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Transition Period in Dairy Goats

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Physiology · Gestation · Small ruminants · Lactation · Mammary gland

Synonyms

Late gestation and early lactation physiology

Other Languages

Spanish: Período de transición; **French**: Période de transition; **German**: Übergangsphase; **Portuguese**: Período de transição

Definition

The transition period in dairy goats is a critical phase that spans between 3 weeks before and 3 weeks after parturition (Matthews, 2016). In this period, animals experience significant physiological and metabolic changes while they shift from the dry period to a new lactation cycle. To meet the energy demands for fetal growth and colostrum and milk production, dairy goats must mobilize fat reserves, which can increase the risk of metabolic disorders. Proper nutrition as well as dry-off and health management are essential to support energy needs, minimize health risks, and ensure an optimal lactation performance. This entry addresses the main physiological and mammary gland adaptations, the colostrum synthesis and its role in the neonate development and the most frequent health disorders observed during the transition period.

Major Features

The Key to Successful Lactations

Both gestation and lactation can be considered homeorhetic states, which are known as those coordinated metabolic adaptations that allow the organism to achieve a physiological balance or homeostasis (Bauman & Bruce Currie, 1980). During the final stage of gestation, multiple metabolic and hormonal changes can be observed, mainly related to fetal growth and the development of the mammary gland. In intensive production systems, dairy goats produce milk for 7–10 months each lactation, with the early stages of gestation often overlapping with the last months of lactation. This type of management

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allows farmers to have continuous and consistent milk production. However, this production system poses significant challenges, particularly in high-yielding animals and those carrying multiple fetuses. Understanding the metabolic, hormonal, and nutritional shifts that occur during this transition period is crucial to improve welfare, health, and productivity in dairy goats.

Metabolic Adaptations

According to Bauman and Bruce Currie (1980), around 70% of fetal growth occurs during the last 6 weeks of gestation. The gravid uterus will compress the rumen, compromising the gastrointestinal tract function, which leads to reduced feed intake capacity (de Souza Castagnino et al., 2015). Despite goats are well-adapted to scarce or low-quality feed sources, energy intake decreases during late gestation, which causes a progressive reduction in circulating glucose concentrations. Under this condition, dairy goats use proteins and fat reserves to meet these high energy demands, increasing blood urea and fatty acids concentrations (Fig. 1). Lipids metabolism results in increased β-hydroxybutyrate (BHB) and free fatty acids (FFA) concentrations, commonly used as biomarkers of negative energy balance (NEB). Indeed, it has been shown that large litter size increases lipid mobilization, as higher levels of FFA and BHB are frequently observed in goats bearing two or three kids compared with those bearing singletons. According to Zamuner et al. (2020), high milk yields have the most significant influence on the magnitude of body tissue mobilization and suggest that endocrine background of high-yielding animals may enhance the partitioning of nutrients to the mammary gland during the transition period. In addition, the same authors described that multiparous goats exhibited greater lipids mobilization compared to primiparous goats at the end of the gestation period. The transition between the dry period and the onset of lactation involves a rapid shift from low density to high-energy diets, achieved by the inclusion of greater amounts of concentrate. Therefore, at the onset of lactation, increased lactate dehydrogenase (LDH) concentrations are commonly observed due to the high lactic acid production in the rumen caused by the fermentation of high-concentrate diets (He et al., 2022). However, prolonged exposure to these dietary conditions can impair nutrient absorption, reduce feed efficiency, and compromise overall animal health.

Fetus Demands

Maternal nutrition and the efficiency of placental nutrient transfer directly influence the adequate fetal development. Glucose is the primary nutrient required by both, the mammary gland and the fetus metabolism. However, the mammary gland converts glucose to lactose while the gravid uterus oxidizes glucose as its primary metabolic source of energy. This nutrient partitioning to the placenta is regulated by a coordinated network of hormones that not only regulates nutrient utilization but also growth and organ development. For instance, insulin promotes glucose uptake and protein synthesis, and its levels have been shown to strongly correlate to fetal growth (Shen et al., 2003). Other hormones such as insulin-like growth factors (i.e., IGF-I and IGF-II), glucocorticoids, thyroid hormones (i.e., T3 and T4), and placental lactogens also play an important role in cell proliferation and differentiation, organ maturation and development (Fowden & Forhead, 2004).

