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REVIEW ARTICLE

Exploring goat's milk cheese: A systematic review of production techniques and innovations (2013-2023)

Explorando o queijo de leite de cabra: uma revisão sistemática das técnicas e inovações de produção (2013-2023)

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Abstract

The global demand for milk and dairy products is rising, with cow's milk dominating production. However, goat dairy products have gained attention due to their nutritional value and bioactive components. Goat milk, in particular, is priced attractively, leading to increased interest from producers and investors. Goat milk-based products like yogurt, cheese, and fermented milk are available in the market and prepared using advanced processing technologies. Goat milk's exceptional quality, nutritional composition, and adaptability make it a superior choice, containing essential minerals and vitamins. The gourmet market has elevated goat cheese to a refined culinary delight. Therefore, this systematic review aims to summarize the state of successful research on goat milk cheese production from 2013 to 2023. The bibliographic search was carried out in September 2023 in electronic databases of scientific journals, namely Google Scholar, Science Direct, PUBMED, SCIELO, and Web of Science. Twenty (20) articles were included to discuss results that addressed the research question, meeting the inclusion and exclusion criteria. The content presented provides a comprehensive overview of the cheese manufacturing process, encompassing stages such as filtration, pasteurization, addition of lactic cultures, coagulation (using various methods such as enzymatic, rennet, charcoal, or enzymes), cutting the curd, molding, salting, and maturation. The inclusion of bibliographic references further enhances understanding, highlighting the evolution of practices over time. These contributions are essential for improving the quality and efficiency of goat milk cheese production, offering valuable insights for researchers, producers, and industry enthusiasts.

Keywords: Dairy products; Quality; Production; Functional properties; Goat milk; Cheese.

Resumo

A demanda global por leite e produtos lácteos está em ascensão, com o leite de vaca dominando a produção. No entanto, os produtos lácteos de cabra têm ganhado destaque devido ao seu valor nutricional e aos seus componentes bioativos. O leite de cabra, em particular, apresenta um preço atrativo, despertando um interesse crescente por parte de produtores e investidores. Produtos à base de leite de cabra, como iogurte, queijo e leite fermentado, estão disponíveis no mercado, e são preparados por meio de tecnologias avançadas de processamento. A qualidade excepcional, a composição nutricional e a adaptabilidade do leite de cabra o tornam uma escolha superior, contendo minerais e vitaminas essenciais. O mercado gourmet elevou o queijo de cabra a uma delícia culinária refinada. Portanto, o objetivo desta revisão sistemática foi resumir o estado da pesquisa bem-sucedida sobre a produção de queijo de leite de cabra de 2013 a 2023. A busca bibliográfica foi realizada em setembro de 2023, em bases de dados eletrônicas de revistas científicas, nomeadamente Google Scholar, Science Direct, PUBMED, SciELO e Web of Science. Vinte artigos foram incluídos para a discussão dos resultados que abordaram a pergunta de pesquisa, atendendo aos critérios de inclusão e exclusão. O conteúdo apresentado oferece uma visão abrangente do processo de fabricação de queijo de leite de cabra, abrangendo estágios, como filtração, pasteurização, adição de culturas lácticas, coagulação (utilizando vários métodos, como enzimática, coalho, carvão ou enzimas), corte da coalhada, moldagem, salga e maturação. A inclusão de referências bibliográficas aprimora ainda mais a compreensão, destacando a evolução das práticas ao longo do tempo. Essas contribuições são essenciais para a melhoria da qualidade e da eficiência na produção de queijo de leite de cabra, oferecendo *insights* valiosos para pesquisadores, produtores e entusiastas da indústria.

Palavras-chave: Produtos lácteos; Qualidade; Produção; Propriedades funcionais; Leite de cabra; Queijo.

Highlights

- Surging global interest in goat dairy products
- In-depth understanding of goat milk cheese manufacturing
- Unveiling functional nutrition and health benefits in goat milk cheeses

1 Introduction

The demand for milk and dairy products has been increasing worldwide, especially in developing countries (Cabral et al., 2020). While the dairy sector encompasses a wide array of products crafted through diverse processes, milk stands out as the fundamental raw material driving this industry. Cow's milk dominates global production, comprising roughly 81%, followed by buffalo milk at 15%. Goat, sheep, and camel milk collectively contribute to the remaining 4%. It is estimated that approximately 6 billion people worldwide consume milk and dairy products. In 2018, global milk production increased by 1.6%, with good growth expectations in the coming years, as reported by the (Organisation for Economic Co-operation and Development, 2019). Milk remains the most consumed dairy product, despite the growing demand for cheese consumption (Cabral et al., 2020).

