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Author	Shine Htet Aung[1,2], Md. Altaf Hossain[1,3], Ji-Young Park[1], Young-Sun Choi[4], and Ki-Chang Nam[1*]
Affiliation	[1]Department of Animal Science and Technology, Sunchon National University, Suncheon 57922, South Korea [2]Department of Zoology, Kyaukse University, Kyaukse 05 151, Myanmar [3]Department of Applied Food Science and Nutrition, Cha ttogram Veterinary and Animal Sciences University, Khul shi-4225, Chattogram, Bangladesh. [4]Livestock Research Institute, Gangin-gun 59213, South Korea
ORCID (for more information, please visit https://orcid.org)	Shine Htet Aung (https://orcid.org/0000-0002-9470-0141) Md. Altaf Hossain (https://orcid.org/0000-0002-4685-8972) Ji-Young Park (0000-0001-9680-8685) Young-Sun Choi (https://orcid.org/0000-0002-6843-7423) Ki-Chang Nam (https://orcid.org/0000-0002-2432-3045)
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CORRESPONDING AUTHOR CONTACT INFORMATION

For the corresponding author (responsible for correspondence, proofreading, and reprints)	Fill in information in each box below
First name, middle initial, last name	**Ki-Chang Nam**
Email address – this is where your proofs will be sent	kichang@scnu.kr
Secondary Email address	
Address	**Ki-Chang Nam** Department of Animal Science & Technology, Sunchon National University, Suncheon 57922, Korea
Cell phone number	+82-10-6747-9298
Office phone number	+82-61-750-3231
Fax number	+82-61-750-3231

Running title: Effects of tenderizers on semi-dried goat meat jerky

Title: **Development of semi-dried goat meat jerky using tenderizers considering the preferences of the elderly**

Abstract

Elderly people avoid eating red meat and dried meat product due to its texture and stiffness; they deprive them of rich sources of nutrients. In addition, food-related diseases are exponentially increasing due to using synthetic additives in food products. Therefore, this research aimed to develop semi-dried goat meat jerky considering geriatric preferences by using natural tenderizers and nitrate. Four treatments were formulated NC (synthetic nitrite without tenderizers), PC (Swiss chard without tenderizers), T1 (Swiss chard with pineapple powder), and T2 (Swiss chard with pineapple and tomato powder). T1 and T2 had higher processing yield, and rehydration capacity compared with NC and PC. The fat content of T1 and T2 was lower than the control groups. Moisture was significantly higher in T1, NC, and T2 than in PC ($p<0.05$). T2 showed the lowest water activity (0.87), lowest shear force (4.82 kgf), and lowest total plate count (TPC). The lowest pH and thiobarbituric acid reactive substances (TBARS) were observed in T1 and T2. T1 showed the lowest lightness and the maximum redness ($p<0.05$) while PC showed the lowest yellowness. During the storage period, moisture and pH decreased, and TPC and TBARS significantly increased whereas water activity is stable regardless of the treatment. The results of the myofibrillar fragmentation index (MFI) and SDS-PAGE gel revealed that T1 and T2 more effectively converted protein to polypeptides. In addition, tenderizers positively affected thrombogenicity, atherogenicity, and hypocholesterolemic/hypercholesterolemic indices. T2 observed the highest overall sensory acceptance by reducing goaty flavor. Overall, jerky treated with tenderizers is easily chewable and digestible for the elderly due to its tenderness and essential fatty acids that would be senior-friendly food.

Keywords: Swiss chard powder, tenderizers, goat meat jerky, goaty flavor, elderly people, dietary supplement.

Introduction

Globally, the number of births is declining and life expectancy is increasing [1]. According to estimates, the world will soon have a super-aged and aging civilization. As people become older, their metabolism, and anatomy undergo some changes, which affect their ability for chewing efficiently, as well as their sense of taste and smell, and also their appetite [2]. According to surveys, senior people require balanced food for maintaining good health during their last stages of life [3, 4]. Loss of muscle mass, a compromised immune system, and wound healing can all be prevented by consuming sufficient protein and exercising regularly [5].

In terms of nutrition, meat is valued since it is a good source of biologically valuable proteins, vitamins, and other minerals [6]. However, older people find meat to be the most difficult food item to chew, as compared to other foods [7]. When senior citizens avoid eating red meat due to its texture and stiffness, they are deprived of all the nutrients present in it. Therefore, numerous researchers are currently trying to develop senior-friendly food items by regulating physical qualities [8], producing drinks that serve as nutritional supplements [9], and treating reconstituted foods with enzymes [10].

Jerky is one of the products obtained from processed meat, which has a high nutritional value as well as a long shelf-life due to its intermediate moisture content, and the curing and drying process used in its manufacture [11]. Jerky is high in protein and low in fat which makes it suitable for the geriatric population from a health point of view [12]. Jerky was traditionally made by slicing the entire muscle followed by marinating and drying it [12]. However, whole-muscle jerky has an undesirable color due to over-drying and is difficult to chew for the elderly person [13]. In addition, excessive moisture loss also results in a harsh texture, making the product too dry, brittle or chewy, and unappealing in color [14]. Therefore, jerky was modified to give it a semi-dried form. The texture was enhanced by modifying the drying conditions [15] and adding ingredients that enhance water holding capacity [16], thus trying to make it more appealing to the elderly.

Among the ingredients, synthetic nitrites and nitrates are widely used in meat products since they enhance the red color characteristics of cured meats, provide flavor, prevent microbial growth, and act as antioxidants [17]. However, people who care about their health expect foods made from natural sources and free of chemicals [18]. Therefore, many food producers have investigated the applicability of nitrites derived from natural plant nitrates, as an alternative to synthetic nitrites [19]. Among the various plant-derived nitrate sources, Swiss chard (*Beta vulgaris L. var. cicla*) is a rich source of nitrate and also acts as an antibacterial agent and antioxidant component [20, 21]. However, a nitrate-reducing starter culture is needed when natural nitrate sources are used to generate the typical cured meat qualities [22]. Starter culture converts nitrate into nitrite; this is the most promising approach to incorporating natural sources of nitrite into processed meats [23]. An initial heat treatment at 40$\pm$2 °C for about 30-60 min is required for converting natural nitrates to nitrites with a starter culture [24].

Additionally, utilizing pineapple and tomato powders as tenderizers while making jerky can enhance the quality attributes, particularly the texture. The enzymes papain, bromelain, and ficin are frequently employed to tenderize meat and meat products in the food processing industry [25]. Bromelain, a proteolytic enzyme found in pineapple, assists in the digestion of protein-rich food products [26]. In addition, lycopene from tomatoes may enhance the storage quality and color of meat products [27].

Recently, beef jerky has become more popular than jerky obtained from other meat sources due to its versatility. The popularity of jerky produced from pork, poultry, and other meats is also growing. When compared to other meats, the popularity of goat jerky is hindered because of its distinctive. Additionally, the number of elderly consumers is on the rise nowadays, and ingesting jerky is difficult for them; as a result, texture modification is necessary. On the other hand, food-related diseases are exponentially increasing due to the addition of synthetic additives, making organic food production very challenging for the food industry. This study desired to explore the potential benefits of using Swiss chard powder as a natural curing agent. The ultimate goal of this study was to improve the texture profile as well as the nutritional composition of goat meat jerky by adding natural tenderizers. In addition, the effects of natural tenderizers on the goaty flavor of jerky were also taken into consideration.

