

SUSTAINABLE CHEESE PACKAGING WITH GELATIN-BASED EDIBLE FILMS: A REVIEW OF A DECADE OF RESEARCH

EMBALAGENS SUSTENTÁVEIS PARA QUEIJO COM FILMES COMESTÍVEIS À BASE DE GELATINA: UMA REVISÃO DE UMA DÉCADA DE PESQUISAS

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ABSTRACT: This review analyses the available literature on gelatin-based edible films in cheese preservation, showing the remaining gaps in the field. The Scopus and Web of Science databases were searched using the combination of keywords edible film OR edible coating OR edible packaging AND gelatin AND cheese, resulting in thirty studies published from 2015 to 2025. A Bibliometric analysis was performed by Bibliometrix package. A significant growth in studies on gelatin-based edible films was observed, particularly in Brazil, the leader in publication output. This review highlights the efficacy of gelatin-based films in preserving cheese, reducing microbial growth, and mitigating lipid oxidation. Additionally, when combined with essential oils and plant extracts, they have positive effects on cheese quality, shelf life, and sensory attributes. Despite demonstrating the positive effects of gelatin-based edible films applied to cheese, the reviewed literature lacks studies about sensory evaluations, applicability to various cheese types, and economic feasibility for large-scale industrial implementation.

Keywords: Active edible films. Cheese packaging. Food conservation. Sustainability.

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RESUMO: Esta revisão analisa a literatura disponível sobre filmes comestíveis à base de gelatina na conservação de queijos, evidenciando as lacunas ainda existentes nesse campo. As bases de dados Scopus e Web of Science foram consultadas utilizando a combinação de palavras-chave *edible film OR edible coating OR edible packaging AND gelatin AND cheese*, resultando em trinta estudos publicados entre 2015 e 2025. Uma análise bibliométrica foi realizada por meio do pacote *Bibliometrix*. Observou-se um crescimento significativo dos estudos sobre filmes comestíveis à base de gelatina, especialmente no Brasil, país com maior número de publicações. Esta revisão destaca a eficácia desses filmes na preservação do queijo, na redução do crescimento microbiano e mitigação da oxidação lipídica. Além disso, quando combinados com óleos essenciais e extratos vegetais, os filmes apresentam efeitos positivos na qualidade, vida útil e atributos sensoriais dos queijos. Apesar de demonstrar os efeitos positivos dos filmes comestíveis à base de gelatina aplicado ao queijo, a literatura revisada ainda carece de estudos relacionados à avaliação sensorial, aplicabilidade em diferentes tipos de queijos e viabilidade econômica para implementação em escala industrial.

Palavras-chave: Filmes comestíveis ativos. Embalagem de queijos. Conservação de alimentos. sustentabilidade.

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INTRODUCTION

Consumption of packaged foods increased significantly in recent decades, with most packaging made from plastic materials designed for single use and discarded after a short period. Although this improves product shelf life, enhancing storage conditions, and reducing food waste and loss, this type of packaging has a significant environmental impact (BIZYMIS; TZIA, 2022; KAN; MILLER, 2022). Furthermore, synthetic coatings films may pose health risks due to the potential migration of harmful molecules into the food (GUPTA *et al.*, 2024).

Cheese is predominantly consumed dairy product worldwide. According to the USDA, in 2024, global domestic cheese consumption reached 21.8 billion tons, with Brazil accounting for 837 million tons (USDA 2024). As a perishable food, cheese is susceptible to contamination during production, storage, and transportation by various microorganisms, originating from multiple sources. Thus, appropriate packaging is essential to enhancing storage conditions and preventing deterioration.

Cheese packaging has become a critical concern in the cheese industry and market. Determining the most suitable packaging involves balancing functionality, sustainability and food safety considerations while accounting for factors such as the type of cheese, storage conditions, consumer preferences and shelf-life requirements (EL-SAYED; YOUSSEF, 2024).

In order to minimise this impact, various alternatives have been developed and tested, including edible films and coatings made from proteins, polysaccharides, lipids and composites derived from natural sources (MOHAMED; EL-SAKHAWY; EL-SAKHAWY, 2020).

