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Review

A review of the microbiological hazards of dairy products made from raw milk

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ABSTRACT

This review concentrates on information concerning microbiological hazards possibly present in raw milk dairy products, in particular cheese, butter, cream and buttermilk. The main microbiological hazards of raw milk cheeses (especially soft and fresh cheeses) are linked to *Listeria monocytogenes*, verocytotoxin-producing *Escherichia coli* (VTEC), *Staphylococcus aureus*, *Salmonella* and *Campylobacter*. *L. monocytogenes*, VTEC and *S. aureus* have been identified as microbiological hazards in raw milk butter and cream albeit to a lesser extent because of a reduced growth potential compared with cheese. In endemic areas, raw milk dairy products may also be contaminated with *Brucella* spp., *Mycobacterium bovis* and the tick-borne encephalitis virus (TBEV). Potential risks due to *Coxiella burnetii* and *Mycobacterium avium* subsp. *paratuberculosis* (MAP) are discussed. Pasteurisation ensures inactivation of vegetative pathogenic microorganisms, which increases the safety of products made thereof compared with dairy products made from raw milk. Several control measures from farm to fork are discussed.

Contents

1. Introduction

Consumers' attitudes show a trend towards increased consumption of foods that are not or only minimally processed such as raw milk and dairy products made from raw milk. Cheeses made from raw cow, sheep and goat milk are the most frequently

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consumed type of dairy products made from raw milk; however, other types of dairy products made from raw milk are also consumed such as mozzarella made from raw buffalo milk, as well as raw milk butter made from cow milk. The consumption of raw milk can hold a risk for the consumer, due to the possible presence of human pathogenic microorganisms. The risks and benefits of the consumption of raw cow milk were described in a review by Claeys et al. (2013) and the nutritional and health benefits of the consumption of raw milk from animal species other than cows were described in a review by Claeys et al. (2014). The microbiological hazards of raw milk from animal species other than cows were described in a review by Verraes et al. (2014). Also EFSA evaluated the public health risk from the consumption of raw drinking milk (EFSA, 2015).

In the present review, a collation is made of available information in the scientific literature concerning the microbiological hazards of dairy products made from raw milk, in particular cheese, butter, cream and buttermilk. Dairy products made from raw milk from cows, sheep and goats are taken into account. Dairy products made from raw milk from other animal species are less relevant in Europe, with the exception of mozzarella made from raw buffalo milk. Only zoonotic human pathogenic microorganisms and pathogens originating from the environment have been taken into consideration. Pathogenic agents originating from human contamination due to human illness, e.g., *Salmonella* Typhi, *Shigella* spp. and noroviruses are not covered in this review.

2. Occurrence of human pathogenic microorganisms in raw milk and dairy products made from raw milk

In general, pathogenic microorganisms can contaminate raw milk in two ways. The first way is an endogenous contamination where the milk is contaminated by a direct transfer from the blood (systemic infection) to the milk or via an infection in the udder called mastitis. The second way is an exogenous contamination, where the milk is contaminated during or after milking by the faeces, the exterior of the udder and teats, the skin, the environment, etc.

Based on recent review documents (Claeys et al., 2013; EFSA, 2015; Sci Com, 2011, 2013; Verraes et al., 2014), the following human pathogenic microorganisms are considered as the main microbiological hazards associated with raw milk consumption from cows, goats and sheep: *Bacillus cereus*, *Campylobacter coli* and *Campylobacter jejuni*, enterotoxin-producing *Staphylococcus aureus*, *Helicobacter pylori*, human pathogenic verocytotoxin-producing *Escherichia coli* (VTEC), human pathogenic *Yersinia*, *Leptospira*, *Listeria monocytogenes*, *Salmonella* spp., *Streptococcus agalactiae*, *Streptococcus equi* subsp. *zooepidemicus*, *Clostridium botulinum*, *Brucella* spp., *Mycobacterium bovis*, *Cryptosporidium parvum* and *Toxoplasma gondii*. Some microbiological hazards are indicated as hypothetical because they are still not confirmed, but have the hypothetical potential to be pathogenic for humans (*Mycobacterium avium* subsp. *paratuberculosis*; MAP) or to be foodborne (*Coxiella burnetii*).

