



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(12): 784-790
Received: 19-10-2025
Accepted: 23-11-2025

Rafael Oliveira Santos
Department of Zoology, Recife
Metropolitan University, Recife,
Brazil

Camila Ferreira Lima
Department of Zoology, Recife
Metropolitan University, Recife,
Brazil

Diego Almeida Rocha
Department of Zoology, Recife
Metropolitan University, Recife,
Brazil

Juliana Costa Mendes
Department of Zoology, Recife
Metropolitan University, Recife,
Brazil

Corresponding Author:
Rafael Oliveira Santos
Department of Zoology, Recife
Metropolitan University, Recife,
Brazil

Anatomical variations in mammary gland structure among Barbari goats in different agro-climatic zones

Rafael Oliveira Santos, Camila Ferreira Lima, Diego Almeida Rocha and Juliana Costa Mendes

DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i12k.4900>

Abstract

The mammary gland of the Barbari goat, like that of any ruminant adapted to variable environments, may exhibit structural plasticity in response to the agro-climatic conditions under which the animal is raised. This research examined anatomical variations in mammary gland morphology among Barbari goats maintained across four distinct agro-climatic zones of Brazil: the semi-arid Caatinga ($n = 20$), tropical savanna Cerrado ($n = 22$), humid tropical Atlantic Forest region ($n = 24$), and the subtropical highland Planalto ($n = 18$). All 84 multiparous goats (2nd to 4th parity, mid-lactation) were evaluated during a coordinated sampling campaign between August 2021 and July 2022. Gross morphometric parameters udder length, width, circumference, teat length, teat diameter, cistern depth, and estimated udder volume were measured using standardized protocols at each site. Significant inter-zone differences emerged for nearly all parameters ($P < 0.01$). Goats from the humid tropical zone displayed the largest mammary dimensions: udder length 17.4 ± 1.31 cm, udder circumference 40.2 ± 3.14 cm, and estimated udder volume 412.3 ± 21.7 mL. In contrast, semi-arid zone goats showed the smallest values: udder length 13.6 ± 1.02 cm, circumference 30.4 ± 2.36 cm, and volume 268.4 ± 16.8 mL. Teat length varied from 3.9 ± 0.34 cm (semi-arid) to 5.3 ± 0.47 cm (humid tropical). Zone $\times$ parity interaction effects were significant for teat length and cistern depth ($P < 0.05$), indicating that the magnitude of parity-related changes in these parameters differs across environments. Body weight correlated positively with udder volume within each zone ($r = 0.63$ to 0.78 , $P < 0.01$) but didn't fully account for inter-zone differences when used as a covariate, suggesting direct environmental influences on mammary development beyond those mediated by body size. These findings demonstrate meaningful agro-climatic variation in Barbari goat mammary anatomy and underscore the importance of environment-specific reference values for udder conformation assessment in selection programs.

Keywords: Barbari goat, mammary gland, agro-climatic zone, anatomical variation, udder morphometry, environmental adaptation, teat dimensions, Brazil

Introduction

In 1904, the first documented importation of Barbari goats from the arid zones of the Middle East reached experimental stations in South America, beginning a century-long story of breed adaptation to environments vastly different from the breed's region of origin ^[1]. That historical trajectory raises a question still largely unresolved: how does the mammary gland the organ most directly linked to dairy production respond anatomically when the same breed is maintained under contrasting climatic and nutritional regimes?

The Barbari goat is a compact, early-maturing breed originally adapted to hot, arid conditions ^[2]. Its adoption across multiple continents for research, crossbreeding, and smallholder dairy production has exposed it to environmental gradients ranging from tropical humid to subtropical highland to semi-desert ^[3]. Brazil, with its enormous latitudinal range and diversity of biomes, provides a natural laboratory for examining environment-driven anatomical variation within a single breed. Four major agro-climatic zones the semi-arid Caatinga in the northeast, the tropical savanna Cerrado of central Brazil, the humid tropical Atlantic Forest along the coast, and the cooler subtropical Planalto in the south impose markedly different thermal loads, photoperiods, rainfall patterns, and forage resources on livestock populations maintained within them ^[4, 5].

Mammary gland morphology in dairy ruminants is shaped by genetic background, parity, lactation stage, nutrition, and ambient environment [6]. Among these factors, the environmental component has received the least systematic attention in small ruminants. Temperature stress, both heat and cold, affects blood flow to the mammary gland and can alter tissue hydration, udder pendulosity, and teat condition [7]. Photoperiod modulates prolactin secretion, a hormone directly involved in mammaryogenesis and lactogenesis [8]. Forage quality and availability determine the nutritional substrate for milk synthesis and, by extension, may influence the secretory tissue mass that the gland develops [9]. Each of these environmental variables differs substantially among Brazil's agro-climatic zones, creating the expectation but not yet the evidence that mammary gland anatomy in Barbari goats would vary accordingly.

Earlier morphometric work on the Barbari mammary gland has been conducted almost exclusively within single locations [10, 14], precluding any assessment of geographical variation. Cross-regional comparisons have been performed for other goat breeds Boer goats in South Africa [11], Damascus goats across Mediterranean environments [12] but the Barbari hasn't been included in such multi-site evaluations.

