Chapter 10

The Course of Machine Milking in Small Ruminants

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1. Introduction

1.1. Machine milking of small ruminants: A review

During the last 20 years the reported worldwide goat populations have increased by 52% (56% in the developing countries and 17% in the developed countries), while the sheep populations worldwide decreased by 3% (6% in the developed countries, while increasing by 14% in the developing countries). Dairy goat and sheep farming are important economically in many developed countries, especially in the Mediterranean area, such as France, Italy, Spain and Greece (Haenlein, 2001). Many of the benefits of dairy sheep and goat farms are also recognized in the developing countries, that provide a significant proportion (from 2 to 7%) of sheep and goat milk of the total world milk production. Milk production by small ruminants accounts for about 3.5 percent of world milk production; however, this percentage is higher in the developing countries (7.5%) than in the developed countries (1.5%) (Boyazoglu & Morand-Fehr, 2001). Milk of small ruminants is a valuable raw material for the production of yoghurt, milk powder and UHT milk, cheese brine and ripening hard cheeses (Haenlein, 2001; Olechnowicz & Jaśkowski, 2004; Olechnowicz & Jaśkowski, 2005). The quality of these products is assessed in relation to their hygienic, sanitary, dietary and nutritional value, as well as flavor (Boyazoglu & Morand-Fehr, 2001). Deterioration of sensory attributes and shortening of the shelf life of finished products is associated with an excessive number of somatic cells in bulk tank milk, i.e.; bulk tank somatic cell count – BTSCC (Boyazoglu & Morand-Fehr, 2001; Haenlein, 2001; Gonzalo et al., 2005; Zweifel et al., 2005). BTSCC is the main indicator of udder health in small ruminants (Fernández et al., 1999; Muehlherr et al., 2003; Diaz et al., 2004). Factors that influence log BTSCC include herd and breed, lactation stage, the course of the drying-off period of animals and milking system (Zeng & Escobar, 1996; Diaz et al., 2004; Zweifel et al., 2005). In machine milking log BTSCC is also influenced by factors such as vacuum level, pulsation frequency and pulsator ratio in milking installations (Billon et al., 1999; Fernández et al., 1999; Sinapis et al., 2000; Peris et al., 2003a, 2003b). In sheep and goats daily milk yield and composition (fat, protein and lactose percentage contents) as well as log BTSCC are also affected by the frequency of milking (Knight & Gosling, 1995; Synapis et al., 2000; Negrão et al., 2001; Salama et al., 2003; Capote et al., 2008) and the use or omission of machine stripping (Knight & Gosling, 1999; Molina et al., 1999; McKusik et al., 2000, 2003). In the course of machine milking in small ruminants it is also important to monitor the health status of mammary glands by diagnostic tests and dipping of teats after milking has been completed (Bergonier & Berhelot, 2003; Bergonier et al., 2003). Improvement of hygienic conditions during milking is important in assessing the microbiological quality of milk. Zweifel et al. (2005) reported that in Switzerland the standard plate counts (SPC) for bulk tank milk from small ruminants was median SPC of 4.71 log cfu/ml (mean SPC 6.86 log cfu/ml). For goat's milk median SPC was 4.68 log cfu/ml (mean SPC was 6.92 log cfu/ml), whereas for ewe's milk median SPC was 4.79 log cfu/ml (mean SPC 6.05 log cfu/ml). The highest median SPC (5.24 log cfu/ml) was found in June. Microbiological quality of milk from small ruminants was significantly influenced by the month of sample collection, the number of milkings from which milk was contained in the bulk tank, the technique of milking, and flock size. *Enterobacteriaceae* were detected in 212 (61.6%) goat's milk and 45 (71.4%) ewe's milk samples, whereas *Staphylococcus aureus* were detected in 109 (31.7%) samples of goat's milk and 21 (33.3%) samples of ewe's milk (Muehlherr et al., 2003). At present breeders pay increasing attention to the level of milk yield and the clinical status of the udder in small ruminants. The values of genetic and phenotypic correlation coefficients between somatic cell counts and morphological traits of the udder suggest that some of the latter, such as e.g. the depth, shape and attachment of the udder, and the location and the size of teats, need to be taken into consideration in the evaluation of suitability of small ruminants for machine milking (Fernández et al., 1999; Peris et al., 1999; Dzidic et al., 2004; Legarra & Ugarte, 2005; Marie-Etancelin et al., 2005). In relation to the influence of many factors on bulk tank somatic cell counts (BTSCC) it seems justified to show the course and consequences of machine milking in small ruminants on milk quality and health of the teat end.

1.2. Physiological aspects of machine milking in small ruminants

Milk in the udder of cows is usually stored in the alveolar compartment (around 80%) and only up to 20% is stored in the cistern. In contrast, in small ruminants the cisternal fraction amounts to more than 50% (Bruckmaier et. al., 1994; Bruckmaier & Blum, 1998). In dairy ewes and goats after a normal 12-hour milking interval the cisternal milk represents between 50 and 80% (Marnet & McKusik, 2001). These larger cisterns play an important role in milk collection and storage and have a significant influence on milk ejection during milking. The cisternal milk fraction is available for machine milking or to suckling before the occurrence of milk ejection. In animals, in which the mammary glands do not have the capacity to store milk (e.g. rodents) the milk let-down reflex is necessary to maintain the secretory function, while in ruminant animals exclusion parts of the innervation of glandular sinuses have no effect on the end of lactation (Marnet et al., 1998). It follows that the release of oxytocin is not crucial for the maintenance of milk production in small ruminants (Bruckmaier et al., 1997; Marnet et al., 1998, Marnet & McKusik, 2001). As a result of stimulation of the teats and mammary glands either by the sucking young or machine milking followed by the transmission of nerve impulses to the anterior pituitary, which secretes oxytocin, it is transported to the mammary gland and its myoepithelial cells, which surround the alveoli and small intralabular ductules. Contraction causes a flattening of the alveolar lumen and results in the transfer of milk through the ductules to the cistern and teat for milk removal (Lollivier et al., 2002). In contrast to cows, the time of oxytocin release during milking in goats does not influence significantly the model curve of milk flow and an increasing pressure of milk in the cisterns probably induces milk ejection (Bruckmaier et al., 1994; Marnet et al., 1998). On this basis one can identify goats with high milk production and high rate of milk flow (Marnet et al., 1998). The release of oxytocin is significantly diversified in goats and the curve of milk flow during milking often has two or three peaks (Bruckmaier et al., 1994; Marnet et al., 1998). In White German Goats higher rates of milk flow (ml/min) were reported in the group of goats without stimulation of teats when compared with goats, who were subjected to teat stimulation and goats stimulated by 2 kids (Mueller & Kaufmann, 2005). In ewes there is latency in milk removal when applied to the teat milking cups, but a lack of stimulation before milking, similarly as in goats, has no effect on the model curve of milk flow during milking (Bruckmaier et al., 1994; Marnet et al., 1998). The release of oxytocin in ewes, however, is necessary for the removal of milk during a short time of milking, although blood oxytocin concentration is not related to milk yield. However, determination of blood oxytocin concentrations in ewes may be useful in determining the efficiency of milking machine providing optimal stimulation of mammary glands. On the other hand, oxytocin stimulates milk flow from the lumen of alveoli to the cistern between milkings (Marnet et al., 1998). Moreover, 92% Lacaune ewes demonstrate significant increases in plasma oxytocin concentrations in response to machine milking; however, large variations are noted in oxytocin concentration between ewes, ranging from 10 to more than 150 pg/ml (Marnet et al., 1998). In ewes of this breed oxytocin concentration significantly increased within 0.5 minutes after the start of stimulation or milking, while in East Friesian ewes low levels of oxytocin or a lack of its release were reported. Stimulation of the teats before milking resulted in the release of oxytocin within 1-2 minutes after the start of milking, indicating a delayed response while waiting for the onset of milk flow (Bruckmaier et al., 1997). Anatomically mammary glands in ewes and in goats differ slightly; however, in ewes the outlet duct of the teat is not always located on the edge of the mammillary part of the cistern, from which proportionally to the amount of milked milk the stripping fraction is obtained (Labussiére, 1988; Bruckmaier et al., 1997). This anatomical peculiarity is the cause of obtaining a large quantity of milk from machine stripping. On the other hand, the apparent latency in the release of oxytocin in ewes results in a situation when the curves have two milk peaks, with the second peak referring to the alveolar fraction of milk, which is not always milked due to the short time of milking (Bruckmaier &

