

Colostrum of various dairy species in tropical and subtropical regions

Raden Febrianto Christi¹, Ajat Sudrajat², Aulia Andhikawati³

¹ Faculty of Animal Husbandry, Padjadjaran University, Jatinangor, Sumedang Regency, West Java, Indonesia

² Faculty of Agroindustry, Mercu Buana University, Yogyakarta, Bantul Regency, Special Region of Yogyakarta, Indonesia

³ Faculty of Fisheries and Marine Science, Padjadjaran University, Jatinangor, Sumedang Regency, West Java, Indonesia

Abstract

Colostrum is the first fluid secreted from the mammary gland following parturition, containing essential immunoglobulins (IgG), nutrients, and bioactive compounds vital for the survival of newborn dairy livestock, including cattle, buffaloes, sheep, and goats. However, increasingly erratic global climate patterns mean that colostrum production and quality are heavily influenced by environmental conditions, particularly the climatic differences between tropical and subtropical regions. This article aims to analyze differences in the chemical composition of colostrum, the effects of heat stress, inter-species comparisons, post-milking management, and the internal and external factors affecting colostrum production and quality in dairy livestock across these two climatic zones. The results indicate that colostrum quality and composition vary significantly among species. In tropical regions, the primary challenges include heat stress, fluctuating feed quality, and higher disease risks, all of which have the potential to reduce immunoglobulin concentrations and the efficiency of passive immunity transfer. Conversely, in subtropical regions, more controlled management systems generally yield colostrum with more consistent quality, although it remains influenced by the dam's genetic and physiological factors. Successful passive immunity transfer in both tropical and subtropical regions depends heavily on colostrum quality. To maintain this quality, critical attention must be paid to the timing of milking, storage conditions, the volume administered, and the timing of consumption. This review concludes that colostrum from various dairy livestock exhibits distinct compositional differences, particularly when compared between tropical and subtropical countries.

Keywords: Colostrum, dairy livestock, tropical, subtropical, immunoglobulin

Introduction

The mammary gland is a gland composed of a collection of alveolar cells that are clearly separated between the left and right sides and regulated by hormones (Zhou *et al.*, 2025)^[42]. Colostrum is the first fluid from the mammary gland after birth that has a unique nutritional and immunological composition compared to normal milk. As the first source of nutrition for dairy calves after birth, it plays a role in providing passive transfer of immunoglobulins (especially IgG), growth factors, and nutrients necessary for survival and the development of the early immune system (Wicki *et al.*, 2024)^[40]. In various countries, dairy animals such as cows, buffaloes, goats, and sheep are the main sources of colostrum, which is not only used for livestock offspring but is also being developed as a functional food for humans due to excess milk production and its good nutritional composition for the body (Playford, 2022)^[32].

The quality and composition of colostrum cannot be said to be uniform for all dairy animals. This is due to external factors that can affect the productivity and quality of mammary gland secretion, namely environmental conditions, one of which is the difference between tropical and subtropical climates. In tropical regions, dairy cattle often face challenges such as heat stress and high humidity throughout the year. However, when compared to subtropical regions, cattle are exposed to extreme seasonal fluctuations, including winter and summer (Michael *et al.*, 2022)^[25]. These differences can affect cattle physiology, feed intake, and metabolic profiles, which ultimately influence colostrum component synthesis. Cattle experiencing heat stress tend to produce colostrum with a lower volume of 4 kg and lower immunoglobulin concentration compared to cattle in cooler environments

(Dado *et al.*, 2019)^[8]. Cows that gave birth experienced a 5 kg decrease in colostrum when subjected to heat stress (Seyed *et al.*, 2021)^[36]. Stress due to high heat stress for 3 days in dairy sheep reduced milk production by 5.22 grams/day (Corredu *et al.*, 2025). Danso *et al.* (2024)^[9] also reported that goats in cold conditions were able to increase colostrum by 21% and milk production, but the opposite was true in hot conditions. In addition to climatic factors, other factors affecting colostrum differences include the species or type of dairy livestock (species), which changes environmental conditions, resulting in changes in composition.

