





# Effect of storage time on the physicochemical characteristics of apple paste

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## ABSTRACT

**Objective:** To produce apple paste (ate) and evaluate its acceptance and physicochemical changes during storage.

**Design/Methodology/Approach:** Golden Delicious apples were processed to obtain the apple paste. The product was molded, cooled, cut, packaged, and stored at room temperature. A sensory analysis was conducted with 29 panelists to assess consumer acceptance.

**Results:** Soluble solids, titratable acidity, moisture content, texture, and color were measured at time 0 and after 1, 2, and 3 months. The apple paste maintained its quality after 3 months of storage, received no negative feedback, and achieved 89.65% acceptance.

**Findings/Conclusions:** To maximize the apple harvest in the state of Chihuahua, it is essential to raise awareness of the importance of adding value to apples through the production of paste.

**Keywords:** Apple, paste, storage, shelf life, sensory analysis.

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## INTRODUCTION

The state of Chihuahua is the leading apple producer in Mexico, with a production of 624,696 tons (SIAP, 2020). The apple-growing region in Chihuahua includes the municipalities of Cuauhtémoc, Álvaro Obregón, Bachíniva, Guerrero, La Junta, and Namiquipa, which account for the highest apple production (Arredondo Bustillos *et al.*, 2021; Ramírez Legarreta *et al.*, 2011). Apple commercialization is mainly in fresh form, and its distribution is primarily domestic.

During apple production, losses of up to 25% are estimated due to pre- and postharvest handling and storage conditions. When apples do not meet quality standards —because they are overripe or show mechanical damage (caused by insects or hail)— they are classified as cull fruit, which is allocated to the agroindustry at low cost and, in some cases, discarded because transportation and redistribution are not economically viable (FAO, 2011). This fruit can be utilized through processing to obtain high-quality, nutritious, and safe products.

Added value in the agricultural sector consists of transforming raw materials into products with higher commercial value while maintaining quality and extending shelf life (Moctezuma López *et al.*, 2011). Apples are highly versatile fruits, making them suitable for a wide range of processes and products. One simple, profitable, and easy-to-implement alternative is the production of apple paste (ate in Spanish), a traditional sweet highly valued in national and regional markets. Ate is a fruit paste prepared by cooking fruit pulp with sugar until a thick mass is obtained, which solidifies upon cooling (Medellín-Cruz *et al.*, 2019). The desired consistency of apple paste is achieved due to the high pectin content naturally present in the fruit. When fruit pulp is combined with sugar and heated, pectin forms a three-dimensional gel network, resulting in a thick and firm texture (Said *et al.*, 2023). Apple paste is a microbiologically stable product because sugar acts as a preservative; by dissolving in the water present in the fruit, it reduces the amount of free water available for microorganisms. This hinders the growth of bacteria, yeasts, and molds, which require water to proliferate (Jay *et al.*, 2005; Jakubczyk *et al.*, 2021). Ate or fruit paste is mainly produced with fruits such as guava and quince; however, apples have the desired characteristics to serve as raw material for the production of this sweet. Nevertheless, little information is available on apple paste and its properties, which may be influenced by storage time. Therefore, the aim of this study was to produce apple paste, evaluating its acceptance and the effect of storage on its physicochemical properties.

## **MATERIALS AND METHODS**

### **Raw material**

Golden Delicious apples were used, obtained directly from an orchard in the Cuauhtémoc region, Chihuahua.

### **Study area**

This study was conducted at the Faculty of Agrotechnological Sciences, Cuauhtémoc campus, in collaboration with the Technological Institute of Cd. Cuauhtémoc.

### **Apple processing**

The process began with the cleaning and disinfection of equipment, utensils, and the production area. Apples were disinfected using sodium hypochlorite (10 ppm) and then transferred to the sorting table, where pieces unsuitable for consumption were discarded. The chopped apples were weighed, crushed, and processed in a semi-industrial pulper to obtain apple puree, which was stored in 20-kg barrels at  $-18\text{ }^{\circ}\text{C}$ . Once the apple puree was obtained, the production of apple paste proceeded.

### **Apple paste production**

Approximately 40 kg of apple puree were poured into a semi-industrial kettle with an automatic stirrer and heated with steam. The puree was heated for 30 minutes, after which 22.5% sugar was added. Following one hour of stirring, 0.5% pectin and 0.1% citric acid were incorporated. The apple puree reached a temperature of  $90\text{ }^{\circ}\text{C}$ , sufficient to eliminate pathogenic bacteria. During the cooking process, soluble solids were continuously

monitored using a refractometer until a value of 68 °Bx was reached. Once the desired point was achieved, the mixture was poured into trays and allowed to rest for 24 hours. After this period, the product was unmolded, cut, packaged, weighed, and labeled, and subsequently stored in a cool, dry environment at room temperature. Some images of the process and the final product are shown in Figure 1.

