Improving Goat Meat (Longissimus Muscle) Tenderization by Using Moringa Oleifera Leaves

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Abstract. Moringa oleifera leaves has potential as a natural tenderizing agent for goat meat, explicitly targeting the longissimus muscle. The study aimed to improve goat meat tenderization by using Moringa Oleifera and provide an eco-friendly and health-conscious method for improving the quality of goat meat. Treatments with fresh moringa leaves (as paste 10 gr/100 meat) were applied to goat meat samples (Control = Untreated sample, T1 = treated for 3hr, T2 = treated for 6hr). The treat samples were left in the fridge at temperatures 4 to 3 and 6 hr followed by assessments of texture profile (TPA), pH, color, and cooking loss (CL); the results show texture profile (hardness and toughness) significant ($p< 0.05$) between control and treat samples, (Adhesiveness et al.) insignificant ($p< 0.05$), without adverse effects on cooking loss (CL). On the other hand, the Moringa leaves paste increased the PH of treated samples compared with the control. It was some changes in color characteristics, especially in (Redness (a*) and (Yellowness (b*), without adverse effects on (lightness L*); these changes are beneficial for enhancing the visual appeal of particular meat and meat products while also contributing to their nutritional quality to consumers. The present results suggest that Moringa oleifera seems to be a promising source of exogenous enzymes for meat tenderization.

1 Introduction

Red meat is an essential nutrient for the human body. Consumers worldwide are more health-conscious and have pertinent information regarding the effects of food. Among red meats, goat meat has lower fat, which gives it a more complex texture than other red meat. It has saturated fat and cholesterol but a higher polyunsaturated fatty acid content, making it more healthful than other red meat. According to [1], meat tenderness refers to the texture and softness of meat when cooked and consumed. It is an essential characteristic of meat quality and dramatically affects the eating experience [2]. Defined tenderness as the ease with which the consumer perceives a product structure disintegrating by the combination of shear, compression, and grinding actions during mastication. It is one of meat's most important quality parameters in consumer perceptions.

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In the tenderization process, the structural proteins of meat and collagen are degraded to meat toughness [3]. On the other hand, some muscles may lack palatability because of myofibrillar proteins, while others may lack palatability because of connective tissue proteins [4].

Technological advancements have led to the development of several novel methods for maximizing tenderness, benefiting consumers and the meat industry [5]. Among novel methods are plant protease enzymes (such as Papain, Bromelain, Ficin, Actinidin, and Zingibain) are among them; in addition, the plant proteases offer a natural alternative to chemical tenderizers. Using plant-derived enzymes aligns with consumer preferences for clean-label products without artificial additives.

Moringa oleifera is a plant found in some parts of Africa and Asia. Due to its high nutritional content, it has high biotechnology potential [6]. The study [7] Found that using Moringa oleifera leaf powder improved chemical composition and microbial growth. Thus, Moringa Oleifera leaf powder can be utilized as a natural preservative in

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ground beef to enhance its nutritional value and inhibit lipid oxidation.

Limited studies on moringa oleifera, especially those focusing on goat meat, are scarce, and most existing research has concentrated on other types of meat, leaving a gap in understanding how Moringa impacts goat meat quality, particularly in terms of tenderness. There is insufficient exploration into the biochemical mechanisms by which Moringa oleifera contributes to meat tenderization. Understanding the enzymatic activity or the impact of specific compounds in Moringa that facilitate muscle fiber relaxation or collagen breakdown could provide valuable insights. On the other hand, most studies focused on methods for incorporating Moringa leaves into goat diets without directly studying the affected meat tenderization. [8] Concluded that adding Moringa oleifera leaves to the diet of broiler chicks improved meat quality and composition. [9] It was also found that Moringa Oleifera leaves could be used as a feed ingredient for broilers to enhance meat quality and composition without adversely affecting growth performance. The present study highlighted the potential benefits of Moringa oleifera leaves for tenderization. The texture profile analysis yielded new data on how Moringa affects various textural attributes such as hardness, chewiness, springiness, and overall mouthfeel, which are critical to consumer acceptance. This research investigates the effects of M. oleifera leaves on Goat Meat tenderness. The parameters studied include cooking loss, texture profile, acidity (pH), and color.

