Casein: The technological key to processed and analogue cheeses

Technical paper

LACTALIS INGREDIENTS

LACTALIS

SUMMARY

I. Processed Cheese vs. Analogue Cheese: Two Approaches, Two Formulations

The differences in composition and formulation between processed and analogue cheeses, focusing on their respective functional goals and industrial applications.

II. A Changing Global Market: Growth, Geography, and Diversity

Global market trends, regional growth dynamics, and the cultural diversity that shapes product development in the processed cheese sector.

III. Listening to Consumers: Trends and Aspirations

How consumer demand for naturalness, transparency, and innovation is driving changes in product formulation, texture, flavor, and format.

IV. Understanding Cheese Producers' Needs in Processed and Analogue Cheese

The key requirements of manufacturers, including ingredient functionality, cost-efficiency, and ease of integration into production processes.

V. Rennet Casein: The Reference Protein for Formulating Processed and Analogue Cheeses

Rennet caseins as a strategic ingredient, comparing their properties with other protein sources and showcasing their benefits through industrial applications.

VI. Lactalis Ingredients Expertise Supporting Cheese Performance

Lactalis Ingredients' tailored solutions, emphasizing the functional advantages of its casein range and its contribution to cost-effective, high-performance cheese products.

Introduction

In response to evolving eating habits and the growing demand for convenience, variety, and nutrition, the market for processed and analogue cheeses is experiencing sustained growth. These products are valued for their ease of use, long shelf life, and low cost, meeting diverse needs such as snacking, quick cooking, and nutritional reformulation. At the same time, manufacturers face major challenges related to cost optimization and improving the nutritional profile of their products.

In this context, rennet caseins emerge as a strategic technological lever. Derived from the enzymatic coagulation of skimmed milk using rennet, they retain an intact structure, giving them functional properties distinct from acid caseins or caseinates. Their ability to form firm gels, interact effectively with melting salts, and stabilize complex matrices makes them a preferred ingredient for the formulation of processed cheese products.

I. Processed Cheese vs. Analogue Cheese: Two Approaches, Two Formulations

Processed cheeses are made from ripened cheeses to which water, dairy fats, melting salts (such as phosphates and citrates), and optionally other ingredients like milk proteins, starches, or flavorings are added.
The melting process results in a homogeneous, stable, and smooth texture.

Analogue cheeses, on the other hand, are generally composed of casein, vegetable fats, water, melting salts, and may also include cagliata, starch, or texturizing agents depending on the desired characteristics of the final product.

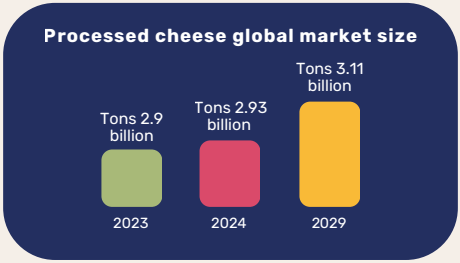
These formulations aim to achieve good stretch, uniform spreadability, and controlled oil exudation, meeting the functional requirements of industrial applications.

II. A Changing Global Market: Growth, Geography, and Diversity

In 2024, the global processed cheese market reached 2.96 million tons, with a stable annual growth rate of +1% over five years[1]. This trend is expected to continue until 2029, reaching 3.11 million tons.

Historically dominated by Europe and North America, the market is seeing Asia and Oceania emerge as strategic regions, with estimated annual growth of +3%, driven by urbanization and the rise of fast food. These regions offer new opportunities for manufacturers.

Consumption habits vary significantly across regions, reflecting distinct cultural and culinary preferences. This diversity drives the development of tailored formats and formulations suited to local markets.