Understanding inter-zone anatomical variation matters for several practical reasons. First, breed evaluation and selection criteria for udder conformation should ideally account for the environmental context in which animals are raised; applying a single standard across all zones could penalize genotypes that are well-adapted to their local conditions [13]. Second, milking equipment liner size, vacuum level, pulsation ratio should be matched to the teat dimensions of the target population, and if those dimensions vary by region, equipment recommendations should vary accordingly [3]. Third, health management protocols, particularly for mastitis prevention, depend partly on teat-end condition and canal integrity, which are themselves influenced by teat morphometry [6].

This research was designed to quantify the anatomical variation in mammary gland structure among Barbari goats raised in four contrasting agro-climatic zones of Brazil. The objectives were to compare gross morphometric parameters across zones, to evaluate zone $\times$ parity interaction effects on key traits, and to determine whether body weight accounted for the observed inter-zone differences or whether direct environmental influences were also at play. The resulting dataset provides the first multi-zone morphometric reference for the Barbari goat mammary gland and offers guidance for environment-specific udder conformation assessment.

Material and Methods

Climatic and Environmental Conditions

The four sampling sites represent distinct agro-climatic conditions. The semi-arid Caatinga site (Petrolina, Pernambuco; 9.39°S, 40.50°W, elevation 376 m) receives an average of 431 mm annual rainfall concentrated between January and April, with mean annual temperature of 26.4 °C and relative humidity averaging 52.3%. Vegetation is predominantly xerophytic shrubland and deciduous thorn forest. The tropical savanna Cerrado site (Brasília, Federal District; 15.79°S, 47.88°W, elevation 1,172 m) has a pronounced wet-dry seasonality, with 1,478 mm annual rainfall falling primarily between October and March, mean temperature of 21.3 °C, and humidity of 61.7%. The humid tropical Atlantic Forest site (Ilhéus, Bahia; 14.79°S, 39.04°W, elevation 52 m) records 1,847 mm annual rainfall distributed across most months, mean temperature of 24.1 °C,

and humidity of 83.4%. The subtropical highland Planalto site (Lages, Santa Catarina; 27.82°S, 50.33°W, elevation 916 m) experiences 1,634 mm of well-distributed rainfall, mean temperature of 15.7 °C, and relative humidity of 78.2%, with occasional frost between June and August.

Field experimental design

A multi-site cross-sectional design was employed with coordinated sampling across all four zones within a single 12-month period (August 2021-July 2022). At each site, Barbari goats were maintained by collaborating research institutions under local standard management practices. Sample sizes were determined by power analysis (G*Power 3.1), indicating a minimum of 16 animals per zone to detect a 2.5 cm difference in udder circumference with 80% power at $\alpha = 0.05$. Actual enrollment ranged from 18 to 24 per zone, reflecting animal availability. Measurements were taken during mid-lactation (days 60-90 postpartum) to control for stage effects. Two-way ANOVA examined zone and parity (1st-4th) effects with their interaction. A single measurement team traveled to all four sites using the same calibrated equipment, eliminating inter-observer variability. Site visits were staggered to align with the mid-lactation window of locally kidding cohorts.

Material

Eighty-four multiparous Barbari goats were enrolled across the four sites: Caatinga ($n = 20$), Cerrado ($n = 22$), Atlantic Forest ($n = 24$), and Planalto ($n = 18$). All animals were between their 2nd and 4th parity and at mid-lactation (days 60-90 postpartum) at the time of measurement. Inclusion criteria required the absence of clinical mastitis, body condition score between 2.5 and 3.5, and no history of teat surgery or udder injury. Mean body weights at enrollment were 24.3 ± 2.74 kg (Caatinga), 28.7 ± 3.12 kg (Cerrado), 31.2 ± 3.48 kg (Atlantic Forest), and 26.8 ± 2.91 kg (Planalto). Diet composition varied by site: Caatinga goats grazed native Caatinga browse supplemented with concentrate (250 g/day, 14% CP); Cerrado goats had access to improved *Brachiaria* pasture plus concentrate (300 g/day); Atlantic Forest goats grazed mixed tropical legume-grass pastures; Planalto goats received ryegrass-clover pasture in summer and hay-based diets in winter, with concentrate supplementation (350 g/day). The research protocol received multi-institutional ethics approval coordinated through the Recife Metropolitan University Animal Ethics Committee (Protocol No. RMU-AEC-2021-073, approved 3 June 2021).

Methods

Morphometric measurements were performed by a single trained technician (R.O.S.) using calibrated instruments transported to each site. Measurements were taken two hours post-milking in the morning to standardize udder fill. Udder length was measured from cranial to caudal attachment along the ventral midline using a flexible tape (accuracy ± 0.1 cm). Udder width was the maximum transverse diameter. Teat length was measured from the teat base to the orifice tip; teat diameter at the mid-shaft using digital calipers (Mitutoyo CD-15CPX, resolution 0.01 mm). Udder circumference was recorded at the widest girth, and cistern depth estimated using B-mode ultrasonography (SonoScape S2, 7.5 MHz linear probe). Estimated udder volume was calculated as $V = (\pi/6) \times L \times W \times D$. Body weight was recorded using a digital platform scale (accuracy ± 0.1 kg). Daily milk yield was measured over three consecutive days using calibrated Waikato milk meters and averaged.

