

Mastitis in small ruminants

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Summary

The importance of mastitis in small ruminants is important from the point of view of 3 perspectives: economic (mortality of animals, treatment costs, reduced quantity and quality of milk); hygienic (the risk of infection or poisoning of consumers by consuming infected milk), and legal (definitions of bacteriological milk quality). Coagulase-negative staphylococci are the most prevalent pathogens of the mammary gland in sheep and goats with subclinical mastitis (affecting from 45 to 48% in sheep and from 60 to 80.7% in goats). Prevalence of clinical mastitis in small ruminants is usually below 5%. Several pathogens can cause mastitis, but *Staphylococcus* spp. are the most frequently diagnosed causal microorganisms of intramammary infections in goats and sheep. Somatic cell counts in milk of dairy ewes can be used to define subclinical mastitis and a threshold of about 200,000 to 400,000 cells/ml will accurately identify most infected ewes. In ewe milk somatic cell counts between 300,000 cells/ml and 1,000,000 cells/ml cause changes in the composition and plasmin activity, and suggest that milk secretion is in a period of transition from normal to mastitic milk. In goats infected glands also lead to an increase in somatic cell counts; however, increased somatic cell counts in milk are also caused by other non-infection factors, such as estrus, season of milking, milk yield or stage of lactation. A standard tool in the diagnosis of mastitis for small ruminants is bacteriological examination of milk. During milking of small ruminants there is usually a transmission of Gram-positive bacteria, mainly *Staphylococci*. Therefore, the control of mastitis in small ruminants should take into account the optimal milking routine and milking hygiene. In particularly justified cases and the large prevalence of disease antibiotic treatment should be administered in the dry-period.

Keywords: small ruminants, mastitis, intramammary infections, diagnostic tools, prevention, treatment

Mastitis is any inflammation of the mammary gland or udder regardless of its origin, severity or evolution (6). The term *mastitis* comes from the Greek words: *mastos* (for breast) and *itis* (for inflammation). *Mastitis*, especially the sub-clinical form, can be a significant problem in sheep and goat flocks that are managed intensively for meat or milk production. Ewes with mammary glands with no clinical signs and giving apparently normal milk but bacteriologically positive and with a somatic cell count (SCC) of $\geq 500 \times 10^3$ cells/ml are considered to have subclinical mastitis (18). According to Bergonier and Berthelot (6), *mastitis* is of importance from 3 perspectives: economic (reduced growth of lambs and their mortality, as well as mortality of ewes, treatment costs, reduced milk production, milk prices dependent on cellular quality in certain areas); hygienic (risk of infection or intoxication of consumers by milk bacteria such as *Escherichia coli*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Salmonella* spp., etc.) and legal (E.U. Directive 46/92, modified by Directive 71/94, defining milk bacteriological quality). *Coagulase-negative staphylococci* (CNS) are the most prevalent pathogens of the mammary

gland in sheep and goats with subclinical *mastitis* (6, 7, 9, 12, 19, 24, 25, 28, 45, 46). The reported prevalence of CNS in caprine subclinical *mastitis* ranges between 60% and 80.7% (9, 17, 28, 45); however, in ovine subclinical *mastitis* CNS were recovered from 45 to 48% of culture positive milk samples (46). The more frequent isolates are *Staphylococcus aureus* in clinical cases in intramammary infections (7, 10). Prevalence of clinical *mastitis* in small ruminants is usually below 5% (7), while subclinical *mastitis* ranges from 9 to 50% (17, 23, 28), and according to other authors this prevalence in small ruminants averages 5-30% (10). Animals with deep and pendulous udders and with high implanted teats are more prone to udder inflammation or *mastitis* during their stay in the herd (8). For this reason the evaluation of the udder condition is an important tool for increasing the hygienic status of the herd. Subclinical *mastitis* is a serious economic and health problem of the udders in goats (6, 9), and ewes (1-3). Sheep milk is an important raw material for the production of high-quality cheeses and yogurts of the Mediterranean countries (13). Thus, the microbiological quality of milk should be high. However,

the situation in the dairy sector of sheep and goats keeping varies considerably between developed and undeveloped countries (38). Hence the difficulties arise with the development of a system of payments for milk from small ruminants. According to these authors only a few countries, especially in Europe, have good sanitary conditions for the production of milk and dairy products. Both milk yield and milk composition parameters in dairy ewes showed an impairment starting from 300,000 cells/ml. Increased SCCs from 300,000 cells/ml to 1,000,000 cells/ml suggests that such a secretion could be regarded as transition milk from normal to mastitic milk (3). Similar relationships were found between the presence of bacterial pathogens and total SCC, contents of total leukocytes and their subpopulations in goat milk (4). Infected udder halves in dairy German Improved Fawn goats had significantly higher levels of SCC, lactoferrin and N-acetyl- β -D-glucosaminidase activity when compared with udder halves without any infection (5).

