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REVIEW

Cheese industry in Brazil: Innovation, regulation and consumer perception

RENATA GOLIN BUENO COSTA,[1,*] DENISE SOBRAL,[1] JUNIO CÉSAR JACINTO DE PAULA[1] and KENNYA BEATRIZ SIQUEIRA[2]

[1]*Empresa de Pesquisa Agropecuária de Minas Gerais, Instituto de Laticínios Cândido Tostes, R. Tenente Luiz de Freitas, 116, 36045-560, Juiz de Fora, Minas Gerais, Brazil, and* [2]*Embrapa Gado de Leite, Av. Eugênio do Nascimento, 610, 36038-330, Juiz de Fora, Minas Gerais, Brazil*

Background:
Brazil is among the top five milk producers in the world, producing over 35 billion litres annually, while its cheese industry grew more than 26% between 2017 and 2024. The cheese production sector, combined with innovation, legislative updates and changes in consumer behaviour, highlights the importance of scientific knowledge for both the academic community and the dairy industry.

Aim (s):
This review synthesises research published between 2016 and 2026 on industrialised Brazilian cheeses, integrating evidence on technological innovation, regulatory changes and consumer perception to identify key trends and research gaps shaping the sector's scientific and industrial agenda.

Methods:
A systematic literature search was conducted using scientific bases. Current Brazilian regulations and industry statistics were also analysed to contextualise market and regulatory developments, in addition to research on consumer perception of Brazilian industrial cheeses.

Major Findings:
Major research trends were identified across all cheese categories reviewed: (i) healthier reformulations, including sodium and fat reduction and incorporation of probiotics, prebiotics and bioactive compounds; (ii) shelf life extension and safety improvement through technologies such as essential oils, high hydrostatic pressure and active packaging. Consumer perception remains culturally positive and strongly linked to sensory appeal, although concerns regarding salt, fat and price continue to affect purchasing behaviour.

Scientific or Industrial Implications:
The results highlight the importance of technological innovation combined with compliance with regulatory requirements and consumer expectations. The integration of science, industry and consumer behaviour can support the development of healthier, more sustainable and competitive products, strengthening the Brazilian cheese sector.

Keywords Production, Legislation, Advances, Consumer perception, Brazilian cheese.

*Author for correspondence. E-mail: renata.costa@epamig.br

INTRODUCTION

Brazil is among the top five milk producers in the world, behind India, the United States, Pakistan and China (FAO 2025). In 2024, Brazil produced 35.743 billion litres of milk (IBGE 2024), an increase of 2.38% over the previous year (Hott *et al*. 2025). Over the total milk received by industries in Brazil, 36.6% is used to manufacture industrial cheese (Rentero 2025).

Cheese production in Brazil was influenced by European immigrants, such as the Dutch, Danish and Italians, and numerous varieties of cheese originated from Dutch, Italian and Swiss

cheesemaking traditions. However, there were adaptations in production technology and maturation methods that differentiated them from the original cheeses (Cichoscki *et al*. 2002), leading to the development of Brazilian cheeses such as Prato and Reino, which originated from Danbo/Tybo and Gouda, respectively.

Among Brazilian industrial cheeses, there are fresh cheeses such as Minas Frescal and Coalho, matured cheeses such as Minas Padrão and Minas meia cura, Reino and Prato, and processed cheeses such as Requeijão cremoso. These cheeses are intended for direct consumption (Minas Frescal, Requeijão, Minas Padrão) and also indirect as ingredients in ready meals, sandwiches and among others. In 2024, the production of these industrial cheeses in Brazil amounted to 1 416 237 tonnes, representing a 26.7% increase from 2017 to 2024 (ABIQ 2025). Table 1 shows the production of major Brazilian industrial cheeses in 2024.

Despite this significant expansion, no review has yet to synthesise a decade of research on Brazilian industrialised cheeses across the dimensions of technological innovation, regulatory evolution and consumer perception. The present review fills this gap by critically mapping the literature published between 2016 and 2026, identifying convergent innovation trajectories, regulatory transitions and consumer-perception patterns, with the explicit aim of revealing persistent knowledge gaps and opportunities for both research and industry.

METHODOLOGY

A systematic bibliographic search was conducted on Google Scholar, ScienceDirect, SciELO and Web of Science, Scopus, between 2016 and 2026. The search strategy combined cheese-category keywords (Prato, Minas Frescal, Minas Padrão, Coalho, Reino, Requeijão) with methodological and thematic terms (innovation, legislation, consumer perception). Only articles addressing industrialised production using pasteurised milk, published in English, Portuguese or Spanish, were included. Records were screened by title and abstract; full texts were retrieved for all potentially eligible articles. A total of approximately 117 articles were included. Data were synthesised narratively across four thematic axes: technological innovation, regulatory evolution, consumer perception and category comparisons.

Table 1 Production of brazilian industrial cheeses in 2024 (in tonnes).*

Cheeses	2024
Prato cheese	66 133
Requeijão cremoso	174 902
Minas Frescal cheese	39 883
Minas Padrão cheese	18 946
Minas Meia Cura cheese	3397
Coalho cheese	24 715
Reino cheese	4869

Source: ABIQ (2025). * Data obtained from Brazilian dairy industries under federal inspection.