Among protein-based films, those made from gelatin have been extensively studied in recent years (COZMUTA *et al.*, 2015; LEE; LEE; SONG, 2015; BONILLA; SOBRAL, 2019; JRIDI *et al.*, 2020; REYES; LANDGRAF; SOBRAL, 2021; REYES MÉNDEZ *et al.*, 2023). Naturally derived from various animal sources, including pig, cattle, and fish skin, and possessing excellent film-forming properties, gelatin stands out as one of the most promising biomaterials for biopolymers development (RIGUETO *et al.*, 2023).

Despite producing films with good mechanical properties, this material exhibits high permeability to water vapor due to its hydrophilic and hygroscopic nature. Incorporating certain types of lipids into film-forming solutions may correct this while also imparting antioxidant and antimicrobial properties (REYES; LANDGRAF; SOBRAL, 2021). The incorporation

of essential oils has been an example of this, because of its hydrophobic characteristics, it contributes to reduce the permeability to water vapor of the gelatin-based films (LEE; LEE; SONG, 2015; FLORES-MARTÍNEZ 2018; ESPARVARINI *et al.*, 2022). Moreover, the interaction of gelatin with other polysaccharide polymers such as pectin, chitosan and gellan has improved gelatin mechanical properties and water vapor permeability (JRIDI *et al.*, 2020).

Therefore, a literature review and bibliometric analysis was conducted to assess the development of gelatin-based edible films, its application in cheese preservation, and the evolution of this research theme over time, showing the still gaps in the field.

METHODS

DATA SOURCES AND SEARCH STRATEGIES

A literature search was carried out in May of 2025 using the databases Scopus (<https://www.scopus.com/>) and Web of Science (<https://clarivate.com>), with the following combination of keywords: (“*edible film**” OR “*edible coating**” OR “*edible packaging**”) AND (*gelatin**) AND (*cheese*). The search was performed within “Article title, abstract and keywords” in Scopus database, corresponding to “Topic (title, abstract, keyword plus and author keywords)” in the Web of Science database. Only research and review articles were selected, with no restrictions on publication date, to obtain a chronological order of articles published up to the search.

Twenty-six (26) articles were found in the Scopus database and forty-seven (47) in the Web of Science database. The metadata was exported in Comma-Separated-Values (CSV) and plaintext formats for each database, respectively, following the recommendations from the Bibliometrix website (ARIA 2021).

DATA CLEANING

These documents were analysed using the *Bibliometrix* tool (ARIA; CUCCURULLO, 2017) for *RStudio*® 4.4.1 version software. After installing the package in *RStudio*®, the exported data were converted to Bibliometrix format using the “`convert2df(file, dbsource, format)`” command. Duplicated articles were then removed using the “`mergeDbSources(source1, source2,..., sourceN, remove.duplicated = TRUE)`” command, resulting in the exclusion of

twenty (20) duplicated articles. Preliminary reading of the articles titles and abstracts was conducted to eliminate publications that were off-topic. Consequently, an additional twenty-two (22) articles and one (1) erratum were removed, leaving a total of thirty (30) articles selected for bibliometric analysis.

BIBLIOMETRIC ANALYSIS AND VISUALIZATION

Using *RStudio*®, the data were exported to a Microsoft *Excel*® sheet by the “write.table(source, file, sep, row.names = FALSE)” command, creating a CSV file, with a “;” separator. This file was then saved in “.xlsx” format to enable further editing.

The data was summarized and analyzed using the “biblioanalysis(source)”, “summary(object, k)” and “plot(source, k)” commands, where the “k” variable represents the number of top articles to be analyzed. These functions generated tables, plots and general information about the articles included in the resource.

In the next step, the “biblioshiny()” command was executed to perform bibliometric visual analyses of data (figure, plots, tables) across four different level metrics: source, authors, documents and clustering by coupling. So, this enabled an evaluation of the annual production evolution, the main authors and most cited articles, the most relevant countries and sources, word cloud, and other pertinent information.