Calcium Homeostasis

In healthy multiparous dairy goats, serum calcium concentrations can range between 2.3 mmol/L and 2.5 mmol/L during the last weeks of gestation. However, these values can drop rapidly from kidding to day 2 postpartum and then return to prepartum values by day 10 after parturition (Brugger & Liesegang, 2025). Research indicates that goats have a unique ability to adapt to calcium challenges. Does can compensate for low calcium availability by increasing mobilization from bones and enhancing active calcium absorption in the small intestine more efficiently than other ruminants (Wilkens et al., 2012). Despite calcium homeostasis is primarily regulated by the parathyroid hormone (PTH), vitamin D, and calcitonin, serotonin (5-HT) has been identified as a regulator of calcium metabolism in dairy goats.

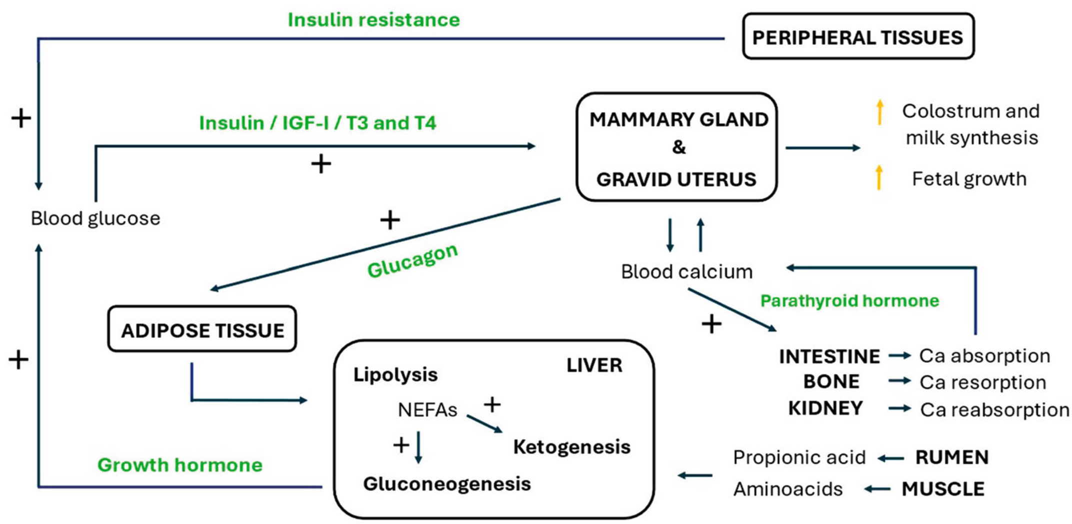
Administration of 5-hydroxytryptophan (5-HTP), a precursor of serotonin, has shown positive effects on calcium concentrations during the transition period, suggesting a potential therapeutic approach to manage calcium homeostasis (Zhang et al., 2022).

Endocrine Adaptations

In addition to fetal growth, the last weeks of the dry period are marked by the accumulation of nutrients and bioactive components in the mammary gland, a process involving coordinated molecular mechanisms in which the neuroendocrine system plays a crucial role (Fig. 1). Although research on these endocrine adaptations in dairy goats is limited, it is reasonable to assume that they follow a similar pattern to those in dairy cows. During late gestation, blood progesterone concentrations progressively decrease, with a sharp drop occurring around 24 hours before parturition, while estrogen levels progressively increase, peaking at parturition (Bigler et al., 2023). Simultaneously, growth hormone increases, promoting nutrient partitioning towards the mammary gland by stimulating blood flow, gluconeogenesis, and lipolysis. Similarly, insulin plays a key role at the end of gestation, regulating glucose metabolism by limiting maternal peripheral glucose uptake to enhance its availability for fetal growth and the mammary gland development. Additionally, the placental lactogen, a hormone secreted by the trophoblast cells of the placenta, also enhances fetal growth by stimulating maternal lipolysis and insulin resistance (Bell & Bauman, 1997). Indeed, reduced concentrations of this hormone have been associated with intrauterine growth restriction and poor fetal outcomes (Freemark, 2006). Other hormones, such as oxytocin, prostaglandin F2α, and cortisol rise at the end of gestation to trigger the onset of parturition and ensure the successful progression and expulsion of the fetuses. Subsequently, the onset of lactation is marked by a rapid increase in prolactin concentrations which is known as a mammogenic hormone, mainly secreted in response to the milking stimulus (Lérias et al., 2014).