Traditional dairy products are a significant component of contemporary diets. When consumers opt for traditional cheeses, they not only express their concern for the environment and the sourcing of raw materials but also actively contribute to the preservation of tradition and the promotion of economic development (Miller and Lu, 2019). The production of goat dairy products is a prominent global activity, with an increasing significance in the manufacturing of various food items.

In this regard, goat dairy products have garnered considerable attention as they are perceived to be beneficial for a well-balanced diet and the maintenance of health, owing to their high nutritional value and the presence of bioactive components (Hammam et al., 2021). The attractive pricing of goat dairy products, particularly goat milk, has drawn new producers and investors to the field (Miller & Lu, 2019). Nowadays, a wide range of goat

milk-based products is available in the market, including yogurt, cheese, fermented milk, goat milk powder, and others, with the majority of them prepared using advanced processing technologies (Nayik et al., 2021). Furthermore, the unique qualities of goat milk can be attributed to its physiological and biochemical properties, often described as superior to those found in cow's milk (Lad et al., 2017).

The goat yields milk of exceptional quality and displays a remarkable adaptability to both management practices and varying environmental conditions (Catunda et al., 2016). Goat's milk has good nutritional qualities, it is composed of 87% water, 4% lipids, 4% lactose, 3.5% protein, and 1% ash content (Hammam et al., 2021). Additionally, it contains noteworthy mineral content, including calcium, copper, manganese, zinc, and selenium, as well as vitamins A, niacin, and riboflavin (Lima et al., 2016). The lipid profile of goat milk is primarily composed of triacylglycerols (98%), with trace amounts of phospholipids, cholesterol, and free fatty acids. This unique composition, coupled with the presence of small fat globules and a high concentration of medium and short-chain fatty acids, facilitates the digestion process (Taylor & MacGibbon, 2011).

In this sense, cheeses crafted from goat's milk command a premium market value when compared to cheeses made from cow's milk. This is attributed to their superior nutritional quality and the demand for alternatives to bovine milk and its derivatives in cases of nutritional disorders (Ranadheera et al., 2018, 2019). Furthermore, the gourmet product market has elevated goat cheese to a refined, high-value-added culinary delight (Pulina et al., 2018).

Therefore, this systematic review aims to summarize the state of successful research on goat milk cheese production from 2013 to 2023. In addition to discussing the health benefits associated with goat milk cheese components, this review addresses the primary production strategies and tools employed for its enhancement. Given the increasing consumption of goat milk by the population, as people seek the positive effects of caprine dairy products in their diet, this review emphasizes the functional properties of goat milk cheese and explores strategies for maximizing its potential health benefits, based on available literature data.

2 Material and methods

2.1 Systematic literature review protocol

This systematic review followed the PRISMA statement (Moher et al., 2009) and focused on the following question: what are the properties, characteristics, and biotechnological potential for goat milk cheese? The challenge was to identify the properties or attributes of goat milk cheese that could form a foundation or assist in research about the assessment (1) and evaluation of effective practices and the exploration of production possibilities in goat milk cheese studies (2).

The bibliographic search was carried out in September 2023 in electronic databases of scientific journals, namely Google Scholar, Science Direct, PUBMED, SCIELO, and Web of Science. The manuscripts were selected based on the inclusion criteria: articles published in English, Portuguese, or Spanish. They prioritized work from 2013 to 2023. Other duplicate articles that did not meet the inclusion criteria were excluded from this systematic review, as well as unreliable 'publications', such as drafts, website articles, and preprints of submitted articles, scientific reports, and articles by conferences. The selected articles were manually reviewed to identify and exclude works that did not meet the criteria described above.

The following search strategy was performed in the PUBMED database:

#1 - goat milk cheese associated with production processes [Title/Abstract] and/OR functional properties [Title/Abstract] and/OR new products [Title/Abstract] and/OR potential spices [Title/Abstract].

The aforementioned search strategy was adopted in the other databases, independently searching titles, abstracts, and full texts to find relevant studies.

