Research Article

Biometry and Maximum Compressive Strength of the Hoof Capsules of Goats (*Capra hircus* LINNAEUS, 1758)

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Abstract

Hoof disorders represent one of the main causes of lameness in goats, directly impacting productivity and animal welfare. Among the structures involved, the hoof capsule plays a fundamental role in locomotor integrity. This study aimed to determine the maximum compressive strength of the hoof capsule of the thoracic and pelvic limbs of adult goats. Through destructive mechanical tests on the dorsoventral axis, using a Universal Testing Machine controlled by the Tesc program, forty pairs of digits, thoracic and pelvic, from both antimers, of crossbred males, were evaluated. They were collected at the Municipal Slaughterhouse of Petrolina (PE) and subjected to hoof biometry and compressive testing. It was observed that, in both limbs, deformation occurred predominantly in the horn torus, highlighting it as the region of greatest structural fragility. Biometric data and the parameters of maximum compressive strength and deformation were collected and compared between the limbs, supporting the development of techniques or biomaterials with mechanical properties similar to the hoof capsule. The results obtained provide a technical-scientific basis for applications in veterinary clinical practice, surgery, and biomedical engineering.

Introduction

In this context, this study aimed to comparatively analyze the resistance of the hoof capsule in the thoracic and pelvic limbs of goats, simulating compressive loads and identifying the region's most vulnerable to deformation.

Methodology

Samples

Hoof capsules from forty pairs of digits, thoracic and pelvic, from both antimers, of adult male crossbred goats were used, collected at the Municipal Slaughterhouse of Petrolina (PE). After collection, the specimens were cleaned, identified, and sent to the Laboratory of Anatomy of Domestic and Wild Animals (LAADS/UNIVASF).

Biometry

Each capsule was subjected to biometry using a digital caliper, measuring (Figure 1A, 1B & 1C):

1. Height of the parietal surface (cm)
2. Width (cm)
3. Length (cm)
4. Height and width of the horn torus (cm).

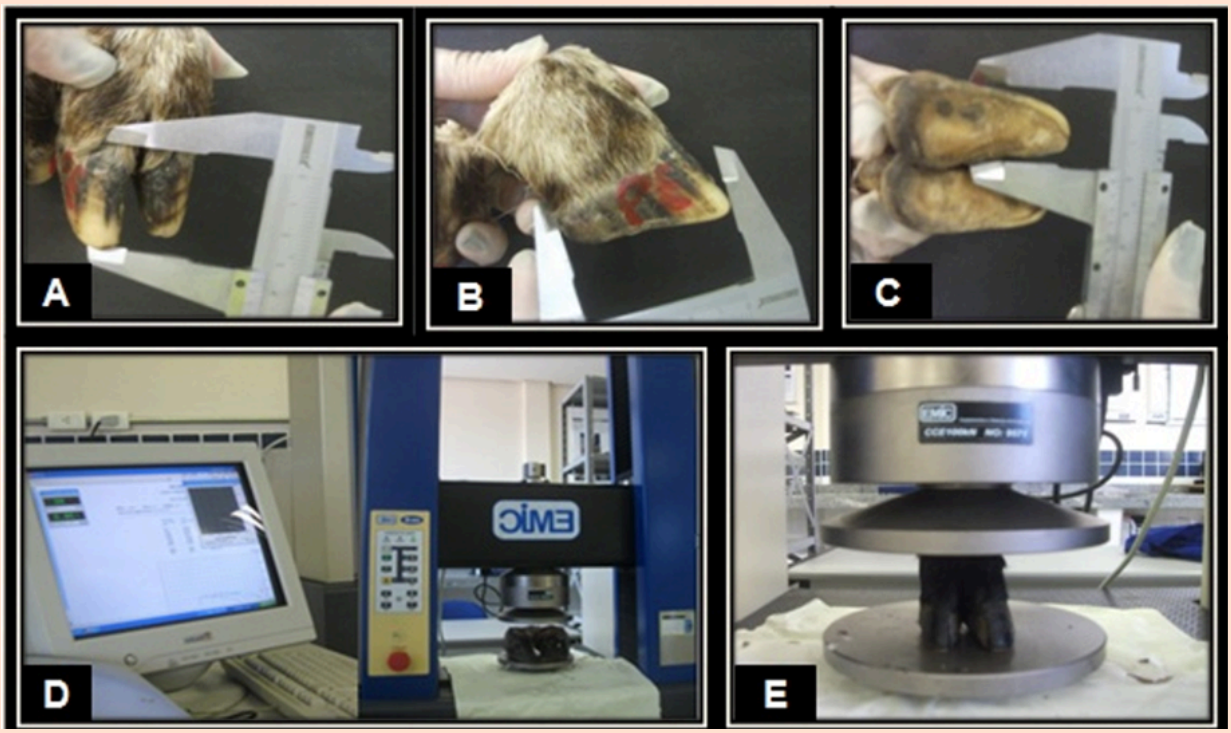

Figure 1: Hoof capsule biometry of goats, showing the parameters of parietal surface height (A), length (B), and width (C). Photograph D shows the Universal Testing Machine, and in E, the compression of the capsule in the dorsoventral direction – Petrolina (PE), 2025.
Source: Personal collection.