RESULTS AND DISCUSSION

A total of thirty (30) articles were obtained, published between 2015 and 2025, with an average of 19.93 citations per document.

Research on the use of gelatin-based edible films and its application in cheese showed a significant increase in 2023, with nine (9) articles published, over 4 (four) times the average of publications from previous years (Figure 1). Brazil contributed substantially to this growth, always demonstrating a consistent increase in publications since 2018. However, a decline in global publications was observed in the subsequent year.

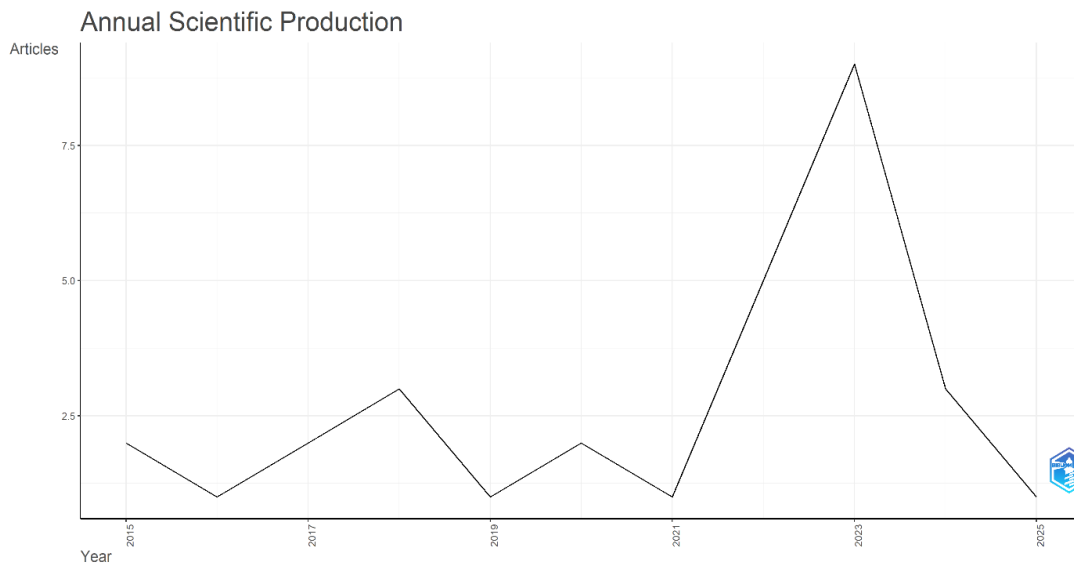


Figure 1. Annual Scientific Production about the use of gelatin-based edible films and its application in cheese. Source: *Bibliometrix* tool (ARIA; CUCCURULLO, 2017).

COUNTRY PRODUCTION

Between 2015 and 2025, 21 countries published about the use of gelatin-based edible films and their application in cheese. Overall, Brazil ranked first with 17 articles on this topic. Portugal and Tunisia followed with six articles each, while Iran, Serbia, and Spain, each contributed four articles (Figure 2). In contrast, countries in Africa, South Asia, and Oceania were considerably underrepresented. Moreover, no studies on gelatin-based edible films and their applications in cheese were published in the United States. However, research in this country has focused on edible films made from whey, chitosan, zein, and others materials (LAKSHMIBALASUBRAMANIAM; TAJVIDI; SKONBERG, 2024; SONGY *et al.*, 2024; CHARLES *et al.*, 2025; DENG *et al.*, 2025).