Blum, 1998). In small ruminants milk is readily transferred from the alveoli to the cistern during the period between milkings. This phenomenon of milk transfer during the periods between milkings is not fully understood (Marnet & McKusik, 2001). There are several theories on this subject. It seems that the variations in the microanatomy of the mammary gland may affect milk transfer. On the other hand, it is possible that a spontaneous contraction of the smooth muscle causes the removal of milk out of the alveoli and small ducts to the cistern. Oxytocin was also found to have a considerable effect as a promoter of milk transfer from the alveolar lumen to the cisternal cavity between milkings (Marnet et al., 1998). Ewes with a considerable cistern volume well tolerated milking once a day, but were not adapted to the increased frequency of milkings (Labussiére, 1988). More recent data indicate that an accumulation of proteins synthesized in the gland (FIL – feedback inhibitor of lactation) reduces the synthesis of milk in the alveoli. The inhibition of milk ejection may occur as a result of emotional stress. In most species (except for cattle) β-endorphin plays an important role. The milk ejection rate is regulated by the adrenergic system and peripheral inhibition of milk ejection may be caused by the adrenergic receptor stimulation or an oxytocin receptor blockade (Wellnitz & Bruckmaier, 2001). An increased frequency of milkings in ewes positively affected the secretion of milk (Labussiére, 1988; Knight & Gosling, 1995; Negrão et al., 2001). Multiparous Lacaune ewes breed between 60. and 65. days of lactation were milked at different frequencies during the day (1x, 2x, 3x, 4x, 5x, and 7x). To determine the concentration of oxytocin during milking, blood samples were taken 30 s before milking and 30, 60 and 120 s after the start of milking. Milking cups were applied to the teats at time 0 (with no teat washing or the massage) and were removed from the teats after 90 s. Basic levels of oxytocin (30 seconds before milking) were low at all milking frequencies, while a significant increase in oxytocin levels was noted in all groups of ewes after the start of milking. Single milking in ewes induced higher levels of oxytocin in comparison to all the frequencies of milking (Negrão et al., 2001). A hypothesis was proposed on the hindering of milk flow through the blocking of oxytocin release from the pituitary gland, as well as a local blocking of its influence in mammary glands. Blood concentration of noradrenaline in blood in East Friesian ewes at above 300pg/ml, and above 700 pg/ml in Lacaune ewes stops the release of oxytocin. In small ruminants the management system can have a significant impact on milk ejection. Dairy ewes and goats are frequently suckled by the young for a period of 30 to 60 days, and after that period they are only machine-milked. In the period of adaptation to the milking machine a significant decrease (about 30%) is observed in total milk production (Labussiére, 1988). The decrease in milk production during this period is affected by three important physiological factors. An important factor in the transitional period is connected with a less frequent udder evacuation from many sucklings per day, compared with the udder being emptied only twice per day at milking. Another factor influencing the lower milk production during the transitional period is the less effective stimulation of the udder by the machine milking compared to the presence and suckling stimulus by the young. This is also linked with a long time of the release of oxytocin during suckling compared to milking, i.e. 5 vs. 2

minutes, respectively (Marnet & McKusik, 2001). The third factor is the milking environment-induced stress, when ewes and goats are milked in the milking parlor as compared to suckling in the barn (Marnet & Negrão, 2000). In addition to these factors an important role is also played by management factors, such as a mixed management system, which allows for lambs to suckle their mothers for 8 to 12 hours per day, then they are separated from their mothers at night, and the ewes are machine-milked in the morning (McKusik et al., 2000). The release of oxytocin in ewes milked in the mixed management system does not differ from the baseline levels, indicating a total inhibition of the milk ejection reflex (Marnet & Negrão, 2000). If ewes were milked in the presence of their lambs, the release of oxytocin would be normal; however, if lambs are not present during the milking, oxytocin release is again inhibited. This inhibition of oxytocin release only slightly influences the recuperation of the cisternal milk fraction, while the alveolar fraction is retained in the udder (McKusik et al., 2000). The mother-young bond plays an important role in the modulation of maternal endocrinology also in goats (Hernández et al., 2002). In addition, a prolonged period of maternal nursing may have positive effects on the welfare of the mothers and their young (Hernández et al., 2007). Dairy ewes produce 25% of total milk production in lactation during their first month of lactation. Taking into account the fact that in ewes milk yield is increased up to approximately 24 days after parturition, when ewes are not machine milked, the mixed management system seems to be beneficial both for the growth of the lamb and also due to the commercial nature of milk production (McKusik, 2000). This inhibition in the release of oxytocin and the related decrease in milk production persist until several days following weaning. If the adopted management system used in a suckling period of more than 30 days, then a higher proportion of ewes does not show normal milk ejection following weaning. During the first few weeks of adaptation to the machine milking a gradually increasing secretion of oxytocin and better release synchronization of the oxytocinergic system are observed (Marnet & McKusik, 2001).

1.3. Technique and course of machine milking

Ewes are most often milked at the high pulsation frequency (from 120 to 180 cycles/minute), a low level of negative pressure (from 32 to 40 kPa) and a 50% pulsator rate. In the least years a tendency was observed to reduce the weight of the milking cluster as well as to lower the level of negative pressure in milking installations (to 34 – 36 kPa) and to apply a 50% pulsator rate (Billon et al., 1999). High frequency pulses are used to ensure an optimal milk let-down reflex and accurate milking of ewes (Marnet et al., 1998; Marnet, 2002). In recent years a trend towards a further reduction in milking vacuum (to 34 - 36 kPa) has been observed due to the decreasing mass of milking clusters (Billon et al., 1999). In a study on Manchega ewes creasing the pulse frequency from 120 to 180 cycles per minute at 36 kPa vacuum and a pulsator rate of 50% did not have a detrimental impact on the health status of the udder and teat end condition (Peris et al., 2003b). Optimal conditions of machine milking for goats include pulsation frequency of 70 – 90 cycles/minute, at the negative pressure in milking installation of 36 – 44 kPa and a 65% pulsator rate (Sinapis et al., 2000).

In the Alpine and Saanen breeds high frequency pulses (90 and 120 cycles/minute with a high pulsator rate of 60%) reduced the milking time (higher average milk flow rate), while low frequency pulses (60 cycles/minute) and pulsator rate of 50% lengthened the milking time and decreased the average milk flow rate (Billon et al., 2005). The milking installation in the milking parlor mounted at more than 1.26 m from the level of the position is the high-level system (HL), and below 1.25 m – midlevel (ML), while a milk pipeline placed below the position of the milked sheep is regarded as the low level milking system (LL). ML and LL milking systems in Manchega ewes do not have a significant influence on milk production, the volume of individual milk fractions, the frequency of falling teatcups, milking time, somatic cell counts or milk composition (Diaz et al., 2004). A stable vacuum in the milk system milk and a pipeline diameter of 76 cm positively influenced the milking routine, that was not interrupted by linear slips (Caria et al., 2008). In Assaf, Awassi, Churra and Castelana ewes, being hand- and machine-milked, log BTSCC was higher in hand-milked (6.07) than in machine-milked animals (5.94). In ewes milked in the ML and LL systems log BTSCC was 5.88 and 5.94, respectively, and that was less than in the bucket system (6.04). High frequency pulses (180 cycles/minute) and low levels of vacuum are considered equally important as the optimum conditions of ewe milking determining udder health (Gonzalo et al., 2005). In dairy goats of the Alpine and Nubian breeds the milking system (machine, bucket and hand milking) did not significantly influence log SSC, which was 5.94; 5.97 and 6.01, respectively (Zeng & Escobar, 1996). In that study milk of hand-milked goats was more infected (standard plate count, log SPC 3.62 cfu/ml^{-1}) than that of machine-milked and bucket-milked goats, for which log SPC was 2.97 cfu/ml^{-1} and 2.44 cfu/ml^{-1}, respectively. The SPC results in bulk-tank milk of small ruminants are significantly influenced by the month of sample collection, the number of milkings contained in the bulk-tank, milking technique and flock size. The introduction of the milking machine in place of hand milking in dairy ewes will improve the work conditions of breeders, because the milking procedure accounts for 40-50% of all the work on the farm. The mechanization of milking not only improves the working conditions of farmers, but also improve the hygienic quality of milk (Sinapis, 2007). The main indicators of milking performance of sheep are the proportions of various milk fractions, i.e. milked, stripping and residual milk fractions. These values depend on the breed, routine milking and technical characteristics of the milking equipment, and are as follows: milk from the milking of 60 to 75, and stripping of milk from 10 to 20 and residual milk from 10 to 15% (Labussiére, 1988; Fernández et al., 1999; Molina et al., 1999). In a study by McKusik et al. (2000) the waiting time to the onset of milk flow in crossbred East Friesian ewes in mid-lactation (90 days) was determined to be 13.1 s, while the peak milk flow rate (ml/minute) was found after 34.3 s milking. According to those authors the time of milk flow is 105.9 s (0.92 l), time of machine stripping is 26 s (0.22 l) and the total milking time (without overmilking time) is 132 s (1.14 l), respectively. In a study on Saanen goats by Bruckmaier et al. (1994) the waiting time to the onset of milk flow after attaching the clusters on teats was 12.09 s, and was characterized by low variability (sd=0.45 s) at individual milkings. The average milk flow rate is significantly correlated with milk yield and the stage of lactation (Mottram et al., 1994). In Alpine goats the waiting time for milk flow was 12.8 s, and time milk flow was 236.3 s. Small ruminants are generally milked in groups, thence homogeneity in milkability of the whole flock is also essential (Casu et al., 2008). The main objective of machine milking in small ruminants is to obtain large quantities of valuable milk in a short time with few manual interventions (McKusik et al., 2003). Manual or machine stripping is not widely used in Lacaune ewes in France, while it is practiced in most dairy ewes in the United States and Canada (McKusik et al., 2003). The amount of milk obtained from stripping, i.e. the massage of the udder with the clusters still attached, depends on the breed of sheep, formation of the udder (morphology traits), lactation rank, and vacuum level, and accounts for 10 to 30% of the average amount of milk yield (Labussiére, 1988). Stripping milk yield depends also on blood oxytocin concentration during milking (Bruckmaier et al., 1997). The factor limiting the use of one or two milkings a day in dairy ewes should be the capacity of the cisternal storage (Negrão et al., 2001). It seems that the release of oxytocin is not a limiting factor in milk production when high milking frequencies are used. Increasing the frequency of milkings from 5 to 7 a day gave modest gains in milk production, hence probably the limiting factor was the milk synthesis rate. The results of a study by Negrão et al. (2001) indicate that a better interaction between continuous milk synthesis and alveolar milk ejection was found at 3 milkings daily. Given the profitability of milk production from dairy ewes and goats the results suggest that an increase of milking frequency can improve the income from milk production in many breeds. In New Zealand in view of the considerable amount of work connected with double milking the afternoon milking and machine stripping were abandoned in ewes of such breeds as Poll Dorset, Romney, Coopworth and Perendale (Knight & Gosling, 1995). In East Friesian dairy ewes the omission of machine stripping during mid- and late lactation reduced milk yield by approx. 14%; however, it did not affect milk composition, lactation length or SCC (McKusik et al., 2003). Such an action improves parlor throughput by eliminating machine stripping and significantly decreases the incidence of overmilking. Through a simplified procedure and milking routine additional ewes may be added to the flock, which can compensate for potential losses in milk production. In crossbred East Friesian ewes the frequency of milkings was associated with the system of rearing lambs, and the periods between milkings ≤ 16 hours during the mid- and late lactation did not affect significantly the yield and composition of milk (McKusik et al., 2000). In Murciano-Granadina goats, regardless of differing periods between milkings (8, 16 and 24 hours), milk production in the alveolar fraction increased after milking time from 8 to 16 hours, but a longer interval did not result in any increase in milk production. The glandular area index for follicular sinuses (measured by ultrasound) increased with the length of the periods between milkings (from 57 : 43 to 75 : 25), but the difference was significant at an 8-hour interval between milkings (Salama et al., 2004). A single daily milking in goats of this breed moderately reduced milk yield, whereas it did not affect milk composition and udder health. Due to the higher losses in milk production, a single milking is not recommended for goats in early lactation and for dairy goats at less than four parities (Salama et al., 2003). Increasing milking frequency from once to twice a day in Tinerfeña dairy goats admittedly statistically significantly affected machine stripping milk (MSM) and residual milk (RM) and fat content; however, it did not improve milkability and did not affect milk yield (Capote et al., 2008). Machine milkability of dairy ewes tends to deteriorate with the lactation stage and parity. Milk emission traits show a high individual variability, suggesting that they are genetically determined and can be improved through selection (Casu et al., 2008).