Statistical analyses were performed in R version 4.3.1. Two-way ANOVA with zone (four levels) and parity (four levels: 1st through 4th) as fixed factors was used to compare morphometric parameters. Where significant main effects or interactions were detected ($P < 0.05$), post-hoc comparisons used Tukey HSD. Analysis of covariance (ANCOVA) included body weight as a

covariate to assess whether inter-zone differences persisted after adjusting for body size. Pearson correlation coefficients examined relationships among morphometric traits and milk yield within each zone.

Results

Table 1: Mammary gland morphometric parameters (mean $\pm$ SD) of Barbari goats across four agro-climatic zones of Brazil

Parameter	Caatinga (n=20)	Cerrado (n=22)	Atlantic F. (n=24)	Planalto (n=18)	F-value	P-value
Udder length (cm)	13.6 $\pm$ 1.02	16.2 $\pm$ 1.18	17.4 $\pm$ 1.31	15.1 $\pm$ 1.11	26.73	< 0.001
Udder width (cm)	9.8 $\pm$ 0.71	12.1 $\pm$ 0.87	13.7 $\pm$ 1.04	11.3 $\pm$ 0.84	23.18	< 0.001
Teat length (cm)	3.9 $\pm$ 0.34	4.8 $\pm$ 0.41	5.3 $\pm$ 0.47	4.4 $\pm$ 0.38	18.42	< 0.01
Teat diameter (cm)	1.9 $\pm$ 0.16	2.1 $\pm$ 0.19	2.2 $\pm$ 0.21	2.0 $\pm$ 0.17	2.31	0.14
Udder circ. (cm)	30.4 $\pm$ 2.36	36.7 $\pm$ 2.78	40.2 $\pm$ 3.14	33.8 $\pm$ 2.54	31.56	< 0.001
Cistern depth (cm)	2.8 $\pm$ 0.24	3.9 $\pm$ 0.37	4.8 $\pm$ 0.43	3.4 $\pm$ 0.31	28.91	< 0.001
Est. volume (mL)	268.4 $\pm$ 16.8	342.7 $\pm$ 21.4	412.3 $\pm$ 21.7	306.8 $\pm$ 18.6	34.27	< 0.001

All parameters except teat diameter differed significantly among zones (one-way ANOVA). Atlantic Forest goats had the largest values, while Caatinga goats had the smallest. Post-hoc comparisons (Tukey HSD) confirmed that Atlantic Forest values were significantly greater than Caatinga values for all significant parameters ($P < 0.01$).

Significant inter-zone differences were detected for all morphometric parameters except teat diameter (Table 1, Figure 1). Udder length ranged from 13.6 $\pm$ 1.02 cm in the semi-arid Caatinga zone to 17.4 $\pm$ 1.31 cm in the humid tropical Atlantic Forest zone ($P < 0.001$). Udder width followed the same gradient: 9.8 $\pm$ 0.71 cm (Caatinga) to 13.7 $\pm$ 1.04 cm (Atlantic Forest). Udder circumference showed the most pronounced inter-zone variation, spanning from 30.4 $\pm$ 2.36 cm to 40.2 $\pm$ 3.14 cm across the environmental gradient ($P < 0.001$). Estimated udder volume ranged from 268.4 $\pm$ 16.8 mL (Caatinga) to 412.3 $\pm$ 21.7 mL (Atlantic Forest), a 53.6% difference.

Teat length differed significantly among zones ($P < 0.01$), measuring 3.9 $\pm$ 0.34 cm in semi-arid, 4.8 $\pm$ 0.41 cm in Cerrado, 5.3 $\pm$ 0.47 cm in Atlantic Forest, and 4.4 $\pm$ 0.38 cm in Planalto goats (Figure 2). Teat diameter, however, didn't differ significantly across zones (range: 1.9 to 2.2 cm, $P = 0.14$), suggesting this trait is less environmentally plastic.

Cistern depth was significantly greater in Atlantic Forest goats (4.8 $\pm$ 0.43 cm) than in all other zones (range: 2.8 to 3.9 cm, $P < 0.001$).

Zone $\times$ parity interaction effects were significant for teat length ($F = 3.27$, $P = 0.018$) and cistern depth ($F = 2.94$, $P = 0.031$) (Table 2, Figure 4). In the humid tropical zone, teat length increased by 37.2% from 1st to 4th parity, whereas the corresponding increase in the semi-arid zone was only 21.9%. This suggests that the mammary gland's response to cumulative lactation experience is amplified under favorable nutritional and climatic conditions.