BRAZILIAN INDUSTRIAL CHEESES

Prato cheese

Prato cheese originated from the Dutch cheeses Danbo and Gouda, with characteristics of a semicooked cheese and the use of annatto dye (Sobral *et al*. 2016). It may have no rind or a thin, smooth rind, with no holes or a few small, well-distributed holes and a characteristic flavour and aroma, with a yellowish or straw-yellow colour, and physicochemical characteristics as shown in Table 2 (Brasil 1997b). Prato cheese has functional properties, such as the ability to be sliced and melted (Landin *et al*. 2022a).

Prato cheese can be produced using mesophilic cultures alone or combined with thermophilic cultures. During manufacture, part of the whey is removed and the curd is heated with hot water to 41–42°C, followed by salting either in brine. In fully mechanised systems, heating occurs indirectly; the curd is then fermented to pH 5.4–5.5, crushed and dry-salted, pressed into blocks, cooled, packaged and ripened at 5–10°C (Costa *et al*. 2024a, 2024b).

Regarding technological innovations, studies (Table 3) focussed on developing healthier products, including probiotic and adjunct cultures, sodium and fat reduction, and natural colourants with antioxidant properties, while maintaining sensory and physicochemical characteristics. Also focussed on cheese production are biodegradable and intelligent packaging to improve microbiological safety and sustainability; process optimisation and quality control technologies (spectroscopy and chemometrics) aimed at industrial standardisation.

Coalho cheese

Coalho cheese is a traditional product from Northeast Brazil that has functional properties, such as resistance to melting, flavour and colour development, and a firm texture, which explains its high consumer acceptance (Machado *et al*. 2011). The relatively high pH, combined with proteolysis control by the high salt content, maintains the integrity of the protein matrix, preventing the cheese from melting and losing its original shape when exposed to high temperatures, whether grilled or baked (Machado *et al*. 2011; Costa *et al*. 2018).

During the heating of Coalho cheese, the Maillard reaction occurs, giving it a golden colour that consumers

Table 2 Comparison among Brazilian industrial cheese according to legislation.

	Prato cheese	Coalho cheese	Reino cheese	Minas Frescal cheese	Minas Padrão cheese	Minas Meia Cura cheese	Requeijão cremoso
Heating of curd	Semicooked (<45°C)	No heating, semicooked to cooked (< 55 °C)	Semicooked (<45°C)	No heating	No heating/ Semicooked (<45°C)	Semicooked (<45°C)	Cooked (minimum 80°C/15 s)
Maturation (days)	25 (minimum)	10 (maximum)	35 (minimum)	No maturation	20 (minimum)	10 (minimum)	No maturation
Moisture (% w/w)	36–45.9	36–54.9	≤40	≥55	36–45.9	36–45.9	≤65
Fat in dry matter (% w/w)	45–59.9	35–60	45–59.9	25–44.9	42–57	42–59.9	≥55
Reference	Brasil (1997b)	Brasil (2001)	Brasil (2018)	Brasil (1997a)	Brasil (2020a)	Brasil (2020b)	Brasil (1997c)

appreciate (Sobral *et al*. 2007). Another typical characteristic of Coalho cheese is the crunchiness or chewiness observed during chewing, which is associated with the low elasticity and mechanical resistance of the protein matrix (Sobral *et al*. 2007; Costa *et al*. 2019b).

According to legislation, Coalho cheese has a semihard, elastic consistency, compact texture (without mechanical holes or mechanical opening, which are holes of irregular shape caused by trapped whey) or open texture (with mechanical holes), uniform yellowish-white colour, slightly acidic odour of fresh curd, mild, slightly acidic flavour, which may be salty, thin rind and not very defined (Table 2; Brasil 2001).

Research on Coalho cheese is also focussed on healthy products, just like Prato cheese, involving the use of probiotic cultures combined with prebiotics (Table 4), as well as reduced fat and sodium content. Since it is a cheese with a higher moisture content than Prato cheese, there is significant work in microbiological control, along with the application of advanced technologies, including the combination of packaging and high hydrostatic pressure, in addition to new production technologies and product diversification to enhance sensory acceptance.

Reino cheese

Reino is a typical Brazilian cheese, derived from Dutch Edam, which was formerly imported from the 'kingdom' of Portugal to Brazil, Reino in portuguese means 'kingdom', so the origin of the name. Reino has historical significance for the Brazilian cheese industry, as it was the first ripened cheese produced industrially in Brazil. Reino is a much firmer, drier cheese with a stronger flavour than Edam. The manufacturing process for Reino cheese involves combining thermophilic and mesophilic cultures, as well as adding annatto during milk processing and curd heating, to intensify the colour and flavour, resulting in a firmer, drier and more yellowish cheese, similar to the product originally sold in colonial Brazil (Dutra 2017).

