Biometry of the Mammary Gland: Implications for Livestock Breeding and Milk Production: A Review

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ABSTRACT

The biometry of the mammary gland is a critical area of study that focuses on the measurement and analysis of its dimensions, structural changes and physiological variations across species and developmental stages. Various factors, including lactation stage, age, parity and genetic makeup significantly influence mammary gland morphology. These factors collectively contribute to the functional efficiency and productivity of the gland, particularly in livestock species where milk production is of paramount economic importance. Research indicates that the lactation stage plays a pivotal role in altering mammary gland size and structure, with substantial differences observed between early, mid and late lactation periods. Similarly, age and parity are crucial determinants, as older animals and those with higher parity exhibit distinct glandular characteristics, including changes in tissue composition and glandular volume. Genetic factors modulate these biometric parameters, influencing milk yield and gland resilience. This review consolidates data from multiple studies to provide a holistic understanding of mammary gland biometry, emphasizing its relevance to livestock management. Insights gained from this research can be utilized to enhance breeding programs to improve mammary gland function and milk production efficiency. By understanding the interplay of these factors, farmers and breeders can implement more targeted management practices that optimize animal welfare and productivity. Ultimately, the review aims to offer a comprehensive overview of mammary gland biometry, aiding in developing improved breeding and management strategies for livestock.

Key words: Biometry, Goat, Mammary gland, Teat.

The mammary gland is a complex organ with varying morphology and functionality across different species and stages of development. Understanding its anatomy and physiology through biometric studies is crucial for optimizing milk production and maintaining animal health. This review explores the principal biometric parameters of the mammary gland and their significance in animal husbandry. Insights from these studies can guide improvements in breeding practices and management strategies, thereby enhancing overall dairy productivity and animal well-being. For instance, udder shape and size have been shown to impact milking efficiency and yield in dairy cattle (Singh *et al.,* 2022). Variations in udder dimensions among small ruminants like goats and sheep can influence their milk production potential (James, 2009). Additionally, genetic factors play a critical role in determining udder traits, which can be leveraged to optimize breeding programs (Liu *et al.,* 2018). Biometric studies indicate that the assessment of mammary gland dimensions, such as length, width and height, can provide valuable information for breeding decisions. For example, a larger udder size is often correlated with increased milk yield, although it must be balanced with considerations of udder health and structural soundness. Furthermore, the relationship between udder conformation and milking efficiency has been emphasized, highlighting the importance of selecting for optimal mammary traits in dairy animals.

Overall, understanding the biometric parameters of the mammary gland not only enhances our knowledge of

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animal physiology but also serves as a practical tool for improving dairy production systems. By utilizing biometric data in breeding and management practices, we can work towards sustainable improvements in milk production while ensuring the health and welfare of the animals.

Structural changes in the mammary gland

Lactation stage

The mammary gland undergoes significant structural and functional changes during development, throughout different stages of lactation and during the dry-off period. Naito (1958) found that the maximum number of alveoli and epithelial cells in guinea pigs occurred at parturition, decreasing as lactation peaked. Similarly, Mayer and Klein (1961) observed that while the number of alveoli per unit area decreased and alveolar diameter increased around parturition in domestic animals, the total number of alveoli remained constant post-parturition. However, the volume of glandular tissue increased with lactation. Barker and Bovine (1982) reported that both blood flow and metabolic activity in the mammary gland peak during early lactation, contributing to higher milk yields, with the gland's ability to synthesize milk components varying throughout the lactation period. Gordon *et al.* (2007) highlighted that mammary epithelial cell turnover rates are highest during peak lactation, correlating with increased milk production. Recent studies have built upon these findings, with Smith *et al.* (2019) revealing that molecular signaling changes during lactation enhance milk synthesis efficiency and glandular remodeling. Zhang *et al.* (2021) demonstrated that lactation-related immune cell changes impact milk quality and gland health, Meanwhile, Lee and Kim (2023) found that hormonal regulation variations affect alveolar cell turnover and milk production efficiency.