Mammary Gland Physiology During the Transition Period

The mammary gland structure involves two primary components, the parenchyma, which comprises the epithelial and myoepithelial cells, and the stroma, which includes smooth muscle cells,



Transition Period in Dairy Goats, Fig. 1 Metabolic and endocrine adaptations to meet energy demands during the transition period. References: Bell and Bauman (1997), De Koster and Opsomer (2013). Abbreviations: *NEFA* non-esterified fatty acids, *Ca* calcium, *IGF-I* insulin-like growth factor 1, *T3* triiodothyronine, *T4* thyroxine. Endocrine positive stimulus is represented as "+"

blood vessels, and the ductal system (Lérias et al., 2014). The development of the mammary gland takes place in two different stages, embryonic and postnatal. The first functional changes begin before birth in a phase called mammogenesis, which extends to the beginning of the first lactation (Knight & Peaker, 1982). Following parturition, the structure of the mammary gland undergoes different morphological and functional changes, primarily controlled by the neuroendocrine system which are divided into four cyclical stages: (1) Colostrogenesis also known as lactogenesis I, which consists in the synthesis and secretion of colostrum; (2) lactogenesis II, or the onset of milk production; (3) galactopoiesis or maintenance of lactation and, and (4) involution or regression of the mammary glandular secretory tissue. Since involution, colostrogenesis and lactogenesis II are framed within the transition period, this entry exclusively focuses on these key stages (Fig. 2).

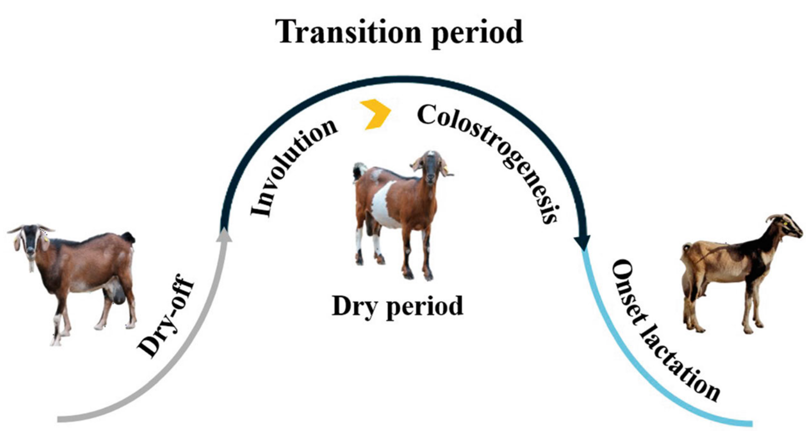
Involution or Regenerative Regression

Gestation and lactation overlap for approximately 3 months in the productive cycle of dairy goats. Therefore, the onset of gestation typically occurs between 90 and 150 days in milk. During the last 2 months of gestation, also known as the dry period, the mammary gland undergoes a complex and dynamic process called involution, characterized by the cessation of milk production, extensive tissue regression and regeneration. This stage begins with a rapid decline in milk synthesis and secretion, accompanied by apoptosis and autophagy of mammary epithelial cells (Lérias et al., 2014). The gland transitions through an active involution and development, during which epithelial cells are removed and replaced by new secretory cells. Therefore, an increase in the size and complexity of the duct system and proliferation of epithelial cells can be observed at the end of gestation. These changes are tightly controlled by shifts in gene expression and are highly dependent on hormonal and nutritional factors (Tsiplakou et al., 2020).

Colostrogenesis

Physiological changes during the dry period are primarily adaptive and prepare the doe for the expulsion of the fetus and the onset of lactation. Although there is no clear sign to differentiate between the end of involution and the onset of colostrum synthesis, involution and colostrogenesis appear to be consecutive over the dry period. Therefore, around 2–3 weeks before parturition and after tissue regression and regeneration, the mammary gland starts synthesizing a thick liquid, also known as colostrum. Depending on the needs of the offspring, ruminants have evolved to produce colostrum containing specific proportion of nutrients and bioactive components that are essential to ensure survival and the proper development of the immune system and gastrointestinal tract (Stelwagen et al., 2009).

Transition Period in Dairy Goats, Fig. 2 Schematic representation of the transition period



The chemical composition and immune properties of colostrum can vary depending on multiple factors such as the species, breed, parity, nutrition, length of the dry period, and the mammary gland health (González-Cabrera et al., 2025). Among all the bioactive components present in colostrum, immunoglobulins, particularly IgG_1, are the main proteins transferred from blood via specific receptors (Baumrucker et al., 2023). Other components, such as leukocytes and cytokines, oligosaccharides, enzymes like chitotriosidase, and antimicrobial proteins like lactoferrin, can be synthesized or transferred from blood to the mammary gland (Argüello et al., 2008; Hiss et al., 2008; Marziali et al., 2018). These molecules have been shown to modulate immune responses and promote gut health by supporting beneficial microbiota, intestinal maturation, and limiting parasite and pathogenic bacteria growth (Table 1). Recently, some studies have focused on elucidating the role of exosomes or extracellular vesicles in colostrum, which are known for carrying microRNAs involved in cell signaling, growth, and development (Castro et al., 2024). Despite this, further studies are still needed to fully understand the impact of goat colostrum bioactive components on the offspring health and performance.