Limited systematic data were available on prevalences of human pathogenic microorganisms in dairy products made from raw milk. In a baseline study (EFSA, 2013b) performed at a European level, 1 sample from 476 raw milk cheese samples exceeded 100 cfu g^{-1} for *L. monocytogenes*. The EU summary report mentioned that non-compliance of *L. monocytogenes* primarily occurred in soft and semi-soft cheeses made from raw or low heat-treated cows' milk (EFSA & ECDC, 2015). In addition, studies in the scientific literature describing detection frequencies of human pathogenic microorganisms in dairy products made from raw milk provide an indication of prevalences. Data of such frequencies of occurrence were collected for Europe and are shown in Table 1, where the detection frequency, the type of food, the method of analysis and the country are given.

Frequencies of occurrence were found for several raw milk cheeses, butter and cream. No frequencies were found for buttermilk made from raw milk as such products are less often produced. No *Salmonella* has been detected in any tested samples of raw milk cheeses, butter and cream with the exception of one publication where the prevalence in cheese was 4.3% (n = 70 samples; Almeida et al., 2007). Concerning VTEC in raw milk cheeses, *E. coli* strains with virulence genes are detected with frequencies between 0 and 55.3%. Farrokh et al. (2013) stated that the prevalence of *vtx* genes, detected by PCR, does not necessarily reflect the occurrence of a viable *E. coli* isolate containing those genes. VTEC was also detected in butter (Messelhäusser, Beck, Gallien, Schalch, & Busch, 2008). As illustrated in Table 1, *L. monocytogenes* was detected in raw milk cheeses, butter and cream with frequencies varying between 0 and 41.9%, 3.6 and 29.9%, and 0.7 and 8.3% respectively, although in some cases the numbers were lower than 100 cfu g^{-1}. Of 70 cheese samples, 11.4% were positive for *L. monocytogenes* per 25 g, whereby 1.4% contained counts higher than 200 cfu g^{-1} and 10.0% lower than 100 cfu g^{-1} (Almeida et al., 2007). Of 474 cheese samples and 519 butter samples, respectively, 0.6% and 0.2% of the samples that were taken in Belgium by the sector of small cheese producers in the Walloon region had counts higher than 100 cfu g^{-1} (Sci Com, 2015). No *Campylobacter* were detected in 199 tested raw milk cheeses, which contrasts the higher reporting in raw milk (0–12%) (EFSA, 2015; Verraes et al., 2014). As indicated in Table 1, *S. aureus* was found in raw milk products with frequencies between 5 and 100% in cheeses, and between 1.6 and 20.3% in butter, but the possibility of the strains to produce enterotoxins varies and the share of such strains is difficult to deduce from the available information. Jørgensen, Mørk, and Rørvik (2005) also detected *S. aureus* in sour cream. *B. cereus* was detected in 28% of 25 samples of cheeses made from raw milk of several animal species. All strains were able to produce enterotoxins (Williams & Withers, 2010). MAP was detected in 4.2 and 20% of raw milk cheese samples using PCR (Stephan, Schumaher, Tasara, & Grant, 2007; Williams & Withers, 2010). *C. burnetii* was detected with PCR in 57.0% of unpasteurised cheese samples and in one of two cream samples, but the relation of these PCR results with the presence of infectious strains is not clear (Eldin, Angelakis, Renvoisé, & Raoult, 2013).

3. Reported human cases and outbreaks due to the consumption of dairy products made from raw milk

The development of a disease after consumption of contaminated dairy products made from raw milk depends on several factors such as the pathogenicity of the strain, the number of ingested microorganisms, the physiological state of the microorganism, the health condition of the consumer at the moment of ingestion, etc. Persons belonging to the YOPI group (young, old, pregnant, immunodeficient) have a higher risk of infection for certain pathogens such as *L. monocytogenes* and healthy persons can also be infected. The likelihood of developing a disease follows a dose–response curve with a higher number of cells increasing the chance of developing a disease. This relationship was categorised by the EFSA BIOHAZ Panel in the framework of a risk ranking exercise of foods of non-animal origin as follows: score 1 stands for a dose–response curve where the pathogen has to grow to high numbers (often higher than 5 log cfu g^{-1}) to produce toxins and cause illness; score 2 stands for a dose–response curve where the pathogen must grow to cause illness; and score 3 stands for a dose–response curve where the pathogen can cause illness in low numbers (Da Silva et al., 2015; EFSA, 2013a). *Salmonella*,