Revista ARACÊ
ISSN: 2358-2472

IMPACT OF NON-THERMAL TECHNOLOGIES ON FOOD PRESERVATION: MICROBIOLOGICAL SAFETY, QUALITY AND SUSTAINABILITY - A REVIEW

https://doi.org/10.56238/arev6n4-405

Submitted on: 11/24/2024 **Publication date:** 12/24/2024

Maria Geovana de Jesus Lopes[1], Mariana Elene Costa Pereira Benevides[2], Lucélia Alves Paixão[3], Pedro Carvalho Araújo[4], Daniel Barbosa dos Santos[5], Ariel Vitoria Gonçalves[6], Juliana Gonçalves Vidigal[7] and Lucas Martins da Silva[8].

ABSTRACT
The growing demand for safe, nutritious, high-quality sensory foods whose production does not cause significant environmental impact has driven the development of innovative technologies aimed at food preservation, which are essential to meet market demands and reduce food waste. This article presents a comprehensive review on the impact of non-thermal technologies on food preservation, addressing aspects such as microbiological safety, quality, and sustainability. Innovative methods, such as high-pressure processing

[1] Master's student in Plant Production at Universidade Estadual do Norte Fluminense Darcy Ribeiro – UENFE
E-mail: dejesusmaria854@gmail.com
ORCID: 0009-0006-2340-806X
LATTES: http:/lattes.cnpq.br/1724633413778756
[2] Master's student in Plant Production State University of Norte Fluminense Darcy Ribeiro – UENFE
E-mail: mariana.elenee@gmail.com
ORCID: 0009-0003-0259-9061
LATTES: http:/lattes.cnpq.br/9252411177666915
[3] Master's student in Plant Production at Universidade Estadual do Norte Fluminense Darcy Ribeiro – UENFE
e-mail: luceliaaaa@gmail.com
ORCID: 0009-0005-0061-404X
LATTES: http:/lattes.cnpq.br/1724633413778756
[4] Master's student in Plant Production
Universidade Estadual do Norte Fluminense Darcy Ribeiro – UENF
Email: praimia@gmail.com
ORCID: 0009-0002-8918-8806
LATTES: http:/lattes.cnpq.br/5788350979218316
[5] Master's student in Plant Production at the State University of Norte Fluminense Darcy Ribeiro - UENF
Email: danielbdossantos.1999@gmail.com
ORCID: 0009-0003-6325-231X
LATTES: http://lattes.cnpq.br/5788350979218316
[6] Master's student in Plant Production
State University of Norte Fluminense Darcy Ribeiro - UENFE-e-mail: arvitoria.zoo@gmail.com
ORCID: 0009-0009-6713-8163
LATTES: http://lattes.cnpq.br/6930589123595562
[7] PhD in Food Science and Technolog
Instituto Federal Fluminense - *Bom* Jesus do Itabapoana campus
E-mail: jvdigal@iff.edu.br
ORCID: 0009-0000-7971-5364
LATTES: http://lattes.cnpq.br/0845455390489129
[8] Dr. in Plant Productio
Universidade Estadual do Norte Fluminense Darcy Ribeiro - UENFE-e-mail:
lucasmartinsdasilvalms@gmail.com
ORCID: 0000-0003-0862-7863
LATTES: http://lattes.cnpq.br/3422339601424137

Revista ARACÊ
ISSN: 2358-2472

(HPP), ultrasound, pulsed electric fields (PEF), ultraviolet light (UV) and ozonation, are presented as advantageous alternatives to conventional thermal methods, being effective in reducing microorganisms and preserving the sensory and nutritional attributes of food. Despite challenges, such as high initial costs and operational complexities, these technologies show more promise, standing out for their energy efficiency and lower environmental impact. The study identifies scientific trends and gaps in knowledge through a bibliometric approach and systematic review, highlighting the predominance of PPH and ultrasound as the most investigated methods. In addition, it addresses the feasibility of large-scale application, pointing to combined technologies as solutions to overcome industrial limitations. Thus, it is evident that the modernization of the food industry depends on investments in research and development of these technologies, which are presented as potential solutions to meet the needs of food that combine safety, superior quality and sustainability.

Keywords: Non-Thermal Processing. Food Conservation. Sustainability. Food Security. Sensory Quality.