Research on colostrum has been extensively studied, but comprehensive reviews comparing the quality of colostrum from various types of dairy cattle with a focus on geographical conditions are still limited (tropical vs. subtropical). Therefore, understanding is essential for farmers and should be applied in order to manage colostrum feeding appropriately and obtain standard colostrum quality for the processing industry in various regions. The purpose of this review article is to explore the differences in nutritional composition, immunoglobulin profile, and bioactive components of colostrum from various dairy animals (cows, goats, sheep, and buffalo) raised in tropical and subtropical regions. On the other hand, this review will discuss the management and environmental factors that cause these differences in order to provide insights for the development of more adaptive and solution-oriented dairy farming strategies in the future.

Materials and Methods

This review article was written through a systematic literature review to identify, evaluate, and interpret all

relevant studies on colostrum quality in dairy cattle in tropical and subtropical regions. Literature sources between 2015 and 2025 included ScienceDirect, PubMed, Google Scholar, Scopus, and ResearchGate. Keywords used in the search included combinations of the following terms: colostrum quality, ruminant colostrum, immunoglobulin G (IgG), tropical environment, subtropical climate, heat stress, seasonal variation. Dairy cattle, dairy goat, dairy sheep, buffalo colostrum. This study collected data on the chemical composition (protein, fat, lactose) or immunological profile of colostrum as well as the geographical location or climatic conditions where the samples were taken. The articles used had criteria including not having clear quantitative data and literature that only discussed normal milk without colostrum

data. Articles that were not available in full text. The collected data were then extracted into a summary table format that included dairy species, research location (climate classification based on geographical location), colostrum quality parameters (particularly IgG and macro-nutrient levels), and findings on environmental influences. The analysis was conducted by comparing colostrum quality parameters between livestock in tropical regions (generally high temperature and high humidity) and subtropical regions (with seasonal fluctuations). The differences found were then discussed in relation to physiological factors, feed management, and the level of heat stress experienced by livestock in each region. The scope map includes Tropical and Subtropical regions in the world.

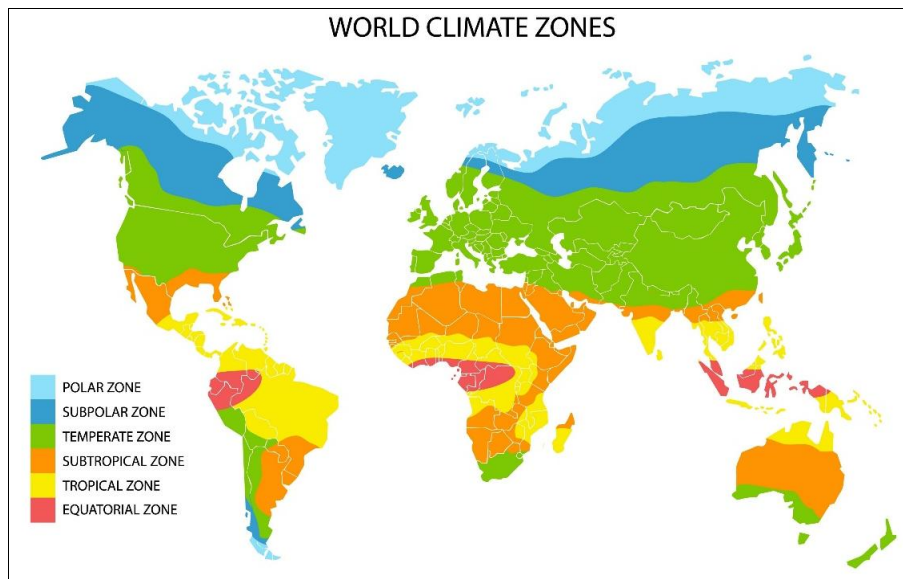


Fig 1: Tropical and subtropical countries in the world.

Results and Discussion

1. Chemical Composition of Colostrum in Tropical and Subtropical Regions

Colostrum is a white fluid containing numerous antimicrobials, antiviral, antifungal, and immunoregulatory substances (Saldana *et al.*, 2019) [35]. The most common definition of bovine colostrum is a thick, yellow fluid with a pH of 6.8. Colostrum contains chemical elements such as carbohydrates, proteins, fats, vitamins, and minerals

(Delhom *et al.*, 2017). The chemical composition of dairy cattle colostrum is strongly influenced by internal and external factors. Internal factors include species or breed, physiological status, parity, immunity, udder condition, and age of the sow. However, other external factors also influence the cow, such as environmental climate, season, feed, milking techniques, and health programs. Differences in dairy cattle in tropical and subtropical regions produce different results, as can be seen in Table 1.

Table 1: Chemical Composition of Colostrum from Various Dairy Species.

