Public health and the safety of milk and milk products from sheep and goats

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Summary
Goats and sheep rank third and fourth in terms of global milk production from different species, but unlike cow milk, which has stringent hygiene and quality regulations, microbiological standards for the production and distribution of goat milk and sheep milk are more relaxed. Difficulties in managing the sanitary quality of sheep and goat milk derive from a series of factors including the low level of production per head, the milking system, the difficulty involved in machine milking, the conditions under which the herds or flocks are raised, adverse climatic conditions and the spread of production over a wide geographic area.

Fresh goat milk is consumed by infants and others with allergies to cow milk and is also used for on-farm manufactured cheese, with or without thermal treatment. The high fat content and peculiar taste of cheeses made from ewe milk are also very popular. These cheese varieties, which are mostly still of 'artisan-type', are not covered by regulatory definitions and the dispute over the use of raw versus pasteurised milk is still alive. However, in documented intoxications recorded after the consumption of cheese, there has always been evidence of incorrect temperature control during pasteurisation, the deliberate addition of raw milk, or contamination during storage.

Compositional differences between the milk from cows, ewes and goats (chemical composition of lipids, phosphatase level, freezing point, natural bacterial inhibitor levels, somatic cell count, etc.) preclude the nondiscriminatory use of bovine standards for regulatory purposes. Quality standards adjusted for the specificities of ewe/goat milk should be considered. The production of safe cheese is linked to a series of conditions which ensure consumer health, primarily pasteurisation. In the absence of pasteurisation, all cheeses made from raw milk should be subjected to strict periodic controls.

Keywords

Introduction

Despite the low production of milk and the short lactation period, ewe and goat milk are of major importance in countries where climatic conditions and tradition are not conducive to raising dairy cattle. World figures indicate that there are some 1,087 million head of sheep and 609 million head of goat, which are used for meat, milk and wool. Goats and sheep rank third and fourth (after cows and water buffalo) in terms of global milk production (10.5 million and 8 million tons per year, respectively) (6). The composition of ewe and goat milk varies according to breed, stage of lactation, climate, diet, season of the year, etc. (4, 9, 19) (Table I).

The Middle East, Eastern Europe, the Mediterranean basin and India are the traditional regions for production of ewe and goat milk. However, the increasing market for specialised cheeses, and the image of healthy food attached to goat and ewe milk and milk products have increased the economic importance of both sources of milk beyond these traditional geographical borders.
A high demand for goat milk is also created by infants and others with allergies to cow milk. Clinical symptoms associated with this impairment (which include rhinitis, diarrhoea, vomiting, asthma, anaphylaxis, urticaria, eczema, chronic catarrh, migraine, colitis and epigastric distress) are due to multiple immunological mechanisms induced mostly by ß-lactoglobulin, a major whey protein not found in human milk. Typically 40% to 100% of patients who are allergic to cow milk proteins can tolerate goat milk, in spite of the fact that some proteins share immunological cross-reactivity between species. The greater buffering capacity of caprine milk as compared to cow milk (which results from the higher content of protein, nonprotein nitrogen and phosphate) may explain this phenomenon. In addition, smaller fat globules, higher percentages of short and medium chain fatty acids and the softer curd of goat milk improve digestibility and lipid metabolism. Furthermore, in experimental animals goat milk was found to provide better iron bioavailability than cow milk (18).

**Hygiene controls for sheep and goat milk and milk products**

Unlike cow milk, which has stringent hygiene and quality standards, the production and distribution of sheep and goat milk in Israel is controlled only by general regulations related to safe foods (this may also be true world-wide). The information available on the microbiology is limited, and there are no generalised legal microbiological standards. Difficulties in managing the sanitary quality of these milks arise from a series of factors which include:

a) the low level of production per head  
b) the milking system  
c) the difficulty involved in machine milking  
d) the conditions under which the herds are raised  
e) adverse climatic conditions  
f) the spread of production over a wide geographic area.