Materials and Methods

Manufacturing of semi-dried goat meat jerky containing tenderizers

A total of three Korean native black goats *(Capra hircus coreanae,* female, age 16 mon, live weight 25.94±2.56 kg) were randomly selected at the goat farm, Gangjin-gun, Jeollanam-do, Suncheon, Republic of Korea. *M. biceps femoris* and *M. semitendinosus* portions were dissected from each carcass, transported to the laboratory with oxygen-permeable packaging at 4ºC, and stored at a temperature of -18℃ until use. The curing solution for the production of semi-dried goat meat jerky included salt (1.2%), water (10%), sugar (2.5%), glycerol (3%), ginger (0.4%), black pepper (0.3%), garlic (0.2%), and onion (0.2%) powders, as shown in Table 1. To analyze the effects of Swiss chard powder as a replacement for synthetic nitrite, negative control (NC) was made using synthetic nitrite (0.06% pickling salt) without tenderizers, and positive control (PC) using natural nitrate (0.2% Swiss chard powder) to ensure that the residual nitrite level was less than 70 ppm, as determined by the pre-test (data not shown). Additionally, T1 (0.5% pineapple powder) and T2 (0.5% pineapple and 0.25% tomato powder) were prepared using natural nitrate sources in order to assess the impact of tenderizers on the semi-dried goat meat jerky. Pineapple powder and tomato powder (100% pure powder) were purchased from a local food additives company (Sanmaeul Co., Ltd., Changnyeong-gun, Gyeongsangnam-do, Korea).

Jerky preparation

The manufacturing procedure for semi-dried goat meat jerky with tenderizers has been depicted in Fig. 1. The frozen goat meat was thawed by keeping it overnight, at 4℃. The meat was then defatted, and all visible connective tissue was removed. The meat was first trimmed and then minced twice, first through 5 mm, and then 3 mm diameter plates in a grinder. The blood was allowed to drain off from the ground meat by keeping it at 4ºC for 3 h after grinding.

A curing solution was also used to cure the ground meat. The meat preparation was created in square shapes with dimensions of 20 cm × 20 cm and a thickness of 2 cm. Initially, the semi-dried goat meat jerky was dried at 40°C for 30 min to transform the nitrate ions present in the vegetable chard powder into nitrite ions in the presence of the denitrifying culture (Bactoferm F-RM-52). It was then dried at 60°C for 16 h in a hot air drier (Enex-CO-600, Enex, Yongin, Korea) and then cut into stick-shaped pieces (18 cm × 1 cm × 1 cm). It was vacuum-packed and stored at room temperature for use on the first day, 15-day, and 30-day storage investigations of jerky quality traits. During processing, the jerky was first created in square shapes for drying and was then cut into stick shapes (commercial type) after drying because jerky that is dried in this manner (square shape) is two times more tender than directly drying as stick-shaped, as determined by the pre-test (data not shown).

Analytical methods

Processing yields

Processing yields were determined based on the difference between the weights before and after drying [15].

$$\text{Processing yields (\%)} = \frac{\text{jerky weight after drying}}{\text{cured meat weight before drying}} \times 100$$

Rehydration capacity

The rehydration capacity was determined by the method described by Kim et al. [28]. The samples were sliced into (1.0 × 1.0 × 1.0) cm^3 volumes. Fifty milliliters of distilled water was added to a 100 mL beaker. The jerky was weighed before and after rehydration for 15, 30, 45, and 60 min at room temperature. The following formula was used to compute the percentage of rehydration capacity:

$$\text{Rehydration capacity (\%)} = \frac{\text{Weight of the jerky after swelling}}{\text{Weight of the jerky before swelling}} \times 100$$

Moisture, water activity, and fat content

The moisture content was measured based on the weight loss of semi-dried jerky after 12 h at 105ºC in a drying oven [29]. Samples used to measure water activity were chopped into pieces with sharp scissors and analyzed with a water activity meter (rotronic Hygromer, AWC, USA). The amount of fat in 5 g of jerky sample was assessed using a chloroform/methanol (2:1) ratio as earlier described by Folch and Lees [30].

Color and pH

The color of semi-dried jerky was measured using a colorimeter (CR-410, Minolta, Osaka, Japan), calibrated with a black, and white calibration plate. The surface of the cut sample was used for the purpose of color. The lightness (L*), redness (a*), and yellowness (b*) were determined by taking the average of three repeated measurements. For pH measurement, two grams of the sample were homogenized with 18 mL of distilled water for 1 minute using a homogenizer (Polytron PT 10-35 GT, Kinematica AG, Luzern, Switzerland) at 11,000 rpm, followed by filtration through a Whatman No.4 filter paper. The pH of filtrates was measured at room temperature with a pH meter (Seven Excellence™, METTLER TOLEDO, Switzerland).

Microbiological analysis

The filter bag contained a 10 g sample of minced jerky that had been diluted with 90 mL of sterile saline solution (0.85% NaCl). After that, it was stomached for 2 min in a blender (LED Embossing Stomacher, Bnf Kore, Gimpo, Korea). After homogenizations, serial decimal dilutions of the homogenate were prepared. For determining the total plate count and detecting the presence of *Salmonella spp.*, each appropriate dilution was immediately inoculated onto the surface of dry film culture medium (Aerobic Count Plate; 3M Petrifilm) and XLT4 (Merck, Darmstadt, Germany). After drying the plates, they were incubated at 37°C for 24 h. The total number of bacteria was determined by multiplying the number of red colonies generated by the rate of dilution. The bacteria count is represented as (Log CFU/g) [31].

TBARS (2-thiobarbituric acid reactive substance)

The amount of lipid oxidation was determined by adding 5 g of sample and 15 mL of distilled water in a 50 mL test tube along with 50 uL of butylated hydroxytoluene (7.2 per cent in ethanol, w/v) and homogenized according to the TBARS (2-thiobarbituric acid-reactive substances) measuring technique [32]. Subsequently, 2 mL of the homogenized sample was transferred into a 15 mL tube, and 4 mL of thiobarbituric acid/trichloroacetic acid solution (20 mM TBA/15% TCA, w/v) was added. The mixture was heated in a hot-water bath at 90ºC for 15 min and then cooled for 15 min with cool water. After cooling, 3 mL of the mixture was centrifuged at 3,000 rpm, 4ºC for 15 min, and the absorbance of the supernatant solution was measured at 531 nm. The blank solution was prepared by mixing 1 mL of distilled water with 2 mL of TBA/TCA solution and the amount of TBARS was quantified in mg of malondialdehyde (MDA) per kg of the jerky samples.