2 Methods

2.1 Materials

The primary research material is Goat meat (Longissimus muscle Samples of longissimus dorsi muscle were collected between the 9th and 12th rib of the left and right side), obtained from the meat shop after being slaughtered, carried to the lab, put in the freezer for one week, and then used. M. oleifera seeds are obtained from the marketplace, and the leaves are from a farm near campus. The study was conducted in the Faculty of Animal Science (Animal Products Technology Laboratory) at Jenderal Soedirman University, Indonesia.

2.2 The preparation of Moringa Oleifera and the meat samples

We weighed 20g Moringa Oleifera leaves (for each sample) and washed them, and then we created a paste by grinding leaves. The meat samples (each 100 g) were divided into three treatments: T0 (control), T1, and T2; with three replications, we covered the meat generously with the Moringa leaves paste, ensuring it covered the entire surface. We covered them with aluminum foil and put them in the refrigerator (T1 for 3 hours, T2 for 6 hours). The control samples were left as a control without any additions. The samples were analyzed for pH, color, cooking loss, and texture profile.

2.3 Determination of pH

The measurement was done by dipping a calibrated pH-meter probe into a mixture of homogenized meat. All measurements were performed at room temperature.

2.4 Cooking loss (CL)

We cut three cubes from each sample, weighed them, and placed each cube in a plastic bag with labels. Then we Cooked it in a water bath at 80ºC for 15 minutes. Then, the cooked muscles were chilled, blot dry, and weighed. The CL percentage will be determined using the equation “cooking loss % = ((initial sample weight - sample weight after cooking)/ initial sample weight) x 100.” [10].

2.5 Texture Profile Analysis

Texture Profile Analysis was measured using the Food Texture Analyzer. Meat samples were cut into uniform pieces to ensure homogeneity. Then, the meat samples were placed between two plates of the texture analyzer. Parameters measured during these cycles include hardness, springiness, cohesiveness, chewiness, gumminess, Resilience, Firmness, and adhesiveness.

2.6 Color

The colorimetric evaluation of samples treated and controlled was performed using a spectrophotometer to determine the colorimetric parameters L* (Lightness), a* (green to red coordinate), and *b (blue to yellow coordinate).

2.7 Statistical analysis

The obtained data were statistically analyzed using the Windows SPSS program (Versions 20 and 22). color for parameters of T1, T2 treatments, and control (T0) were analyzed using the General Linear Model. At the same time (texture profile, PH, and cooking loss) were tested using one-way ANOVA, followed by Duncan's multiple range test, which was used to compare the difference between means (Data expressed as mean values ± standard deviation (SD) ($p<0.05$) was the accepted significance level for all comparisons, and the experiments were conducted in triplicates.

3 Results

3.1 Effects of Moringa Oleifera paste on the Texture profile analysis of goat meat (longissimus muscle)

Table 1 shows the texture profile analysis (TPA) parameters of the control (T0), T1, and T2 treatments from longissimus muscle treated with Moringa paste and stored for different durations (3 and 6 hours) at a temperature of 4°C. At both 3 and 6 hours, a significant difference ($p < 0.05$) in hardness was observed compared to the control. The analysis revealed significant differences ($p < 0.05$) in toughness at all treatments, but the ratios were noted less in 3-6 hours compared with control samples. Additionally, there were significant differences in chewiness or firmness when comparing all treatments and the control, but the ratio was firmness less in the 3-6-hour treatment compared with the control. Similarly, there were significant differences in toughness when comparing all treatments, but the ratio was less in the 3-hour compared with the 6-hour treatment and the control. For the other texture attributes, adhesiveness, springiness, cohesiveness, resilience, and gumminess, significant differences were found between the treated and the control samples, with different ratios.

3.2 Effects of Moringa leaves paste on the PH and cooking loss of goat meat (longissimus muscle)

Table 2 shows significant differences between all treatments and controls regarding PH and cooking loss.

3.3 Effects of Moringa leaves paste on the color of goat meat (longissimus muscle)

Table 3. shows significant differences between treatments and controls in color, observed on Redness (a*) the percentage was lower in 3-hour more than in 6-hour and control, which was 5.73 ±1.80, and also, (Yellowness (b*) the rate was higher in 3-hour more than 6-hour and control which was 13.04 ± 3.38, with a smaller percentage in Lightness (L*) in all treatment and control.