Asia & Oceania
Estimated Annual Growth
+3%

III. Listening to Consumers: Trends and Aspirations

Naturalness and Clean Label: Toward Claimed Transparency

The processed cheese market is shifting toward healthier and more transparent products, in line with the Clean Label trend[2]. Manufacturers are reducing additives like preservatives and artificial flavors, in favor of natural and understandable ingredients, strengthening consumer trust.
Using origin cheeses (Emmental, Comté, Cheddar…) enhances authenticity and taste, while meeting nutritional and sensory expectations such as meltability, stretching, and oil release.

Product Innovation: Textures, Flavors, and Formats in Full Revolution

The processed and analogue cheese segment is evolving through innovations combining taste and convenience. Manufacturers are developing ultra-melting textures for snacking and foodservice, while exploring new flavors such as truffle or curry. Portable formats, such as mini-portions and pods, meet modern usage and enhance category appeal[3].

Street Food Trends: Processed Cheeses as a Driver of Culinary Creativity

Processed and analogue cheeses are becoming essential ingredients in the world of street food and premium fast food. Their melting texture and comforting taste make them ideal for generous and inventive recipes, such as gourmet burgers, reinvented grilled cheese sandwiches, or melty snacks[4]. Their ease of use and performance when heated also make them a perfect base for ready-to-use sauces, especially appreciated in out-of-home catering. This trend reflects a desire to offer rich and accessible culinary experiences, inspired by street food codes while maintaining quality and practicality.

IV. Understanding Cheese Producers' Needs in Processed and Analogue Cheese

Processed cheese and cheese analogue producers operate in highly competitive markets. They must control their production costs without compromising the quality of their products.

Control of formulation costs:

Optimizing formulation costs is a constant concern, especially for processed cheese producers. They have several levers to reduce costs:

- Lowering dry matter content
- Replacing proteins with starch
- Substituting dairy fat with vegetable fat

These formulation adjustments carry risks of altering the texture or taste of the final product. They may also impact the manufacturing process control, for example by affecting the hot texture.

To maintain the quality of the final product and avoid disrupting process control, it is essential to retain key ingredients in the recipe that ensure the technical mastery of production and the final product. Rennet casein, due to its unique functional properties as we will see later, is precisely an irreplaceable ingredient.

Preservation of organoleptic qualities:

Processed cheeses and cheese analogues encompass a wide variety of products, ranging from spreadable to sliceable and shreddable items. Originally, all these products were formulated with very high cheese content. Formula optimization has gradually led to a reduction in cheese content. Nevertheless, there is always a desire to preserve a final product texture similar to that obtained with cheese-rich recipes.

This is especially true for cheese analogues, where the goal is to replicate all the properties of block mozzarella. The product must be firm and shreddable, melt when heated, and exhibit a stringy behavior once melted.

V. Rennet Casein: The Reference Protein for Formulating Processed and Analogue Cheeses

As a preliminary remark, let us establish a simple fact: rennet casein is produced using the same manufacturing principles as those used to make traditional cheeses, which are themselves used in the preparation of processed cheeses or as pizza toppings. Indeed, just like in traditional cheesemaking technologies, rennet casein is obtained by the action of rennet on milk. More precisely, skimmed milk is used, resulting in a fat free curd that is then washed to remove lactose and soluble minerals, and finally dried.

Based on this observation, it is easy to see that rennet casein is the ideal ingredient for providing protein in processed cheese or pizza cheese analogue recipes. This is indeed the case, and we will detail here the functionalities provided by rennet casein in these products. We will also explain the mechanisms by which these functionalities can be controlled.

> Rennet casein is the ideal ingredient for providing protein in processed cheese or pizza cheese analogue recipes.

V. Rennet Casein: The Reference Protein for Formulating Processed and Analogue Cheeses

1. Hydration and Solubilization of Rennet Casein: A Necessary Step to Enable Functional Expression

Rennet casein is essentially a fat free cheese curd with specific characteristics: it is not ripened (the casein undergoes no secondary proteolysis), it is drained and washed (making it a purified casein), and finally it is dried. Rennet casein is presented as a powder, with particle size varying depending on the drying technique used and any sieving or grinding operations applied afterward.