The primary search identified 184 results, 54 from Science Direct, 26 from PUBMED, 6 from SCIELO, 9 from Web of Science, and 89 from academic Google. However, 68 results were indexed in two or more

databases and were considered only once, resulting in 116 articles. After an initial screening of titles, abstracts, full text, and publication time, 20 articles were selected (n = 20), while the others did not meet the inclusion criteria. The illustrated result of the selection of the study is shown in Figure 1 and Table 1.

2.2 Data extraction

The researchers independently extracted information from all included and discussed studies, always seeking consensus on the information. Data extraction was performed in a spreadsheet explicitly developed for the present study. The following variables were extracted: author, year of publication, study design, production process, incubation conditions, parameters, and other relevant information (Table 1).

Corresponding authors were contacted by email when missing data was detected. It was not possible to perform a meta-analysis, as a small number of articles and high heterogeneity among the included studies were detected. Therefore, the results are presented descriptively in tables and figures.

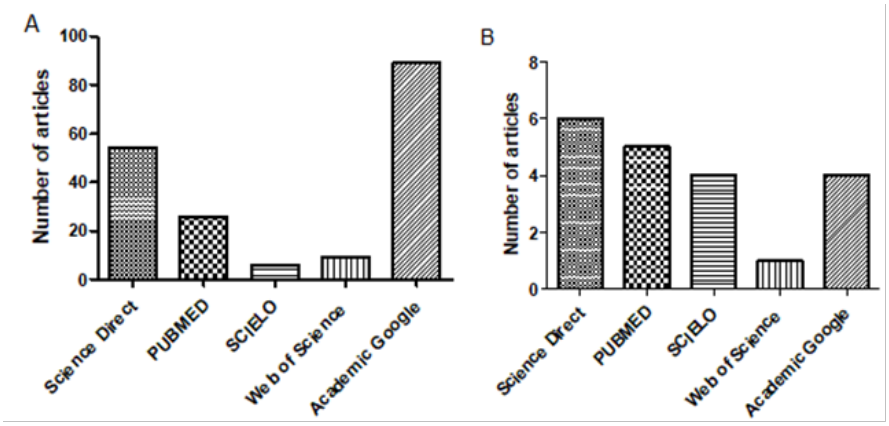

Figure 1. A. Search results of online databases. All results were obtained from four keyword combinations. B. final selection of articles by database.

3 Results and discussions

After the selection of the works, a comprehensive content analysis was conducted. Overall, all works presented a clear and concise structure for the entire research. The methodology was employed to address the initial queries and achieve the proposed objectives in this study. The presentation and discussion of the results occur in this stage of the review, allowing for the synthesis of the published studies and guiding the reflections of the manuscripts to general conclusions regarding the study of goat milk-derived products.

The total number of publications has now reached a significant milestone of 20, demonstrating a noteworthy linguistic distribution: 13 in English, two (2) in Spanish, and five (5) in Portuguese. Examining the temporal evolution, the year 2013 witnessed one publication, followed by two in 2017, 2018, and 2019, one each in 2020 and 2021, three in 2022, and the most recent contributions comprising eight in 2023 (refer to Table 1). These publications encompass diverse geographic regions, with a substantial presence of eight (8) in the Americas, seven (7) in Europe, and five (5) in Asia.

Table 1 provides a comprehensive overview of the cheese manufacturing process, encompassing stages such as filtration, pasteurization, addition of lactic cultures, coagulation (using various methods such as enzymatic, rennet, charcoal, or enzymes), cutting the curd, molding, salting, and maturation. Few studies have addressed packaging as a relevant part of the process, thus highlighting considerations for the preservation and commercialization of the final product. These insights reflect the diversity of approaches in cheese manufacturing, showcasing specific practices adopted across different studies over time. Table 1 and Figure 2 provide a summary of the production of cheese made from goat's milk.

Table 1. Main characteristics and results of the included studies that deal with the activities and quality aspects of goat milk for cheese production.