Revista ARACÊ
ISSN: 2358-2472

INTRODUCTION

Food preservation has been a matter of great concern since the dawn of civilization, with traditional methods such as drying, salting, and fermentation playing key roles in preserving perishable foods. With the advancement of science and technology, thermal processes have emerged, such as pasteurization and sterilization, which have revolutionized the food industry, due to their proven effectiveness in eliminating pathogenic microorganisms and enzymatic inactivation, ensuring safety and extending the shelf life of food. However, as highlighted by Moreno-Vilet et al. (2018) and Silva et al. (2021), these methods often expose foods to high temperatures for prolonged periods, which results in the loss of heat-sensitive, bioactive, and functional nutritional compounds, in addition to impairing sensory attributes such as flavor, texture, and color.

Given this scenario, according to Cristianini et al. (2023), due to the growing consumer search for foods that are not only microbiologically safe, but also functional, emerging non-thermal processing technologies have attracted significant attention as alternative, innovative, and viable sources. Methods such as high hydrostatic pressure, pulsed electric fields and ionizing radiation stand out among non-thermal technologies (Jermann et al., 2015), conferring, by minimizing the negative impacts associated with conventional heating, a better preservation of nutrients and the original characteristics of food.

Although non-thermal technologies can present a number of advantages for the food industry, such as those mentioned above, their large-scale applications still face several challenges. Among them, according to Picart-Palmade et al. (2019), the limitation of consolidated data on its effectiveness in different food matrices, the high implementation costs, and the operational complexity in industrial scenarios stand out. These gaps highlight the need for in-depth research, which is capable of systematically exploring the microbiological safety, quality and sustainability of these methods, thus promoting viable solutions to overcome the existing barriers in the food sector.

Thus, exploratory, descriptive and quantitative studies are characterized as essential tools to investigate little-known phenomena, detail aspects and analyze numerical data objectively. Exploratory studies help identify gaps and trends in broad themes, descriptive studies detail observable patterns and characteristics, and quantitative studies use metrics for objective analysis. The integration of these approaches is recurrent in bibliometric studies, allowing the mapping of scientific trends, the detection of theoretical

Revista
ARACÊ
ISSN: 2358-2472

insufficiencies, and the proposal of new guidelines for future research (Macedo et al., 2022).

This work is characterized, therefore, as a qualitative-quantitative research, of exploratory character and in the bibliographic modality, with bibliometric bias. As it is bibliographic, it is based on the analysis of previously published scientific productions, allowing a systematic review of relevant and reliable data. Bibliometric bias, in turn, provides a quantitative perspective on scientific production, facilitating the identification of publication patterns, collaboration networks, and academic impact of research in the field. Thus, the central objective of this work is the analysis of scientific productions on the impact of non-thermal technologies on food preservation, addressing fundamental aspects such as microbiological safety, quality and environmental sustainability. By exploring these themes, the study seeks not only to understand the current state of research, but also to suggest new directions for future advances in the food sector.

METHODOLOGY

The present study used a bibliometric and systematic review approach to understand the impact of non-thermal technologies on food preservation. The methodology was structured to identify, analyze and synthesize relevant publications, highlighting the main technologies, their effects on food quality and safety, and their feasibility in terms of sustainability. The steps outlined below detail the process of selecting, analyzing, and organizing the data collected.

SEARCH STRATEGY

The selection of scientific articles was carried out on December 12, 2024, using the Scopus database, focusing on publications in the period of 10 years (2013-2023) and in English. The keywords used were: "non-thermal technologies", "food preservation", "ultrasound", "high pressure", "ozone", "cold plasma", "ionizing radiation" and "ultraviolet light", connected by the Boolean operator "AND" to refine the results.

A query gerada para a busca foi: (TITLE-ABS-KEY (non-thermal AND technologies) AND TITLE-ABS-KEY (food AND preservation) AND TITLE-ABS-KEY (non-thermal AND processing) AND TITLE-ABS-KEY (ultrasound) OR TITLE-ABS-KEY (high AND pressure) OR TITLE-ABS-KEY (ozone) OR TITLE-ABS-KEY (cold AND plasma) OR TITLE-ABS-KEY (ionizing AND radiation) OR TITLE-ABS-KEY (ultraviolet AND light)) AND PUBYEAR >

Revista ARACÊ
ISSN: 2358-2472

2013 AND PUBYEAR < 2023 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")).

The search resulted in 67 scientific articles, including original and review publications.

INCLUSION AND EXCLUSION CRITERIA

Inclusion criteria

- Publications between 2013 and 2023.
- Language: English.
- Type of document: scientific articles and review articles.
- Thematic focus on non-thermal technologies for food preservation.

Exclusion criteria

- Duplicate documents.
- Articles outside the scope of the search or unavailable in full.

DATA EXTRACTION AND ANALYSIS

The data extraction focused on the following aspects:

- Authors and year of publication.
- Raw material analyzed.
- Non-thermal technology used.
- Microbiological results.
- Aspects of quality and general results.

