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ORIGINAL ARTICLE

Use of sweeteners in the preparation of a prickly pear (*Opuntia ficus-indica*) based preserve

Utilización de edulcorantes en la elaboración de una conserva en base de tuna (*Opuntia ficus-indica*)

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Abstract This article presents a research study on the preparation and analysis of tuna preserves using three types of sweeteners: white sugar, panela, and brown sugar. The study, carried out at the Escuela Superior Politécnica de Chimborazo, spanned six months. During this period, analyses of pH, soluble solids, and sensory preferences of the products were conducted. The results showed that white sugar was the preferred sweetener, followed by panela, while brown sugar was the least accepted. Regarding microbiological stability, white sugar exhibited lower growth of yeasts and molds than the other sweeteners. These findings highlight the importance of sweetener choice not only in consumer acceptance but also in the shelf life and safety of the product. The research suggests that innovation in the formulation of preserves can contribute to the diversification of healthy and sustainable food products.

Keywords tuna preserves, sweeteners, sensory analysis, pH, microbiological analyses.

Resumen Este artículo presenta una investigación sobre la elaboración y análisis de conservas de tuna utilizando tres tipos de edulcorantes: azúcar blanco, panela y azúcar moreno. La investigación, realizada en la Escuela Superior Politécnica de Chimborazo, duró seis meses. Durante este período, se realizaron análisis de pH, sólidos solubles y preferencia sensorial de los productos obtenidos. Los resultados mostraron que el azúcar blanco fue el edulcorante preferido, seguido por la panela, mientras que el azúcar moreno fue el menos aceptado. En cuanto a la estabilidad microbiológica, el azúcar blanco presentó un menor crecimiento de levaduras y mohos en comparación con los otros edulcorantes. Estos hallazgos destacan la importancia de la elección del edulcorante no solo en la aceptación del consumidor, sino también en la vida útil y seguridad del producto. La investigación sugiere que la innovación en la formulación de conservas puede contribuir a la diversificación de productos alimenticios saludables y sostenibles.

Palabras clave conservas de tuna, edulcorantes, análisis sensorial, pH, análisis microbiológicos.

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PUBLIS EDITORIAL

Introduction

Due to the high availability of industrialized products and fast food, it is essential to promote the consumption of fruits and vegetables among the Ecuadorian population (Villar et al., 2023). Prickly pear is not well known among young people, as evidenced by the 22nd ESPOCH Gastronomic Entrepreneurship Fair in 2023.

A significant portion of the population is constantly seeking innovations in food products, such as light beverages, sweeteners for diabetics, lean meats, organic fruits, and vegetables (Saraiva et al., 2020), products without chemical additives, as well as new raw materials for various traditional preparations.

Moreover, in the local market, products made from prickly pear are difficult to find, and the raw material itself has low availability. This research aims to familiarize the target market with the flavors and colors of this fruit.

The use of three varieties of sweeteners will allow for the preparation of three types of preserves, which will be analyzed in the laboratory under various parameters. The results will help us determine if the raw material used is suitable for developing innovative processed foods that do not require chemical preservatives and are distinct from one another (Saraiva et al., 2020). This search for innovation in the research process involves using lesser-known raw materials and unusual syrups, while also avoiding chemical additives that, although they improve the shelf life and properties of the final product, will not be used in this study.

In terms of preserves, the market mainly offers peaches and pineapples in syrup. However, other products are not necessarily packed in water and sugar solutions, such as tuna in sunflower oil, sardines in tomato sauce, pre-cooked soups and lentils, pickled vegetables and salads (in vinegar), whole or chopped tomatoes in oil, and grains in their cooking liquid, as well as seasonal fruits in their juice. Many of these products contain chemicals that are harmful to health in the long term. Nevertheless, large-scale processing using prickly pear in this way has not yet been observed (Barbaet al., 2017).

Another issue lies in the use of chemical raw materials in the production of processed foods, whose function focuses on preventing and limiting the possible effects of microorganisms in these products, while maintaining their organoleptic and sensory properties (Thakur et al., 2022). However, there is currently a growing interest in organic food and the elimination of these substances. This research aimed to prepare a prickly pear (*Opuntia ficus*-indica) preserve for subsequent analysis.

Materials and methods

The research was conducted at the Escuela Superior Politécnica de Chimborazo (ESPOCH) in the Experimental Kitchen and Microbiology Laboratories over six months. Products were developed, and shelf-life analyses and organoleptic tests were carried out. The study used quantitative and quasi-experimental methodologies, applying evaluation templates to 30 Gastronomy students, considered consumer judges.