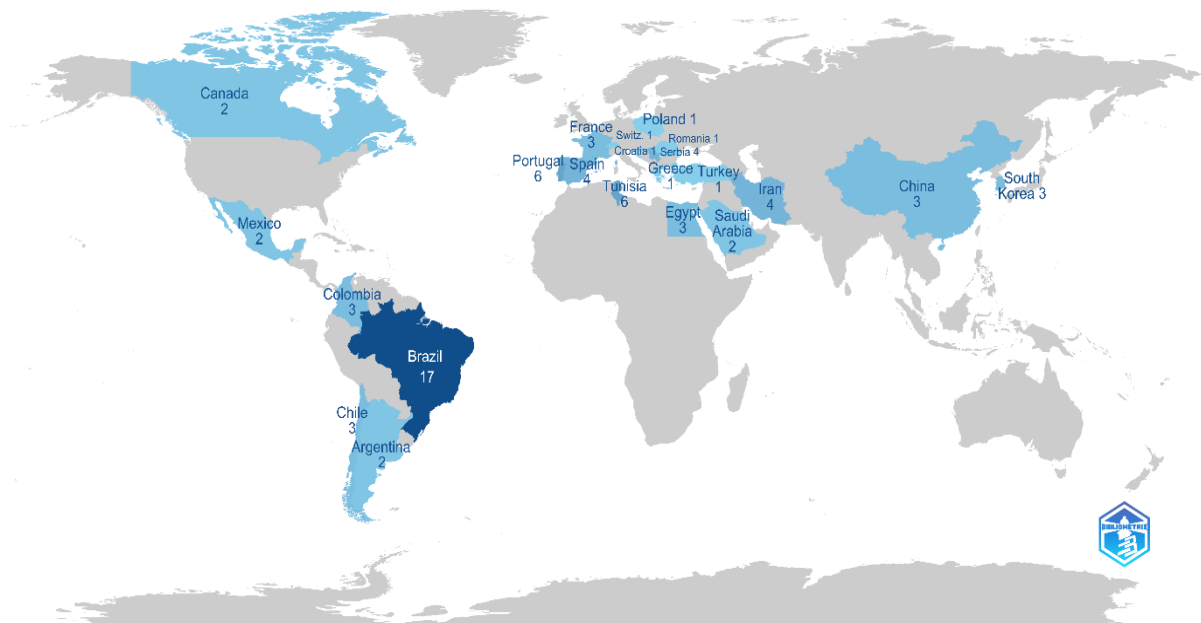


Figure 2. Most relevant countries scientific production about the use of gelatin-based edible films and its application in cheese over time. Source: Author’s adaptation from *Bibliometrix* tool (ARIA; CUCCURULLO, 2017) using Canva tool.

MAIN SOURCES OF ARTICLES

The thirty (30) selected articles were published across twenty-four (24) different sources. Among the most relevant sources (Figure 3), *Food Hydrocolloids* is the top contributor, with 3 articles. Following these, *Food Control*, *International Journal of Biological Macromolecules*, *International Journal of Food Science and Technology* and *Journal of Applied Polymer Science*, each have published 2 articles.

Figure 3 shows the evolution of source production over time. *Food Hydrocolloids* has been the leading journal since 2015, publishing two articles in that year and an additional article in 2020, totaling three publications over the years. The other four sources mentioned earlier each reached two publications starting from 2018.

