Journal of Food and Nutrition Sciences
2024, Vol. 12, No. 2, pp. 107-118
https://doi.org/10.11648/j.jfns.20241202.13

Research Article

Development of Natural Liquid and Powdered Meat Tenderizer Based on Papaya Peel, Ginger and Garlic

Abdulsudi Issa-Zacharia*, Happiness Samuel Muhimbula, Anastazia Niyonkulu Bikuba, Joachim Dotto Matondo

Department of Food Science and Agro-Processing, School of Engineering and Technology, Sokoine University of Agriculture, Chuo Kikuu, Morogoro, Tanzania

Abstract

Recently, the application of exogenous enzymes for meat tenderization has turned the attention of food technologists and meat scientists. This research investigates the synergistic impact of natural tenderizers derived from the combination of papaya peels (P), ginger (G), and garlic (Ga) on the sensory attributes of goat meat such as color, aroma, taste, tenderness and overall acceptability. The tenderizers were formulated in different concentration ratios of 3:2:1 in both liquid and powdered form. The sensory quality parameters for all tenderized goat meat samples under observation including the control, were evaluated by 60 semi-trained panelists using a five-point hedonic scale. The effect of tenderizers was compared to the control which was devoid of tenderizing ingredients. Tenderness was greatly improved ($p<0.05$) by tenderizer P:G:Ga (3:2:1) in both liquid and powder forms at 45- and 90- minutes of tenderization. Alternatively, liquid and powdered Ga:G:P (3:2:1) were highly significantly rated ($p<0.05$) in taste compared to all other tenderizer formulations for 45- and 90-minute tenderization. From the samples tested, the control sample in both setups was the least rated in all sensory attributes, except for color in powdered tenderization. Generally, liquid and powdered P:G:Ga (3:2:1) and Ga:P:G (3:2:1) tenderizers received significantly higher ($p<0.05$) overall acceptability scores than G:G:aP (3:2:1) and the control sample. While liquid tenderizers mostly performed better compared to powdered tenderizers for all sample combinations, there was a significant improvement ($p<0.05$) in tenderness when both liquid and powdered tenderizers were used for 90 minutes compared to 45-minute marination. This suggests that, the longer the tenderization time, the greater the effect on tenderness. These findings underscore the importance of natural tenderizers in enhancing consumer satisfaction with meat products.

Keywords

Natural Tenderizer, Papaya, Garlic, Ginger, Sensory Quality, Goat Meat

1. Introduction

Meat is the most valuable livestock product and is the first choice of animal protein for many people. After slaughter, the animal's natural process or rigor mortis shortens muscle protein fibers and results in meat becoming tough [15]. Consumer acceptance of meat is heavily influenced by the eating quality of both fresh and processed meat, encompassing factors like color, flavor, juiciness, water holding capacity, cooking losses, and texture. Tenderness stands out as the key

*Corresponding author: aissazac@gmail.com (Abdulsudi Issa-Zacharia)

Received: 29 February 2024; **Accepted:** 15 March 2024; **Published:** 12 April 2024

factor impacting consumer satisfaction and overall taste perception [15, 25]. The animal's sex, age, muscle type, species, and state of nutrition are several factors that may affect the tenderness of meat [5].

Meat tenderization is a complex process that involves several sub-mechanisms, including aging-related chemical and structural changes, post-slaughter breakdown of myofibrillar proteins, breakdown of collagen, reduction of muscle fiber bundle diameter, and changes in sarcomere length during rigor mortis [10]. The concept mainly applies to red meat due to its high toughness (beef, mutton, horse, pork, buffalo, and lamb), and is minimally related to white meats such as chicken and fish [5, 25].

Recently, the application of exogenous enzymes for meat tenderization has become an increasing focus of interest among food technologists and meat scientists. Natural meat tenderizers are fruits and vegetables that contain proteolytic enzymes that are responsible for the tenderization of tough meat, such as pineapple, kiwi fruit, papaya, and mango, as well as ginger, garlic and tea [8] Plant proteases are proven to improve meat tenderness by the mechanism of proteolytic degradation [25]. They have unique properties and activity over a wide variety of pH and temperature, as well as large stability and substrate specificity that make them suitable to tenderize meat [14]. Exogenous enzymes that are added to meat to enhance tenderness react differently to the myofibrillar and connective tissue portions [21]. The common exogenous plant proteases used in meat tenderization are *bromelain, papain, ficin, actinidin* and *zingibain* [16]. These proteases breakdown the muscle proteins in the connective tissues by hydrolyzing the peptide linkages in the proteins in to the peptides and finally in to amino acid components, thereby reducing meat's toughness [25]. Papain is a protease of 212 amino acids that has a molecular mass of 23KDa which is extracted from papaya (*carica papaya*) latex [14]. It is one of the most common plant enzymes used for the artificial tenderization of meat due to its ability to break down both myofibrillar proteins and connective tissues [21]. Another protease is zingibain which is extracted from zingiber officinale roscoe (*Ginger rhizome).* Ginger is an aromatic and spicy food that is widely used in places all over the world. The ginger protease is a thiol proteinase with an optimum activity at 60 ℃ [34]. Zingibain expresses a greater proteolytic activity on collagen than actomyosin, and thus the combined proteolytic activity of these two muscle proteins improves the tenderness of meat [2, 34]. Garlic is known for its antifungal, antibacterial, hypolipidemic, anti-atherosclerosis, and anticarcinogenic properties, not to mention that garlic is a world-famous culinary spice [9].

The quality of meat products is a major issue that affects both the meat industry and consumers [22]. In Tanzania, the quality of meat is highly affected by both pre-slaughtering and post-slaughtering factors [26]. The majority of research on meat tenderness focuses on the use of various natural, chemical, mechanical, and chemical tenderizers; however, some of these chemical tenderizers have been found to have limitations when used in restaurants or at home, which means they only partially succeed in softening tough meat [36]. In addition to that, natural meat tenderizers are not expensive compared with other types of meat tenderizers. Some can be prepared at home not necessarily to be produced from industry although industrial made meat tenderizers saves time for preparation of meat. Therefore, it is very important to determine the combination effect of papaya, garlic and ginger on the tenderization of meat and overall acceptability. This is important for domestic households and other small unit restaurants in tenderizing meat, and thus ensuring consumer acceptability and satisfaction.

2. Material and Methods

The study was conducted in Morogoro municipality. Papaya peels, ginger, and garlic were obtained from Kingalu market in Morogoro district council and subsequently taken to the laboratory of the Department of Food Science and Agro-processing at Sokoine University of Agriculture. A natural meat tenderizer was developed using papaya peels, garlic, and ginger in a food science laboratory.

2.1. Research Design

A cross-sectional research design was used in this study. The study was empirical since it involved laboratory setting. A relationship was established between a dependent variable (meat tenderness) and independent variable (natural meat tenderizer).