The objective of this paper is to review literature relating to the etiology of intramammary infection in small ruminants, diagnostic tools and control (prevention) strategies in combating *mastitis*.

Etiology of intramammary infections in small ruminants

Basic definitions. *Mastitis* is a bacterial disease that occurs in several different forms. In general, *mastitis* is divided into clinical, sub-clinical, and chronic in scientific literature (6, 7, 10, 12, 13). Clinical *mastitis* is the term used for bacterial infections of the mammary gland that are present with obvious symptoms. Visible indications of clinical *mastitis* include swelling, redness or necrosis of one or more half udders and abnormal discharge of milk (presence of clots or serum), as well as other symptoms such as anorexia, fever or agalactia. Usually the consequence of clinical *mastitis* is toxemia and gangrenous necrosis of the udder (31). The rate of new clinical cases in lactation is usually below 5% for both milk and meat flocks (6). Clinical *mastitis* can lead to mortality or culling of up to 90% of mastitic ewes in the flock. Several pathogens can cause *mastitis*, but *Staphylococcus* spp. are the most frequently diagnosed causal microorganisms of intramammary infections (IMI) in goats and sheep (6, 10). Clinical incidence is generally lower in ewes than in cows. Subclinical *mastitis* is characterized by inflammation of the udder detected by enumeration of inflammatory cells in milk (48). Ewes with mammary glands having no clinical abnormalities and giving apparently normal milk, which is bacteriologically positive and with a SCC of $\geq 500 \times 10^3$ cells/ml, are considered to have subclinical *mastitis* (18). Chronic *mastitis* can be clinical or subclinical, but it is characterized as an inflammation of the udder that continues over a long period of time (7). Other definitions are available for the classification of clinical *mastitis* as hyperacute,

acute, and subacute. Hyperacute *mastitis* is characterized by severe udder inflammation accompanied by an evident systemic reaction; acute *mastitis* is characterized also by severe inflammation, but without systemic symptoms, whereas subacute *mastitis* is clinically less evident compared to acute *mastitis* (6, 7).

Classic etiology of mastitis. Several pathogens can cause *mastitis*, but *Staphylococcus* spp. are the most frequently diagnosed causal microorganisms of IMI in small ruminants (10). Other pathogens such as *Streptococcus* spp., *Enterobacteriaceae*, *Pseudomonas aeruginosa*, *Mannheimia haemolytica*, *Corynebacteria* and fungi can produce IMI in small ruminants, but occurrence rates are lower (6, 7, 10). In addition, severe cases of *mastitis* related to incorrect preventative strategies have been attributed to the pathogens *Aspergillus fumigatus*, *Serratia marcescens*, *P. aeruginosa* or *Burkholderia cepacia* (6, 10).

Contagious agalactia syndrome. The main mycoplasmal diseases of sheep and goats include contagious agalactia, caused by *Mycoplasma agalactiae*; atypical pneumonia, caused by *M. ovipneumoniae*; and infectious keratoconjunctivitis ("pink-eye"), caused by *M. conjunctivae*: all are important diseases, but rarely life-threatening in their own right (29). Studies on ewes and goats have shown that the prevalence of contagious pathogens is reduced as a result of the effective application of control and prevention strategies, while environmental pathogens are becoming a major problem in well-managed flocks (10). The "milk-drop syndrome of ewes" is defined as a pathological entity at the flock level and a syndrome characterized by a reduced milk yield of lactating ewes, with no clinical signs specific to a disease. Subclinical *mastitis* (in the majority of cases, caused by CNS) was one of reasons of the syndrome in 11 flocks, together with other disorders in another three flocks. Contagious agalactia (caused by *Mycoplasma agalactiae*) was recorded in three flocks as sole cause of the syndrome, as well as co-existing with other disorders in another flock (14). The bacteria causing *mastitis* are often classified as "contagious" if it is believed that the source of infection of milk is an infected mammary gland with subclinical mastitis pathogens, or "environmental" if the bacteria are considered to be opportunistic pathogens that normally reside in the environment of the animals (42). However, such a description is not as clear for small ruminants as it is for dairy cattle. During the milking of ewes the likely source of CNS is the skin on the teats, along with skin on the inner side of legs; thus many CNS infections become long-term chronic infections. CNS may leak out to the milk from the infected udder and then spread via the milking equipment to other ewes. Thus, the source of mastitis pathogens in small ruminants should not be assumed based simply on the behavior of these pathogens in dairy cows.