Filtration and Pasteurization	Addition of Dairy Cultures	Coagulation	Curd Cutting	Molding	Salting	Maturation (or Cured)	Packaging	Author/Year
Not	Yes	$CaCl_2$ and veal rennet	Yes	Yes	Yes	Yes	Yes	Boutoial et al. (2013)
Not specified	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified	Gámbaro et al. (2017)
Not specified	Yes	Not specified	Not specified	Not specified	Not specified	Not specified	Not specified	Bezerra et al. (2017)
Yes	Not specified	Not specified	Not specified	Yes	Not specified	Yes	Yes	Santurino et al. (2017)
Yes	Yes	Not specified	Not specified	Not specified	Not specified	Yes	Not specified	Fernandes et al. (2018)
Not	Yes	Not specified	Not specified	Not specified	Yes	Yes	Not specified	Cais-Sokolińska et al. (2018)
Yes	Yes	Rennet	Yes	Yes	Yes	Not specified	Not specified	Shabbir et al. (2019)
Yes	Yes	Rennet	Not specified	Yes	Not specified	Yes	Not specified	Pazzola et al. (2019)
Yes	Yes	Rennet	Yes	Yes	Yes	Yes	Yes	Cabral et al. (2020)
Yes	Yes	Enzymes	Yes	Yes	Yes	Yes	Yes	Islam et al. (2021)
Yes	Yes	Rennet or enzymes	Yes	Yes	Yes	Yes	Yes	Amaral et al. (2022)
Yes	Yes	Enzymatic	Yes	Yes	Yes	Yes	Yes	Santos et al. (2022)
Yes	Yes	Not specified	Not specified	Yes	Yes	Not specified	Not specified	Ortíz-Deleón et al. (2023)
Yes	Yes	Charcoal or enzymes	Yes	Yes	Yes	Yes	Yes	Mata-Gómez et al. (2023)
Yes	Yes	Rennet	Yes	Yes	Yes	Yes	Yes	Santos et al. (2023)
Not specified	Yes	Proteolysis and enzymes	Not specified	Yes	Yes	Yes	Not specified	Kondyli et al. (2023)
Yes	Yes	Not specified	Yes	Yes	Yes	Yes	Not specified	Baleswaran et al. (2023)
Not specified	Yes	Coal	Yes	Yes	Yes	Yes	Not specified	Levak et al. (2023)
Yes	Yes	Enzymatic	Yes	Yes	Yes	Yes	Yes	Martin & Cotter (2023)
Yes	Yes	Rennet	Yes	Yes	Yes	Yes	Yes	Sesín et al. (2023)

The research addressed a wide range of cheeses and their corresponding production methods, revealing the presence of cheeses made from both raw and pasteurized milk, as evidenced in Table 1. The substantial volume of references regarding the thermal treatment of milk, as noted by Skeie (2014), Fernandes et al. (2018), Mata-Gómez et al. (2023), Ortíz-Deleón et al. (2023), and Amaral et al. (2022), cited in the research, may suggest a current preference or trend in the cheese industry. However, this does not exclude the possibility of cheeses made from raw milk still being present in the market and research.

A notable example is the cheese "Murcia al Vino," mentioned by Boutoial et al. (2013) and their collaborators, which is produced with raw goat's milk. However, it is crucial to highlight that the absence of direct references in the research does not rule out the existence of cheeses made from raw milk. The necessity of milk thermal treatment, as mentioned in the research, may reflect a predominant preference in the current cheese industry, but this does not negate the continuation of production and research on cheeses made from raw milk.

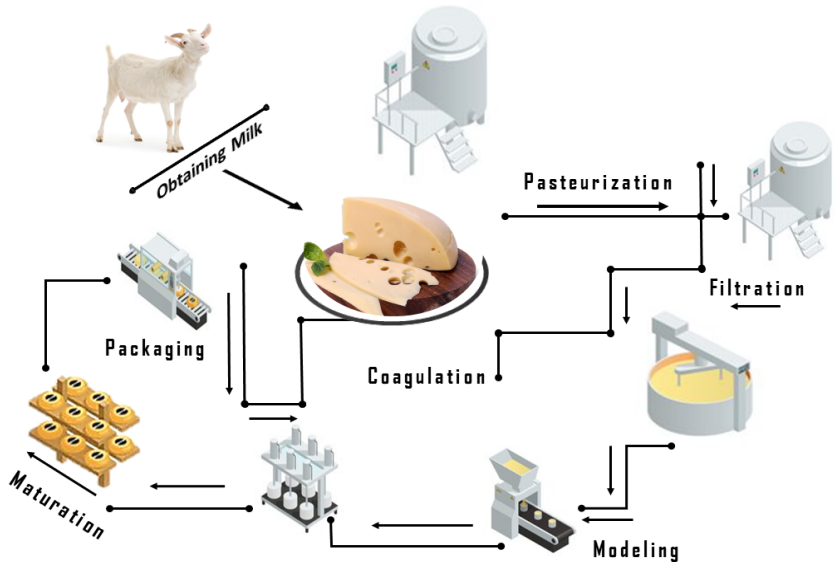

Figure 2. The stages of the goat's milk cheese making process.