Parameter	Dairy cattle (bovine)	Dairy Goat (goat)	Dairy Sheep	Buffalo	Sources/ Literature
IgG (mg/mL / g/L)	~20–150 g/L (200–150 mg/mL)	~48–75 mg/mL	~62–65 mg/mL	~33.2 mg/mL	Bovine colostrum IgG range (Kazimierska and Kalinowska-Lis, 2021) [19]; Goat & sheep ranges from comparative study (Kessler <i>et al.</i> , 2019) [20]; Buffalo IgG data (Lotito <i>et al.</i> , 2023) [22]
Total Protein (%)	~13–20%	~10–15%	~16% (avg.)	~13–15%	General colostrum protein info (Kazimierska and Kalinowska-Lis, 2021 & Lotito <i>et al.</i> , 2023) [19, 22]
Fat (%)	~4–8%	~4% (varies by breed)	~7.8% avg.	~6.4–9.6%	MDPI review & sheep study (Kessler <i>et al.</i> , 2019) [20]; Buffalo fat reported in PMC review (Lotito <i>et al.</i> , 2023) [22] (Nayik <i>et al.</i> , 2022) [29]
Lactose (%)	~2–3%	~4.0–4.5%	~3.6%	~2.7%	MDPI table values (Kazimierska and Kalinowska-Lis, 2021) [19]; Buffalo milk review (Lotito <i>et al.</i> , 2023) [22] (Nayik <i>et al.</i> , 2022) [29]
Total Solids (%)	~24–30%	~12.65–12.81%	~16–17% (Varies)	~23–27%	Buffalo vs bovine colostrum study (Abd

		(varies by breed)	by breed)		El-Fattah <i>et al.</i> , 2012) (MM Ferro <i>et al.</i> , 2017) ^[27]
IGF-1 (ng/mL)	~722	~686.8–730.4	~323.2–381.1	~802	Buffalo vs cow colostrum (BMC Vet Res) (Abd El-Fattah <i>et al.</i> , 2012) ^[11] (MM Ferro <i>et al.</i> , 2017) ^[27]
Notes	Protein & IgG >> mature milk	Breed variation strong	Sheep colostrum fat & protein is often high	Buffalo fat & total solids often higher	Values depend on postpartum milking time

Immunoglobulin G (IgG): the primary immune component of bovine colostrum, which plays a crucial role in the transfer of passive immunity from the mother to the calf. It constitutes approximately 70–85% of the total colostrum immunoglobulins and is a key indicator of colostrum quality (Hurley and Theil, 2011)^[18]. In colostrum, IgG is released from the mother's circulation into the early milk through active transport by the neonatal Fc receptor (*FcRn*) during colostrogenesis, thereby helping to provide passive immunity to the neonate (Conneally *et al.*, 2013). Colostrum IgG concentration decreases by 3.7% during each subsequent hour after calving due to postpartum secretion by the mammary glands. The interval between calving and the first milking and colostrum volume are significantly and negatively related to colostrum IgG concentration, with the former being more dominant. Photoperiod has no effect on colostrum IgG concentration or volume. Serum protein concentrations at parturition correlate poorly with colostrum IgG concentrations (Morin *et al.*, 2010)^[28].

Total protein: an important indicator in early lactation contained in colostrum because it contains immunoglobulins and non-immune proteins that reflect the passive and bioactive immunity of dairy cattle. Immunoglobulin proteins consist of IgG, IgA, and IgM while non-immune proteins are casein, whey protein, enzymes, serum albumin, and lactoferrin (Godden, 2008)^[15]. Approximately 70% of total colostrum protein is colostrum while the rest is casein and whey protein. The role or function of total protein besides the immune system is to provide protection for the neonatal digestive tract and then as a provider of essential amino acids and bioactive proteins (McGuirk, 2011)^[24].

Fat: An important component of milk, composed of globules, plays a role in the development of the animal's body. Colostrum, which contains fat, produces differences based on the lactation period and the animal's living environment. The fat content of milk from newly delivered mothers (days 1-10) has a higher percentage value compared to that from day 15 and onward (Laskhari *et al.*, 2025). Fat, which is a collection of various fatty acids, produces differences in the percentage of fat content until day 5 (O'Challagan *et al.*, 2020). The functions of fat include providing energy for fetal development after birth, absorbing vitamins A, D, E, and K, and supporting the nervous and immune systems. Fatty acids are needed by the nervous system for the formation of neurogenesis and synaptic plasticity (Smolinska *et al.*, 2024).

