J. Food Sci. Gastron. (July - December 2025) 3(2): 23-29
https://doi.org/10.5281/zenodo.16741117
ISSN 3073-1283

JFSG
JOURNAL OF FOOD SCIENCE AND GASTRONOMY

ORIGINAL ARTICLE

Evaluation of the pasteurization process and its relationship with quality defects in bottled beer

Evaluación del proceso de pasteurización y su relación con los defectos de calidad en cerveza embotellada

Osmaida Vinajera • **Belquis I. González**

Received: 11 April 2025 / Accepted: 09 July 2025 / Published online: 31 July 2025

Abstract This study evaluated the pasteurization process at the "Guido Pérez" Brewery to identify the causes of bottled beer returns due to quality defects. Defective samples were analyzed, and a 3^2 factorial experiment was conducted, combining temperatures of 55, 60, and 65 °C with residence times of 20, 25, and 30 minutes. Pasteurization units (PU) were determined, and microbiological and sensory analyses were conducted over a 20-day storage period. Results showed that 41% of returns were due to pasteurization failures linked to operational issues, while the remaining 59% were caused by physical contamination such as residues and dirty bottles. A treatment of 60 °C for 25–30 minutes (25–30 PU) provided a balance between microbial safety and sensory preservation. Lower thermal intensities were insufficient, while higher ones led to overpasteurization. The study concluded that optimizing thermal parameters and improving packaging hygiene can enhance product quality and reduce economic losses.

Keywords pasteurization, bottled beer, pasteurization units, microbial stability, quality control.

Resumen Este estudio evaluó el proceso de pasteurización en la Cervecería "Guido Pérez" para identificar causas de devoluciones de cerveza embotellada por defectos de calidad. Se analizaron muestras defectuosas y se diseñó un experimento factorial 3^2 que combinó temperaturas de 55, 60 y 65 °C con tiempos de 20, 25 y 30 minutos. Se determinaron las unidades de pasteurización (UP) y se realizaron análisis microbiológicos y sensoriales durante 20 días de almacenamiento. Los resultados indicaron que el 41 % de las devoluciones se debieron a fallas en la pasteurización, asociadas a deficiencias operativas, mientras que el 59 % restante respondió a problemas físicos como residuos y suciedad en las botellas. Se estableció que 60 °C durante 25–30 minutos (25–30 UP) logra un equilibrio entre seguridad microbiológica y conservación sensorial, mientras que intensidades térmicas más bajas resultan ineficientes, y las más altas producen sobrepasteurización. Se concluyó que optimizar los parámetros térmicos y fortalecer la higiene del envase puede mejorar la calidad del producto y reducir pérdidas económicas.

Palabras clave pasteurización, cerveza embotellada, unidades de pasteurización, estabilidad microbiológica, control de calidad.

How to cite
Vinajera, O., & González, B. I. (2025). Evaluation of the pasteurization process and its relationship with quality defects in bottled beer. *Journal of Food Science and Gastronomy*, *3*(2), 23-29. https://doi.org/10.5281/zenodo.16741117

✉ Osmaida Vinajera
osmaida.cruet1220@gmail.com

Empresa Cervecería "Guido Pérez", La Habana, Cuba.

[1]Empresa Cervecería "Guido Pérez", La Habana, Cuba.

PUBLIS EDITORIAL

Introduction

The history of beer is closely linked to the rise of agriculture, particularly the cultivation of barley (*Hordeum vulgare*), one of the first cereals domesticated in the Fertile Crescent more than 9,000 years ago (Martínez-Moreno et al., 2024). The term "beer" is presumed to come from the Latin cervisia, in honor of Ceres, goddess of agriculture, and vis, which refers to strength. In its origins, farmers discovered that by mixing ground grains with water and leaving this mixture exposed to the environment, spontaneous fermentation occurred due to the action of natural microorganisms present in the environment, generating a beverage that was well received for its flavor and effects (Hornsey, 2003).

The incorporation of hops (*Humulus lupulus*) into the brewing process is documented as far back as the 13th century, highlighting their antiseptic properties and their contribution to the flavor and microbiological stability of the product (Karabín et al., 2016). The Industrial Revolution marked the beginning of large-scale beer production in the late 18th century. However, a significant portion of historical beers were artisanal, primarily produced in domestic settings by women (Nelson, 2005). Nowadays, interest in craft beer has resurfaced in various parts of the world, as part of a movement towards local and differentiated quality products (Garavaglia & Swinnen, 2017).