2.2. Sample Preparation and Analysis

2.2.1. Preparation of Liquid Tenderizer from Papaya Peels, Ginger and Garlic

Papaya, ginger, and garlic were purchased from a local market in Morogoro. The papaya, ginger, and pepper were peeled, washed with distilled water to remove dirt, and then sliced or cut into small pieces. The papaya was peeled to acquire the papaya peels that were for further analysis. The papaya peel, garlic, and ginger were individually mashed into paste. This paste was subsequently blended with an equal amount of chilled distilled water in a blender (Make: Ploytron PT 2100) for 1 to 2 minutes. The homogenate of papaya, garlic, and ginger solutions was separately squeezed through 4 layers of muslin cloth and preserved for future use [28] in the formulation of liquid tenderizer in Table 1.

2.2.2. Preparation of Garlic Powder

A clean, mature, fresh garlic bulb without worm eaten or stain was peeled, crushed to make garlic paste and dried. Using a garlic paste grinding machine, garlic bulbs were ground to the garlic paste and put in to a drying oven at a temperature of 60-65 ℃ for 6-8 hours. After every 2 hours of oven-drying, the garlic paste was turned over to allow evenly drying. After that, the dried garlic

paste was ground using an electric grinder and sieved using a 45 mesh (355 micron). The garlic powder was collected, packed in to polyethene bags and stored for further use.

2.2.3. Preparation of Ginger Powder

Fresh ginger rhizomes purchased from local market in Morogoro were thoroughly hand-scrubbed and washed in running tap water, twice. Afterwards, they were peeled to remove the scaly epidermis to facilitate drying. Ginger rhizomes were cut in to 2-5 mm slices to reduce the drying time. Initially, they were dried under the sun and later oven dried at 50±5 ℃ for 6-8 hours. Dried ginger slices were ground using an electric grinder and sieved using a 45 mesh (355 micron) for making fine powder. Prepared ginger powder was stored at 4 ℃ in low dense airtight polyethylene bags for further analysis.

2.2.4. Papaya Peel Powder

The papaya fruit (*Carica papaya*) was obtained from the local market in Morogoro, thoroughly washed with distilled water to eliminate debris, and then peeled. The peeled samples were dried in the oven at 105 ℃ for 24 hours until they reached a crisp texture. The oven-dried samples were ground using an electric grinder and sieved using a 45 mesh (355 micron). The final powder was stored in an airtight container for the further tenderization process.

2.2.5. Liquid and Powdered Tenderizer Formulations

Tenderizer formulas were developed (P:G:Ga = Papaya:Ginger:Garlic-, G:Ga:P=Ginger:Garlic:Papaya, and Ga:P:G: Garlic:Papaya:Ginge) in liquid and powder forms. Additionally, a control formulation was developed and it contained only oil (10 ml), salt (7.5 g), and vinegar (7.5 ml). For the liquid tenderizer formulation, the pre-prepared liquid papaya, garlic, and ginger were used to formulated a tenderizer in a combination ratio of 3:2:1 interchangeably as shown in Table 1. The powder form of meat tenderizer was also formulated in the similar ratio as described in Table 2. The powder form meat tenderizer was kept away from moisture by packing in paper bags and stored at cool temperatures of about 20 ℃. During the experiment, one table spoon was applied to one kilogram of meat to test the tenderization effect. The shelf-life of powder meat tenderizer is about one year [24].

Table 1. *Formulation of liquid meat tenderizer based on Papaya peel, Ginger and garlic.*

Tenderizer	Tenderizer Formulation Ingredients						
	Papaya peel (ml)	Ginger (ml)	Garlic (ml)	Oil (ml)	Salt (g)	Vinegar (ml)	Total (ml)
P:G:Ga^{L}	250	170	80	10	7.5	7.5	525
G:Ga:P^{L}	80	250	170	10	7.5	7.5	525
Ga:P:G^{L}	170	80	250	10	7.5	7.5	525
CONTROL	0	0	0	10	7.5	7.5	25

The liquid formulations of tenderizer from the mix of ginger, papaya and garlic were all made at the ratio of 3:2:1, where; P:G:Ga^{L}=Papaya:Ginger:Garlic-liquid mix, G:Ga:P^{L}=Ginger:Garlic:Papaya-liquid mix, and Ga:P:G^{L}: Garlic:Papaya:Ginger-liquid mix

Table 2. *Formulation of powdered tenderizer based on papaya peel, ginger and garlic.*

Tenderizer	Tenderizer Formulation Ingredients						
	Papaya peel powder (g)	Ginger powder (g)	Garlic powder (g)	Oil (ml)	Salt (g)	Vinegar (ml)	Total (g)
P:G:Ga^{P}	28	18	9	10	7.5	7.5	80
G:Ga:P^{P}	9	28	18	10	7.5	7.5	80
Ga:P:G^{P}	18	9	28	10	7.5	7.5	80
CONTROL	0	0	0	10	7.5	7.5	25

The powdered formulations of tenderizer from the mix of ginger, papaya and garlic were all made at the ratio of 3:2:1, where; P:G:Ga^{P}=Papaya:Ginger:Garlic-powder mix, G:Ga:P^{P}=Ginger:Garlic:Papaya-powder mix, and Ga:P:G^{P}: Garlic:Papaya:Ginger-powder mix

2.2.6. Preparation of Goat Meat Chunks

Immediately after slaughter, the goat meat chunks were obtained from the slaughter unit, packed in low-density polyethylene bags and stored in a refrigerator at 4±1 ℃ for 24 hours. After 42-hour chilling, muscles were taken out of the refrigerator and cut in to small chunks of approximately 3 cm^3 size. Goat meat chunks were randomly divided in to eight-500 g groups and packed in paper foils for further procedures.

2.2.7. Tenderization and Goat Meat Cooking

A 10 ml or grams of formulated natural tenderizer (P:G:Ga = Papaya:Ginger:Garlic, G:Ga:P=Ginger: Garlic:Papaya, and Ga:P:G:Garlic:Papaya:Ginge) and the control was added to 500g of the chopped goat meat chunk samples [17]. All samples, were flavored with about 5g of mixed spices (cardamom, turmeric and black pepper) and were left to marinate for 45 minutes while the other group of samples were left to marinate at room temperature (22-27 ℃) for 90 minutes. The samples were cooked in an oven for 1 h at a temperature of 180 ℃. The samples were removed from the oven, left to cool and distributed to the panelist for sensory evaluation. Sample analysis was conducted at the Department of Food Science and Agro-processing at the Sokoine University of Agriculture.

2.3. Sensory Evaluation

The meat quality parameters were evaluated in different cooked goat meat samples treated with various tenderizers and the control at different time intervals. Sensory evaluation was carried out for cooked goat meat samples using a five (5) point hedonic scale, (whereby, 1=dislike extremely to 5= like extremely). A total of 60 semi-trained panelists from the Department of Food Science and Agro-processing were used to assess the sensory attributes (color, aroma, tenderness, taste and overall acceptability) of the tenderized cooked goat meat samples. Sensory analysis was conducted at the Department of Food Science and Agro-processing, at Sokoine University of Agriculture.

