**RESEARCH ARTICLE**

**OPEN ACCESS**

# RESISTANCE OF GOAT LEATHER OBTAINED AFTER PROCESSING IN A TANNERY IN THE SÃO FRANCISCO SERTÃO, NORTHEASTERN BRAZIL

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## ARTICLE INFO

## ABSTRACT

Approximately 90% of goat farming in Brazil is concentrated in the Northeast, representing a relevant economic activity, although its potential remains underexploited, particularly in the leather market. Less than 10% of the skins delivered to tanneries are of superior quality, resulting in high industrial idleness. This study aimed to evaluate the physical-mechanical properties of goat leather, with emphasis on tensile strength in different anatomical regions: cervical, dorsal thoracic, thoracic limbs, and pelvic limbs. For the analysis, tensile tests were performed using an electromechanical Universal Testing Machine and Digital Line Micro Processing. The specimens were fixed in the machine clamps and subjected to increasing axial force until rupture. Statistical analysis included ANOVA, Tukey's test (15%), Shapiro-Wilk, Bartlett, and verification of error independence, ensuring the validity of comparisons. Results indicated higher average resistance in the cervical region (234.19 N), followed by dorsal thoracic (204.66 N), pelvic limbs (204.29 N), and thoracic limbs (197.16 N), evidencing superior mechanical support capacity in the cervical area. This region also showed greater variability, while the dorsal thoracic region demonstrated higher structural homogeneity. The observed differences highlight the importance of leather anatomy for its selection in specific applications.

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# INTRODUCTION

Goat farming, one of the oldest forms of animal production for human consumption, remains relevant in developing countries such as Brazil. Although its distribution is uneven across the national territory, it is particularly prominent in the Northeast, which concentrates approximately 95% of the Brazilian goat herd, due to the adaptability of these animals to semi-arid conditions and their natural hardiness (Vasconcelos *et al*., 2025). In addition to meat and milk production, goat skin represents a high-value by-product, serving as an essential raw material for the leather industry, with applications in footwear, bags, and clothing. The agribusiness of goat and sheep skins has significant potential in Brazil, with an expressive domestic market and the capacity to strengthen production chains such as fashion and accessories (Embrapa, 2001). The production of high-quality skins, however, faces significant challenges, particularly related to inadequate animal management and slaughter conditions, which compromise both yield and material integrity.

The skin—or cutis—is removed through flaying and subsequently subjected to the tanning process, which aims to transform it into leather, making it more stable and resistant to decomposition. The final quality of the leather depends directly on the initial condition of the skin and the efficiency of the processing. Despite the high availability of land and the favorable conditions for goat farming in the semi-arid Northeast, the leather production chain faces structural obstacles. Although the Northeast leads in terms of animal numbers, its production value (977 thousand) is lower than that of the South region (2.59 million), according to IBGE data (2019), highlighting deficiencies in value addition. Informality, low remuneration, and the absence of effective public policies contribute to the sector's disarticulation, directly affecting tanneries, which face irregular supply and low-quality skins (Monteiro *et al*., 2021). According to Jacinto (2007), Brazilian tanneries have the installed capacity to process twice the current volume, but the low quality of raw material and unstable demand lead many companies to resort to imports. The city of Petrolina (PE), located in the Sertão of the São Francisco Valley, has the infrastructure for leather processing but operates at

only 50% of its capacity due to irregular supply and poor-quality skins—factors that are fully identified only during the tanning stage. Given this scenario, it becomes essential to evaluate the mechanical strength of goat leather as an indicator of the quality of processed skins. Such analysis allows the identification of losses during the tanning stage and the proposal of improvements that result in greater productive efficiency and better remuneration for breeders. Thus, the objective of this study was to analyze the strength of goat leather obtained after processing in a tannery located in the municipality of Petrolina (PE), contributing to the enhancement of the regional production chain.

# MATERIALS AND METHODS

**Collection and identification of leather:** Thirty goat leathers were used, provided by Curtume Moderno, located in Petrolina (PE), with a total weight of 25.35 kg. Each leather was numerically identified (from 1 to 30) and taken to the Laboratory of Anatomy of Domestic and Wild Animals (LAADS), affiliated with the Campus of Agricultural Sciences (CCA) of the Federal University of the São Francisco Valley (UNIVASF). In the laboratory, measurements of thickness, length, and width of each leather were performed using a measuring tape and a digital caliper. Weighing was conducted on an electronic scale manufactured by Brasmed®.