Fatty acid composition analysis

A minimally altered method was used to assess the fatty acid composition of semi-dried jerky [33]. Each sample weighing 1 g was combined with 0.7 mL of 10 N KOH and 6.3 mL of methanol for the separation of fatty acid methyl esters. This mixture was then put into a water bath that was maintained at a constant temperature of 55°C. During heating, the samples were vigorously shaken every 30 min. The product was then treated with 0.58 mL of (24 N) H_2SO_4 after cooling it in ice-cold water for two minutes. The mixture was heated once more using the same steady temperature and a similar procedure. After adding 3 mL of hexane, the mixture was centrifuged at 3,000 rpm for 5 minutes (HANIL Combi-514R, Inchon, Korea), and then it was transferred to a vial with a Pasteur pipette. The mixture was then run through a gas chromatography-flame ionization detector (Agilent 7890 series, Wilmington, USA), which had the following settings. The injector was a split mode injector with a split ratio of 25:1, the temperature was maintained at 250ºC, and the detector was a flame ionization detector. High-purity air, H_2, and He were used as the carrier gas, and the flow rate was 40 mL/min for H_2 and 400 mL/min for air. The column for analysis was HP-88 (60 m × 250 μm × 0.2 mm). The fatty acid composition was expressed in terms of percentage.

Nutritional quality indexes

The fatty acid profile was used to assess the nutritional quality index of semi-dried goat meat jerky. The indexes of thrombogenicity (TI) and atherogenicity (AI) were computed following the procedure described by Ulbricht and Southgate [34], and the hypocholesterolemic/hypercholesterolemic (HH) index was estimated according to the work done by Santos-Silva et al. [35] work. The corresponding atherogenicity index (AI), thrombogenicity (TI), and HH indices were calculated using the following formulas. Additionally, PUFA/SFA and the ratio of n6/n3 PUFA were examined as additional nutritional quality measures.

$$\mathrm{AI} = \frac{[\mathrm{C12{:}0} + 4 \times (\mathrm{C14{:}0}) + \mathrm{C16{:}0}]}{[\sum \mathrm{MUFA} + \sum \mathrm{PUFA}]}$$

$$\mathrm{TI} = \frac{[\mathrm{C14{:}0} + \mathrm{C16{:}0} + \mathrm{C18{:}0}]}{[0.5 \times (\sum \mathrm{MUFA} + \sum \mathrm{n6}) + 3 \times \sum \mathrm{n3} + \frac{\sum \mathrm{n3}}{\sum \mathrm{n6}}]}$$

$$HH = \frac{[C18{:}1cis9 + C18{:}2n6 + C20{:}4n6 + C18{:}3n3 + C20{:}5n3 + C22{:}5n3 + C22{:}6n3]}{[C14{:}0 + C16{:}0]}$$

Warner-Bartzler Shear Force (WBSF)

The measurement of WBSF of jerky was assessed using a Warner-Bratzler shear blade on a texture analyzer (TA-XT2, Stable Micro System, Surrey, UK). Each piece of jerky was cut into cross-sections measuring 2.0 cm ×1.0 cm ×0.8 cm, and samples were evaluated for the shear force after being placed in the center of the blade. The crosshead was moving at a speed of 2 mm/s with a full-scale load of 49 N. Data were gathered from the shear force values, analyzed, and converted into kgf to determine the maximum force necessary to shear through each sample.

Residual nitrite content

The method of Shin et al. [36] was used to estimate the residual nitrite content in the jerky with just minor modifications. Firstly, 10 g of the jerky sample was placed in a 300 mL volumetric flask and 10 g of distilled water was prepared for the blank sample. After that, the sample was combined with 150 mL of 80ºC preheated distilled water before being homogenized. The sample was mixed with 10 mL of 0.5 N sodium hydroxide (NaOH) and 10 mL of 12% Zinc sulfate solution. The mixture was heated for 20 min in a hot water bath (80ºC) while being shaken every 3 minutes. After cooling, 20 ml of ammonium acetate buffer (pH 9.0) and 10 mL of distilled water were added to the samples to increase their volume to 200 ml. After mixing the sample very well and keeping it at a standard temperature for 10 min. The mixture was filtered through No.1 filter paper (Whatman No.1) and the first filtrate about 20 mL was discarded. After filtration, 20 mL of filtrate was mixed with 1 mL of sulfanilamide solution, 1 mL of N-(1-naphthyl) ethylenediamine dihydrochloride reagent, and 3 mL of distilled water. This mixture was then left at room temperature for 20 min to develop the color reaction. The absorbance was measured at 540 nm and the residual nitrite concentration was estimated using the standard curve created using nitrite solutions.

Myofibrillar fragmentation index (MFI)

The myofibrils were obtained according to the method described by Olson and Stromer [37], using an MFI buffer (0.1M KCl, 0.02M KH_2PO_4, 0.001M EDTA, 0.001M MgCl, and 0.001M NaN_3). Two grams of sample were mixed with 20 mL of ice-cold MFI buffer and homogenized at 15000 rpm for 30 sec. The mixture was centrifuged at 1000×g for 15 min before the supernatant was decanted. The sediment was re-mixed in 20 mL of cool ice MFI buffer and the procedure was repeated. The resulting residue was re-suspended in 10 mL MFI buffer, and the homogenate was filtered through an 18 mesh filter to remove fat and connective tissue after vortexing. The extracted liquid will be used to determine the protein content at 540 nm by the biuret method. MFI values were recorded as absorbance of units per 0.5 mg/mL myofibril protein concentration multiplied by 200 [38].

SDS-polyacrylamide gel electrophoresis (SDS-PAGE)

The protein denaturation of semi-dried goat meat jerky treated with tenderizers was analyzed using sodium dodecyl sulfate-polyacrylamide gel (SDS-PAGE), as described by Green and Sambrook [39]. The jerky samples were lyophilized using a freeze dryer (Lyoph-Pride, LP03; Ilshin BioBase Co., Ltd., Korea). The lyophilized samples were mixed with the sample loading buffer (0.25 M Tris-HCl pH 6.8, 4% SDS, 20% glycerol, 10% 2-mercaptoethanol, and 1% bromophenol blue) at a 1:1 (v/v) ratio, and the mixture was heated in the heat blot for 15 min. Each sample (1mg/ml) was loaded using sodium dodecyl sulfate-polyacrylamide gel (5% stacking and 15% separating gels) on the mini-gel electrophoresis (SDS-PAGE) under reduced conditions using Mini Protein Gels (Mini-PROTEAN Precast Gels, Ready Gel® Precast Gels, Bio-Rad). After gel electrophoresis, the gels were stained with 0.25% Coomassie blue, 10% standard acetic acid, 50% methanol, and 40% distilled water. A standard broad-range protein marker (Precision Plus Protein Unstained Standards) after de-staining (5% standard acetic acid, 25% methanol, and 70% distilled water) was used for the calculation of the molecular weight of the protein bands.