The dispute over raw versus pasteurised goat milk has been particularly intense and emotional, since the subject touches on the spheres of tradition and health. In an attempt to prevent human infection with brucellosis and tuberculosis, many countries require mandatory pasteurisation of milk. Goats are susceptible to *Brucella melitensis* infection (more virulent than *B. abortus* which is associated with cow milk), and also to most other diseases which affect cows. An ever-growing number of additional infectious agents have been isolated from goat milk (20). These infectious agents are particularly threatening for certain population groups, namely: those with impaired immunosystems, babies, the aged and the sick, who coincidentally are the target consumer groups for goat milk. A recent outbreak of Q fever (the clinical signs include fever, weakness, arthralgia and headaches) occurred in southern France among 61 workers on a farm where goats were raised for raw milk and cheese production. The goats had all been vaccinated with a commercial vaccine containing phase II *Coxiella burnetii* antigen. Vaccination of this herd did not prevent the outbreak and might have increased shedding of *C. burnetii* in the dairy products (5).

**Pasteurisation**

Pasteurisation efficiency is routinely confirmed for cow milk by the deactivation of the native alkaline phosphatase activity following the heat treatment. Unfortunately, no similar analytical method exists to measure the efficiency of pasteurisation of goat milk. Raw goat milk has been reported to have a low native alkaline phosphatase activity, with values ranging from 228 to 636 µg phenol/ml, while raw cow milk has values of 1,872-4,740 µg phenol/ml, and ewe milk values of 8,301-17,280 µg phenol/ml. As a result, the test using

### Table I  
**Composition of goat and ewe milk**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Goat milk</th>
<th>Ewe milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solids (%)</td>
<td>11.3-18.6</td>
<td>15.8-23.4</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>2.8-7.7</td>
<td>4.5-12.6</td>
</tr>
<tr>
<td>Total protein (%)</td>
<td>2.5-5.3</td>
<td>4.3-7.1</td>
</tr>
<tr>
<td>Lactose (%)</td>
<td>3.9-8.3</td>
<td>4.2-6.2</td>
</tr>
<tr>
<td>Energy (kcal/100 ml)</td>
<td>70-86</td>
<td>78-105</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>0.7-8.9</td>
<td>0.8-9.9</td>
</tr>
<tr>
<td>Calcium (mg/100 ml)</td>
<td>123-203</td>
<td>162-259</td>
</tr>
<tr>
<td>Sodium (mg/100 ml)</td>
<td>35-65</td>
<td>41-132</td>
</tr>
<tr>
<td>Potassium (mg/100 ml)</td>
<td>157-255</td>
<td>101-152</td>
</tr>
<tr>
<td>Magnesium (mg/100 ml)</td>
<td>13-36</td>
<td>14-19</td>
</tr>
<tr>
<td>Phosphorus (mg/100 ml)</td>
<td>86-120</td>
<td>82-183</td>
</tr>
<tr>
<td>Cholesterol (mg/100 ml)</td>
<td>105-259</td>
<td>48-285</td>
</tr>
<tr>
<td>Iron (µg/100 ml)</td>
<td>42-112</td>
<td>29-139</td>
</tr>
<tr>
<td>Copper (µg/100 ml)</td>
<td>20-69</td>
<td>18-130</td>
</tr>
<tr>
<td>Manganese (µg/100 ml)</td>
<td>0.9-19</td>
<td>3-13</td>
</tr>
<tr>
<td>Sulfur (µg/100 ml)</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Zinc (µg/100 ml)</td>
<td>192-475</td>
<td>486-1,180</td>
</tr>
<tr>
<td>Freezing-point depression (°C)</td>
<td>-0.53-0.61</td>
<td>-0.546</td>
</tr>
<tr>
<td>pH</td>
<td>6.33-6.53</td>
<td>6.6-6.9</td>
</tr>
</tbody>
</table>

