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Posharvest Characteristics and Preservation of Pulp of Curuba (*Passiflora mollissima*)

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Curuba (*Passiflora mollissima*) is a tropical fruit which is considered exotic, highly perishable and susceptible to post-harvest losses. In this research, the physical, physiological and physico-chemical characteristics of this fresh fruit from the municipality of Sonsón, Antioquia, Colombia, were evaluated. After the pulp was obtained, the following conservation treatments were applied: sucrose addition, heat treatment, chemical treatment, and control. The characteristics of pH, acidity, °Brix, color, and browning and sensory indexes for days zero, five, ten and fifteen were evaluated. It was possible to conclude that the best preservation treatments in terms of sensory characteristics of the curuba pulp were the thermal treatment and the sucrose addition and the treatment with sucrosa was the one that presented the most appropriate acidity, while the chemical and thermal treatments did not present a significant difference with respect to the control, also the treatment that least affected the color of the curuba pulp was the thermal treatment.

1. Introduction

Curuba (*Passiflora mollissima*) is a typical fruit of cold zones which grows well between 2,000 and 3,000 meters above sea level, with temperatures of 8 °C to 16 °C, and is mainly produced in the mountains of Colombia and Venezuela. It possesses high levels of vitamins and minerals. Due to its pleasant flavor it offers the possibility of being used in juices, nectars, concentrates, jams and liqueurs. It is rich in calcium, phosphorus, iron, and vitamins A, B1, B2, B3 and C. Like passion fruit, it belongs to the family of pasifloras, so it has sedative properties, and is recommended to combat insomnia and nervous system problems (FAO, 2003).

It is a berry of ellipsoidal form of 7 to 10 cm of length, of green color when it is immature and completely yellow when mature. The pulp is firm, fleshy, juicy and with small black seeds. Its flavor is exotic, soft, pleasant, perfumed, somewhat acid and astringent (Rojano, 2013).

Some researchers have studied the properties of curuba and have found that this fruit is rich in flavonoids, especially C-glycosyl, among other compounds, which is why sedative and tranquilizing properties are attributed to it (Zucolotto et al. 2012).

The β-D-glucopyranoside and 6-O-α-L-rhamnopyranosyl-β-D-glucopyranoside of methyl salicylate and the β-D-glucopyranoside of eugenol have been characterized in purple passion fruit (*Passiflora edulis* SIMS) and (*Passiflora mollissima*) (Chassagne et al. 1997).

Also researchers have identified linalool, hexyl acetate, 1,8-cineole, and butyl acetate as key aroma compounds of this fruit. Other odorants relevant because of their contribution to the overall aroma were: 2-methylpropyl acetate, (Z)-3-hexen-1-ol, and (*Z*)-3-hexenyl acetate. Sulphur compounds, 3-sulfanylhexyl acetate and methional, were reported here for first time as odour-active volatiles in curuba (Conde et al. 2014).

In addition, several studies have found that curuba has great antioxidant potential because of its high content of flavonoids and tannins, which are its main secondary antioxidant metabolites (Zapata et al. 2015; Rojano et al. 2012). Other researchers have studied 24 exotic fruits in Colombia, of which the curuba is one of the fruits that present the greatest amount of antioxidant capacity, especially for its high content of phenolic compounds and Vitamin C. Some researchers have studied 68 species of tropical fruits; among them the curuba was studied to evaluate macrominerals and microminerals. It was found that this fruit contains many of them, of

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which the most abundant macromineral is potassium and the most abundant micromineral is iron (Contreras et al. 2011; Leterme et al. 2006).
Other researchers have reported improvements in the physical characteristics of the pulp of *Passiflora* sp. with the addition of hydrocolloids such as getatin, pectin and alginates (Moreira et al. 2011).
In Colombia there is a shortage of technologies that allow the fruit and pulp to be conserved for a long time in optimum conditions. This is necessary to help the producer or marketer to have greater possibilities to generate income from being able to commercialize the fruit and its derivatives in the national and international markets, since the demand for curuba abroad has been growing. The fruit pulp can be considered a product that allows the preservation of the fruit with all its properties for a longer time than the intact fruit (Camacho and Romero, 1996).
The objective of the present research was to evaluate the main postharvest characteristics of curuba in the state of maturity of consumption and to obtain the pulp to apply thermal, chemical and sucrose addition conservation methods to evaluate some response variables in fifteen days of storage in refrigeration.