Sensory evaluation

Eight panels were recruited for sensory analysis, and they were instructed to perform a descriptive analysis. The panelists participated in eight introductory sessions to help them become familiar with the standards and scales which were to be used. The sample was evaluated using a scale of 1 to 9 points based on 5 points of the negative control. The color (1 = unattractive, 9 = extremely attractive), flavor preference (1 = off-flavor, 9= tasted good), goaty flavor (1 = very weak, 9 = very strong), tenderness (1 = very hard, 9 = very tender), juiciness (1 = very dry, 9 = very juicy), and overall acceptability (1 = unacceptable, 9 = extremely acceptable) of the jerky were assessed by the panelists. The Sunchon National University Institutional Review Board (1040173-202107-HR-010-02) approved the sensory evaluation.

Statistical analysis

The SAS program (Version 9.3 SAS Institute Inc., NC, USA) was used for statistical analysis of the experimental data from three replications. When significant differences were discovered following a one-way ANOVA, the significance test between the mean values ($p < 0.05$) was conducted. The boxplot of the outcomes was produced using the R statistical program (version 4.2.1). Results were presented in terms of the mean value and standard error of the means (SEM), which is the standard error of the treatment interval.

A multivariate analysis of the quality parameters for all treatments was performed using Principal Component Analysis (PCA), except for processing yields and rehydration capacity. MetaboAnalyst 5.0 (www.metaboanalyst.ca) was used to carry out principal component analysis (PCA), partial least squares-discriminant analysis (PLS-DA), variable important projection (VIP) score, and heatmap.

Results and Discussion

Processing yields (%)

One of the key elements influencing processing yields was the meat product additives because the amount of moisture that evaporates during the drying of jerky significantly impacts its processing yield. Figure 2 illustrates how tenderizers affect the processing yields of semi-dried goat meat jerky. In the present results, the highest processing yield of semi-dried goat meat jerky was found in T1, followed by T2, NC, and PC, with yields varying between 47.1%, 45.9%, 43.9%, and 40.8%. The yields demonstrated by the tenderizer-treated jerky (T1, T2) were significantly higher than those of the non-treated jerky ($p < 0.05$). Song [11] had postulated that humectants may be better at holding water because beef jerky treated with humectants had higher processing yields than the control. In this investigation, tenderizers were observed to have a good impact on the processing yields of semi-dried goat meat jerky due to their potential for water retention. As a result, the pineapple powder was more successful in terms of increasing product yield.

Rehydration capacity (%)

Rehydration capacity depends on the capillaries and cavities near the surface of dried foods, a crucial component influencing sensory qualities including tenderness and smoothness during chewing [40]. The rehydration capacity of semi-dried goat meat jerky is displayed in Figure 3. The rehydration capacity of the goat jerky of the tenderizer-treated groups was found to increase with increased rehydration time after soaking in distilled water. Especially, T1 and T2 underwent faster rehydration as compared to NC and PC, showing 25.42% and 25.21% rehydration respectively after 60 min. This outcome may be a result of the various water-binding abilities and structural stabilities of the constituents. Kim et al. [41] reported that restructured jerky analogue treated with TVB (textured vegetable protein) observed higher rehydration capacity, Kim et al. [42] concluded that this may be because of the components' strong water-binding capability and structural stabilities. Therefore, tenderizers (pineapple and tomato powder in this study) are likely to improve the rehydration capacity of T1 and T2 due to their fixed structure and high porosity. In contrast, NC and PC (without tenderizers) demostrated weak water-binding capabilities and interaction strengths.

Moisture content, water activity, and Warner-Bartzler Shear Force (WBSF)

The moisture content, water activity, and shear force of semi-dried goat meat jerky samples are shown in Table 2. Moisture content is one of the most critical characteristics of jerky because it can alter its texture and shelf life. The higher moisture content of the meat products provides desirable tenderness, however, which also results in rapid deterioration of the product due to greater microbial proliferation [43]. Therefore, moisture levels in the semi-dried jerky should range from 30% to 50%, and water activity should be between 0.82 and 0.90 [44]. In our study, the moisture content of the semi-dried goat meat jerky ranged from 35.67% to 39.33%. The pineapple-treated jerky (T1) had the highest moisture content, which was considerably greater than PC ($p < 0.05$) but did not significantly vary from T2 and NC ($p > 0.05$). Probably, the pineapple and tomato powder may have an ability to retain water, so the addition of these tenderizers enhanced the moisture content of the jerky. Kim et al. [44] reported that humectants and tenderizers can enhance water absorption and retention, leading to higher moisture content in jerky. After being stored for 15 days, the moisture content in the jerky samples receiving all treatments increased. One possible reason for this could have been that the jerky's moisture distribution was unequal when it was first drying, but equilibration may have taken place in storage time and resulted in a more consistent moisture distribution. However, the moisture content in samples receiving all treatments was found to dramatically decrease following 30 days of storage because through natural evaporation and dispersion throughout the course of prolonged storage, the jerky may have continued to lose moisture.

The rate of microbial development and the shelf life of the jerky are both significantly influenced by water activity. Extreme drying of the jerky to reduce the water activity gives it a gritty texture and makes it too dry [14]. Therefore, while manufacturing jerky, controlling water activity below a certain level is a crucial consideration since it contributes to a good texture, inhibits microbial growth, and lengthens shelf life. The water activity of samples receiving all treatments was observed lower than 0.9, although T2 demonstrated the lowest water activity (0.87) compared to other treatments ($p < 0.05$). In addition, there were no noticeable changes in the water activity in any type of jerky after 30 days of storage. Yamaguchi et al. [45] mentioned that jerky needs to possess steady water activity in order to prevent deterioration in quality during storage. Labuza [46] reported that this is a useful approach to characterize the thermodynamic equilibrium of the jerky.

Tenderness is one of the most crucial considerations when making semi-dried jerky for the elderly population. The Korean Industrial Standards (KS) employ three grades (grade 1: 5 kgf - 0.5 kgf; grade 2: 0.5 kgf - 0.2 kgf; and grade 3: lower than 0.2 kgf) to determine the level of tenderness required for senior-friendly foods [47]. Extreme dehydration during processing can result in a rough texture in the jerky, but the addition of tenderizers or humectants makes the texture more palatable [44]. Generally, jerky is associated with a high shear force score due to the drying process which renders it inappropriate for elderly persons. Therefore, the shape of the jerky during the drying process is an important factor. According to the pre-test results, square-pattern jerky demonstrated a lower shear force value than other patterns (data not shown). In this investigation, T1 (5.19 kgf) and T2 (4.82 kgf) observed a significantly lower shear force than NC and PC ($p<0.05$). Kim et al. [48] reported that the addition of tenderizers and humectants resulted in a lower shear force value than the control. Furthermore, the addition of black rice powder [49] and red pepper powder [50] in jerky resulted in a lower shear force value than without these additions. After 15 days of storage, the shear values of all treatments were observed to have significantly decreased, with T2 having the lowest shear force value

(3.12 kgf). Most likely, the shear force value is affected by the increased moisture value during storage. However, the shear force value of all the treatments was observed to have increased again after 30 days of storage period, but the increase was not significant. As a result, jerky that has been treated with tenderizers like pineapple and tomato powders is suitable for the geriatric population, because it is more tender and they can easily enjoy the dried meat product. Probably, the dietary fiber present in tenderizers enables the physical trapping of protein and water, which then enhances the water-holding capacity and modifies its texture. In addition, the pattern of jerky plays an important role in achieving the desirable tenderness for elderly persons.