Data analysis was carried out in two main stages:

Tools used

- The VOSviewer9 software was used for bibliometric analysis and construction of collaboration networks.
- Microsoft Excel was used to organize the data and create graphs and tables.

Revista ARACÊ
ISSN: 2358-2472

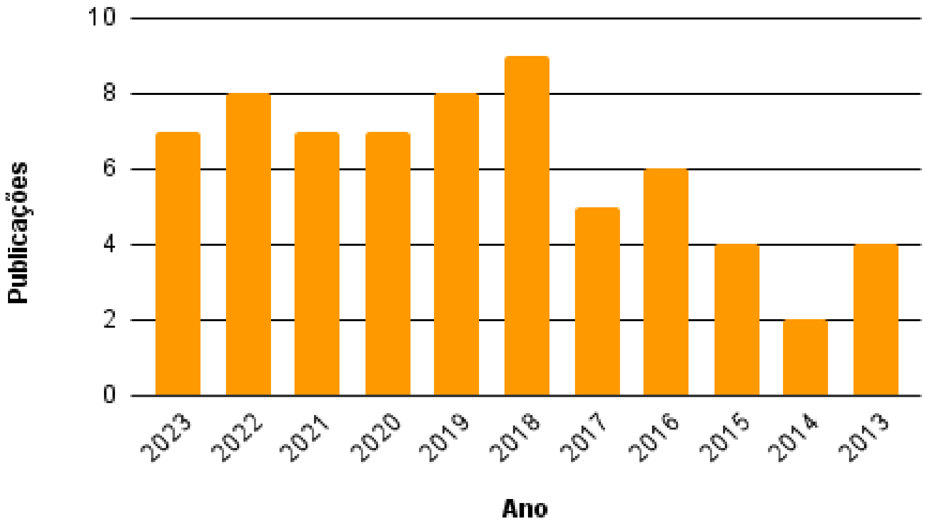
Stages of reading (following Severino, 2017)

- Exploratory Reading: Initial evaluation of titles, abstracts and keywords to identify thematic relevance.
- Selective Reading: Analysis of specific sections (introduction, methodology, and results) for extraction of relevant data.
- Analytical Reading: In-depth understanding of trends and gaps presented in studies.

RESULTS

The search carried out in the Scopus database resulted in a total of 67 scientific publications. The year with the highest number of publications was 2018, with 9 records, followed by the years 2019 and 2022, with 8 publications each. The years 2020 and 2021 had 7 publications each, as illustrated in Figure 1.

Figure 1 - Scientific production between 2013 and 2023.



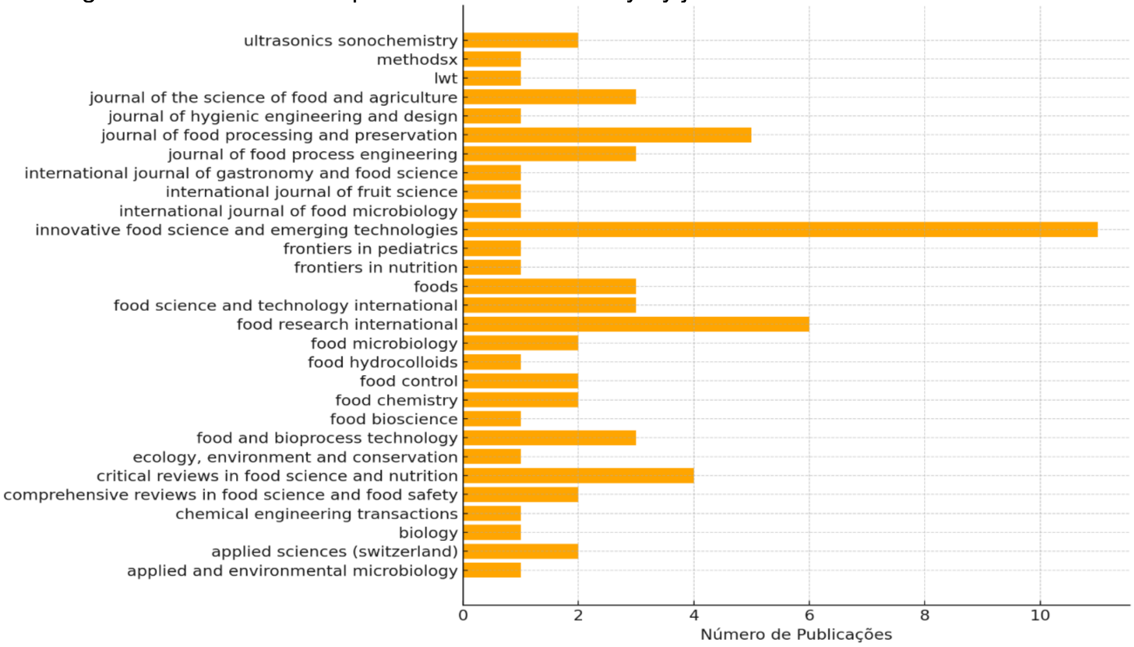
Source: Authorship (2024).

