurea de Productores y exportadores de rambután[3], the fruit contains 82% water. However, it is rich in vitamins and minerals, including vitamin C and other B vitamins, such as folic acid. It has a high potassium content and, to a lesser extent, other minerals such as magnesium. The fruit is rich in carbohydrates and provides an important contribution of fibra.

The fruit is mainly consumed fresh, extracting the pulp and separating the seed; it can also be stewed and used in desserts. In Thailand, it is made in syrup either alone or combined with pia, it is also marketed in juice or the whole fruit frozen[4]. In Mexico, rambutan is mainly marketed fresh, due to its attractive color and shape. However, its good appearance is preserved for a short time, mainly due to dehydration and darkening of the epicarp[5]. García-Gurría *et al*.[6] observed that weight loss was greater than 10% after three days of storage under ambient conditions, which affects the appearance of the product. According to Fiszman[7], lively and uniform fruit colors, as well as fresh appearance, determine fruit acceptability by consumers.

Although the commercial acceptability of rambutan can be quickly affected by its external appearance, García-Gurría *et al*.[6] observed that external deterioration did not affect the internal quality of the fruit, whose internal sensory characteristics were maintained for up to 9 d, depending on the type of packaging. In this sense, it is important to consider conservation alternatives for the fruit beyond its external appearance, with the finality of expanding its areas of use and commercialization. One of these alternatives may be minimal processing.

Minimal fruit processing consists of the application of operations such as washing, sanitizing, peeling, chopping, and the use of partial preservation treatments such as minimal heating, immersion in chlorinated water, use of preservative agents, pH control, UV radiation, packaging in modified atmospheres and refrigeration, which allows to obtain products ready for consumption, and with the sensory and nutritional characteristics of fresh-cut fruits[8].

However, this process also has disadvantages, such as an increase in the speed of biological reactions, which implies a rapid deterioration of desirable physicochemical and sensory characteristics, and a greater speed of undesirable changes, such as microbial growth[9].

One of the first changes observed in minimally processed fruits is the loss of superficial moisture, which causes a dull appearance. In this regard, Cook[10] indicates that appearance is the first attribute perceived by the consumer, and is directly associated with the freshness of the product, thus directly influencing the purchase decision. Likewise, González *et al*.[9] observed that the attributes with the greatest changes in minimally processed rambutan are freshness, aroma and appearance. In this sense, an alternative to reduce the loss of quality can be the application of edible coatings, which, together with appropriate packaging, can help in the preservation of minimally processed fruits. The application of edible films and coatings, both on fresh and minimally processed fruits, has generated advances in the evaluation of their effects on product preservation, in synergy with other treatments[11]. According to Ramos-García *et al*.[12], an edible coating is a continuous and thin matrix, which is structured around the product generally by immersion in the coating-forming solution.

One of the potential products for fruit coating may be nopal (*Opuntia ficus-indica*) mucilage, a complex compound capable of forming molecular networks and strongly retaining large amounts of water. This mucilage is a biopolymer composed of pectin-like polysaccharides, and its rheological characteristics suggest an important potential for use as a raw material in the chemical and food industry[13].

Accordingly, the objective of this study was to evaluate the effect of coating with cactus mucilage on the preservation of minimally processed rambutan stored at 5 °C in two types of packaging.

2. Methodology

The rambutan fruits were harvested at maturity for consumption in the state of Chiapas and transferred to the laboratories of the Centro de Investigación de Ciencias Agropecuarias (CICA) in the División Académica de Ciencias Agropecuarias (DACA) of the UJAT on the same day. The fruits were selected to eliminate damaged fruit and obtain a homogeneous sample.

The fruits for the experiment were sanitized by immersion in chlorinated water at 80 ppm and then excess moisture was removed using a vegetable wringer. The process was carried out using hygienic measures consisting in the use of lab coats, mouth covers, cofia and latex gloves. Also, the work area, containers, surfaces and utensils were sanitized with 200 ppm chlorine solution.