Staphylococcus aureus. Several pathogens can cause *mastitis*, but *Staphylococcus* spp. are the most

frequently diagnosed causal microorganisms of IMI in goats and sheep. Intramammary infections caused by these pathogens need to be treated with particular caution, because this bacterium is responsible for both acute clinical *mastitis* (gangrenous *mastitis*) and subclinical *mastitis* (10, 44). In both forms of *mastitis* there is a qualitative and quantitative decline in milk production (6, 7). The results of many studies of clinical *mastitis* indicate the high prevalence of *Staphylococcus aureus*: 17 to 57% isolated bacteria at the mean of approximately 36% (6). It should however be stressed here that this prevalence is only found in sporadic cases for sheep and goats, as the incidence is usually below 5% per year (7, 10). *Staphylococcus aureus* must be considered a "major pathogen" in goats and it is responsible for a considerable increase in SCC (9). *Staphylococcus aureus* secretes several toxins contributing to the pathogenesis of *mastitis* and also plays a role in foodborne diseases; even with pasteurized milk because of the thermostable enterotoxins (10). The latest data compares the *S. aureus* seroproteome in the colonization versus mastitis context in ruminants (44). These results are opening up new possibilities in the understanding of the balance between infection and commensal lifestyle; additionally, they provide preventive new strategies against this opportunist pathogen.

Coagulase-negative staphylococci. The many studies of subclinical *mastitis* in ewes showed that the CNS are the most prevalent, ranging from 25 to 93%, at a mean of approximately 62%, whereas in meat ewes CNS are less frequent (12-34%) (6, 7, 32, 45). In ewes the most often isolated pathogens among the CNS were *S. epidermidis*, *S. xylosum*, *S. chromogenes* and *S. simulans*. In goats the most prevalent species is *S. caprae*. In both sheep and goats, among the CNS *S. epidermidis* is generally associated with the highest average values of SCC (7). Out of 2198 Sarda dairy sheep examined in a study by Marogna et al. (27) at least one clinical sign of *mastitis* was detected in 1666 sheep (75%). Positive results in bacteriological examination of milk samples from 1093 ewes were recorded 49.7%. Among the entire population of isolated pathogens, three species caused 55.3% of all *mastitis* cases: *Streptococcus uberis* (25.6% of positives and 12.7% of total), *Staphylococcus epidermidis* (16.2% of positives and 8% of total), and *Staphylococcus aureus* (13.5% of positives and 6.7% of total). The opportunistic nature of the CNS results in their prevalence increasing together with deficiencies in the machine milking system or in milking hygiene. The main CNS species causing intramammary infection reside on the skin of the udders and teats in small ruminants (9). The dynamics of intramammary infection and somatic cell counts differ in sheep and goats (28). The results of some studies confirm an increasing need to standardize a genotypic method for the identification of CNS isolated from caprine udders (32).

Impact of mastitis on milk yield, quality and composition in small ruminants

The reduction of milk yield (MY) in ewes can be caused by various diseases and disorders. The lowered milk production resulting from these diseases is defined as the "milk-drop syndrome of ewes" (14). Among the various diseases subclinical *mastitis* is considered the most important cause of reduced milk yield (21, 22, 24, 25, 30, 40). In a study by Koop et al. (21) on goats, udder infection by major pathogens caused losses in milk production of 0.13 kg/d, but such a reduction was not statistically significant; yet when the infection status in the first month of lactation was taken into account as a predictor for the production in the remainder of the lactation, the estimated MY loss was higher (0.29 kg/d). The authors are of an opinion that IMI caused an increase of SCC. The effect of infections in goat udders on MY varies for various groups of pathogens (20, 21). Infections by major pathogens are associated with a small reduction of MY, while infections by CNS was not associated with any significant change in MY. In contrast, infections by *C. bovis* have been reported to be associated with a significantly higher MY (20). There are 2 explanations for such trends: either high producing animals are at a greater risk of infection with minor pathogens, or infection with these pathogens has a beneficial effect on milk production. Gougoulis et al. (16) demonstrated that subclinical *mastitis* (SCM) caused not only a reduction of milk yield from the affected mammary gland, but it also caused a preference for lambs to suck from the unaffected gland. It did not affect the growth of lambs. Those authors stressed that it would be valuable to investigate the behavioural effect of SCM in ewes rearing twins. One of the factors predisposing to intramammary infection is connected with the transfer of bacteria such as *S. aureus* and Mannheimia species by suckling lambs (31). A method to reduce such infections is connected with early weaning of lambs by removing lambs carrying the bacteria in their nasopharynx.