**Delimitation of anatomical regions and preparation of test specimens:** After the initial measurements, the leathers were sent to the Mechanical Engineering Laboratory of UNIVASF, Juazeiro Campus (BA). The following anatomical regions were delineated using a permanent ink brush: cervical, dorsal thoracic, thoracic limbs, and pelvic limbs (Figure 1).
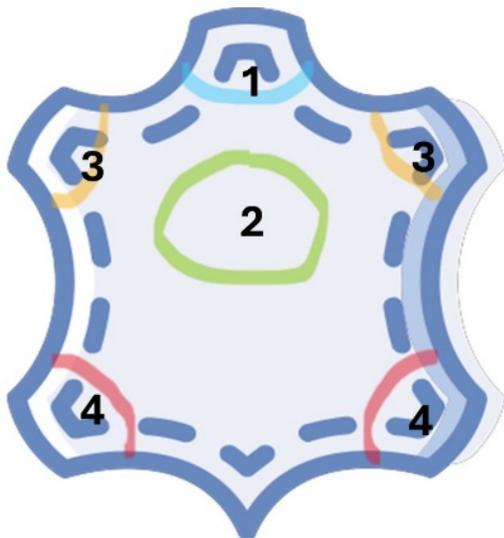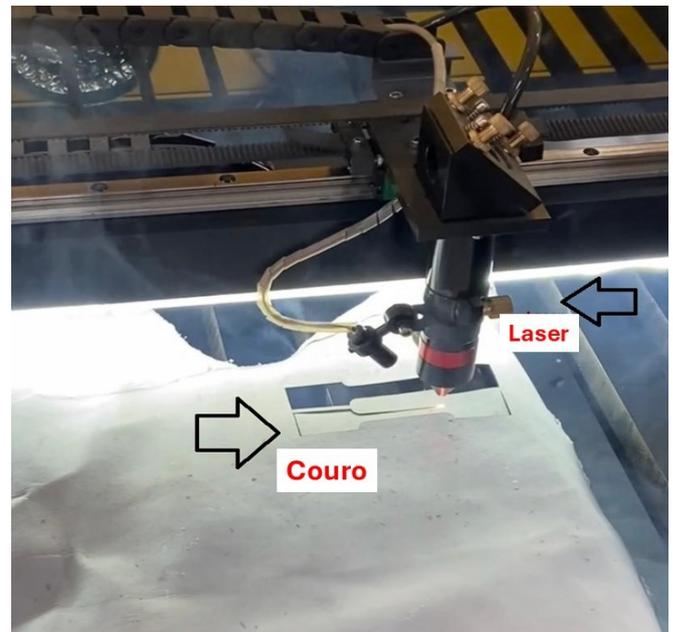


Source: Developed by the author.

**Figure 1. Delimitation of the anatomical regions cervical (1), dorsal thoracic (2), thoracic limbs (3), and pelvic limbs (4) used for obtaining test specimens from stretched goat leather. Location: Petrolina (PE), 2025**

Each region was subjected to cutting of the test specimens using an infrared laser cutter, following the standardized dimensions according to the NBR ISO 3376 standard (ABNT, 2014). For each region, three test specimens were obtained, totaling 12 samples per leather (Figure 2).

**Tensile Test:** The tensile tests were conducted based on the procedures described by Garcia *et al.* (2012), using the EMIC® electromechanical universal testing machine, equipped with a 20 kN load cell and two clamping grips. Each test specimen was secured at the ends of the grips and subjected to the application of axial force until material failure (Figure 3).



Source: Developed by the author.