In contrast to goat milk, ewe milk, which has high viscosity and a peculiar taste, is not consumed fresh, but instead is an important raw material for cheese. Excellent cheeses, characterised by savoury flavours, are made from goat and ewe milk, which are used either alone or blended with cow milk. There is an assortment of regional cheese varieties rooted in specific milk composition, production, maturing and preservation methods (10, 15). Most of these cheeses are of 'artisan-type' and recipes and manufacturing methods are passed on from generation to generation without a standardised technology or regulatory definition. Due to the absence of carotene in the milk, sheep and goat cheeses are white.
alkaline phosphatase activity as an indicator of the completeness of pasteurisation was satisfactory for cow and ewe milk, but with goat milk this test indicated that pasteurisation was complete after only 10 minutes at 63°C (22) (the authors assume that the units of mg phenol/ml in this report, are a printing error; µg phenol/ml is the correction). Therefore, the phosphatase test seems to be of little value as a legal standard for the pasteurisation of goat milk (15). Roseiro and Barbosa (23) recently reported that phosphatase activity, after batch pasteurisation of goat milk at the prescribed conditions of 63°C for 30 minutes, was higher than the limit established for correctly pasteurised milk, even though the treatment reduced total bacterial count. Seemingly, the residual phosphatase was of microbial origin.

**Potential contaminants of sheep and goat milk and milk products**

Goat milk is commonly used for on-farm manufactured cheese, with or without thermal treatment, but relatively few studies on the bacterial flora of goat milk cheese have been published. A microbiological analysis of 42 samples of a 60-day ripened, Spanish farm cheese showed a satisfactory hygienic quality (16). A study of *Enterobacteriaceae* presence throughout the manufacture and ripening of hard goat cheese showed altered viability of microbial flora along the production line. The abundant species present in raw goat milk were *Serratia liquefaciens*, *Morganella morganii*, *Hafnia alvei*, *Klebsiella oxytoca* and *Yersinia enterocolitica*. *Y. enterocolitica* was not subsequently isolated from curd or cheese. *H. alvei* counts increased in curd and in one-week old cheese. However, *Escherichia coli*, which was not isolated from milk, curd or one-week old cheese, was the predominant organism in two-week old cheese. This suggests that *E. coli* is one of the most resistant species in ripening cheeses (25).

**Listeria species**

The contamination of goat and ewe milk with *Listeria* spp. is assumed to occur by the same contamination routes as for cow milk, i.e. through silage, other feeds, cross-contamination of feeds by manure, poor-quality bedding, contaminated milking equipment or mastitic infection attributable to *Listeria*. Close monitoring of hygiene on dairy farms, with particular attention to milk produced for processing into raw milk cheeses, are the general prevention measures. Infection of the mammary gland by *L. monocytogenes* (the most prevalent pathogenic strain, as a source of milk contamination) is more common in sheep, and presumably in goats, than in cows. There is some indication that even goats with no previous history of listeriosis can produce infected milk (13). In Parma, Italy, *L. monocytogenes* was not isolated from milk or cheese in 40 samples of sheep milk and 24 samples of goat milk. However, a significant level of contamination of cheese by *Enterobacteriaceae* spp. was detected, including the isolation of *Y. enterocolitica* in one sample of mozzarella cheese. In this study, 17% of the cheeses were contaminated with *Streptococcus faecalis* (1). Samples from a German market revealed 29 strains of *L. monocytogenes* and 31 strains of *L. innocua*, isolated from 60 cheeses out of 509 samples (245 were locally made and 264 imported). Semi-hard, soft and fresh goat milk cheeses contained *Listeria*, but hard goat milk and ewe milk cheeses did not (26). In another case, listeriosis was traced to fresh goat cheese made using milk from an *L. monocytogenes*-infected goat. This cheese may have contaminated refrigerator shelves which then served as a *Listeria* reservoir for new cheeses (3).

Pathogenic micro-organisms, if present in raw milk, are thought to remain viable in cheese unless the cheese is ripened for several months before consumption. However, in goat cheese intentionally contaminated with *L. monocytogenes*, the maximum survival time was 18 weeks. This suggests that *L. monocytogenes* has the ability to survive in semi-soft cheese manufactured from unpasteurised goat milk during the normal two- to three-month curing process (24).