2.4. Data Analysis

The data obtained were analyzed by the statistical package for social sciences (SPSS, V26), whereby, one way Analysis of Variance (ANOVA) was performed. There in which three dependent variables are compared to perform sensory evaluation, especially tenderness of meat. Turkey's post-hoc was used for means separation at the 5% level of significance. An independent t-test was conducted to determine the effect of time on sensory attributes.

3. Results and Discussion

3.1. The Effect of Different Natural Tenderizer Formulations on the Sensory Attributes of Goat Meat

3.1.1. Effect of Combined Liquid or Powder Tenderizer Applied for 45 Minutes

This study investigated the impact of three liquid or powder tenderizers formulated with varying combinations of papaya peel, ginger, and garlic (P:Ga:G, G:Ga:P, and Ga:P:G) on the sensory attributes of goat meat compared to a control sample. The results of synergistic effects of papaya peel, ginger, and garlic as a liquid tenderizer, applied for 45 minutes, on the sensory attributes of goat meat are shown in Table 3. The effectiveness of both liquid and powder meat tenderizers depends on several factors including the type and concentration of enzymes, meat thickness and duration of application [29]

Table 3. *Effect of combined liquid and powdered tenderizer applied for 45 minutes on sensory attributes of goat meat.*

a. Liquid tenderizer

	Color	Aroma	Tenderness	Taste	Overall acceptability
P:G:Ga^L	4.67±0.479^a	4.30±0.479^a	3.63±0.669^a	4.23±1.006^b	3.80±0.466^b
G:Ga:P^L	3.50±0.572^b	2.90±0.481^a	3.10±0.96^b	2.90±0.845^a	2.20±0.664^a
Ga:P:G^L	4.53±0.629^a	4.03±0.490^b	2.97±0.414^b	4.13±0.681^b	3.70±0.407^b
Control	2.70±1.208^b	1.50±0.974^a	1.27±0.691^b	1.27±0.521^a	1.63±0.890^a

b. Powdered Tenderizer

	Color	Aroma	Tenderness	Taste	Overall acceptability
P:G:Ga^{P}	2.97 ±0669^{a}	3.60 ±0.629^{b}	3.93 ±0.758^{a}	3.33 ±0.758^{b}	3.90 ±0.305^{b}
G:Ga:P^{P}	2.97 ±0.718^{a}	3.67 ±0.479^{b}	3.47 ±0.681^{a}	3.00 ±0.525^{b}	3.40 ±0.498^{b}
Ga:P:G^{P}	3.37 ±0.430^{a}	3.97 ±0.928^{b}	2.97 ±0.490^{a}	3.98 ±0.254^{a}	3.77 ±0.679^{b}
Control	3.07 ±0.928^{a}	1.93 ±0.828^{a}	1.27 ±0.450^{b}	1.33 ±0.549^{c}	1.50 ±0.877^{a}

The liquid/powdered formulations of tenderizers from the mix of ginger, papaya and garlic were all made at the ratio of 3:2:1, where; P:G:Ga=Papaya:Ginger:Garlic, G:Ga:P=Ginger:Garlic:Papaya, and Ga:P:G: Garlic:Papaya:Ginger. The superscripts in the first column (L and P) refer to liquid and powder, respectively. The superscripts with different letters along the sensory attribute columns show a significant difference at $p<0.05$.

Trials in the current study has shown that using liquid tenderizers leads to improved sensory qualities including color, aroma, taste, tenderness, and overall acceptability. Liquid meat tenderizers penetrate faster, ensuring even tenderization. They are also easy to apply and simpler to use than powdered tenderizers [29]. This study compared tenderizers with different proportions of ingredients. Papaya leaves, ginger, and garlic were the ingredients. The ingredients utilized in marinade formulations are critical in achieving the desired sensory properties, such as flavor and texture, that ultimately determine the quality of the end products [11].

Effect of natural tenderizer on Tenderness

Tenderness is widely considered as the most important eating quality attribute associated with consumer preferences [27]. From the results in Table 3(a), although all tenderized samples P:G:Ga^{L}, G:Ga:P^{L}, and Ga:P:G^{L} showcased significantly improved tenderness scores (3.63, 3.10, and 2.97) compared to the control (1.27), only P:G:Ga^{L} demonstrated statistically superior tenderness ($p<0.05$). This indicates that P:G:Ga^{L} served as the most effective tenderizer, achieving a significant textural improvement. Similar to the liquid tenderizer, P:G:Ga^{P}, G:Ga:P^{P}, and Ga:P:G^{P} were not significantly different ($p>0.05$) in terms of tenderness. However, the powdered tenderizer P:G:Ga^{P} outperformed all the other formulations with the highest mean score of 3.93 as depicted in Table 3(b). The control sample scored significantly lower ($p<0.05$) and was the least desirable by the panelists.

The current study revealed a significant difference in tenderness across various tenderizers utilized for goat meat tenderization treatments, at a $p< 0.05$. Tenderness is an important quality trait that determines consumer's satisfaction with repeated purchases and willingness to pay premium prices [37]. While the control sample was less appealing, the results of the current investigation showed that goat meat chunks treated with a combination of tenderizers P:G:Ga were rated as highly desired. The high quantity of papain enzyme in tenderizer P:G:Ga may have caused this outcome, followed by ginger and a lower concentration of garlic which also influenced tenderness. In biochemical investigations, papain is utilized, for example, in meat tenderization tests. Following slaughter, hens treated with papain reported significantly higher levels of tenderness, juiciness, and overall acceptability [1]. Ginger rhizome has been shown to have a powerful proteolytic enzyme, which can be used as a tenderizing agent for tough meat, with an additional antioxidant property [34]. According to a study by Akpan & Omojola [3], the enzyme-treated meat samples showed a gradual reduction in shear force, with an increase in papain enzyme concentration. That was mainly due to the effect of papain and proteases on improving the meat quality, as a result of the biochemical changes of the tenderized meat. Papain enzyme is good for meat tenderization, which is why the papain meat sample scored the highest overall. The combination of papain and ginger is effective in meat tenderization. A significant increase in collagen solubility and sensory scores was observed when ginger, papain, and their mixture were added to burger patties with a significant reduction in shear force [39]. The control sample was less desirable since it was marinated with vinegar, oil, and salt. These results are in line with the research findings of Fencioglu et al. [12], which showed that the beef samples treated with vinegar did not show any significant increase in tenderness, since there was no difference in hardness, water content, cooking loss, and chewiness. A study by Abdel-Naeem & Mohamed [2] also concluded that, addition of ginger and papain and their mixture resulted in significant ($p<0.05$) increase of the collagen solubility and sensory scores with significant reduction of the shear force values.