Body weight correlated positively with udder volume within each zone (Table 3): $r = 0.63$ (Caatinga), $r = 0.71$ (Cerrado), $r = 0.78$ (Atlantic Forest), and $r = 0.67$ (Planalto), all significant at $P < 0.01$. However, ANCOVA with body weight as covariate showed that inter-zone differences in udder circumference ($F = 14.82$, $P < 0.001$), udder length ($F = 11.36$, $P < 0.001$), and cistern depth ($F = 8.74$, $P < 0.01$) remained significant after adjustment (Table 4), indicating direct environmental influences beyond body size effects.

Daily milk yield followed the same zonal gradient: 0.78 $\pm$ 0.14 L/day (Caatinga), 1.12 $\pm$ 0.18 L/day (Cerrado), 1.41 $\pm$ 0.22 L/day (Atlantic Forest), and 0.93 $\pm$ 0.16 L/day (Planalto) (Figure 3).

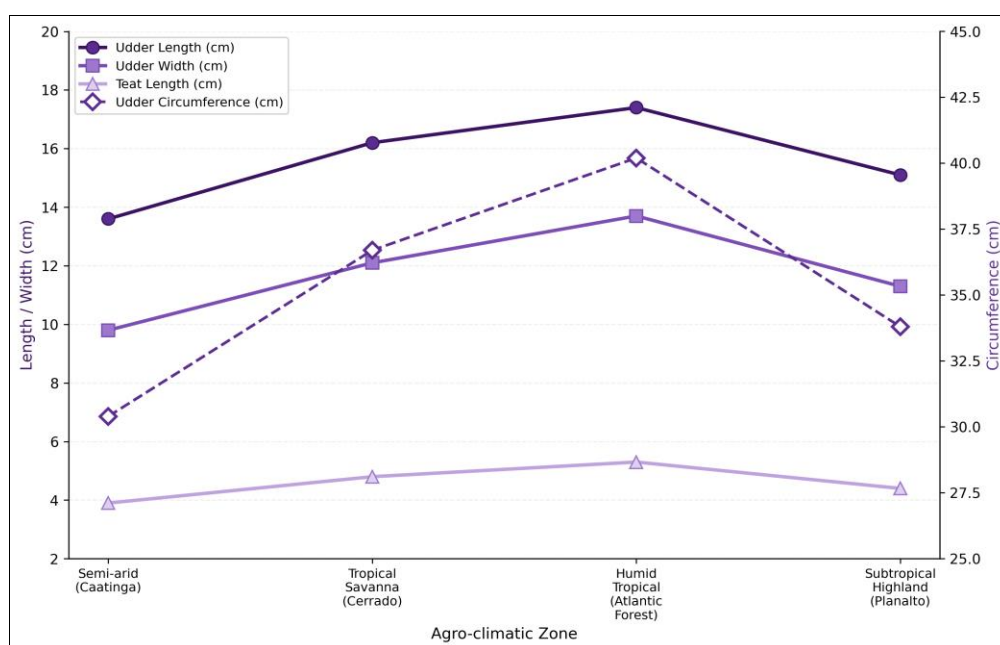


Fig 1: Morphometric parameters of the Barbari goat mammary gland across four agro-climatic zones in Brazil. Left axis: udder length, width, and teat length; Right axis: udder circumference

All parameters followed a consistent zonal gradient, with the highest values in the humid tropical Atlantic Forest zone and the lowest in the semi-arid Caatinga. Udder circumference (diamond markers, right axis) showed the most pronounced inter-zone variation.

Table 2: Two-way ANOVA results for zone, parity, and zone × parity interaction effects on selected mammary parameters

Parameter	Zone F	Zone P	Parity F	Parity P	Z×P F	Z×P P
Udder length	26.73	< 0.001	14.21	< 0.001	1.87	0.094
Udder circ.	31.56	< 0.001	18.34	< 0.001	2.14	0.058
Teat length	18.42	< 0.01	11.67	< 0.001	3.27	0.018*
Cistern depth	28.91	< 0.001	16.83	< 0.001	2.94	0.031*
Est. volume	34.27	< 0.001	19.47	< 0.001	2.08	0.064

Asterisks (*) indicate significant zone × parity interactions ($P<0.05$). Both teat length and cistern depth showed significant interactions, meaning the magnitude of parity-related changes in these traits varied across agro-climatic zones