2. Materials and methods

Vegetal material. The curuba used in the study came from orchards located in the Municipality of Sonsón, Department of Antioquia, Colombia, located at coordinates 5°42'34"N and 75°18'38"W; with 2,365 mm of average annual precipitation, at an altitude of 2,475 m above sea level, and with an average temperature of 14.5 °C. The fruits were processed in consumption maturity, which was reached six days after the harvest. The experiment was carried out in the laboratory of fruits and vegetables of the National University of Colombia in the city of Medellin.
The main physical, physicochemical and physiological characteristics were evaluated for fresh curuba at maturity of consumption corresponding to day six of postharvest.

Characteristics of fresh fruit. The physical characteristics that were evaluated for fruits at maturity of consumption were fruit size, weight and percentage of yield in pulp, peel and seeds. The gravimetric method was applied to determine the amount of pulp, peel, and seeds and the results were expressed in percentage. An Ohaus digital analytical balance model AV-3102 was used (Camacho and Romero, 1996).

Physico-chemical characteristics. Total soluble solids (°Brix), total acidity (%) and pH. The determination of the total soluble solids was performed by the refractometric method, using a Leica auto ABBE equipment with 0-32 % scale at 23 °C and the results were expressed as (°Brix). The acidity was obtained by potentiometric titration with base acid reaction and the results were expressed in (% citric acid). The spent NaOH was counted and the conversion was performed, taking into account the gram equivalents of citric acid, as the most representative acid in the curuba composition (Eq.(1)). A Schott potentiometer model CG-840B was used.

Acidity = (mL NaOH spent x Normal NaOH x equivalent g)/(sample weight)*100 (1)

The pH was determined with a Schott potentiometer model CG-840B and the maturity index was calculated, expressed as °Brix on the percentage of acidity (Bernal de Ramírez, 1993).

Measurement of respiration rate. The respiration rate was determined by adaptation of the Petenkoffer chemical method, in which the sample was weighed and placed in a sealed vessel. The CO_2 product of respiration was driven to a base (NaOH O.1 N), neutralizing part of it. By difference of concentrations, the equivalents of carbonic acid (H_2CO_3) that were formed were calculated by stoichiometry and the amount of CO_2 produced by the fruit during 1 hour of experimentation at 23 °C was quantified. The results were expressed in mg of $CO_2 \cdot kg^{-1} \cdot h^{-1}$. Eq.(2 and 3) (Angueira et al. 2003).

$$CO_2 + H_2O \rightarrow H_2CO_3 \quad (2)$$

$$H_2CO_3 + 2\,NaOH \rightarrow Na_2CO_3 + 2H_2O \quad (3)$$

Percentage of physiological weight loss. The physiological weight loss was performed for 10 U.E. The daily weight was evaluated by gravimetry and compared with the initial weight for day 0. The evaluation was performed from day 0 to postharvest day 12 under conditions of 24 °C and 65 % relative humidity. The instrument used was an Ohaus Model Navigator 1121 analytical balance (Márquez, 2016).

Color measurement. An X-Rite sphere spectrophotometer, model SP-60, with an aperture of 4 mm, a D-65 illuminator and a 10° observer were used for the measurement of the color. From the reflection spectra the coordinates CIE-L*a*b* were obtained, where L* is brightness, a* is chromaticity green (-) to red (+) and b* represents chromaticity blue (-) to yellow (+). For each experimental unit, three equatorial measurements were made on the epidermis or peel and were expressed as arithmetic mean. The color parameters L * a * and b * were replaced in equations 3 and 4 to calculate the browning index (Almela et al., 2000).

BI = (x-0.31) / 0.172 x 100 (3)

Where:

X = (a + 1.75 * L) / (5.645 * L + (a-3.012) * b) (4)

Obtaining the pulp. The fruits were selected, washed and disinfected with sodium hypochlorite at 100 ppm; then they were conditioned and processed in a Technologies and Supplies® brand equipment with a 0.5 mm pore size screen (Márquez, 2016).

Pulp conservation treatments. The pulp was obtained and the different conservation treatments were applied: addition of sugar up to 40 °Brix of final concentration in the pulp; chemical additives of 0.125 %; heat treatment consisting of three minutes at 96 °C; and control. Then all treatments were packed in low density polyethylene bags in portions of 100 g each, for a total of 24 bags and 2,400 g per treatment (Márquez, 2016). All treatments were stored at 4 °C and the physicochemical characteristics were evaluated for days 0, 5, 10 and 15: °Brix, pH, acidity, color, browning index and sensory attributes, appearance, aroma, color and taste. Six determinations were performed per treatment per day, 24 samples per day were evaluated and a total of 96 experimental units were evaluated during the 15 days.