The nopal mucilage used to coat the fruits was obtained from developing cladodes (nopal verdura) of 15 to 21 cm in length, which were manually deboned, washed and then scalded by immersion for 30 s in boiling water. Subsequently, the nopales were cut into julienne strips and crushed in a homemade blender with the addition of the necessary water to carry out the process, the product was liquefied for 4 to 5 minutes and then filtered in a fine mesh strainer.

Table 1. Treatments to be evaluated on minimally processed rambutan stored at 5 °C

Treatment	Time (d)	Factor			
		Coating		Packaging	
		With	No	Bag	Container
1	0	X		X	
2	0	X			X
3	0		X	X	
4	0		X		X
5	3	X		X	
6	3	X			X
7	3		X	X	
8	3		X		X
9	6	X		X	
10	6	X			X
11	6		X	X	
12	6		X		X
13	10	X		X	
14	10	*X*			X
15	10		X	X	
16	10		X		X
17	12	X		X	
18	12	X			X
19	12		X	X	
20	12		X		X

2.1 Processing and application of treatment

The process consisted of removing the epicarp from the fruit, for which a longitudinal cut was made without damaging the pulp and then the epicarp was separated manually to obtain the rest of the fruit (pericarp and seed). The product obtained was separated into two batches, one of which was treated with cactus mucilage by immersion for 2 min, the excess was removed using a homemade centrifuge for vegetables. Then the fruits from each lot were assigned to the different treatments resulting from the combinations of the factors: coating and type of container, as shown in **Table 1**. Thus, the product of each treatment, with or without cactus mucilage coating, was placed in polystyrene containers with lids, previously sanitized, or in Ziploc(MR) polyethylene bags. All treatments were stored at 5 °C during the different established times (**Table 1**).

Samples for sensory evaluation and samples for the evaluation of the physicochemical variables and color change monitoring will be prepared from each of the treatments. A total of 24 containers of different capacity were prepared for each evaluation time: 0, 3, 6, 10 and 12 days.

The physicochemical variables of color, firmness and TSS were determined with 10 replicates, the experimental unit was one fruit. In the affective sensory evaluation, samples of 15–20 g of product were used, served and presented to the judges in polystyrene containers (3 fruits/pack), coded with three-digit random numbers.

The physicochemical changes and sensory acceptability were evaluated on each evaluation date and for each storage period.

2.2 Psychochemical variables

The TSS content was determined using an ATAGO PR-101 digital refractometer, for which a drop of the juice of the cut fruit was placed and the corresponding reading was taken. The hardness was determined as the force (N) required to introduce a conical punch into the fruit pulp, measured using a Chatillon penetrometer equipped with a conical punch of 1.2 mm diameter.

Color was measured with a Minolta Chroma Meter CR-300 colorimeter, using the CIE Lab system. From the coordinates L*, a*, and b*, the derived parameters: chroma (C*) and hue angle (h°) were calculated using Equations (1) and (2).

$$C^* = (a^{*2} + b^{*2})^{1/2} \quad (1)$$

$$h^{\circ} = arctg \frac{b^*}{a^*} \quad (2)$$

Where: C^* = chroma; a^* = color coordinate a^*; b^* = color coordinate b^*; $h°$ = hue angle.

2.3 Sensory evaluation

The sensory evaluation was carried out by means of an affective test, with 40 untrained judges (47% men and 53% women) who evaluated the overall acceptability of the product, using a nine-point hedonic scale. In addition, the intention to consume and the acceptance/rejection of the samples for the different storage times were determined.

2.4 Statistical analysis

The data obtained for the physicochemical variables were analyzed by t-student test for independent samples for the effects of package type and coating application, and by ANOVA for a completely randomized design, to determine significant differences due to the effect of storage time. Likewise, a Tukey test was performed to identificate differences between treatments. In all cases the tests will be performed with a confidence degree of 95% (α = 0.05). The analyses were performed with STATGRAPHICS Plus Statistical Software. The data of sensory changes were analyzed using descriptive statistics to determine the differences in the acceptability of the treatments and to obtain the percentages of acceptance and rejection of the product in each storage period.