Compressive Strength Test

A compressive strength test was performed on the dorsoventral axis using a Universal Testing Machine, controlled by the Tesc program (Figures 1D & 1E). The recorded parameters were: a) Maximum force applied until failure (N); b) Deformation (mm); c) Region of structural collapse.

Statistical Analysis

Initially, descriptive statistics (mean, standard deviation, and 95% confidence interval) were performed. Data normality was verified using the Shapiro-Wilk test. For comparison between thoracic and pelvic limbs and between medial and lateral digits, Student's t-test or the nonparametric Mann-Whitney and Wilcoxon tests were applied, according to data distribution. A significance level of 5% ($p < 0.05$) was adopted.

Methodology

Biometry of the Thoracic Limb

In the right thoracic limb, the results for the parietal surface height (A), width (L), and length (C) of the lateral digit were, respectively, 2.9 cm ± 0.4; 2.28 cm ± 0.17; and 4.68 cm ± 0.35; while the medial digit presented A = 2.92 cm ± 0.19; L = 2.22 cm ± 0.21; C = 4.68 cm ± 0.35. Regarding the horn torus height and width in the lateral digit, the values were 2.58 cm ± 0.19 and 2.36 cm ± 0, and in the medial digit, 2.52 cm ± 0.23 and 2.34 ± 0.18. In the left thoracic limb, the lateral digit presented A = 2.9 cm ± 0.15; L = 2.34 cm ± 0.32; C = 4.66 cm ± 0.29; and the horn torus showed a height of 2.4 cm ± 0.22 and a width of 2.24 cm ± 0.16.

The medial digit reached A = 2.72 cm ± 0.17; L = 2.24 cm ± 0.11; and C = 4.68 cm ± 0.26; while the horn torus height and width were 2.48 cm ± 0.14 and 2.28 cm ± 0.19, respectively. It was found that only the horn torus underwent deformation, highlighting it as the weakest point of the hoof region. These data are presented in Tables 1 & 2.

Table 1: Hoof biometry of the right and left pelvic limbs regarding the parameters of parietal surface height (A), width (L), and length (C), expressed in centimeters (cm) – Petrolina, 2025.
Source: Personal collection.

Antimer	Lateral Digit			Medial Digit		
	A (cm)	L (cm)	C (cm)	A (cm)	L (cm)	C (cm)
Right	3,0±0,15	1,6±0,23	5,1±0,87	2,9±0,13	1,8±0,61	5,1±0,27
Left	3,0±0,20	1,6±0,16	5,1±0,13	2,9±0,07	1,5±0,08	5,0±0,27

Table 2: Biometry of the horn torus regarding the parameters of height (A) and width (L), expressed in centimeters (cm) – Petrolina, 2025.
Source: Personal collection.

Antimer	Lateral Digit		Medial Digit	
	A (cm)	L (cm)	A cm)	L (cm)
Right	2,5±0,19	2,3±0,15	2,5±0,23	2,5±0,23
Left	2,4±0,22	2,2±0,16	2,4±0,14	2,2±0,19

According to Prado *et al.* [3], in thoracic digits of dairy goats, after growth, there was proportionality between the height, width, and length of the hoof capsule, with small variations between the medial and lateral digits. Furthermore, values similar to those of the horn torus were reported by Zhang *et al.* [4], who highlighted the function of this structure in impact absorption and in increasing the contact area with the ground, which emphasizes its greater susceptibility to deformation under mechanical pressure. Additionally, in areas with flat surfaces or moderate slopes, the dimensions of the hoof capsule of the thoracic limbs tend to follow a stable morphometric pattern, which favors balanced load distribution and may explain the absence of significant differences between antimers [5].

Biometry of the Thoracic Limb

In the right pelvic limb, the measurements observed in the lateral digit were 3.0 cm ± 0.15 for parietal surface height; 1.62 cm ± 0.23 for width; and 5.18 cm ± 0.87 for length; while the horn torus height and width were 1.42 cm ± 0.33 and 1.9 cm ± 0.07, respectively. For the medial digit, the height was 2.92 cm ± 0.13; width 1.84 cm ± 0.61; length 5.12 cm ± 0.27; with the horn torus measuring 1.4 cm ± 0.24 in height and 1.84 cm ± 0.15 in width. In the left pelvic limb, the lateral digit reached a height of 3.06 cm ± 0.20; width of 1.68 cm ± 0.16; length of 5.18 cm ± 0.13; while the horn torus height and width were 1.44 cm ± 0.21 and 1.9 cm ± 0.18, respectively. The medial digit measured 2.9 cm ± 0.07 in height; 1.56 cm ± 0.08 in width; and 5.08 cm ± 0.27 in length; with the horn torus height and width of 1.5 cm ± 0.23 and 1.88 cm ± 0.14, respectively. It was observed that only the horn torus underwent deformation, highlighting the point of greatest fragility of the hoof capsule. These data are presented in Tables 3 & 4.