The 67 scientific productions analyzed were published in 15 different journals. The journals Innovative Food Science and Emerging Technologies (Qualis A1) and Food Microbiology (Qualis A1) stand out, which concentrated, respectively, 11 and 6 publications, totaling approximately 25% of the set. Other relevant journals include the Journal of Food Process Engineering (Qualis A4) and Food Science and Technology International (Qualis A3), each with 4 publications. These data show that most of the productions were published in recognized journals of high relevance in the area, as illustrated in Figure 2. Publication in journals with a Qualis A classification reinforces the credibility and quality of

Revista ARACÊ
ISSN: 2358-2472

the research carried out, ensuring that the results presented are supported by vehicles of scientific excellence.

Figure 2 - Distribution of publications under study by journals between 2013 and 2023.

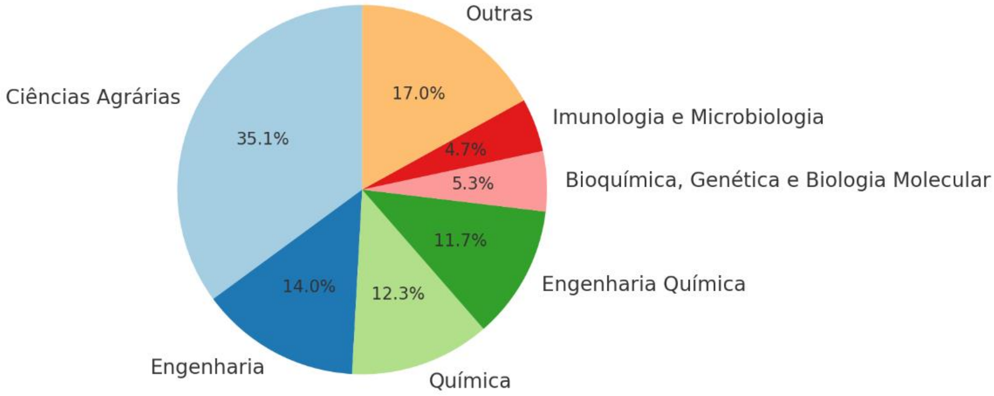


Source: Authorship (2024).

Figure 3 shows the distribution of scientific productions related to non-thermal technologies by areas of knowledge. Agricultural Sciences lead, with 35.1% of the publications, followed by Engineering, which occupies the second place with 14%, and Chemistry, with 12.3%. Chemical Engineering appears next, representing 11.7% of the total, while Biochemistry, Genetics and Molecular Biology contribute with 5.3%. Immunology and Microbiology comprise 4.7% of production. Areas with 3% or less participation, such as Physics and Astronomy, Social Sciences, Health Professions, Nursing, Medicine, among others, were grouped in the "Other" category with 17%. These data highlight the predominance of applied areas, such as Agricultural Sciences and Engineering, in research on non-thermal technologies, while smaller areas present more punctual contributions.

Revista ARACÊ
ISSN: 2358-2472

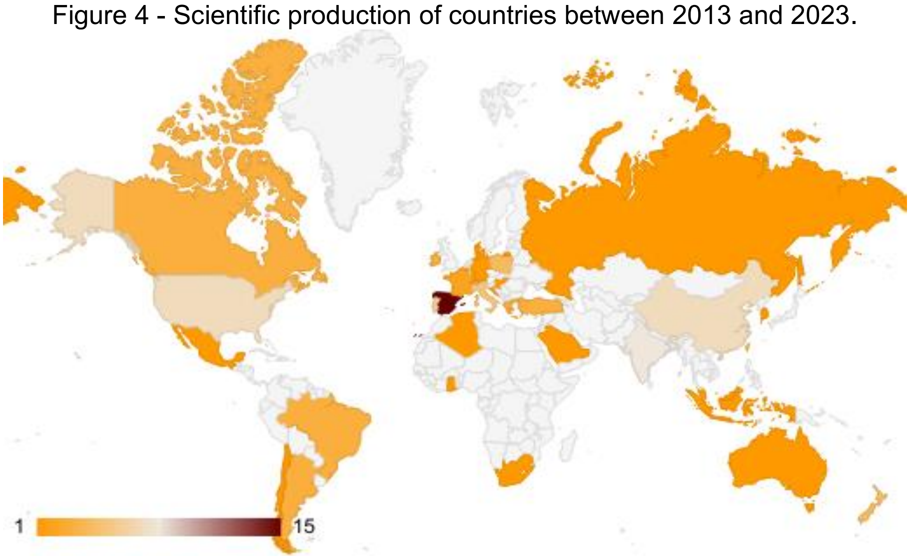
Figure 3 - Areas of study *versus* percentage of scientific production between 2013 and 2023.