Effect of natural tenderizer on the color

The liquid tenderizers P:G:Ga^{L} and Ga:P:G^{L} exhibited notably similar but superior color scores ($p<0.05$) as compared to G:Ga:P^{L} (Table 3a) suggesting a more visually appealing appearance. Among the three liquid formulations, G:Ga:P^{L} notably received the lowest score that was not significantly different from control ($p>0.05$), suggesting potential undesirable discoloration. The inclusion of papaya peel, ginger, and garlic in varying ratios within P:G:Ga^{L} and Ga:P:G^{L} likely contributed to their favorable color profiles. On the other end, the synergistic effect of papaya peel, ginger and garlic as a powdered tenderizer applied for 45 minutes on the

sensory attributes of goat meat. From the results in Table 3(b), it was observed that there was no significant ($p>0.05$) difference in all the applied powdered tenderizer formulations. However, the sample containing higher garlic concentration ($Ga:P:G^{P}$) tended to have a higher mean color score of 3.37. Lipid oxidation is a major factor influencing meat quality. It occurs ubiquitously in muscle foods and is responsible for the development of off-flavor and discoloration in a variety of meat [20]. The color of meat is a pivotal qualitative trait that significantly affects consumer satisfaction and serves as a vital marker for meat utilized in culinary and associated sectors [11]. Garlic (*Allium sativum L.)* is a major food ingredient widely used in our cookery. Allium possess antioxidant properties, and contain powerful sulfur and phenolic compounds which have been of great interest as antioxidants [20]. Antioxidants are applied in the meat processing industry to prevent lipid oxidation which can lead to undesirable changes in quality attributes such as color, taste and aroma [35]. Garlic has been shown to have effective antioxidant activity in chicken sausages, in ground beef, in broiler diets and in pig diets [20]. In all tenderizer formulations, at different time treatments, tenderizer A was known to have a higher acceptability than other tenderizer formulations.

Effect of natural tenderizer on the aroma

Paralleling the color assessment, $P:G:Ga^{L}$ and $Ga:P:G^{L}$ obtained significantly higher ($p<0.05$) aroma scores (4.30) compared to the control (1.50) and $G:Ga:P^{L}$ (2.90) as revealed in Table 3(a). This implies that the presence of papaya peel and ginger in $P:G:Ga^{L}$, and garlic in $Ga:P:G^{L}$, introduced desirable aromatic tones. Application of powdered tenderizer gave more or less similar results on goat meat tenderization. Although aroma scores for the formulations $Ga:G:Pa^{P}$, $G:Ga:Pa^{P}$ and $Pa:G:Ga^{P}$ did not significantly differ ($p>0.05$), they all showed significantly higher aroma scores ($p<0.05$) of 3.97, 3.67 and 3.60, respectively, as compared to the control (1.93) sample (Table 3(b)). Marination with tenderizer Ga:P:G scored the pronounced acceptability in terms of aroma. This formulation has a high concentration of garlic and ginger. Ginger contains up to 3% of an essential oil that causes the aroma of the spice [34]. This notably explains that the various seasonings applied (papaya, garlic and ginger) contributed to the aroma of the tenderized meat samples. The observed similarity between the formulation on aroma could be due to presence of other spices and seasoning that play a role in influencing the attributes making the natural tenderizers used in the experiment less affective and similar to the control. Spices and seasoning used (turmeric, cinnamon, cardamom and black pepper) have peculiar properties that influence the meat's aroma, overall acceptability and taste. Turmeric possesses a sweet aroma and commonly used to remove rancid smell in food [7], while cardamom and cinnamon possess sweet spice smell and taste that enhances the meat flavor [38]. On the other hand, black pepper has a sharp, penetrating aroma and characteristic woody piney flavor that is desire by many consumer [6].

Effect of natural tenderizer on the Taste

Interestingly, from Table 3(a), the formulations with higher papaya ($P:G:Ga^{L}$;4.23) and garlic ($Ga:P:G^{L}$;4.13) concentrations, exhibited statistically higher taste scores ($p<0.05$), than both $G:Ga:P^{L}$ (2.90) and the control (1.27). These results suggest that the incorporation of papaya peel, ginger, and garlic favorably influenced the taste perception of the goat meat. Likewise, powdered tenderizer with high garlic concentration ($Ga:G:Pa^{P}$) had significantly higher score of 3.98 ($p<0.05$) demonstrating its high preference in terms of taste (Table 3(b)). This is because this tenderizer formulation is rich in garlic and ginger which are good seasonings, imparting a good taste to the tenderized goat meat. On the other hand, the control sample which was treated with only vinegar, salt and oil was the least preferred with a mean score of 1.5. Formulations with higher papaya (P:G:Ga) and garlic (Ga:P:G) concentrations, which exhibited statistically higher taste scores ($p<0.05$), could be due to fact that tenderizer Ga:P:G is made up of a higher concentration of garlic and ginger similarly to the higher amount of papain in P:G:Ga. Seasonings and spices add flavor to the meat. The taste and aroma of meat and meat products is enhanced after biological marination [11]. Ginger possesses a mixed composition of zingerone, shogaols and gingerols which are responsible for the pungent taste of ginger [34].

Effect of natural tenderizer on the Overall acceptability

Overall acceptability, as it pertains to food, refers to how satisfied or approved a product is by consumers. The degree to which a product meets the needs and wants of its target audience is quantified by this metric [13]. In the meat business, overall acceptability is key since it shows how well a product satisfies customers' sensory expectations and tastes. Generally, $P:G:Ga^{L}$ (3.80) and $Ga:P:G^{L}$ (3.70) received significantly higher overall acceptability scores ($p<0.05$) than $G:Ga:P^{L}$ (2.20) and the control (1.63). These findings aligns with the positive assessments observed in color, aroma, and tenderness for $P:G:Ga^{L}$ and $Ga:P:G^{L}$ compared to the control and $G:Ga:P^{L}$. Tenderizers comprising papaya peel, ginger, and garlic in various ratios were generally preferred by the panelists. Tenderization of goat meat using powdered tenderizer for 45 min resulted in improved degree of acceptability. Overall acceptability among all formulated powdered tenderizers ($P:G:Ga^{P}$, $G:Ga:P^{P}$, and $Ga:P:G^{P}$) did not significantly differ ($p>0.05$), $Pa:G:Ga^{P}$ showing the highest mean score of 3.90. The control sample, however, scored significantly lower ($p<0.05$) than tenderizers. The results indicated that samples treated with enzymes demonstrated enhanced flavor, aroma, tenderness, and overall acceptability compared to the control sample. Ginger's protease enzyme in ginger can break down protein, making goat meat tender in marinades, whereas papain in papaya used in the current study can break down myofibrillar proteins and connective tissues [39]. Ginger's protease enzyme can degrade protein, resulting in the softening and tenderizing of meat in marinades. Papain can break down both myofibrillar proteins and connective tissues in goat meat, resulting in increased tenderness [39].

3.1.2. Effect of Combined Liquid or Powder Tenderizer Applied for 90 Minutes

This study examined how three different liquid or powder tenderizers, using different combinations of papaya peel, ginger, and garlic (P:Ga:G, G:Ga:P, and Ga:P:G), affected the sensory characteristics of goat flesh in comparison to a control sample following 90 minutes of tenderization.