Table 3: Biometry of the horn torus regarding the parameters of height (A) and width (L), expressed in centimeters (cm) – Petrolina, 2025.
Source: Personal collection.

Antimer	Lateral Digit			Medial Digit		
	A (cm)	L (cm)	C (cm)	A (cm)	L (cm)	C (cm)
Right	2,9±0,4	2,2±0,17	4,6±0,35	2,9±0,19	2,2±0,21	4,6±0,35
Left	2,9±0,15	2,3±0,32	4,6±0,29	2,7±0,17	2,2±0,11	4,6±0,26

Table 4: Biometry of the horn torus regarding the parameters of height (A) and width (L) – Petrolina (PE), 2025.
Source: Personal collection.

Antimer	Lateral Digit		Medial Digit	
	A (cm)	L (cm)	A (cm)	L (cm)
Right	1,4±0,33	1,9±0,07	1,4±0,24	1,8±0,15
Left	1,4±0,21	1,9±0,18	1,5±0,23	1,8±0,14

The dimensions of height, width, and length of the parietal surface in the pelvic digits corroborate the findings reported by Zhang *et al.* [4]. However, these authors performed hoof trimming on the dairy goats used to standardize the measurements between digits before and after management. The relationships obtained for the dimensions of the horn torus were similar to those reported by Li *et al.* [6] in the plantar areas of bovine hoof capsules, which, due to their α-keratin composition and layered arrangement, provide cushioning capacity, although they exhibit a lower elastic modulus than the lateral walls. Furthermore, subtle modifications in the width of the medial digit may result from postural adjustments during locomotion on irregular surfaces and from mechanical overload of different muscle groups and forces acting on the limb, which could explain the slight differences observed in this sample group [7,8].

Mechanical Compressive Strength Test

In both limbs, deformation was observed only in the horn torus, demonstrating it as the point of lowest structural resistance. The characteristics regarding the maximum force supported and the deformation of the horn torus under the application of the destructive mechanical test are presented in Table 5.

Table 5: Maximum force supported (Newton - N) and deformation (millimeter - mm) of the hoof capsule when subjected to a destructive mechanical testing machine – Petrolina (PE), 2025.
Source: Personal collection.

Parameters	Thoracic Limb		Pelvic Limb	
	Right (R)	Left (L)	Right (R)	Left (L)
Maximum Force	7895,01±3734,47	6372,78±2859,82	6425,39±771,44	5032,72±2778,17
Deformation	34,60±4,99	33,06±4,80	37,80±3,64	32,49±7,02

The results obtained for the maximum force in the compressive mechanical test, which ranged from approximately 5.0 to 7.9 kN, are also consistent with the conclusions of Zhang *et al*. [4], who investigated functional components of the goat hoof capsule and noted that, even under different inclinations during evaluations, mechanical performance remained stable across various regions, highlighting a structural adaptation that preserves the capacity to withstand high loads. It is worth noting that the anomaly identified in the horn torus aligns with the findings of Li *et al*. [6] in their study of the bovine hoof wall, where they observed that the innermost keratin regions exhibited a lower elastic modulus and a greater capacity for deformation, in relation to the cushioning function they perform.

The results emphasize that the structural heterogeneity of the hoof capsule is fundamental for load distribution and impact absorption, which may explain why compressive resistance of both thoracic and pelvic limbs shows such similarity despite size variations. Thus, it can be stated that the thoracic limb exhibited greater robustness in measurements, but without significant differences in compressive resistance compared to the pelvic limb; additionally, the exclusive deformation of the horn torus demonstrates that this region concentrates impact absorption, being the point of greatest structural vulnerability of the hoof capsule. Furthermore, the dimensional difference between thoracic and pelvic limbs may be related to load distribution in the animal, as the thoracic limbs support the majority of body mass (60% to 65%). Despite morphometric differences, the resistance values were similar, indicating functional homogeneity of the hoof capsules [9-12].

Conclusion

The hoof capsules of the thoracic and pelvic limbs of goats demonstrated similar resistance under dorsoventral compression, with the horn torus being the structural point of greatest fragility. This study provides a foundation for clinical and technological applications aimed at hoof rehabilitation in goats, being relevant for fields such as veterinary orthopedics and materials engineering.

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