Color, pH, and TBARS

The color of the product is the primary element that influences consumer acceptability, choice of purchases, and enjoyment of the meat product's color. Table 3 displays the impacts of using Swiss chard powder (natural nitrate) use instead of synthetic nitrites, as well as the influence of tenderizers on the color of semi-dried goat meat jerky. Nitrite is one of the main ingredients that must be utilized to cure meat. Nitrite is responsible for the reddish-pink color of the cured meat and for making it a desirable color. Nitrite needs to be converted to nitric oxide by reductants (ascorbic acid), which reacts with myoglobin to produce the nitric oxide myoglobin complex and produces nitrosyl hemochrome (bright pink color) after heating [51]. Swiss chard powder (*Beta vulgaris var. cicla*) is natural nitrate which is reduced to nitrite by denitrifying culture (Bactoferm F-RM-52). Under the restrictions of residual nitrite content (70 ppm), this experiment found that using Swiss chard powder (PC) produced a more desirable red color as compared to synthetic nitrite (NC). The redness color was found to substantially vary between PC and NC (9.27 and 5.80, respectively). The formation of the nitorsoheme pigment is entirely responsible for the red color of the cured meat [52]. Swiss chard powder probably produces a greater quality of nitorsoheme pigment. Therefore, Swiss chard powder (*Beta vulgaris var. cicla*) can be used as a synthetic nitrite substitute in cured meat under the limitations of residual nitrite content (70 ppm).

When the effects of tenderizers on semi-dried jerky were evaluated, the highest lightness value (L*) was noted in T2 and did not differ significantly from the lightness value of PC ($p > 0.05$) whereas T1 color appeared darker on the first day. According to some experts, meat can brown either enzymatically or non-enzymatically when fruit and protein are combined [53]. However, Kim et al. [48] reported that the addition of kiwi and pineapple did not dramatically alter the lightness of the jerky. After 15 days of storage, the lightness value (L*) of semi-dried goat meat jerky was found to have increased in all treatments. Probably, higher moisture content impacts the lightness of the jerky, the aqueous layer on the surface results in enhanced light scattering and hence results in a higher L* value [54]. The lightness value of PC did not undergo considerable changes during the 30-day storage period, however, that of T1 and T2 underwent significant changes.

Kim et al. [48] reported that the addition of tenderizers or humectants positively affects the redness (a*) of jerky. Similar results were observed in our study, T1 (pineapple) and T2 (pineapple and tomato) had significantly higher redness (a*) values as compared to PC ($p < 0.05$). The pigments present in the tenderizers are most likely responsible for the impact on the color. In the case of T2, which contained pineapple and tomato, the pigment lycopene is present in tomato powder and has a higher redness value, which may be responsible for the impact on color improvement. Similarly to this, tomato peel positively impacted all color parameters for sausages which had been treated with a dry fermentation process [55]. Additionally, Østerlie and Lerfall [56] postulated that a combination of minced meat and lycopene could possibly reduce the nitrite demand. The redness (a*) color of the tenderizer-treated jerky did not undergo major change over the first 15 days of storage. After 30 days of storage, however, a significant drop in the redness (a*) value was observed, which may be a result of higher levels of metmyoglobin (MMb) production [57]. The addition of tenderizers (T1 and T2) produced greater yellowness (b*) compared with the control (PC) sample ($p < 0.05$). In addition, the yellowness (b*) was found to increase significantly during the storage periods. Similarly, Kim et al. [27] revealed that kiwi-tenderized pork jerky showed a greater yellowness (b*) value. Also, pork jerky that contained tomato powder had a greater yellowness (b*) rating than jerky without tomato powder [48].

The pH of the semi-dried goat meat jerky is depicted in Table 3. Jose et al. [58] and Han et al. [59] described that the average pH of beef jerky ranged from 4.72 to 6.73 and that of pork jerky was between 5.71 to 5.75. According to our observations, the average pH value of goat meat jerky ranged from 6.43 to 6.18. Factors such as jerky prepared without the addition of tenderizers (NC) or by using synthetic nitrites did not affect pH during storage. Furthermore, the pH of the tenderizer-treated jerky (T1 and T2) was observed to be significantly lower than that of the control groups (NC and PC) ($p < 0.05$). After 15 days of storage, none of the treatments appreciably altered pH, it was considerably affected, and declined in PC, T1, and T2 groups throughout the 30 days storage period (5.87, 5.96, and 5.87) respectively. pH values that are close to the isoelectric point (pH 5.0–5.4) could have negatively impacted the qualitative characteristics of the jerky [41]. The pH range of every treatment used in this study is distinct from the isoelectric point, therefore the effect of a lower pH might be negligible.

Lipid oxidation significantly affected the shelf life of the jerky throughout the drying process. Malondialdehyde (MDA) is a byproduct of secondary lipid oxidation and is frequently observed as an oxidation marker [60]. TBARS is a common technique used to measure lipid oxidation by determining the MDA concentration in meat products [61]. The TBARS values of semi-dried goat meat jerky are depicted in Table 3. Regardless of the treatments, TBARS readings for the jerky belonging to every group showed a considerable increase throughout the storage period compared to the initial day. The reason for this may be the decrease in pH values, which was the main reason for the rising water-solubility and enhanced activity of iron in acidic environments [62]. The natural nitrate group (PC) was observed to have a higher TBARS value as compared to NC (synthetic nitrite) ($p < 0.05$). However, tenderizer-treated jerky (T1 and T2) showed significantly decreased TBARS values than the control groups (NC and PC) ($p < 0.05$). Most likely, ingredients such as phenolic compounds and flavonoids present in pineapples are instrumental in the prevention of oxidation during storage. According to Hossain and Rahman [63], pineapple has a high concentration of phenolics, making it a rich source of antioxidants. Additionally, lycopene also suppresses the lipid oxidation of jerky by exerting antioxidative activity.

Microbial analysis

Table 3 displays the variations in total plate counts (TPC) of semi-dried goat jerky throughout the storage period (30 days). From a microbiological point of view, there is no discernible change when natural nitrate (Swiss chard powder) is used in place of synthetic nitrite. Probably, nitric oxide from the denitrified Swiss chard powder by the starter culture and ascorbic acid most likely interacts with the iron-sulfur protein and retards microbial growth. Irrespective of the treatments, a substantial increase was observed in the total plate counts (TPC) of the samples during storage ($p < 0.05$). However, none of the samples tested positive for *E.coli/*coliform, molds, or yeast during the storage period. The TPC value was lower in the T2 group than in the other treatment groups ($p < 0.05$) followed by T1, PC, and NC. Probably, the low water activity (a_w) was responsible for the low microbial levels. According to Gould and Christian [64], the reduction in microbial growth in beef products was a result of low water activity. According to a report by Leistner [65], several food-spoiling bacteria cannot thrive at a_w values lower than 0.95. All treatments in this investigation had water activity (a_w) values between 0.89 and 0.87, while T2 had the lowest value at 0.87. This suggests that semi-dried goat meat jerky treated with tenderizers may have longer shelf life than jerky that has not been treated.