4 Discussion

In order to control the effects of treatment with Moringa oleifera leaves on improving the Tenderness of goat meat, it is essential to understand how these leaves influence the organoleptic quality, particularly texture. Key texture attributes like (Hardness, Chewiness, Firmness, Toughness, Adhesiveness, Gumminess, Cohesiveness, Springiness, and Resilience) were notably affected by the moringa treatment. Toughness, defined as a material's ability to absorb energy and deform without breaking, is significant as it relates to the ease of cutting and chewing the meat. Changes in toughness suggest that Moringa could make the meat more palatable [11]. Some cuts of meat can present resistance during mastication. This resistance can lead to oral discomfort, especially for elderly consumers, potentially discouraging them from eating meat. Thus, Moringa Oleifera leaves could offer a solution to enhance meat tenderness and improve overall consumption experiences for this demographic. Tender steaks often come with a high price tag, limiting access for many consumers.

The changes in hardness due to Moringa Oeifera indicate its potential to enhance the softness of meat, which can significantly improve the sensory experience during consumption. Increase in softness in raw samples treated with papain [12]. Additionally, the observed changes in chewiness and firmness suggest that Moringa facilitates the breakdown of meat fibres, making it easier to chew. Alterations in firmness also play a critical role in overall mouthfeel and the eating experience. Marinating chicken thighs in kiwi protein for varying durations at 4 ± 1 °C improved chewiness and reduced hardness. Their study highlighted that the duration of enzyme exposure significantly affected the degradation of meat proteins, similar to the effects noted with the

Moringa treatment. Overall, these findings suggest that *Moringa oleifera* could effectively improve the Tenderness and palatability of goat meat, making it more accessible to a broader range of consumers.

The results indicate that when comparing samples treated with Moringa oleifera to the control (untreated) samples, there were significant differences in texture attributes, including adhesiveness, springiness, cohesiveness, resilience, and gumminess, with ratio differences. This suggests that the treatment with *Moringa oleifera* has a notable impact on these specific texture characteristics; these findings may imply that other factors, such as the duration of storage or the amount of moringa leaf paste used in the study, could have influenced the outcomes. Further research could explore different treatment times or concentrations of Moringa to determine if they yield more pronounced effects on these texture attributes.

Further investigation into these variables could provide deeper insights into optimizing the use of Moringa oleifera for improving meat texture. Tenderness and overall acceptability increase significantly when using Moringa oleifera leaf extract on goat meat nuggets [14].

Moringa oleifera leaf extract had no effect on shear value, which is inconsistent with the present study's findings [15]. Several factors, including the animal's pre-mortal handling and post-mortem methodologies (such as the chilling regime, electrical stimulation, or hanging method) and those during aging, influence the shear force values, on the other hand, optimal storage conditions and appropriate processing techniques can enhance protease activity within the meat, potentially improving tenderness [16]. Additionally, Tenderness is influenced by muscle type, as meat toughness is associated with the integrity of two muscle structure components: connective tissue (commonly referred to as "background toughness") and sarcomere shortening (the contractile apparatus of the muscle) that occurs during the development of rigor mortis [1].

The PH and tenderness in goat meat are significant and are affected by many factors pre- and post-mortem. The PH is vital because it affects meat's physic-chemical composition and quality properties [17]. This study showed significant differences in PH consistent with the present study [18], which studied the effect of Moringa oleifera leaf extract on raw beef stored in modified atmosphere packaging under 12 days of refrigerated temperature. It was proven that it has a significant impact on PH. Treatment and storage periods have significantly decreased the pH of raw nuggets [14].

Cooking loss refers to the reduction in weight of products during the cooking process. It is an important parameter used to predict how products behave during processing. This study showed significant differences in cooking loss among all treatments and controls. This finding is consistent previous study result [14], who reported substantial differences in the cooking loss of nugget samples across various storage treatments. The decreasing trend in cooking loss observed in their study may be attributed to denatured meat proteins and reduced water and fat loss from the nuggets.

Moringa oleifera leaves have been shown to significantly influence the color of meat, particularly in processed meat products like patties, where lightness (L*), Redness (a*), and yellowness (b*) significantly decreased according to [19] A study on the influence of Moringa leaf extract on the nutritional properties of meat products found that the effects are attributed to the high levels of antioxidants and green pigments in the leaves [20]. Suggests that dietary supplementation with moringa leaves can enhance the overall color quality of meat by improving its visual appeal. By adding moringa leaves by up to 4%, the color can be intensified. This is consistent with the study on Moringa oleifera leaves to improve goat meat, which changed color characteristics. These changes enhance the visual appeal of particular meat and meat products while contributing to consumers' nutritional quality.