Lactose: A carbohydrate found in colostrum that plays a crucial role as the primary energy source for newborn cattle, contributing to their initial metabolism and body balance. Lactose is formed from two monosaccharides: glucose and galactose (Polidori *et al.*, 2022)^[33]. Lactose is derived from the alveolar cells in the udder. However, there are differences in the percentage of lactose. Newborn cows have

low lactose levels on the first day, but these levels continue to increase over time (Martini *et al.*, 2020)^[23]. This is due to the influence of postpartum feeding management to restore good livestock performance.

Total Solids: the total amount of solid nutritional components in colostrum, such as protein, carbohydrates, fat, vitamins, and minerals, except air. Total solids can be used as an indicator of colostrum nutrients, so the comparison is water. Viscosity, which means the level of thickness, the higher the better (Smolinska *et al.*, 2024). This can be used to meet the needs of young livestock. As young livestock get older, colostrum with Total Solids will result in good growth (Martini *et al.*, 2020)^[23].

IgF-1 (Insulin-Like Growth Factor-1): a bioactive component found in colostrum immediately after giving birth. This bioactive component is similar to insulin-1, which plays a crucial role postpartum as a stimulus for digestive system development, enhancing metabolism, and promoting physiological adaptation (Behan *et al.*, 2024)^[4]. The highest concentration of IgF-1 is found in colostrum compared to colostrum development that occurs after 15 days. IgF-1 is permanent until the milk reaches one month of age. The growth and development of livestock is highly dependent on the food consumed after parturition and is included in determining the Body Condition Score (BCS) (Fischer *et al.*, 2025)^[12].

2. The Effect of Heat Stress on Colostrum Quality

Today's global climate is increasingly different from what it was decades, even hundreds of years ago. Current climate predictions are no longer a reliable guide for human action, particularly in the agricultural sector. Livestock is a subsector that provides meat, eggs, and milk. The impact of climate change will generally impact the performance of dairy cattle, which produce milk. Dairy livestock, such as cows, goats, sheep, and buffalo, are typically raised in different regions, resulting in different production levels. Regions can be divided into tropical and subtropical regions.

Tropical Regions: High temperature and humidity index (THI) triggers livestock, especially ewes, to experience oxidative stress. This article discusses the relationship between ewes and various dairy herds that experience heat stress during the dry season (before calving), resulting in lower colostrum volume and lower antibody quality. Highly stressed dairy herds due to heat stress negatively impact their performance (Chen *et al.*, 2024)^[5]. Such temperature and humidity conditions are known as a combined index called the Temperature Humidity Index (THI) (Galik *et al.*, 2021)^[13]. A THI of 72 or higher in dairy herds can disrupt metabolism, resulting in decreased feed intake, impacting health and the production and quality of colostrum. Lactating or postpartum cattle will show signs of discomfort if the THI exceeds 68. If not promptly addressed, this can

lead to overheating and stress, which can reduce performance (Becker *et al.*, 2021) ^[3]. However, not only milk production but also the chemical quality of colostrum significantly influences its percentage, triggering an increase in the Somatic Cell Count (SCC). The effect of heat stress on changes in colostrum and milk composition is visible from day 10 to day 60 when the sow enters lactation (Georgiades *et al.*, 2025; Rodriguez-Venegas *et al.*, 2023) ^[14, 34].

Subtropical Regions: Livestock farming can be practiced not only in tropical conditions but also in subtropical regions. In countries within this region, extreme heat is only disrupted during the summer. These conditions can disrupt livestock, causing high stress. High stress can reduce livestock performance, especially for dairy animals such as

cows, sheep, goats, and buffalo entering early lactation or after giving birth. Comfortable conditions for livestock are when the THI index is less than 68-72 (Becker *et al.*, 2021; Galik *et al.*, 2021) ^[3, 13]. Exceeding this figure can cause heat stress, disrupting the body's metabolic system. Early in lactation, it is crucial for mothers to maximize colostrum production, as this will be used as food for their calves. If the mother's condition is compromised early in lactation, colostrum production and quality will generally be suboptimal. Avendano *et al.*, (2024) reported that early lactation cows raised in (summer vs. winter) produced excellent production and quality in winter, while they were in the good category in summer. Therefore, subtropical conditions will also provide comfort for livestock, resulting in optimal performance.