Source: Authorship (2024).

The countries that stood out in number of publications on non-thermal technologies were Spain, which led with 15 publications, followed by India, with 8 records. China and the United States shared the third position, both with 7 publications each. Italy and Portugal contributed 5 publications each, while Poland recorded 4. Brazil, Canada, Ireland, Greece and Taiwan presented 3 publications each in the period analyzed. Finally, Algeria, Germany and Malaysia registered only 1 publication each, showing a lower contribution to the theme. The map presented in Figure 4 uses a color system to illustrate the geographic distribution of the publications, in which the darker shades indicate the countries with the highest number of records, while the lighter colors represent those with the lowest production.

Figure 4 - Scientific production of countries between 2013 and 2023.



Source: Authorship (2024).

Revista ARACÊ
ISSN: 2358-2472

In addition, it is noteworthy that the European continent is the largest contributor in terms of scientific production with 47 studies, while Africa has a limited participation, with only 3 publications, from Nigeria (2) and South Africa (1). These data reinforce the predominance of developed and emerging countries in research on non-thermal technologies, while less developed regions have a more restricted participation.

DISCUSSION

Of the 67 articles analyzed, 16 were within the scope of this research, evaluating the effects of non-thermal technologies on food preservation and their influence on quality. Chart 1 presents the selected scientific productions, detailing the characteristics of each study, including the raw material used, the technology applied, the microbiological results, the quality aspects and the general results found.

Table 1: Summary of the results obtained in the studies on non-thermal technologies applied to food preservation and influence on quality.

Author/Year	Raw material	Non-Thermal Technology Used	Microbiological Results	Quality Aspects	Overall Results
Amaro-Blanco et al. (2018)	Cured pork popsicles	HPP and active packaging	HPP reduced pathogens and mesophilic flora.	Sensory quality preserved with PPH.	HPP was effective in microbial reduction while maintaining sensory quality.
Sirohi et al. (2021)	Food grains	Cold plasma, ozone and radiation	Cold plasma reduced surface microorganisms.	Retention of sensory quality and absence of residual odors.	Cold plasma was effective in decontaminating grains, preserving quality.
Fundo et al. (2018)	Cantaloupe melon juice	Ozonization	It reduced 2.22 log of *A. acidoterrestris spores.*	Negative impacts on the preservation of vitamin C (-76%) and carotenoids (-83%).	Ozonation demonstrated microbiological efficacy, but with significant losses of nutrients.
Yildiz et al. (2021)	Strawberry juice	HPP, US e PEF	HPP and US maintained <2 log CFU/mL counts for 42 days.	Preserved bioactive compounds.	HPP and US extended shelf life while maintaining microbiological and sensory quality.
Van Wyk et al. (2018)	Red wine	HPP and PEF	HPP eliminou *Brettanomyces* (>5 log).	Preservation of color and phenolic compounds with HPP.	HPP proved to be more effective in microbiological and sensory preservation.

