

Influence of Sex and Physiological Traits on Kacang Goat Meat Tenderness

Zaid Al Gifari^{1*}, Ikhwan Firhamsah¹, Khairil Anwar², Muhamad Ali², Firmansah²

¹Laboratory of Animal Production, Faculty of Animal Sciences, University of Mataram, Mataram, Indonesia;

²Laboratory of Biotechnology and Animal Product Processing, Faculty of Animal Sciences, University of Mataram, Mataram, Indonesia;

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*Corresponding Author: **Zaid Al Gifari**, Laboratory of Animal Production, Faculty of Animal Sciences, University of Mataram, Mataram 83125, Indonesia;
Email: zaidalgifari@staff.unram.ac.id

Abstract: Differences in meat tenderness between male and female animals are influenced by physiological and hormonal factors that affect muscle composition and connective tissue development. Understanding the effect of sex on meat tenderness is important for improving the quality of local goat breeds such as the Kacang goat, which is commonly raised under traditional semi-intensive systems. This study analyzed and compared the tenderness profile of meat from one-year-old male and female Kacang goats reared semi-intensively. Meat samples from the loin and shank of three male and three female goats were collected and tested using the Warner–Bratzler Shear Force (WBSF) method, and data were analyzed using an independent t-test to determine differences in tenderness between muscle types and sexes. The results showed a significant difference in male goats, with shank meat being tougher than loin meat, while in female goats, tenderness between both cuts was relatively uniform. These variations are attributed to physiological and hormonal differences, particularly higher testosterone levels in males that increase connective tissue density in more active muscles. In conclusion, sex significantly influences the tenderness of Kacang goat meat, with females producing meat of more consistent tenderness across different cuts, whereas males exhibit greater variation. The findings contribute to a better understanding of sex-related factors affecting meat quality and provide a scientific basis for improving goat meat production and management practices.

Keywords: Goat meat, Kacang goat, meat tenderness, shear force, traditional breeding system.

Introduction

The demand for high-quality goat meat continues to grow globally, driven by increasing consumer awareness of the nutritional value of red meat and the need for sustainable livestock production in tropical regions. In Indonesia, local goat breeds play a vital role in rural livelihoods and food security. Among them, the Kacang goat often referred to as the Kacang Goat is one of the most important indigenous breeds due to its strong adaptability to tropical climates and efficiency in utilizing local forage resources (Amiruddin & Nur, 2024; Muatip et al., 2023). On Lombok

Island, farmers typically apply a traditional semi-intensive system using natural feeds such as mango leaves, jackfruit leaves, and various grasses. Meat produced from goats raised in such systems is considered healthy, low in fat, and rich in protein and essential fatty acids (Subagyo & Nugroho, 2019).

Meat tenderness is a critical sensory attribute influencing consumer acceptance and market competitiveness (Gonzalez et al., 2024; Luz et al., 2018). It reflects the complex interplay of genetic, physiological, and biochemical factors that occur before and after slaughter (Kim et al., 2019; Mapiye et al., 2024). Physiological aspects, including age,

muscle activity, and hormonal balance, significantly influence the formation of connective tissue and muscle fiber structure, thereby affecting tenderness levels. Testosterone, for example, increases collagen cross-linking in active muscles, resulting in tougher meat in males compared to females of the same age (Kim *et al.*, 2019). Consequently, understanding the physiological mechanisms underlying tenderness variation between sexes is essential for improving the consistency and quality of goat meat.

Empirically, the quality of local goat meat in Indonesia often faces tenderness inconsistency, which directly affects consumer satisfaction and market value (Gonzalez *et al.*, 2024). Despite the increasing goat population nationwide, meat production has shown a declining trend (Muhtarudin *et al.*, 2024), indicating inefficiencies in meat quality management. The Warner-Bratzler Shear Force (WBSF) test is widely used as an objective standard for measuring meat tenderness (Luz *et al.*, 2018). However, WBSF benchmarks are primarily derived from beef studies, which differ physiologically from goat meat, thus necessitating specific research on local goat breeds to establish appropriate tenderness references.