Lower milk production efficiency and changes in its composition begin from 300,000 cells/ml (3). In ewe milk, SCCs between 300,000 cells/ml and 1,000,000 cells/ml cause changes in milk composition and plasmin (PL) activity, which suggest that milk secretion is in the period of transition from normal to mastitic milk. Numerous studies (22, 30) have reported on the impact of an increased SCC on milk and subsequent changes in most parameters related to biochemical aspects and cheese processing. These modifications in milk composition have a variable impact on the quality of dairy products. In general, an increase in SCC has a negative influence on cheese processing and in pasteurized milk grading during storage. Cheeses made from milk with a high bulk tank SCC (BTSCC) have a reduced fat content and increased pH and fat acidity. In yoghurt, high BTSCC was associated with a higher

protein content and the highest level of syneresis (30). Both in goats and sheep infection by CNS decreased curd yield and increased milk-clotting time, and these changes were reflected in increased casein degradation, increased content of CN degradation products and decreased calcium activity. The results suggest that the plasmin system functions at a lower rate in goats than in sheep and that its response to external factors, such as infection, that augment its activity in other species is more attenuated in goats (24).

Diagnostic tools for mastitis in small ruminants

Bacteriological detection. A standard tool in the diagnosis of mastitis in small ruminants is provided by bacterial culture (10). For two reasons, economic and practical, only one sample of milk is taken to diagnose IMI. It was found that a positive diagnosis in isolating the same pathogen from the half of the udder in the following samples of milk shows high sensitivity (96.2%) and specificity (96.1%) (9). Intramammary infection (IMI) by coagulase-negative staphylococci (CNS) is one of important factors affecting IMI of the flock, and as such it reduces profits from small ruminants (25, 28, 33, 45). The mean prevalence of subclinical mastitis in three herds of goats in a study by Hall and Rycroft (17) ranged from 33 to 42%. Among the pathogens isolated from infected udder halves CNS ranked first (47%), followed by *Corynebacterium* species (31%), *Staphylococcus aureus* (13%), and α -haemolytic streptococci (6%). Of the total number of 1388 goats from 31 farms analysed by Marogna et al. (26) IMI infections were detected in 22.7% of all goats. In infected samples *Staphylococcus* spp., *Streptococcus* spp., and *Mycoplasma* spp. were detected in 73.5%, 9.7%, and 4.7% of positive milk cultures, respectively. The results presented by Onni et al. (32) confirm and stress the need of applying genotypic methods for the identification of CNS isolated from goat udders. The genotypic identification method can be a good tool for the suitable identification of CNS isolated from caprine udders. Pastures shared by horses and goats are the most likely factor causing an outbreak of *Streptococcus equi* ssp. *zooepidemicus* (SEZ) mastitis; however, an epidemiological relationship could not be confirmed with molecular methods (39). In milk samples collected from 2198 udders of the Sarda sheep breed half (49.7%) gave positive results (27). The most frequently detected bacterial genus was *Staphylococcus*. *Staphylococcus* spp. were present in 20.7% of samples. *Streptococcus* spp. and *Enterococcus* spp. represented 33.3% of all isolates and were present in 16.6% of samples. Knowledge concerning the etiology of infection in a flock can be a useful tool in reducing economic losses due to decreased milk yields and the deterioration of its quality (25).

Somatic cell count. There are substantial differences between sheep and goats in terms of diagnosis of mastitis based on milk SCC. These differences result mainly from the fact that in uninfected halves of goat