According to the legislation, its physical characteristics include a thin, intact rind without cracks, with a red or pink colour resulting from the product's characteristic painting (Table 2). The use of fuchsin or magenta dyes is permitted, exclusively on the rind, in accordance with specific legislation (Brasil 2018). However, Mercosul revised the list of authorised additives for dairy products, including maturation cheeses such as Reino (Brasil 2024). This update prohibited (with a compliance deadline of October 2025) the use of fuchsin for painting the rind of cheeses such as Reino, Gouda, Prato Bola and Edam. With the removal of fuchsin, it was suggested that edible films replace traditional painting. In addition, the use of the natural dye cochineal carmine is under discussion, with its approval process still ongoing (Silemg 2025).

Although it is a widely consumed cheese, there is not much research on it. Only one study was found during the last decade, which was the microencapsulation of *Lactobacillus acidophilus* in ripened Reino cheese, which conferred the highest viability of the microorganism during maturation, with potential for industrial cheese application (Lopes Neto *et al*. 2021).

Minas cheeses

Minas Frescal cheese and Minas Padrão cheese stand out in the Brazilian dairy sector due to their wide availability and ease of purchase, distinctive sensory qualities and adaptability to industrial production (Paula *et al*. 2011a, 2011b).

Minas Frescal cheese has a soft, smooth texture, a mild odour and a mild or slightly acidic flavour, with the possibility of some mechanical holes (Table 2; Brasil 1997a). Minas Padrão cheese has a semihard consistency, tending to be soft, with a homogeneous colour ranging from creamy white to slightly yellowish, a slightly acidic to mild flavour, and a closed texture with few small mechanical holes (Table 2; Brasil 2020a). Another variation of Minas Padrão cheese is Minas Meia Cura, which gets its name from having half the maturation time. This cheese has an open texture, slightly unctuous mass, with some mechanical holes, a

Table 3 Main research conducted on Prato cheese during 2016–2026.

Key technologies	Main challenges	Recent advances	Future perspectives	References
Adjunct cultures (*Lactobacillus helveticus LH-B02*)	Flavour development; improve maturation, bioactive peptides generation	Enhanced peptide profile; ACE-inhibitory activity (antihypertensive potential); improved proteolysis and sensory characteristics	Functional cheeses	Azambuja de *et al.* (2017); Baptista *et al.* (2020); Baptista and Gigante (2022)
Probiotic incorporation (*Lactobacillus acidophilus L10, Lactocaseibacillus casei L26, Bifidobacterium lactis B94; Lactobacillus casei 01*)	Viability during storage and digestion; sensory properties; health effects	Survival in gastrointestinal tract simulated *in vitro*; results in health outcomes	Functional cheeses	Cordeiro *et al.* (2019); Vasconcelos *et al.* (2019); Calsavara *et al.* (2025)
Sodium reduction and sodium reduction with flavour enhancers	Sensory and proteolysis changes; interference of sodium reduction on probiotic *Lactobacillus casei*-01	Partial substitution without major sensory loss. Use of flavour enhancers; sodium reduction and flavour enhancers allowed the growing of probiotic	Health-oriented reformulation; regulatory compliance	Baptista *et al.* (2017); Costa *et al.* (2018); Silva *et al.* (2018); Balthazar *et al.* (2021)
Fat reduction (whey protein concentrate- WPC)	Texture problems; flavour alteration	Fat reduction and WPC affect the volatile compound cheese.	Low-fat cheeses	Domingos *et al.* (2019)
Standardisation (casein/fat ratio)	Functional and sensory properties	Standardisation (casein/fat ratio) favours functional properties	Standardised manufacturing process	Landin *et al.* (2022a, 2022b)
Biodegradable films with bacteriocins produced for *Lactobacillus curvatus* P99 and edible films (gelatin –chitosan with Boldo extract) in sliced cheese	Microbial contamination; shelf life	Film with boldo extracts enabled significant protection against oxidation, not allow psychrotrophic microorganism growth; microbiological stability. Bacteriocins control *L. monocytogenes* Scott A	Biodegradable and antimicrobial packaging systems	Marques *et al.* (2017); Bonilla and Sobral (2019)
Smart edible coating (whey and anthocyanin from jabuticaba peel- bioactive indicator)	Shelf life	Changes in colour and pH patterns, which gave the coating bioactivity	New packaging	Silva *et al.* (2023)
Process engineering (salting dynamics; CO_2 use)	Process variability; salt diffusion control	Modelling (self-organising map (SOM) combined with the Finite Element Method (FEM), self-organising map (SOM)-type neural networks) improves understanding of salting; CO_2 impacts processing	Process optimisation and industrial scaling	Paula *et al.* (2019); Oliveira *et al.* (2020); Borsato *et al.* (2022)
Spectroscopy and chemometrics (NMR, MIR)	Product authenticity; quality control	Advanced tools enable metabolic profiling of probiotic cheese and fraud detection	Digital quality control and authentication systems	Balthazar *et al.* (2021); Tolentino *et al.* (2023)
Natural colourant (lutein)	Natural yellow food pigment with potent antioxidant properties	Lutein as alternative natural colourant (annatto)	Functional cheeses with antioxidant property	Sobral *et al.* (2016)
Coagulants alternative	Dependence on traditional coagulants	Alternative coagulants (adult rabbit stomach) influence composition, not yield	Innovation in coagulation	Jiménez and Richards (2023)
Exopolysaccharide-producing cultures	Texture properties, yield, sensory characteristics and physicochemical characteristics	EPS improves yield and can change physicochemical properties	New cultures for cheese processing	Nepomuceno *et al.* (2016); Alzate Montoya *et al.* (2019)

Table 4 Main research conducted on Coalho cheese during 2016–2026.