The steps to prepare the prickly pear preserve included washing, peeling, and cutting the fruit, measuring the pH, and discarding those that did not meet the required range. The syrup was prepared with sugar, water, and spices. Then, the jars were sterilized, filled with prickly pear and syrup, and hermetically sealed. The preserves were stored at 4 ºC, following good hygiene practices.

The pH of the three varieties of covering liquid was analyzed using a pH meter, and the Brix degrees of the preserve samples were measured with a refractometer. The determination of molds and yeasts was carried out following the NOM-111-SSA1 (1994) standard. To assess shelf life, the formula ($\text{Ln } A = \text{Ln } A_o + kt$) was applied.

Two surveys were conducted with 30 consumer judges. In the first, sample acceptability was evaluated using a hedonic scale, and the results were analyzed with the Infostat program. In the second survey, a preference test was applied, interpreting the results according to the percentage of choices to identify significant differences.

Results and discussion

General analyses were carried out, as well as pH and Brix degree measurements on the three types of prickly pear-based preserves. Table 1 shows the results of the pH analysis of the prepared preserves.

Table 1. Values of pH and soluble solids of prickly pear preserves with different sweeteners

Sweetener	pH	Soluble solids (°Brix)
White sugar	3.0	34.0
Panela	4.0	32.0
Brown sugar	4.0	31.0

The preserve made with white sugar presented a bright yellowish color, characteristic of the raw material used. This refined sweetener not only gave the product an attractive appearance but also provided a pleasant aroma and a sweet flavor that is highly appreciated sensorially.

On the other hand, the preserve made with brown sugar exhibited a dull brown color, the result of using an unrefined sweetener, which allowed it to retain its dark tone. Although its aroma is also pleasant, its flavor is less sweet compared to the other preserves, making it unique in its sensory profile.

Finally, the preserve made with panela had a dark but clear color, derived from the raw material used in its preparation. Unlike the other varieties, its aroma and flavor were more intense, distinguishing it in terms of sensory appreciation.

The table presents the results of the pH and Brix degree analysis of the three types of prickly pear preserves made with different sweeteners: white sugar, panela, and brown sugar. In terms of pH, the preserve made with white sugar showed a value of 3.0, indicating an acidic character, while both panela and brown sugar had a pH of 4.0, placing them in a more neutral range.

The lower pH of the white sugar preserve could be advantageous in terms of preservation (Amit et al., 2017), as a more acidic environment generally inhibits microorganism growth, increasing the product's shelf life. However, this acidity could also alter the sensory profile, affecting its taste and consumer acceptance.

As for the soluble solids, the white sugar preserve also had the highest value of 34 °Brix. This suggests that the syrup in this preserve is denser and sweeter, which could influence its palatability and acceptance. In contrast, the preserves with panela and brown sugar had 32 and 31 °Brix, respectively, indicating a lower soluble solids content and potentially a less sweet taste.

The combination of a low pH and high soluble solids content in the white sugar preserve could offer an attractive sensory profile, but it is crucial to consider that excessive sweetness may not be well received by all consumers (Amit et al., 2017). In contrast, the panela and brown sugar preserves, with a higher pH profile and lower concentration of soluble sugars, may appeal to a segment of consumers who prefer less sweet and more natural products.

Table 2 shows the microbiological results of prickly pear preserves made with white sugar, brown sugar, and panela. As can be seen, the table provides data on mold growth (expressed in Colony Forming Units per gram, CFU/g) in prickly pear preserves made with three types of sweeteners: white sugar, panela, and brown sugar, over 30 days.

Table 2. Microbiological results of prickly pear preserves with different sweeteners

Sweetener	Time (Day)	Molds (CFU/g)	Yeast (CFU/g)
White sugar	0	0	46
	15	3	51
	30	13	52
Panela	0	0	40
	15	8	51
	30	20	62
Brown sugar	0	4	110
	15	10	120
	30	11	191

When analyzing mold behavior in the preserves, it was observed that the preserves made with white sugar showed a gradual increase in mold count over time. On day 15, 3 CFU/g were recorded, and by day 30, the count increased to 13 CFU/g. Although this growth was progressive, it remained relatively low, suggesting that the acidic environment provided by white sugar may have contributed to inhibiting microorganism growth compared to other sweeteners (Mizzi et al., 2020).

On the other hand, the preserves made with panela showed a more concerning growth pattern. From an initial 0 CFU/g, 8 CFU/g were recorded on day 15, and 20 CFU/g on day 30. This indicates that the more neutral pH of panela may be favoring mold growth, posing a greater risk for long-term product preservation.