3. Results

3.1 Physicochemical changes

The results indicated that TSS content was significantly influenced only by storage time. In this regard, although values were slightly higher, and decreased more gradually in coated fruit, these differences were not statistically significant ($p \geq 0.05$) (**Figure 1A**).

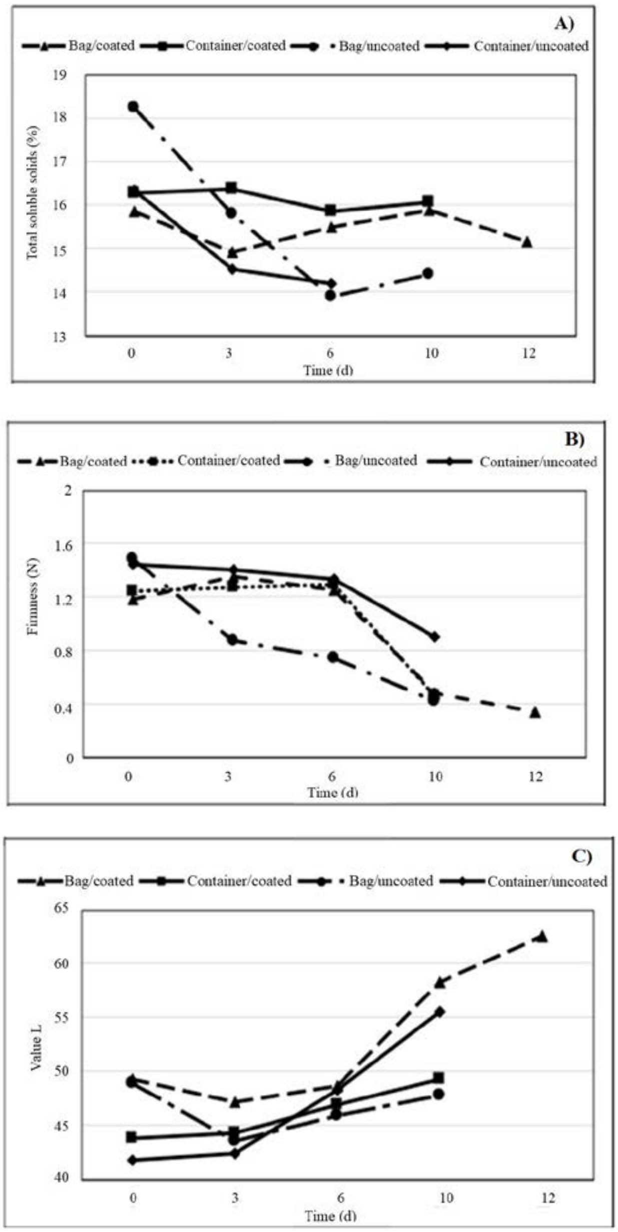

Figure 1. Changes in total soluble solids (%) (A), firmness (N) (B) and L* value (C), in minimally processed rambutan, with or without edible coating, packaged in PE bag or PP tray and stored at 5 °C for 0, 3, 6, 10, 12 days.

Regarding the firmness, this was significantly ($p \leq 0.05$) affected by the type of packaging, the values were lower in fruits packed in bags, with respect to those packed in containers. Likewise, firmness decreased significatively ($p \leq 0.05$), with storage time in all treatments. On firmness, coating had no significant effect ($p \geq 0.05$) (**Figure 1B**).

In the case of the L value, this variable was significantly ($p \leq 0.05$) affected by the different factors evaluated. Regarding packaging, significantly higher values ($p \leq 0.05$) were observed in fruits packed in bags, with respect to those packed in containers. Likewise, L values were significantly higher ($p \leq 0.05$) in coated fruits than in those that did not receive such treatment. As storage time increased, L values increased gradually, being consistently higher in coated fruit throughout the evaluation time (**Figure 1C**).

In this regard, Quintero *et al*.[11] indicate that coatings generate a modified atmosphere that influences the transfer of solutes, solvents and gases between the product and the environment; substances can also migrate from the matrix, formed by the coating on the surface, to the product, with positive effects such as the reduction of microbial growth or the preservation of desirable characteristics such as the brightness and color of the fruit. Likewise, these authors indicate that the use of biomaterials is desirable, which increases the benefits for the consumer.