Revista ARACÊ
ISSN: 2358-2472

Cassani et al. (2020)	Enriched strawberry juice	Ultrasound	Reduction of up to 3.64 log for molds and yeasts.	Increased bioactive compounds and color preservation.	Ultrasound improved bioactives and maintained microbiological and sensory quality.
Zhu et al. (2023)	Salmon fillets	PASW, PAW, SAEW	PASW reduced 2.08 log bacteria.	Preservation of texture and color with PASW.	PASW was more effective for bacterial inactivation and sensory preservation.
Tomadoni et al. (2020)	Strawberry juice	Ultrasound and natural compounds	Reduced 3.64 log pathogens and molds with ultrasound.	Sensory preservation and increase in antioxidants (+16%).	Ultrasound was effective in microbial control and improving the preservation of antioxidant compounds.
Evrendilek et al. (2019)	Cherry juice	PEF, Ozone & Ultrasound	It reduced >4.38 log of *P. expansum* with PEF and ultrasound.	Retention of phenolic compounds and color stability.	The combination of PEF and ultrasound was the most effective in microbial inactivation and quality preservation.
Mizi et al. (2019)	Beef burger	HPP and sage	HPP significantly reduced microorganisms for 60 days.	Sensory preservation with HPP.	HPP ensured long-term microbiological and sensory quality.
Artés-Hernández et al. (2021)	Fruit and vegetable drinks	HPP, US, PEF, UV e plasma frio	5-log reduction in pathogens with combined technologies.	Preservation of bioactive compounds and sensory stability.	Combined technologies increase safety and sensory quality.
Ward et al. (2018)	Skimmed milk	UV-C	Reduziu >5 log de *E. coli, S. Typhimurium e L. monocytogenes*.	Preservation of chemical and sensory properties.	UV-C was efficient in microbial inactivation and maintenance of sensory quality.
Bernardo et al. (2022)	Goat milk	Thermosonic	Inactivation of up to 6.6 log of *E. coli O157:H7.*	Preservation of bioactive compounds and low lipid oxidation.	Thermosonics has demonstrated efficacy in microbial inactivation and preservation of chemical quality.
Pérez-Won et al. (2021)	Coho salmon fillets	PEF, CO_2 e HP	Bacterial counts acceptable for 25 days with PEF.	Preservation of texture, color and reduced enzyme activity.	PEF extended the microbiological shelf life and maintained sensory attributes.
Cao et al. (2018)	Bayberry Suco	Ultrasound (US and USC)	Inactivation of PPO and POD without microbial growth.	Increase in phenolic compounds (+9.57%) and color preservation.	Ultrasound was effective in enzymatic inactivation and maintenance of sensory quality.

Source: authorship.

Legend: HPP: *High Pressure Processing*. US: Ultrasom (*Ultrasound*). PEF: Pulsed *Electric Fields*. PL: Pulsed *Light*. UV-C: Ultraviolet C light.

Revista ARACÊ
ISSN: 2358-2472

PASW: *Plasma-Activated Slightly Acidic Water*. PAW: *Plasma-Activated Water*. SAEW: Slightly *Acidic Electrolyzed Water*. PPO: Polyphenoloxidase. POD: Peroxidase. CFU: Colony *Forming Unit*. E. coli: *Escherichia coli*. A. acidoterrestris: *Alicyclobacillus acidoterrestris*.

In this analysis, it was found that 26.7% of the studies evaluated used high-pressure processing (HPP), consolidating it as one of the most investigated technologies. Examples include its application in cured pig shoulders for pathogen reduction and sensory preservation (Amaro-Blanco et al., 2018), in strawberry juice for shelf life extension and preservation of bioactive compounds (Yildiz et al., 2021), and in red wine for *Brettanomyces elimination* and color preservation (Van Wyk et al., 2018).

Ultrasound (US), also present in 26.7% of the studies, showed efficacy in applications such as the reduction of microorganisms in enriched strawberry juice, with color preservation (Cassani et al., 2020), the increase of antioxidants in strawberry juice (Tomadoni et al., 2020) and the retention of phenolic compounds in sour cherry juice (Evrendilek et al., 2019).

Electrical pulses (PEF) appear in 20% of the studies, with emphasis on their application in strawberry juice, contributing to microbiological and sensory maintenance (Yildiz et al., 2021), and in Coho salmon fillets, where they extended microbiological shelf life and preserved sensory attributes (Pérez-Won et al., 2021).

Ozonation and cold plasma, identified in 13.3% of the studies each, were successfully applied to Cantaloupe melon juice for microbial spore reduction (Fundo et al., 2018) and to nutritious grains for decontamination, without altering sensory quality (Sirohi et al., 2021).

Emerging technologies, such as pulsed light (PL), ultraviolet light (UV-C), thermosonics, and plasma-activated water (PASW, PAW, SAEW), were explored in 6.7% of the studies each, evidencing their potential in specific applications. For example, pulsed light was effective in reducing pathogens in clear liquid foods (Mandal et al., 2020), and ultraviolet (UV-C) light demonstrated efficiency in microbial inactivation in skim milk while preserving chemical and sensory properties (Ward et al., 2018).

The microbiological efficacy of these technologies has been widely demonstrated. In 73.3% of the studies, there were microbial reductions greater than 3 log, and 46.7% achieved reductions above 5 log, levels that guarantee adequate food safety. HPP, for example, eliminated more than 5 log of *Brettanomyces* in red wine (Van Wyk et al., 2018), while ultrasound combined with natural compounds such as geraniol and pomegranate

Revista ARACÊ
ISSN: 2358-2472

extract achieved a reduction of up to 3.64 log of *E. coli O157:H7* in strawberry juice (Tomadoni et al., 2020). Technologies such as UV-C have also demonstrated excellent performance, inactivating pathogens such as *Listeria monocytogenes* in skim milk, without generating toxic compounds (Ward et al., 2018). However, PEF showed limited efficacy in more complex feed matrices, such as wine, where the reduction was only 0.8 log (Van Wyk et al., 2018).