Although several studies have examined factors influencing goat meat quality, comparative analyses between male and female local goats reared traditionally remain limited (Sari & Lestari, 2024). This study addresses this gap by analyzing and comparing the tenderness of one-year-old male and female Kacang goats raised under semi-intensive traditional systems on Lombok Island. The research also explores the underlying physiological and hormonal causes of observed differences, providing empirical support for local slaughtering preferences that favor female goats for their perceived tenderness and milder aroma. The findings are expected to contribute to a better scientific understanding of sex-related meat quality variation and to support evidence-based decision-making for farmers and meat producers in improving local goat meat production systems.

Materials and Methods

Research Design

This study employed a comparative experimental design to analyze differences in meat tenderness between male and female Kacang goats. The design was chosen because it enables controlled comparison of two biological groups under similar rearing and environmental conditions, allowing for an objective evaluation of the effect of sex on meat tenderness.

Literature Source and Selection

Supporting literature was obtained through a systematic search using databases such as Google Scholar, ScienceDirect, and ResearchGate. Keywords included *goat meat tenderness*, *Kacang goat*, *sex differences in meat quality*, and *Warner-Bratzler Shear Force (WBSF)*. These sources were used to strengthen the theoretical framework, validate methodological approaches, and interpret the experimental results.

Sampling and Meat Preparation

The study utilized one-year-old local Kacang goats (three males and three females) reared semi-intensively with forage feed consisting of mango leaves, jackfruit leaves, and mixed tropical grasses. Sampling was conducted in Praya and West Sakra Districts, Central Lombok, Indonesia. A total of nine meat samples, comprising loin (back) and shank (thigh) cuts, were collected post-slaughter following standard meat sampling protocols (USDA, 2016). Samples were immediately placed in sterile polyethylene bags, stored in a cool box containing ice packs (approximately 4°C), and transported to the laboratory within two hours to maintain freshness and prevent microbial contamination (ISO 17604:2015). Upon arrival, the samples were allowed to rest for 7 hours to reach the rigor mortis phase before further processing, as recommended for accurate texture measurement (Honikel, 1998).

Tenderness Testing Procedure

Meat tenderness was measured using the Warner–Bratzler Shear Force (WBSF) method, which determines the maximum shear force required to cut through cooked meat samples (Luz *et al.*, 2018; USDA ARS, n.d.). Each sample was cooked in a water bath at 65°C for 45 minutes and cooled to room temperature. Testing was performed using the RH-N50 Meat Tenderness Tester with a measurement range of 0–250 N and $\pm 1\%$ accuracy. Three sub-samples ($1 \times 1 \times 3$ cm) were taken from each meat cut and tested perpendicularly to the muscle fiber direction. Lower WBSF readings indicated higher tenderness levels.

Data Analysis

Quantitative data obtained from WBSF measurements were processed using SPSS version 26.0 (IBM Corp., USA). An independent t-test was applied to determine significant differences in tenderness between muscle types and sexes at a significance level of $p < 0.05$. All data were presented as mean $\pm$ standard deviation (SD). Qualitative observations regarding animal characteristics, feeding patterns, and slaughtering conditions were analyzed thematically and described narratively to complement quantitative findings.

Results and Discussion

Effect of Feeding and Maintenance Management on Meat Tenderness

Feeding management has a crucial role in determining meat tenderness, as nutritional intake directly affects the biochemical processes of muscle development and post-mortem proteolysis. In this study, Kacang goats reared under traditional semi-intensive systems were fed a combination of natural forages such as mango leaves, jackfruit leaves, and mixed tropical grasses. The overall tenderness values ranged from 2.01 kgf to 5.43 kgf, showing that muscle type and physiological condition strongly influence meat softness. These results reflect the quality of forage-based diets commonly used by smallholder farmers on Lombok Island.