The first step in cheese manufacturing is to choose the raw material, that is, the type of milk to be used. Care begins with the animals' diet, handling, milking, and transportation to ensure the quality of the milk. Subsequently, it is necessary to thermally treat the milk to prevent the presence of harmful microorganisms to health. After the selection process, the milk undergoes filtration to remove residues and pasteurization to destroy pathogenic microorganisms, conducted at 72 °C for 15 seconds. The milk is then subjected to the coagulation process, and after the curdling, it is necessary to drain the whey from the milk and separate it from the solid part. The harder the cheese, the more it is necessary to remove whey. In the formation and pressing stage, there are numerous variables such as acidification, cheese moisture, and maturation time, which vary for different types of cheese.

The final step involves the packaging process, ensuring the preservation of its characteristics. With all these precautions and stages completed, the cheese is ready for sale or consumption, attesting to its quality and integrity.

3.1 Exploring the nutritional and functional benefits of goat milk cheese production

Artisanal cheese production from goat milk reflects a rich tradition shaped by local practices and resources. Choosing traditional cheeses goes beyond taste, that is, expressing environmental awareness and dedication to preserving culture and economic development, particularly in resource-limited areas. An intriguing example is the Croatian islands' practice of preserving goat milk cheeses in oil, showcasing diverse preservation methods that impart unique sensory characteristics. The maturation process involves variables like temperature, humidity, and maturation media, influencing biochemical processes and defining cheese's sensory properties. Surprisingly, cheeses aged with animal skin yield distinctive aromas and flavors, emphasizing the complexity and diversity of this gastronomic realm (Levak et al., 2023; Kondyli et al., 2023).

The use of goat milk in this production deserves special attention as it is considered the closest to human milk in terms of specific characteristics. Its smaller fat globules facilitate digestion, and goat milk is often

used as a substitute for those allergic to cow's milk. Additionally, goat milk forms a softer curd, making the digestive process smoother (Levak et al., 2023). Manufacturing technologies and varying maturation periods yield a fascinating array of cheeses, ranging from semi-hard, round-bodied cheeses with dry rinds to those coagulated with rennet. It is necessary to add a starter culture, whose main function is to convert lactose into lactic acid. This process not only affects the texture and flavor of the cheese but can also influence levels of lipolysis and proteolysis (Baleswaran et al., 2023).

Within lactic acid bacteria (LAB), strains of *Lactobacillus*, *Streptococcus*, and *Lactococcus* play a crucial role. The specific use of *L. helveticus* in some varieties of Swiss and Italian cheeses illustrates how the choice of the starter culture can impact maturation, antioxidant activity, and flavor development (Kondyli et al., 2023; Yang et al., 2021). Literature reflects a significant interest in using alternative foods to meet growing needs. Several researchers have attempted to prepare cheese from goat milk, applying various processing parameters (Fernandes et al., 2018; Amaral et al., 2022; Kondyli et al., 2023).

Goat milk stands out among the most consumed animal-derived foods by humanity. It provides calories and essential amino acids in proportions equal to or even higher than those recommended by the World Health Organization (WHO). This food is notable as a source of nutritional and functional value. Its acquisition must occur hygienically, from healthy, well-nourished goats, adequately accommodated (Lima et al., 2023).

The Functional Food Center (FFC) defines "functional foods" as "natural or processed" foods that contain biologically active compounds; which, in defined, effective, and non-toxic quantities, provide clinically proven and documented health benefits using specific biomarkers, to promote optimal health and reduce the risk of chronic/viral diseases and manage their symptoms (Gur et al., 2018). From the analysis of the studies, it was possible to identify that cheese, not only provides nutritional value but also exhibits functional properties beneficial to health (Figure 3).