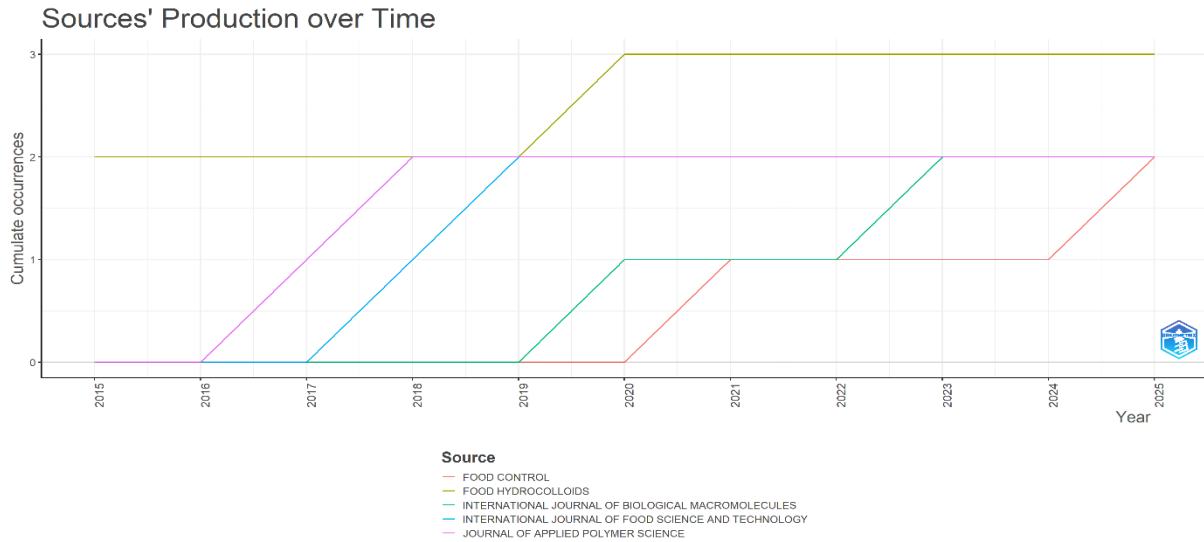


Figure 3. Evolution of source production about the use of gelatin-based edible films and its application in cheese over time. Source: *Bibliometrix* (ARIA; CUCCURULLO, 2017).

PRODUCTIVITY AND IMPACT BY AUTHOR AND INSTITUTION

A total of 140 contributing authors were identified. Among them, the 10 most relevant authors, according to their total citations, are presented in Table 1. They all published 2 manuscripts with h-index 2.

Table 1 - The 10 most relevant authors, according to total citations.

Author	Total of citations
Lee J	142
Abdelhedi O	132
Jridi M	132
Salem A	132
Song K	43
Marceti I	33
Rendueles M	33
Silva C	20
Silva S	20
Teixeira J	20

Source: Author's adaptation from *Bibliometrix* tool (ARIA; CUCCURULLO, 2017).

The author's total of citations parameter represents how many times their articles were referenced in documents indexed within a bibliographic database. Similarly, the article's total citation determines how many times each paper was cited. The h-index quantifies scientific research productivity and impact by correlating scientific publications with the citations they receive.

The author leader of citations, Lee J. is from Republic of Korea, a country that is not listed as a major world producer of cheese. The second and third most cited authors, Abdelhedi O. and Jridi M. are from the same research group in Tunisia.

Figure 4 highlights the top 10 most relevant publications on gelatin-based edible films, ranked by total citations. The leading article is the work by Jridi *et al.* (JRIDI *et al.*, 2020), titled “Physicochemical, antioxidant and antibacterial properties of fish gelatin-based edible films enriched with orange peel pectin: wrapping application”, published in *Food Hydrocolloids* in 2020, which has received a total of 120 citations. This study evaluated the physicochemical, mechanical and thermal parameters of ricotta cheese, as well as the antioxidant and antibacterial capacities of the film. Chemical analysis (pH, color) microbiological assessments (total viable aerobic and psychrotrophic bacteria, yeast, and molds) and textural parameters (hardness, elasticity and cohesiveness) were performed. The study demonstrated improvements in physicochemical and textural properties, as well as enhanced microbial stability of ricotta cheese during refrigerated storage.

