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Lactation of Small Ruminants

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Keyword

Lactation period

Synonyms

Milk production period; Milk secretion period; Milking period

Other Languages

Spanish: *Periodo de Lactación*; **French**: *Période de Lactation*; **German**: *Laktationsperiode*; **Portuguese**: *Período de Lactação*

Definition

Lactation in small ruminants, primarily goats and sheep, is a vital physiological process characterized by the synthesis and secretion of milk by the mammary gland. The onset of lactation immediately postpartum facilitates initial colostrum delivery, essential for neonatal immune development. While lactation is a natural strategy of mammals aimed to meet offspring nutritional requirements, specialized dairy breeds of sheep (e.g., East Friesian, Awassi, Lacaune, or Manchega) and goats (e.g., Saanen, Alpine, Nubian, or Tinerfeña) have been selectively bred to produce milk above offspring nutritional requirements (Haenlein, 2007). Therefore, milk from dairy goat and sheep breeds is directly consumed by humans or manufactured as milk products (i.e., cheese, yogurt, kefir, among others), having a significant economic importance in dairy production systems and contributing to agricultural economies and rural livelihoods globally (Park et al., 2007).

Lactation is regulated by a complex neuroendocrine system, involving coordinated hormonal interactions and physiological feedback mechanisms (Gonzalez-Cabrera et al., 2025). Milk synthesis is stimulated by prolactin, a hormone secreted by the anterior pituitary gland that acts on the alveoli within the mammary tissue (Lacasse et al., 2016). In addition, oxytocin causes milk let-down, triggering the contraction of myoepithelial cells surrounding the alveoli (Knight & Peaker, 1984). These mechanisms are activated by suckling stimuli from the offspring or by mechanical milking. Lactation duration and intensity is affected by factors such as species,

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breed, nutrition, management, and physiological factors.

This entry aims to describe critical aspects of lactation in small ruminants, focusing on milk yield and composition, nutritional requirements, effective herd management strategies, and most prevalent diseases. An improved understanding of these elements will support producers, veterinarians, and researchers in enhancing small ruminant dairy production systems, promoting sustainability, animal welfare, and economic viability.

Major Features

Milk Yield and Composition in Dairy Sheep and Goat Breeds

Dairy goats and sheep play a vital role in milk production, particularly in Mediterranean and mountainous regions, where their adaptability to harsh environments and high-quality milk contribute significantly to the rural economy and traditional dairy products. The milk yield and composition vary widely depending on breed, management practices, and environmental factors.

In dairy sheep, lactation usually lasts between 150 and 180 days. Among dairy sheep, the most prominent breeds include East Friesian, Lacaune, and Assaf. The East Friesian breed is considered one of the highest-yielding dairy sheep breeds, with average annual milk yields ranging from 500 to 700 kg per lactation (Li et al., 2022). The Lacaune breed yields about 350–500 kg per lactation. The Assaf breed, a cross between Awassi and East Friesian, is particularly productive under intensive conditions, with average milk yields within 300 and 440 kg per lactation (Li et al., 2022).

In dairy goats, lactation often lasts up to 210 days, especially in intensive systems rearing high-yielding dairy breeds such as Saanen, Alpine, Murciano-Granadina, or Majorera dairy goats, although, in some conditions, this period can be extended to 300 days (Haenlein, 2007). The Saanen breed is well-known for its high milk yield and is widely used in commercial dairy farms with an average lactation yields range between 700 and 1000 kg, with exceptional individuals producing over 1200 kg. The Alpine breed produces slightly less milk, typically around 700 and 900 kg. The Murciano-Granadina and the Majorera breeds, both Spanish breeds adapted to arid climates, yield within 500 and 700 kg.

Milk composition in both species changes throughout the lactation period. Generally, milk from small ruminants is rich in total solids, particularly fat and protein, making it highly suitable for cheese and other dairy product manufacturing (Park et al., 2007). However, milk composition in goats and sheep depends on many aspects such as breed, nutrition, and management. Sheep milk usually contains 6.0–7.5% fat, 5.0–6.5% protein, and 4.5–5.5% lactose, with total solids exceeding 18% (Park et al., 2007). In addition, goat milk is characterized by 3.5–4.5% fat, 2.8–3.8% protein, and 4.1–4.7% lactose (Park et al., 2007). Interestingly, goat milk contains smaller fat globules, and a different protein profile compared to cow milk, contributing to its better digestibility and reduced allergic reactions.