Table 2: Colostrum Parameters in Calves in Tropical and Subtropical Regions

Colostrum Parameters	Thermoneutral Condition	Heat Stress Conditions	Biological Impact on Livestock
Colostrum volume	Normal–high	Decrease	Colostrum intake is not optimal
Total protein (%)	Tall	Decrease	Decreased supply of amino acids & antibodies
Immunoglobulin G (IgG)	Tall	Significant decrease	The risk of Failure of Passive Transfer (FPT) increases
Total solids (%)	Tall	Decrease	Reduced nutrient and energy density
Fat (%)	Normal	Tends to decrease	Initial energy for thermoregulation decreases
Lactose (%)	Relatively stable	Slight decrease / no change	Minor impact on energy
IGF-1 & growth factors	Tall	Decrease	Neonatal intestinal maturation is inhibited
Antimicrobial activity	Optimal	Decrease	Protection against pathogens is reduced

3. Comparison of Dairy Cattle Species and Post-Milking Management

Colostrum is the first fluid produced by dairy cattle such as cows, buffalo, sheep, and goats. Colostrum has different chemical characteristics among species, particularly in concentrations and percentages. However, this does not eliminate the nutritional components contained in colostrum. A review of the results revealed different responses in various dairy cattle raised in tropical and subtropical conditions.

Dairy Cattle and Buffalo: Concentration is more important in large ruminant dairy cattle because they produce higher volumes and yields than small ruminant dairy cattle. Colostrum produces the highest levels of nutrients, including fat, protein, and immunoglobulins (Goetz *et al.*, 2025) ^[16]. Differences in nutrient levels vary depending on region. Subtropical conditions can increase production volume and improve quality compared to tropical regions.

Goats and Sheep: These animals are also ruminants, with smaller body proportions compared to cattle and buffalo. Their advantage lies in their high adaptability to all conditions in subtropical and tropical regions (Todaro *et al.*, 2023) ^[39]. Although goats and sheep can thrive in tropical conditions, farmers maintain the quality of goat colostrum in tropical regions by providing good care for their livestock, such as by maintaining a stable environment that regulates temperature and humidity to ensure a comfortable life (Kessler *et al.*, 2019) ^[20].

Post-Milking Management

Colostrum is a nutritional source needed for dairy cattle calves after birth, serving as a source of passive immunity (Silva *et al.*, 2024) ^[37]. For colostrum to be active, it needs to be supplemented with other nutrients sourced from other

food ingredients. Colostrum quality must be maintained to maintain good condition and prevent rapid spoilage. There are stages of good post-milking management, where milking is necessary 1-2 hours after birth because IgG is still at a high level (Mitman *et al.*, 2025) ^[26]. If milking is delayed, the quality will decrease, negatively impacting the calf's performance. Cleanliness and hygiene during the milking process must be maintained; equipment must be clean and sterilized to suppress the growth of microorganisms. Colostrum containing high levels of microbes, such as bacteria, increases the risk of disease and can interfere with intestinal absorption. To prevent microbial growth, colostrum quality requires special treatment, including refrigeration and freezing. In some tropical regions, the risk of stress is so high that eating behavior stops. This results in decreased colostrum quality and decreased IgG levels (Mitman *et al.*, 2025) ^[26]. In subtropical conditions, the same measures are necessary as in tropical regions. However, in both climates, special attention is needed to postpartum management, including regular IgG quality checks, every minimum of one day and a maximum of seven days, for the following period (Goetz *et al.*, 2025) ^[16].

4. Internal and External Factors Differences in Colostrum Production and Quality

Colostrum quality is highly dependent on various internal and external factors. Several environmental factors contribute significantly to colostrum production. Tropical and subtropical conditions differ, but optimal management can lead to consistent and continuous improvement (Silva *et al.*, 2024) ^[37]. Besides differences in breed or species of dairy cattle, environmental factors also contribute to colostrum production, including the following.

Feeding: In the southern part of the country, there are a number of places to visit in the southern part of the world,

where the number of places in the area of the tropics is small, and the number of places in the area of the tropics is small (Gross and Bruckmaier, 2019)^[17].

Storage: In the subtropics, colostrum freezing technology (colostrum banking) is common, while in tropical regions, education on hygienic colostrum handling remains a major focus to improve the survival of calves from various species (Silva *et al.*, 2024)^[37].