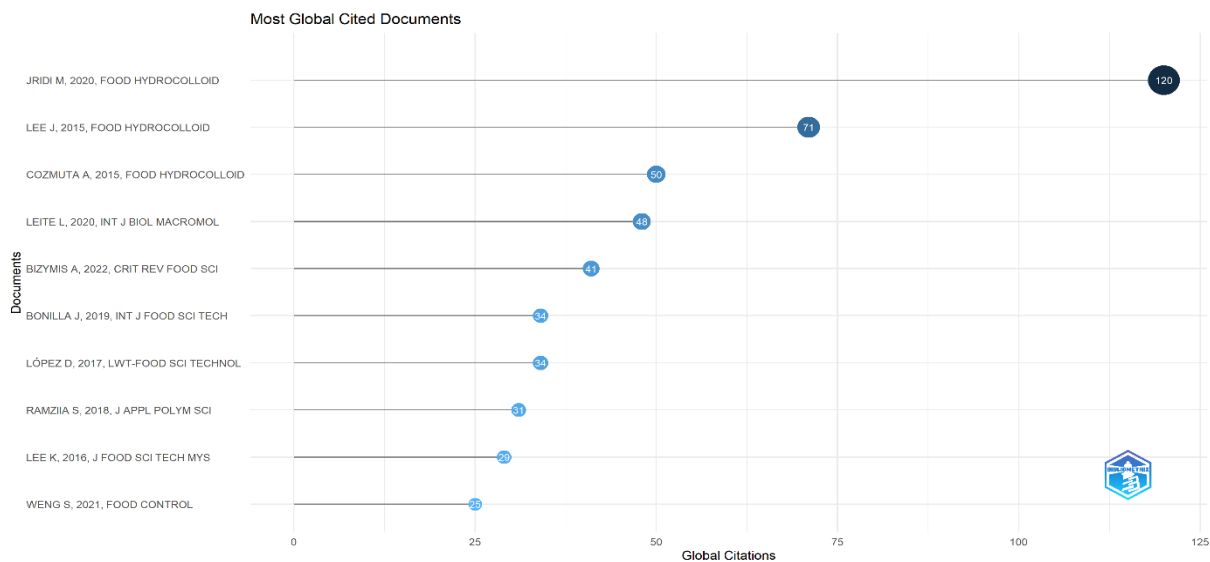


Figure 4. Most global cited articles about the use of gelatin-based edible films and its application in cheese. Source: *Bibliometrix* tool (ARIA; CUCCURULLO, 2017).

The second most cited article, titled “Development of a chicken feet protein film containing essential oils”, by Lee *et al.* (LEE; LEE; SONG, 2015), was also published in 2015 in *Food Hydrocolloids* journal and has accumulated 71 citations. In this study, the addition of marjoram, coriander and clove bud essential oils, imparted antimicrobial activity to the gelatin-based film

against *Escherichia coli*, *Salmonella* Enteritidis, *Listeria monocytogenes* and *Staphylococcus aureus*, with the coriander displaying the best inhibition against all tested pathogenic bacteria. Additionally, the application of these films to sliced cheddar cheese demonstrated notable antioxidant activity.

The most cited keywords in the found articles included “antioxidant”, “edible films”, “coatings”, “gelatin” and “chitosan”. The studies evaluated mainly mechanical, chemical and physical properties, besides the antimicrobial and antioxidant activity of edible films enriched with different essential oils and extracts and seeking to verify its effect in cheese shelf-life (Figure 5).