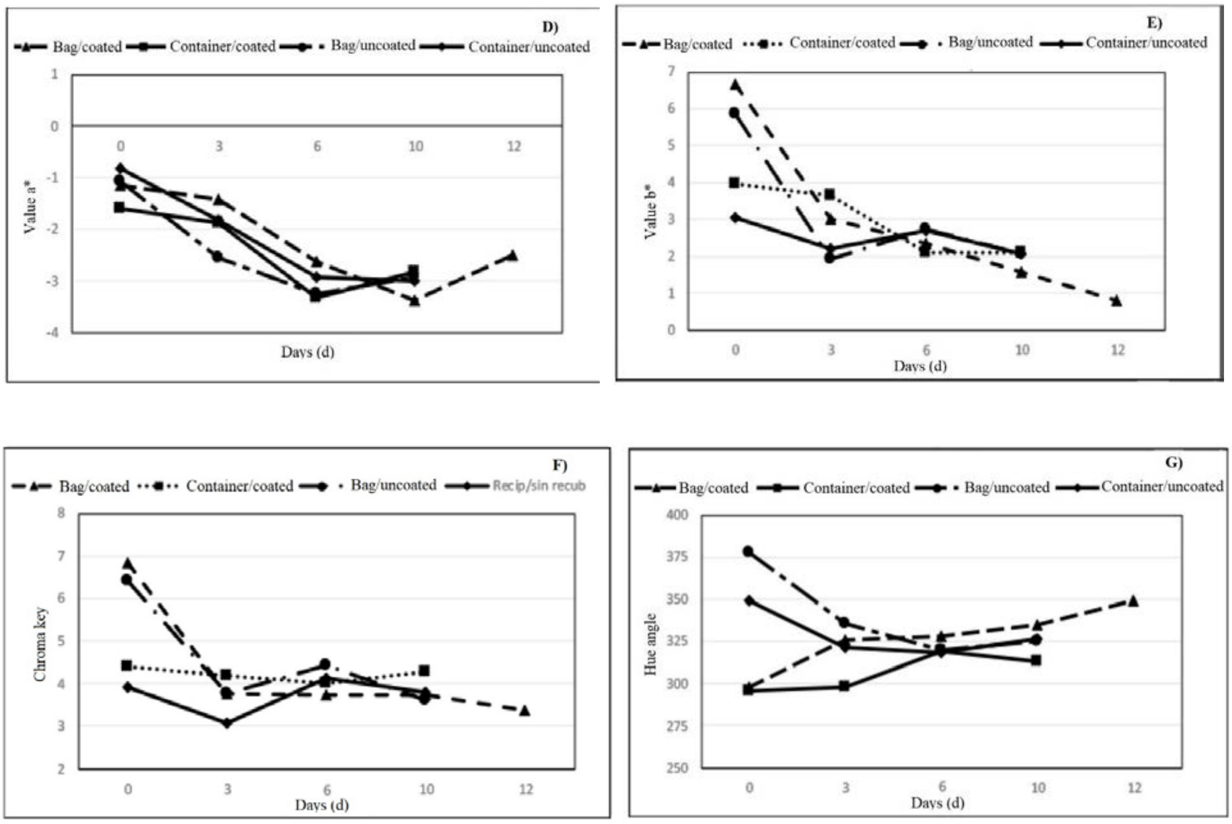

Figure 2. Changes in a* value (D), b* value (E), chroma (F) and hue angle (G), in minimally processed rambutan, with or without edible coating, packaged in PE bag or PP tray and stored at 5 °C for 0, 3, 6, 10, 12 days.

In the case of a* and b* values of the color, only a significant effect ($p \leq 0.05$) of storage time was observed, i.e., no significant effect ($p \geq 0.05$) of packaging or coating on the behavior of these variables was observed (**Figure 2D** and **Figure 2E**). However, if a significant effect ($p \leq 0.05$) of the type of packaging on chroma and hue was observed, both variables had higher values in fruits packed in bags, with respect to those placed in containers (**Figure 2F** and **Figure 2G**).