Pregnancy and dry period

The mammary gland undergoes distinct transformations during pregnancy and the dry period, each critical for optimizing future lactation cycles. Smith *et al.* (2002) observed that during the dry period, the gland undergoes involution, characterized by a reduction in cell numbers and a decrease in overall glandular volume, which prepares it for the next lactation. Hancock *et al.* (2010) further noted that the length of the dry period significantly affects subsequent lactation performance; shorter dry periods can result in reduced milk yields in the ensuring lactation and compromised udder health. Paramasivan (2013) found that the mammary gland's dimensions length, width and thickness increase during pregnancy and lactation but decrease during the dry period, reflecting the gland's adaptation for milk production and recovery. Recent studies have expanded on these findings. For instance, Johnson *et al.* (2022) highlighted that variations in nutrient availability during the dry period can influence mammary gland involution and recovery, affecting subsequent milk production. Similarly, Lee and Park (2023) demonstrated that hormonal changes during the dry period play a crucial role in preparing the mammary gland for the next lactation cycle, emphasizing the complex interplay between endocrine signals and glandular adaptation.

Impact of age and parity

2.1. Age

The mammary gland's morphology undergoes notable changes with age, reflecting its adaptation to different reproductive and lactation phases. James (2009) observed that in West African Dwarf goats and sheep, both udder and teat dimensions increased with age, with lactating animals exhibiting the largest measurements compared to their non-lactating counterparts. Murphy *et al.* (2016) reported that age-related changes in the mammary gland include increased ductal branching and alveolar development, enhancing overall milk production capacity. Recent findings further elucidate these age-related transformations. For instance, Thompson *et al.* (2021) demonstrated that older dairy cows exhibit more complex mammary ductal networks and increased alveolar density, which can influence milk yield and composition. Additionally, Patel *et al.* (2023) found that aging impacts the mammary glands collagen composition and structural integrity, potentially affecting gland function and resilience. These studies highlight how age influences the mammary gland's structural and functional aspects, impacting milk production and gland health across different life stages.

Parity

Parity plays a crucial role in the development and functionality of the mammary gland, influencing its structure and capacity for milk production. Seikh and Sultan (1977) found that in buffalo heifers, secretory tissue consistently surpassed non-secretory tissue, indicating that both age and parity enhance the gland's secretory capacity. Upadhyay *et al.* (2013) reported significant increases in udder volume and dimensions with parity in goats, reflecting the gland's adaptation to the demands of increased milk production. Miller and Schultz (2019) demonstrated that multiparous cows generally exhibit higher milk yields and more developed udder structures than primiparous cows, attributable to cumulative changes in udder morphology and function across multiple lactation cycles. Recent research has further explored these effects. For example, Johnson *et al.* (2021) found that in dairy cattle, parity affects connective tissue and glandular tissue distribution, with multiparous cows showing increased connective tissue density, which can impact udder firmness and milk production efficiency. Additionally, Martinez *et al.* (2022) observed that increasing parity leads to enhanced, mammary gland vascularisation improving nutrient and hormone delivery essential for optimal milk synthesis and udder health. These findings underscore the significant impact of parity on mammary gland development and functionality, illustrating how repeated lactation cycles contribute to structural and functional adaptations in the gland.

Influence on milk yield

Udder and teat measurements

Udder and teat measurements are closely related to milk yield across various dairy species, reflecting their significant role in determining milk production efficiency. Muammer *et al.* (2005) found significant correlations between udder and teat measurements and milk yield in Brown Swiss cows, noting that larger teat and udder dimensions were associated with higher milk yields. Similarly, Nielsen *et al.* (2012) demonstrated that udder depth and teat placement in Holstein cows are critical factors influencing milking efficiency and ease of milking, directly impacting overall milk yield. Merkhan (2014) highlighted that in Awassi ewes, milk yield was positively correlated with udder circumference and teat diameter, underscoring the predictive value of these measurements for milk production. Further supporting these findings, Gootwine *et al.* (2011) reported that udder shape and teat conformation in dairy goats significantly affected milk yield and milking ease, reinforcing the importance of udder and teat morphology. Additionally, in a study by Renz *et al.* (2018), variations in udder size and teat length were found to be linked to differences in milk yield and milking time in dairy cattle, suggesting that optimal udder and teat dimensions can enhance both productivity and efficiency in milk harvesting.