**Figure 2. Preparation of the test specimen with the aid of an infrared laser cutter – Juazeiro (BA), 2025**

The thickness, length, and width of each sample were entered into the machine control software, according to the specifications of NBR ISO 3376 (ABNT, 2014). The tests were carried out in a climate-controlled environment, with a temperature of $25 \pm 2\,°C$ and relative humidity of $50 \pm 5\%$. All tests were performed by a single trained operator to minimize technical variability. The resistance and deformation data were captured by the TESC® software (Simmetro, 2015), connected to the testing machine, and subsequently tabulated in Microsoft Excel® spreadsheets.
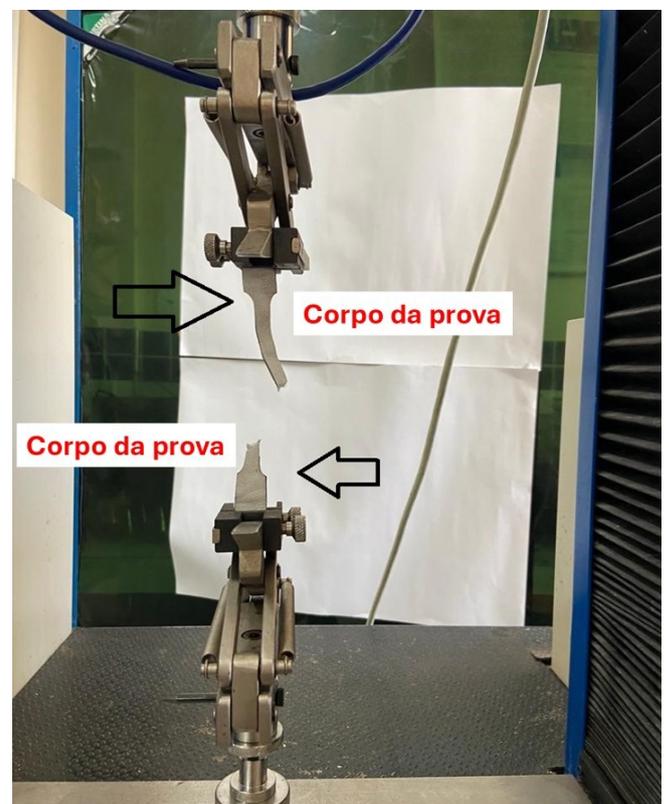


Source: Developed by the author.

**Figure 3. Tensile test performed on a destructive mechanical testing machine, showing the goat leather test specimen after rupture. Juazeiro (BA), 2025**

**Statistical Analysis**

The data obtained were subjected to statistical analysis using R® software (version X.X). The mean resistance (in Newtons), standard deviation, and coefficient of variation were calculated for each anatomical region. Data normality was assessed using the Shapiro-Wilk test, and variance homogeneity was evaluated using the Bartlett test. Comparison of the means among different regions was performed through analysis of variance (ANOVA), adopting a significance level of 5%. The independence of errors was also evaluated to validate the statistical models.

# RESULTS AND DISCUSSION

The tensile tests performed on goat leather samples from different anatomical regions revealed significant variations in mechanical resistance among the evaluated segments (Table 1).

to 368.57 N. These regional differences are consistent with the findings of Dal Monte *et al.* (2004), who highlight the influence of the anatomical position of the samples on the results of physical-mechanical tests. The observed variation can be attributed to the morphological characteristics of the leather, such as thickness, fiber orientation, and local biomechanical function (Embrapa, 2012). The analysis of the coefficient of variation (CV), presented in Table 2, reinforces the interpretation of the data. The cervical and dorsal thoracic regions exhibited the lowest CVs (28.96% and 26.38%, respectively), indicating greater homogeneity among the samples. In contrast, the thoracic and pelvic limbs showed higher variability (30.15% and 32.09%), which may compromise the predictability of mechanical performance in these areas. The CV is a widely used statistical measure to evaluate the consistency of experimental data, with lower values indicating higher reliability (Zar, 2010). Table 2 – Assessment of data homogeneity based on the coefficient of variation (CV), which expresses the relative degree of dispersion in relation to the mean; lower CV values indicate greater data homogeneity.

**Table 1. Results of tensile tests on goat leather. Juazeiro (BA), 2025**

| Regions | Numberof samples | Meanresistance (Newtons) | Standard deviation | Minimumvalue (N) | Maximumvalue (N) |
|---|---|---|---|---|---|
| Cervical | 30 | 234,19 | ±67,82 | 116,03 | 460,04 |
| Dorsal Thoracic | 30 | 204,66 | ±53,98 | 131,05 | 310,56 |
| ThoracicLimbs | 30 | 197,16 | ±59,44 | 105,79 | 296,22 |
| PelvicLimbs | 30 | 204,29 | ±65,56 | 92,14 | 368,57 |