The nutrient content of mango and jackfruit leaves provides a relatively balanced composition of fiber, protein, and secondary metabolites (Subagyo & Nugroho, 2019). Mango

leaves contain tannins and crude fiber that can modulate rumen fermentation, while jackfruit leaves supply higher crude protein levels essential for muscle growth (Kim *et al.*, 2019). However, compared to commercial feed supplements, traditional forage sources have limited bioavailability of micronutrients, particularly zinc and selenium, which are known cofactors in enzymatic systems responsible for post-mortem tenderization (Muhtarudin *et al.*, 2024). Studies by Dou *et al.* (2023) and Rangkuti *et al.* (2024) confirmed that goats receiving higher-quality protein and mineral-enriched feed produced significantly more tender meat due to increased activity of calpains and cathepsins key enzymes in muscle fiber degradation.

The present results therefore suggest that while traditional forage feeding supports acceptable meat quality, it cannot fully eliminate physiological differences that affect tenderness between muscles or sexes. This aligns with findings by Pophiwa *et al.* (2020), who emphasized that management factors, including feed and stress levels, contribute up to 70% of total tenderness variation, exceeding the influence of genetic factors. Hence, optimizing traditional feeding through supplementation or fermentation (e.g., silage) may help improve nutrient absorption and collagen solubility, producing softer meat without altering the indigenous production system (Muatip *et al.*, 2023).

Sex Differences in Meat Tenderness

Significant tenderness differences were observed between male and female goats. Male shank meat showed the highest shear force value (5.43 ± 0.71 kgf), while female loin meat had the lowest (2.01 ± 0.34 kgf). This confirms that sex is a major determinant of meat texture in Kacang goats. The biological basis of this phenomenon lies in hormonal regulation. Testosterone, the primary androgen hormone in males, promotes muscle hypertrophy by increasing the synthesis of myofibrillar proteins and collagen cross-linking. These physiological changes enhance muscle strength but reduce tenderness (Al-Juhaimi *et al.*, 2023). Conversely, female goats, with lower testosterone levels, exhibit slower muscle fiber thickening and more uniform collagen distribution, leading to softer meat. Kim *et al.* (2019) also reported that testosterone

stimulates the formation of heat-stable collagen, which reduces solubility and increases toughness.

Table 1. Comparison of Average Meat Tenderness Value (kgf) Based on Body Part and Sex

Sex	Meat Parts	Average (kgf) ± SD
Male	Loin	3.32 ± 0.90
	Shank	5.43 ± 0.71a
Female	Loin	2.01 ± 0.34
	Shank	2.25 ± 0.44

These differences are not only physiological but also biochemical. Male muscles tend to have higher activity and oxygen demand, promoting oxidative stress and altering sarcoplasmic protein profiles, which further affects tenderness. Al-Juhaimi *et al.* (2023) demonstrated that these biochemical pathways persist even when diet and management are standardized. The current study reinforces those findings by showing that, under identical feeding conditions, male goats still exhibited significantly higher shear force values, emphasizing sex as an intrinsic determinant of meat quality. Practically, this result justifies the common preference among local slaughterers for female goats, as their meat is consistently tender and emits a lighter aroma. The data support the idea that sex-based selection before slaughter can enhance the market value and consumer acceptability of goat meat, particularly for traditional dishes where tenderness is crucial.

Influence of Muscle Type and Activity on Tenderness

Differences in tenderness between loin and shank muscles can be explained by the contrasting physiological functions of these body parts. The shank, being a locomotive muscle, contains a higher proportion of connective tissue, primarily collagen and elastin, to support weight-bearing and movement. The loin, on the other hand, functions mainly in posture maintenance, involving less contraction and therefore less connective tissue density (Kim *et al.*, 2019; Al-Juhaimi *et al.*, 2023).