Key technologies	Main challenges	Recent advances	Future perspectives	References
Natural preservatives (essential oils, plant extracts)	Microbial contamination; demand for clean label	Essential oils (orégano) and aqueous extract of passion fruit (*Passiflora cincinnata* Mast.) show antimicrobial effects	Replacement of synthetic preservatives	Costa *et al.* (2020); Bezerra *et al.* (2023)
Microencapsulation of essential oils	Volatility and instability of bioactive compounds; sensory impact	Microencapsulation lemongrass (*Cymbopogon flexuosus*) essential oil controls microorganisms during storage	Advanced natural preservatives	Melo *et al.* (2020)
Active films with controlled release (essential oil)	Rapid loss of antimicrobial activity; uncontrolled diffusion	Cellulosic films incorporating *Cymbopogon citratus* essential oil enable controlled release and improved cheese quality	Alternative package with natural preservative	Oliveira *et al.* (2017)
Advanced preservation technologies (coatings; high hydrostatic pressure- HPP)	Short shelf life; contamination risk	Combined antimicrobial packaging (oregano essential oil) and HPP; bioactive coatings (chitosan, galactomannan + *Cymbopogon citratus* essential oil-based, *Ziziphus joazeiro* fruit pulp) improve safety	Integrated preservation systems (hurdle technology)	Barros *et al.* (2019); Gonçalves *et al.* (2021a, 2021b); Leandro *et al.* (2021); Lima *et al.* (2020)
Probiotic cultures (*Enterococcus faecium*, *Lactobacillus casei* LAFT-L)	Safety concerns	Probiotic viability, with sensory acceptability	Functional cheeses	Machado *et al.* (2021); Leite *et al.* (2021)
Prebiotics (inulin)and synbiotic systems (*Lactobacillus plantarum* + *inulin*)	Developing a product with functional characteristic	Inulin does not affect sensorial properties	Prebiotic and synbiotic product development	Rekowsky *et al.* (2021); Teixeira *et al.* (2024b)
Fat reduction	High fat content; consumer health concerns	Whey protein concentrate viable as fat replacer with texture changes	Low-fat dairy products	Cruz *et al.* (2020)
Sodium reduction	High sodium levels; regulatory pressure	Partial replacement with KCl reduces sodium without sensory loss	Health-oriented reformulation	Costa *et al.* (2018)
Process modification (acidification and new cogulant microbial proteases)	New technologies for production	Acidification controled improves consistency and microbial proteases show technological potential	Innovation in cheesemaking	Merheb-Dini *et al.* (2016); Costa *et al.* (2019b)
Flavouring and product diversification	Market differentiation; sensory acceptance	Alcoholic beverages and marinades enhance sensory acceptance	Premium/gourmet cheeses	Silva *et al.* (2020b); Cavalcanti *et al.* (2023)

straw-yellow to creamy white colour and a characteristic pronounced milky and slightly acidic flavour (Table 2). It can be smoked or flavoured with alcoholic beverages (Brasil 2020b).

The production of Minas Frescal involves the use of lactic acid (20–25 mL/100 L at 85% purity, diluted) or starter, cutting the curd into cubes (2 cm of edge), gentle stirring, moulding without pressure and various types of salting (dry salting, in the mass or brine). The high moisture content (>60%) favours syneresis and a short shelf life (≤2 weeks) due to its high water activity (Paula *et al*. 2011a, 2011b).

Minas Padrão adapts the technology of Minas Frescal with mesophilic starter type O (*Lactococcus lactis* ssp. *lactis/Lactococcus lactis* ssp. *cremoris*), more minor grain cutting (1–1.5 cm of edge), with or without heating up to 45°C, moulding and heavy pressing, acidification to pH <5.6, salting and maturation (Paula *et al*. 2011a, 2011b; Moreira *et al*. 2023).

Research on Minas Frescal has been explored as a vehicle for probiotic cultures and bioactive compounds that promote health, while innovations in preservation technologies have aimed at on overcoming the intrinsic microbiological instability and short shelf life of this fresh cheese (Table 5). The research on Minas Padrão cheese has focussed on healthier formulations, yield optimisation and sensory diversification.

Requeijão

Requeijão is a typically Brazilian product, widely consumed at the table and also used as an ingredient in national cuisine, in the food service sector and in frozen preparations (Sobral *et al*. 2025).

Requeijão is obtained by a technological process of blending a washed and drained (without whey) curdled mass, with or without the addition of cream and butter or butter oil may be used as a source of fat (Table 2; Brasil 1997c).

