



## Review

# Processed cheese contamination by spore-forming bacteria: A review of sources, routes, fate during processing and control



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## ABSTRACT

**Background:** Processed cheese is produced by blending natural cheese of different ages and degrees of maturity in the presence of emulsifying salts and other dairy and nondairy ingredients, followed by heating and continuous mixing to form a homogeneous product with an extended shelf life. However, due to the thermal processing applied and the extended shelf life, spore-forming bacteria may result in safety and stability issues.

**Scope and approach:** The primary sources of contamination by spore-forming bacteria, routes of contamination and their fate throughout the processing and storage of processed cheese and analogues are reviewed. In addition, the main consequences of the survival and growth of these organisms in processed cheese are discussed. Lastly, aiming to ensure the quality and safety of processed cheese, strategies for controlling spore-forming bacteria from farm to processing and storage are highlighted.

**Key findings and conclusions:** The main bacterial genera found in processed cheese are *Bacillus* spp. and *Clostridium* spp., which is due to their wide presence in milk and the dairy farm environment as well as their abilities to form spores and withstand harsh processing conditions. Knowledge of the spore diversity in processed cheese and their responses to efforts used to increase the product's stability are critical for developing more stable formulations.

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## 1. Introduction

Processed cheese can be characterized as a viscoelastic matrix, the basic material of which consists of cheeses at different stages of maturity. It is made by using a wide range dairy (e.g., cream, butter, anhydrous milk fat, curd, milk powder, whey powder, caseinates) and nondairy ingredients and additives (e.g., hydrocolloids, coloring, sensory active mixtures), which are applied to modify the content (e.g., DM content, fat content, protein content) or functional properties of the product (e.g., firmness, meltability) (Nagyová et al., 2014). Processed cheeses are manufactured in many countries, offering numerous variants that have different denominations such as 'pasteurized', 'emulsified', 'pasteurized blended', 'American', 'cooked' or 'sterilized' cheese (Tamime, 2011).

In addition, processed cheese products are available in many different versions, including pieces, slices, and individually packaged portions such as snacks, cups and tubes (Kapoor & Metzger, 2008).

Processed cheese is among the leading cheese varieties consumed worldwide, and its popularity can be attributed to its numerous end-use applications. Indeed, processed cheese is widely used as an ingredient in various food preparations (processed foods and food service) (Kapoor & Metzger, 2008). According to the standards of the U.S. Food and Drug Administration, only products prepared using natural cheese and salts ( $\leq 3\%$  w/w) with a certain level of moisture ( $< 43\%$  w/w) and fat content (more than  $47\%$  w/w) can be categorized as processed cheese (Ferrão et al., 2016). Processed cheeses can essentially be classified into three categories: processed cheese (PC), processed cheese food (PCF) and processed cheese spread (PCS) (Kapoor & Metzger, 2008), which differ with regard to the raw material and emulsifying salts employed as well as the fat and moisture contents of the final product (Table 1). In

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**Table 1**  
Classification and characteristics of the major categories of processed cheese and “requeijão”.

Category	Major and optional ingredients	Moisture (%w/w)	Fat (%w/w)	pH	Example
Processed cheese (PC)	Cheese Emulsifying salts ( $\leq 3\%$ (w/w) of the final product) Acidifying agent Cream, anhydrous milk fat, dehydrated cream (weight of the fat derived is $\leq 5\%$ (w/w) of the final product) Water, salt, coloring, spices or flavorings, mold inhibitors	$\leq 40$	$\geq 30$	$\geq 5.3$	Pasteurized processed sandwich slices
Processed cheese food (PCF)	Cheese ( $\geq 51\%$ (w/w) of the final product) Other optional ingredients and their permitted levels include all of the ingredients allowed in PC in addition to milk, skim milk, butter milk and cheese whey	$\leq 44$	$\geq 23$	$\geq 5.0$	Pasteurized prepared cheese product
Spread processed cheese (SPC)	Cheese ( $\geq 51\%$ (w/w) of the final product) Other optional ingredients and their permitted levels include all of the ingredients allowed in PCF in addition to food gums, sweetening agents and nisin ( $\leq 250$ ppm of the final product)	44 to 60	$\geq 20$	$\geq 4.0$	Pasteurized processed cheese spread
Requeijão	Obtained by fusion of a curd mass, washed, obtained by acid coagulation and/or enzymatic coagulation of the milk with or without addition of cream and/or butter and/or anhydrous fat.	$\leq 60$	45.0 to 54.9	–	–
Spread requeijão	Obtained by fusion of a curd mass, washed, obtained by acid coagulation and/or enzymatic coagulation with cream addition and/or butter and/or anhydrous fat of milk and/or butter oil.	$\leq 65$	$\geq 55.0$	5.2 to 5.7	–
Butter requeijão	Obtained by prolonged fusion of a curd mass with stirring of a mixture of butter and curd mass and whole milk mass or skimmed milk mass.	$\leq 58$	25.0 to 59.9	–	–