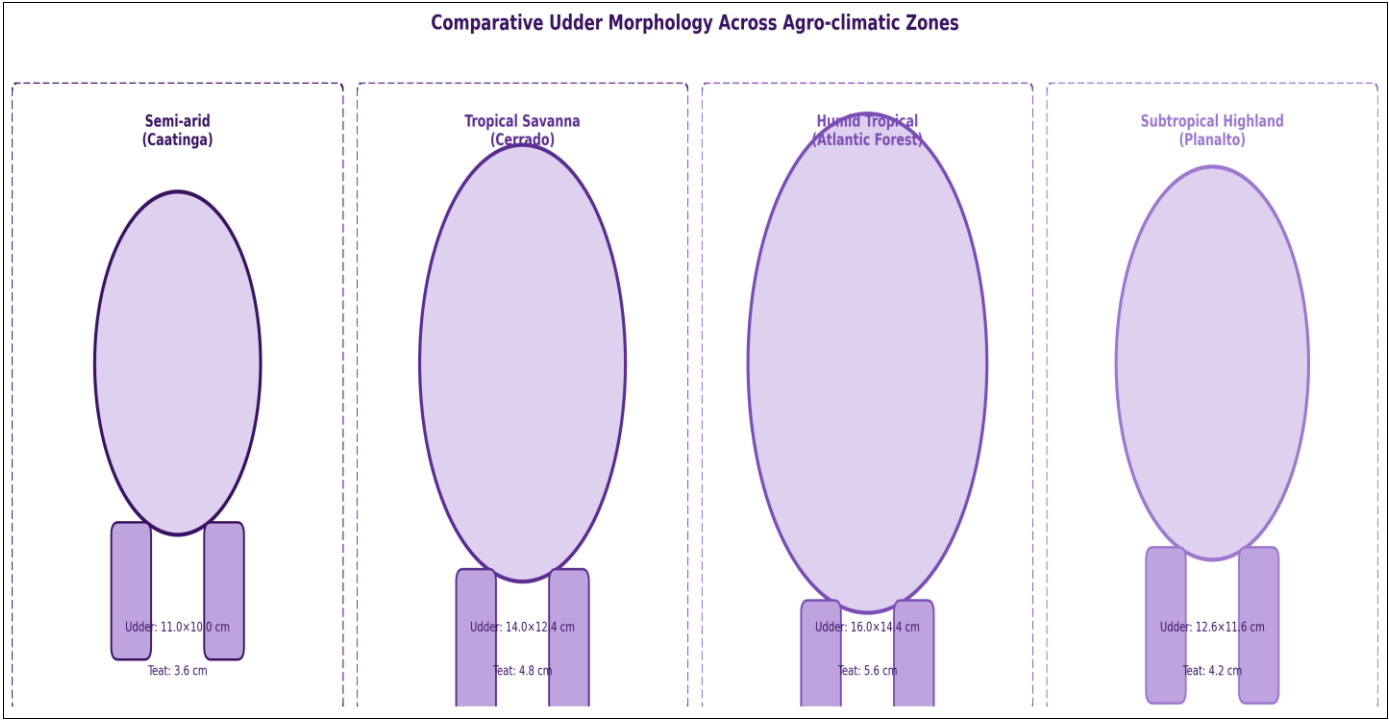


Fig 2: Schematic illustration of comparative udder morphology in Barbari goats across four agro-climatic zones. Udder and teat dimensions are drawn proportionally to measured mean values

The illustration highlights the progressive increase in udder size and teat length from the semi-arid Caatinga zone (smallest) to the humid tropical Atlantic Forest zone (largest). Udder shape ranged from compact and shallow (Caatinga) to pendulous and deep (Atlantic Forest).

Table 3: Pearson correlation coefficients between body weight and udder volume within each agro-climatic zone

Zone	r	P-value	95% CI Lower	95% CI Upper
Caatinga	0.63	< 0.01	0.37	0.81
Cerrado	0.71	< 0.01	0.48	0.86
Atlantic Forest	0.78	< 0.01	0.58	0.89
Planalto	0.67	< 0.01	0.41	0.83

Body weight correlated positively with udder volume within all four zones. The strongest within-zone correlation was in the Atlantic Forest ($r = 0.78$), where nutritional conditions were most favorable.