Several studies have also focused on the importance of the transition milk, which refers to the milk obtained after colostrum and before the onset of mature milk production, typically from the second to the fifth day postpartum in once-a-day milking herds (Sánchez-Macías et al., 2014). Its composition reflects a gradual shift from the highly concentrated and immunoglobulin-rich colostrum to the more stable profile of mature milk (Table 2). Compared to colostrum, transition milk has lower concentration of immunoglobulins but still contains elevated levels of other bioactive components (Salama et al., 2005). It also contains higher fat, protein, and total solids than mature milk, contributing to the immune and digestive development on the first days of life.

Transition Period in Dairy Goats, Table 1 Colostrum bioactive components and their functions

Component	Function
Immunoglobulins (i.e., IgG, IgA, IgM)	Neutralize pathogens and support mucosal immunity
Lactoferrin and lysozyme	Limit bacterial growth by binding iron and degrading cell walls respectively
Immune cells (i.e., lymphocytes, macrophages, neutrophils)	Transfer pathogen-specific memory, cytokine production and maturation of gut-associated lymphoid tissues
Fatty acids	Support brain development and anti-inflammatory properties
Cytokines (i.e., IL-1, IL-6, TNF-α)	Modulate immune cell signaling and inflammation
Oligosaccharides	Promote beneficial gut microbiota and prevent pathogen adhesion
Hormones (i.e., IGF, insulin, leptin)	Promote intestinal development and neonate metabolism
Exosomes (i.e., extracellular vesicles containing peptides, miRNA)	Modulate gene expression, cell signaling, and immune development

References: Silva et al. (2024), Stelwagen et al. (2009)
Abbreviations: *Ig* immunoglobulin, *IL* interleukin, *TNF-α* Tumor necrosis factor, *IGF* insulin-like growth factor, *miRNA* micro-RNA

Lactogenesis II

This stage refers to the onset of copious milk synthesis driven by intense hormonal changes. During this phase, the mammary gland transitions from a lower secretory activity in late pregnancy to full milk production (Fleet et al., 1975). At this point, the mammary gland tissue undergoes important adaptations, including the replacement of adipose tissue by secretory cells, enhancing the secretory capacity and promoting a greater udder volume and fluid accumulation. The increased blood flow and the inflammatory cascade triggered by parturition often results in a swollen and tight udder that might extend to 1–2 weeks postpartum. Interestingly, Anderson and Wahab (1990) reported that mammary gland development in dairy goats from different breeds normally peak around day 5 postpartum while milk production peaks around 6–8 weeks after kidding. It is important to note that udder volume is highly associated with milk yield but also with litter size, being greater in twin and triplet bearing goats.

Transition Period in Dairy Goats, Table 2 Gross chemical composition and IgG concentration in colostrum, transition milk and mature milk in dairy goats

	Chemical composition[a]			
	Lactose (%)	Fat (%)	Protein (%)	IgG (mg/mL)
Colostrum	2.0–4.4	4.0–8.6	8.2–17.1	26.6–41.3
Transition milk	3.9–4.5	3.3[b]–6.4	4.9–5.7	1.9–8.2
Mature milk	4.2–5.5	3.8–4.5	4.3–4.5	0.7–1.3

References: González-Cabrera et al. (2024), Kessler et al. (2019), Salama et al. (2020), Sánchez-Macías et al. (2014)
[a]Gross chemical composition of colostrum, transition, and mature milk will depend on several factors such as genetics (i.e., breed), milking frequency (i.e., once- or twice a day), nutrition, and health status of the doe
[b]Data extracted from graphical representation

Strategies for a Successful Transition Period

Nutrition Management

During late gestation, dietary strategies should aim to maximize dry matter intake, minimize negative energy and protein balances, stimulate rumen papillae development, maintain calcium homeostasis, and support the immune system. Nutrient requirements, feed composition, and formulation guidelines for dairy goats can be found in *Nutrient Requirements of Small Ruminants* (NRC, 2007) and the *Feeding System for Ruminants* (Sauvant et al., 2018). In brief, diets should be energy-dense and nutritionally balanced, incorporating high-quality forages and concentrates based on body condition and litter size. A gradual increase in dietary energy prior to kidding is essential for rumen adaptation and to reduce excessive fat mobilization. Providing free access to clean water and ensuring adequate body reserves at parturition are critical for optimizing health and early lactation performance. Mineral supplementation, particularly of calcium, phosphorus, and trace elements, must be carefully managed to prevent deficiencies and metabolic disorders. In this context, high-calcium forages such as alfalfa hay should be limited in late gestation to enhance calcium mobilization at the onset of lactation.