Table 3: Internal and External Factors on Colostrum

Factor Group	Effect on Colostrum
Species & genetics	Determining the basic composition pattern
Nation & parity	Affects IgG and proteins
Parent nutrition	Determine total solid & energy
Environment (heat stress)	Reduces the quality of colostrum
Udder health	Changing protein composition
Milking time	Determining the concentration of components

Conclusion

Colostrum is the first fluid secreted from the udder gland and plays a crucial role in the survival and early performance of dairy cattle, particularly in tropical and subtropical regions. Colostrum contains bioactive compounds, including immunoglobulins (IgG and IgF), protein, fat, vitamins, and minerals, which act as a source of passive immunity, provide initial nutrients, and stimulate the development of the digestive system and metabolism in neonates. Studies have shown that the quality and composition of colostrum vary across dairy cattle species (cows, goats, sheep, and buffaloes) due to environmental factors, management, the physiological status of the mother, parity, and udder health. In tropical regions, major challenges include heat stress, fluctuating feed quality, and a higher risk of disease, potentially reducing immunoglobulin concentrations and the efficiency of passive immune transfer. Conversely, in subtropical regions, more controlled management practices generally result in colostrum of more consistent quality, although this is still influenced by the mother's genetic and physiological factors. The success of passive immune transfer in both tropical and subtropical regions is highly dependent on colostrum quality. Therefore, to ensure consistent and consistent improvement, careful attention must be paid to milking timing, storage, feeding amount, and consumption. Therefore, implementing colostrum management strategies that adapt to tropical and subtropical climates is essential to improve the health, vitality, and productivity of dairy herds in the future.

References

1. Abd El-Fattah AM, Abd Rabo FH, EL-Dieb SM, *et al.* Changes in composition of colostrum of Egyptian buffaloes and Holstein cows. *BMC Veterinary Research*,2012;8:19. <https://doi.org/10.1186/1746-6148-8-19>
2. Avendaño-Reyes L, Macías-Cruz U, Sánchez-Castro MA, Anzures-Olvera F, Vicente-Pérez R, Mellado M, *et al.* Effects of parity, seasonal heat stress, and colostrum collection time postpartum on colostrum quality of Holstein cattle in an arid region. *International Journal of Biometeorology*,2024;68(3):427–434. <https://doi.org/10.1007/s00484-023-02601-5>
3. Becker CA, Aghalari A, Marufuzzaman M, Stone AE. Predicting Dairy Cattle Heat Stress Using Machine Learning Techniques. *Journal of Dairy Science*,2021;104:501–524.
4. Behan AA, Ahmed S, Hassan MF, Buzdar JA, Shah QA, Khan KA, *et al.* Nutritional and health beneficial applications of lactoferrin in some animal species: An updated review. *Proceedings of the Indian National Science Academy*, 2024, 1–13.
5. Chen L, Thorup VM, Kudahl AB, Østergaard S. Effects of Heat Stress on Feed Intake, Milk Yield, Milk Composition, and Feed Efficiency in Dairy Cows: A Meta-Analysis. *Journal of Dairy Science*,2024;107:3207–3218.
6. Conneely M, Berry DP, Sayers R, Murphy JP, Lorenz I, Doherty ML, *et al.* Factors associated with the concentration of immunoglobulin G in the colostrum of dairy cows. *Animal*,2013;7(11):1824–1832. <https://doi.org/10.1017/S1751731113001444>
7. Correddu F, Cesarani A, Gaspa G, Carta S, Fois G, Peana I, *et al.* Effect of heat stress on milk production traits and milk coagulation properties in dairy sheep. *Journal of Dairy Science*, 2025.
8. Dado-Senn B, Skibiél AL, Fabris TF, Dahl GE, Laporta J. Dry period heat stress induces microstructural changes in the lactating mammary gland. *PLOS One*,2019;14(9):0222120. <https://doi.org/10.1371/journal.pone.0222120>
9. Danso F, Iddrisu L, Lungu SE, Zhou G, Ju X. Effects of Heat Stress on Goat Production and Mitigating Strategies: A Review. *Animals*,2024;14(12):1793. <https://doi.org/10.3390/ani14121793>
10. Davies R, Renaud D, Macrae A. Impact of passive immunity and quality of transition milk on preweaning dairy and dairy-beef cross calf health in a pasture-based block calving system: A cohort study. *Journal of Dairy Science*, 2025. <https://doi.org/10.3168/jds.2025-26809>
11. Denholm K, Hunnam J, Cuttance E, McDougall S. Associations between management practices and colostrum quality on New Zealand dairy farms. *New Zealand Veterinary Journal*,2017;65:257–263.
12. Fischer-Tlustos AJ, Cartwright SL, Hare KS, Innes DJ, Cant JP, Tortadès M, *et al.* Insulin, IGF-I, and lactoferrin concentrations and yields and their associations with other components within colostrum, transition, and whole milk of primiparous and multiparous Holstein cattle. *JDS Communications*,2025;6(1):137–142.
13. Galik R, Luttmerding G, Bod'ó Š, Knížková I, Kunc P. Impact of Heat Stress on Selected Parameters of Robotic Milking. *Animals*,2021;11:3114.
14. Georgiades P, Economou T, Proestos Y, Araya J, Lelieveld J, Neira M. Global Projections of Heat Stress at High Temporal Resolution Using Machine Learning. *Earth System Science Data*,2025;17:1153–1171.
15. Godden S. Colostrum management for dairy calves. *Veterinary Clinics of North America Food Animal Practice*,2008;24(1):19–39.
16. Goetz HM, Steele MA, Nott K, McCarthy HR, Lopez AJ, Cantor MC, *et al.* Evaluating the changes in immunoglobulin G and accuracy of assessing transfer of passive immunity during the first 7 days of age in Holstein dairy calves fed colostrum replacer. *Journal of*