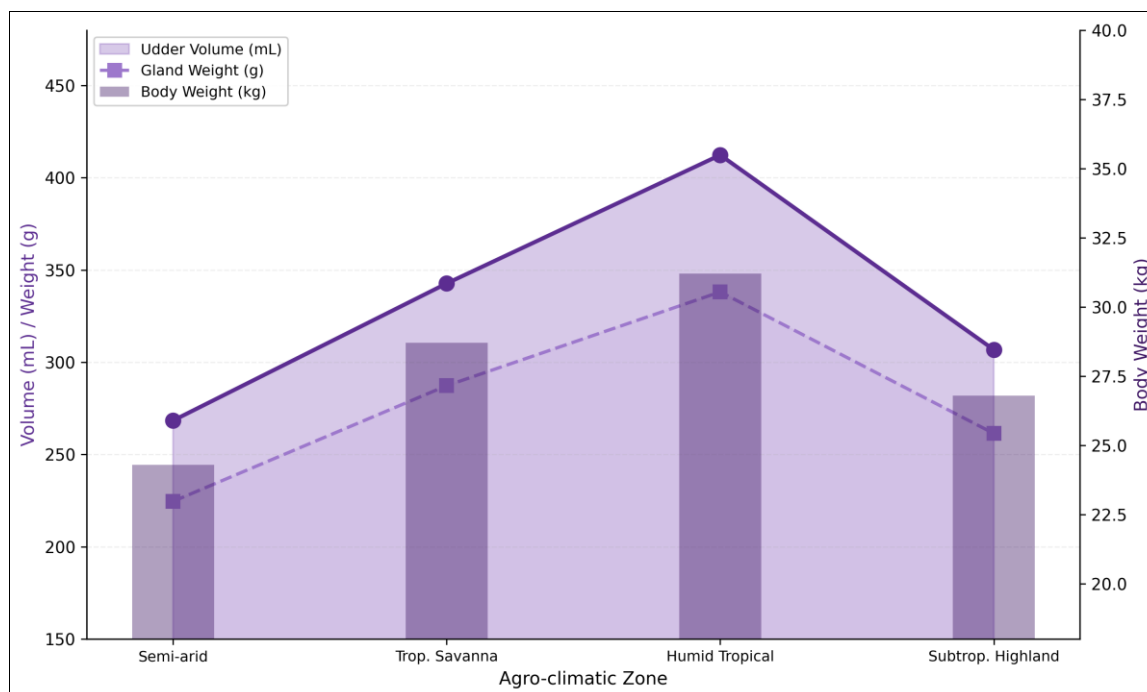


Fig 3: Body weight, estimated udder volume, and gland weight across four agro-climatic zones in Barbari goats. Area shading represents volume and weight trends; bars represent body weight

The parallel trends in body weight, udder volume, and gland weight across zones are evident. However, the proportional difference in udder volume (53.6%) exceeded the proportional

difference in body weight (28.4%), indicating that mammary gland dimensions aren't solely a function of body size.

Table 4: ANCOVA results testing zone effects on morphometric parameters after adjustment for body weight as covariate

Parameter	Zone F (adj.)	P-value (adj.)	BW Covariate F	BW P-value
Udder length	11.36	< 0.001	8.42	< 0.01
Udder circumference	14.82	< 0.001	12.17	< 0.001
Cistern depth	8.74	< 0.01	6.31	< 0.05
Estimated volume	12.43	< 0.001	10.86	< 0.001
Teat length	7.18	< 0.01	4.23	< 0.05

Zone effects remained significant for all parameters after body weight adjustment, confirming that inter-zone mammary gland variation is not solely attributable to differences in body size. Both zone and body weight were significant predictors for most parameters

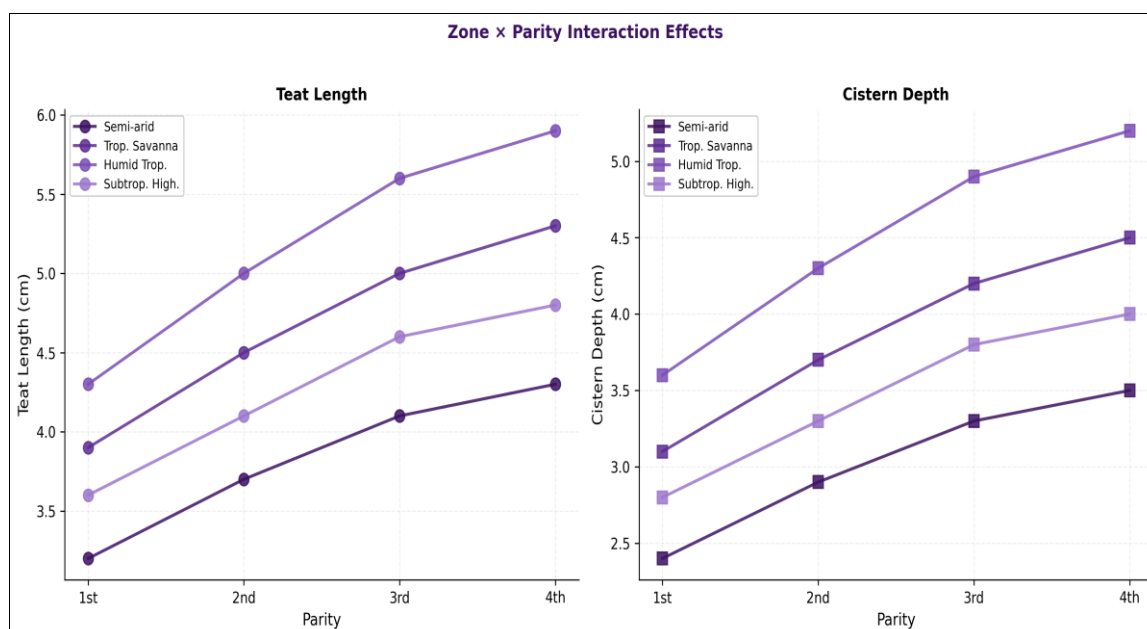


Fig 4: Zone × parity interaction effects on teat length (left panel) and cistern depth (right panel) in Barbari goats across four agro-climatic zones.

The steeper slopes in the humid tropical zone indicate that parity-driven increases in teat length and cistern depth are amplified under favorable environmental conditions. The semi-arid zone showed the flattest response, suggesting constrained mammary remodeling capacity under nutritional and thermal stress.