Dry-Off Management

Dairy goats usually produce more milk than the offspring requirements and are generally unable to naturally stop lactating 2 months before kidding. Any disruption or shortening of this involution period can compromise tissue regeneration and reduce milk yield in the subsequent lactation. Indeed, it has been reported that omitting the dry period between lactations reduces colostrum quality (i.e., IgG concentrations) and milk yield, and it can also worsen the prepartum NEB and reduce goat kid birth body weight (Caja et al., 2006). Therefore, adequate management practices allowing for proper mammary gland involution and replacement of the secretory cells are vital to ensure a successful lactation.

Dry-off protocols in dairy goats typically involve a gradual reduction in dietary energy, mainly by limiting cereal grain intake, combined with decreased milking frequency and the use of preventive mastitis treatments (Petridis & Fthenakis, 2019). However, to reduce antimicrobial use and treatment costs, mastitis therapies should be applied selectively, based on risk and clinical signs.

Health Disorders

Pregnancy Toxemia

Failure in the adaptation to physiological and metabolic challenges during late pregnancy could lead to a pathological condition which involves abnormal ketone bodies (Marutsova & Binev, 2017), systemic inflammation, acute phase response, and compromised liver function (Doelman et al., 2012). This condition represents an important cause of production losses in small ruminant flocks, with high culling rates reported across studies. This condition, known as pregnancy toxemia, is linked to impaired energy balance and gluconeogenesis that can result in hypoglycemia, excessive fat breakdown, and elevated ketone bodies in blood and urea. The main risk factors of this condition include multiple fetuses, advanced maternal age, and inadequate nutrition management. Early clinical signs are often nonspecific and may include loss of appetite, distal limb edema, depression, prolonged recumbency, and general weakness. If the disease persists for more than 3–6 days, symptoms usually progress to more severe neurological and systemic manifestations such as lateral recumbency, blindness, nystagmus, stargazing, tremors, ataxia, coma, and eventually death (Doré et al., 2015). Treatment of this condition focuses on restoring energy balance and glucose levels. This often involves oral supplementation with propylene glycol or glucose, intravenous dextrose, and in some cases, induction of parturition.

Ruminal Acidosis

Feeding excessive amounts of high proportions of fermentable concentrate and forage with low effective fiber may trigger ruminal acidosis in early lactating dairy goats. This condition is exacerbated after parturition as does rapidly shift from low-energy dry diets to high-concentrate lactation diets, which can disrupt rumen fermentation and lead to prolonged periods of low ruminal pH (i.e., 5.2–5.8). The increased energy demand for milk synthesis in early lactation often requires feeding high-concentrate diets. Consequently, the rapid fermentation of these carbohydrates produces excesses of volatile fatty acids, saturating buffering capacity and lowering ruminal pH. Goats may initially adapt to such diets over weeks, but early-lactation metabolic demands leave them vulnerable to pH fluctuations before rumen papillae fully develop. The effects of subacute rumen acidosis on gut and metabolic health of dairy goats have been explored by Sun et al. (2010) and Dong et al. (2013). According to these studies, rumen acidosis can lead to reduced food intake, diarrhea, laminitis, and inflammatory response, which ultimately result in the reduction of milk yield and quality. Effective management of rumen acidosis in dairy goats focusses on adequate dietary formulation and feeding practices during the transition period to maintain optimal rumen pH and prevent excessive acid accumulation. Supplementing rations with buffer substances such as sodium bicarbonate, magnesium oxide, or potassium carbonate can stabilize rumen pH and mitigate the risk of acidosis.

Hypocalcemia or Milk Fever

Nutritional management during the transition period influences the risk of hypocalcemia in early lactation, even though this disorder is less prevalent in dairy goats compared to dairy cows. However, when dairy breeds bear twins or triplets, their risk of developing hypocalcemia before and after kidding increases due to high calcium demands for fetal skeletal development during the last 4 weeks of gestation and the high milk yield demands at the onset of lactation (Brugger & Liesegang, 2025). As reviewed by Hernández-Castellano et al. (2019), the parathyroid hormone regulates blood calcium levels through the control of gut calcium absorption, reabsorption in the kidneys, and resorption from bones. Clinical signs of hypocalcemia include loss of appetite and stiff gait, which can progress to sternal recumbency. Treatment of hypocalcemia in dairy goats involves careful administration of intravenous calcium borogluconate, while monitoring heart rate to avoid arrhythmias.