Table 4. *Effect of combined liquid and powdered tenderizer applied for 90 minutes on sensory attributes of goat meat.*

a. Liquid tenderizer

	Color	Aroma	Tenderness	Taste	Overall acceptability
P:G:Ga^{L}	4.87 ±0.49^{b}	4.73 ±0.596^{b}	4.57 ±0.504^{a}	4.30 ±0.702^{b}	3.90 ±0.305^{b}
G:Ga:P^{L}	4.67 ±0.479^{b}	3.97 ±0.414^{a}	3.97 ±0.414^{b}	2.90 ±0.845^{a}	3.57 ±0.568^{a}
Ga:P:G^{L}	4.77 ±0.430^{b}	4.67 ±0.547^{b}	3.63 ±0.556^{b}	4.30 ±0.596^{b}	3.87 ±0.434^{b}
Control	3.83 ±0.592^{a}	2.43 ±0.626^{a}	1.40 ±0.770^{b}	1.47 ±0.730^{a}	2.07 ±0.691^{a}

b. Powdered Tenderizer

	Color	Aroma	Tenderness	Taste	Overall acceptability
P:G:Ga^{P}	3.13 ±0.346^{a}	4.83 ±0.461^{b}	4.90 ±0.305^{a}	4.43 ±0.504^{b}	4.97 ±0.813^{a}
G:Ga:P^{P}	3.10 ±0.305^{a}	4.67 ±0479^{a}	4.00 ±0.00^{b}	3.37 ±0.718^{b}	3.80 ±0.407^{b}
Ga:P:G^{P}	3.60 ±0.430^{a}	4.93 ±0.254^{b}	3.67 ±0.479^{b}	4.30 ±0.596^{b}	3.97 ±0.183^{b}
Control	3.23 ±0.894^{a}	3.83 ±0.828^{a}	1.45 ±0.507^{b}	1.47 ±0.730^{a}	1.67 ±0.547^{b}

The liquid/powdered formulations of tenderizers from the mix of ginger, papaya and garlic were all made at the ratio of 3:2:1, where; P:G:Ga=Papaya:Ginger:Garlic, G:Ga:P=Ginger:Garlic:Papaya, and Ga:P:G: Garlic:Papaya:Ginger. The superscripts in the first column (L and P) refer to liquid and powder, respectively. The superscripts with different letters along the sensory attribute columns shows a significant difference at $p<0.05$

The effect of combined liquid or powder tenderizer applied for 90 minutes on color, aroma, tenderness, taste and overall acceptability scores is shown Table 4(a). Despite the lack of a significant difference ($p>0.05$) in color attribute, the panelists highly approved of the goat meat treated with liquid tenderizer (P:G:Ga^{L}, G:Ga:Pa^{L} and Ga:P:G^{L}), awarding mean color ratings of 4.87, 4.67, and 4.77, respectively. This indicates a more visually pleasing appearance compared to the control that gave a significantly lower ($p<0.05$) color mean score of 3.83 (Table 4(a)). The inclusion of papaya peel, ginger, and garlic in varying ratios within the formulated tenderizer formulations likely contributed to their desirable color profiles. Similarly, tenderization using powdered tenderizers showed no significant difference in color ($p>0.05$) in all the tenderizer formulations (P:G:Ga^{P}, G:Ga:Pa^{P}, Ga:P:G^{P}). The Ga:P:G^{P} received the highest acceptability mean score of 3.60 (Table 4(b)). Unlike liquid tenderizers, the effect in color attribute was not much pronounced in powdered tenderizers.

In examining the resulted aroma in Table 4(a), P:G:Ga^{L} and Ga:P:G^{L} obtained significantly higher ($p<0.05$) aroma mean scores of (4.73 and 4.67) compared to the control (2.43) and G:Ga:P^{L} (3.97). This implies that the presence of papaya peel and ginger in P:G:Ga^{L}, and garlic and ginger in Ga:P:G^{L}, introduced desirable aromatic tones. From Table 4(b), the effect of powdered tenderizers P:G:Ga^{P} and Ga:G:Pa^{P} on aroma was significantly different ($p<0.05$) from G:Ga:Pa^{P} and the control sample. The tenderizer with the highest garlic concentration Ga:P:G^{L} had the highest aroma rating of 4.93. Generally, the effect of powdered tenderizers on the aroma of goat meat was highly pronounced compared to the liquid tenderizers. This may be due to evaporation of the liquid tenderizers components during cooking, which is not the case in powdered tenderizers.

Liquid tenderizers P:G:Ga^{L} and Ga:P:G^{L} had a similar taste rating of 4.30, which were statistically equal ($p>0.05$) and considerably higher ($p<0.05$) than G:Ga:P^{L} and the control sample, in line with the aroma results, (Table 4(a)). These results suggest that the incorporation of papaya peel, ginger, and garlic favorably influenced the taste perception of the goat meat. On the other hand, powdered tenderizers P:G:Ga^{P}, G:Ga:Pa^{P} and Ga:P:G^{P} exhibited a significantly similar ($p>0.05$) acceptability in terms of taste as shown in Table 4(b). Nevertheless, P:G:Ga^{P} was greatly preferred with a mean score of 4.43, while the taste of the control sample was least preferred by the panelists, with a mean score of 1.47.

All liquid tenderized samples (P:G:Ga^{L}, G:Ga:P^{L}, and

Ga:P:G^{L}) illustrated significantly improved tenderness scores (4.57, 3.97, and 3.63) compared to the control (1.40) as indicated in Table 4(a). Among these, only P:G:Ga^{L} demonstrated statistically superior tenderness ($p<0.05$) to G:Ga:P^{L} and Ga:P:G^{L}. This indicates that P:G:Ga^{L} could serve as the most effective tenderizer in achieving a significant textural improvement. Since P:G:Ga^{L} has the highest concentration of papaya extract, it favors its potential of exhibiting a higher tenderization effect. For the case of powder tenderizer treatments (Table 4(b)), P:G:Ga^{P} was significantly preferred ($p<0.05$) compared to all the other tenderizer treatments, with a high tenderness mean score of 4.90. With a mean score of 1.45, the control sample was deemed the least acceptable. This proves that P:G:Ga^{P} was the best tenderizer, greatly improving the texture. Papaya and ginger powder are known proteolytic tenderizers, and the highest concentrations of these ingredients were found in tenderizer P:G:Ga^{P}. Goat meat chunks were tenderized to a substantial degree with both liquid and powdered tenderizers, albeit the results were slightly different in terms of tenderness scores.

The results in Table 4(a) show that tenderizers P:G:Ga^{L} and Ga:P:G^{L} had considerably higher overall acceptability scores ($p<0.05$) compared to G:Ga:P^{L} and the control. These results are in line with the fact that tenderizers P:G:Ga^{L} and Ga:P:G^{L} had higher acceptance ratings in a number of sensory attributes, including color, aroma, and tenderness. Meanwhile, the statistically higher overall acceptability of goat meat subjected to powdered tenderizer was recorded in P:G:Ga^{P} at ($p<0.05$) with a mean score of 4.97 as shown in Table 4(b). The control sample had the least overall acceptability of 1.67.

3.2. The Effect of Tenderization Time on the Sensory Attributes of Goat Meat

The effectiveness of both liquid and powder meat tenderizers depends on several factors including the type and concentration of enzymes, meat thickness and duration of application [29].