1.4. Udder morphology and machine milking ability

Healthy and well-shaped udders of small ruminants, suitable for machine milking, should have the following characteristics: a great volume, a globose shape and clearly defined teats, soft and elastic tissues, with palpable cisterns inside, moderate height, not surpassing the hock, a marked intermammary ligament, and teats of medium size, implanted near the vertical position (Labussiére, 1988). Figure 1 illustrates mammary traits, in the rear and lateral view (Rovai et al., 2004).

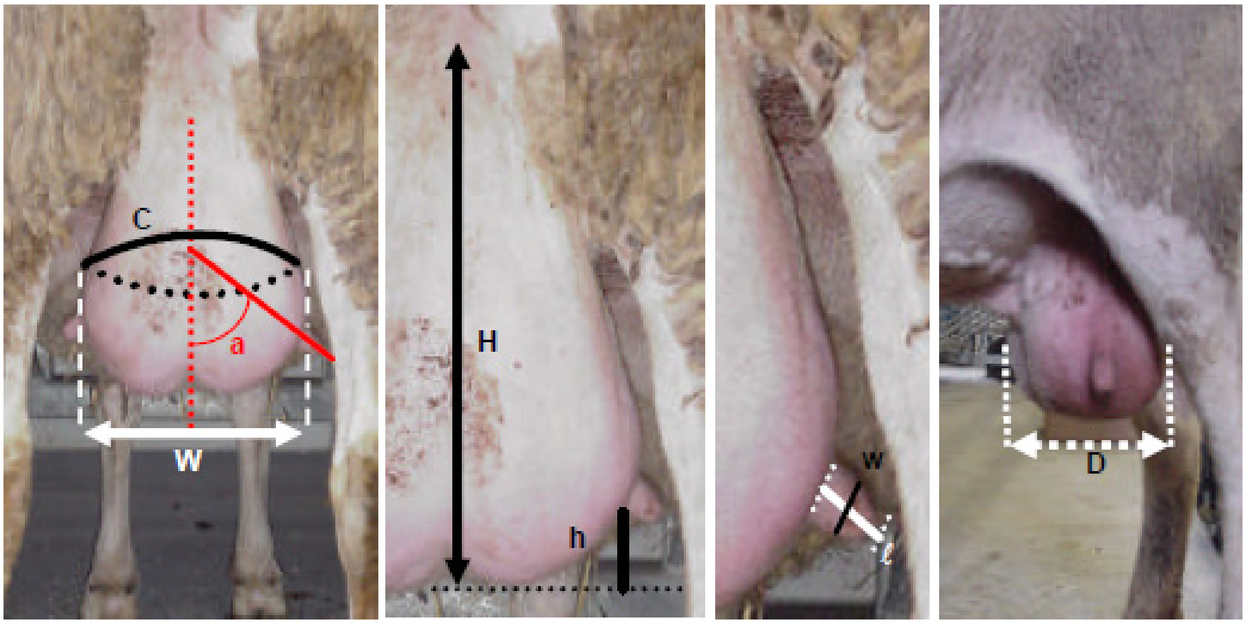

Figure 1. Mammary traits, rear and lateral view. **C**: udder circumference, **a**: teat angle, **W**: udder width, **H**: udder depth, **h**: cistern height, **I** and **w**: length and width of the teat and **D**: udder depth

Lactation stage significantly influences the dimensions of the udder in small ruminants (Fernández et al., 1995). On the other hand, the impact of breed on the length of the udder and the distance between the teats was not significant; similarly, there was little effect of lactation on the teat angle and length of the udder. Breed and parity of animals are significantly associated with the length of teats, and with the width and height of cisterns (Labussiére, 1988). Positive and significant correlations between morphology traits of the udder are included in the evaluation of the udder and selection of animals (Fernández et al., 1995). Valuation of the udders is performed as part of testing in ewes of the following breeds: Churra, Manchega, Latxa and Lacaune (Marie-Etancelin et al., 2005). Cisternal size and udder morphology traits are correlated with milk secretion rate and milk emission kinetics during machine milking in dairy ewes (Labussière, 1988; Marnet & McKusik, 2001; Ayadi et al., 2011). As it was stated by Ayadi et al. (2011) in Tunisia Sicilo-Sarde ewes are adapted to machine milking in terms of the morphological traits of the udder, because of their medium-sized cisterns and teats. According to those authors udder morphology traits showed positive correlations with milk yield. Another study also showed a moderate association between the udder measurements and milk production in Frizarta dairy sheep (Kominakis et al., 2009). In ewes of that breed the most important without space; predicors for milk yield include udder circumference, udder width, udder height and teat length. Associations of morphological traits of the udder with quantitative and qualitative milk production and milking ability are of particular importance to machine milking of ewes. Similar conclusions are presented in a study by Iñiguez et al. (2009) for two Awassi sheep genotypes and their crosses. Genetic correlation coefficients for Latxa ewes between traits of the udder in the first and following lactations, ranging from 0.85 to 0.95, indicate that they are almost identical. Genetic correlations between milk yield and the depth of the udder, suspension of the udder and the location and size of the teat amounted to 0.43, 0.10, - 0.25 and – 0.10, respectively (Diaz et al., 2004). Genetic correlations between somatic cell counts in milk in the evaluation scoring (somatic cell score – SCS) and the depth of the udder, suspension of the udder, and the location and size of the teat were 0.10, - 0.27, - 0.01 and 0.29, respectively. In another study it was found that linear udder traits present a favorable genetic correlation with SCS (Casu et al., 2010). A well-formed udder in sheep is less prone to subclinical inflammation. Ewes with large and vertically located teats, as well as those with a greater amount of milk obtained from machine stripping (portion machine stripping – PMS) had a higher log SCC. In PMS a significant effect was found for teat size (r_P = 0.177) and suspension of the udder (r_P = - 0.205), and form of the udder (r_P = - 0.141) (Legarra & Ugarte, 2005). Few significant relationships between suspension of the udder and milk production suggest that in recent years there has been a deterioration in some of the characteristics, especially the depth of the udder and suspension of the udder (Legarra & Ugarte, 2005; Marie-Etancelin et al., 2005). It is possible, however, to combine important morphological traits of the udder with its health status in a selection index (Marie-Etancelin et al., 2005). More recent data show relationships between udder morphology traits and udder health (Casu et al., 2010). According to those authors ewes with deep and pendulous udders and with high implanted teats are more prone to udder inflammation or *mastitis*. Bearing in mind the hygienic status of the flock, these traits of the udder should be an indication for culling of these sheep from the flock. Dzidic et al. (2004) in their study stated that the capacity of the udder in Istrian ewes significantly affects the volume of milk production, milking time, average and peak milk flow rates, whereas the teat angle has a negative effect on all traits characterizing the course of machine milking in ewes). As it was reported by Peris et al. (2003a, 2003b), Murciano-Granadina goats rearing twins had a larger capacity of the udder (2.86 l) and a shorter teat-floor distance (23.57 cm) than in the case of nanny goats rearing single kids, where it was 1.60 l and 26.39 cm, respectively. According to the above mentioned authors, the capacity of the udder is positively correlated with body weight (r_P = 0.80) and milk production (r_P = 0.69). Those authors also found phenotypic positive correlations between teat length and milk flow rate (r_P = 0.55) and between residual milk yield and teat length in early and mid-lactation (r_P = 0.47), and teat diameter (r_P = 0.58). Murciano-