### Yield determination

The yield of apple paste was calculated as the ratio between the weight of the finished product and the weight of the raw material, according to Equation 1:

$$Yield(\%) = \frac{(\text{Weight of final product})}{(\text{Weight of raw material})} \times 100 \quad (1)$$

### Sensory evaluation

An affective sensory test was conducted to assess the acceptance of apple paste. Affective tests allow researchers to determine whether consumers accept a product for consumption, would purchase it, or how much they like it (Severiano-Pérez, 2019). The evaluation was performed using freshly prepared apple paste in the sensory analysis laboratory of the Technological Institute of Cd. Cuauhtémoc, following the guidelines established for this type of test. The analysis was carried out by a panel of 29 young consumers, both men and women (aged 18-20), without prior training, who evaluated the paste according to their level of liking. A 5-point hedonic scale was used, with the levels of liking shown in Table 1.



Figure 1. Images of the apple paste production process.

**Table 1.** Hedonic scale used for the sensory analysis of apple ate.

| 1                 | 2                  | 3                        | 4               | 5              |
|-------------------|--------------------|--------------------------|-----------------|----------------|
| Dislike very much | Dislike moderately | Neither like nor dislike | Like moderately | Like very much |

Moisture content of the samples was determined using the AOAC method 934.06. Acidity, expressed as citric acid, was determined by titration with NaOH according to the method reported by Salvatori *et al.* (1998). Total soluble solids were analyzed using a digital refractometer (Atago, USA). Texture was measured using a Brookfield Texture Analyzer, model CT3, with a 7 mm diameter flat metal probe, via direct reading. Firmness was expressed in Newtons. For color, CIELab parameters ( $L^*$ ,  $a^*$ , and  $b^*$ ) were determined to calculate the color difference ( $\Delta E$ ) using a Minolta CR-400 colorimeter and Equation 2,

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

where:  $\Delta L^* = L^*$  sample  $- L^*$  control,  $\Delta a^* = a^*$  sample  $- a^*$  control, and  $\Delta b^* = b^*$  sample  $- b^*$  control.

All measurements were carried out in triplicate, and the results are presented as mean values.

### Statistical analysis

Analysis of variance (ANOVA) and Tukey's test were performed at a 95% confidence level to identify significant differences between treatments, using Minitab 19 software (Statistical Software, USA).

## RESULTS AND DISCUSSION

### Yield

Figure 1 shows the apple paste obtained, which exhibited a firm and homogeneous consistency with amber hues characteristic of the cooking process. These features are similar to commercial quince and guava products. Although it is possible to clarify the color using chemical additives, this study opted for producing a more natural product, avoiding excessive use of acidulants and synthetic colorants. A yield of 55% was obtained, due to weight loss during the cooking process from water evaporation. In addition, the pulping process, which allows partial removal of the peel and seeds, also contributes to reduced yield. The value obtained falls within the range reported for fruit pastes (Kader, 2002).

### Physicochemical properties of apple paste

The physicochemical parameters of freshly prepared apple paste and at different storage times are shown in Table 1. No significant differences were observed in total soluble solids, indicating that the sweetness of the paste remains constant during storage. The soluble

solids values are similar to those reported for pastes made from other fruits, as reaching 67 °Bx is a process requirement to achieve the desired consistency. Acidity showed only minimal changes, suggesting that the product's acidic taste is also preserved. The acidity values (~1%) are slightly lower than those reported for quince past (Najman *et al.*, 2023). The results obtained for total soluble solids and titratable acidity are consistent with those reported by Haroon *et al.* (2024) for apple jam.

The texture of the paste increased during storage, which could be related to moisture loss processes, as observed by Pérez-López *et al.* (2016) in processed fruit products. This result is consistent with a 10% decrease in moisture content of the samples (Table 2), which likely contributed to the increase in product firmness. Lower moisture content implies a reduction in water activity, decreasing the likelihood of microbial growth and consequently extending the shelf life of apple paste (Jakubczyk *et al.*, 2021). Color changes in the paste became more pronounced from the second month and intensified during the third month, which could be attributed to oxidation or non-enzymatic browning reactions, common in sugar-rich foods (Lyu *et al.*, 2018). However, the characteristic amber-brown color remained appreciable in the product. The shelf life of apple paste produced without preservatives can extend up to three months or more; however, it is essential to evaluate its physicochemical, microbiological, and sensory characteristics after this period to ensure safety and quality.