- Dairy Science,2025:108(6):6340–6348.
<https://doi.org/10.3168/jds.2024-25854>
17. Gross JJ, Bruckmaier RM. Metabolic challenges in lactating dairy cows and their assessment via established and novel indicators in milk. *Animals*,2019;13(1):75–81.
 18. Hurley WL, Theil PK. Perspectives on immunoglobulins in colostrum and milk. *Nutrients*,2011;3(4):442–474.
<https://doi.org/10.3390/nu3040442>
 19. Kazimierska K, Kalinowska-Lis U. Milk proteins—Their biological activities and use in cosmetics and dermatology. *Molecules*,2021;26(11):3253.
 20. Kessler EC, Bruckmaier RM, Gross JJ. Immunoglobulin G content and colostrum composition of different goat and sheep breeds in Switzerland and Germany. *Journal of Dairy Science*,2019;102(6):5542–5549. <https://doi.org/10.3168/jds.2018-16235>
 21. Lashkari S, Charoy L, Pons L, Jensen SK. Transition of milk fatty acid profile and vitamins A and E from colostrum to mature milk in Danish Holstein cows. *PLOS One*,2025;20(8):0328897.
<https://doi.org/10.1371/journal.pone.0328897>
 22. Lotito D, Pacifico E, Matuozzo S, Musco N, Iommelli P, Zicarelli F, *et al.* Colostrum Composition, Characteristics and Management for Buffalo Calves: A Review. *Veterinary Sciences*,2023;10(5):358.
<https://doi.org/10.3390/vetsci10050358>
 23. Martini M, Licitra R, Altomonti I, Salari F. Quality of donkey mammary secretion during the first ten days of lactation. *International Dairy Journal*,2020;109:104781.
 24. McGuirk SM. Disease management of dairy calves and heifers. *Veterinary Clinics of North America Food Animal Practice*,2011;27(2):357–372.
 25. Michael P, de Cruz CR, Mohd Nor N, Jamli S, Goh YM. The Potential of Using Temperate–Tropical Crossbreds and Agricultural by-Products, Associated with Heat Stress Management for Dairy Production in the Tropics: A Review. *Animals*,2022;12:1.
<https://doi.org/10.3390/ani12010001>
 26. Mitman SL, Jenkins H, Chamorro MF, Mzyk DA, Foster DM, Gamsjäger L. Impact of 3 colostrum replacement strategies on immunoglobulin G absorption efficiency, passive immunity, health, and growth in beef calves. *Journal of the American Veterinary Medical Association*, 2025, 263(11).
<https://doi.org/10.2460/javma.25.03.0139>
 27. Ferro MM, Tedeschi LO, Atzori AS. The comparison of the lactation and milk yield and composition of selected breeds of sheep and goats. *Translational Animal Science*,2017;1(4):498–506.
<https://doi.org/10.2527/tas2017.0056>
 28. Morin DE, Nelson SV, Reid ED, Nagy DW, Dahl GE, Constable PD. Effect of colostrum volume, interval between calving and first milking, and photoperiod on colostrum IgG concentrations in dairy cows. *Journal of the American Veterinary Medical Association*,2010;237(4):420–428.
<https://doi.org/10.2460/javma.237.4.420>
 29. Nayik GA, Jagdale YD, Gaikwad SA, Devkatte AN, Dar AH, Ansari MJ. Nutritional Profile, Processing and Potential Products: A Comparative Review of Goat Milk. *Dairy*,2022;3:622–647.
<https://doi.org/10.3390/dairy3030044>