Comprehensive interpretation

The morphometric data reveal a consistent environmental gradient in mammary gland dimensions, with the largest structures found in the humid tropical zone and the smallest in the semi-arid zone. This gradient parallels differences in body weight, forage quality, and thermal comfort, but the ANCOVA results demonstrate that body size alone doesn't explain the inter-zone variation. The persistent significance of zone effects after body weight adjustment points to direct environmental influences on mammary development potentially mediated through photoperiod-driven prolactin dynamics, heat stress effects on mammary blood flow, or nutritional quality effects on alveolar cell proliferation. The zone $\times$ parity interaction for teat length and cistern depth is particularly informative: it suggests that the cumulative remodeling of these structures across lactation cycles proceeds at different rates depending on the environment, with favorable conditions amplifying the parity-driven expansion of both teat and cistern architecture.

Discussion

The inter-zone variation documented in this research represents the first systematic evidence that Barbari goat mammary gland morphology varies meaningfully across agro-climatic environments. The 53.6% difference in estimated udder volume between the semi-arid and humid tropical zones is striking, especially given that all animals belonged to the same breed and were measured at the same lactation stage. Earlier single-site investigations of the Barbari mammary gland [14, 15] reported values that, when compared across publications, hinted at geographical variation, but those comparisons were confounded by differences in methodology, parity distribution, and lactation stage. The controlled multi-site design employed here removes those confounders.

The observation that body weight didn't fully account for inter-zone differences aligns with findings in dairy cattle by Dahl *et al.* [8], who demonstrated that photoperiod manipulation altered mammary parenchymal mass independently of feed intake and body condition. Brazil's four sampled zones span from 9°S to 28°S latitude, generating photoperiod differences of approximately 1.4 hours between the equatorial Caatinga and the subtropical Planalto during mid-year. This photoperiod gradient could influence prolactin secretion patterns and, by extension, mammogenesis [8, 16].

Heat stress offers another plausible mechanism. The semi-arid Caatinga, with mean temperatures of 26.4 °C and frequent peaks above 35 °C, imposes chronic heat load that has been shown to reduce mammary blood flow by 18-23% in dairy cattle [17]. Reduced perfusion during mammogenesis could limit alveolar cell proliferation and the resulting secretory tissue mass, producing the smaller gland dimensions observed in Caatinga goats [7, 18].

Nutritional quality varied across zones in both quantity and composition. The Caatinga's xerophytic browse is lower in digestible energy and crude protein compared with the tropical legume-grass mixtures available in the Atlantic Forest region [5, 19]. Although concentrate supplementation partially compensated

for forage quality differences, the total nutrient intake likely remained higher in zones with abundant high-quality pasture.

The zone $\times$ parity interaction merits attention from a breeding perspective. If teat length and cistern depth respond differently to parity in different environments, then selection indices for udder conformation should ideally be environment-specific rather than universal [13, 20]. A goat selected for optimal teat dimensions in the Cerrado may not retain that advantage when transferred to the Caatinga, and vice versa.

One limitation of this research is its cross-sectional design, which compares different animals across zones rather than tracking the same genotypes in different environments. A reciprocal transfer experiment moving Barbari goats between zones and tracking mammary development would more rigorously disentangle genetic from environmental effects. Additionally, the multi-site approach relied on local management practices rather than strictly uniform protocols, introducing some management-related variation that the statistical model may not have fully captured [21].

Conclusions

This research provides the first comprehensive multi-zone comparison of mammary gland morphology in Barbari goats raised across four contrasting agro-climatic environments in Brazil. The findings demonstrate that nearly all measured morphometric parameters udder length, width, circumference, teat length, cistern depth, and estimated udder volume differ significantly among zones, with the humid tropical Atlantic Forest region producing the largest mammary dimensions and the semi-arid Caatinga producing the smallest.

The magnitude of this inter-zone variation is substantial. Estimated udder volume differed by 53.6% between the extreme environments, udder circumference by 32.2%, and teat length by 35.9%. These differences are large enough to carry practical consequences for milking equipment selection, udder health management, and the interpretation of conformation scores used in breeding programs.

Body weight, while positively correlated with mammary dimensions within each zone, didn't account for the full extent of inter-zone variation. Significant zone effects persisted after adjustment for body weight, pointing to direct environmental influences on mammary gland development. These influences likely operate through multiple pathways, including photoperiod-mediated hormonal modulation, heat stress effects on mammary perfusion, and nutritional substrate availability for secretory tissue growth.

The zone $\times$ parity interaction observed for teat length and cistern depth carries implications for breeding program design. The mammary gland's cumulative response to successive lactation cycles appears to be modulated by the environment, with favorable conditions amplifying the parity-driven expansion of key structures. This interaction means that breed evaluation criteria optimized for one agro-climatic zone may not be directly transferable to another.

From a management standpoint, the data support the development of environment-specific reference values for udder conformation in the Barbari goat. Milking equipment specifications, particularly liner size and teat cup dimensions, should be calibrated to the teat morphometry typical of the target zone rather than relying on generic breed averages. Similarly, mastitis risk assessment protocols should account for the regional variation in teat and cistern dimensions that this research has documented.

Future work should employ reciprocal transfer designs and common-garden experiments to separate genetic from environmental contributions to the observed variation. Molecular phenotyping of mammary tissue from different zones could reveal whether the anatomical differences are accompanied by differences in gene expression profiles related to mammaryogenesis and lactogenesis.