### Sensory analysis

Figure 2 shows images of the sensory analysis laboratory where the evaluation of freshly prepared apple paste was conducted. The images illustrate the process from sample preparation to the individual booths used by panelists to perform the sensory tests.

The results of the sensory analysis carried out with a panel of 29 participants are presented in Figure 3. A 5-point hedonic scale was used, ranging from “dislike very much” to “like very much.”

The results indicate a high sensory acceptance of apple paste, with 26 out of 29 panelists expressing liking for the product: 14 reported “like very much” and 12 “like moderately.” Only 3 participants remained neutral (“neither like nor dislike”), and none expressed dislike. This absence of negative responses suggests that the formulation is sensory balanced, which is consistent with the findings of Mesías *et al.* (2021), who observed that more natural products tend to achieve higher acceptance. Overall, apple paste demonstrated a

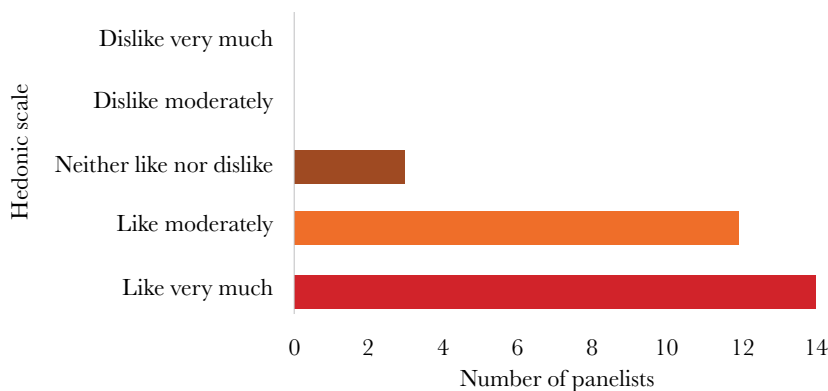
**Table 2.** Physicochemical properties of apple paste at different storage times.

| Parameters             | Storage time (months)     |                          |                          |                           |
|------------------------|---------------------------|--------------------------|--------------------------|---------------------------|
|                        | 0                         | 1                        | 2                        | 3                         |
| Soluble solids (°Bx)   | 67.36 <sup>a</sup> ±0.70  | 67.13 <sup>a</sup> ±0.90 | 69.96 <sup>a</sup> ±0.25 | 67.00 <sup>a</sup> ±0.80  |
| Titratable acidity (%) | 1.00 <sup>abc</sup> ±0.03 | 0.80 <sup>ab</sup> ±0.14 | 1.07 <sup>ac</sup> ±0.02 | 0.96 <sup>abc</sup> ±0.01 |
| Moisture content (%)   | 39.29 <sup>a</sup> ±1.00  | 39.27 <sup>a</sup> ±1.85 | 35.47 <sup>b</sup> ±0.86 | 35.77 <sup>b</sup> ±0.64  |
| Firmness (N)           | 4.77 <sup>a</sup> ±0.11   | 5.81 <sup>a</sup> ±0.15  | 8.54 <sup>b</sup> ±0.61  | 10.33 <sup>c</sup> ±1.42  |
| Color difference (ΔE)  | --                        | 0.751 <sup>a</sup>       | 3.179 <sup>b</sup>       | 4.088 <sup>c</sup>        |

Different letters indicate significant differences ( $p \leq 0.05$ ) in the parameters with respect to storage time (Degrees of freedom: treatments=3, groups=8).



**Figure 2.** Images of the sensory analysis conducted on apple paste



**Figure 3.** Results of the sensory evaluation of apple paste using a hedonic scale

favorable sensory profile, with potential for market acceptance, particularly among young consumers.

### CONCLUSIONS

Apple paste was obtained with flavor, color, and texture characteristics that met the expectations of 89.65% of the panelists, with no negative evaluations, reinforcing the quality of the product. Apple paste retained its flavor characteristics during three months of storage, while texture, moisture content, and color showed minimal changes that did not affect product quality. The processing of apples to produce paste resulted in a yield of 55%, making it a viable alternative to add value to apples that do not meet commercial quality

standards. This strategy not only contributes to the reduction of postharvest losses but also represents an opportunity for the development of productive and entrepreneurial projects in rural communities, promoting the full utilization of local resources.

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