To express its functionalities, rennet casein must be rehydrated and solubilized—this is an essential prerequisite. We have characterized the hydration kinetics of rennet casein using an internal method (see graph below).

This graph shows that at 30°C, hydration of rennet casein in a sodium citrate solution begins only after about 9 minutes and continues for several more minutes before completion. In a processed cheese or cheese analogue manufacturing process, this is a critical point: it is necessary to allow a mixing time before initiating cooking to enable powder hydration and subsequent solubilization of the caseins contained in the powder.

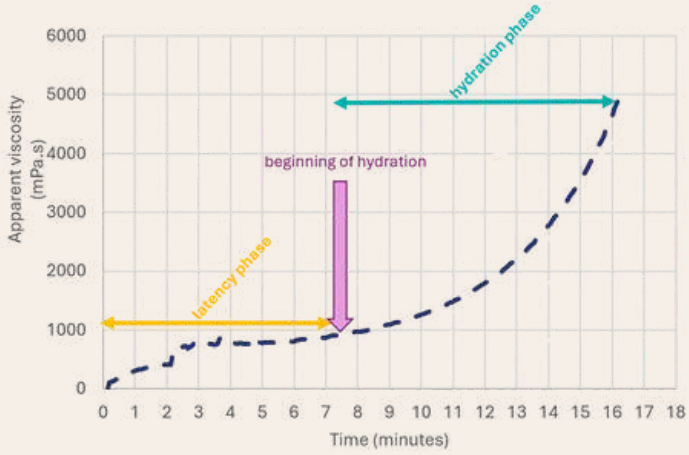


Figure 1 : Hydration kinetics of rennet casein dispersed in a solution of trisodium citrate

Rennet casein at 10 g/l, trisodium citrate over the threshold concentration to obtain maximum peptization, and temperature maintained at 30°C.

V. Rennet Casein: The Reference Protein for Formulating Processed and Analogue Cheeses

2. Peptization of Caseins

Rennet caseins combined with melting salts solubilize into sodium or potassium para-caseinate (depending on the type of melting salt used): this is the mechanism of casein peptization.

Chelation of micellar ionic calcium (Ca^{2+}) by melting salts and its substitution by monovalent cations (Na^{+} or K^{+}) breaks the calcium phosphate bridges that maintain the structure of the casein micelle. This results in micelle expansion and the release of smaller protein fractions.

When the melting salt dosage is sufficient to achieve complete peptization, the casein solution becomes transparent. The small particles formed by para-caseinate fractions no longer scatter light as native casein micelles do, which gives the initial solution its white appearance. (Figure 2)

Figure 2 : Pictures of casein solution (10 g/l) with increasing additions of melting salts

The initial white solution (due to the size of the native casein micelle) gradually becomes transparent (due to size reduction which reduces light scattering).

The peptization mechanism applies to caseins regardless of their source: whether from milk, cheese, or rennet casein powder. However, the peptization rate depends on the source of casein. In this regard, rennet casein has an advantage: it allows for a peptization rate of 100% (compared to a maximum of 80–85% when casein is provided by cheese, such as cheddar).

3. Emulsifying Properties of Rennet Casein

Processed cheeses and cheese analogues are recombined products, incorporating various ingredients and additives, including fat, which must be dispersed and stabilized in an oil-in-water emulsion.

Once rennet caseins have been solubilized and peptized, they provide emulsifying properties that help stabilize the added fat. In the form of sodium or potassium para-caseinate, rennet casein exhibits excellent emulsifying capabilities, comparable to those of caseinates, which are considered the benchmark for evaluating the emulsifying properties of proteins.

This functionality allows for the stabilization of fat droplets during the cooking process and enables the reduction of fat globule size when mixing is prolonged or when agitation speed is increased.