3.2.1. Effect of Liquid Tenderizer on Goat Meat Sensory Attributes at 45 and 90 min of Tenderization

The effect of exposure time of the combined liquid tenderizer on the sensory attribute of goat meat is shown in Table 5.

Table 5. *Sensory attributes of goat meat treated with developed natural liquid tenderizer for 45 and 90 minutes.*

Sensory attribute	Tenderization time (min)	P:G:Ga^{L}	G:Ga:P^{L}	Ga:P:G^{L}
Color	45	4.67 ±0.479	3.50 ±0.572	4.53 ±0.629
	90	4.87 ±0.479	4.67 ±0.479	4.77 ±0.43
	p-value	*0.490*	*0.000*	*0.050*
Aroma	45	4.30 ±0.479	2.90 ±0.481	4.03 ±0.490
	90	4.73 ±0.596	3.97 ±0.414	4.67 ±0.547
	p-value	*0.000*	*0.011*	*0.000*
Tenderness	45	3.63 ±0.669	3.10 ±0.96	2.97 ±0.414
	90	4.57 ±0.504	3.97 ±0.414	3.63 ±0.556
	p-value	*0.010*	*0.000*	*0.000*
Taste	45	4.23 ±1.006	2.90 ±0.845	4.13 ±0.681
	90	4.30 ±0.702	3.43 ±0.728	4.30 ±0.596
	p-value	*0.106*	*0.000*	*0.030*
Overall acceptability	45	3.80 ±0.466	2.20 ±0.664	3.70 ±0.407
	90	3.90 ±0.305	3.57 ±0.568	3.87 ±0.434
	p-value	0.000	0.000	0.540

P:G:Ga^{L}=Liquid Papaya:Ginger:Garlic mix, G:Ga:P^{L}= Liquid Ginger:Garlic:Papaya mix, and Ga:P:G^{L}: Liquid Garlic:Papaya:Ginger mix. The mean value of a sensory attribute is significant different when the p-value < 0.05

In general, when compared to a 45-minute tenderization method, a 90-minute tenderization using all-natural liquid tenderizers that were formulated (P:G:Ga^{L}, G:Ga:P^{L}, and Ga:P:G^{L}) produced higher sensory attribute scores in tender-

ized goat meat (color, aroma, taste, tenderness, and overall acceptability) as indicated in Table 5. A 90-minute tenderization process using P:G:Ga^{L} and G:Ga:P^{L} liquid tenderizers resulted in significantly higher aroma, tenderness, and overall acceptability scores compared to a 45-minute tenderization scheme ($p<0.05$). This suggests that longer tenderization times result in better quality goat meat. In addition, G:Ga:P^{L}, and Ga:P:G^{L} produced statistically superior color and taste scores at 90-minutes tenderization ($p<0.05$) as compared to a 45-minute treatment (Table 5). Furthermore, tenderizer Ga:P:G^{L} did not show a significant difference in terms of overall acceptability ($p>0.05$). Extended marination duration enhances tenderization and taste absorption in goat meat chunks, resulting in a more noticeable sensory impact after 90 minutes compared to 45 minutes. Manufactures of meat tenderizers containing papain usually recommend letting meat stand at room temperature after applying the tenderizer. The recommended time is 90 minutes from all cuts up to 1 inch thick [18]. A current study by Al-Dalali *et al.* [4] showed that with increase in marinating time found to produce more acceptable end with increase in scores in terms of sensory attributes and significant to different marinating time ($p< 0.05$), also increase in marinating time reduced cooking loss and shear force, indicating improved tenderness [23]. Marinating meat for an extended period, such 24 hours, can result in more tender meat with improved water retention, collagen solubility, moisture levels, and decreased effort needed for cutting [32]. This data aligns with the findings of the current investigation, which showed a notable variation in texture based on marination duration. Short marinating intervals, like 20 minutes, can boost the meat's flavor but might not be long enough to notably enhance tenderness [31]. The results align with those of the current investigation in which 45 min tenderization results in a significantly low scores in all sensory attributes tested. It is advisable to marinate the meat for a longer period of time to ensure effective tenderization, as some tenderizers may require more than 3 hours to fully tenderize the meat [33].

3.2.2. Effect of Powdered Tenderizer on Goat Meat Sensory Attributes at 45 and 90 min of Tenderization

Table 6 illustrates the changes in the sensory quality of goat meat that occur as a result of the exposure duration to the mixed powdered tenderizer.

Table 6. *Sensory attributes of goat meat treated with developed natural powdered tenderizer for 45 and 90 minutes.*

Sensory attributes	Tenderization time (min)	P:G:Ga^{P}	G:Ga:P^{P}	Ga:P:G^{P}
Color	45	2.97 ±0.669	2.97 ±0.718	3.07 ±0.430
	90	3.13 ±0.346	3.10 ±0.305	3.23 ±0.430
	p-value	*0.000*	*0.016*	*0.000*
Aroma	45	3.60 ±0.629	3.67 ±0.479	3.97 ±0.928
	90	4.83 ±0.461	4.87 ±0.497	4.93 ±0.254
	p-value	*0.000*	*0.000*	*0.000*
Tenderness	45	3.93 ±0.758	3.47 ±0.681	2.97 ±0490
	90	4.90 ±0.305	4.00 ±0.00	3.67 ±0.479
	p-value	*0.000*	*0.000*	*0.000*
Taste	45	3.33 ±0.758	3.00 ±0.525	3.98 ±0.254
	90	4.43 ±0.504	3.37 ±0.718	4.30 ±0.596
	p-value	*0.000*	*0.007*	*0.006*
Overall acceptability	45	3.90 ±0.305	3.40 ±0.498	3.77 ±0.679
	90	4.97 ±0.813	3.80 ±0.407	3.97 ±0.183
	p-value	0.000	0.001	0.133

P:G:Ga^{P}=Powdered Papaya:Ginger:Garlic mix, G:Ga:P^{P}= Powdered Ginger:Garlic:Papaya mix, and Ga:P:G^{P}: Powdered Garlic:Papaya:Ginger mix. The mean value of a sensory attribute is significant different when the p-value < 0.05