Conclusions

Milk production in dairy goats requires a complex coordination of intrinsic and extrinsic factors, particularly during the transition period, which includes the late gestation and early lactation stages. This period is characterized by significant metabolic, hormonal, and structural adaptations necessary to support fetal development, colostrum and milk production. Late gestation is marked by reduced feed intake due to rumen compression, leading to negative energy balance and mobilization of fat and protein reserves. Simultaneously, multiple hormones actively regulate nutrient partitioning to support fetal growth and mammary gland development. Maintaining calcium homeostasis also constitutes a key adaptation, being tightly controlled by mechanisms such as bone mobilization, and intestinal absorption. The mammary gland undergoes an involution followed by colostrogenesis, during which it produces colostrum, rich in multiple bioactive components essential for neonatal immunity and development. Nutritional management is critical, requiring balanced diets and proper mineral supplementation, while dry-off protocols ensure adequate mammary tissue regeneration. Failure to adapt to these physiological demands can trigger health disorders such as pregnancy toxemia, ruminal acidosis, or hypocalcemia. In conclusion, the success of lactation will highly depend on the coordination of these metabolic and hormonal mechanisms and the adequate nutritional and health management during the transition period.

Cross-References

▶ Behavior and Welfare
▶ Colostrum Management
▶ Feeding Systems in Dairy Goats
▶ Quality of Goat Milk and Its Products
▶ Transfer of Passive Immunity

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

References

Anderson, R. R., & Wahab, I. M. (1990). Changes in parenchyma and stroma of goat udders during pregnancy, lactation and involution. *Small Ruminant Research, 3*(6), 605–615. https://doi.org/10.1016/0921-4488(90)90055-B

Argüello, A., Castro, N., Batista, M., Moreno-Indias, I., Morales-DelaNuez, A., Sanchez-Macias, D., Quesada, E., & Capote, J. (2008). Chitotriosidase activity in goat blood and colostrum. *Journal of Dairy Science, 91*(5), 2067–2070. https://doi.org/10.3168/JDS.2007-0826

Bauman, D. E., & Bruce Currie, W. (1980). Partitioning of nutrients during pregnancy and lactation: A review of mechanisms involving homeostasis and homeorhesis. *Journal of Dairy Science, 63*(9), 1514–1529. https://doi.org/10.3168/jds.S0022-0302(80)83111-0

Baumrucker, C. R., Gross, J. J., & Bruckmaier, R. M. (2023). The importance of colostrum in maternal care and its formation in mammalian species. *Animal Frontiers: The Review Magazine of Animal Agriculture, 13*(3), 37. https://doi.org/10.1093/AF/VFAD012

Bell, A. W., & Bauman, D. E. (1997). Adaptations of glucose metabolism during pregnancy and lactation. *Journal of Mammary Gland Biology and Neoplasia, 2*(3), 265–278. https://doi.org/10.1023/A:1026336505343/METRICS

Bigler, N. A., Gross, J. J., Baumrucker, C. R., & Bruckmaier, R. M. (2023). Endocrine changes during the peripartal period related to colostrogenesis in mammalian species. *Journal of Animal Science, 101*, skad146. https://doi.org/10.1093/JAS/SKAD146

Brugger, D., & Liesegang, A. (2025). Antepartum high dietary supply of calcium affects bone homeostasis and offspring growth in dairy sheep and dairy goats. *Journal of Dairy Science, 108*(6), 5786–5802. https://doi.org/10.3168/JDS.2024-25587

Caja, G., Salama, A. A. K., & Such, X. (2006). Omitting the dry-off period negatively affects colostrum and milk yield in dairy goats. *Journal of Dairy Science, 89*(11), 4220–4228. https://doi.org/10.3168/JDS.S0022-0302(06)72467-5

Castro, N., Argüello, A., González-Cabrera, M., Morales-delaNuez, A., Torres-Krupij, A., & Santana, A. (2024). Goat colostrum-derived exosomes: The shocking secrets of cellular communication. In *Performance, Health and Welfare of Small Ruminants under Changing Climate Scenario, ISSGPUCON 2024* (pp. 37–141).