Granadina goats are adapted to the milking machine and do not require increased selection criteria. Selection of Lacaune ewes should improve milking traits, and consequently increase milk production, while the latency time is shortened and the phase of high flow is extended, thereby improving milking ability (Marie-Etancelin et al., 2006). The key adaptations of sheep to the milking machine include the relatively high occurrence of bimodal and plateau milk flow curves, which are very important in the assessment of milkability, because it is assumed that they ensure milk ejection during milking (Mačuhova et al., 2008). Such observations were conducted on Tsigai sheep, improved Valachian sheep and their crosses with the Lacaune breed. One can assume that in around 69% milkings the sheep released oxytocin during machine milking. The assessment of milkability in these breeds of sheep delivers complete and precise information on milk production related to milk flow kinetics throughout lactation in the East European breeds (Tančin et al., 2011). High production of milk and similar average and peak flow rates were characteristic of Istrian crossbred ewes with an advantageous udder shape, which shows good adaptation to the milking machine (Dzidzic et al., 2004). In that study the udder volume of those sheep positively influenced all milking characteristics however, the teat angle had a negative effect on milking time and milk yield, but not milk flow rate. The milk flow and udder morphology traits mainly influenced milking efficiency and milk yield, while Istrian dairy sheep should be included in breeding programs for further improvement of their milk yield. Ewes with a more horizontal teat position and larger teats had higher SCC. These ewes are more prone to develop subclinical *mastitis* (Margetin et al., 2005). Ewes producing more milk within 30 and 60 s (with a quicker milk ejection) had lower log SCC. Conversely, ewes with a higher machine stripping rate had higher log SCC. The level of milk production in high-yielding dairy sheep depends mainly on the capacity of their udder cisterns and greater storage of milk between milkings (Rovai et al., 2008). In that study ewes of two breeds, Manchega and Lacaune, produced approximately the same amount of alveolar milk; however, Lacaune ewes had greater volumes and larger areas of the cisterns, and greater milk yield when compared with Manchega ewes. According to those authors, their results reduce the importance of the alveolar and indicated a greater role of the udder cisterns. For a thorough assessment of udder compartments in high-yielding ewes, such as the Lacaune sheep, in order to prevent spontaneous milk ejection when entering the milking parlor an oxytocin receptor blocking agent should be used. The occurring genetic antagonisms between udder conformation and milk production in primiparous Lacaune ewes suggests that it should be taken into account in the current selection the udder-type traits, the more that there were positive associations between udder traits and SCC in milk (Marie-Etancelin et al., 2005). Results indicated a possibility to combine four traits for conformation and health in a global udder selection index.

1.5. Adverse consequences of machine milking

Irregular and cyclical fluctuations in the vacuum level in the milking cluster result in a situation when the drain stream of milk hits back with some force at the end of the teat, or even milk is pumped back to the teat canal, transferring pathogens. Mainly during machine stripping the air getting into the milking cluster results in a stroke back of milk, which also occurs when the milking clusters are removed from the udder without the vacuum being shut down. In France, over 50% of farmers practiced sporadically machine stripping, and 65% did not turn off the vacuum before removing the clusters from the udder (Bergonier & Berthelot, 2003). The use of machine stripping in small ruminants causes a significant increase of overmilking time, which occurs in 33% and 92% ewes, at two and single milkers, respectively (McKusik et al., 2003). Extended milking time results in a daily interaction of overmilking on the teat tissue and the simultaneous entry of milk into the teat canal, transferring bacteria (Molina et al., 1999; McKusik et al., 2003). Overmilking causes congestion, swelling and dysfunction of the sphincter muscle of teats, and damages the epithelium and the mouth of the teat canal (Bergonier & Berthelot, 2003; Bergonier et al., 2003). This results in a limited capacity to produce keratin by the epithelium of the teat canal and an incomplete closure of the teat canal (Bergonier et al., 2003). In the California Mastitis Test increasing the overmilking time in two groups of machine-milked sheep at different pulse frequencies and different levels of vacuum (180 cycles/minute; 34kPa, and 120 cycles/minute; 40 kPa) did not influence the health status of the udder. A two-fold higher SCC, however, was found in the milk of ewes milked at a lower frequency of pulsation and a higher level of vacuum, 1598.8 x 10^3 cells/ml and 770.4 x 10^3 cells/ml, respectively. At a high frequency of pulsation (180 cycles/minute) and different levels of vacuum (36kPa and 42 kPa) the time of overmilking extended from 1.5 to 2 minutes in the half of the udder throughout 35 days did not influence the frequency of new infections. The percentage of new infections in halves of the udder with overmilking at vacuum levels of 36 kPa and 42 kPa was 10% and 13%, respectively, while in halves without overmilking it was 7% and 11%, respectively (Peris et al., 2003a; 2003b). A high frequency of pulsation (180 cycles/minute) and a low level of vacuum (36 kPa) significantly decreased irritation of the teat end during milking (Fig. 2).

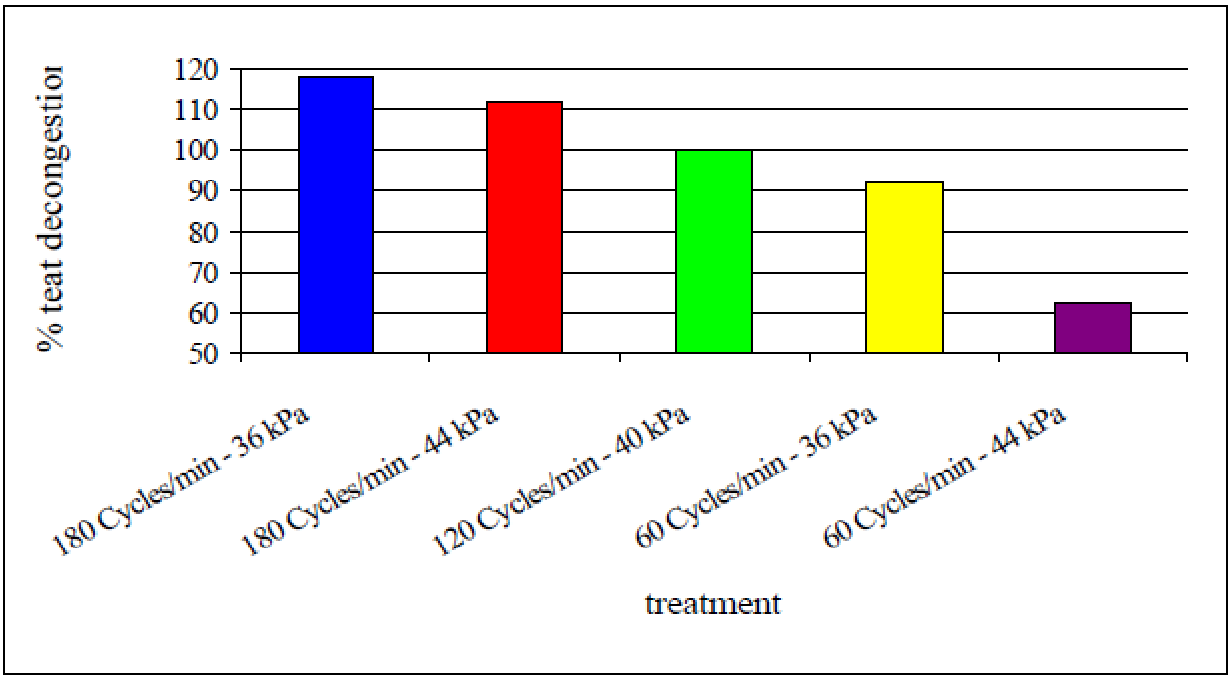

Figure 2. A relationship between teat end condition and pulsation rate and working vacuum level (Marnet, 2002).

Many observations conducted in France on different breeds of sheep showed that pulsation rate should not be less than 150 cycles per minute, while 180 cycles/min should be the pulsation rate applied for high-yielding ewes, such as the Lacaune breed. To improve the quality of machine milking in ewes of the Greek Boutsiko breed, the use of vacuum level of 38 kPa is better, wherein machine stripped milk % is low and irritation of teats is reduced, without affecting the health status of the udder (Sinapis et al., 2006). The results indicate that the low vacuum level of 16.5 kPa is required for the opening of the teat sphincter in ewes of this breed (Sinapis et al., 2007). However, low vacuum significantly modifies the kinetics of milk ejection. The vacuum level of 28 kPa causes an extended latency time for the first milk emission, reduces the average milk flow rate and peak flow rate, and prolongs by about 17% the milking time for milking of a single ewe (Caria et al., 2008). In small ruminants SCC is a good indicator of subclinical inflammation of the udder. Healthy mammary glands in ewes and goats in regular studies during lactation should produce less 500 x 10^3 cells/ml of milk (Bergonier & Berhelot, 2003). For Murciano-Granadina goats at such a physiological threshold only 62.3% of milk samples could be correctly classified. At the level of the flock (SCC above 1 million/ml) BTSCC was a good indicator detecting the degree of mammary gland infections (r^2 =845). During the drying-off period in ewes and goats an antibiotic therapy effectively reduces the proportion of infected mammary glands (Bergonier & Berhelot, 2003). Regular maintenance and inspection carried out every year in terms of the technical parameters of milking machines significantly contribute to the health of the udder and hygienic quality of milk; however, in a survey of milking machine maintenance in different countries Billon et al. reported that only 40-60% of milking machine instalations are controlled every year (Billon et al., 2005). The etiological factor of infection in mammary glands in small ruminants is connected with staphylococci (Ameh & Tari, 2000; Bergonier et al., 2003). *Staphylococcus aureus* is the most common organism isolated from milk in cases of clinical *mastitis*, while in sub-clinical *mastitis* it is coagulase-negative staphylococci (CNS). According to Bergonier & Berhelot (2003), the proportion of clinical mastitis typically does not exceed 5% and it is associated with the start of the milking machine, whereas the percentage of subclinical inflammation ranges from 10% to 50%. The causes of damage to the end of the teat in small ruminants during lactation (apart from the overmilking time) include machine stripping and the period of suckling when lambs or kids try to suckle other females (Bergonier & Berhelot, 2003). Halves of udders with damaged teats are infected more frequently when compared with the halves with healthy teats (Ameh & Tari, 2000; Bergonier & Berhelot, 2003). In goats teat size and their distance from the floor do not influence the percentage of subclinical inflammation in the mammary glands (Ameh & Tari, 2000). Omission of machine stripping in the middle and late lactation decreases milk production by 14%; however, it eliminates the incidence of overmilking time. The elimination of machine stripping does not affect milk composition, length of lactation, or SCC in milk, while it increases the number of milked sheep from 15 to 28/h, at one or two milkers, respectively (McKusik et al., 2003). In Poll Dorset ewes omitted afternoon machine milking and machine stripping in the 8-week period of milking (Knight & Gosling, 1995). The consequence was a decrease of 19.4% (7.9 l/ewe) in milk production in that period. For Murciano-Granadina goats the reduction in the frequency of milkings from 2x to 1x daily had a negative quantitative and qualitative effect on the milk production and health status of mammary glands (Mottram et al., 1994).