From a technical and nutritional point of view, beer is a fermented beverage with a low alcohol content (between 4 and 5%), obtained from a wort made with barley malt, water, and hops, and fermented with selected yeasts such as Saccharomyces cerevisiae or Saccharomyces pastorianus. It contains minerals, B vitamins, soluble fiber, antioxidants, and polyphenols, which contribute to its moderate nutritional value (Zugravu et al., 2023; Martínez-Moreno et al., 2024). Furthermore, several studies have highlighted its functional potential, including antioxidant properties and benefits for cardiovascular health when consumed in moderation (Di Domenico et al., 2020; Rothe et al., 2023).

In Cuba, the "Guido Pérez" Brewery, initially called "Modelo" and built in 1948 by the Bacardi company, stopped producing beer broth in 2005, relying on broth provided by other breweries, such as Tínima and Manacas, since then. The brewery's production is intended for both state agencies and the retail chain, within a self-financing business model.

The objective of this study was to evaluate the pasteurization process to increase beer shelf life and reduce returns due to quality defects. The importance of this work lies in its economic impact, as continuous returns due to quality defects represent a significant loss for the company. Improving the pasteurization process is expected to significantly reduce these returns, increase product shelf life, and boost consumer confidence.

Methodology

Samples from customer returns, as well as samples of pasteurized beer processed in the laboratory, were evaluated to identify potential causes of quality loss associated with the pasteurization process. Various measuring instruments and equipment were used to perform the analyses, including a thermostatic bath, a tape measure, a stopwatch, an optical microscope, and a tunnel pasteurizer. Sensory evaluation of the samples was complemented by microbiological analyses conducted by international standards. ISO 21527-1 (2008) was used for enumerating yeasts and molds using the poured plate technique, incubated at 25°C, and ISO 4833-1 (2013) was used for enumerating mesophilic microorganisms at 30 °C. Additionally, the requirements established for detecting microbiological contaminants in food for human consumption were considered.

The beer pasteurization process was evaluated using a 32-factorial design, analyzing the effect of temperature (55, 60, and 65 °C) and residence time (20, 25, and 30 minutes) on the accumulation of pasteurization units (PU). The experiment was conducted on a laboratory scale, using a thermostatic bath and four bottles per run, one of which was open to monitor the internal temperature. The number of PUs was calculated based on the average temperature and the time between checkpoints, considering that 1 PU is equivalent to holding the beer at 60 °C for one minute. The acceptance criterion was to achieve at least 20 PUs per sample. In addition, microbiological monitoring of the bottles was performed at 1, 5, 10, and 20 days, allowing the evaluation of the effectiveness of the thermal process and its impact on the microbiological stability of the product. The results enabled the identification of optimal pasteurization conditions to ensure the quality and durability of the beer.

Statistical analyses were performed using Statgraphics Plus version 5.1, which enabled the evaluation of the significance of the studied factors and their potential interactions on the effectiveness of the pasteurization process.

Results and discussion

In analyzing the data in Table 1, a total of 4,092 defective bottles, equivalent to 170.50 cases, were recorded over the six consecutive days of sampling. These losses correspond to two types of defects: those detected through microbiological analysis (lack of pasteurization) and those identified on the production line (particles and flakes), which reveals the need for differentiated approaches to improve product quality.

The most serious and costly defect was the lack of pasteurization, with 1,680 returned bottles—equivalent to 70 cases—detected exclusively through microbiological testing. This figure represents 41% of the total returns and demonstrates a critical failure in heat treatment control, which jeopardizes food safety and significantly reduces operational

efficiency.

On the other hand, physical defects detected on the production line totaled 2,412 affected bottles (100.50 boxes), equivalent to 59% of the losses. In this group, large particles were the second most frequent defect (851 bottles; 35.46%), followed by "pirey" (1,350 bottles; 56.25%), and small particles (211 bottles; 8.79%). The constant presence of "pirey" over the six days suggests recurring deficiencies in the equipment cleaning and sanitation processes, as well as possible accumulations of residues that alter product quality.

These results highlight the urgent need to optimize two areas of action: first, strengthen and monitor pasteurization parameters to ensure the elimination of microbiological risks; second, review and improve hygiene and maintenance routines for packaging equipment to reduce the formation of particles and "pirey". Implementing more rigorous controls and internal audits will help reduce returns, safeguard food safety, and ensure consistent product quality.