udders there is a higher apocrine component of goat milk secretion and a larger number of non-infectious factors that can increase SCC in milk (35). However, on account of apocrine milk secretion in goats, compared to merocrine secretion in cows, SCC for goats is naturally higher than SCC for cows (34). An association between SCC and pathogenic bacteria can contribute to a better understanding of the pathogenesis of subclinical mastitis in small ruminants (2). SCC of milking ewes can be used to define subclinical mastitis and a threshold of about 200,000 to 400,000 cells/ml will accurately identify most infected ewes (42). In ewe milk samples with SCC > 1,000,000 cells/ml there are differences in leukocyte production and also in their counts between infected glands and healthy glands. Numerous studies have shown a close relationship between the presence of bacteria in ewe and goat milk and SCC (4, 5, 21); however, some studies indicate an ambiguous relationship between subclinical mastitis and an increased SCC in goat milk samples (24, 26, 35). More recent data indicate that often scientific literature sources reported subclinical mastitis in small ruminants after diagnosis with the California Mastitis Test (CMT) and SCC, without reference to the methodology, strategy or details of clinical examinations (26). The increased SCC in milk (MSCC) of cows and sheep due to the stage of lactation and parity is mainly caused by IMI. However, when intramammary infections in goats increase MSCC, other non-infections factors such as estrus, season of milking, milk yield and stage of lactation also cause an increase in MSCC (35, 40). According to those authors non-infections factors cause difficulties for the dairyman to maintain a level of 1,000,000 cells/ml in goat milk. Moreover, this threshold MSCC is not a legal limit for goat milk in the European Union. These non-infectious factors should be taken into account when determining the legal limit for MSCC in milk goats. In ewe milk the determination of SCC is a good tool for the detection of subclinical mastitis in Pirlak sheep with a threshold level of 374×10^3 cells/ml (33).

Control and prevention strategies

Vaccination. In the 1990's a staphylococcal vaccine was tested on the Latxa ewes. Two injections were administered, a month before and a month after lambing (6). The prevalence of IMI did not differ significantly between the vaccinated and control groups of ewes; nevertheless, the frequency of clinical mastitis was reduced. Vaccination with the proper killed vaccine can reduce the frequency of new infections by *Pseudomonas aeruginosa*, although the outbreaks were caused by multiple strains with varied virulence (23). Today, however, the vaccine does not seem to be a tool to prevent subclinical mastitis on a wide scale (7).

Milking procedures and teat dip disinfection. During milking of small ruminants usually there is a transmission of Gram-positive bacteria, mainly *Staphylococci*. The control of mastitis in small ru-

minants should take into account the optimal routine milking and milking hygiene (6). Prophylaxis to prevent infection of the udder is the key to the control of *mastitis*. Good animal welfare and hygienic practice of milking minimize the impact of these diseases on the health and quality of milk (42). CNS are normally present on the skin of the teat of ewes; however, the use of a 0.5% iodine solution in pre-milking teat dips for ewes did not influence IMI incidence in sheep, in contrast to cows (46).

Other management measures. Measurements of electrical conductivity (EC) are used successfully in dairy cows; moreover in recent years this method of preventing subclinical *mastitis* has been adapted to small ruminants, particularly goats (11, 41, 47). The concentration of Na^+ and Cl^- increases in milk of infected glands; however, similarly as in cows, EC in milk of small ruminants may also depend on such factors as the number and lactation stage, fraction of milk, and milk composition. Díaz et al. (11) reported that EC (mS/cm) significantly increased in infected halves of the Murciano-Granadina goats, especially in bilaterally infected glands (11). This system for the detection of subclinical *mastitis* based on daily measurements of EC, however, should be improved for measurement of other variables (e.g. SCC). In addition, *mastitis* detection requires on-line and quick measurements of temperature to provide proper EC data (41). Also some technical EC applications should be adapted to the conditions of machine milking. A number of studies indicated that EC is not a good tool for the detection of subclinical *mastitis* in goats, although it could be used in monitoring of udder health in dairy goats (47). A positive correlation was found in goats between lactoperoxidase (LP) activity and SCC in a study by Seifu et al. (43). Those authors suggested that the enzyme lactoperoxidase could be used as a useful screening test to diagnose subclinical *mastitis* in goats. The results obtained by Persson and Olofsson (37) indicated that SCC measurement by CMT or a deLaval cell counter (DCC) can predict IMI in goats. In dairy sheep selenium deficiency and reduced serum vitamin A concentration may be risk factors for subclinical *mastitis* (15). An epithelium weakened due to vitamin A deficiency may lead to increased bacterial entry into the mammary gland and thus increase risk of disease.