V. Rennet Casein: The Reference Protein for Formulating Processed and Analogue Cheeses

4. “Creaming” of Caseins

Technologists overseeing the production of processed cheeses know how to detect the increase in viscosity that indicates the product has undergone the desired “creaming” reaction, which facilitates hot dosing of the product.

Creaming is a process of protein aggregation under heat. Caseins, which contain non-polar amino acids in their sequences, have the ability to form hydrophobic bonds with one another, leading to aggregation and, consequently, an increase in viscosity.

Creaming occurs under the influence of temperature (ideally around 80°C) and moderate mechanical agitation. It requires a prior activation time and stabilizes at a certain viscosity level. This activation time can be shortened by adding a “rework” product—that is, a product that has already undergone creaming.

The creaming plateau only lasts for a limited time (typically around 20 minutes), because beyond that, the ongoing protein aggregation is no longer offset by shear forces, leading to a renewed increase in viscosity.

This “over-creaming” must be avoided to ensure proper process control (especially maintaining optimal viscosity for hot dosing) and to preserve the texture of the final product after cooling.

The figure below illustrates the complete melting process, which includes both peptization and creaming.

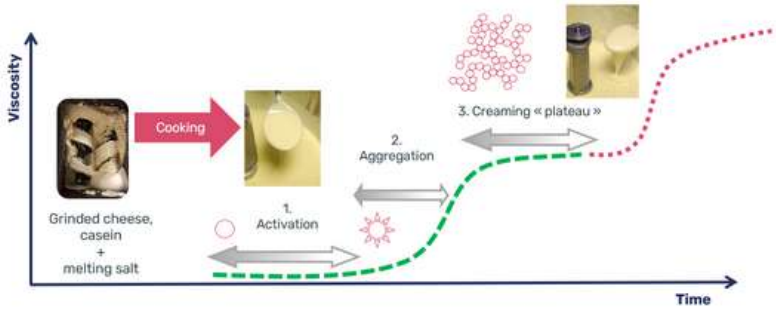


Figure 3 : Illustration of the mechanisms involved during manufacturing of processed cheese

V. Rennet Casein: The Reference Protein for Formulating Processed and Analogue Cheeses

5. Stretching Capability: Essential for Producing Mozzarella Analogues

Mozzarella and other pasta filata cheeses have a distinctive fibrous texture. This fibrous structure results from the organization of the protein matrix, achieved through a thermomechanical stretching treatment applied to the raw curd (called cagliata): cooking at approximately 65°C combined with mechanical stretching.

This stretching process transforms the protein gel structure. Initially, cagliata has a disordered gel structure composed of aggregated casein micelles. After stretching, these micelle aggregates are reorganized into aligned fibers. The figure below clearly illustrates this transformation.

To achieve this unique texture, two conditions must be met:

- The curd used for stretching must be a cheese curd composed of caseins
- The caseins in this curd must be partially demineralized (decalcified) to allow fiber formation. In traditional mozzarella production, demineralization is achieved through controlled acidification.

In the production of cheese analogues, rennet casein replaces the partially demineralized cheese curd. Demineralization of rennet casein is achieved by adding an appropriate dose of melting salts to reduce micellar calcium content, producing an effect similar to controlled acidification in cagliata.
Among the various milk proteins available as protein ingredients, rennet casein is the only one that enables replication of the stretching process. This makes it an irreplaceable protein ingredient in the formulation of pizza cheese analogues.