Except for the Ga:P:G^{P} powdered tenderizer, which did not show a significant difference ($p>0.05$) in overall acceptability, a 90-minute tenderization of goat meat using all-natural powdered tenderizers (P:G:Ga^{P}, G:Ga:P^{P}, and Ga:P:G^{P}) resulted in

significantly higher scores ($p<0.05$) in color, aroma, taste, tenderness, and overall acceptability compared to a 45-minute tenderization treatment (Table 6). Moreover, out of all the powdered tenderizers that were tested, the one with the highest papaya leaf content ($P:G:Ga^P$) and a tenderization time of 90 minutes yielded the best results in terms of aroma (4.83), tenderness (4.9), taste (4.43), and overall acceptability (4.97). A tenderizer formula with a high quantity of garlic, followed by papaya leaf powder ($Ga:P:G^P$), was applied for 90 minutes in tenderization, resulting in remarkable sensory attribute scores for aroma (4.93) and taste (4.30) as shown in Table 6. The spices that were mixed with goat meat chunks also contributed to sensory attributes that is observed in the current study. Cinnamon, cardamom, black pepper, and turmeric are spices that can be used to enhance the sensory attributes of meat. These spices have unique chemical compounds that create specific, unique flavor profile [38]. Cardamom has cineole, pinene, sabinene, and porneol compounds that give it a unique flavor. Black pepper contains peperine, which gives it a spicy taste turmeric has curcumin, crocerin, and gingerol compounds so this flavoring compound contributes to the aroma, taste and overall acceptability sensory attribute of the meat [30]. According to Kaewthong *et al.* [19], after marinating in plant juices for 60 minutes, the goat meat became more tender. On the other hand, according to Rossami *et al.* [33], beef that was marinated for 24 hours was found to be more tender and had higher levels of moisture, soluble collagen, and water holding ability. The present study's findings demonstrated a noticeably improved sensory profile in goat meat that was tenderized for 90 minutes using powdered natural tenderizer ($p<0.05$). According to a recent study, after just 90 minutes of treatment, goat meat showed improvements in color, aroma, taste, tenderness, and overall acceptability. These results are in line with Rostamani *et al*. [33] who reported increase in meat tenderness when marination time is extended.

4. Conclusion

The findings of this research indicate that using liquid and powdered tenderizers containing papaya peel, ginger, and garlic in different ratios positively influences the sensory characteristics of goat meat, including color, aroma, taste, tenderness, and overall acceptability. Liquid tenderizers notably produced a more pronounced sensory effect compared to powdered ones. Particularly, the tenderizer with a ratio of papaya peel, ginger, and garlic at 3:2:1 in both liquid and powdered forms consistently outperformed others in most sensory aspects, followed closely by the ratio of garlic, papaya peel, and ginger at the same proportions. Additionally, marinating the meat for a longer duration significantly enhances sensory attributes compared to shorter marination times, as observed in the experiment. These findings imply that these natural tenderizers can effectively improve the sensory quality of goat meat, potentially leading to greater consumer satisfaction.

Acknowledgments

The authors wish to acknowledge the participation of Anna Salehe Msoffe in data collection and preparations for laboratory analysis.

Financial Support

The authors received no financial support for this research.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Abdalla, H. O., Ali, N. N. A., Siddig, F. S., & Ali, S. A. M. (2013). Improving tenderness of spent layer hens meat using papaya leaves (carica papaya). *Pakistan Veterinary Journal*, *33*(1), 73–76.

[2] Abdel-Naeem, H. H. S., & Mohamed, H. M. H. (2016). Improving the physico-chemical and sensory characteristics of camel meat burger patties using ginger extract and papain. *Meat Science*, *118*, 52–60. https://doi.org/10.1016/j.meatsci.2016.03.021

[3] Akpan, I. P., & Omojola, A. B. (2015). Quality Attributes of Crude Papain Injected Beef. *Journal of Meat Science and Technology*, *3*(4), 42–46.

[4] Al-Dalali, S., Li, C., & Xu, B. (2022). Evaluation of the effect of marination in different seasoning recipes on the flavor profile of roasted beef meat via chemical and sensory analysis. Journal of Food Biochemistry, 46(6), e13962.

[5] Ali Ikram, Saadia Ambreen, Amber Tahseen, Areeg Azhar, Khadija Tariq, T., Liaqat, Muhammad Babar Bin Zahid, Muhammad Abdul Rahim, W. K., & Nasir, N. (2021). Meat Tenderization through Plant Proteases- A Mini Review. *International Journal of Biosciences | IJB |*, *18*(1), 102–112. http://dx.doi.org/10.12692/ijb/18.1.102-112

[6] Ashayerizadeh, O., Dastar, B., Shams Shargh, M., A. Soumeh, E., & Jazi, V. (2023). Effects of black pepper and turmeric powder on growth performance, gut health, meat quality, and fatty acid profile of Japanese quail. Frontiers in Physiology, 14, 1218850. https://doi.org/10.3389/FPHYS.2023.1218850/BIBTEX

[7] Aulia, N., Andriyono, S., & Saputra, E. (2022). The Effect of Turmeric (Curcuma domestica) Addition ont the Consumer Acceptance Level of Milkfish Crackers. IOP Conference Series: Earth and Environmental Science, 1036(1). https://doi.org/10.1088/1755-1315/1036/1/012079

[8] Blancke, R. (2016). *Tropical fruits and other edible plants of the world: An illustrated guide*. Cornell University Press.

[9] Budianto, B., Arifin, M. J., Naryani, N., Sukmawati, E., Suwaji, S., Wibowo, T. H. M., Luviana, S. V., & Putri, L. D. V. (2023). Plant proteases and anti-bacterial substances in Allium sativum L. varieties. *Foods and Raw Materials*, *12*(2), 240–248. https://doi.org/10.21603/2308-4057-2024-2-606

[10] Dong, Y., Zhang, H., Mei, J., Xie, J., & Shao, C. (2022). Advances in application of ultrasound in meat tenderization: A review. *Frontiers in Sustainable Food Systems*, *6*. https://doi.org/10.3389/fsufs.2022.969503

[11] Ehsanur Rahman, S. M., Islam, S., Pan, J., Kong, D., Xi, Q., Du, Q., Yang, Y., Wang, J., Oh, D. H., & Han, R. (2023). Marination ingredients on meat quality and safety - a review. *Food Quality and Safety*, *7*(June), 1–17. https://doi.org/10.1093/fqsafe/fyad027

[12] Fencioglu, H., Oz, E., Turhan, S., Proestos, C., & Oz, F. (2022). The Effects of the Marination Process with Different Vinegar Varieties on Various Quality Criteria and Heterocyclic Aromatic Amine Formation in Beef Steak. *Foods*, *11*(20), 1–22. https://doi.org/10.3390/foods11203251

[13] Fiorentini, M., Kinchla, A. J., & Nolden, A. A. (2020). Role of Sensory Evaluation in Consumer Acceptance of Plant-Based Meat Analogs and Meat Extenders: A Scoping Review. Foods, 9(9), 1334. https://www.mdpi.com/2304-8158/9/9/1334

[14] Gagaoua, M., Dib, A. L., Lakhdara, N., Lorenzo, M., & Botines, C. (2021). Artificial meat tenderization using plant cysteine proteases. *Current Opinion in Food Science*, *38*, 177–188. https://doi.org/10.1016/j.cofs.2020.12.002

[15] Habtu, E., Mekonnen, B., Kiros, H., Fesseha, H., & Getachew, B. (2020). *Meat Tenderization of Efficiency of Papain, Bromelain and Zingiber officinale on Old Aged Beef Carcass of local Zebu cattle*. *4*(1). https://doi.org/10.19080/TTSR.2020.04.555628

[16] He, F. Y., Kim, H. W., Hwang, K. E., Song, D. H., Kim, Y. J., Ham, Y. K., Kim, S. Y., Yeo, I. J., Jung, T. J., & Kim, C. J. (2015). Effect of ginger extract and citric acid on the tenderness of duck breast muscles. *Korean Journal for Food Science of Animal Resources*, *35*(6), 721–730. https://doi.org/10.5851/kosfa.2015.35.6.721

[17] Islam, M. N., & Molinar-Toribio, E. M. (2013). Development of a meat tenderizer based on papaya peel. J Revistade ID Techno (RIDTEC), 9(2), 24-29.