Ewe milk, as compared with cow and goat milk, has a protective effect on Gram-negative bacteria and *Listeria* spp. in batch pasteurisation conditions. The protective effect could not have been solely due to the higher fat content, since cow milk which had been artificially enriched to 10% homologous fat was not as protective. However, whole ewe, cow and goat milk containing high levels of *L. monocytogenes* (10⁶ colony-forming units (CFU)/ml) could not survive the current high-temperature short-time (HTST) plate pasteurisation protocol (11).

**Salmonella species**

A tragic case of intoxication occurred in France in 1993 (2). A nation-wide outbreak of 273 confirmed infections with *Salmonella enterica* serotype paratyphi B led to one fatal casualty and the hospitalisation of one third of affected individuals. Cheese made with unpasteurised goat milk in a single plant was incriminated. This incident, associated with morbidity and death, could have been prevented by the use of pasteurised milk and strict hygiene. In all intoxications recorded following the consumption of cheese made from pasteurised milk, there has always been evidence of incorrect temperature control during pasteurisation, the deliberate addition of raw milk, or contamination during storage (21).

**Staphylococcus aureus**

Since pasteurisation does not destroy preformed staphylococcal enterotoxins, the risk of contamination of milk by *Staphylococcus aureus* is possible. *S. aureus* enterotoxin type B affected three Bedouin children in Israel who drank milk from a goat with mastitis (7). In Germany, a two-year bacteriological survey of goat and ewe milk and cheese revealed *S. aureus* in 12.8% and 13.0% of individual milk samples from goats and ewes, respectively, and in 23.2% and
37.5% respectively of bulk milk samples. In the majority of cases, the presence of *S. aureus* was due to post-secretory contamination. Similar levels of *S. aureus* were found in cheese at farm level but the organism was not detected in any retail cheeses tested. Other pathogenic bacteria, including *Salmonella*, *Listeria* and *Campylobacter* spp., were not detected. Numbers of coliforms and presumptive *E. coli* were less than 100/ml in 60% of bulk milk samples (8).

Recommended methods for reducing the risk of *S. aureus* infection of the mammary gland include regular monitoring of udders, teats, milking equipment and milk, and the maintenance of scrupulous hygiene practices, including the isolation of goats with mastitic infection (14).

**Chemical residues**

There are also other differences between cow and ewe/goat milk with implications for public health. Analytical tests typically used for the detection of antibiotic contamination of cow milk may be inaccurate when applied to ewe or goat milk. This antagonistic action is explained by natural inhibitors inherent in the lipid fraction of ewe and goat milk. The consumption of milk which is contaminated by undetected drug residues may lead to allergic reactions in sensitive people and to induced resistance to antibiotics in opportunistic micro-organisms.

Furthermore, as a result of the browsing habits of sheep and goats and thus the greater chance to consume poisonous plants, the potential for natural plant toxins to be excreted in ewe and goat milk is higher than for cow milk (17). Pyrrolizidine alkaloids from comfrey may cause hepatoxic and veno-occlusive disease and may be carcinogenic. Tremetol, a higher alcohol found in white snakeroot and rayless goldenrod, causes a syndrome called milk sickness. Although the excretion of these toxins at a high enough level to constitute an accidental human health hazard is unlikely, concern should exist, particularly for the consistent consumers of goat milk and neonates with immature detoxification pathways.

The risk of aflatoxins being present in goat and ewe milk has scarcely been documented. The reduction of aflatoxin levels by 90% after fermentation of goat milk for 48 h has been noted. Aflatoxins B1 and M1 were detected in the liver, kidney and muscle of rabbits fed with contaminated milk. However, the tissues of animals fed fermented milk contained no aflatoxin residues (12).