| REGIONS | COEFFICIENT OF VARIATION |
|---|---|
| Cervical | 28,96 |
| Dorsal Thoracic | 26,38 |
| ThoracicLimbs | 30,15 |
| PelvicLimbs | 32,09 |
| Overall coefficientofvariation | 29,40 |
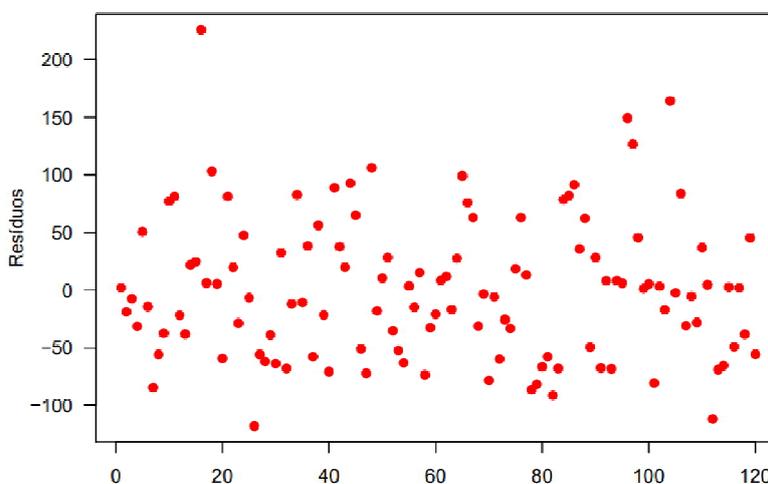


Source: Developed by the author.

**Figure 4. Graphical representation of the test for error independence, showing that the residuals occur randomly and without dependence on each other, a condition essential for the validity of statistical tests. Petrolina (PE), 2025**

The samples from the cervical region exhibited the highest mean resistance (234.19 N), followed by the dorsal thoracic region (204.66 N), pelvic limbs (204.29 N), and thoracic limbs (197.16 N). These results indicate that the cervical region has a greater capacity to withstand mechanical stress, which may be related to the higher density and organization of collagen fibers in this area (Garcia *et al.*, 2012). Regarding data dispersion, the cervical region also presented the highest standard deviation (±67.82 N), while the dorsal thoracic region showed the lowest deviation (±53.98 N), suggesting greater structural homogeneity in the latter. Analysis of the extreme values reinforces this trend: the cervical region presented the highest maximum value (460.04 N) and a minimum value of 116.06 N, whereas the dorsal thoracic region ranged from 131.05 N to 310.56 N. The thoracic limbs showed the lowest resistance, with values between 105.79 N and 296.22 N, while the pelvic limbs ranged from 92.14 N

Petrolina (PE), 2025. To ensure the validity of the statistical tests, the test of error independence was performed (Figure 4), which confirmed that the errors occur randomly, without dependence on each other (Montgomery, 2017). This verification is essential to ensure that the repetitions can be considered independent, preventing biases in the interpretation of the results, as it guarantees that the statistical inferences drawn from the data are reliable and not biased by correlation among the residuals. ANOVA was used to compare the mean resistance between the different anatomical regions. The residual value of 0.1023 suggests considerable dispersion among the data, which is expected in biological materials, such as leather, due to their natural variability (Carvalho, 2024). The Shapiro-Wilk test, with a value of 0.002, indicates that the data deviate from normality, which may affect the validity of ANOVA, as this test assumes a normal distribution of the data. In such cases, non-parametric tests can be

considered, or data transformations can be applied. The Bartlett test, with a value of 62.07, confirms the homogeneity of variances, which is a positive point for the reliability of ANOVA (Miot, 2017). Homogeneity is essential to ensure that comparisons between groups are fair and not influenced by differences in data dispersion. Despite the violation of normality indicated by the Shapiro-Wilk test, the data show homogeneity of variances and independence of errors (as shown in Figure 5), which allows ANOVA to be applied with caution. Therefore, the statistical analysis is valid for identifying differences between anatomical regions, but the results should be interpreted considering the biological nature of the material and the expected variability. The statistical analysis of the mean tensile strength among the different anatomical regions of goat leather was complemented by the 15% Tukey test, as illustrated in Figure 5. The graph shows the confidence intervals for pairwise comparisons between regions, allowing the identification of statistically significant differences. It can be observed that the comparisons between the cervical region and the thoracic (a3–a1) and pelvic limbs (a4–a1) resulted in intervals that do not cross the zero reference line, indicating a statistically significant difference. These results confirm that the cervical region exhibits superior tensile strength compared to the other regions. On the other hand, the comparisons between the dorsal thoracic and cervical regions (a2–a1), thoracic limbs and dorsal thoracic (a3–a2), pelvic limbs and dorsal thoracic (a4–a2), as well as between pelvic and thoracic limbs (a4–a3), showed intervals that cross zero, suggesting no statistically significant differences between these regions. These findings reinforce the structural heterogeneity of goat leather, highlighting that the cervical region possesses more favorable mechanical properties, which can directly influence the selection of this area for specific industrial applications, such as the manufacture of items requiring higher strength. This regional differentiation underscores the importance of considering leather anatomy when evaluating its physical-mechanical properties (Dal Monte *et al.,* 2004).