Table 1. Analysis of defects in beer bottles

No.	Type of defect	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Total bottles	Equivalent in boxes
1	Unpasteurized	–	–	–	–	1680	–	1680	70.00
2	Small particles	35	22	40	32	57	25	211	8.79
3	Large particles	104	152	119	145	184	147	851	35.46
4	Pirey	220	230	225	227	220	228	1350	56.25
Total bottles		359	404	384	404	2141	400	4092	170.5

Figure 1 illustrates the cause-and-effect diagram, which identifies the direct and indirect factors influencing the effectiveness of pasteurization, to guide opportunities for improvement in quality control and assurance. The analysis of the diagram revealed the presence of multiple causes. Among the work environment factors (noise, lighting, and heat leaks), a direct impact on operator performance was identified, which favored improper handling of the pasteurizer. In this regard, staff training, instruction, and accountability were decisive. From a technical and operational perspective, the availability of maintenance materials, cleaning agents, and spare parts proved critical in avoiding sprinkler blockages, jams in conveyor belts, and unplanned motor shutdowns, all of which could compromise the thermal continuity of the process and result in significant losses.

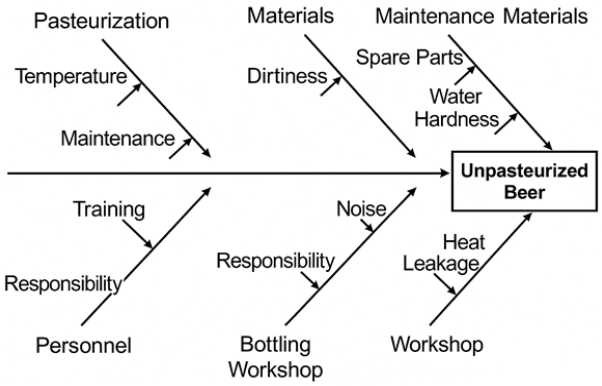

Figure 1. Cause-and-effect diagram of direct and indirect factors related to the effectiveness of pasteurization.

From a thermohydraulic approach, the results are in line with other published studies on water hardness and the effect on scaling is consistent with previous studies: hard water causes carbonate build-up in pipes and sprinklers, significantly reducing heat transfer and decreasing the effectiveness of the thermal process, as documented in the technical literature on thermal hydraulic systems (Junqi et al., 2018). In the beer industry, similar research has linked this scaling to longer times to reach the required pasteurization units, resulting in both decreased yield and microbiological safety of the product (Carvalho et al., 2023).

Regarding the phenomenon of heterogeneity between runs and the effects of the human factor, the results were consistent with a study of thermal dynamics in beer bottle pasteurization using CFD modeling. This work demonstrated that different areas of the pasteurizing tunnel exhibit significant differences in the thermal profile, and that inconsistencies in residence time—often caused by variable operating practices—generate pasteurization unit results distributed between 15 and 30, some of which are insufficient to ensure sterility (Szpicer et al., 2025; Ding et al., 2025).

The risk of over-pasteurization and sensory deterioration by excessively prolonging the exposure time has been reinforced by other studies, in which it has been shown that heat treatments above the optimal window (60–65 °C for 15-20 min) compromise functional compounds such as B vitamins and ferulicoids, in addition to increasing aldehydes associated with product aging (Gomes et al., 2023; Ding et al., 2025).

The emphasis on pre-packaging hygiene is consistent with studies that have highlighted beer's susceptibility to post-fermentation contamination. Even in highly controlled breweries, undesirable organisms such as lactic acid bacteria and wild yeast can enter during bottling, compromising product

stability if package washing and sanitation are not correctly controlled (Tan et al., 2024).

Figure 2 shows the pasteurization units (PU) obtained from the measurements taken at the pasteurizer. The last four measurements correspond to tunnel 1, which was operated during shift 2, and increased the bottle flow rate, creating a risk of not reaching the minimum PU threshold required for effective pasteurization.