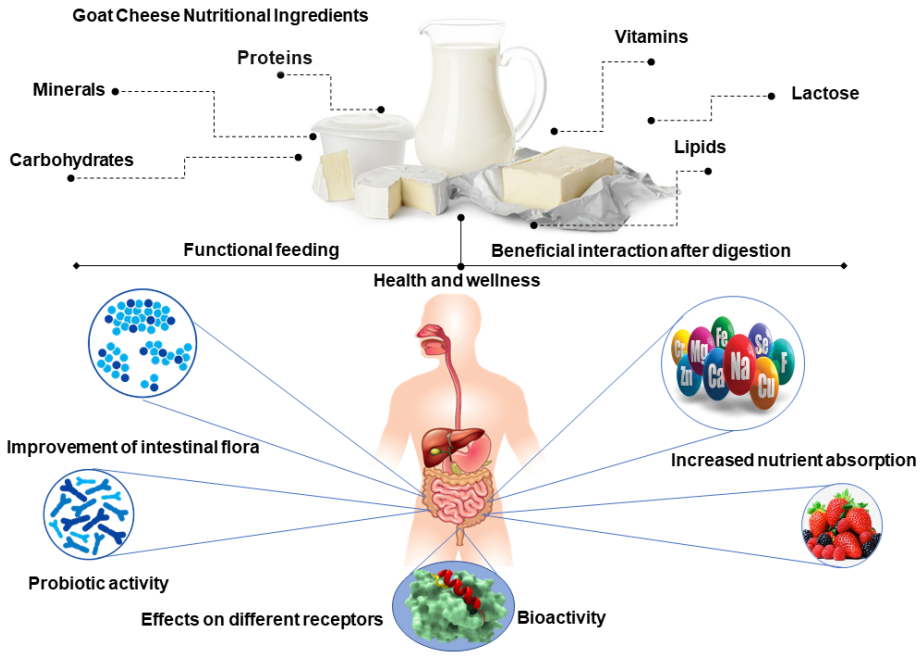

Figure 3. Exploring the benefits of functional nutrition through goat milk cheese production.

Functional foods play a vital role in promoting health and well-being, extending beyond basic nutrition. In this context, goat milk possesses a unique composition, standing out for its high-quality proteins, healthy fats, and lactose. In addition to macronutrients, it is rich in micronutrients such as calcium, phosphorus, and

vitamins B2 and B12. Its fat is characterized by medium-chain fatty acids, providing potential health benefits (Pulina et al., 2018; Ranadheera et al., 2019).

Goat milk also contains bioactives, such as peptides and oligosaccharides, imparting functional properties and contributing to its nutritional relevance and potential innovation in dairy production (Martin & Cotter, 2023; Cabral et al., 2020).

The production of goat milk cheese proves to be an intriguing avenue for exploring the benefits of functional nutrition. The nutritional components of goat cheese, encompassing minerals, proteins, carbohydrates, and lipids, contribute to its distinctive functional feeding profile (Fernandes et al., 2018; Mata-Gómez et al., 2023). Rich in essential minerals such as calcium and phosphorus, goat cheese becomes a valuable dietary source. The proteins present in goat milk are of high quality, offering crucial essential amino acids for various bodily functions (Amaral et al., 2022).

Carbohydrates and lipids play a role not only in providing energy but also in delivering unique health benefits. After digestion, goat cheese demonstrates beneficial interactions, exhibiting probiotic activity that positively influences intestinal flora. The effects on different receptors contribute to a holistic improvement in digestive health (Delgadillo-Puga & Cuchillo-Hilario, 2021; Ortíz-Deleón et al., 2023). By promoting a balanced and diverse intestinal microbiota, goat milk cheese aligns with the principles of functional nutrition, ultimately fostering health and wellness. The combination of these nutritional elements, coupled with the bioactives inherent in goat milk, positions goat cheese as a functional food with the potential to positively impact overall health.

3.2 Production process

The composition of goat milk can vary due to various factors, such as breed, diet, sanitary conditions, management, lactation stage, and climatic conditions (Alves et al., 2020). Its primary consumers are typically children with cow's milk allergies, the elderly, and convalescent individuals who consume it under medical guidance (Lima et al., 2023). The cheese manufacturing process is similar for all types, with minor adjustments in the steps, allowing for the production of cheeses with diverse shapes and distinct flavors. During production, fats and proteins concentrate in the curd, while whey proteins, lactose, and soluble solids are removed along with the whey (Silva, 2023).