In the case of the brown sugar preserves, an initial count of 4 CFU/g was observed, which increased to 10 CFU/g at 15 days and stabilized at 11 CFU/g by day 30. Although the growth was moderate, the initial count already suggests that this type of sweetener may be less effective in preventing mold growth compared to white sugar.

The results indicated that the type of sweetener used has a significant impact on the shelf life of prickly pear preserves. White sugar, with a more acidic environment, appears to offer better preservative properties in terms of inhibiting mold growth. In contrast, both panela and brown sugar showed a notable increase in mold growth over time, suggesting that these sweeteners may not be ideal for preserving this product type. These findings highlight the importance of considering both sensory characteristics and preservative properties when selecting a sweetener for preserves (Saraiva et al., 2020).

When analyzing yeast counts (CFU/g) in prickly pear preserves sweetened with different sweeteners over a 30-day period, an increase in yeast counts was observed in all samples, though with significant variations depending on the type of sweetener.

In the case of the product with white sugar, the initial count was 46 CFU/g. Over 15 days, a slight increase to 51 CFU/g was recorded, and by day 30, the count reached 52 CFU/g. This modest increase suggests that white sugar maintained relatively good control over yeast growth compared to other sweeteners.

On the other hand, panela started with a count of 40 CFU/g initially. After 15 days, the count remained the same, but by day 30, a notable increase to 62 CFU/g was observed. This growth indicates that panela, although it initially had a lower yeast count, favored a more significant increase over time, even surpassing white sugar.

In contrast, brown sugar showed markedly different behavior. It started with a high initial count of 110 CFU/g. After 15 days, this value increased to 120 CFU/g, and by day 30, it spiked to 191 CFU/g. This abrupt increase suggests that brown sugar not only favored yeast growth but also did so much more significantly than the other sweeteners, indicating a higher risk of spoilage in preserves made with this type of sweetener.

Susanti et al. (2021) indicated that various types of sweeteners significantly influenced the physical, chemical, and hedonic properties of a red dragon fruit marmalade (RDFM). RDFM prepared with high-fructose syrup exhibited the greatest brightness, while RDFM containing sorbitol showed the highest levels of redness and water activity (a_w). In contrast, RDFM sweetened with honey had the highest yellowness, while the RDFM with sucrose demonstrated the highest total soluble solids, viscosity, and overall hedonic scores, along with the lowest water activity. Therefore, it can be concluded that sucrose is the optimal sweetener for RDFM, as it yielded the highest overall hedonic test scores, making the final product more likely to be accepted compared to those made with other sweeteners. Table 3 shows the microbiological data of the prickly pear preserve with the three sweeteners (white sugar, brown sugar, and panela) for calculating shelf life.

Table 3. Microbiological data for the shelf-life calculation of prickly pear preserves with the three sweeteners

Sweetener	Time (days)	Ln A (Molds)	Ln A (Yeast)
	0	0	3.8286
White sugar	15	1.0986	3.9318
	30	2.5649	3.9512
	0	0.6021	3.6889
Panela	15	2.3026	3.9318
	30	2.3980	4.1271
	0	0	4.7005
Brown sugar	15	2.0794	4.7875
	30	2.9957	5.2523

The following equations correspond to a quantitative analysis of microorganism growth in a product; specifically in the context of determining the growth, constant (K) and calculating the shelf life of the preserves based on mold and yeast growth data.

The equation $\text{Ln } A - \text{Ln } A_o = Kt$ allows for the calculation of the constant K, which describes the microorganism growth rate over time. By isolating K, we get:

$$K=t(\text{Ln } A - \text{Ln } A_o)/t$$

In this case, K has been calculated using the value of Ln A (which represents the natural logarithm of the microorganism count at a specific moment) as 2.5649 and the initial count $\text{Ln } A_o$ as 0, over a time t of 30 days:

$$K=30(2.5649 - 0) = 0.0855$$

This K value indicates the rate at which microorganisms could grow in the product. A higher K value would imply faster growth, which could indicate a shorter shelf life for the product, while a lower value suggests slower growth and, therefore, a possible extension of the shelf life.

The second part of the discussion uses the same equation to calculate the shelf life t of the preserves based on the logarithmic data of the microbial population. By solving for t, we arrive at:

$$t= K(\text{Ln } A – \text{Ln } A_o)/K$$

In this case, by using Ln A = 6.9078 (which could correspond to a maximum logarithmic value allowed for product safety) and the previously calculated K, we have:

$$t= 0.0855(6.9078 - 0) \approx 80.8 \text{ days}$$

This result suggests that, under the observed conditions, the preserve could maintain its organoleptic properties and safety for approximately 80.8 days. This information is valuable as it provides a period for the safe storage and consumption of the product.