2. Machine milking of small ruminants: based on the results of a study by Olechnowicz (2006)

2.1. Introduction

The rationale of this study is to determine the relationship between the organization and course of milking sheep and goats on the Zlotniki farm belonging to the University of Life Sciences in Poznan and qualitative and quantitative levels of milk production. In this farm one milker operates six milking clusters, which can have a significant impact on the course of milking, mainly through prolonged overmilking time. Such an organization of milking may result in an increased SCC in milk, infection of mammary glands, and teat-end damage in small ruminants. The results obtained can be used in practice, the recommendation for the milking milker to shorten or to eliminate overmilking time. On the other hand, the results will be used when selecting individuals to operate milking machines. The aim of the study was to evaluate milking of small ruminants and its effect on some characteristics of milk (SCC and composition). Additional objectives were to determine the influence of some factors on the course of milking, assess the degree of teat end damage and contamination of milk, evaluate dimensions of the udder and their relationship with the course of milking. Correlation coefficients between the phenotypic traits of the udder and milking characteristics were also calculated. Such ratios were also calculated between parameters of machine milking course and morphological traits of the udder and selected milk characteristics.

2.2. Material and methods

The study was conducted at the Zlotniki farm (Poznan University of Life Sciences, Poland). On the farm machine milking is performed on dairy sheep of line 05 with the shares of East-Friesian genes in their genotype amounting to 50 – 75%, and 76 – 90% (13/16 East-Friesian sheep and 3/16 Polish Merino), a prolific ewe sheep 09 (25% of the Finnish sheep, 31% East-Friesian and 44% Polish Merino), white-headed and black-headed sheep, and meat and dairy goats of the White Improved breed. In the years 2000 - 2002 a total of 755 sheep and 207 goats were analyzed. Ewes were milked for 16 weeks in two calendar seasons: spring - summer (March to June) and summer - autumn (July to October). Milking was performed on ewes with clinically healthy udders, after two months of lamb nursing. Milking performance of ewes was tested at monthly intervals and milk production was described from both morning and evening milkings (ml); additionally, milk samples were collected before the morning milking for laboratory testing. Nanny goats with clinically healthy udders were selected for milking after 70 days of rearing kids. Goats were milked from May till November. At monthly intervals each year six milking tests were carried out, with measurements of both morning and evening milking production (ml). Milk samples were collected for laboratory analyses before the morning milking. The technical condition of the milking machine was tested annually in accordance with the Polish Standards. The measurements of pulsation frequency and pulsator coefficients were taken with the use of a Milko Test 2000 electronic pulsograph (Bilgery). Ewes and goats were milked in 14 and 11 stands, respectively, of a milking parlor (Westfallen). The ewes were milked at milking vacuum of 41 kPa, the pulsation rate of individual clusters ranged from 121.7 to 126.7 pulses/min and pulsation ratio was 50±5%. Milking of goats was conducted at a vacuum level of 41 kPa, pulsation rate of 69.9 to 76.7 pulses/min and pulsation ratio of 60 ± 5%. During three or four sheep milking performance tests, as well as two and five goat milking performance tests, milk samples of approximately 15 ml each were collected for bacteriological tests under sterile conditions. Directly after the samples had been collected they were cooled down to the temperature of 4^{o}, and next, after freezing (- 20^{o}C), they were delivered to the microbiological laboratory of the State Veterinary Institute in Pulawy (Branch in Bydgoszcz). Microbiological determination was carried out according to the laboratory diagnostics of *mastitis*. At each milk test day before the morning milking, after fore-stripping, washing and drying of the teats, approximately 50 ml of milk (preserved with a CC preparation) were collected from ewes and nanny goats from their udder halves in order to determine the percentage contents of fat, total protein and lactose, as well as SCC. Analyses of milk samples were carried out at the Laboratory of Milk Evaluation in Krotoszyn. The basic milk composition was determined with the use of a MilkoScan apparatus, while SCC was analyzed with Fossomatic appliances. All parameters were measured to monitor the course of milking in seconds. Measurements of activities related to milking were taken every month for 3 days (milk test day ± 1 day) during the morning milking. Measurements of the duration of individual milking tasks (the time of milk flow from udder halves, the time of overmilking of udder halves, the time of machine stripping, and the total milking time) were recorded using electronic timers for the same three-person team. One person supervised milking time simultaneously in two sheep/goats. Udder zoometric measurements were carried out on sheep and goats on milk test days accurate to 0.1 cm applying both zoometric callipers and a measurement tape. The following parameters were measured in ewes and nanny goats: length, width, depth and circumference of udder, teats dimensions and teat length. Additionally, in goats the distance of teats from the floor was measured and teats were evaluated in terms of their morphology, distinguishing the following types: cylindrical, funnel-shaped, pear-shaped and bottle-shaped. Directly after milking the clinical condition of the teat ends was examined, adopting the following criteria: teats without injuries – canal of teat impalpable, flabby and thin, teat end injuries of the first group – livedo or white ring in the region of escape of teat canal; the teat canal lightly pachynsic and perceptible, teat end injuries of the second group – escape of teat canal enclosed with grommet pachyepidermi, hypertrophy of the epidermis and the circular muscular layer; the canal of teat more perceptible. Winter feeding of ewes was based on haylage, maize silage, mangolds, meadow hay, and all-mash, while the basis for summer feeding of sheep was green fodder from lucerne and cereal grain. The estimated nutritive value of the ration for milked ewes was 11 MJ energy and 320 g crude protein in 2.3 kg DM. During lactation goats were fed green lucerne forage (7-8 kg), concentrate (0.8 kg), meadow hay (0.3 – 0.5 kg) and fodder straw (0.4 kg). The study used mathematical models, applying the statistical package by SAS, Version 8 (2000).

2.3. Results

2.3.1. Parameters of the course of milking

The results of measurements of the course of machine milking in ewes and goats are shown in Table 1. In the groups of ewes with a greater number of somatic cells (over 250 000 in 1 ml), shorter times of milk flow from both halves of the udder were reported, overmilking time was the longest in the groups of sheep with injuries to the end of the teat. In these ewes longer milking times were also observed. In the course of machine milking in ewes observed high variability of the studied traits, which indicates the necessity of improving the ewes (by selection) towards better milkiness.

The time of milk flow and time of overmilking depend on a calendar year, and indicate a variety of external environmental conditions in particular years. The level of nutrition of ewes, as well as the quality of feed were also likely to vary in subsequent years. Ewes' milking season (March-June and July-October) had a significant effect on the time of milk flow from both halves of the udder, and the probable cause was the quality of feed used in the nutrition of ewes in both milking seasons. The month of lactation had a significant effect on all parameters of the course of machine milking. At the start of milking longer times of milk flow from udder halves, and longer times of overmilking from both halves were observed, which resulted in a simultaneous extension of stripping and milking times. It should be noted that the time of stripping was prolonged with the number of lambs reared, and was longer in the ewes with the number of somatic cells of less than 250 000 in 1 ml. This table contains also the values of these parameters in the groups of goats evaluated for the degree of teat end injuries, the degree of milk contamination and the type of teats. The descriptive statistics of the parameters characterizing the average milking in goats show large standard deviations, indicating a lack of improvement towards milking performance. On the other hand, the long and variable time of overmilking for the halves of the udder depends on the organization of machine milking (one milker operates 5 clusters), and the fact that nanny goats occupy different positions during subsequent milkings. Variability in assigning milking stations to the animals and the sequence of goat milking results in an increase or decrease in overmilking time. The time of milk flow, stripping time and milking time were significantly different in both years of the study (2001 and 2002). External environmental conditions affect the course of milking in goats, mainly through the variable forage base resulting from weather conditions. In the successive months of lactation there were no statistically significant differences in milk flow time, overmilking time, stripping time, and milking time. Nursing a greater number of kids by nanny goats had a considerable effect on the prolonged milk flow time and extended the milking time.

Milking parameters in ewes (s)							
Somatic cell count in 1ml	Number of udder halves	Milk flow from udder half		Overmilking of udder half		Stripping of udder	Milking
		left	right	left	right		
≤ 250 000	474	56.7±23.2	55.6±23.7	147.4±110.2	145.9±111.5	33.7±18.9	235.1±116.2
> 250 000	281	53.9±26.8	51.7±28.6	131.1±111.0	133.2±110.8	30.0±16.1	215.3±117.8
Total	755	55.0±24.7	54.2±26.1	141.4±110.6	141.2±111.1	32.3±18.1	228.0±118.1
Case–sensitive degree of teats end injuries							
≤ 250 000	168	49.9±21.5	47.3±21.9	204.6±149.1	196.3±113.0	37.2±22.8	228.0±132.6
> 250 000	81	37.1±16.2	36.3±15.7	211.7±114.6	212.3±106.9	33.6±30.2	283.6±120.9
Total	249	45.7±20.2	43.7±20.4	206.9±136.5	201.5±110.2	36.0±25.7	286.6±126.8
Case-sensitive degree of milk infection							
≤ 250 000	120	59.2±32.8	52.9±38.6	143.3±118.2	145.3±122.9	32.5±18.5	236.4±182.3
> 250 000	60	46.1±26.7	49.2±34.9	151.4±97.4	148.4±93.6	27.0±12.7	224.9±100.4
Total	180	54.8±31.8	51.6±30.2	146.0±110.9	146.3±113.8	30.7±17.0	231.8±118.3
Milking parameters in goats (s)							
	207	129.2±46.7	116.3±48.2	95.9±98.7	107.9±101.4	33.3±24.6	258.5±99.3
	414	122.7±47.1		101.9±97.3		33.3±23.7	258.5±99.3
	Case-sensitive degree of teat end injuries						
	92	106.8±49.7	96.0±46.3	100.3±87.2	109.3±93.0	26.7±20.2	234.3±106.0
	184	101.4±47.3		104.8±88.3		26.7±19.9	243.3±103.3
	Case-sensitive degree of teat end injuries						
	67	126.3±53.4	107.3±45.8	102.2±113.8	121.2±117.3	32.4±23.4	261.0±122.3
	134	115.9±50.3		110.9±114.1		32.4±22.5	261.0±119.9
	Case-sensitive types of teats						
	184	101.4±47.3		104.8±88.3		26.7±19.9	243.3±103.3