Nutritional Requirements of Dairy Goats and Sheep

Nutritional management is a critical factor during lactation, as energy and protein demands for milk production increase rapidly after parturition. Inadequate nutrition can result in decreased milk yield and negatively impact maternal health (Nouri et al., 2023). Several key organizations worldwide develop nutritional guidelines for goats and sheep, including the National Research Council (NRC) in the United States and the Institut National de la Recherche Agronomique (INRA) in France. Other important entities are the Agricultural and Food Research Council (AFRC) in the UK and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia. These institutions conduct extensive research to establish energy, protein, mineral, and vitamin requirements tailored to different production systems and environments. Their recommendations form the basis for ration formulation and animal health management worldwide.

Despite goats and sheep are small ruminants with similar digestive physiology, their nutritional requirements differ due to variations in metabolism, production, and adaptive behavior. According to the guidelines published by the NRC (2007), the energy requirements of goats and sheep are expressed in terms of total digestible nutrients (TDN) and metabolizable energy (ME). Maintenance energy needs for adult sheep are estimated at around 2.2–2.6 Mcal ME/day depending on body weight and environmental conditions. For goats, maintenance ME requirements are slightly higher on a metabolic weight basis due to their higher activity and metabolic rate (Lu, 1989). In contrast, the guidelines published by INRA (2018) express energy needs in UFL (*Unité Fourragère Laitaire*; net energy for lactation) and confirm that goats require more energy per kg of metabolic weight compared to sheep, especially under extensive or mountainous systems. Protein requirements are similarly influenced by physiological stage and production level. The NRC guidelines include these requirements as crude protein (CP) and digestible undegradable protein (DUP), while INRA guidelines use PDI (protein digestible in the intestine). For instance, a lactating ewe producing 2 kg of milk/day may require up to 160 g CP/day, whereas a high-producing dairy goat (i.e., Saanen or Alpine) yielding 3–4 kg of milk/day can require 200–250 g CP/day (NRC, 2007). Goats also exhibit greater selectivity in foraging, allowing them to ingest diets richer in protein and secondary compounds (Nyamukanza & Sebata, 2020). Mineral and vitamin requirements vary between species, although both NRC and INRA guidelines highlight the importance of Ca, P, Mg, Na, Se, and vitamins A and E for reproductive and productive performance. Goats are generally more tolerant to dietary imbalances and may require higher levels of certain trace elements, such as copper, though careful management due to the risk of toxicity in sheep (Suttle, 2022).

During late gestation and lactation, nutritional demands increase significantly. The NRC advises gradual adaptation to higher-energy and higher-protein diets to avoid metabolic disorders such as pregnancy toxemia or ketosis. Similarly, the INRA guidelines emphasizes the balance between energy and nitrogen intake and stresses the importance of ruminal synchrony to optimize microbial protein synthesis. In conclusion, while both goats and sheep are managed under similar ruminant systems, their nutrient requirements must be assessed species-specifically. The INRA (2018) model offers a dynamic approach considering feed characteristics and animal physiology, while the NRC (2007) remains a widely used reference in North America. Integrating both models provides a robust framework for formulating balanced rations that support health, productivity, and sustainability in small ruminant systems.

Effective Herd Management Strategies

Optimizing milk production and ensuring the health and welfare of lactating small ruminants requires an integrated approach. Effective herd management strategies integrate nutrition (as addressed in the previous section), reproduction, milking routines, health monitoring, housing, and data analyses. All of them support sustained lactation performance and animal welfare.

Reproductive Synchronization

Efficient reproductive management ensures consistent and timely lambing and kidding intervals. Breeding synchronization enables grouped parturitions, which supports uniform lactation stages and efficient resource allocation, labor optimization, and reduced kid and lamb mortality (Leboeuf et al., 2008). The most used synchronization protocols include intravaginal progestogen-releasing devices (e.g., CIDR or sponges), often applied for 9–14 days, followed by administration of equine chorionic gonadotropin (eCG) to stimulate follicular development and ovulation (Abecia et al., 2012). Alternatively, prostaglandin $F_{2}\alpha$ ($PGF_{2}\alpha$) analogs can be used to induce luteolysis in animals with a functional *corpus luteum*, requiring two treatments within 11–14 days to ensure synchronization (Romano et al., 2017). In addition, the introduction of sexually active males into the herd, also known as male effect, induces estrus in both goats and sheep, which is triggered by pheromones and sexual behavior (Chemineau et al., 2006). Each method has specific advantages and limitations depending on breed, season, and farm management practices. Combining hormonal and behavioral cues often improves the efficacy of the synchronization protocol.