The results showed that male shank meat was the toughest, while female loin meat was the most tender. This finding is consistent with

Gonzalez *et al.* (2024), who stated that collagen cross-linking increases with muscle activity, reducing solubility and tenderness. The WBSF values observed in the current study align with previous studies on tropical goat breeds, confirming that muscle-specific function directly impacts the physical texture of meat. Furthermore, post-mortem degradation of muscle fibers occurs more efficiently in less active muscles, resulting in softer meat after cooking (Mapiye *et al.*, 2024). From a technological perspective, understanding this anatomical variation can help processors optimize cooking and marination methods. For example, enzyme-assisted tenderization or aging techniques could be selectively applied to tougher cuts like shank meat to achieve a more uniform texture.

Relationship Between Nutrient Intake, Enzymatic Activity, and Collagen Solubility

Tenderness improvement is closely related to enzymatic activity, particularly calpains and collagenases. Adequate intake of trace minerals such as zinc and selenium enhances the functionality of these enzymes during post-mortem aging (Muhtarudin *et al.*, 2024). The natural forage used in this study likely provided moderate levels of these nutrients, leading to intermediate tenderness values compared to supplemented feeding systems. Dou *et al.* (2023) highlighted that dietary antioxidants also prevent excessive oxidative stress, which otherwise inactivates proteolytic enzymes and limits tenderization. Therefore, integrating micronutrient-rich feeds or natural antioxidants (such as from legume leaves or fermented feed) could further improve meat texture in traditional systems without major cost increases.

Comparative Context with Previous Studies

When compared to Boer or Saanen goat breeds, the tenderness of Kacang goat meat in this study was slightly lower, likely due to breed-specific collagen characteristics. Rangkuti *et al.* (2024) reported average shear force values of 2.5-3.0 kgf for Boer goats under controlled feeding, whereas Kacang goats in this study ranged up to 5.43 kgf. This difference can be attributed to genetic adaptation; Kacang goats possess more active musculature and leaner body composition suited for tropical environments. Despite this, the tenderness values still fall within

acceptable consumer standards for small ruminant meat. These comparative findings reinforce the need for breed-specific meat quality standards rather than adopting benchmarks from beef or exotic goat breeds (USDA ARS, n.d.). Establishing local reference values will ensure fair evaluation and help improve marketing strategies for indigenous goat meat.

Integrated Interpretation and Implications

Overall, the findings confirm that meat tenderness in Kacang goats results from the combined effects of sex, muscle activity, and nutritional management. External factors such as feed composition and storage conditions interact with intrinsic physiological variables, creating complex variations in tenderness. The consistent pattern across studies (Kim et al., 2019; Al-Juhaimi et al., 2023; Pophiwa et al., 2020) validates that tenderness cannot be optimized through a single factor but requires integrated management encompassing nutrition, genetics, and processing practices.

From an applied perspective, these results hold significant implications for smallholder farming. Female goats should be prioritized for meat-oriented production to achieve consistent tenderness, while nutritional management especially mineral supplementation should be improved. Moreover, tougher cuts from male goats can be value-added through processing innovations such as marination or enzymatic tenderization. This combination of physiological understanding and applied management can enhance product uniformity, increase market value, and support the sustainability of local goat farming in tropical regions.

Conclusion

The tenderness quality of Local Kacang goat meat are the result of a complex interaction between internal factors, such as sex and body parts, as well as external factors, such as maintenance and nutrition management. Although raised with a traditional system that utilizes local forage feed, the data show a significant difference between the tenderness of male and female goat meat. The *Warner-Bratzler Shear Force* (WBSF) test objectively proved that in one-year-old male goats, the thigh meat had a statistically higher *shear force* value ($5.43 \pm$

0.71 a kgf) than *the loin* meat (3.32 ± 0.90 kgf). This difference is scientifically due to the higher density of connective tissue and collagen in the active thigh muscles. In contrast, in female goats, no significant differences were found between the tenderness of *loin* meat (2.01 ± 0.34 kgf) and thigh (2.25 ± 0.44 kgf), which could be attributed to lower levels of the hormone testosterone, resulting in smoother muscle fibers overall.

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