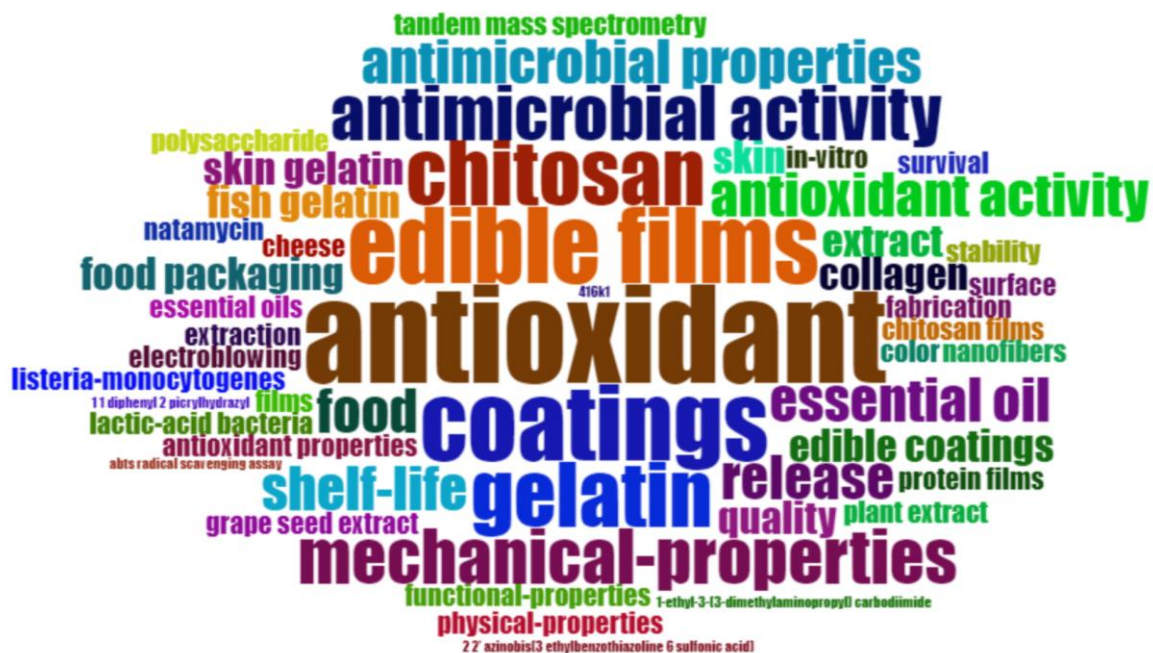


Figure 5. The 50 most cited words in researched articles. Source: *Bibliometrix* tool (ARIA; CUCCURULLO, 2017).

GELATIN SOURCES

The gelatin sources used in the studies were primarily derived from fish skin (LEE; YANG; SONG, 2016; LÓPEZ *et al.*, 2017; RAMZIIA *et al.*, 2018; JRIDI *et al.*, 2020; MEZHOU DI *et al.*, 2022) and chicken bones (LEE; LEE; SONG, 2015; KIM *et al.*, 2018). Various studies incorporated other compounds into the gelatin network, such as chitosan (RAMZIIA *et al.*, 2018; BONILLA; SOBRAL, 2019; HASSAN *et al.*, 2022; REYES MÉNDEZ *et al.*, 2023; ERCEG *et al.*, 2024), cellulose (LEITE *et al.*, 2020),

starch (ESPARVARINI *et al.*, 2022), whey (ANDRADE *et al.*, 2017; SILVA; TEIXEIRA; SILVA, 2023), xanthan (ROFEAL; ABDELMALEK 2023), and beef broth (JANOWICZ *et al.*, 2024). The incorporation of these compounds was shown to enhance the mechanical, chemical, and physical properties of edible films (COZMUTA *et al.*, 2015; LEE; YANG; SONG, 2016; KIM *et al.*, 2018; RAMZIHA *et al.*, 2018; MEZHOUDI *et al.*, 2022; SÁEZ-ORVIZ *et al.*, 2022; REYES MÉNDEZ *et al.*, 2023; ROFEAL; ABDELMALEK 2023).

THE USE OF ESSENTIAL OILS AND PLANT EXTRACT

Furthermore, the studies aimed to verify the use of essential oils and plant extract with hydrophobic characteristics, which not only improve the water vapor barrier but also confer antioxidant (RAMZIHA *et al.*, 2018; JRIDI *et al.*, 2020; HASSAN *et al.*, 2022; MEZHOUDI *et al.*, 2022; DAYISOYLU *et al.*, 2023; AYAR; ELMACI 2024) and antimicrobial properties (COZMUTA *et al.*, 2015; JRIDI *et al.*, 2020; WENG *et al.*, 2021; HASSAN *et al.*, 2022; DAYISOYLU *et al.*, 2023; SILVA; TEIXEIRA; SILVA, 2023).

Sharafi *et al.* (2023) conducted a systematic review and meta-analysis on the use of plant essential oils and extracts in development of antimicrobial edible films for dairy applications. They concluded that it is possible to enhance the shelf life and sensory attributes of dairy products by selecting suitable edible film incorporated with essential oils and extracts at appropriate concentrations.

SHELF LIFE

The reviewed studies demonstrated that the application of these active films improves the shelf life of various types of cheese. Bonilla and Sobral (2019) verified that incorporating boldo extract into gelatin-chitosan film, when applied in sliced *Prato* cheese, provided protection against oxidation, reduced Coliforms development, and inhibited the growth of psychrotrophic microorganisms. Likewise, Lee, Yang and Song (2016) observed antioxidant activity when using *Moringa oleifera* Lam. Leaf extract in films wrapping Gouda cheese. This application not only exhibited antimicrobial activity against *L. monocytogenes* but also retarded the lipid oxidation in the cheese.