Acknowledgements

Funding Sources

This research was supported by the Recife Metropolitan University through the Multi-Site Livestock Adaptation Research Program. Travel costs for the coordinated sampling campaign were partially funded by the Brazilian National Council for Scientific and Technological Development under the Universal Projects scheme.

Institutional Support

The authors acknowledge the collaborating institutions that provided access to their Barbari goat herds and research facilities: the Petrolina Semi-Arid Research Station, the Brasília Cerrado Animal Science Centre, the Ilhéus Tropical Livestock Unit, and the Lages Subtropical Agricultural Research Station.

Contributions Not Qualifying for Authorship

The authors thank Mr. Lucas Barbosa for logistical coordination across the four sampling sites, Ms. Beatriz Nogueira for ultrasonographic measurements, and Dr. Anderson Moura from the Statistical Consulting Service for assistance with the two-way ANOVA and ANCOVA modeling.

References

- Mason IL. A World Dictionary of Livestock Breeds, Types and Varieties. 4th ed. Wallingford: CAB International; 1996.
- Devendra C, Burns M. Goat Production in the Tropics. 2nd ed. Farnham Royal: Commonwealth Agricultural Bureaux; 1983.
- Boyazoglu J, Hatziminaoglou I, Morand-Fehr P. The role of the goat in society: past, present and perspectives for the future. *Small Rumin Res.* 2005;60(1-2):13-23.
- Ab'Sáber AN. The natural organization of Brazilian inter- and subtropical landscapes. *Rev Inst Geol.* 2000;21(1-2):57-70.
- Araújo Filho JA. Manejo Pastoril Sustentável da Caatinga. Recife: Projeto Dom Helder Câmara; 2013.
- Rovai M, Thomas DL, Berger YM, Guarín JF. Udder morphology and its relationship with milk yield in Lacaune sheep. *Small Rumin Res.* 2018;161:27-33.
- Tao S, Bubolz JW, do Amaral BC, Thompson IM, Hayen MJ, Johnson SE, Dahl GE. Effect of heat stress during the dry period on mammary gland development. *J Dairy Sci.* 2011;94(12):5976-5986.
- Dahl GE, Buchanan BA, Tucker HA. Photoperiodic effects on dairy cattle: a review. *J Dairy Sci.* 2000;83(4):885-893.
- Chilliard Y, Ferlay A, Rouel J, Lamberet G. A review of nutritional and physiological factors affecting goat milk lipid synthesis and lipolysis. *J Dairy Sci.* 2003;86(5):1751-1770.
- Kumar A, Mehta SC, Mishra AK. Body biometry and udder morphology of Barbari goats in organized farm conditions. *Indian J Anim Res.* 2017;51(4):715-720.
- Malan SW. The improved Boer goat. *Small Rumin Res.* 2000;36(2):165-170.
- Mavrogenis AP, Papachristoforou C, Lysandrides P, Roushias A. Environmental and genetic effects on udder characteristics and milk production in Damascus goats. *Small Rumin Res.* 2006;65(1-2):154-161.
- Montaldo HH, Valencia-Posadas M, Wiggans GR, Shepard L, Torres-Vázquez JA. Short communication: genetic and environmental relationships between milk yield and kidding interval in commercial dairy goats. *J Dairy Sci.* 2010;93(1):370-372.
- Singh N, Kumar M, Singh KN, Sathapathy S, Chaurasia DK, Lade D, Verma A. Gross morphological studies on mammary gland of Barbari goat. *Int J Vet Sci Anim Husbandry.* 2024;9(2):796-800. doi:10.22271/veterinary.2024.v9.i2k.1322.
- Bhatt SS, Sharma MC. Morphological attributes of the udder in Indian goat breeds: a review. *Indian J Small Rumin.* 2019;25(1):12-19.
- Auchtung TL, Rius AG, Kendall PE, McFadden TB, Dahl GE. Effects of photoperiod during the dry period on prolactin, prolactin receptor, and milk production of dairy cows. *J Dairy Sci.* 2005;88(1):121-127.
- Collier RJ, Dahl GE, VanBaale MJ. Major advances associated with environmental effects on dairy cattle. *J Dairy Sci.* 2006;89(4):1244-1253.
- West JW. Effects of heat-stress on production in dairy cattle. *J Dairy Sci.* 2003;86(6):2131-2144.
- Santos MVF, Lira MA, Dubeux Jr JCB, Guim A, Mello ACL, Cunha MV. Potential of Caatinga forage plants in ruminant feeding. *Rev Bras Zootec.* 2010;39(Suppl):204-215.
- Rupp R, Clément V, Piacere A, Robert-Granié C, Manfredi E. Genetic parameters for milk somatic cell score and relationship with production and udder type traits in dairy Alpine and Saanen primiparous goats. *J Dairy Sci.* 2011;94(7):3629-3634.
- Haenlein GFW. Goat milk in human nutrition. *Small Rumin Res.* 2004;51(2):155-163.