De Koster, J. D., & Opsomer, G. (2013). Insulin resistance in dairy cows. *Veterinary Clinics of North America – Food Animal Practice, 29*(2), 299–322. https://doi.org/10.1016/j.cvfa.2013.04.002

de Souza Castagnino, D., Härter, C. J., Rivera, A. R., de Lima, L. D., de Oliveira Silva, H. G., Biagioli, B., de Resende, K. T., & de Almeida Teixeira, I. A. M. (2015). Changes in maternal body composition and metabolism of dairy goats during pregnancy. *Revista Brasileira de Zootecnia, 44*(3), 92–102. https://doi.org/10.1590/S1806-92902015000300003

Doelman, J., Cao, H., Purdie, N. G., Kim, J. J. M., Swanson, K. C., Osborne, V. R., Tey, J., Ali, A., Feng, Z., Karrow, N. A., & Cant, J. P. (2012). Transcript profiling of the ruminant liver indicates a unique program of transcriptional regulation of ketogenic enzymes during food restriction. *Comparative Biochemistry and Physiology Part D: Genomics and Proteomics, 7*(3), 303–310. https://doi.org/10.1016/J.CBD.2012.06.002

Dong, H., Wang, S., Jia, Y., Ni, Y., & Zhang, Y. (2013). Long-term effects of subacute ruminal acidosis (SARA) on milk quality and hepatic gene expression in lactating goats fed a high-concentrate diet. *PLoS One, 8*(12), 82850. https://doi.org/10.1371/journal.pone.0082850

Doré, V., Dubuc, J., Bélanger, A., & Buczinski, S. (2015). Definition of prepartum hyperketonemia in dairy goats. *Journal of Dairy Science, 98*, 4535–4543. https://doi.org/10.3168/jds.2014-9172

Fleet, I. R., Goode, J. A., Hamon, M. H., Laurie, M. S., Linzell, J. L., & Peaker, M. (1975). Secretory activity of goat mammary glands during pregnancy and the onset of lactation. *The Journal of Physiology, 251*(3), 763–773. https://doi.org/10.1113/JPHYSIOL.1975.SP011120

Fowden, A. L., & Forhead, A. J. (2004). Endocrine mechanisms of intrauterine programming. *Reproduction, 127*(5), 515–526. https://doi.org/10.1530/REP.1.00033

Freemark, M. (2006). Regulation of maternal metabolism by pituitary and placental hormones: Roles in fetal development and metabolic programming. *Hormone Research, 65*(3), 41–49. https://doi.org/10.1159/000091505

González-Cabrera, M., Torres, A., Salomone-Caballero, M., Castro, N., Argüello, A., & Hernández-Castellano, L. E. (2024). Intramammary administration of lipopolysaccharides at parturition enhances immunoglobulin concentration in goat colostrum. *Animal, 18*(2), 101082. https://doi.org/10.1016/J.ANIMAL.2024.101082

González-Cabrera, M., Morales-delaNuez, A., Argüello, A., Castro, N., & Hernández-Castellano, L. E. (2025). Review: Mammary gland physiology and modulation during colostrogenesis in dairy goats. *Animal*, 101487. https://doi.org/10.1016/J.ANIMAL.2025.101487

He, B., Fan, Y., & Wang, H. (2022). Lactate uptake in the rumen and its contributions to subacute rumen acidosis of goats induced by high-grain diets. *Frontiers in Veterinary Science, 9*, 964027. https://doi.org/10.3389/FVETS.2022.964027

Hernández-Castellano, L. E., Hernandez, L. L., & Bruckmaier, R. M. (2019). Review: Endocrine pathways to regulate calcium homeostasis around parturition and the prevention of hypocalcemia in periparturient dairy cows. *Animal, 14*(2), 330–338. https://doi.org/10.1017/S1751731119001605

Hiss, S., Meyer, T., & Sauerwein, H. (2008). Lactoferrin concentrations in goat milk throughout lactation. *Small Ruminant Research, 80*, 87–90. https://doi.org/10.1016/J.SMALLRUMRES.2008.07.027

Kessler, E., Bruckmaier, R., & Gross, J. (2019). Immunoglobulin G content and colostrum composition of different goat and sheep breeds in Switzerland and Germany. *Journal of Dairy Science, 102*, 5542–5549. https://doi.org/10.3168/jds.2018-16235

Knight, C. H., & Peaker, M. (1982). Development of the mammary gland. *Reproduction, 65*(2), 521–536. https://doi.org/10.1530/JRF.0.0650521

Lérias, J. R., Hernández-Castellano, L. E., Suárez-Trujillo, A., Castro, N., Pourlis, A., & Almeida, A. M. (2014). The mammary gland in small ruminants: Major morphological and functional events underlying milk production. *Journal of Dairy Research, 81*(3), 304–318. https://doi.org/10.1017/S0022029914000235

Marutsova, V., & Binev, R. (2017). Body condition score, nonesterified fatty acids and beta-hydroxybutyrate concentrations in goats with subclinical ketosis. *Agricultural Science and Technology, 9*(4), 282–285. https://doi.org/10.15547/AST.2017.04.053

Marziali, S., Guerra, E., Cerdán-Garcia, C., Segura-Carretero, A., Caboni, M. F., & Verardo, V. (2018). Effect of early lactation stage on goat colostrum: Assessment of lipid and oligosaccharide compounds. *International Dairy Journal, 77*, 65–72. https://doi.org/10.1016/J.IDAIRYJ.2017.09.004

Matthews, J. G. (2016). The periparturient goat. In *Diseases of the goat* (4th ed., pp. 41–60). Wiley.