Antibiotic dry-off treatment. Antibiotics used in the dry period in small ruminants significantly reduce the incidence of IMI (12, 18, 36, 46). The antibiotic treatment of animals should be carried out under veterinary supervision and ensuring hygienic administration (10). The best treatment results were obtained by intramammary applications of ampicillin dicloxacillin. The combination of intramuscular amoxicillin clavulonic acid was also successful. Intramuscular injections as the sole treatment using clavulonic acid and amoxicillin were not as effective as intramammary treatment (12). Kiossis et al. (18) in the treatment of infected mammary glands in Chios ewes administered

2,000,000 iu Penethamate hydroiodide daily for three consecutive days. The authors were of the opinion that with the combination of such a program and other managerial practices such as milking routine and housing hygiene, the udder health status could remain high during lactation. In the antibiotic treatment of dairy sheep the frequently applied procedure usually is used to treat the grace bovine mammary gland (36). However, inter-species differences prevent the use of the same procedures in sheep as in cows. Residues of antibiotics in milk sheep are still found 192 h after the last infusion and this period is significantly longer than in cows.

Conclusion

Staphylococcus spp. and especially *Staphylococcus aureus* are common sources of intramammary infections in small ruminants that can cause clinical and subclinical *mastitis*. Coagulase-negative staphylococci are the most prevalent pathogens of the mammary gland in sheep and goats with subclinical *mastitis*. Among small ruminants the prevalence of subclinical *mastitis* ranges from 9 to 50%, while clinical mastitis is usually below 5%. Intramammary infections in ewes and goats cause milk yield losses and a deterioration of its quality, mainly due to increased somatic cell counts. In ewe milk somatic cell counts between 300,000 cells/ml and 1,000,000 cells/ml cause changes in milk composition, with milk in this range of somatic cell contents being produced in the period of transition from normal to mastitic milk. In goat milk it is quite difficult to maintain the level of 1,000,000 cells/ml and non-infectious factors should be taken into account when determining the legal limit of somatic cell counts in bulk tank milk. A standard tool in the diagnosis of *mastitis* in small ruminants is provided by bacterial culture and somatic cell counts. Prevention of *mastitis* should be focused on the optimisation of the milking routine and hygiene. In particularly justified cases and the large prevalence of disease antibiotic treatment should be administered in the dry-period.

References

1. Albenzio M., Caroprese M.: Differential leukocyte count for ewe milk with low and high somatic cell count. J. Dairy Res. 2011, 78, 43-48.
2. Albenzio M., Santillo A., Caroprese M., Ruggieri D., Ciliberti M., Sevi A.: Immune competence of the mammary gland as affected by somatic cell and pathogenic bacteria in ewes with subclinical mastitis. J. Dairy Sci. 2012, 95, 3877-3887.
3. Albenzio M., Santillo A., Caroprese M., Schena L., Russo D. E., Sevi A.: Composition, indigenous proteolytic enzymes and coagulating behaviour of ewe milk as affected by somatic cell count. J. Dairy Res. 2011, 78, 442-447.
4. Bagnicka E., Winnicka A., Józwick A., Rzewuska M., Strzałkowska N., Kościuczuk E., Prusak B., Kaba J., Horbańczuk J., Krzyżewski J.: Relationship between somatic cell count and bacterial pathogens in goat milk. Small Ruminant Res. 2011, 100, 72-77.
5. Barth K., Aulricha K., Müller U., Knappstein K.: Somatic cell count, lactoferrin and NAGase activity in milk of infected and non-infected udder halves of dairy goats. Small Ruminant Res. 2010, 94, 161-166.
6. Bergonier D., Berthelot X.: New advances in epizootiology and control of ewe mastitis. Livest. Prod. Sci. 2003, 79, 1-16.
7. Bergonier D., de Crémoux R., Rupp R., Lagriffoul G., Berthelot X.: Mastitis of dairy small ruminants. Vet. Res. 2003, 34, 689-716.