In the cheese manufacturing process, four main phases can be identified: coagulation, draining, salting, and aging (Gonçalves, 2019; Boutoial et al., 2013; Cabral et al., 2020; Islam et al., 2021; Mata-Gómez et al., 2023; Dos Santos et al., 2023). Kondyli et al., (2023) emphasized that ensuring product quality is essential for the dairy industry, and this can be achieved through the adoption of Good Manufacturing Practices (GMP), which ensures both quality and food safety (Silva, 2023). The cheese production is directly influenced by two crucial groups of factors: the quality of the milk and the environmental conditions, in addition to the technologies applied in the production process. These conditions encompass the health and proper nutrition of the milk-producing animals, as well as hygiene during milking and milk storage (Gonçalves, 2019; Amaral et al., 2022).

The manufacturing characteristics of cheese play a fundamental role in monitoring the efficiency of operations in dairies, reflecting the relationship between the number of inputs and the results obtained in production (Silva, 2023). According to Silva (2023), in line with the specificities of manufacturing, the percentage yield of cheese represents the amount of cheese obtained from a certain quantity of milk, being the most crucial economic characteristic of the cheese industry. The percentage yield is determined not only by the fat and protein content of the milk but also by the ability of the curd to retain the greatest possible portion of proteins, fats, and available water (Stocco et al., 2023).

The variability in goat milk can lead to inconsistency in cheese production when applied to a large number of goats. This is evident in differences in texture, flavor, and aroma of the cheese due to variations in milk

coagulation and microbial development during the manufacturing process. Therefore, managing this variability is essential to ensure the consistency and quality of the cheese produced (Paschino et al., 2020). However, the manufacturing characteristics of cheeses are often challenging to control, primarily due to logistical issues, especially related to the costliness of sampling and the high expenses associated with analyses (Stocco et al., 2023).

3.3 Coagulation

Curd cheese is characterized as a product resulting from the coagulation of milk by rennet, with or without the involvement of LAB. It exhibits a uniform color, mild flavor, and a subtle acidic aroma, while its shape and weight may vary. The manufacturing process of curd cheese involves several stages, including coagulation, cutting and stirring, partial removal of whey, heating of the curd, salt addition, pressing, turning, packaging, and storage at a temperature between 10 and 12 °C for a period of up to 10 days. It is important to note that, other varieties of cheese, may require a significantly shorter aging or maturation period, or even not require it at all (Silva, 2022).

The coagulation of milk represents one of the most crucial steps in cheese production, involving modifications to the casein micelle through the action of specific proteins. This results in the aggregation of micelles in the presence of calcium. For a considerable period, animal rennet was widely used as a coagulant in the production of most cheese varieties (Jesus, 2023).

This coagulation process is performed by the action of rennet or other suitable agents, followed by the partial draining of whey. This process adheres to the principle that cheese manufacturing leads to a concentration of milk protein, especially in the casein fraction (Rodrigues, 2023).

The discovery of the milk coagulation process occurred accidentally in ancient times when this food was stored in dried animal skins. For a long time, calf stomachs were extensively used as a milk coagulant in cheese production due to the presence of enzymes, particularly chymosin (Lima Júnior, 2022).

3.4 Salting

The salting stage is crucial in the cheese manufacturing process, playing a significant role in defining the physicochemical properties of the final product (Sezer et al., 2019). Salting aims to prevent the deterioration of cheese by exerting its osmotic effect to remove moisture and act as a preservative (Rodrigues, 2023).

Salting is a critical factor contributing to food safety and the suppression of unwanted bacteria that can compromise the organoleptic qualities of cheese (Santapaola et al., 2013). However, excessive salting hinders lactic fermentation, resulting in imperfect maturation of cheeses, with casein not fully unfolding, leading to the formation of brittle cheeses with less plastic characteristics. Various salting methods are employed, including direct application to the curd, direct application to the cheese surface, immersion of the cheese in brine, or a combination of the latter two methods (Rodrigues, 2023).

3.5 Maturation

Cheese maturation can be defined as a series of complex microbiological and biochemical events that lead to the breakdown of chemical components in the product, such as lactose, proteins, and lipids. These processes contribute to the sensory characterization and safety of the cheese (Valente, 2022).