**Conclusion**

The differences in chemical and microbiological composition between cow and ewe/goat milk (structure of lipids, phosphatase level, freezing point, natural bacterial inhibitor levels, contamination by pathogens, somatic cell count, etc.) preclude the nondiscriminatory use of bovine standards to ascertain the safety of ewe and goat milk. However, quality standards adjusted specifically for ewe/goat milk should be considered. The production of safe cheese should be linked to a series of conditions to ensure consumer health, primarily pasteurisation. In the absence of pasteurisation, all cheeses made from raw milk should be subjected to strict periodic controls.
sans traitement thermique. La teneur élevée en matières grasses et le goût particulier des fromages élaborés à partir du lait de brebis sont également très appréciés. Ces variétés de fromages, qui restent, pour la plupart, de fabrication artisanale, ne sont régies par aucun texte réglementaire et le débat sur la préférence à donner au lait cru ou au lait pasteurisé pour leur fabrication reste ouvert. Il a, toutefois, été établi que les toxi-infections alimentaires liées à la consommation de fromage étaient dues à un contrôle incorrect de la température lors de la pasteurisation, à une addition délibérée de lait cru ou à une contamination en cours de stockage.

Compte tenu de la composition différente du lait de vache, du lait de brebis et du lait de chèvre (composition chimique des lipides, teneur en phosphatase, point de congélation, niveaux naturels d’inhibition bactérienne, numération des somatocytes, etc.), les normes applicables au lait de vache ne peuvent être utilisées pour uniformiser la réglementation. L’adaptation des normes de qualité aux spécificités du lait de brebis ou de chèvre devrait donc être envisagée. La production de fromage sans risque sanitaire dépend d’un ensemble de conditions destinées à protéger la santé du consommateur, notamment la pasteurisation. En l’absence de pasteurisation, tous les fromages fabriqués à partir de lait cru devraient être soumis à des contrôles périodiques stricts.

Mots-clés

Salud pública e inocuidad de la leche y productos lácteos de origen ovino o caprino

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Resumen
La cabra y la oveja se sitúan en tercer y cuarto lugar respectivamente entre las especies animales productoras de leche en el mundo. Sin embargo, y a diferencia de la leche de vaca, sujeta a estrictas reglamentaciones de higiene y calidad, las normas microbiológicas para la producción y distribución de leche de cabra y oveja son menos rigurosas. La dificultad de monitorear la calidad sanitaria de la leche de cabra y oveja obedece a una suma de factores, entre ellos la baja productividad por cabeza, el sistema de ordeño, los problemas que presenta el ordeño mecánico, las condiciones en las que se crián los rebaños, las condiciones climáticas adversas y la dispersión de las actividades productivas en grandes áreas geográficas.

Además de subvenir al consumo de niños y de adultos alérgicos a la leche de vaca, la leche fresca de cabra sirve para la fabricación de queso de granja, con o sin tratamiento térmico. Por su parte, el elevado contenido en grasas y el peculiar sabor de los quesos fabricados con leche de oveja explican su gran aceptación. Estas variedades de quesos, en su mayoría de fabricación artesanal, no están sujetas a reglamento alguno, y sigue viva la controversia en torno al uso de leche cruda o bien pasteurizada para su fabricación. Sin embargo, los casos documentados de intoxicación debida al consumo de queso fueron asociados a una pasteurización a temperatura inadecuada, a la mezcla deliberada con leche cruda o a una contaminación durante el almacenamiento.
Las diferencias existentes entre la leche de vaca, la de oveja y la de cabra en cuanto a su composición (composición química de sus lípidos, contenido en fosfatasas, punto de congelación, nivel de inhibidores bacterianos naturales, número de células somáticas, etc.) impiden generalizar a las demás especies la reglamentación que se aplica a la leche de vaca. Sería preciso contemplar normas de calidad que tomaran en consideración las particularidades de la leche de oveja y cabra. La producción de quesos sin riesgos microbiológicos exige el respeto de una serie de condiciones que garantizan su inocuidad para el consumidor, ante todo la pasteurización. En ausencia de ésta, todos los quesos fabricados a partir de leche cruda deberían ser sometidos a estrictos controles periódicos.

**Palabras clave**

**References**