The sustainability development Goals of this study, investigating Moringa as a sustainable alternative to synthetic tenderizers, align with current trends toward natural food additives to attract interest from both consumers and producers focused on sustainable practices; also, given that goat meat is a staple in many cultures, particularly in developing regions, exploring practices of using Moringa could provide culturally relevant insights into improving meat quality while respecting traditional methods. The findings from this study on the tenderization of goat meat could potentially be extrapolated to other ruminants, creating a broader impact on livestock management practices across different species. Finally, the research on improving goat meat tenderization using Moringa oleifera leaves can contribute significantly to academic knowledge and practical applications in the meat industry.

Table 1. Texture profile analysis (TPA) (means ± standard deviation) affected by Moringa leaves paste during different aging pe

Item	Control	Tenderization period (hr.)	
	0	3	6
Hardness (g)	4720.313[b] ± 2354.28	2759.168[a] ± 1204.42	2503.25[a]
Chewiness (mJ)	1057.018[b] ± 670.86	608.2167[ab] ± 277.43	505.888[a]
Firmness	3971.5617[b] ± 885.95	3043.4017[a] ± 520.80	3790.160[ab]
Toughness	25448.591[b] ± 5561.73	18077.025[a] ± 2738.70	24287.745[b]
Adhesiveness	-47.17817[a] ± 30.31	-46.2688[b] ± 9.08	-40.2451
Gumminess (g)	1886.873[c] ± 959.17	1081.433[b] ± 513.26	1070.771[a]
Cohesiveness	0.40200[b] ± 0.08	0.38800[a] ± 0.04	0.43517
Springiness (mm)	0.54133[b] ± 0.14	0.58100[c] ± 0.13	0.48417
Resilience	0.24833[c] ± 0.06	0.21067[a] ± 0.03	0.2295[b]

Different letters in the row indicate significant differences between means (p 0.05).

Table 2. PH and cooking loss (means ± standard deviation) affected by Moringa leaves paste during different aging periods at

Item	Control	Tenderization period (hr.)	
	0	3	6
PH	5.88 [a] ± 0.24	5.99 [b] ± 0.18	6.2 [c] 1± 0.37
Cooking loss (%)	36.78 [a] ± 1.59	37.58 [a] ± 3.29	36.80 [a] ± 3.42

Different letters in the row indicate significant differences between means (p 0.05).

Table 3. Color (means ± standard deviation) affected by Moringa leaves paste during different aging periods at a temp

Item	Control	Tenderization period (hr.)	
	0	3	6
Color			
Lightness (L*)	43.72 [a] ± 2.9	42.01[a] ± 2.76	45.33 [a]± 8.20
Redness (a*)	6.51[b] ± 1.42	5.73 [a] ± 1.80	6.43[b] ± 1.86
Yellowness (b*)	11.85[a] ± 2.18	13.04 [b] ± 3.38	11.54[a] ± 2.36

Different letters in the row indicate significant differences between means (p 0.05).

Enhancing goat meat quality through natural additives like Moringa can increase farmers' productivity and profitability, supporting local economies and food systems. By improving the Tenderness and overall quality of goat meat, Moringa supplementation can lead to better consumer health outcomes. Moringa is a natural additive that reduces the need for synthetic tenderizers or antibiotics, leading to safer food products for consumers. Moringa leaves can be sourced from local agricultural practices, reducing waste and promoting a circular economy within livestock production.

5 Conclusion

The study concluded that Moringa oleifera significantly enhances goat meat's hardness, chewiness, firmness, and toughness, with minor effects on pH, cooling loss, or color. Further research is recommended to explore various application methods for Moringa, including different extraction techniques and concentrations. Additionally, long-term studies on consumer preference metrics would provide valuable insights into the market potential for Moringa-treated goat meat. Incorporating Moringa oleifera leaves in meat changed color characteristics, enhancing the visual appeal of particular meat and meat products while contributing to their nutritional quality. Applying Moringa leaves as a natural additive for improving goat meat tenderization supports multiple Sustainable Development Goals. By enhancing nutritional quality, promoting sustainable agricultural practices, and contributing to climate action, this approach offers a holistic solution that benefits farmers, consumers, and the environment.

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