In addition to their microbiological efficacy, non-thermal technologies preserve and, in some cases, improve the nutritional quality of food. In 73.3% of the studies, an increase or preservation of bioactive compounds was detected. Ultrasound stood out by increasing phenolic compounds by up to 9.57% in bayberry juice (Cao et al., 2018), while HPP preserved bioactives in nutrient-rich beverages and foods (Yildiz et al., 2021). On the other hand, ozonation had negative impacts on certain matrices, such as melon juice, where there were losses of up to 76% of vitamin C and 83% of carotenoids (Fundo et al., 2018). These reinforce the importance of selecting the most appropriate technology for each type of food, considering its specific characteristics.

Another important point is the prediction and sustainability of the technologies under study. Technologies such as pulsed light and UV-C have proven to be highly efficient in terms of energy consumption and environmental impact, being ideal for decontamination of surfaces and clear liquids (Mandal et al., 2020; Ward et al., 2018). However, challenges such as high upfront costs and operational complexity still limit large-scale adoption. Strategies such as the combination of technologies, exemplified by the joint use of HPP and CO_2 in salmon fillets, have been shown to be effective in overcoming these barriers, extending the shelf life of food and preserving sensory attributes (Pérez-Won et al., 2021).

In summary, non-thermal technologies offer a modern and effective approach to food preservation, balancing safety, quality, and sustainability. PPH and ultrasound stand out as the most robust technologies, with the greatest support in the literature (Amaro-Blanco et al., 2018; Yildiz et al., 2021). Despite challenges such as cost and operational complexity, advances in research point to a growing evolution of these technologies on an industrial scale. Investments in development and studies on method transfers can further expand their applications, consolidating them as viable and promising alternatives to thermal methods.

ISSN: 2358-2472

CONCLUSION

Non-thermal technologies have been consolidating themselves as effective alternatives for food preservation, standing out for their efficient microbial inactivation and preservation of sensory and nutritional attributes. Methods such as High Pressure Processing (HPP), ultrasound, and electrical pulses (PEF) show positive results in reducing pathogens, often exceeding 5 logs, ensuring microbiological safety without compromising food quality.

These technologies have also demonstrated potential to preserve bioactive compounds and promote sustainability in the food sector, reducing environmental impacts and waste. However, challenges such as high costs and operational limitations still restrict its large-scale adoption.

The combined use of these techniques, such as HPP with CO_2 or ultrasound with bioactive compounds, presents itself as a promising solution, pointing to future industrial applications. It is concluded that the advancement and integration of these technologies are essential to meet the demands for safe, high-sensory and nutritional quality and sustainably produced food, driving the modernization of the food industry.

Revista ARACÊ
ISSN: 2358-2472

REFERENCES

1. Amaro-Blanco, I., Martínez, L., López-Caballero, M. E., et al. (2018). Active packaging using an olive leaf extract and high-pressure processing for the preservation of sliced dry-cured shoulders from Iberian pigs. Meat Science, 144, 50-58. https://doi.org/10.1016/j.meatsci.2018.06.003

2. Artés-Hernández, F., Castillo, S., Carbonell-Barroso, M., et al. (2021). Phytochemical fortification in fruit and vegetable beverages with green technologies: A review. Frontiers in Nutrition, 8, 124. https://doi.org/10.3389/fnut.2021.676419

3. Bernardo, S., Antonio, N., Mata, M., et al. (2022). Optimizing Escherichia coli O157:H7 inactivation in goat's milk by thermosonication: Effects on quality properties. Journal of Food Process Engineering, 45(1), 13856. https://doi.org/10.1111/jfpe.13856

4. Cassani, L., Trindade, C. S. F., Freitas, R. J. S., et al. (2020). Green ultrasound-assisted processing for extending the shelf-life of prebiotic-rich strawberry juice. Journal of Food Science and Technology, 58(2), 375-386. https://doi.org/10.1007/s11483-020-02244-x

5. Cao, W., Liu, J., Zhang, W., et al. (2018). The inactivation kinetics of polyphenol oxidase and peroxidase in bayberry juice during thermal and ultrasound treatments. Food Chemistry, 277, 96-104. https://doi.org/10.1016/j.foodchem.2018.01.049

6. Cristianini, M., Cruz, A. G. da, Prudêncio, E. S., Esmerino, E. A., Rodrigues, S., & Pimentel, T. C. (2023). Tecnologias emergentes no processamento de alimentos. Blucher.