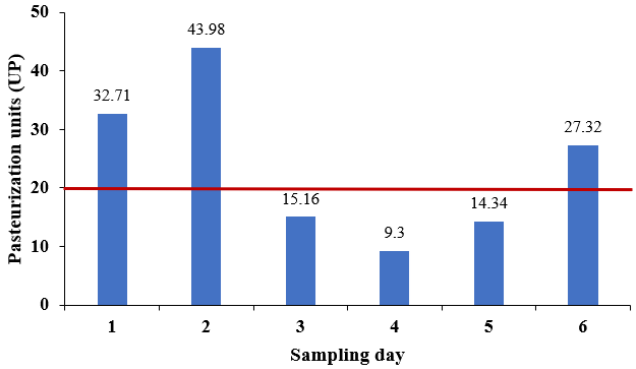

Figure 2. Pasteurization units during the verification of heat treatment.

The results obtained regarding the deficient pasteurization units during the third, fourth, and fifth days, and the adequate value reported on the sixth day (27.32 PU), agree with previous studies that show the difficulty in maintaining homogeneous and controlled thermal conditions in discontinuous or semi-automatic pasteurization processes. For example, Milani and Silva (2022) reported similar fluctuations in temperature during the pasteurization process of bottled beers, associated with thermal imbalances between the heating and cooling stages, which compromise the microbiological effectiveness of the process. The finding of high temperatures in areas corresponding to the cooling phase was also reported by Yin et al. (2017), who showed that poor thermal distribution affects the microbiological stability and organoleptic quality of the final product.

Insufficient temperatures during the critical pasteurization stage and elevated temperatures during the cooling phase have been reported in other studies, underscoring the importance of controlling thermohydraulic parameters to achieve consistent and efficient pasteurization. According to Milani and Silva (2022), inadequate time and temperature regulation directly affects microbial elimination, increasing the likelihood of products with reduced shelf life or residual contamination.

Microbiological and sensory results based on the heat treatment applied show a relationship between the intensity of pasteurization, expressed in PU, and product stability during storage (Table 2). Pasteurization units represent the cumulative intensity of the heat treatment, considering both temperature and exposure time, and allow estimating the effectiveness of the process in terms of microbial inactivation. In this study, it was observed that treatments at 55 °C, with PUs lower than 6, were insufficient to control microbial growth over time, while treatments at 60 °C (20–30 PU) and 65 °C (104–156 PU) achieved higher levels of control, although with notable differences in sensory impact.

After 5 days of storage, treatments at 55 °C (3.8–5.7 PU) resulted in elevated yeast counts (up to 5.7 cells/field) and a persistent presence of rods and cocci, along with a cloudy appearance of the product. This response is attributed to the low intensity of the heat treatment, insufficient to eliminate the initial microbial load or prevent its subsequent multiplication. These findings are consistent with those of Carvalho et al. (2023), who note that treatments with temperatures below 60 °C can allow the survival of heat-resistant microorganisms, thereby compromising product stability even in the early stages of storage.

In contrast, samples treated at 60 °C, with an intensity of 20 to 30 PU, showed a significant reduction in microbial load (0–0.1 cells/field), maintaining a visual appearance classified as "good". This pasteurization intensity appears to be sufficient to achieve effective inactivation of microorganisms without causing visible damage to sensory properties, as stated by Milani and Silva (2022), who highlight that 60 °C is a critical temperature for achieving efficient pasteurization in sensitive products. On the other hand, samples treated at 65 °C, with a much higher intensity (104–156 PU), eliminated detectable microbial flora but presented a "slightly dusty" appearance, suggesting non-microbial physicochemical alterations associated with over-pasteurization, such as the precipitation of proteins or minerals.

At 10 days, the influence of heat treatment intensity on product stability becomes more evident. Samples at 55 °C retained high levels of microorganisms (up to 1.1 cells/field) and exhibited significant sensory deterioration, including turbidity, precipitation, off-odors, and altered flavors, confirming the ineffectiveness of a low-intensity treatment. Samples pasteurized at 60 °C (25–30 PU) maintained low microbial levels (0.2–0.5 cells/field) and a good appearance, reinforcing their suitability for ensuring medium-term stability. However, an exception occurred in the 60 °C for 20-minute treatment (20 PU), which showed higher microbial counts and deteriorated appearance at 20 days, suggesting possible post-pasteurization contamination or defects in the sealing process, as discussed by Ciont et al. (2022), who warn that errors in cleaning or closing the container can compromise the validity of the heat treatment applied.