8. Casu S., Sechi S., Salaris S. L., Carta A.: Phenotypic and genetic relationships between udder morphology and udder health in dairy ewes. *Small Ruminant Res.* 2010, 88, 77-83.
9. Contreras A., Corrales J. C., Sánchez A., Sierra D.: Persistence of subclinical intramammary pathogens in goats throughout lactation. *J. Dairy Sci.* 1997, 80, 2815-2819.
10. Contreras A., Sierra D., Sánchez A., Corrales J. C., Marco J. C., Paape M. J., Gonzalo C.: Mastitis in small ruminants. *Small Ruminant Res.* 2007, 68, 145-153.
11. Díaz J. R., Romero G., Muelas R., Alejandro M., Peris C.: Effect of intramammary infection on milk electrical conductivity in Murciano-Granadina goats. *J. Dairy Sci.* 2012, 95, 718-726.
12. Doğruer G., Saribay M. K., Ergün Y., Aslantaş Ö., Demir C., Ateş C. T.: Treatment of subclinical mastitis in Damascus goats during lactation. *Small Ruminant Res.* 2010, 90, 153-155.
13. Fotou K., Tzora A., Voidarou Ch., Alexopoulos A., Plessas S., Avgeris I., Bezirtzoglou E., Akrida-Demertzi K., Demertzi P. G.: Isolation of microbial pathogens of subclinical mastitis from raw sheep's milk of Epirus (Greece) and their role in its hygiene. *Anaerobe* 2011, 17, 315-319.
14. Giadinis N. D., Arsenos G., Tsakos P., Psychas V., Dovas C. I., Papadopoulos E., Karatzias H., Fthenakis G. C.: "Milk-drop syndrome of ewes": Investigation of the causes in dairy sheep in Greece. *Small Ruminant Res.* 2012, 106, 33-35.
15. Giadinis N. D., Panousis N., Petridou E. J., Siarkou V. I., Lafi S. Q., Pourliotis K., Hatzopoulou K. E., Fthenakis G. C.: Selenium, vitamin E and vitamin A blood concentrations in dairy sheep flocks with increased or low clinical mastitis incidence. *Small Ruminant Res.* 2011, 95, 193-196.
16. Gougoulis D. A., Kyriazakis I., Papaioannou N., Papadopoulos E., Taitzoglou I. A., Fthenakis G. C.: Subclinical mastitis changes the patterns of maternal-offspring behaviour in dairy sheep. *Vet. J.* 2008, 176, 378-384.
17. Hall S. M., Rycroft A. N.: Causative microorganisms and somatic cell counts in subclinical intramammary infections in milking goats in the UK. *Vet. Rec.* 2007, 160, 19-22.
18. Kiossis E., Brozos C. N., Petridou E., Boscós C.: Program for the control of subclinical mastitis in dairy Chios breed ewes during lactation. *Small Ruminant Res.* 2007, 73, 194-199.
19. Koop G., Dik N., Nielen M., Lipman L. J. A.: Short communication: Repeatability of differential goat bulk milk culture and associations with somatic cell count, total bacterial count, and standard plate count. *J. Dairy Sci.* 2010, 93, 2569-2573.
20. Koop G., Nielen M., van Werven T.: Bulk milk somatic cell counts are related to bulk milk total bacterial counts and several herd-level risk factors in dairy goats. *J. Dairy Sci.* 2009, 92, 4355-4364.
21. Koop G., van Werven T., Schuling H. J., Nielen M.: The effect of subclinical mastitis on milk yield in dairy goats. *J. Dairy Sci.* 2010, 93, 5809-5817.
22. Le Maréchal C., Thiéry R., Vautor E., Le Loir Y.: Mastitis impact on technological properties of milk and quality of milk products — a review. *Dairy Sci. Technol.* 2011, 91, 247-282.
23. Leitner G., Krifucks O.: Pseudomonas aeruginosa mastitis outbreaks in sheep and goat flocks: antibody production and vaccination in a mouse model. *Vet. Immunol. Immunop.* 2007, 119, 198-203.
24. Leitner G., Merin U., Silanikove N.: Changes in milk composition as affected by subclinical mastitis in goats. *J. Dairy Sci.* 2004, 87, 1719-1726.
25. Leitner G., Silanikove N., Merin U.: Estimate of milk and curd yield loss of sheep and goats with intramammary infection and its relation to somatic cell count. *Small Ruminant Res.* 2008, 74, 221-225.
26. Marogna G., Pilo C., Vidali A., Tola S., Schianchi G., Leori S. G.: Comparison of clinical findings, microbiological results, and farming parameters in goat herds affected by recurrent infectious mastitis. *Small Ruminant Res.* 2012, 102, 74-83.
27. Marogna G., Rolesu S., Lollai S., Tola S., Leori G.: Clinical findings in sheep farms affected by recurrent bacterial mastitis. *Small Ruminant Res.* 2010, 88, 119-125.