Fat content

The fat in meat is not only instrumental in a favorable perception of texture as well as how juicy, and flavorful the food item is, but it also supplies important fatty acids and vitamins [66]. However, fat is also an important reason that causes jerky to spoil more quickly. Modern meat products also do to take into account consumer preferences for leaner meat and meat products. The ratio of lean to fat in raw meat, as well as how many extra ingredients are used, can have a substantial impact on how much fat is present in meat products [67]. Figure 4 displays the effects of tenderizers on the fat content of jerky. In this study, the fat content in the semi-dried goat meat jerky ranged from 3.91% to 3.15%, and NC had a substantially greater fat content than PC, T1, and T2 ($p < 0.05$). The lowest fat content, which was not substantially different from PC, was found in T1 and T2, which had been tenderized with pineapple and tomato powder. However, Thebaudin et al. [68] pointed out that fat retention in meat products is promoted by the use of dietary fiber in meat products. Kim et al. [42] reported that the fat content of semi-dried chicken jerky in which 2% wheat fiber was incorporated, was lower than in jerky without fiber addition. In any case, it is advisable to remove as much visible fat from the product as possible, to limit the amount of fat in products and to prevent jerky from oxidizing. This study found that semi-dried goat meat jerky prepared by adding tomato and pineapple as tenderizers offer the consumers an option of a nutritious low-calorie snack.

Fatty acid analysis

Semi-dried goat meat jerky was evaluated for sixteen fatty acids and their concentrations. Table 4 displays the evaluated fatty acid composition. In the current study, jerky demonstrated significant amounts of MUFAs, which made up 49.18% - 47.70% of the total full acids, SFAs came in next highest with 37.16% - 33.84% and PUFAs were from 13.9% to 11.56%. Saturated fatty acids (SFAs) such as lauric acid (C12:0), myristic acid (C14:0), and palmitic acid (C16:0) are present in significantly higher quantities in controls (NC and PC), as compared to T1 and

T2 ($p < 0.05$). Oleic acid (C18:1) is the most abundant SFA in semi-dried goat meat jerky, with concentrations ranging from 46.21% to 43.98%, and the quantities are substantially more prevalent in T1 and T2 than in NC and PC ($p < 0.05$). According to De Smet et al. [69], stearoyl-CoA desaturase, which converts SFA into their corresponding MUFA, is responsible for the buildup of oleic acid.

The nutritional indices (AI, TI, HH, n–6/n–3, and PUFA/SFA) for jerky are also depicted in Table 4. It is a well-recognized fact that fatty acids can affect cholesterol in both proatherogenic as well as antiatherogenic ways. The index of atherogenicity (AI) is a proportion of proatherogenic fatty acids (SFAs) especially C12:0, C14:0, and C16:0 and antiatherogenic fatty acids (MUFAs and PUFAs) [70]. Atherogenicity (AI) is considered to be the marker of the effect of fats on cholesterol levels and is associated with the risk of atherosclerosis [71]. In this study, it was observed that AI was considerably lower in the tenderizer-treated jerky groups, and ranged from 0.65 to 0.49, (T1 and T2) ($p < 0.05$). The lower AI value reduces the endothelial strength of blood vessels owing to collapsed lipids and plaque formation [72].

The production of blood clots within blood vessels is measured in terms of the thrombogenicity index or TI [73]. In particular, C14:0, C16:0, and C18:0 saturated fatty acids (SFAs) promote thrombosis, whereas MUFAs and PUFAs inhibit thrombosis and this ability is measured in terms of the thrombogenicity index (TI). In this investigation, TI ranged from 1.11 to 0.96 for jerky and the value is much lower in T1 and T2. Low AI and TI scores indicate that our jerky has less likely to develop cardiovascular or hematological side effects.

HH index is related to the proportion of hypocholesterolemic and hypercholesterolemic fatty acids [70]. In this study, the HH index was reported at various concentrations and was equal to 2.03, 2.19, 2.52, and 2.58 in NC, PC, T1, and T2 respectively. A higher HH index value corresponds to lower cholesterol levels. In addition, according to the UK Department of Health [74], the ratio of PUFA and SFA (PUFA/SFA) should be higher than

0.4. According to our findings, the PUFA: SFA ratio in goat meat jerky ranged from 0.41 to 0.31, with T2 having the highest ratio and NC having the lowest. WHO/FAO has recommended that the ratio of n-6/n-3 (omega 6:omega 3) should be lower than 5 [75]. Our study indicated that n-6/n-3 levels in the goat meat jerky were greater than advised. However, the AI, TI, and HH indices indicate that jerky treated with tenderizers has a good nutritional value and can be used in the diet of the elderly population as a supplement.

Residual nitrite content

Nitrate and nitrite are frequently utilized in meat processing because they have beneficial effects on antimicrobials, lipid oxidation, flavor, and especially the development of red color in cured meat [76]. While curing, nitrite generates a large number of nitrosated reaction chemicals, some of which persist in the final product, in the form of unreacted residual nitrite content. This unreacted nitrite content has been found to cause cancer and is associated with an enhanced risk of leukemia in consumers [77]. Therefore, reducing the residual nitrite content in meat products is crucial and the recommended acceptable daily intake for nitrite is between zero and 0.07 mg/kg body weight per day [78]. In this study, Swiss chard powder (*Beta vulgaris var. cicla*) (0.2%) was utilized as a substitute for synthetic nitrite in PC, T1, and T2 groups, and pickling salt (synthetic nitrite) (0.06%) was treated as the NC to ensure that the residual nitrite level was less than 70 ppm, as determined by the pre-test (data not shown). The results of our investigations (Figure 5) demonstrated that the 0.06% pickling salt used as the NC had the lowest residual nitrite concentration (68.26 ppm), but it was unable to provide the desired red color for the semi-dried goat meat jerky as mentioned color. However, PC, T1, and T2 contained 0.2% Swiss chard powder (natural nitrate), which not only provided the desired red color for our semi-dried goat meat jerky but also had a residual nitrite content lower than 70 ppm. PC, T1, and T2 did not differ substantially from one another ($p > 0.05$), however, T1 and T2 had lower residual nitrite content than PC. Most likely, the dietary fiber present in pineapples lowers the levels of residual nitrite content. In essence, nitrites possibly react with the dietary fiber and bioactive substances in the product in which tenderizers have been added (pineapple and tomato powder), thereby reducing the residual nitrite level in T1 and T2. Fernández-López et al. [79] also observed a lower residual nitrite content in dried-cured products containing orange dietary fibre (ODF) than those without ODF. Thus, the replacement of synthetic nitrite with 0.2% Swiss chard powder will result in eye-catching jerky and will also ensure food safety.