Brazil a variety of processed cheese called “requeijão” is produced, which originated from home fabrication making use of the spontaneous coagulation of milk due to the action of natural milk microbiota (Reyes, 2008). Presently, “requeijão” is produced from raw or pasteurized skim milk, with or without addition of milk culture, and can be classified into three types: “requeijão”, “spread requeijão” and “butter requeijão” (Table 1).

The microbiological stability and safety of processed cheese depend upon the quality of the ingredients used, the intensity of heat treatment, the packaging material and packaging technology and the storage temperature conditions (Glass & Doyle, 2005). Considering that processed cheese has a pH value  $> 4$ , microbiologically stable products with a long shelf life can only be obtained if heat sterilization is applied; however, if the treatment is mild (pasteurization), processed cheese needs to be refrigerated after production (Tamime, 2011). Mild heat treatment inactivates vegetative cells of foodborne pathogens and spoilage organisms (Zwietering, De Wit, & Notermans, 1996). In contrast, spore-forming bacteria can survive, which represents the major challenges for the quality and safety of processed cheeses (Glass & Doyle, 2005). Therefore, ensuring the microbiological safety and stability of processed cheese are important considerations for the cheese-making industry to supply the growing market demand for this product (Cusato et al., 2013; Dias et al., 2012; Kapoor & Metzger, 2008).

Spore-forming bacteria are dairy industry contaminants, and these microorganisms might be responsible for severe economic losses (spoilage) and foodborne disease outbreaks (Gómez-Torres, Ávila, Gaya, & Garde, 2014). However, the effective control of these bacteria in processed cheese remains a challenge due to the limited knowledge about their sources and routes of contamination

as well as fate during processing (Ledenbach & Marshall, 2010). The most common spore-forming bacteria found in dairy products belong to the genera *Bacillus* and *Clostridium*, which contain several species that are of concern from spoilage and public health perspectives (Zeinab, Refaat, Abd El-Shakour, Mehanna, & Hassan, 2015).

Considering the importance of spore-forming bacteria to the quality and safety of processed cheese, in this article, the sources and routes of contamination of processed cheese by spore-forming bacteria are reviewed. In addition, the fate of these microorganisms during the manufacturing of processed cheeses and analogues are discussed and control measures aiming to ensure shelf-stable and -safe products for consumers are highlighted.

## 2. Processed cheeses: definitions, characteristics and processing

### 2.1. Definition and characteristics

Processed cheese is a leader in total supermarket cheese sales, followed by Cheddar and Mozzarella cheeses (Kapoor & Metzger, 2008). Processed cheeses are used as a substitute for butter and, in many cases, are considered to be a more digestible product, with a low cholesterol content, and a very tasty and “light” version of cheese (Kapoor & Metzger, 2008; Tamime, Muir, Shenana, Kalab, & Dawood, 1999).

The term “processed cheese” commonly describes a dairy product that is produced by heating a mixture of various cheese types with different degrees of ripening in the presence of appropriate emulsifying salts (mostly sodium phosphate, polyphosphates, citrates and/or their combinations) (Salek et al.,

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