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Review

MILK DISTRIBUTION IN THE UDDER AND REACTION TO MILKING FREQUENCY IN DAIRY EWES

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ABSTRACT

For proper organization of machine milking it is very important to know and respect the biological needs of ewes. Only if these needs are respected we can achieve maximum milk production with good health of the mammary gland.
The aim of this review is to provide information on mechanism of milk ejection, distribution of milk in the udder and the response of ewes to different milking frequency. The induction of milk ejection is very important for rapid and complete milking and achieving maximal milk production. The milk ejection may be inducted only if oxytocin is released from neuro-pituitary gland. Oxytocin is released as a response to stimulation of the mammary gland by hand milking, machine milking or suckling.
Milk distribution among both compartments varies according to breed, species, age, stage of lactation and milking interval. This is important to know due to the ability of ewes to adapt to different milking interval.
Nowadays we are beginning to look for ways of improvement of quality of farmer's life. As milking takes more than a half of all labours on the farm, there is increasing demand for extended milking intervals. Nevertheless, this may cause negative impact on the milk production. It may be three times milking per two days. This way of milking has the smallest influence on milk production. On the other hand, it creates an unusual work pattern, including 3 different schedules of milking and more often milking at night.
Another possible way of milking may be the omission of one or two milkings per week. This method of milking could be used to reduce labour on farms during critical days, usually throughout the weekend. But omission of milking causes decreased milk production depending on breed and the level of production. The last way of extended milking interval, which is described in this article, is once- daily milking. However, this method of milking mostly decreases milk production.

Key words: dairy ewes; milk distribution; frequency of milking

INTRODUCTION

Milk production is a result of a complex balance between a regulation of milk synthesis and its secretion into the mammary gland lumen. Milk synthesis depends on a correct gland development, nutrition, extraction of metabolic precursors from blood and their conversion into milk products within the alveolar cells of the mammary gland (Caja *et al*., 2000; Silanikove *et al*., 2010).

Ewe milk is mainly processed for cheese, due to increasing demand of consumers, and therefore, dairy sheep are becoming an interesting economic alternative for farmers. Farms with high-yielding dairy sheep usually use machine milking in large flocks and milking is performed twice a day throughout lactation. As a result more than a half of total labour on dairy sheep farm is spent on milking and milking is one of the main factors why people are deterred from dairy sheep production

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(Castillo *et al*., 2008).

Reduction of daily milking frequency in dairy sheep may be a suitable strategy to decrease milk production costs and to improve quality of life of farmers. Recent studies have shown the role of udder cistern for maintaining high milk secretion and differences in the ability of dairy sheep to tolerate longer milking intervals according to the size of their cisternal udder compartment (Wilde *et al*., 1996). Ewes with large udder cisterns are better adapted to extended milking interval than ewes with small cisterns of the udder (Castillo *et al.*, 2009), similar to dairy cows (Davis *et al*., 1998; Davis *et al.*, 1999).

Milk composition

The reason why sheep milk is considered as a food of exceptional quality is due to the complete essential amino acids, adequate mineral supply, similar mass fraction of lactose with human milk, small fat globule it provides and especially its ease to absorb (Wang *et al*., 2011). The composition in macro- and micro-nutrients of ewe milk depends on the main production factors constituting the farming system: genotype, reproduction and sanitary characteristics of animals, agro-climatic conditions and socio-economical environment, farming methods such as feeding and milking (Morand-Fehr *et al.*, 2007).

Sheep milk consists of water (81.5 %) and dry matter (18.5 %). Dry matter contains 7 % fat, 5.6 % protein, 5 % milk lactose and 0.9 % minerals in Improved Valachian dairy ewes (Čapistrák *et al*., 1995).

A major factor that impacts milk fat and protein content is milk yield (Hadjipanayiotou, 1999). In sheep, like other ruminants, phenotypic and genetic correlations among fat and protein concentration and milk yield are negative (Pulina *et al*., 2006). The reduction of fat and protein content of milk as milk yield increases is well-known (Emery, 1988).

Frequency of milking and distribution of milk in the udder also significantly affect the milk composition (De Bie *et al*., 2000).

Anatomical structure of the ewe udder

The sheep udder is saccate organ which is stored in the pubic part. The appearance of the udder is very different and it depends on age, physiological condition, breed of ewe and individual characteristics of the animal (McKusick, 2000; Caja *et al*., 2000).