Artisanal cheese, traditionally produced with goat milk, is a product with significant commercialization and a close connection to people. Currently, there is a trend in introducing goat milk into production along with cheese maturation, resulting in products with distinctive characteristics and good sanitary quality (Silva, 2022). The pH is a fundamental parameter that impacts microbial activity, texture, and cheese maturation. This is due to the biochemical modifications in cheese catalyzed by enzymes from the milk and rennet microbiota, with

these enzymes being pH-dependent. Elevated values for this attribute may suggest food deterioration, as they create favorable conditions for the development of undesirable microorganisms (Mota, 2022).

3.6 Microbiological characteristics

Indicator microorganisms can be employed to reflect the microbiological quality of foods concerning shelf life or safety, especially due to the potential presence of foodborne pathogens (Celia et al., 2016).

In dairy products, the presence of microorganisms becomes undesirable when they are not specific to the product and act as spoilage agents. This affects organoleptic and nutritional qualities, reduces shelf life, and compromises the final product's quality (Agnolucci et al., 2020).

The assessment of the quality of these cheeses through microbiological analyses is essential, as they may carry pathogenic microorganisms. The presence of these pathogens contravenes the standards established by legislation, characterizing these products as unfit for consumption (Gargia Junior et al., 2023).

Brazilian legislation does not establish specific identity and quality standards for cheeses produced with goat milk. In situations like this, the evaluation of the microbiological quality of cheeses generally relies on Resolution RDC No. 12, dated January 2, 2001, from the National Health Surveillance Agency (in Portuguese Agência Nacional de Vigilância Sanitária - ANVISA) (Oriente et al., 2023). Ordinance No. 146, dated March 7, 1996, and Normative Instruction No. 30, dated June 26, 2001, from the Ministry of Agriculture, Livestock, and Supply (in Portuguese Ministério da Agricultura e Pecuária - MAPA), establish microbiological parameters for cheeses regarding moisture content.

3.7 Hygienic-sanitary evaluation of artisanal cheeses

The hygienic-sanitary evaluation of artisanal cheeses aims to ensure product quality and safety through a comprehensive assessment of various parameters. Detailed studies, particularly in Table 1, focus on critical aspects like chemical composition and fatty acid profile in goat milk cheeses with different maturation periods. Results reveal significant differences in protein content, saponifiable matter, and fatty acids. The fatty acid profile proves to be a promising marker for distinguishing maturation stages. This underscores its crucial role in characterizing and classifying artisanal dairy products (Fernandes et al., 2018).

Extended maturation periods for artisanal cheeses do not compromise nutritional value; instead, they lead to specific chemical changes enhancing organoleptic characteristics. Precision in determining protein, fat, moisture, and ash, using advanced techniques like near-infrared spectroscopy (NIR), ensures stringent control over product quality. Fatty acid profile analysis, conducted through techniques like gas chromatography (GS), provides crucial insights into the organoleptic and nutritional characteristics of goat milk cheeses, strengthening the scientific foundation in their production (Fernandes et al., 2018).

Lastly, the emphasis on compliance with local and national sanitary regulations, coupled with regular checks on equipment and facility hygiene, underscores the importance of a preventive approach in artisanal cheese production. This diligent practice significantly contributes to minimizing microbiological risks and preserving sanitary integrity throughout the entire production chain, ensuring that cheeses meet the highest standards of food safety (Amaral et al., 2022).

4 Conclusions

Concluding, this review article provided a comprehensive and enlightening overview of goat milk cheese manufacturing. The inclusion of various studies not only enriched our understanding of the diverse approaches in cheese production but also elucidated critical stages such as filtration, pasteurization, coagulation, cutting, molding, salting, and maturation. The meticulous consideration of factors such as packaging for preservation and commercialization underscores the importance of these studies in enhancing

the quality and efficiency of this product. The information presented serves as a valuable resource for researchers, producers, and industry enthusiasts, contributing to the ongoing evolution of goat milk cheese production practices. The detailed exploration of the initial stages, from raw material selection to the final packaging process, emphasizes the care and precision required to ensure the quality and integrity of the end product. This comprehensive synthesis of knowledge reflects the collaborative efforts of researchers and professionals in advancing the understanding and practices in goat milk cheese production.

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