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Review

A review of the microbiological hazards of raw milk from animal species other than cows

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ABSTRACT

This review concentrates on information concerning the microbiological hazards that can be present in raw milk from animal species other than cows. Total bacterial counts of raw milk are described for several animal species, indicating the quality of the milk, then frequencies of occurrence of several human pathogenic microorganisms are considered and, finally, human cases of illness and outbreaks due to the consumption of raw milk from non-bovine species are covered. Only raw milk from goats and camels has so far been reported to be associated with outbreaks. Raw milk from horse and donkey may have a higher microbiological quality than raw milk from other animal species, although human pathogenic strains of *Streptococcus* are considered as a microbiological hazard for such milk. For raw milk from other animal species, the main microbiological hazards seem to be human pathogenic *Escherichia coli*, *Campylobacter* spp., tick-borne encephalitis virus and *Brucella* spp.

Contents

1. Introduction

In recent years, there has been a growing interest in local food production and consumption, and consumers are looking for foodstuffs that have undergone the least processing. As a result, there is an increased tendency to consume raw milk. Cow milk is the most frequently consumed type of milk; however, other types of raw milk are also consumed such as that from goats, sheep, horses, donkeys, camels, llamas, buffaloes, yaks and even reindeer. The consumption of raw milk holds a risk for the consumer, due to the possible presence of human pathogenic microorganisms in the raw milk (Claeys et al., 2013; FASFC, 2011, 2013).

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Pathogens possibly present in raw milk may originate from animals (even from those that are clinically healthy) or a contamination from the environment during the collection or storage of the milk. A distinction can be made between an endogenous infection, in which the milk is contaminated by direct transfer from the blood stream (systemic infection) or from an udder infection, and a cross-contamination, in which the milk is contaminated by faeces, the skin or the environment (external contamination during or after milking).

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 animals other than cows were described in a review by Claeys et al. (2014). In the present review, a collation is made of data found concerning the microbiological hazards of raw milk from animal species other than cows, in particular goats, sheep, horses, donkeys, camels, llamas, buffaloes, yaks and reindeer. Only zoonotic microorganisms and those originating from the environment have been taken into consideration. Microorganisms originating from humans, e.g., *Shigella* spp. and noroviruses have not been taken into account.

2. Total bacterial counts of raw milk

The microbiological quality of raw milk can be determined using various parameters, such as the number of *Enterobacteriaceae*, the number of coagulase-positive *Staphylococcus aureus* and the total bacterial count. The total bacterial counts presented in Table 1 are derived from studies published in scientific literature. The data must be interpreted with caution, since the counts have been determined in different ways using different methods.

D'Amico and Donnelly (2010) showed that there is no significant difference in the total plate count results of raw milk from goats, sheep and cows. The total plate count results of goat and sheep milk varies according to the month in which the animal is milked, the number of milking sessions making up the milk mix, the milking system used and the size of the herd (Alexopoulos et al., 2011; Gonzalo et al., 2006; Gonzalo, Carriedo, García-Jimeno, Pérez-Bilbao, & De La Fuente, 2010; Zweifel, Muehlherr, Ring, & Stephan, 2005). According to the scientific literature, raw horse milk has a lower total plate count and thus a higher microbiological quality than raw cow milk (Doreau & Martin-Rosset, 2002). One could consider as a possible explanation the difference in concentration of natural antimicrobial components such as lactoferrrin, lysozyme, immunoglobulins and lactoperoxidase. The activity or content of most antimicrobial systems or components in milk varies strongly between animal species. The content of lactoferrin in horse milk, the content of lysozyme in horse and donkey milk and the iron binding capacity of lactoferrin in horse milk are higher than in milk from other animal species (Claeys et al., 2014). However, the antimicrobial components/systems in raw milk have primarily a protective role at mucosal surfaces of the digestive tract in humans and animals. The activity to suppress in raw milk the growth of bacteria and to function as milk preservatives is generally considered as very limited and not of practical relevance. No reference was found documenting an effect of the antimicrobial components on microbial growth in raw milk from horses and donkeys.