Mammary gland consists of two main structures - parenchyma and ligament. The udder is divided into two halves. Each half consists of gland parenchyma (*glandula mammaria*). Parenchyma of the udder consists of tubulo-alveolar structures, which are a secretion component and connecting tissue (collagen and fat). These structures are divided into a large number of small lobes (McKusick, 2000). Parenchyma also consists of intralobular milk duct, alveolus, milk ducts (*ductuli lactiferi lobares*) and milk cistern (*sinus lactiferus*) (Tančin *et al.*, 2001). Milk cistern is divided into two parts: glandular cistern *(S. l. pars glandularis*) and teat cistern (*S. l. pars papillaris*). Both cisterns are separated by the cricoid fold. Permeability of this cricoid fold can significantly affect the milk flow rate from the udder (Caja *et al.*, 2000). Teat cistern ends at the tip of the teat, where the circular sphincter is located. The ducts continue with teat tubule which ends at the top of the teat (Tančin *et al*., 2001).

Milk distribution in the udder of ewes

Milk is produced in the secretory cells of the udder parenchyma continuously. Between milking the milk is divided into two anatomical parts of the udder (Tančin *et al*., 2001). Part of milk is stored in the secretory alveolus lumen and alveolar and intraalveolar ducts - this is called the alveolar compartment. Alveolar fraction can be removed from the udder only if milk ejection occurs during milking. Tactile stimulation of the teat causes the release of oxytocin from the neuro-pituitary. The second part of milk represents the cisternal fraction, which has already been transferred from the alveoli to the milk cistern and it is immediately obtainable for milk removal without occurrence of milk ejection. Overcome the forces which originate in the contraction of teat sphincter is important for mechanical extraction of milk from cistern (McKucisk *et al*., 2002; Castillo *et al*., 2008a).

Milk partitioning between both compartments varies according to species, breed, age, stage of lactation and milking interval (Castillo *et al*., 2008a). Large differences among dairy species exist with respect to proportion of total milk that can be stored within the milk cistern. For example, with a normal milking interval of 12 to 14 h, dairy ewes and goats can store up to 75 % of the total milk within the milk cistern, whereas the cisternal fraction in dairy cattle represents approximately 20 % of the total milk volume (Bruckmaier *et al*., 1997; Davis *et al.*, 1998; McKusick *et al.*, 2002; Salama *et al*., 2004).

Many authors measured milk volume in different parts of the udder in various breeds of ewes. Results were different also within the same breed. However, the results also depended on a milking interval (Davis *et al*., 1998). For instance, in once-daily milking there were even 82 % stored milk in the cistern of the udder in Sarda ewes (Nudda *et al*., 2000). At the same milking interval there were 57 % of the total milk volume in the cistern of the udder in East Friesian ewes. Also Mačuhová *et al*. (2008) found out lower percentage of cisternal volume in Tsigai and Improved Valachian compared with Lacaune in sheep with two emission oj milk during machine milking. The volume of cisternal milk ranged from 38 % to 47 % of the total milk volume, when milking interval decreased to 12 h (McKusick *et al*., 2002). Sicilo-Sarde dairy ewes were characterized by the medium size udders and favourable teat position for machine milking. The volume of cisternal milk was 54 % of the total milk volume (Ayadi *et al*., 2010).

Castillo *et al.* (2008b) and Rovai *et al*. (2008) were concerned with this issue in Manchega and Lacaune breeds. The results of both authors were different. Whilst the first author found out that the volume of milk in cistern of the udder was in the range 47 - 77 % (888 ± 43mL) for Lacaune breed, and in the range 33 - 65 % (316 ± 43 mL) for Manchega breed, the second author already found different milk volume within the same milking interval. The total milk volume consisted of 73 % (299 ± 8 mL) milk volume in cistern of the udder in Lacaune breed and 56 % (122 ± 8 mL) milk volume in Manchega ewes. Volume of cisternal milk increased until 24 h of the udder filling in both breeds. Volume of alveolar milk increased until 16 h in Manchega and 20 h in Lacaune dairy ewes probably as a consequence of different capacity of udder cisterns.