In the case of mucilage coating, this factor had no significant effect ($p \geq 0.05$) on *a, b* and chroma, but it did have a highly significant effect ($p \leq 0.01$) on hue angle, whose values were higher in uncoated fruit.

As for storage time, it had a highly significant effect ($p \leq 0.01$) on a*, b* and chroma values, with the exception of hue angle. The values of these variables decreased with time, in all cases. However, slightly higher values were observed in the coated fruits over storage time, which were statistically significant ($p \leq 0.05$).

In the case of hue angle, values tended to decrease in uncoated fruit over time, while in mucilaginous coated fruit, values showed a slight increase over time. It should be emphasized that changes in hue angle were not significant ($p \geq 0.05$) due to the storage time factor, indicating that the evolution of this variable showed similar changes in all treatments throughout the experiment (**Figure 2G**).

Regarding the effect of the coating on fruit color, Del-Valle *et al*.[14] observed that cactus mucilage applied to strawberry (*Fragaria ananassa*) maintained the texture and color of the fruit. It should be noted that in the case of rambutan the colored pigments are found in the epicarp, which was eliminated in the process, so in this case the changes are more related to the general appearance in relevance to the translucency, brightness or opacity of the fruit pulp.

In this regard, Biquet and Labuza[15] indicated that the coating helps to improve the appearance of the product, which, in this case, is more directly related to the L* value or luminosity of the product surface and is determined by the amount of light it reflects.

3.2 Sensory changes

Changes in sensory acceptability were evident on the third day of storage, while the scores for the coated fruits maintained above 6.0 and 7.0, in the polyethylene bag and polystyrene container samples, respectively, uncoated and container fruit had acceptability of 5.0, and bagged fruit barely exceeded values of 3.0 (**Figure 3H**).

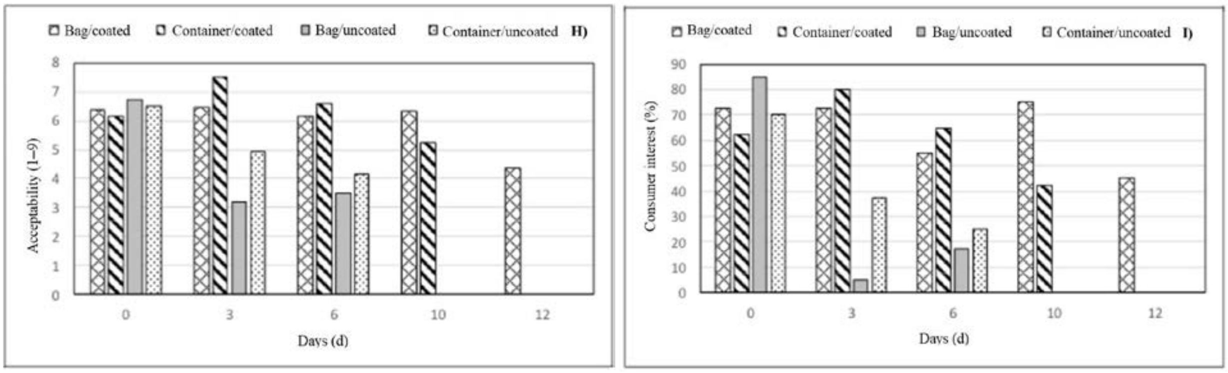

Figure 3. Changes in sensory acceptability (1–9) and consumption intention (%), as assessed by consumers, in minimally processed rambutan, with or without edible coating, packaged in PE bag or PP tray and stored at 5 °C for 0, 3, 6, 10, 12 days.

This trend continued on the sixth day, with decreasing acceptability of uncoated and containerized fruit, while the fruits with coating remained values higher than 6.0 in both containers. After 10 days of storage, the uncoated samples were no longer evaluated due to excessive deterioration. On this date, the bagged and coated samples had values above 6.0, while the bagged fruits barely exceeded 5.0. After 12 days, only the coated and bagged fruit were evaluated, and the scores were barely higher than 4.0, corresponding to slightly disliked (**Figure 3H**).