Table 1. Descriptive statistics of ewes' and goats milking course parameters (arithmetic averages in seconds ± standard deviation)

The results of the effect of selected factors, including injuries to the teat end of milked ewes and goats are given in Table 2. The degree of injury to the end of the teats in ewes in the group with the number of somatic cells below 250 000 in 1 ml had no effect on the course of milking; however, longer times can be seen trailing the times of milk flow and overmilking of teat end injuries. In the second group of ewes (SCC above 250 000/ml) a significant difference was found in the time of overmilking in right halves between the ewes with teat injuries from the first and second groups, amounting to 172.5 and 359.0 s, respectively. The long time of overmilking was associated with a significantly longer time of milking in ewes. In all the groups of sheep longer times of milk flow were recorded in halves with teat end injuries (especially with injuries of the second group) when compared with halves of the udder, which teats sustained no injuries. At the same time shorter times of machine stripping were found for halves with teat end injuries. The longer times of milk flow from halves with teat injuries may indicate disturbances in the milk flow, which may be due to internal damage of the teat canal. The long times of overmilking are caused by injuries of teat ends.

Factor	Milking parameters in ewes (s)							
	Milk flow from udder half		Overmilking of udder half		Stripping of udder halves		Milking of udder halves	
	left	right	left	right	left	right	left	right
Somatic cell count in milk below 250 000 in 1 ml (n = 336)								
Season of milking	**	**	ns	ns	ns	ns	ns	ns
Month of lactation	**	**	ns	ns	ns	ns	*	*
Number of reared lambs	ns	ns	ns	ns	ns	ns	ns	ns
Breed of ewes	ns	**	ns	ns	*	**	**	**
Teats end injuries of:								
- the first group	52.5	55.2	212.7	189.7	37.1	36.0	300.6	290.2
- the second group	59.3	49.9	264.3	212.1	24.1	36.2	258.1	299.1
- teats without injuries	47.5	43.6	192.7	196.4	39.0	37.8	287.0	285.3
Somatic cell count in milk above 250 000 in 1 ml (n = 162)								
Season of milking	**	**	ns	ns	ns	ns	ns	ns
Month of lactation	*	ns	*	*	**	**	*	*
Number of reared lambs	ns	ns	ns	ns	ns	ns	ns	ns
Breed of ewes	ns	ns	ns	ns	ns	ns	ns	ns
Teats end injuries of:								
- the first group	51.1	40.1	211.3	172.5^{A}	36.8	26.7	298.4	239.6^{A}
- the second group	59.1	44.7	263.8	359.0^{A}	23.1	9.3	260.7	413,0^{A}
- teats without injuries	46.2	35.2	194.1	213.5	38.7	36.1	287.1	286.4
Milking parameters in goats (s) n = 92								
Teat end injuries of:	ns	ns	ns	ns	ns	ns	ns	ns
The first group	105.8	92.0	103.0	116.3	28.2	30.6	235.7	240.6
The second group	90.5	89.0	193.5	195.3	37.0	37.0	321.0	321.0
Teats without injuries	108.1	99.3	95.2	100.6	25.5	23.4	230.2	226.0
Month of lactation	*	**	*	*	ns	ns	**	**

Table 2. The effect of teat end injuries on the course of milking in ewes' and goats. Means in columns designated with identical capital letters differ significantly at P≤0.01, *P≥0.05, ns – non-significant difference

Despite the small number of udder halves with teat end injuries of the second group (n = 2), the overmilking time for those halves was doubled when compared with halves of the udder and teats without injuries. No statistically significant impact of injuries to the teat end on the course of machine milking could be explained by large standard deviations and the small number of half exchange with teat end damage.

The degree of microbial contamination of milk in the first and second groups did not significantly influence the course of machine milking in ewes (Table 3). The degree of microbial contamination of milk by major and minor pathogens did not affect significantly the parameters of machine milking in ewes. However, longer times of milk flow from infected halves of the udder were reported when compared with the times of milk flow from healthy halves of the udder. The reason for the lack of significant differences in milking of ewes from these groups might have been connected with the small number of sheep, whose milk was contaminated by the major pathogens.

Milk contamination with microorganisms:	Number of udder halves		Milking parameters in ewes (s)							
			Milk flow from udder half		Overmilking of udder half		Stripping of udder halves		Milking of udder halves	
	left	right	left	right	left	right	left	right	left	right
Somatic cell count below 250 000 in 1 ml (n = 240)										
- major pathogens[1]	6	2	78.7	89.0	140.3	160.0	25.7	13.5	244.7	262.5
- minor pathogens[2]	37	43	66.6	57.4	139.4	134.3	34.9	34.0	241.9	237.6
- milk samples without bacterial growth	77	75	54.1	49.7	145.4	151.7	31.9	31.6	231.4	233.5
Somatic cell count above 250 000 in 1 ml (n = 120)										
- major pathogens[1]	1	2	11.0	57.0	164.0	165.0	22.0	22.5	197.0	244.5
- minor pathogens[2]	30	27	52.7	43.4	148.0	151.8	29.1	29.1	227.4	224.1
- milk samples without bacterial growth	29	31	40.5	53.7	154.5	144.4	25.4	25.4	223.2	224.3
Total (n = 360)										
- major pathogens[1]	7	4	69.0	73.0	143.7	162.5	25.1	18.0	237.9	253.5
- minor pathogens[2]	67	70	60.4	52,0	143.2	141.1	31.2	32.1	235.4	232.4
- milk samples without bacterial growth	106	106	50.3	50.9	147.9	149.5	30.7	29.8	229.2	230.8
Milking parameters in goats (s) n = 67										
- major pathogens[1]	9	5	95.6	120.4	104.1	133.4	28.0	38.4	228.3	292.2
- minor pathogens[2]	12	12	129.7	126.3	80.2	131.4	42.8	49.2	252.7	307.0
-milk samples without bacterial growth	46	50	113.4	101.5	107.6	117.5	30.6	27.8	269.5	246.8

Table 3. The effect of degree of contamination in milk from udder halves on the course of milking in ewes. [1]Staphylococcus aureus and Escherichia coli, [2]Coagulase negative staphylococcus, Micrococcus, Corynebacterium and Bacillus.

Similarly, there was no significant effect of the contamination of milk on the course of milking in goats. Milk flow time and stripping time were found to be about 15 seconds longer in case of the halves infected by minor pathogens when compared to the healthy halves of the udder, but these differences are not statistically significant, probably due to the high variability of parameters that characterize milking.

2.3.2. Milk composition, somatic cell count and milk yield

The results concerning the effect of overmilking time on the number of somatic cells in milk, milk composition and the level of small ruminants milkiness are shown in Table 4. Overmilking time for both halves of the udder of ewes did not have a significant effect on somatic cell counts. In early lactation of ewes (four to six weeks) longer overmilking times were associated on the one hand with longer stripping times, while on the other hand, with the organization adopted for the farm milking machine (one milker handled six milking clusters). With such an organization of machine milking the ewes, in which overmilking lasted longer, were characterized by both higher milk production and a lower percentage of fat and protein in milk. Ewes with somatic cell counts ≤ 250 000 w 1 ml a trend towards a higher lactose content and a higher milk production was observed. Evident differences in milk composition (with an increase in overmilking time) are visible in the group of ewes with lower somatic cell counts in milk (below 250 000 ml/ml). In the group of ewes with high somatic cell counts (above 250 000/ml), and including the two above mentioned groups of sheep such differences were not reported. Overmilking time of halves of the goats udder had no effect on daily milk yield, composition and SCC. Goats with a higher daily milk production were characterized by a longer milk flow and longer stripping time, as well as lower somatic cell counts in milk. In these goats, however, overmilking time was slightly longer.

In the milk of goats from udders halves with short milk flow times (up to 1.5 minutes) somatic cell count was twice as high (1 153 000/ml) when compared with milk of goats with a longer milk flow times (91-180 and 181 - 317s, 615 000 and 572 000 cells/ml, respectively). Shorter milk flow times were significantly associated with a lower daily milk production, a greater percentage of fat and protein in milk, and lower lactose content (P ≤0.01). Stripping time for halves of the udders was associated with daily milk production. The results indicate the need for improvement in terms of raising goats, obtaining large quantities of milk from milking, and a lower machine stripping yield. The selection should be aimed at increasing the capacity of the cisterns.