[18] Jiya, E., Ocheme, O., Musa, G., & Alabi, O. J. (2016). *Effect of papain enzyme treatment on the tenderness of beef from the chuck cut of spent cow*.

[19] Kaewthong, P., Wattanachant, C., & Wattanachant, S. (2021). Improving the quality of barbecued culled-dairy-goat meat by marination with plant juices and sodium bicarbonate. Journal of Food Science and Technology, 58(1), 333–342.

[20] Kim, Y. J., Jin, S. K., Park, W. Y., Kim, B. W., Joo, S. T., & Yang, H. S. (2010). The effect of garlic or onion marinade on the lipid oxidation and meat quality of pork during cold storage. *Journal of Food Quality*, *33*(SUPPL. 1), 171–185. https://doi.org/10.1111/j.1745-4557.2010.00333.x

[21] Ma, Y., Yuan, Y., & Bi, X. (2019). *Tenderization of Yak Meat by the Combination of Papain and High-Pressure Processing Treatments*.

[22] Margean, A., Mazarel, A., Lupu, M. I., & Canja, C. M. (2017). Tenderization, A Method to Optimize the Meat Sensory Quality. *Bulletin of the Transilvania University of Brasov. Series II: Forestry• Wood Industry• Agricultural Food Engineering*, 125–130.

[23] Maxwell, A. D., Bowker, B. C., Zhuang, H., Chatterjee, D., & Adhikari, K. (2018). Descriptive sensory analysis of marinated and non-marinated wooden breast fillet portions. *Poultry science*, 97(8), 2971-2978.

[24] Mohammed, S., Edna, M., & Siraj, K. (2020). The effect of traditional and improved solar drying methods on the sensory quality and nutritional composition of fruits: A case of mangoes and pineapples. Heliyon, 6(6).

[25] Mohd Azmi, S. I., Kumar, P., Sharma, N., Sazili, A. Q., Lee, S. J., & Ismail-Fitry, M. R. (2023). Application of Plant Proteases in Meat Tenderization: Recent Trends and Future Prospects. *Foods*, *12*(6). https://doi.org/10.3390/foods12061336

[26] Mwashiuya, J. T., Manyele, S. V., & Mwaluko, G. (2018). Assessment of Beef Quality Determinants Based on Consumer Preferences. *Journal of Service Science and Management*, *11*(06), 657–690. https://doi.org/10.4236/jssm.2018.116045

[27] Naqvi, Z. B., Thomson, P. C., Campbell, M. A., Latif, S., Legako, J. F., McGill, D. M., Wynn, P. C., Friend, M. A., & Warner, R. D. (2021). Sensory and physical characteristics of M. biceps femoris from older cows using ginger powder (Zingibain) and sous vide cooking. *Foods*, *10*(8), 1936.

[28] Naveena, B. M., Mendiratta, S. K., & Anjaneyulu, A. S. R. (2004). Tenderization of buffalo meat using plant proteases from Cucumis trigonus Roxb (Kachri) and Zingiber officinale roscoe (Ginger rhizome). *Meat Science*, *68*(3), 363-369. https://doi.org/10.1016/j.meatsci.2004.04.004

[29] Pang, C., Yin, X., Zhang, G., Liu, S., Zhou, J., Li, J., & Du, G. (2021). Current progress and prospects of enzyme technologies in future foods. *Systems Microbiology and Biomanufacturing*, *1*, 24–32.

[30] Paswan, V. K., Singh, C. S., Kukreja, G., Bunkar, D. S., & Bhinchhar, B. K. (2021). Health benefits and functional and medicinal properties of some common indian spices. *Herbs and Spices-New Processing Technologies*, 1-18.

[31] Rahman, S. M. E., Sharmeen, I., Pan, J., Kong, D., Xi, Q., Du, Q., Yang, Y., Wang, J., Oh, D.-H., & Han, R. (2023). Marination ingredients on meat quality and safety – a review. *Food Quality and Safety*. https://doi.org/10.1093/fqsafe/fyad027

[32] Rostamani, M., Baghaei, H., & Bolandi, M. (2021). Prediction of top round beef meat tenderness as a function of marinating time based on commonly evaluated parameters and regression equations. *Food Science & Nutrition*, *9*(9), 5006. https://doi.org/10.1002/FSN3.2454

[33] Rostamani, M., Baghaei, H., & Bolandi, M. (2023). Formula Optimization of Marinade to Tenderize Beef Meat and its Effect on Physicochemical and Sensory Properties. *Journal of Chemical Health Risks*, *0*, 0–0. https://doi.org/10.22034/JCHR.2023.1913064.1208

[34] Saranya, S., Santhi, D., & Kalaikannan, A. (2016). Ginger as a tenderizing agent for tough meats-A review. *Journal of Livestock Science*, *7*, 54–61.

[35] Śmiecińska, K., Gugołek, A., & Kowalska, D. (2022). Effects of Garlic (Allium sativum L.) and Ramsons (Allium ursinum L.) on Lipid Oxidation and the Microbiological Quality, Physicochemical Properties and Sensory Attributes of Rabbit Meat Burgers. *Animals*, *12*(15). https://doi.org/10.3390/ani12151905

[36] Terefe, N. S., Sikes, A. L., & Juliano, P. (2016). Ultrasound for structural modification of food products. In *Innovative food processing technologies* (pp. 209–230). Elsevier.

[37] Warner, R., Wheeler, T. L., Ha, M., Li, X., El-din, A., Morton, J., Vaskoska, R., Dunshea, F., Liu, R., Purslow, P., & Zhang, W. (2022). Meat tenderness: Advances in biology, biochemistry, molecular mechanisms and new technologies. *Meat Science*, *185*, 108657. https://doi.org/10.1016/j.meatsci.2021.108657

[38] Zhang, W. ;, Jia, C. ;, Yan, H. ;, Peng, Y. ;, Hu, E. ;, Qi, J. ;, Lin, Q., Zhang, W., Jia, C., Yan, H., Peng, Y., Hu, E., Qi, J., & Lin, Q. (2022). Characteristic Aroma Compound in Cinnamon Bark Extract Using Soybean Oil and/or Water. *Applied Sciences 2022, Vol. 12, Page 1284*, *12*(3), 1284. https://doi.org/10.3390/APP12031284

[39] Zhang, S., Zhang, L., Wang, S., & Zhou, Y. (2019). Comparison of Plant-origin Proteases and Ginger Extract on Quality Properties of Beef Rump Steaks. *Food Science and Technology Research*, *25*(4), 529–538. https://doi.org/10.3136/fstr.25.529