The technological versatility of Requeijão allows it to meet multiple market demands when used as an ingredient, ranging from products that melt easily to firmer, heat-resistant versions that can be used as fillings in baked or fried products (Sobral *et al*. 2025). Over the years, consumption trends have changed. Just over a decade ago, the formation of strands was considered a desirable characteristic of Requeijão cremoso; today, however, creamy or 'mayonnaise-like' textures have become widely accepted and even preferred by some consumers (Sobral *et al*. 2025).

It is important to note that the addition of starch or vegetable fat is not permitted in products that use the name Requeijão (Brasil 1997c). When these ingredients are used, the product must be labelled as a mixture of Requeijão with vegetable fat and starch, as required by current legislation (Sobral *et al*. 2023). The market also offers variations such as 'Requeijão with cheese', a name accepted by the legislation (Brasil 1997c), which allows the use of cheese trimmings in the category of other food substances (Mosquim 2024). This practice has proven relevant to sustainability and production efficiency, as many dairy industries, when producing sliced cheeses such as Prato cheese and Mozzarella, generate trimmings during cutting and slicing. Thus, Requeijão with cheese scraps emerged as a technological and economic alternative for reusing these scraps, reducing losses and adding value to the final product.

As with other cheeses, research into Requeijão cremoso has focussed on health, with efforts including reducing sodium and fat content and adding probiotics, fibre, new emulsifiers and improved production technologies (Table 6).

RESEARCH ON BRAZILIAN INDUSTRIAL CHEESE

An analysis of research on Brazilian industrial cheeses (Tables 3–6) reveals two innovation trajectories: (a) health-oriented reformulation, encompassing sodium and fat reduction and the incorporation of probiotics, prebiotics; and bioactive compounds; (b) extension of shelf life and improvement of safety through biopreservation, active and smart packaging, and nonthermal or emerging processing technologies. Figure 1 summarises the research on all cheeses, categorising them.

Health-oriented reformulation stands out across all types of cheese analysed for sodium and fat reduction and the incorporation of probiotics. The main challenges in this research would be ensuring the viability of probiotics during storage and simulated gastrointestinal transit, maintaining sensory and physicochemical characteristics, and demonstrating health benefits *in vivo* tests. This research highlights a growing demand for functional dairy products, in line with increasing consumer health awareness.

The second trajectory would be to extend shelf life and improve safety through microbiological controls tailored to the vulnerabilities of each cheese category, such as fresh cheeses with higher moisture content and water activity. There is research involving the use of essential oils and plant extracts, technologies such as UV-C radiation, photodynamic inactivation with curcumin, high hydrostatic pressure (HHP), gamma irradiation, modified atmosphere packaging, biodegradable and antimicrobial films incorporating bacteriocins, essential oil and plant extracts, as well as smart packaging with anthocyanin-based indicators. Research is also being conducted on emerging nonthermal processing technologies, such as ohmic heating and thermosonication, to replace or complement conventional thermal treatments, preserving or enhancing nutritional and sensory properties.

Despite the high volume of research, innovations are predominantly validated at the laboratory scale, concentrated in universities, with little industrial integration and limited industrial scalability. It becomes necessary to progress through the Technology Readiness Level (TRL), moving from the initial levels to the intermediate phase

Table 5 Main research conducted on Minas frescal and Minas Padrão cheese during 2016–2026.

Cheese	Key technologies	Main challenges	Recent advances	Future perspectives	References
Minas Frescal	Probiotic incorporation (*Lactobacillus casei Zhang; spore-forming Wezmannia coagulans* GBI-30)	Viability during storage and physical–chemical, rheological and sensory changes	Demonstrated survival in cheese and bioactive compounds	Functional cheeses with health claims	Dantas *et al.* (2016); Silva *et al.* (2024)
Minas Frescal	Probiotic incorporation (*Lactobacillus casei* 01; *Lactococcus lactis* NCDO 2118; *Pediococcus pentosaceus*)	Viability during storage	Demonstrated survival in cheese matrix; bioactivity (antihypertensive, anti-inflammatory)	Functional cheeses with health claims	Sperry *et al.* (2018); Cordeiro *et al.* (2021); Marques *et al.* (2022)
Minas Frescal	Biopreservation (essential oils, plant extracts, microencapsulation)	Short shelf life; pathogen growth	Oregano, oils; pequi extract; rosemary, pink pepper microencapsulation improves stability	Clean label preservation strategies	Fernandes *et al.* (2017); Moreira *et al.* (2019); Diniz-Silva *et al.* (2020); Ribeiro *et al.* (2025)
Minas Frescal	Advanced preservation technologies (UV-C radiation, photodynamic inactivation using photosensitiser [Curcumin]; gamma irradiation; high hydrostatic pressure and UV-C radiation)	High microbial load; contamination risk; cheese spoilage	Effective inactivation of pathogens (*E. coli*, *S. aureus*, *Pseudomonas fluorescens*; total and thermo-tolerant coliform)and spoilage bacteria; improve safety and extends shelf life	Hurdle technology and industrial application	Saraiva *et al.* (2021); Teixeira *et al.* (2024a); Oliveira *et al.* (2025); Carvalho *et al.* (2026)
Minas Frescal	Ohmic heating and thermosonication	New technology to replace pasteurisation or modulating probiotic metabolism	Maintains physicochemical properties; favours bioactive peptides and bioactive compounds (antihypertensive, antioxidant, antidiabetic activities immunomodulatory, and antimicrobial activities)	Emerging processing technologies for fresh cheeses	Rocha *et al.* (2020); Scudino *et al.* (2024); Barros *et al.* (2025a, 2025b)
Minas Frescal	Packaging technologies (modified atmosphere CO_2, N_2, CO_2–N_2, vacuum) in probiotic survival (*Bifidobacterium animalis* subsp. *lactis* BB-12®)	Shelf life; Probiotic survival	Modified atmosphere improves probiotic survival and stability	Smart packaging systems	Silva *et al.* (2021b)
Minas Frescal	Packaging technologies (pequi waste extract vacuum package and vacuum package + UV-C radiation; modified atmosphere (CO_2 + N_2, vacuum))	Shelf life; microbial growth	Control of psychrotrophs and lactic acid bacteria. Pequi waste extract and vacuum package - alternative preservative method	Smart packaging systems	Cabral *et al.* (2019); Moreira *et al.* (2021)