Milking Routines and Equipment

Consistent and hygienic milking routines are essential to maximize milk yield and preserve udder health. Mechanical milking should be performed at regular intervals using well-maintained equipment calibrated to minimize teat damage and optimize milk flow. Milking machines for small ruminants are typically designed as single or double clusters with low vacuum levels (i.e., 36–42 kPa) and short pulsation cycles of 100/120 and 180 cycles/min for goats and ewes, respectively (Dzidic et al., 2019). The 60:40 or 50:50 ratio is generally recommended. Small ruminants usually are often milked twice a day as several studies have demonstrated reduced milk yield by 6–35% in goats milked only once daily (Capote et al., 2006). For instance, Salama et al. (2003) showed that milking three times daily, compared to twice, can increase milk yield by 20%. Similarly, higher milking frequency in sheep during early lactation contributes to prolonged lactation curves and greater overall yield (McKusick et al., 2002). However, the reduced labor and the lower percentage of milk yield losses make once-daily milking a feasible practice in some high-producing breeds which have adapted their udder conformation accordingly.

Udder Morphology

Udder morphology plays a crucial role in the productivity, health, and longevity of dairy small ruminants. Conformation traits such as udder depth, teat placement, attachment strength, and symmetry are directly associated with milking efficiency, susceptibility to mastitis, and ease of machine milking. Thus, symmetrically shaped udders with properly placed teats facilitate complete and rapid milk extraction while minimizing residual milk (Peris et al., 1999). In contrast, poorly shaped udders can reduce milk flow, contribute to higher somatic cell counts (SCC), and increase the incidence of intramammary infections (Margatho et al., 2020). Moreover, udder traits have moderate heritability, suggesting that selective breeding for desirable morphology can lead to long-term improvements in milk yield and udder health (Legarra & Ugarte, 2005). Therefore, regular morphological evaluation and inclusion of udder traits in selection indices are essential for sustainable genetic improvement in dairy sheep and goat populations.

Housing and Welfare Considerations

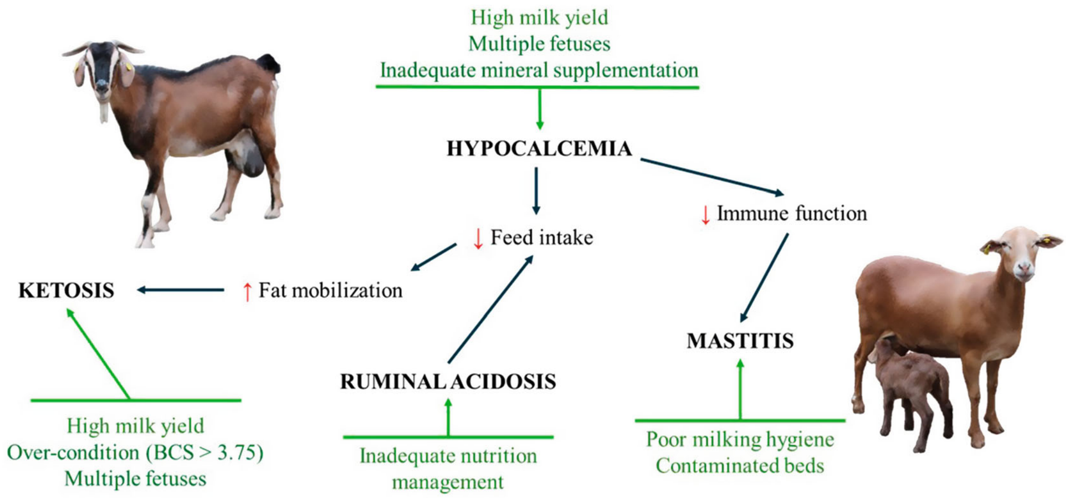
Comfortable housing minimizes stress and supports productivity in lactating animals. Facilities must provide adequate ventilation, dry bedding, shelter from extreme weather, and sufficient space to reduce competition for feed and water (Sevi et al., 2009). Environmental stressors, particularly heat stress, can significantly impair milk yield and immune function. Thus, cooling systems, shade, and water access are essential components of management in hot climates (Silanikove, 2000).

Record Keeping and Data-Supported Decisions

Accurate, consistent recordkeeping enables precision management in dairy herds. Monitoring milk yield, reproductive status, health treatments, and body condition contributes to the early detection of problems and supports decision-making related to discarding, breeding, and nutritional adjustments (Morgan-Davies et al., 2024). Modern herd management software facilitates integration and analysis of this data, improving long-term productivity (Simitzis et al., 2022).