Milk ejection

The main condition for rapid and complete milking and achieving maximal production is the induction of milk ejection (Tančin and Bruckmaier, 2001). For the induction of milk ejection the release of oxytocin is very important (Negrao *et al*., 2001), which is secreted from neuro-pituitary by neuro-endocrine mechanisms (Lollivier *et al*., 2006; Marnet a McKusick, 2001) as a response to stimulation mammary gland by suckling, hand or machine milking (Bruckmaier and Wellnitz, 2008).

Oxytocin regulates multiple central and peripheral functions, including milk ejection, uterine smooth muscle contraction during labour, control of sexual and social behaviours (Lollivier *et al*., 2006).

The process of milk ejection may be divided into two parts. The first phase is associated with stimulation of receptors of the mammary gland and transmission of impulses to the nerve pathways. The second phase is characterized by myoepithelial cell contraction (Lefcourt *et al*., 1982). Oxytocin provokes milk ejection by the contraction of myoepithelial cells, which surround the alveoli and the small intralobular ductules (Lollivier *et al.*, 2006, Marnet and McKusick, 2001; Bruckmaier and Welnitz, 2008). Ejection of milk causes rapid increase of pressure within the cistern of the udder and enlargement of the cisternal size (Bruckmaier and Wellnitz, 2008).

The speed of milk secretion is controlled at the level of the mammary gland by a specific protein (feedback inhibitor of lactation - FIL), which is produced by epithelial cells of the mammary gland and its secretion with milk into the alveoli together (Wilde and Peaker, 1990; Peaker and Wilde, 1996; Stelwagen, 2001). There are two various ways, when FIL acts. One such a mode of action is that it is accumulated in milk until a certain critical concentration when it acts as a negative feedback inhibitor. Another potential mode of action is that FIL is always present in milk but is shielded from its receptor until milk that accumulates in an alveolus stretches its surface enough to expose potential receptors for FIL (Stelwagen, 2001).

Elucidating the exact mode of action of FIL will be greatly facilitated if the gene for FIL could be isolated and when it becomes possible to measure FIL concentrations in milk and thus establish its kinetics in relation to milking frequency (Stelwagen *et al*., 1998).

However, Silanikove *et al*. (2010) in his recently published review presented a more acceptable than the FIL theory the concept of plasmin-derived regulatory peptide affecting the potassium channel responsible for regulation of milk secretion. According to Shamay *et al.* (2002) also the release of caseino-phosphopeptides resulting from the enzymatic hydrolysis of caseins could be one way by which synthesis of milk is regulated. Marnet and Komara (2008) confirmed the role of these caseino-phosphopeptides, which have a prominent effect during dry-off period of the udder at the cessation of lactation. They may inhibit milk synthesis temporarily or could be one of the inhibitory factors also regulating milk production during extended interval between milking (Salama *et al*., 2003).

Response of sheep to different milking frequency

Milking frequency is the main factor regulating milk yield and quality if feeding, welfare, health and environmental conditions are adequate.

In most farms, ewes are milked generally twice a day (once in the morning and once in the evening) with 12 hour milking interval. Milking frequency is one of the most important constraints in this sector, because it does not allow any break in the farmer's activity. For this reason, any possible reduction in the number of milkings would represent significant improvement in farmer's quality of life (Hervás *et al*., 2006).

Three time milking in two days (every 16 hours)

The practice of 3 milking every two days is not commonly used for all ruminant species because it creates an unusual work pattern, including three different schedules of milking and often milking at night. However, it is the only milking system with a strict milking interval of 16 hours, which is within the physiological limits acceptable by the mammary gland (De Bie *et al*., 2000).

Results showed that there are no significant effects of this decreased milking frequency on milk production, fat concentration or protein concentration and somatic cell count in milk of East-Friesian dairy ewes. Also duration of lactation was not affected but a total time of milking was significantly reduced (27 %) (McKusick *et* *al*., 2002). However, it is difficult to apply this method of milking to other breeds of ewes. There is no enough amount of information about this management for other breeds.

Use of 16 hour interval between milking is not deleterious to health for the mammary gland of ewes. Therefore, it seems to be a viable and simple approach without a negative impact on milk quality, milk quantity or net income, but with a positive impact on quality of life for the dairy producers (Marnet and Komara, 2008).