28. McDougall S., Pankey W., Delaney C., Barlow J., Murdough P. A., Scruton D.: Prevalence and incidence of subclinical mastitis in goats and dairy ewes in Vermont, USA. *Small Ruminant Res.* 2002, 46, 115-121.
29. Nicholas R. A. J., Ayling R. D., Loria G. R.: Ovine mycoplasma infections. *Small Ruminant Res.* 2008, 76, 92-98.
30. Olechnowicz J., Jaśkowski J. M.: Somatic cell counts and total bacterial count in bulk tank milk of small ruminants. *Slov. Vet. Res.* 2012, 49, 13-18.
31. Omaleki L., Browning G. F., Allen J. L., Barber S. R.: The role of Mannheimia species in ovine mastitis. *Vet. Microbiol.* 2011, 153, 67-72.
32. Onni T., Vidali A., Bandino E., Marogna G., Schianchi S., Tola S.: Identification of coagulase-negative staphylococci isolated from caprine milk samples by PCR-RFLP of groEL gene. *Small Ruminant Res.* 2012, 104, 185-190.
33. Ozenc E., Seker E., Baki Acar D., Birdane M. K., Darbaz I., Dogan N.: The importance of Staphylococci and threshold value of somatic cell count for diagnosis of sub-clinical mastitis in Pirlak sheep at mid-lactation. *Reprod. Dom. Anim.* 2011, 46, 970-974.
34. Paape M. J., Capuco A. V.: Cellular defense mechanisms in the udder and lactation of goats. *J. Anim. Sci.* 1997, 75, 556-565.
35. Paape M. J., Wiggans G. R., Bannerman D. D., Thomasc D. L., Sanders A. H., Contreras A., Moroni P., Miller R. H.: Monitoring goat and sheep milk somatic cell counts. *Small Ruminant Res.* 2007, 68, 114-125.
36. Pengov A., Kirbis A.: Risks of antibiotic residues in milk following intramammary and intramuscular treatments in dairy sheep. *Anal. Chim. Acta* 2009, 637, 13-17.
37. Persson V., Olofsson I.: Direct and indirect measurement of somatic cell count as indicator of intramammary infection in dairy goats. *Acta Vet. Scand.* 2011, 53, 1-5.
38. Pirisi A., Lauret A., Dubeuf J. P.: Basic and incentive payments for goat and sheep milk in relation to quality. *Small Ruminant Res.* 2007, 68, 167-178.
39. Pisoni G., Zadoks R. N., Vimercati C., Locatelli C., Zanoni M. G., Moroni P.: Epidemiological investigation of Streptococcus equi subspecies zooepidemicus involved in clinical mastitis in dairy goats. *J. Dairy Sci.* 2009, 92, 943-951.
40. Raynal-Ljutovac K., Pirisi A., de Crémoux R., Gonzalo C.: Somatic cells of goat and sheep milk: Analytical, sanitary, productive and technological aspects. *Small Ruminant Res.* 2007, 68, 126-144.
41. Romero G., Díaz J. R., Sabater J. M., Perez C.: Evaluation of commercial probes for on-line electrical conductivity measurements during goat gland milking process. *Sensors* 2012, 12, 4493-4513.
42. Ruegg P. L.: Mastitis in small ruminants. 44th Annual Conference of the American Association of Bovine Practitioners, Small Ruminant Session: Sept 22-25, 2011, St. Louis MO: 1-26.
43. Seifu E., Donkin E. F., Buys E. M.: Potential of lactoperoxidase to diagnose subclinical mastitis in goats. *Small Ruminant Res.* 2007, 69, 154-158.
44. Seyffert N., Le Maréchal C., Jardin J., McCulloch J. A., Rosado F. R., Miyoshi A., Even S., Gwenaël J., Berkova N., Vautor E., Thiéry R., Azevedo V., Le Loir Y.: Staphylococcus aureus proteins differentially recognized by the ovine immune response in mastitis or nasal carriage. *Vet. Microbiol.* 2012, 157, 439-447.
45. Silva E. R. da, Siqueira A. P., Dias Martins J. C., Barbosa Ferreira W. P., da Silva N.: Identification and in vitro antimicrobial susceptibility of Staphylococcus species isolated from goat mastitis in the Northeast of Brazil. *Small Ruminant Res.* 2004, 55, 45-49.
46. Spanu C., Bergerb Y. M., Thomasc D. L., Ruegg P. L.: Impact of intramammary antimicrobial dry treatment and teat sanitation on somatic cell count and intramammary infection in dairy ewes. *Small Ruminant Res.* 2011, 97, 139-145.
47. Tangorra F. M., Zaninelli M., Costa A., Agazzi A., Savoini G.: Milk electrical conductivity and mastitis status in dairy goats: results from a pilot study. *Small Ruminant Res.* 2010, 90, 109-113.
48. White E. C., Hinckley L. S.: Prevalence of mastitis pathogens in goat milk. *Small Ruminant Res.* 1999, 33, 117-121.

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