The low sensory acceptability of uncoated rambutan could be related to the changes in freshness, aroma and appearance reported by Gonzalez *et al*.[9] in minimally processed rambutan, along with the development of off-flavors and odors.

Consumption intention followed a behavior similar to that observed for product acceptability. At the beginning, consumption intention was close to 70% and higher than 80% in the case of uncoated fruit packaged in polyethylene bags. However, on the third day, this treatment obtained a consumption intention close to 5%, while the product in rigid packaging was close to 40%. In contrast, the coated fruit packaged in bags obtained a consumption intention slightly higher than 70% and up to 80% for those packaged in containers (**Figure 3I**).

After 10 days, both uncoated treatments reached consumption intentions close to 20%, while the coated fruit remained values close to 60%. On the tenth day, only the coated fruit were evaluated due to the deterioration observed in the untreated fruit. The values obtained were close to 80% in the case of the product packed in polyethylene bags and just over 40% in the case of fruit packed in polypropylene containers. Finally, on the twelfth day, only the bagged fruit were evaluated and obtained a consumption intention of less than 50% (**Figure 3I**).

The results obtained in the consumption intention are the counterpart of the percentage of rejection shown in **Figure 4** which shows how the percentage of consumer judges who reject the product of the different treatments increases as a function of storage time. In this sense, it is observed that the fruits with coating application and packed in bags, close to 25% after 10 days of storage, and exceeded the rejection percentage of 50% up to 12 days of storage (**Figure 4**).

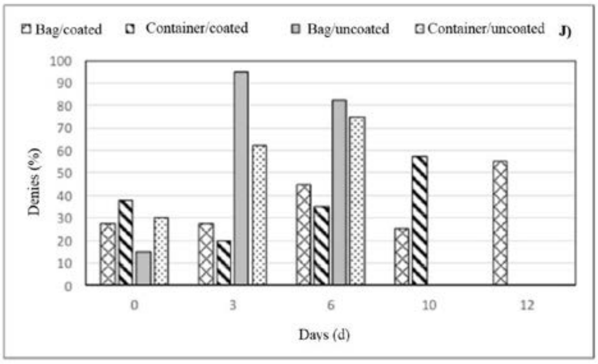

Figure 4. Changes in rejection (%), as assessed by consumers, in minimally processed rambutan, with or without edible coating, packaged in PE bag or PP tray and stored at 5 °C for 0, 3, 6, 10, 12 days.

In this regard, Liu *et al*.[16] indicate that edible coatings, in addition to contributing their properties to preserve the product, must be organoleptically compatible with the fruit. In other words, they should not interfere with or alter desirable properties such as odor or flavor. In this sense, the results obtained indicate that the application of the cactus mucilage-based coating allowed preserving the product without affecting its organoleptic characteristics, which could be reflected as low acceptability of the product by consumers.

These results indicate that, although the shelf life of rambutan is only three to four days for fresh marketing, this marketing margin can be up to 10 days as a minimally processed product, packaged in the appropriate material and with adjuvant treatments that complement the effect of refrigeration to preserve the product. It should be noted that rambutan is an exotic, novel and excellent tasting product, which could favor its introduction in markets eager for new proposals.

On the other hand, Ponce *et al*.[17], indicate that consumers demand that fresh and minimally processed products be free of synthetic chemical substances and look for those containing substances of natural origin, which provide health benefits and maintain the nutritional characteristics and sensory attributes of foods. In this way, the trend is inclined towards the search for substances of natural origin as adjuvants for food preservation, which opens the possibilities for functional natural products such as nopal mucilage.

4. Conclusion

Coating with cactus mucilage favored higher L* values and greater sensory acceptability of rambutan, regardless of the type of packaging. Likewise, the consumption intention was higher, and was maintained for up to 10 days, in the coated fruits packaged in polyethylene bags, stored at 5 ℃.

Conflict of interest

The authors declare that they have no conflict of interest.

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