Omission of one or two milkings per week

Occasional milking omission impairs milk yield to a lesser extent without compromising udder health and could be used to reduce labour on family farms during critical days of the week (usually during the weekend) (McKusick *et al*., 2002; Marnet and Komara, 2008; Castillo *et al.*, 2009).

Many authors found out that omission of one or two milkings per week decreased quantity of total milk from 5 to 25 % (Hervás *et al*., 2006; Castillo *et al*., 2009; McKusick et al., 2002). However, the decrease in milk production depends on two factors - the sheep breed, determinants of characteristics (mammary morphology and cisternal capacity) and the level of production of each animal (Hervas *et al*., 2006).

The ewes with a small cistern have a limited storage capacity in their udder. Therefore, when milking omission or extended milking intervals are practiced intra-mammary pressure increases, alveolar drainage decreases and mammary TJ permeability increases, all of which negatively affect milk secretion and, consequently, daily milk yield (Peaker, 1980). Large-cisterned ewes are adapted better to longer milking interval (Castillo *et al*., 2009).

One milking omission per week increases the amount of milk fat or milk protein throughout the whole lactation in the day after milking omission (Knight and Gosling, 1995). Milk composition returns to normal values 2 or 3 days after milking omission (Hervas *et al*., 2006, Castillo *et al*., 2009).

Hervas *et al*. (2006) found out that fat concentration in the milk increased by 32 % in Assaf breed in one milking omission and 41 % when milking was omitted in two consecutive days. Protein concentration increased by 38 % in one milking omission and 27 %, when two milkings were omitted.

Once-daily milking

Nowadays in several farms abroad once-daily milking is practiced mainly as a result of overproduction of milk. The significance of once-daily milking is also in view of the improvement of labour organization on the farm and quality of the farmer's life (Davis *et al*., 1999; Marnet and Komara, 2008).

The effect of extended milking interval also varies depending on species, breed and genetic parameters of certain animals (Stelwagen, 2001; Marnet and Komara, 2008). Extended milking interval to 24 hours caused significant losses of milk production about 15.4% in Lacaune dairy ewes (Negrao *et al*., 2001), 48 % in Poll Dorset ewes (Knight *et al*., 1993), 18 % in Awassi dairy ewes (Nudda *et al*., 2002) and at average of 15 % in East Friesian dairy ewes (McKusick *et al*., 2002).

Large-cisterned ewes have less losses of the milk production. Primiparous ewes seem to be more sensitive to once-daily milking than other ewes, perhaps because of a less developed mammary gland and lower cisternal capacity. For all the ewes, the negative effect of once-daily milking on milk yield also could be reduced if once-daily milking was applied after 2 weeks of twice-daily milking (Marnet and Komara, 2008). The decrease in milk yield is due to sudden change in the mammary gland, when there is a tight junction permeability among the cells as a result of increase in intra-mammary pressure (Stelwagen, 2001). Also it leads toward the increase in the level of apoptosis. Li *et al*. (1999) examined the effect of once-daily milking in comparison to three daily milking in goats. According to them, once-daily milking increased the occurrence of apoptosis in half of the udder, which reduced the number of secretory cells.

The milk composition also changed during once-daily milking. Extended milking interval decreases percentage of milk fat, whereas percentage of milk protein is increased (Bencini *et al*., 2003). Overall amount of somatic cells during the interval from 4 to 16 hours decreases gradually and also persists during 24 hour milking interval at the same level (McKusick *et al*., 2002; Salama *et al*., 2003; Komara and Marnet, 2009). It was probably due to increased tight junction leakage, allowing serum protein to spill over into the milk (Stelwagen *et al*., 1997).

CONCLUSION

The distribution of milk between cistern and alveoli depends on the breed of ewes, milk production, milking frequency and stage of lactation. Also knowledge about milk distribution in the udder could be a good source of information to better manage the frequency of milking without negative effects on the animal and milk production (economy). There are information concerning the milk distribution in the udder of many breeds and their response to milking frequency. However, there is just little information about Tsigai and Improved Valachian in the literature.

The decrease in milking frequency could be very good tool for improving standard of life of farmers. However, on the other hand the decrease in milking frequency in our conditions could be unprofitable. Also it could have a negative impact on milk secretion and consequently daily milk yield because our breeds of ewes have a smaller cistern of the udder.

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