(continued)

Table 5 (Continued).

Cheese	Key technologies	Main challenges	Recent advances	Future perspectives	References
Minas Frescal	Bioactive compounds (conjugated linoleic acid (CLA), fatty acids profile)	Nutritional quality	CLA-producing bacterial strains (*Lactococcus lactis* subsp. *lactis* LL, *Lacticaseibacillus rhamnosus* LR and *Pediococcus pentosaceus* PP); increased levels of unsaturated fatty acids by supplementing the cows' diet with peanut cake	Targeted functional dairy products	Cerutti *et al.* (2016); Fernandes *et al.* (2025)
Minas Frescal	Antimicrobial metabolites from *Enterococcus faecium*	Pathogen control without synthetic preservatives	Viability probiotic in cheese; metabolites with antilisterial activity	Biotechnological preservation systems; functional cheeses with health claims	Schittler *et al.* (2019); Closs *et al.* (2025)
Minas Frescal	Residues and contaminants (antibiotic monensin, aflatoxin M1)	Safety concerns	Studies on antibiotic residues and aflatoxin M1	Regulatory compliance and monitoring	Silva *et al.* (2020a); Gonçalves *et al.* (2022)
Minas Frescal	Alternative coagulants	Dependence on traditional enzymes	Milk-clotting proteases *of Pleurotus albidus*	Biotechnological diversification	Martim *et al.* (2021)
Minas Padrão	Biopreservation using nanoemulsions encapsulating oregano essential oil	Fungal growth during maturation	Oregano oil nanoemulsions with effective antifungal activity	Application of oregano oil nanoemulsions in Minas Padrão cheese slices	Bedoya-Serna *et al.* (2018)
Minas Padrão	Sodium reduction	Maintaining texture and sensory acceptance	Partial replacement without major quality losses	Development of healthier cheese formulations	Costa *et al.* (2019)
Minas Padrão	Milk production modulation (bovine somatotropin)	Impact on cheese composition and yield	Effects on production performance and cheese characteristics	Integration of primary production and product quality	Ferreira *et al.* (2021)
Minas Padrão	Mineral bioaccessibility (calcium)	Nutritional availability of minerals	Studies on calcium partition and bioaccessibility	Nutritional value of cheese based on calcium bioavailability	Pereira *et al.* (2018)
Minas Padrão	Nonconventional cultures (*Saccharomyces cerevisiae*)	Alternatives for developing flavour and texture in cheese	Yeast application to modulate sensory properties and composition	Hybrid fermentations (bacteria + yeast)	Marques *et al.* (2025)
Minas Padrão	Sensory innovation (coffee incorporation)	Consumer acceptance of unconventional products	Development of differentiated sensory profiles	Premium and specialty cheese	Silva *et al.* (2021a)
Minas Padrão	Incorporation of milk protein concentrate (MPC)	Maintaining physicochemical composition without affecting cheese quality	Addition of MPC (10–20%) increased cheese yield without affecting cheese composition	Improve yield, reduce processing time, and standardise production	Moreira *et al.* (2023)

Table 6 Main research conducted on Requeijão cremoso cheese during 2016–2026.