In a review by Salimei and Fantuz (2012), it was found that the total plate count of horse milk is on average 4.6 log cfu mL^{-1}. Total plate counts are highest at the start of the lactation, and gradually decrease over the lactation period (Dankow, Wójtowski, Pikul, Niżnikowski, & Cais-Sokolińska, 2006). From Table 1, it can be seen that the counts of raw horse milk never exceeded 5 log cfu mL^{-1}, whereas this level was exceeded in the case of raw goat or sheep milk. This lower total plate count was ascribed to the good health status, intrinsic characteristics of the milk and the excellent natural anatomical position of the udder (Salimei & Fantuz, 2012). It is probable that the smaller size of the udder limits exposure of the teats to bacterial contamination (Doreau & Martin-Rosset, 2002). The review of Salimei and Fantuz (2012) however mentioned that the total plate count of donkey milk varies from 2.40 to 5.87 log cfu mL^{-1}, but is similar to that of horse milk. Neither lactation stage nor season had a significant influence on total plate count results (Ivanković et al., 2009). Regarding the other animal species, little information was available on total bacterial counts (see Table 1).

3. Frequencies of occurrence of human pathogenic microorganisms in raw milk

No systematic data were available on the prevalence of human pathogenic microorganisms in raw milk from species other than cows. However, studies of the frequencies of occurrence of pathogens in raw milk that have been published in the international scientific literature provide an indication of the prevalences. A search was made for all publications describing detection frequencies of human pathogenic microorganisms in raw milk from animal species other than cows. Publications with detection frequencies of zero percent were not included. It should be noted that these frequencies can vary according to the sampling and methodological approach. Variation can also be explained by geographical differences, the season in which the samples were taken, the size of the farm, the density of the animal population, regional differences in the keeping and taking care of animals, etc. Table 2 gives an overview of the collected publications.

Salmonella spp. have only been detected in raw milk from sheep and camels, and not in raw milk from goats, horses, donkeys or buffaloes. The frequency of occurrence in raw sheep milk was low, and ranged from 0 to 5%. For raw camel milk, the frequency of occurrence was about 10%. The review of Salimei and Fantuz (2012) confirmed that no reports were available detecting *Salmonella* spp. in raw milk from horse species.

Campylobacter spp. have only been reported in raw milk from sheep, and not in raw milk from goats, horses or buffaloes. However, the possible presence of *Campylobacter jejuni* in raw goat milk is apparent from an outbreak due to raw goat milk consumption (see Section 4 and Table 3).

Several studies have shown the possible presence of human pathogenic verocytotoxin-producing *Escherichia coli* (VTEC) in raw milk from goats, sheep, buffaloes and yaks, but not in raw horse milk.

The frequencies of occurrence of *E. coli* O157:H7 in raw milk from goats and sheep was about 1%, but for VTEC, this can be up to 16.3% for goat milk and 12.7% for sheep milk (Muehlherr, Zweifel, Corti, Blanco, & Stephan, 2003). The same was true for raw buffalo and yak milk, as can be seen from Table 2. The studies in Table 2 do not always mention whether the detected strains contained virulence genes. Human pathogenic VTEC contain genes for the production of verotoxins and a combination of genes coding for virulence factors that permit attachment to the intestines, as well as other adhesion factors and their regulators. However, this is only an indication of pathogenicity, and does not provide absolute certainty. Because of the differences in the methods described in the literature on detected VTEC, these data have to be interpreted with caution. Limited validated methods exist that can be used to isolate the non-O157-serotypes of *E. coli*, and because of this, the prevalence of such serotypes in raw milk is difficult to estimate (Vernozy-Rozand & Roze, 2003).

The frequency of *Listeria monocytogenes* in raw goat milk was found to be less than 8% and below 4% in raw sheep milk. This