Hassan *et al.* (2022) concluded that the use of gelatin-chitosan film fortified with papaya leaf and thyme extract effectively increased the shelf life of Kareish cheese. Furthermore,

gelatin combined with *aloe vera* oil demonstrated antibacterial activity against *E. coli* and *S. aureus* and antifungal activity against *Aspergillus niger* and *Candida albicans* in Kashar cheese. After 20 days of storage, bacterial growth and levels of yeast and mould were log 2.3 CFU/g and log 3.37 CFU/g lower than the control, respectively³⁹. Furthermore, for Kashar cheese, olive oil mill wastewater extract proved to be a novel antioxidant packaging source, as demonstrated by Ayar and Elmaci (2024).

Mezhoudi *et al.* (2022) evaluated the use of *Moringa oleifera* extract in triggerfish gelatin film and observed that after six days of storage, the wrapped Ricotta cheese exhibited a 34% reduction in weight loss, minimal changes in pH, color and texture parameters, as well as reduced lipid oxidation and lower levels of yeast and mould. Similarly, Jridi *et al.* (2020) also verified that incorporating blood orange peel pectin into gelatin film improved the physicochemical and textural properties and microbial stability of Ricotta cheese. Rofeal and Abdelmalek (2023) concluded that combining gelatin, xanthan and *Echinacea purpurea* extract achieved an impressive 95 and 80% reduction in *S. aureus* and *Salmonella enterica*, respectively, after 48 hours of Ricotta storage. These films successfully preserved the properties of Ricotta samples, keeping them much closer to fresh samples in terms of microbiological analysis, visual appearance, pH, and weight loss.

In another study, buriti essential oil incorporated into gelatin films significantly reduced the growth of *Salmonella* spp., *Pseudomonas aeruginosa*, and *E. coli* in Coalho Artisanal Brazilian cheese over 14 days of storage at 5 °C (ANJOS *et al.*, 2023). Additionally, Lee, Lee and Song (2015) reported that incorporating coriander oil into gelatin films significantly inhibited *E. coli*, *S. Enteritidis*, *L. monocytogenes* and *S. aureus* in sliced Cheddar cheese.

GAPS IN LITERATURE

The analysis of the articles revealed that only a few studies included sensory analysis with consumers (ESPARVARINI *et al.*, 2022; HASSAN *et al.*, 2022; AYAR; ELMACI 2024). Although these studies demonstrated good acceptance and improved sensory characteristics of the cheese, various essential oils and extracts can be utilised and it is important to evaluate the sensory attributes and consumer acceptance for each of such compounds. Consequently, further research on this topic may be needed. Moreover, the articles reviewed focused on the

application of films on single types of cheese, making it difficult to generalise their use to other varieties due to the diverse characteristics of different cheeses.

Finally, none of the studies evaluated the cost and economic viability of using these films. Their application was limited to experimental scales, leaving unanswered questions regarding the feasibility of industrial and large-scale implementation.

CONCLUSIONS

The indiscriminate use of plastic packaging in the food industry has raised significant environmental and health concerns. Based on the reviewed literature, the application of gelatin-based edible films and coatings to foods, particularly cheese, appears promising in enhancing shelf life and microbiological safety. Various compounds are being studied to enhance the antimicrobial and antioxidant activity of active films, showing positive effects in their application.

However, limitations of their use include challenges in large-scale industrial applications and the wide variety of cheese types available in the market. Most studies have not included sensory analysis with consumers. Since certain compounds can impart undesirable flavours, odours, or changes in appearance, potentially impacting consumer acceptance, further research is needed. This research should focus not only on sensory analysis but also on the diverse types of cheese to ensure broader applicability and acceptance.

Author contributions

Tatiane Mendonça Nogueira Carneiro de Albuquerque: Conceptualization, methodology, writing – original draft preparation and editing. **Julia Arantes Galvão:** supervision, writing – review and editing. All authors have read and agreed to the published version of the manuscript.

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Conflicts of interest

The authors declare no conflicts of interest.

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