Petridis, I. G., & Fthenakis, G. C. (2019). Mammary involution and relevant udder health management in sheep. *Small Ruminant Research, 181*, 66–75. https://doi.org/10.1016/J.SMALLRUMRES.2019.07.001

Salama, A. A. K., Caja, G., Such, X., Casals, R., & Albanell, E. (2005). Effect of pregnancy and extended lactation on milk production in dairy goats milked once daily. *Journal of Dairy Science, 88*(11), 3894–3904. https://doi.org/10.3168/JDS.S0022-0302(05)73075-7

Salama, A. A. K., Contreras-Jodar, A., Love, S., Mehaba, N., Such, X., & Caja, G. (2020). Milk yield, milk composition, and milk metabolomics of dairy goats intramammary-challenged with lipopolysaccharide under heat stress conditions. *Scientific Reports, 10*, 1–12. https://doi.org/10.1038/s41598-020-61900-8

Sánchez-Macías, D., Moreno-Indias, I., Castro, N., Morales-delaNuez, A., & Argüello, A. (2014). From goat colostrum to milk: Physical, chemical, and immune evolution from partum to 90 days postpartum. *Journal of Dairy Science, 97*(1), 10–16. https://doi.org/10.3168/JDS.2013-6811

Sauvant, D., Delaby, L., & Noziere, P. (2018). *INRA Feeding System for Ruminants*. Wageningen Academic Publishers, Wageningen, Netherlands.

Shen, W., Wisniowski, P., Ahmed, L., Boyle, D. W., Denne, S. C., & Liechty, E. A. (2003). Protein anabolic effects of insulin and IGF-I in the ovine fetus. *American Journal of Physiology, Endocrinology and Metabolism, 284*(4), 748–756. https://doi.org/10.1152/AJPENDO.00399.2002

Silva, F. G., Silva, S. R., Pereira, A. M. F., Cerqueira, J. L., & Conceição, C. (2024). A comprehensive review of bovine colostrum components and selected aspects regarding their impact on neonatal calf physiology. *Animals, 14*(7), 1130. https://doi.org/10.3390/ANI14071130/S1

Stelwagen, K., Carpenter, E., Haigh, B., Hodgkinson, A., & Wheeler, T. T. (2009). Immune components of bovine colostrum and milk. *Journal of Animal Science, 87*(13), 3–9. https://doi.org/10.2527/JAS.2008-1377

Sun, Y. Z., Mao, S. Y., & Zhu, W. Y. (2010). Rumen chemical and bacterial changes during stepwise adaptation to a high-concentrate diet in goats. *Animal, 4*(2), 210–217. https://doi.org/10.1017/S175173110999111X

Tsiplakou, E., Mitsiopoulou, C., Skliros, D., Mavrommatis, A., & Flemetakis, E. (2020). Feeding level regulates the expression of some genes involved with programed cell death and remodeling in goat and sheep mammary tissue. *Journal of Dairy Research, 87*(4), 448–455. https://doi.org/10.1017/S002202992000103X

Wilkens, M. R., Richter, J., Fraser, D. R., Liesegang, A., Breves, G., & Schröder, B. (2012). In contrast to sheep, goats adapt to dietary calcium restriction by increasing intestinal absorption of calcium. *Comparative Biochemistry and Physiology – A Molecular and Integrative Physiology, 163*(3–4), 396–406. https://doi.org/10.1016/j.cbpa.2012.06.011

Zamuner, F., DiGiacomo, K., Cameron, A. W. N., & Leury, B. J. (2020). Endocrine and metabolic status of commercial dairy goats during the transition period. *Journal of Dairy Science, 103*(6), 5616–5628. https://doi.org/10.3168/JDS.2019-18040

Zhang, Z. F., Du, W., Liu, W. Y., Wong, B. T., & Zheng, H. L. (2022). Increasing serotonin concentrations alter calcium metabolism in periparturient dairy goats. *Journal of Animal Science, 100*(3), skac065. https://doi.org/10.1093/JAS/SKAC065

Further Reading

National Research Council. (2007). *Nutrient requirements of small ruminants: Sheep, goats, cervids, and New World camelids*. The National Academies Press.