Ewes					
Trait	Overmilking time (s)				
	0 - 60	61 - 120	121 - 180	181 - 240	> 240
Somatic cell count below 250 000 in 1 ml (n = 988					
Number of udder halves	300	176	167	132	213
Somatic cell count (log SCC)	4.70	4.72	4.77	4.68	4.68
Fat content (%)	5.17	5.59^{AB}	5.11	4.70^{B}	4.72^{A}
Protein content (%)	6.13^{AB}	6.26^{CD}	6.01^{EF}	5.68^{BCE}	5.66^{ADF}

Lactose content (%)	5.11^{A}	5.02^{CE}	5.07^{BD}	5.24^{ABC}	5.21^{DE}
Milk production (ml)	983.7^{AB}	963.8^{DE}	1 059.6^{C}	1 105.3^{BE}	1 218.7^{ACD}
Somatic cell count above in 1 ml (n = 522)					
Number of udder halves	155	121	109	56	81
Somatic cell count (log SCC)	6.10	6.06	6.13	6.15	6.14
Fat content (%)	6.12	6.20	6.35	6.43^{A}	5.49^{A}
Protein content (%)	6.55^{A}	6.48B	6.43B	6.30	6.0^{ABC}
Lactose content (%)	4.54	4.45	4.41	4.57	4.65
Milk production (ml)	799,0^{A}	754.9^{B}	767.2^{C}	804.5^{D}	1 042.0^{ABCD}
Total (n = 1510)					
Number of udder halves	455	297	276	188	294
Somatic cell count (log SCC)	5.18	5.26	5.31	5.11	5.08
Fat content (%)	5.52	5.84	5.60	5.22	4.93
Protein content (%)	6.28	6.35	6.18	5.86	5.75
Lactose content (%)	4.92	4.79	4.82	5.04	5.06
Milk production (ml)	920.8	878.7	944.1	1 015.7	1 170.0
Goats					
Number of udder halves	183	95	61	34	41
Somatic cell count (log SCC)	5.94	5.85	5.81	5.83	5.80
Fat content (%)	3.01	3.16	2.84^{A}	3.19^{A}	3.09
Protein content (%)	3.00	3.13^{A}	2.88^{A}	2.99	2.99
Lactose content (%)	4.21	4.31	4.23	4.20	4.28
Milk production (ml)	2 850.8	2 988.4	2 928.7	3 135.3	3 104.1

Table 4. The effect of overmilking time on milk somatic cell count and composition, and small ruminants milkiness level. Means in rows designated with the same capital letters differ significantly at $P \leq 0.01$.

2.3.3. Teat end injuries and milk infection

Damage to teats of ewes during machine milking can affect the degree of milk contamination. The use of machine stripping is associated with a significant increase of overmilking time. A long overmilking time with an inadequate vacuum level and pulsation ratio may influence teat ends causing injuries. Damaged teats contribute to the penetration of the mammary gland by microorganisms, that cause inflammation of the mammary glands, and milk microbial contamination. Table 5 shows the results of the effect of selected factors, depending on teat end injuries, on milk somatic cell count, composition and production.

In the group of ewes, which were characterized by a smaller number of somatic cell count (SCC≤ 250 000/ml) teat end injuries did not differentiate significantly the number of somatic cells, milk composition or production levels. A greater percentage of fat and protein content in milk was observed in the milk of both halves of the udder with healthy teats. The halves of the udder from the first group of teat injuries (SCC> 250 000/ml) yielded a higher percentage of milk fat, probably resulting from lower milk production. A comprehensive comparison of the results showed no effects of teat end injuries on milk somatic cell count,

Factor	Number of udder halves		SCC from udder half (log SCC)		Percentage content in mil from udder half						Milk production and degree of teat injuries (ml)	
					fat		protein		lactose			
	left	right	left	right	left	right	left	right	left	right	left	right
Somatic cell count below 25 000 in 1 ml												
Teat end injuries of:	168	168	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
The first group	45	44	4.64	5.30	4.61	4.83	5.88	5.73	5.05	4.95	1 078.9	1 126.1
The second group	15	18	4.78	5.12	4.90	4.81	5.62	5.56	5.07	4.99	965.0	1 016.7
Teats without injuries	108	106	4.76	4.96	5.25	5.64	5.87	6.00	4.98	4.84	1 068.7	1 043.4
Season of milking	168	168	ns	ns	**	**	**	*	**	**	ns	ns
Month of lactation	168	168	ns	ns	**	**	**	**	**	**	**	**
Number of reared lambs	168	168	ns	ns	*	*	*	**	ns	*	*	*
Breed of ewes	168	168	ns	ns	ns	ns	ns	ns	ns	ns	**	**
Somatic cell count above 250 000 in 1 ml												
Teat end injuries of:	81	81	ns	ns	*	ns	ns	ns	ns	ns	ns	ns
The first group	17	13	5.98	5.94	8.18A	7.51	6.53	6.09	3.94	4.24	570.06	600.0
The second group	4	3	5.96	5.46	4.95A	6.19	5.85	5.99	4.29	4.77	512.5	500.0
Teats without injuries	60	65	6.00	5.58	6.16	6.71	6.46	6.40	4.51	4.23	803.3	779.2
Season of milking	81	81	ns	ns	**	**	**	**	*	ns	*	*
Month of lactation	81	81	ns	ns	**	**	**	**	**	**	**	**
Number of reared lambs	81	81	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Breed of ewes	81	81	ns	ns	*	*	*	ns	ns	ns	**	**

Table 5. The effect of selected factors in terms of teat end injuries on milk somatic cell count and composition, and ewes' milkiness level. Means in columns designated with the same capital letters differ significantly at P≤0.01.*P≤0.05,**P≤0.01,ns – non-significant difference.

composition and the level of milk production; however, a marked reduction in milk yield was observed in ewes with teat end injuries in the group with higher somatic cell counts (SCC> 250 000/ml). The result is a greater concentration of fat and less protein and lactose in milk. The results of the impact of teat end injuries on somatic cell count, composition and production of goats milk are given in Table 6.

Injuries to the teat end do not differentiate the log SCC, the composition and level of milk production in goats. At the same time it needs to be stressed that significant differences were found in the percentage of milk fat, at higher fat content in the right halves of the udder, while in the left it was lower (P <0.01). The volume of daily milk production in goats with damaged and healthy teats was similar. Month of lactation had an effect on contents of fat and protein in milk, as well as milk production; however, no such effect was observed on somatic cell count and lactose content in milk. Table 7 presents the results concerning the effect of the degree of contamination of ewe and goats milk on somatic cell count, composition and milk production.

Factor	Number of udder halves		Somatic cell count in milk from udder half (log SCC)		Percentage content in milk from udder half						Milk production (ml)	
					fat		protein		lactose			
					left	right	left	right	left	right		
	left	right	left	right	left	right	left	right	left	right	left	right
Teat end injuries of:	92	92	ns	ns	**	**	ns	ns	ns	ns	ns	ns
The first group	35	39	5.84	6.06	3.40^{A}	3.55^{A}	3.22	3.32	4.38	4.05	2 794.3	2 835.9
The second group	2	2	5.77	6.08	4.09	4.14	3.47	3.53	4.39	4.19	3 250.0	3 250.0
Teats without injuries	55	51	6.05	6.14	3.02^{A}	3.98^{A}	2.87	2.99	3.95	3.77	2 607.3	2 560.8
Month of lactation	92	92	ns	ns	**	**	**	**	ns	ns	**	**

Table 6. The effect of teat end injuries on somatic cell count in milk, basic milk composition and goats' milkiness levels.
Means in columns designated with the same capital letters differ significantly at P ≤ 0.01, ns – non-significant difference.

Microbial infections of mammary glands cause great economic losses in dairy sheep farms due to reduced milk production and adverse changes in its composition. The incidence of clinical inflammatory conditions generally does not exceed 5%, and most micro-organisms isolated from milk are *Staphylococcus aureus* bacteria. The etiological agents in subclinical inflammation of mammary glands in most cases are *Coagulase negative staphylococci*, and especially *Staphylococcus epidermidis.* The above-mentioned results do not indicate an association between milk contamination and milk composition and productivity levels, probably due to the low number of milk samples with increased contents of major pathogens. In ewes which are characterized by a smaller number of somatic cells (< 250 000/ml) infection caused by minor pathogens were associated with a smaller increase in somatic cell counts, whereas in ewes with greater numbers of somatic cells in milk (> 250 000/ml) this increase was larger. In the milk of ewes with infected mammary glands the concentration of fat and lactose was lower, at a higher concentration of protein when compared with milk from healthy mammary glands. These ewes produced also less milk.

No significant effect of microbial milk contamination by major and minor pathogens was found on the number of somatic cells (log SCC), milk composition and daily milk production in dairy goats. Somatic cell count in milk from both halves of the udder contaminated by major pathogens was greater (log 5.93, i.e. 858 000 cells/ml and log 6.21 i.e. 1 628 000 cells/ml) than that from both halves of the udder contaminated by minor pathogens (log 5.74 i.e. 548 000 cells/ml and log 5.72 i.e. 522 000 cells/ml). In milk from healthy halves of the udder somatic cell count was similar to that in milk from udder halves infected by minor pathogens (log 5.75 i.e. 561 000 cells/ml and log 5.85 i.e. 705 000 cells/ml). Less fat, protein and lactose was found in milk from infected halves of the udder when compared with the percentage of these components in milk from healthy halves of the udder, but these differences were not statistically significant. The daily milk yield from infected and healthy halves of the udder was similar in goats.