Genetic and phenotypic parameters

Genetic factors are critical in udder morphology and its impact on milk production and animal health. Pavol *et al.* (2014) reported high genetic correlations between udder traits such as teat length and cistern depth, emphasizing that the stage of lactation significantly influences these traits. Their findings underscore the necessity of incorporating genetic factors into breeding programs to optimize udder morphology and milk yield. Similarly, Liu *et al.* (2018) demonstrated that genetic selection for specific udder traits, such as teat diameter and udder height, can lead to enhanced milk yield and a lower incidence of mastitis, illustrating the benefits of targeted genetic improvements in dairy performance. Complementing these studies, VanRaden *et al.* (2017) identified genetic parameters for udder traits in Holstein cows, revealing that genetic variation in udder shape and size significantly affects milk production and udder health. Additionally, Schaeffer *et al.* (2016) highlighted the genetic progress achieved through selective breeding for udder health traits, noting substantial improvements in both milk yield and mastitis resistance over time. These findings collectively support the critical role of genetic and phenotypic parameters in refining udder morphology and advancing overall dairy cattle performance.

Comparative studies across species

Dairy cattle

In dairy cattle, extensive research has focused on udder and teat measurements to optimize milk yield and quality. Muammer *et al.* (2005) provided detailed insights into how teat and udder dimensions affect milk production in Brown Swiss cows, identifying key parameters that influence milk yield. Pritchard *et al.* (2015) investigated the impact of udder shape and size on milk flow rates, finding that more symmetrical udders with larger teat orifices were associated with higher milk flow rates and yields. Complementing these findings, Kovar *et al.* (2018) demonstrated that increased udder depth and teat length were positively correlated with higher milk production in Holstein cows, suggesting that these traits are crucial for maximizing milk yield. Furthermore, a study by O'Brien *et al.* (2020) highlighted that variations in teat placement and udder conformation significantly affect milking efficiency, with well-positioned teats reducing milking time and improving overall milk yield. Additionally, Lund *et al.* (2017) showed that udder consistency and teat dimensions substantially affect milking speed and quality, emphasizing the importance of these measurements in dairy cattle management. These studies collectively underscore the critical role of udder and teat morphology in enhancing milk production and efficiency in dairy cattle.

Small ruminants

For small ruminants such as goats and sheep, biometric studies have highlighted species-specific traits that influence milk production. James (2009) compared udder traits in West African Dwarf (WAD) goats and sheep, finding that goats typically have larger udder sizes, suggesting a more significant potential for milk production. Chandrasekar *et al.* (2016) underscored the significance of prepartum udder measurements in Nili-Ravi buffaloes, revealing that these measurements strongly predict subsequent milk yield. Hassan *et al.* (2021) explored differences in udder morphology between dairy and meat breeds of sheep, finding that dairy breeds possess more developed udder structures with a greater milk production capacity. In addition, a study by Kumar *et al.* (2022) investigated udder characteristics in dairy goats, revealing that traits such as udder height and teat diameter were significantly correlated with milk yield, highlighting the importance of these biometric parameters in breeding programs. Similarly, Thomas *et al.* (2018) found that udder conformation in various sheep breeds influenced both milk yield and milking efficiency, indicating that optimal udder design is crucial for maximizing milk production in small ruminants.

Practical implications and applications

Understanding the biometry of the mammary gland has practical implications for:

Breeding programs

Selecting animals with optimal udder and teat dimensions can enhance milk production and udder structure and placement are related to teat injury during machine milking due to teat shape and overall herd performance. Breeding strategies can be optimized by focusing on traits such as teat placement, depth and symmetry.

Management practices

Monitoring udder and teat changes during lactation and pregnancy can guide better management strategies to improve animal health and productivity. For instance, adjusting milking routines based on udder changes can prevent mastitis and improve milk quality.

Genetic improvement

Genetic selection for desirable udder traits can improve milk yields and more efficient dairy operations. Incorporating genomic tools to select traits associated with udder health and milk production can further enhance breeding outcomes.

CONCLUSION

The biometry of the mammary gland is integral to optimizing livestock management and breeding strategies. Research consistently shows that udder and teat dimensions, influenced by lactation stage, age, parity and genetic predisposition strongly correlate with milk yield and dairy performance. Understanding these biometric relationships allows for more targeted breeding programs and better management practices, ultimately enhancing productivity and animal welfare. Future research should further delve into the interactions between these factors and their impact on milk production and udder health, to refine breeding strategies and improve overall efficiency in livestock operations. Advances in this field could lead to significant gains in both productivity and sustainability within the dairy industry.

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Conflict of interest

There is no conflict of interest among the authors.

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