Table 2. Effect of pasteurization temperature and time on the microbiological and sensory stability of beer during storage

Time (d)	Pasteurization		Pasteurization units (UP)	Yeasts (Cells/field)	Rods (Cells/field)	Cocci (Cells/field)	Aspect
	Time (min)	Temperature (°C)					
5	20	55	3.8	0.2	0.3	0.3	Cloudy
		60	20	0.1	0.1	0.1	Good
		65	104	0	0	0	Light dust
	25	55	4.75	0.1	0.2	0.2	Cloudy
		60	25	0	0.1	0.1	Good
		65	130	0	0	0	Light dust
	30	55	5.7	0.2	0.1	0.2	Cloudy
		60	30	0	0	0.1	Good
		65	156	0	0	0	Light dust
10	20	55	3.8	0.5	0.5	0.6	Cloudy with precipitate
		60	20	0.3	0.4	0.4	Good
		65	104	0	0	0.1	Light dust
	25	55	4.75	0.5	1.1	0.8	Cloudy, bad taste, and smell
		60	25	0.2	0.3	0.5	Good
		65	130	0	0	0	Light dust
	30	55	5.7	0.4	0.5	0.6	Cloudy with precipitate
		60	30	0.2	0.2	0.4	Good
		65	156	0	0	0	Light dust
20	20	55	3.8	0.6	0.5	0.9	Cloudy with precipitate
		60	20	0.4	1.7	1	Cloudy, bad taste, and smell
		65	104	0.3	0.2	0.3	Light dust
	25	55	4.75	0.5	0.5	0.5	Cloudy with precipitate
		60	25	0.2	0.5	0.7	Good
		65	130	0.1	0.1	0.3	Light dust
	30	55	5.7	0.4	0.3	0.8	Cloudy with precipitate
		60	30	0.2	0.5	0.7	Good
		65	156	0	0	0	Light dust

Samples treated at 65 °C continued to show an absence of microorganisms for up to 20 days, but the "light dust" appearance persisted under all tested conditions. This observation is consistent with the findings of Ding et al. (2025), who report that high heat intensities degrade aromatic compounds and promote protein denaturation, resulting in visible aggregates and loss of sensory quality.

Conclusions

The pasteurization process is the primary cause of beer returns by customers. However, other factors, such as the presence of suspended particles and poor bottle washing, are also significant contributing factors. A large portion of bottled beer is not pasteurized adequately due to operational failures, including poor handling by personnel, inefficient automatic temperature control, high water hardness, and

inadequate equipment maintenance. The minimum effective pasteurization temperature is 60 °C, regardless of exposure time; however, excessive time inside the pasteurizer can deteriorate product quality due to over-pasteurization. Although pasteurization is also achieved at 65 °C, its implementation would require operational adjustments, such as increasing the water temperature and reducing the bottle residence time. The results suggest a direct relationship between the intensity of heat treatment and the microbiological stability of the product, as well as an inverse relationship with sensory quality when excessively high intensities are reached. A moderate intensity range (25–30 PU), such as that obtained at 60 °C for 25–30 minutes, appears to offer an adequate balance between microbiological safety and sensory acceptance, provided that post-treatment hygiene conditions are adequately controlled.

References

Carvalho, G., Leite, A. C., Leal, R., & Pereira, R. (2023). The role of emergent processing technologies in beer production. *Beverages, 9*(1), 7. https://doi.org/10.3390/beverages9010007

Ciont, C., Epuran, A., Kerezsi, A. D., Coldea, T. E., Mudura, E., Pasqualone, A., Zhao, H., Suharoschi, R., Vriesekoop, F., & Pop, O. L. (2022). Beer safety: New challenges and future trends within craft and large-scale production. *Foods, 11*(17), 2693. https://doi.org/10.3390/foods11172693

Di Domenico, M., Feola, A., Ambrosio, P., Pinto, F., Galasso, G., Zarrelli, A., Di Fabio, G., Porcelli, M., Scacco, S., Inchingolo, F., Quagliuolo, L., Ballini, A., & Boccellino, M. (2020). Antioxidant effect of beer polyphenols and their bioavailability in dental-derived stem cells (D-dSCs) and human intestinal epithelial lines (Caco-2) cells. *Stem Cells International*, *2020*, 8835813. https://doi.org/10.1155/2020/8835813

Ding, J., Hou, X., Li, J., Zhao, X., & Hu, S. (2025). The effects of pasteurization and beer type on the functional compounds and flavor substances in beer. *Beverages, 11*(3), 63. https://doi.org/10.3390/beverages11030063