Ewes												
Factor	Number of udder halves		SCC from udder half (log SCC)		Percentage content in milk from udder half						Milk production and degree of udder half infection (ml)	
					fat		protein		lactose			
	left	right	left	right	left	right	left	right	left	right	left	right
Somatic cell count in milk below 25 000 in 1 ml (n = 240)												
Major pathogens[1]	6	2	4.52	5.64	4.90	4.62	6.08	6.02	5.42^{A}	5.01	1 004,2	835.4
Minor pathogens[2]	37	44	4.69	5.15	5.57	6.03	6.38	6.36	5.11	4.98	855.1	967.3
Without bacteria	77	74	4.68	4.85	6.12	6.26	6.22	6.22	4.95^{A}	4.90	968.5	943.1
Somatic cell count in milk above 250 000 in 1 ml (n = 120)												
Major pathogens[1]	1	2	5.94	6.02	7.19	5.18	7.42	7.03	4.17	4.94	450.0	500.0
Minor pathogens[2]	30	27	6.20	5.91	6.64	7.43	6.63	6.66	4.35	4.26	768.3	686.1
Without bacteria	29	31	6.03	5.70	7.65	7.41	6.98	6.86	3.95	4.44	762.1	841.1
Goats												
Major pathogens[1]	9	5	5.93	6.21	2.67	2.96	2.76	3.10	3.84	4.39	2 677.8	2 820.0
Minor pathogens[2]	12	12	5.74	5.72	2.93	3.14	2.94	2.93	4.36	4.23	3 233.3	3 116.7
Without bacteria	46	50	5.75	5.85	3.04	2.92	3.02	3.05	4.52	4.15	2 810.9	2 814.0
Calendar year	67	67	ns	**	**	*	ns	ns	*	**	*	*
Month of lactation	67	67	*	ns	**	**	**	**	ns	ns	*	*

Table 7. The effect of the degree of milk contamination on milk somatic cell count and composition, and the level of milk production. Means in columns designated with identical capital letters differ significantly at $P \leq 0.01$. [1]*Staphylococcus aureus and Escherichia coli,* [2]*Coagulase negative staphylococcus, Micrococcus, Corynebacterium and Bacillus.* *$P \leq 0.05$, **$P \leq 0.01$, ns – non-significant difference.

2.3.4. Phenotypic correlations

Table 8 presents the correlation coefficients between the phenotypic characteristics of udders and the parameters of machine milking in ewes and in goats.

Ewes with greater udder dimensions were characterized by a longer time of milk flow. Similarly, a longer time of milk flow was recorded in ewes with a greater distance between the teats. Correlation coefficients between the overmilking time for both halves of the udder and the udder dimensions were small, but significant. Ewes with a greater depth and circumference of udders were characterized by a longer stripping time. Milking time was significantly correlated with traits of the udder and distance of the teats. Teat length was not related with the course of machine milking.

Ewes							
Parameter (s)	Udder dimensions (cm)				Teats dimensions (cm)		
	Length	Width	Depth	Circumference	Distance	Teat length	
						left	right
Milk flow from the left udder half	0.356**	0.115**	0.121**	0.415**	0.177**	0.019	-
Milk flow from the right udder half	0.331**	0.171**	0.179**	0.414**	0.194**	-	0.027
Overmilking of the left udder half	0.114**	0.093**	0.165**	0.118**	0.167**	- 0.007	-
Overmilking of the right udder half	0.094**	0.090**	0.164**	0.108**	0.157**	-	- 0.021
Stripping of udder	0.046	0.118**	0.250**	0.146**	0.194**	0.053	0.070*
Milking	0.158**	0.119**	0.224**	0.188*	0.188*	0.002	- 0.014
Goats							
Milk flow from the left udder half	0.107	0.297**	0.405**	0.433**	0.460**	0.072	0.076
Milk flow from the right udder half	0.116*	0.287**	0.444**	0.390**	0.370**	0.105	0.231**
Overmilking of the left udder half	0.076	- 0.004	0.022	0.115*	0.117*	- 0.095	- 0.043
Overmilking of the right udder half	0.076	0.007	0.020	0.146**	0.172**	- 0.098	- 0.104
Stripping of the udder	0.169**	0.014	0.146**	0.259**	0.157**	- 0.097	- 0.142
Milking	0.181**	0.131*	0.259**	0.362**	0.363**	- 0.073	- 0.045

Table 8. Coefficients of phenotypic correlations between udder traits and parameters of the course of milking in ewes (n = 747) and in goats (n = 621), *P≤0.05, **P≤0.01.

There were significant and positive correlation coefficients between milk flow times from both halves of the goats udders and the width, depth and circumference of udders (r_P from 0.29 to 0.44). Statistically significant correlation coefficients were also calculated between the milk flow time and distance between teats (r_P =0.46 and r_P =0.37). Goat teat length was not related to the milk flow time. Longer milk flow times were recorded for udder halves with a shorter distance from the teat end to the floor. Overmilking time was slightly dependent on the circumference of the udder and distance between teats. Stripping time of the udder was positively and significantly correlated with the length, depth and circumference of the udder. Milking time was significantly dependent on all udder dimensions, with the exception of teat length. The calculated correlation coefficients indicate a slight relationship to the udder dimensions on overmilking time. The probable cause for the long overmilking time was the use of stripping of the udder, often in excess of 30 s, and milking organization adopted on the farm (one milker operating six clusters). Table 9 shows correlation coefficients between udder dimensions and ewes' milkiness parameters.

The number of somatic cells in case of both halves of the udder (log SCC) was negatively correlated with udder dimensions and the distance between the teats, but the calculated values of correlation coefficients were small. Similarly, negative and significant correlation coefficients were calculated between the percentage of fat and protein in the milk and all the dimensions of the udder. Ewes with a large circumference of the udder have less fat and protein in milk, and this trait was also associated with a higher milk production and lower concentrations of these components in milk. Lower contents of these components in milk were also found in ewes with longer teats. The lactose content in milk from both halves of the udder was positively correlated with all dimensions of the udder. The calculated values of correlation coefficients between the dimensions of the udder, teat length and the amount of milk produced were positive and statistically significant. Table 10 shows the correlation coefficients between phenotypic traits of the udder and the traits of goats' milkiness. Phenotypic correlation coefficients between all the dimensions of the udder and the number of somatic cells in milk from both halves of the udder were negative and statistically significant. A similar interdependence was found between the distance between the teats and log SCC for both halves of the udder. The greater distance from the teats end from the floor was associated with higher somatic cell counts in milk. The dimensions of the udder and the distance and the length of the teats were negatively and significantly correlated with percentage contents of fat and protein in milk (P≤0.05).

Parameter (s)	Udder dimensions (cm)				Teats dimensions (cm)		
	Length	Width	Depth	Circumference	Distance	Teat length	
						left	right
Somatic cells in the left udder half (log SCC)	- 0.091**	- 0.081*	- 0.051	- 0.146**	- 0.076*	0.007	-0.082*
Somatic cells in the right udder half (log SCC)	- 0.126**	- 0.118**	- 0.092**	- 0.164**	- 0.163**	-	-
Fat content in milk from the left udder half (%)	- 0.441**	- 0.207**	- 0.148**	-0.544**	- 0.341**	- 0.208**	- 0.123**
Fat content in milk from the right udder half (%)	- 0.279**	- 0.180**	- 0.127**	- 0.510**	- 0.323**	-	-
Protein content in milk from the left udder half (%)	- 0.403**	- 0.191**	- 0.160**	- 0.474**	- 0.372**	- 0.102**	0.010
Protein content in milk from the right udder half (%)	- 0.340**	- 0.155**	- 0.112**	- 0.458**	- 0.347**	-	-
Lactose content in milk from the left udder half (%)	0.326**	0.249**	0.166**	0.490**	0.342**	0.172**	0.095**
Lactose content in milk from the right udder half(%)	0.324**	0.274**	0.138**	0.459**	0.349**	-	0.105**
Ewes' milkiness (ml)	0.323**	0.372**	0.408**	0.509**	0.413**	0.132**	

Table 9. Coefficients of phenotypic correlations between udder traits and ewes' (n = 747) and milkiness parameters, *P≤0.05, **P≤0.01.

Parameter	Udder dimensions (cm)				Teat dimensions (cm)				
	length	width	depth	circumference	distance	Teat length		Distance of teats from floor	
						left	right	left	right
Log SCC, left udder	- 0.376**	- 0.248**	- 0.233**	- 0.601**	- 0.446**	0.007	0.036	0.245**	0.136*
Log SCC , right udder	- 0.282**	- 0.168**	- 0.297**	- 0.524**	- 0.380**	0.010	- 0046	0.176**	0.201*
Fat, left udder, %	- 0.214**	- 0.107**	- 0.288**	- 0.414**	- 0.358**	- 0.180**	- 0.152**	0.005	0.075
Fat, right udder, %	- 0.342**	- 0.016	- 0.418**	- 0.417**	- 0.385**	- 0.217**	- 0.151**	- 0.007	0.093
Protein, left udder, %	- 0.469**	- 0.074	- 0.484**	- 0.472**	- 0.411**	- 0.192**	- 0.082	0.098	0.196**
Protein, right udder, %	- 0.382**	- 0.104	- 0.448**	- 0.423**	- 0.382**	- 0.208**	- 0.152**	0.049	0.221**
Lactose, left udder, %	0.083	0.213**	0.024	0.326**	0.353**	- 0.240**	- 0.256**	-0.037	0.153*
Lactose, right udder, %	0.086	0.196**	0.143**	0.313**	0.238**	- 0.071	- 0.071	0.152**	0.074
Goats' milkiness, ml	0.439**	0.383**	0.516**	0.787**	0.586**	0.079	- 0.007	-0.186**	-0.207**

Table 10. Coefficients of phenotypic correlation between udder traits and goats' milkiness parameters (n = 621). **P ≤ 0.01, P ≤ 0.05.

The width and circumference of the udder and the distance between teats were significantly positively correlated with the percentage of lactose in milk (P≤0.05). Teat length was not related to the content of lactose in milk. All dimensions of the goats' udder, mainly circumference, were positively correlated with daily milk production. The greater distance from the teat end to the floor was associated with lower milk production.

2.4. Conclusion

A long overmilking time of udder halves in ewes is closely connected with teat end injuries. The injuries bring about a certain reduction of ewe milk production and an increased fat content, while protein and lactose contents are lower. In order to reduce the overmilking time or to eliminate it from the milking process the author suggests employing two milkers in the milking process. Injuries of goat teats do not influence milk yield, SCC or milk composition. The degree of milk infection in small ruminants does not influence the levels of production either in qualitative or quantitative terms. In future studies on the course of machine milking in small ruminants and its implications for quantitative and qualitative levels of milk production it is proposed to investigate the milking schedule and increase the overmilking time at different stages of lactation.

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