Myofibrillar fragmentation index (MFI)

Proteolysis, which occurs in meat and meat products is a prominent aspect affecting meat tenderness [80]. MFI is an indicator of protein denaturation and the presence of more protein fragments that are broken into smaller pieces makes the meat more tender [81]. MFI was also measured in the current study to assess the protein denaturation in the jerky treated with tenderizers (Figure 6). According to the findings, T1 had the greatest MFI value ($p < 0.05$), followed by T2, which had higher MFI values than NC and PC. More likely, the proteolytic enzyme (bromelain) in pineapple likely alters the myofibril breaking it down into small fragments, thereby degrading muscle integrity. Similar findings have been reported by Kim et al. [48], in which the myofibrillar proteins in pork jerky treated with pineapple degraded more quickly on sodium dodecyl sulfate-polyacrylamide gel (SDS-PAGE). The MFI results supported the shear force value (kgf) data and sensory tenderness as mentioned in this study. A report by Ku et al. [82] has indicated that MFI values and sensory tenderness ratings, as well as shear force, were strongly correlated. In the present study, T1 and T2 was no significant difference in shear force value but T1 had higher MFI value than T2. One possible explanation for this could be the jerky's surface because shear force assesses tenderness by determining how much force is required to shear through the sample. Whatever the case, tenderizers (pineapple and tomato) cause physical disruption of myofibrillar protein and contribute to enhanced proteolysis that positively impacts the tenderness of semi-dried goat meat jerky.

SDS-polyacrylamide gel electrophoresis (SDS-PAGE)

The SDS-polyacrylamide gel electrophoresis patterns of semi-dried goat meat jerky are depicted in Figure 7. The efficiency of tenderizers in protein degradation was observed among treatments based on the 15% Tris-glycine SDS-PAGE patterns. According to the patterns, pineapple-treated jerky (T1) and pineapple and tomato-treated jerky (T2) demonstrated a higher proportion of degradation of proteins than jerky without tenderizers (NC and PC). MFI indicated a similar tendency across all groups. In contrast to the 50 kDa protein band, which was dramatically diffused in T2 and T1, the intensity of the band corresponding to 75 kDa was noticeably lower in all treatments. A greater rate of myofibrillar protein breakdown was observed in the jerky with 5% pineapple [48]. Probably, the proteolytic enzyme bromelain, which is present in pineapple, modifies the disintegration of proteins into smaller pieces. These results suggest that the protein structure of goat meat jerky is denatured by the addition of tenderizers. Therefore, a jerky made with tenderizers (pineapple and tomato powder) could be more tender and chewable for elderly people.

Sensory Evaluation

The sensory panels evaluated how the color, flavor, typical goaty flavor, tenderness, juiciness, and overall acceptability of semi-dried goat meat jerky changed after being treated with tenderizers (Figure 8). The three main sensory qualities are tenderness, flavor, and color, and they may vary based on the raw materials and processing formulas [83]. Sensory evaluation results in the current study, indicate that the tenderizer positively affects color, texture, flavor, and overall acceptance. Regarding the restrictions of residual nitrite concentration, the sensory color score of PC was significantly higher than NC ($p < 0.05$). The color score of the T2 sample was the highest among all treatments ($p < 0.05$). Additionally, the panelists preferred the T2 flavor over the other treatments ($p < 0.05$), but there was no noticeable difference in the T1 flavor ($p > 0.05$), however, the flavor scores of NC and PC were lower due to the typical goaty smell which the panelists found unpleasant. Jerky (T2) treated with pineapple and tomato flavor was preferred over the other groups since it had a lower goaty flavor. In addition, one of the most crucial sensory characteristics in meat products for the elderly that influence pleasure and acceptability is the texture of the jerky. According to the sensory attributes, the overall tenderness scores of the semi-dried goat meat jerky ranged from 7.2 to 5, and jerky treated with tenderizers (T2 and T1) had the greatest tenderness scores ($p < 0.05$). T2 and T1 were also judged to be juicier as compared to NC and PC ($p < 0.05$). The overall acceptability scores varied from 7.3 to 5, with T2 achieving the highest approval. The reason for this may be improved textural properties. Mori et al. [84] mentioned that tenderness is the first factor that influences the overall quality of meat and meat products. Therefore, tenderizers used in jerky may improve the quality traits, including flavor, tenderness, juiciness, and overall acceptance.

Multivariate analysis

Multivariate analysis was carried out on samples of the different experimental treatments to classify the semi-dried goat meat jerky according to its quality features. PCA (principal component analysis) and PLS-DA (partial least squares-discriminant analysis) of different treatments (NC, PC, T1, and T2) were performed. Each group was geographically isolated from the others, with PC1 accounting for 87.6% and Component 1 for 82.8% of the total variation (Figure 9a, b). Additionally, the six quality attributes (MFI, moisture, a*, shear force, PUFA, and n-6) were represented by the variable importance in projection (VIP) score, which illustrates the significance of the variables for group discrimination in PLS-DA (Figure 9c). Group T1 had the highest MFI, moisture, and redness (a*) values, indicating that myofibrillar breakdown and redness color attributes were enhanced in the jerky made with pineapple and natural nitrate. The jerky is made without tenderizers, NC and PC had the highest shear force. In addition, PUFA and n-6 fatty acids were higher in T2 (pineapple and tomato).

According to the heatmap, all the sensory evaluation values except the goaty flavor were highly correlated with T1 and T2 (Figure 9 (d)). In addition, the redness color attribute (a*) was highly correlated with PC, T1, and T2 groups, indicating that natural nitrate (Swiss chard powder) can provide the desirable redness color. Shear force and goaty flavor are negatively linked with T1 and T2, respectively.

Conclusion

Nutritional deficiency in the elderly is a crucial problem all over the world because of their compromised digestion and weak absorption of essential nutrients like protein, vitamins, and minerals. Meat products which are easily chewable and digestible as well as packed with nutrients are necessary for them to combat aged-related malnutrition. Goat meat jerky prepared with added tenderizers had a higher moisture content and lower water activity. The texture of this jerky was also unique and suitable for this age group. The results have provided evidence suggesting that the presence of tenderizers caused proteins to lose structural integrity, as evident from MFI and SDS-PAGE patterns. According to sensory evaluation, the jerky's qualities, including flavor, tenderness, juiciness, and overall acceptance, seem to be enhanced by the addition of tenderizers. With regards to color attributes, tenderizers enhanced the redness color of the jerky. In addition, jerky with tenderizers had a lower pH value and lower total plate counts during storage. Also, tenderizers inhibited the growth of *E. coli* and coliforms and extended shelf life by reducing lipid oxidation. Moreover, tenderizers lowered the SFA and increased PUFA thereby positively affecting AI, TI, and HH indices. In the current research, Swiss chard powder (0.2%) aids in improving microbial safety, suppression of oxidation, and color developing an appropriate red color by denitrification through a starter culture. Our semi-dried goat meat jerky which has essential fatty acids, amino acids, and lower shear force would serve as an alternative snack item for this vulnerable group. In addition, jerky can be stored for a long time at room temperature as it has low water activity and microbial growth.

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Competing Interests

The authors declare no potential conflict of interest.