Most Common Lactation-Related Diseases in Dairy Goats and Sheep

As described above, lactation is a critical period in the reproductive cycle of dairy goats and sheep. Similar to dairy cows, goats and sheep experience a period characterized by intense metabolic demands and heightened vulnerability to a range of diseases, potentially affecting milk yield, udder condition, and animal welfare (Hernández-Castellano et al., 2021). The most prevalent lactation-related diseases in these small ruminants include mastitis, hypocalcemia, ketosis, and rumen acidosis, with mastitis being the most economically significant (Fig. 1).



Lactation of Small Ruminants, Fig. 1 Association between lactation-related health disorders and their risk factors

Mastitis

Mastitis (i.e., mammary gland inflammation) is one of the most common lactation-associated diseases in dairy goats and sheep. Despite mastitis may occasionally be triggered by physical trauma, the main cause of mastitis is usually associated with bacterial infections. Depending on the presence or absence of visible clinical signs and symptoms, mastitis can be classified as either clinical or subclinical. Clinical mastitis is characterized by intense udder inflammation with visible signs such as swelling, redness, heat, pain, and abnormal milk secretion that may contain clots, pus, or discoloration (Contreras et al., 2007). In contrast, subclinical mastitis can remain undetectable based on clinical signs, although it can be diagnosed through reduced milk yield, SCC, and bacterial cultures. Due to physiological differences in milk composition between goats and cows, the use of SCC as a mastitis indicator in goats is challenging, as apocrine milk secretion leads to high variability in SCC (Paape et al., 2001). Consequently, it is likely to detect healthy goats showing higher milk SCC than others suffering clinical or subclinical mastitis. Thus, an animal suffering subclinical mastitis may serve as a silent reservoir for the microorganism within herds (Smith et al., 2013). The etiological agents associated in both forms commonly include *Staphylococcus aureus*, *Streptococcus* spp., and coliform bacteria, although the prevalence and pathogenicity can vary between clinical and subclinical presentations (González et al., 2016). While clinical mastitis can rapidly impair milk yield and quality and can require immediate intervention, subclinical mastitis leads to chronic milk yield reduction and increased risk of disease transmission. Moreover, differences in immune response dynamics, detection methods, and management strategies between the two forms underscore the importance of precise diagnosis for effective control programs. Therefore, effective mastitis control relies on hygienic milking practices, proper machine maintenance, and selective dry-off therapy (Contreras et al., 2007). In addition, antibiotic therapy remains the cornerstone of treatment, although antimicrobial resistance poses growing concerns (Moroni et al., 2005).

Hypocalcemia

Despite this disease is more common in high-yielding dairy cows (Hernández-Castellano et al., 2021), hypocalcemia, also known as milk fever, can affect periparturient ewes and does, particularly in flocks with intensive feeding regimens (Brozos et al., 2011). Calcium homeostasis in the bloodstream is tightly regulated through coordinated mechanisms involving bone calcium resorption, intestinal absorption, and renal reabsorption. These fluxes are principally modulated by the coordinated action of parathyroid hormone (PTH), calcitriol, and calcitonin (CT). A decline in circulating calcium levels is detected by calcium-sensing receptors located on the chief cells of the parathyroid glands, leading to the secretion of PTH, which acts to restore normocalcemia through its effects on target organs. At the onset of lactation, calcium homeostasis mechanisms are not fast enough to compensate for the high calcium demands of the mammary gland for milk production, reducing circulating blood concentrations and causing hypocalcemia (Hernández-Castellano et al., 2020). Clinical signs are similar to those found in cows, including weakness, ataxia, and recumbency (Hernández-Castellano et al., 2020). The incidence of this disease increases with parity, milk yield, and nutritional imbalances, particularly diets with a high cation–anion difference (DCAD) or rich in calcium content (Hernández-Castellano et al., 2017; Pugh & Baird, 2012). Based on this, several studies have evaluated the effect of adding low calcium diets or reducing intestinal calcium absorption to stimulate prepartum calcium mobilization from bones (i.e., calcium resorption) and increase circulating calcium concentrations around parturition (Hernández-Castellano et al., 2020). In case that these prevention strategies fail, clinical treatment involves intravenous or subcutaneous calcium administration (i.e., calcium gluconate and calcium borogluconate).