Experimental design and statistical analysis. A completely randomized block design with four treatments and six replicates was applied for a total of 24 experimental units per treatment, to evaluate 6 experimental units for each day of experimentation. The statistical analysis consisted in establishing the mean and standard deviation for each of the response variables. The statistical package used was Statgraphics plus.

3. Results and discussion

Physical characteristics of fresh curuba fruit at day six of postharvest. Fruit weight, 80 g ± 10 g; size, length, 9 ± 1,5 cm; thickness, 4,5 ± 1,0 cm; color, L* 40 ± 5, a* 11 ± 4 and b* 37 ± 6. For n = 10.

Physical-chemical characteristics for fresh fruit pulp at day six of post-harvest. °Brix, 12 ± 2; pH, 3.7 ± 0.3; acidity, 1.2 ± 0.2 (%); maturity index, 10. For n = 10.

Physiological characteristics (rate of respiration and weight loss). The respiration rate for the fruit at the maturity of consumption was 65 mg/kg-h ± 15, and the weight loss was 17 ± 3 % at 24 °C and 65 % relative humidity, which were the normal conditions of the Fruit and Vegetables Laboratory of the National University of Colombia in the city of Medellín, where the experiment was carried out. Figure 1 shows the physiological loss of weight for curuba fruits.

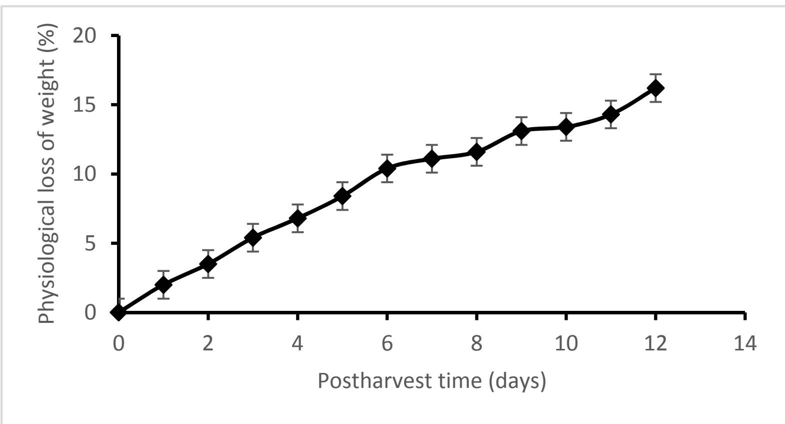

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Figure 1: Behavior of physiological loss of weight in curuba fruits (Passiflora mollisima) stored at average conditions of 24 °C and 65 % RH. The symbols show the mean, and the vertical bars the SD values for n = 12

Characteristics of pH and acidity of pulps in conservation. It can be established that for the storage days the pulps had a very similar behavior. The control pulp had an increase in the acidity correlated with the drop in pH, more marked than the other pulps analyzed. The pulps with chemical thermal and sweetening treatments had a slight decrease in pH correlated with a slight increase in acidity, but remained very stable during the time of evaluation. Figure 2 shows the acidity for the treatments and the control.