### Nível de confiança global 15%
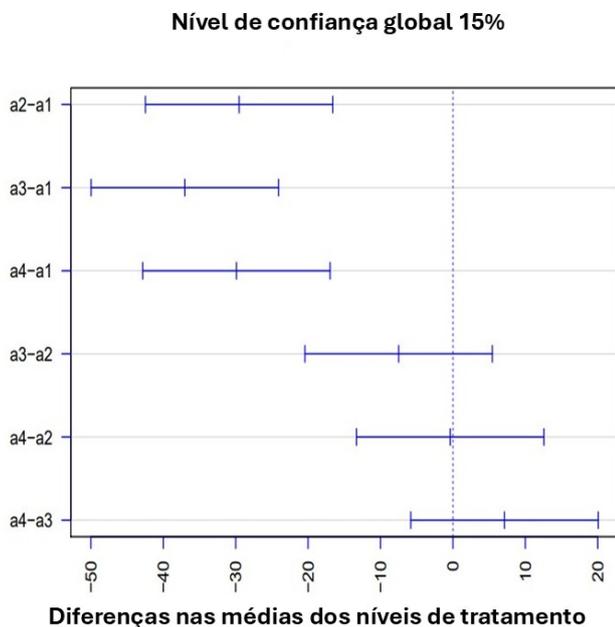


Legend: a1 = cervical region; a2 = dorsal thoracicregion; a3 = thoraciclimbsregion; a4 = pelviclimbs region.

**Figure 5. Tukey test at 15%, used for multiple pairwise comparisons after ANOVA, highlighting statistically significant differences between anatomical regions of goat leather. Petrolina (PE), 2025**

The values obtained in this study fall within the minimum parameters described by the Quality Control Laboratory of the National Industrial Learning Service (SENAI – CTCC, 2015) for industrial-quality leathers. Furthermore, the results were similar to those reported by Oliveira *et al. (*2008), who obtained an average force of 24.40 kgf. In the present study, after conversion, the average was 21.50 kgf,

demonstrating compatibility with industrial standards. The absence of data regarding age, breed, biometrics, and feeding of the goats limits the correlation of the results with these variables, which are recognized as influential on the physical-mechanical characteristics of leather. Nevertheless, the findings reinforce the potential of goat leather as a high-performance raw material, especially in regions such as the cervical area, which exhibit greater resistance and homogeneity. From an industrial perspective, goat leather stands out for its flexibility and strength, making it ideal for luxury items such as handbags and shoes (Jacinto & Leite, 2003). In comparison, bovine leather is thicker and more robust due to the higher density of collagen fibers, being widely used in the clothing and furniture industries. Sheep leather has a structure similar to goat leather but differs in fiber composition, which influences its mechanical properties and industrial applications (Jacinto & Leite, 2003). Meanwhile, dog and cat leather is thinner and less resistant, and fish leather, composed of scales, has unique properties adapted to aquatic environments, which can be explored in specific applications (Souza *et al.,* 2009; Jafari *et al*., 2020). Recent studies, such as Oliveira *et al.* (2021), demonstrate that nutritional factors, like the inclusion of propolis in tilapia diets, can positively influence leather thickness and resistance, opening new perspectives for the valorization of alternative materials. Finally, the development of the tanning industry in the Northeastern semi-arid region, with a focus on the valorization of goat leather, can significantly contribute to improving the quality of life of local producers and to the conservation of native breeds, promoting the sustainable development of goat farming (Rey *et al*., 2007).

## CONCLUSION

The study demonstrated that goat leather exhibits significant variations in tensile strength according to the anatomical region, with the cervical region standing out for its superior mechanical performance and greater homogeneity. Despite the violation of normality, statistical tests confirmed the validity of the comparisons, showing significant differences between the cervical region and other areas. The values obtained are within industrial standards, reinforcing the potential of goat leather as a high-quality raw material. Valorizing this resource in the Northeastern semi-arid region can drive the sustainable development of goat farming, promoting productive inclusion, conservation of native breeds, and strengthening the local economy.

## ACKNOWLEDGMENTS

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