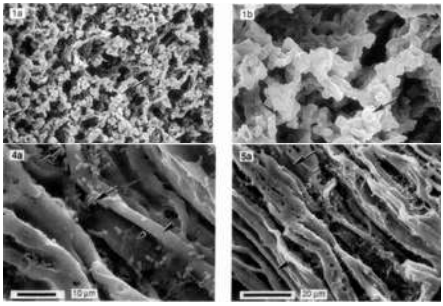


Figure 4 : Microstructure of mozzarella cheese during manufacture
From C. J. Oberg et al., Food Structure, vol. 12 (1993), pp. 251-258

1a and 1b: scanning electron micrographs of Mozzarella curd sampled at 10 minutes heating at 40,5°C
4a and 5a: scanning electron micrographs of Mozzarella cheese curd after stretching

V. Rennet Casein: The Reference Protein for Formulating Processed and Analogue Cheeses

6. Melting and Stretching Behaviour of Cheese Analogues

In addition to cold texture, cheese analogues are also expected to replicate the hot texture of block mozzarella, particularly its melting behaviour, which ensures even coverage on pizza, and its stretchability when slices are pulled apart.
Rennet casein enables the reproduction of this hot texture. However, achieving the desired result requires careful optimization of both the formulation and the cooking process.

Two key formulation parameters must be considered:

- **Choice of emulsifying salt:** It must promote peptization without encouraging creaming, as excessive creaming can hinder melt flow and spreading during heating.
- **pH adjustment:** pH has a direct impact on the firmness, meltability, and stretchability of the analogue cheeses.

It's also important to note that different recipe bases require different emulsifying salt dosages and pH settings. Based on extensive trials, we have developed optimized formulations for three main recipe bases, which cover a wide range of applications:

- **A formulation based on rennet casein and vegetable fat**
- **A formulation based on rennet casein, starch, and vegetable fat**
- **A formulation based on rennet casein, cagliata, starch, and vegetable fat**

While we do not present these optimized recipes here, they are available upon request for clients interested in further discussion.

VI. Lactalis Ingredients Expertise Supporting Cheese Performance



At Lactalis Ingredients, we offer a range of rennet and acid caseins specifically developed to meet the needs of processed and analogue cheese manufacturers. Derived from a controlled enzymatic coagulation process of skimmed milk, our caseins retain a structure that ensures optimal functional properties.

Thanks to their complete functional profile, our rennet caseins help reduce formulation costs by limiting the use of expensive additives. Compatible with melting salts, they integrate easily into a wide range of recipes, from economical products to premium processed cheeses.

A Range Adapted to Industrial Needs:

Our portfolio includes several casein references distinguished by:

- Excellent melting capacity, ensuring a smooth and homogeneous texture
- Good stretch, ideal for snacking and fast-food applications
- Enhanced thermal stability, reducing oil exudation and visual defects
- High texturizing power, effectively structuring cheese matrices

Conclusion

Rennet casein stands out as a cornerstone ingredient in the formulation of processed and analogue cheeses, offering unmatched functional versatility.

Its ability to undergo complete peptization, stabilize emulsions, and support thermomechanical transformations makes it indispensable for achieving the desired textures, meltability, and stretchability in modern cheese applications.

As consumer expectations evolve toward cleaner labels, enhanced convenience, and culinary creativity, rennet casein provides manufacturers with a reliable and cost-effective solution to meet these demands.

With its proven performance across diverse formulations and its compatibility with industrial processes, rennet casein continues to drive innovation and quality in the cheese sector.

Bibliography

[1] Global Data. Data from the retail sector.

[2] Dairy Reporter. Clean label dairy and consumer attitudes. April 25, 2024. Available at: https://www.dairyreporter.com/Article/2024/04/25/clean-label-dairy-and-consumer-attitudes/

[3] FoodNavigator. Market trends. Accessed July 16, 2025. Available at: https://www.foodnavigator.com/News/Market-trends/

[4] Bokkala PR. Fusion foods catch consumer fancy in Asia, says GlobalData. GlobalData. September 19, 2024. Available at: https://www.globaldata.com/media/consumer/fusion-foods-catch-consumer-fancy-asia-says-globaldata/

Lactalis Ingredients
15 Rue de l'Etang • ZA Les Placis • CS30016 • 35230 BOURGBARRE Cedex • France
Tel: 00 33 2 99 26 63 33 email: lactalisingredients@fr.lactalis.com

www.lactalisingredients.com