Key technologies	Main challenges	Recent advances	Future perspectives	References
Prebiotic incorporation (galactooligosaccharides)	Adding functionality without compromising texture	Development of functional processed cheese	Prebiotic dairy products	Belsito *et al.* (2017)
Fat replacement (green banana biomass) and encapsulated *Lactobacillus acidophilus*	Impact on texture and acceptance	Fat replacement and probiotic enrichment	Functional processed dairy products	Pivetta *et al.* (2020)
Enrichment of bamboo shoot powder	Enhance the physicochemical and technological properties	Nutritional enrichment with high source of fibre	Development of healthiness source of fibre and protein	Oliveira *et al.* (2024)
Parcial milk protein substitution with plant proteins (fava beans, peas and lentils)	Increase of the texture parameters	Reformulation with vegetable proteins	Alternative dairy products with plant-based	Rodrigues *et al.* (2021)
Emulsifying salts alternative (bamboo flour)	Alternative substitute for emulsifying salt	Impact on the texture and higher volatile compounds formation.	Alternative emulsifying salt for production	Costa *et al.* (2024a)
Emulsifying salts (phosphates)	Control of water mobility and texture	Influence of phosphate chain length on structure	Optimization of emulsification systems	Viotto and Dias (2016)
Sodium reduction	Replacement of potassium-based emulsifying salt	Partial replacement (50%) without adverse influence sensory quality or physicochemical properties.	Development of healthier cheese formulations	Nogueira *et al.* (2018)
Emerging technologies (thermosonication)	High temperature can affect the nutritional compounds	Replacement of fusion step not affect the gross composition. Softer texture, lighter color, modified fatty acid profile, few effects on the volatile compounds	Promising technology for dairy processing	Moura *et al.* (2024)
Probiotic incorporation (*Lactobacillus acidophilus*; *B. coagulans* GBI-30 6086)	Viability in processed matrix (microencapsulation with spray chilling)	Demonstrated probiotic survival	Functional processed dairy products	Soares *et al.* (2019); Pivetta *et al.* (2022); Silva *et al.* (2022)
Microbiological safety	Presence of spore-forming bacteria	Identification and control strategies	Improved thermal processing and formulation resulting in shelf-stable and safer products.	Oliveira *et al.* (2018)
pH adjustment and sheep milk	Stability, texture properties and colour	Milk type affects texture and structure	Optimise pH tailoring cheese properties	Raimundi *et al.* (2023)
Direct acidification using lactobionic acid (LBA)	Microbial control	Use of organic acids (lactobionic acid) with antimicrobial effect and antioxidant activity	Application of LBA in dairy products	Cardoso *et al.* (2021)

Figure 1 Categorisation of research conducted on Minas Frescal, Minas Padrão, Reino, Prato, Coalho and Requeijão cheeses between 2016 and 2026.

(development and testing—TRL 4–6) until reaching the advanced phase (demonstration and market—TRL 7–9).

BRAZILIAN CONSUMERS' PERCEPTION OF CHEESE

Understanding consumer perception is essential for situating the current and future role of cheese within Brazil's rapidly evolving dairy market. In contrast to the extensive body of literature available for traditional European cheeses, research focussed specifically on Brazilian consumers remains limited. Nonetheless, the evidence to date demonstrates that cheese perception in Brazil emerges from a multifaceted combination of sensory expectations, cultural identity, culinary practices, and emerging health- and sustainability-related concerns. These dimensions interact in complex ways, shaping acceptance, preferences and purchasing behaviour and carrying important implications for product development and market communication.

Recent studies conducted by Embrapa Dairy Cattle (Nogueira *et al*. 2002; Soares *et al*. 2021; Rodrigues *et al*. 2024) provide valuable insights into how Brazilians cognitively and emotionally relate to cheese. These studies also show that cheese consumption in Brazil is higher among men and tends to increase progressively with age, a pattern that helps contextualise perception findings across demographic groups. Overall, findings consistently reveal a strongly positive perception, understood as a favourable consumer evaluation, with taste, pleasure and familiarity emerging as central drivers of acceptance. High-frequency associations such as *tasty*, *delicious* and *good* reflect the primacy of hedonic cues, consistent with international evidence that flavour and texture remain the most influential factors in cheese liking (Santagiuliana *et al*. 2019; Martin *et al*. 2024). In the Brazilian context, Mozzarella stands out as the dominant variety, not only because of its everyday use and compatibility with popular dishes such as pizza, sandwiches and baked foods but also because it is the most-consumed cheese in the country (IBGE 2020). In addition, it is consistently the cheese most readily recalled by consumers when asked about cheese in general. The widespread reference to Mozzarella in consumer studies indicates not only its recognition as a staple cheese but also the combined influence of large-scale production, broad distribution and

high culinary applicability across numerous Brazilian dishes. Together, these factors have helped Mozzarella become deeply embedded in food habits and firmly established in consumers' preferences.

Beyond the central role of sensory attributes, Brazilian consumers often associate cheese with its culinary versatility, describing it not only as an ingredient or a standalone food but also as an important accompaniment in everyday meals. This is consistent with the product's deep integration in domestic cooking and foodservice menus. Words such as pizza, cheesebread, sandwich, coffee and bread are frequently mentioned by consumers alongside cheese, reflecting habitual pairings that position the product within Brazilian eating routines. The strong culinary framing also reinforces the role of cheese as a culturally embedded element, carrying symbolic and emotional associations that go beyond its nutritional profile.