Table 3 shows the data on the growth of microorganisms in tuna preserves sweetened with panela and brown sugar measured at different time intervals and represented in terms of Ln A, which is the natural logarithm of the colony-forming units (CFU) count.

When analyzing the results for panela, it was observed that at the beginning (day 0), the value of Ln A was 0.6021, indicating a relatively low number of microorganisms present. As time progressed, a significant increase was recorded: by day 15, Ln A rose to 2.3026, and by day 30, it reached 2.3980. This pattern suggests that, over time, the storage conditions allowed for the growth of microorganisms in the panela preserve, although the rate of increase appears moderate, which may be related to the natural antimicrobial properties of panela.

In the case of brown sugar, the growth of microorganisms was also evidenced through the Ln A values. On the initial day, the count was 0 CFU/g, indicating that there were no detectable microorganisms at that time. However, by day 15, Ln A showed a notable increase to 2.0794, and by day 30, it rose even further to 2.9957. This behavior suggests that brown sugar may have provided a more favorable environment for microbial growth than panela, as the value at day 30 is significantly higher.

Both sweeteners showed an increase in microbial growth over time. However, the growth was more significant in the case of brown sugar at 30 days. This may imply that brown sugar is less effective in inhibiting microbial growth compared to panela, which could affect the shelf life and safety of preserves made with this type of sweetener.

The Ln A values related to yeast growth in tuna preserves sweetened with different sweeteners over 30 days were also analyzed. A growth pattern was observed in all sweeteners, although with significant variations.

In the case of white sugar, the initial Ln A value was 3.8286. Over the following 15 days, there was a slight increase to 3.9318, and by day 30, the value reached 3.9512. This suggests that the growth of yeast in preserves with white sugar was relatively controlled, with a gradual increase but not drastic compared to other sweeteners.

For panela, the initial Ln A value was 3.6889, which was lower than that of white sugar. By day 15, the value remained at 3.9318, showing that conditions allowed for moderate growth. However, by day 30, the value increased to 4.1271, indicating that panela favored a more significant growth of yeast compared to white sugar over the same period.

On the other hand, brown sugar showed notably different behavior. Its initial Ln A value was 4.7005, considerably higher than the other sweeteners. By day 15, the value rose to 4.7875, and by day 30, it further increased to 5.2523. This growth indicates that brown sugar not only favored yeast development but also did so largely than the other sweeteners.

The preference for the three preserves made with the different sweeteners used in the tuna preserves was evaluated. The data revealed that white sugar was the preferred sweetener with 14 responses. This level of acceptance suggests that consumers positively valued the sensory characteristics of the product made with this sweetener, which can be attributed to its sweet flavor and ability to enhance the fruit's flavors.

Panela, with 10 responses, ranked second. Its acceptance suggests that despite its earthier and less sweet flavor, it may have contributed unique characteristics that some consumers appreciated. Therefore, panela could be a viable option for those seeking a more natural and less refined alternative to white sugar.

Finally, brown sugar received only six responses, making it the least accepted among the three evaluated sweeteners. This lower level of acceptance may indicate that it is stronger and less sweet flavor did not align with consumer expectations. The presence of more intense notes may have influenced consumer decisions, who may have preferred subtler and more pleasant flavors.

Conclusions

The results indicated that white sugar was the most preferred sweetener among participants, suggesting a higher acceptance of its flavor and aroma. However, panela also showed good acceptance, although it did not reach the popularity of white sugar. In contrast, brown sugar was the least preferred, which may be related to its less sweet flavor. In microbiological terms, white sugar exhibited significantly lower yeast and mold growth compared to panela and brown sugar, suggesting that the choice of sweetener affects not only the flavor and consumer preference but also the stability and shelf life of the product. These findings highlight the need to consider both sensory quality and microbiological safety when developing new food products.

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Conflicts of interest
The authors declare that they have no conflicts of interest.

Author contributions
Giusseppe Modenesi, Pedro A. Badillo and Paul R. Pino: Conceptualization, data curation, formal analysis, investigation, methodology, supervision, validation, visualization, drafting the original manuscript and writing, review, and editing.

Data availability statement
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Statement on the use of AI
The authors acknowledge the use of generative AI and AI-assisted technologies to improve the readability and clarity of the article.