Ketosis

Energy imbalance during late gestation and early lactation represents a critical metabolic challenge for small ruminants, often predisposing them to ketosis. This metabolic disease is associated with energy demands exceeding dietary intake, which results in extent fat mobilization and consequently high production of ketone bodies. In dairy goats and sheep, the incidence of ketosis is high in the last weeks of gestation as animals carrying multiple fetuses have reduced capacity for feed intake and increased glucose demands from the fetuses. The incidence of these metabolic diseases is also high in early lactation, especially in high yielding animals, as the energy for milk production exceeds the feed intake capacity during the first weeks postpartum (Pugh & Baird, 2012). Animals affected by ketosis often show anorexia, lethargy, and weakness. In case of severe ketosis, neurological signs such as ataxia, tremors, and head pressing may appear, and if not properly treated, animals might die. Animals suffering ketosis are commonly diagnosed by measuring elevated concentrations of ketone bodies (i.e., acetate, acetoacetate, and β-hydroxybutyrate) in blood, milk, or urine samples (Hernández-Castellano et al., 2021). Nutritional strategies are essential to prevent this metabolic disease. These include maintaining appropriate body condition scores, ensuring gradual dietary transitions before parturition, and providing sufficient energy density in the ration, particularly high prolificacy or high yielding animals (Smith et al., 2013). Monitoring high-risk animals and implementing targeted nutritional interventions remain key components in reducing the incidence and severity of ketosis in small ruminants. In case of animals suffering ketosis, they should be treated with oral or intravenous administration of glucose precursors such as propylene glycol, as well as correction of electrolyte imbalances and provision of high-energy feeds.

Rumen Acidosis

Ruminal acidosis is a metabolic disease caused by feeding large amounts of carbohydrates, mainly starch, which causes the rapid fermentation of these carbohydrates by amylolytic bacteria, resulting in a high production of propionic and lactic acids, decreasing rumen pH (Hernandez-Castellano et al., 2021). While rumen pH decreases to 5.5, lactic acid-producing bacteria populations, such as *Streptococcus bovis* and *Lactobacillus* spp., proliferate, further acidifying the rumen environment. The decline in pH disrupts normal microbial populations and impairs rumen motility, leading to systemic effects such as dehydration, metabolic acidosis, and endotoxemia (Nagaraja & Titgemeyer, 2007). Consequently, this metabolic disorder challenges animal health, welfare, and productivity, particularly in intensive or transitioning feeding systems. Ruminal acidosis is commonly classified into acute rumen acidosis and subacute rumen acidosis (SARA). Acute ruminal acidosis is often associated with a sudden dietary change and is characterized by severe clinical signs, including depression, ataxia, abdominal distension, and in severe cases, death. On the other hand, SARA is associated with rumen pH fluctuating between 5.5 and 5.8 over extended periods, and it is characterized by reduced feed intake, decreased milk yield, recurrent bloat, and laminitis (Plaizier et al., 2008). Although more extensively studied in cattle, SARA is increasingly recognized in small ruminants under high-energy feeding conditions.

The prevention of this metabolic disease is based on efficient nutritional strategies. Some of these strategies include gradual dietary transitions, inclusion of physically effective fiber, and limitation of grain-based concentrates. The use of dietary buffers (e.g., sodium bicarbonate), probiotics, and rumen modifiers (e.g., monensin) can also contribute to stabilize rumen pH and microbial populations (Krause & Oetzel, 2006). Proper feed mixing and monitoring of total mixed rations (TMR) are particularly important in intensive dairy goat and sheep production systems. In case these prevention strategies fail, the treatment of animals suffering from acute rumen acidosis or SARA depends on the severity of the condition. In mild cases, restricting concentrate intake and providing good-quality forage may be sufficient to restore rumen pH. In severe cases, oral administration of alkalinizing agents (i.e., magnesium hydroxide or sodium bicarbonate), intravenous infusion of saline solution (NaCl 0.9%), or lactated Ringer's solution to correct dehydration and acidosis, in addition to antibiotics to control secondary infections (Andrews et al., 1996). In cases of recumbency or shock, intravenous bicarbonate and anti-inflammatory drugs may be also needed. In extreme cases, rumenotomy may be required to evacuate fermenting contents.

Conclusions

Lactation in dairy goats and sheep is a vital physiological process with significant impact on milk production, particularly in Mediterranean and mountainous regions. Factors such as breed, nutrition, and management greatly influence milk yield and quality. Proper diet formulation according to species-specific requirements is essential to maintain productivity and prevent metabolic diseases like hypocalcemia, ketosis, and ruminal acidosis. Moreover, mastitis remains a common threat, making early diagnosis and prevention crucial. Overall, an integrated management approach that considers genetics, nutrition, and health is key to optimizing production and animal welfare in small ruminant dairy systems.

Cross-References

▶ Lactation Curve
▶ Milk Composition
▶ Milk Synthesis
▶ Milk Yield

Competing Interest Declaration The author(s) has no competing interests to declare that are relevant to the content of this manuscript.

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