Garavaglia, C., & Swinnen, J. (2017). *Economic perspectives on craft beer: A revolution in the global beer industry*. Palgrave Macmillan. https://doi.org/10.1007/978-3-319-58235-1

Hornsey, I. S. (2003). *A history of beer and brewing*. Royal Society of Chemistry. https://doi.org/10.1039/9781847550026

ISO 21527-1. (2008). *Microbiology of food and animal feeding stuffs — Horizontal method for the enumeration of yeasts and moulds. Part 1: Colony count technique in products with water activity greater than 0.95.*

ISO 4833-1. (2013). *Microbiology of the food chain — Horizontal method for the enumeration of microorganisms. Part 1: Colony count at 30 °C by the pour plate technique.*

Junqi, D., Xianhui, Z., & Jianzhang, W. (2018). Experimental study on thermal hydraulic performance of plate-type heat exchanger applied in engine waste heat recovery. *Arabian Journal for Science and Engineering, 43*, 1153–1163. https://doi.org/10.1007/s13369-017-2765-y

Karabín, M., Hudcová, T., Jelínek, L., & Dostálek, P. (2016). Biologically active compounds from hops and prospects for their use. *Comprehensive Reviews in Food Science and Food Safety, 15*(3), 542–567. https://doi.org/10.1111/1541-4337.12201

Martínez-Moreno, F., Solís, I., & Igartua, E. (2024). Barley history and breeding in Spain. *Agriculture, 14*(10), 1674. https://doi.org/10.3390/agriculture14101674

Milani, E. A., & Silva, F. V. M. (2022). Pasteurization of beer by non-thermal technologies. *Frontiers in Food Science and Technology*. https://doi.org/10.3389/frfst.2021.798676

Nelson, M. (2005). *The barbarian's beverage: A history of beer in ancient Europe*. Routledge.

Rothe, J., Fischer, R., Cotterchio, C., Gastl, M., & Becker, T. (2023). Analytical determination of antioxidant capacity of hop-derived compounds in beer using specific rapid assays (ORAC, FRAP) and ESR-spectroscopy. *European Food Research and Technology, 249*, 81–93. https://doi.org/10.1007/s00217-022-04135-3

Szpicer, A., Bińkowska, W., Stelmasiak, A., Zalewska, M., Wojtasik-Kalinowska, I., Piwowarski, K., Piepiórka-Stepuk, J., & Półtorak, A. (2025). Computational fluid dynamics simulation of thermal processes in food technology and their applications in the food industry. *Applied Sciences, 15*(1), 424. https://doi.org/10.3390/app15010424

Tan, Z., Gong, X., Zhang, J., Shi, S., Liu, C., Wang, Y., … Meng, L. (2024). Strategies for detection and control of microorganisms contamination in fermented foods: A review. *CyTA - Journal of Food, 22*(1). https://doi.org/10.1080/19476337.2024.2401031

Yin, H., Deng, Y., He, Y., Dong, J., & Lu, J. (2017). A preliminary study of the quality attributes of a cloudy wheat beer treated by flash pasteurization. *Journal in Brewing Science, 123*(3), 366–372. https://doi.org/10.1002/jib.429

Zugravu, C. A., Medar, C., Manolescu, L. S. C., & Constantin, C. (2023). Beer and microbiota: Pathways for a positive and healthy interaction. *Nutrients, 15*(4), 844. https://doi.org/10.3390/nu15040844

Conflicts of interest

The authors declare that they have no conflicts of interest.

Author contributions

Conceptualization: Osmaida Vinajera. **Data curation:** Osmaida Vinajera. **Formal analysis:** Osmaida Vinajera,

Belquis I. González. **Research:** Osmaida Vinajera, Belquis I. González. **Methodology:** Belquis I. González. **Supervision:** Belquis I. González. **Validation:** Belquis I. González. **Visualization:** Osmaida Vinajera. **Writing-original draft:** Osmaida Vinajera, Belquis I. González. **Writing-review & editing:** Osmaida Vinajera, Belquis I. González.

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.

Disclaimer/Editor's note

The statements, opinions, and data contained in all publications are solely those of the individual authors and contributors and not of the *Journal of Food Science and Gastronomy*.

Journal of Food Science and Gastronomy and/or the editors disclaim any responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products mentioned in the content.