Consumer perception in Brazil is also shaped by regional identity, particularly through the strong association between specific regions and traditional dairy products. This is especially evident in the coexistence of large-scale industrial products and artisanal cheeses with deep cultural roots. In this context, Minas Gerais, the country's largest cheese-producing state, frequently emerges in perception studies as a key reference, reflecting its strong reputation and symbolic connection to cheese production (Cardoso *et al*. 2023). The well-known artisanal cheeses from the region, such as Canastra and Serro, influence how consumers judge cheese in general. Their prestige, historical value and cultural importance create expectations related to quality, authenticity and tradition. This intersection between industrial and artisanal imagery creates both challenges and opportunities: while industrial cheeses must compete with the strong identity of artisanal varieties, they can also benefit from the positive consumers already hold towards cheese as a culturally meaningful food.

Health considerations increasingly influence consumer perception, though to a lesser extent than hedonic and cultural aspects. Negative associations (representing a minority in most datasets) tend to focus on saltiness, fat content, caloric value or digestive constraints such as lactose intolerance. As observed in other emerging dairy markets, these concerns do not necessarily lead to avoidance; rather, they create ambivalent attitudes in which pleasure coexists with precaution. Importantly, these perceptions do not always align with scientific evidence: the literature shows that moderate cheese consumption can be compatible with cardiometabolic health (Mozaffarian 2019; Hu *et al*. 2022; Zhang *et al*. 2023) and that many varieties, especially aged cheeses, contain naturally low lactose levels (Metry *et al*. 2017; Monti *et al*. 2017; Facioni *et al*. 2021). This gap between perceived and actual health impacts indicates the need for clearer, evidence-based communication strategies, whether through labelling, educational campaigns, or product reformulation.

Price sensitivity also shapes perceptions and purchase decisions. Economic factors have historically been strong determinants of dairy consumption in Brazil, particularly among lower income groups (Siqueira and Guimarães 2021). Although cheese benefits from economies of scale, it still remains more expensive than other protein sources or dairy products such as fluid milk and yoghurt. Consequently, price is often cited as one of the few negative associations in consumer studies. Willingness to pay tends to increase when consumers perceive value through flavour, convenience, brand familiarity or alignment with traditional foods (Braghieri *et al*. 2014; Fan *et al*. 2019). This highlights the importance of emphasising cost–benefit, functional attributes and product differentiation to increase consumer confidence and justify price positioning.

Another relevant dimension of perception relates to behavioural economics and nonrational drivers of food choice. Studies demonstrate that cheese consumption in Brazil is shaped not only by individual sensorial preference but also by habits, social norms and affective memory. Foods such as cheese bread (*pão de queijo*) or cheese paired with guava paste (*Romeo e Juliet*) evoke emotional and cultural attachments that strengthen preference through familiarity and tradition. Such associations reveal that cheese operates as part of a social and symbolic system, serving as a marker of hospitality, social interaction and regional belonging. These factors reinforce loyalty to specific categories or brands and influence purchasing patterns.

The coexistence of extrinsic cues, such as packaging, labelling and perceived origin, with intrinsic attributes such as flavour, texture and aroma, also plays a meaningful role. Brazilians often rely on visual cues to assess freshness, quality and authenticity, particularly when choosing among similar products. Innovations in packaging that enhance convenience, safety and shelf life have positively impacted perceptions, especially in urban markets (Taufik *et al*. 2023; Falih *et al*. 2024). At the same time, the growing interest in sustainability and transparent supply chains, although less pronounced than in European contexts, suggests future relevance for cheese positioning linked to environmental impact, nutritional quality and responsible sourcing.

Overall, the consumer perception of cheese in Brazil is positive, multidimensional and culturally anchored, characterised by high hedonic appeal, strong culinary integration and emotional resonance with national and regional identity. Although concerns related to consumer beliefs and nutritional evidence, as well as economic constraints, appear in perception studies, they account for a smaller share of associations than the predominance of hedonic and practical dimensions. For the segment, recognising these contrasting forces is critical. Enhancing communication around health benefits, diversifying product applications and exploring culturally aligned product narratives may reinforce trust and stimulate innovation.

In summary, understanding consumer perception is fundamental for aligning Brazil's cheese production with current and emerging market expectations. It provides opportunities to support product development, strengthen brand positioning, and improve public health messaging. As the Brazilian dairy sector continues to expand and modernise, integrating consumer-driven insights will be crucial to ensuring competitiveness, promoting cheese across diverse dietary patterns and positioning cheeses not only as convenient everyday foods but also as products that can express identity, tradition and quality within a dynamic, evolving marketplace.

CONCLUSION

It can be concluded that innovations in Brazilian industrial cheeses are focussed on health (reduction of sodium and fat, incorporation of probiotics and prebiotics) and safety and extended shelf life (biodegradable films, active and smart packaging, nonthermal processing). In addition, there is a significant amount of laboratory-level research that needs to be tested at the industrial level, with collaboration between academia and industry, to develop products that meet legal and functional requirements for cheese while also meeting consumer expectations.

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AUTHOR CONTRIBUTIONS

Kennya Beatriz Siqueira: Conceptualization; writing – original draft; methodology; writing – review and editing. **Renata Golin Bueno Costa:** Conceptualization; writing – original draft; supervision; visualization; writing – review and editing; methodology. **Denise Sobral:** Conceptualization; writing – original draft; methodology. **Junio César Jacinto de Paula:** Conceptualization; writing – original draft; methodology.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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