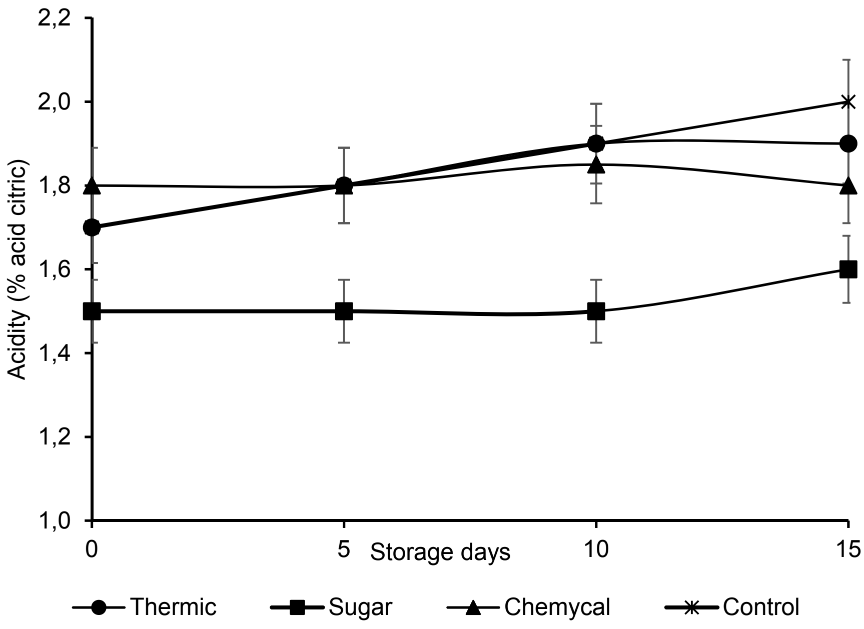

Figure 2: Acidity for the three treatments and the control

The results show a pH that varies between 3.3 and 3.5 throughout the evaluation period for the control pulp and the pulp with chemical treatment, coinciding with the values reported by other researchers. The trend presented by the pulp of curuba for all treatments varied between 12 and 2, similar to the limits established by Landírez et al. (2011).

Soluble solids. The soluble solids of the curuba pulp with control treatment were similar to the ones with chemical treatment and heat treatment. During the storage time the soluble solids of all the treatments remained stable, since the changes were minimal; in some analyzes the standard deviation was zero.

The trend of soluble solids observed during the research shows values above 10 °Brix for all treatments, which are higher than the range established by other researchers. However, the treatment sweetened at 40 °Brix also remained constant (Landírez et al*.* 2011).

Browning index. The browning index for the control and chemical treatments was very similar. Since the first evaluations those two treatments showed greater affection of the pulps, whereas the thermal and the sweetness treatments presented better characteristics for the pulp. This is probably due to the heat treatment that may have denatured them and to the action of sucrose, which compromises some substrates necessary for the enzymatic activity (Márquez et al*.* 2009; Fennema, 1993), most probably due to the inhibition of the enzymatic activity of polyphenoloxidase enzymes. The average values obtained for the browning index were between 32 and 44, with the heat treatment having the lowest browning index. Figure 3 shows the result for the browning index.

Sensory analysis. The results of the sensory evaluation can be seen in Table 1. They allowed to establish that the best characteristics were presented by the heat and the sweetening treatments, whereas the control treatment presented the most inappropriate characteristics for consumption after 15 days of storage. As the storage time increases, the scores assigned to the treatments decrease, but these were favorable for all treatments during the 15 days of storage with the exception of the control.

Table 1: Mean of sensory analysis for treatments for days 0, 5, 10 and 15 of storage, for 15 judges

Treatments	Day 0	Day 5	Day 10	Day 15
Control	9.0	8.5	7.5	5.0
Thermic	9.0	9.0	8.0	7.5
Chemical	8.6	8.4	8.2	7.0
Sugar	9.0	8.0	8.0	7.5

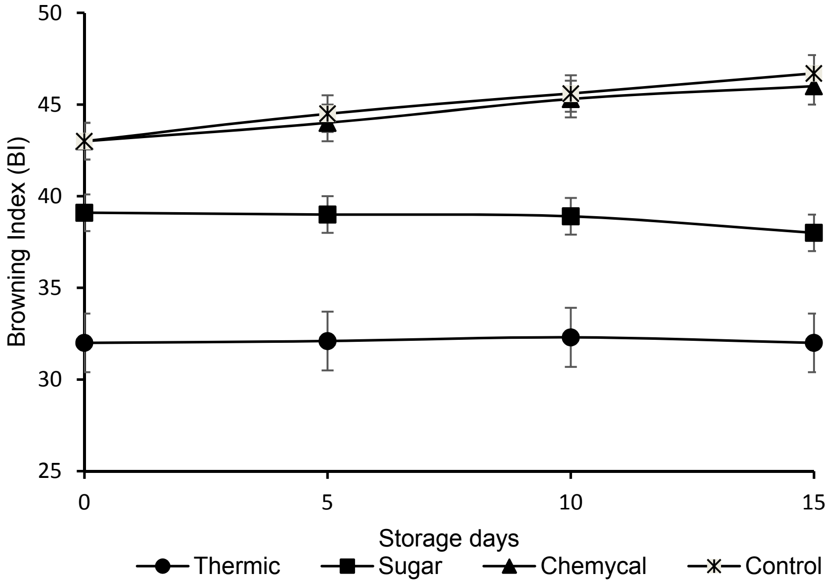

Figure 3: Browning index for the three treatments and the control

4. Conclusions

The thermal and sweetening treatments allowed to preserve the sensory characteristics of the pulp of curuba during fifteen days of storage at refrigeration temperature. The treatment that least affected the color of the curuba pulp was the thermal treatment.
The treatment with sugar was the one that presented the most appropriate acidity, while the chemical and thermal treatments did not present a significant difference with respect to the control.

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