7. Evrendilek, G. A., Evrendilek, F., & Akdeniz, B. (2019). Interaction and multi-objective effects of multiple non-thermal treatments on cherry juice. Innovative Food Science and Emerging Technologies, 52, 89-97. https://doi.org/10.1016/j.ifset.2018.12.005

8. Fundo, J. F., Miller, F. A., Brandão, T. R. S., et al. (2018). Ozone processing for preservation of cantaloupe melon juice: Effect on quality, bioactive compounds and microbial inactivation. Food Chemistry, 239, 761-768. https://doi.org/10.1016/j.foodchem.2017.07.015

9. Macedo, V. P., Lebres, V. F., & Junior, R. B. (2022). Hackathon as an instrument for innovation in collaborative networks: A bibliometric analysis. Revista Produção e Desenvolvimento, 8, e602. https://doi.org/10.48144/rpd.v8.e602

10. Mandal, R., Agarwal, D., Joshi, S., et al. (2020). Applications of pulsed light decontamination technology in food processing: An overview. Food Control, 123, 107773. https://doi.org/10.1016/j.foodcont.2020.107773

11. Mizi, L., Tsimogiannis, D., Ordóñez, J., et al. (2019). Antimicrobial and antioxidant effects of combined high-pressure processing and sage in beef burgers during prolonged chilled storage. Meat Science, 162, 108033. https://doi.org/10.1016/j.meatsci.2019.108033

12. Moreno-Vilet, L., Hernández-Hernández, H. M., & Villanueva-Rodríguez, S. J. (2018). Current status of emerging food processing technologies in Latin America: Novel thermal processing. Innovative Food Science and Emerging Technologies, 50, 196–206. https://doi.org/10.1016/j.ifset.2018.07.004

13. Pérez-Won, M., Rosales-Acuña, C., Jiménez, J., et al. (2021). Combined PEF, CO2, and HP application to chilled Coho salmon and its effects on quality attributes under different rigor conditions. Food Science and Technology International, 27(2), 174-184. https://doi.org/10.1177/1082013221990475

14. Picart-Palmade, L., Cunault, C., Chevalier-Lucia, D., Belleville, M.-P., & Marchesseau, S. (2019). Potentialities and limits of some non-thermal technologies to improve sustainability of food processing. Frontiers in Nutrition, 5, 1-12. https://doi.org/10.3389/fnut.2018.00098

15. Severino, A. J. (2017). Metodologia do trabalho científico (24th ed.). Cortez.

16. Silva, C. O., Teixeira, L. J. Q., & Lima Filho, T. (2021). Cadeia do frio na indústria de alimentos. In Tecnologia de Alimentos: Processamento Não Térmico (pp. 29-44). Editora Rubio.

17. Sirohi, R., Kumar, M., Tarafdar, A., et al. (2021). Technologies for disinfection of food grains: Advances and way forward. Food Control, 123, 107-131. https://doi.org/10.1016/j.foodcont.2020.107678

18. Tomadoni, B., Paredes, A., Masso, M., et al. (2020). Natural antimicrobials combined with ultrasound treatments to enhance quality parameters and safety of unpasteurized strawberry juice. Food Control, 110, 106985. https://doi.org/10.1016/j.foodcont.2020.106985

19. Van Wyk, J., Gil, M., Gamiz-Grande, A., et al. (2018). SO2, high pressure processing and pulsed electric field treatments of red wine: Effect on sensory, Brettanomyces inactivation and other quality parameters during one-year storage. Food Chemistry, 239, 111-118. https://doi.org/10.1016/j.foodchem.2017.06.139

20. Ward, C., Dempsey, C., Lynch, A., et al. (2018). UV-C treatment on the safety of skim milk: Effect on microbial inactivation and physico-chemical properties. Journal of Food Processing Engineering, 42(5), 13169. https://doi.org/10.1111/jfpe.13169

21. Yildiz, S., Bozkurt, F., Kaplan, M., et al. (2021). Shelf life extension of strawberry juice by equivalent ultrasound, high pressure, and pulsed electric fields processes. Journal of Food Science and Technology, 58(1), 295–303. https://doi.org/10.1007/s11483-020-00980-0

22. Zhu, Z., Li, Y., Sun, J., et al. (2023). Evaluating the effects of plasma-activated slightly acidic electrolyzed water on bacterial inactivation and quality attributes of Atlantic salmon fillets. Food Chemistry, 395, 133-144. https://doi.org/10.1016/j.foodchem.2022.133229