 30. O'Callaghan TF, O'Donovan M, Murphy JP, Sugrue K, Mannion D, McCarthy WP, *et al.* Evolution of the bovine milk fatty acid profile—From colostrum to milk five days post parturition. *International Dairy Journal*,2020;104:104655.
 31. Okuyucu İC, Erdem H. Effect of Environment- and Animal-Based Factors on the Main Components and Bioactive Substances in Buffalo Colostrum and Calf Serum. *Animal Science Journal*, 2025, 96(1).
<https://doi.org/10.1111/asj.70108>
 32. Playford RJ. The Use of Bovine Colostrum in Medical Practice and Human Health: Current Evidence and Areas Requiring Further Examination. *Nutrients*,2022;14:92.
<https://doi.org/10.3390/nu14010092>
 33. Polidori P, Rapaccetti R, Klimanova Y, Zhang JJ, Santini G, Vincenzetti S. Nutritional Parameters in Colostrum of Different Mammalian Species. *Beverages*,2022;8(3):54.
<https://doi.org/10.3390/beverages8030054>
 34. Rodriguez-Venegas R, Meza-Herrera CA, Robles-Trillo PA, Angel-Garcia O, Legarreta-Gonzalez MA, Sánchez-Vocanegra HF, *et al.* Effect of THI on Milk Production, Percentage of Milking Cows, and Time Lying in Holstein Cows in Northern-Arid Mexico. *Animals*,2023;13:1715.
 35. Saldana DJ, Gelsinger SL, Jones CM, Heinrichs AJ. Effect of different heating times of high-, medium, and low-quality colostrum on immunoglobulin G absorption in dairy calves. *Journal of Dairy Science*,2019;102:2068–2074.
 36. Seyed Almoosavi SMM, Ghoorchi T, Naserian AA, Khanaki H, Drackley JK, Ghaffari MH. Effects of late-gestation heat stress independent of reduced feed intake on colostrum, metabolism at calving, and milk yield in early lactation of dairy cows. *Journal of Dairy Science*,2021;104(2):1744–1758.
<https://doi.org/10.3168/jds.2020-19115>
 37. Silva KN, Martin CC, Camargo L, Daza IM, Defensor ML, Gomes V. Immunological quality of colostrum and specific antibodies against enteropathogens in the colostrum and transition milk of crossbred Gir× Holstein cows. *Journal of Animal Science*,2024;102:342.
 38. Smolińska K, Szopa A, Sobczyński J, Serefko A, Dobrowolski P. Nutritional Quality Implications: Exploring the Impact of a Fatty Acid-Rich Diet on Central Nervous System Development. *Nutrients*,2024;16(7):1093.
<https://doi.org/10.3390/nu16071093>
 39. Todaro M, Scatassa ML, Gannuscio R, Vazzana I, Mancuso I, Maniaci G, *et al.* Effect of lambing season on ewe's colostrum composition. *Italian Journal of Animal Science*,2023;22(1):14–23.
 40. Wicki M, Fassier T, Huau C, Corbière F, Rupp R. Genetic and environmental determinants of Immunoglobulin G in kid serum and adult colostrum of dairy goats. *Journal of Dairy Science*, 2024.
<https://doi.org/10.3168/jds.2024-25113>
 41. Zamuner F, Carpenter EK, Gebrekidan H, Arcos-Gómez G, Parkinson A, Cameron AWN, *et al.* Successful transfer of passive immunity: the natural alternative to antibiotics for boosting the survival of intensively reared dairy goat kids. *Animals*, 2023.
<https://doi.org/10.1016/j.animal.2023.101040>
 42. Zhou X, Ullah A, Shi L, Dou M, Wang C, Khan MZ, *et al.* Molecular Regulatory Mechanisms of Mammary Gland Development: A Review. *Animals*,2025;15:3480.
<https://doi.org/10.3390/ani15233480>