Author's Contributions

Conceptualization: Nam KC, Aung SH. Formal analysis: Aung SH, Md.Altaf Hossain, Park JY. Methodology: Aung SH, Md.Altaf Hossain, Park JY. Software: Park JY, Choi YS. Validation: Nam KC, Choi YS. Investigation: Aung SH, Md.Altaf Hossain, Park JY. Writing - original draft: Aung SH. Writing - review & editing: Aung SH, Md.Altaf Hossain, Park JY, Choi YS, Nam KC.

Ethics approval and consent to participate

The Sunchon National University Institutional Review Board (1040173-202107-HR-010-02) approved the sensory evaluation.

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Tables and Figures

Table 1. Formulation of semi-dried goat meat jerky

Item	NC	PC	T1	T2
Meat (100%)	800	800	800	800
Salt (1.2%)	9.5	9.6	9.6	9.6
Water (10%)	80	80	80	80
Sugar (2.5%)	20	20	20	20
Pickling salt (0.06%)	0.48	-	-	-
Swiss chard powder (0.2%)	-	1.6	1.6	1.6
Starter culture (0.05%)	-	0.4	0.4	0.4
Ascorbic acid (0.05%)	0.4	0.4	0.4	0.4
Glycerol (3%)	24	24	24	24
Ginger (0.4%)	3.2	3.2	3.2	3.2
Black Pepper (0.3%)	2.4	2.4	2.4	2.4
Garlic (0.2%)	1.6	1.6	1.6	1.6
Onion (0.2%)	1.6	1.6	1.6	1.6
Pineapple (0.5%)	-	-	4	4
Tomato (0.25%)	-	-	-	2

Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers; T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato powder

Table 2. Effects of tenderizers on quality characteristics of semi-dried goat meat jerky

Items	Treatments[1)]	Storage period (d)			SEM[2)]
		1	15	30	
Moisture (%)	NC	39.17^{ay}	42.67^{x}	34.50^{abz}	0.64
	PC	35.67^{by}	38.33^{x}	35.50^{ay}	0.39
	T1	39.33^{ax}	41.00^{x}	35.33^{ay}	0.69
	T2	38.17^{ax}	39.67^{x}	33.17^{by}	1.81
	SEM	0.29	1.71	0.47	
Water activity (aw)	NC	0.89^{a}	0.89	0.88	0.003
	PC	0.89^{a}	0.89	0.88	0.004
	T1	0.89^{a}	0.89	0.88	0.004
	T2	0.87^{b}	0.88	0.87	0.004
	SEM	0.32	0.01	0.002	
Shear force (kgf)	NC	9.10^{ax}	6.14^{az}	7.74^{ay}	0.28
	PC	6.87^{bx}	6.47^{ax}	5.26^{by}	0.24
	T1	5.19^{cx}	4.69^{bxy}	4.16^{cy}	0.23
	T2	4.82^{cx}	3.12^{cy}	4.53^{cx}	0.09
	SEM	0.26	0.23	0.18	

[a-c] Means with a column with different letters are significantly different ($p < 0.05$).

[x-z] Means with a row with different letters are significantly different ($p < 0.05$).

[1)]Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers; T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato powder

[2)]SEM: Standard error of the mean ($p < 0.05$)

Table 3. Effects of tenderizers on colour attributes, pH, microbial safety, and oxidation of semi-dried goat meat jerky

Items		Treatments[1)]	Storage period (d)			SEM[2)]
			1	15	30	
Color	L*	NC	26.60^{by}	27.63^{abx}	27.12^{bxy}	0.15
		PC	27.07^{ab}	27.16^{b}	27.86^{a}	0.28
		T1	26.61^{by}	26.95^{by}	27.85^{ax}	0.19
		T2	27.48^{ay}	28.39^{ax}	27.30^{aby}	0.13
		SEM	0.19	0.25	0.14	
	a*	NC	5.80^{cy}	6.13^{cx}	6.19^{bx}	0.08
		PC	9.27^{b}	9.26^{b}	9.11^{a}	0.27
		T1	9.76^{ax}	9.96^{ax}	9.19^{ay}	0.16
		T2	9.68^{ax}	9.75^{ax}	9.13^{ay}	0.05
		SEM	0.12	0.14	0.21	
	b*	NC	1.06^{by}	1.63^{bx}	1.74^{bx}	0.12
		PC	0.98^{bz}	1.15^{cy}	2.27^{ax}	0.03
		T1	1.42^{az}	1.64^{by}	1.89^{abx}	0.06
		T2	1.36^{az}	2.88^{ax}	2.04^{aby}	0.02
		SEM	0.03	0.06	0.1	
pH		NC	6.43^{ax}	6.38^{ay}	6.39^{ay}	0.01
		PC	6.21^{bx}	6.18^{by}	5.87^{dz}	0.01
		T1	6.19^{cx}	6.07^{cy}	5.96^{cz}	0.01
		T2	6.18^{cx}	5.87^{dz}	6.08^{by}	0.01
		SEM	0.006	0.01	0.007	
TPC (Log CFU/g)		NC	2.99^{az}	3.14^{by}	4.97^{ax}	0.01
		PC	2.97^{abz}	3.48^{ay}	4.92^{bx}	0.01
		T1	2.95^{bz}	3.13^{by}	4.89^{bx}	0.01
		T2	2.84^{cz}	3.11^{by}	4.68^{cx}	0.01
		SEM	0.01	0.01	0.01	
TBARS (mg MDA/kg)		NC	1.49^{by}	1.54^{bcx}	1.48^{by}	0.01
		PC	1.63^{ay}	1.67^{ax}	1.53^{az}	0.01
		T1	1.35^{cy}	1.49^{cx}	1.46^{cx}	0.02
		T2	1.37^{cz}	1.55^{bx}	1.44^{cy}	0.01
		SEM	0.02	0.01	0.01	

$^{a\text{-}d}$ Means with a column with different letters are significantly different ($p < 0.05$).

$^{x\text{-}z}$ Means with a row with different letters are significantly different ($p < 0.05$).

[1)]Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers; T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato powder

[2)]SEM: Standard error of the mean ($p < 0.05$)

Table 4. Effects of tenderizers on the fatty acid composition of semi-dried goat meat jerky

Items (%)	Treatments$^{1)}$				SEM$^{2)}$
	NC	PC	T1	T2	
10:0	0.05^{b}	0.04^{b}	0.06^{a}	0.06^{a}	0.002
12:0	0.53^{a}	0.46^{b}	0.29^{c}	0.29^{c}	0.002
14:0	3.71^{a}	3.31^{b}	2.49^{c}	2.42^{d}	0.02
16:0	23.59^{a}	22.60^{b}	20.91^{c}	20.59^{d}	0.03
16:1	3.42^{a}	3.30^{a}	2.54^{b}	2.55^{b}	0.03
18:0	9.29^{a}	9.37^{a}	10.56^{b}	10.48^{c}	0.02
18:1	44.24^{a}	43.98^{b}	46.21^{c}	45.67^{d}	0.04
18:2	7.13^{d}	7.83^{c}	7.87^{b}	8.47^{a}	0.001
18:3	0.50^{b}	0.55^{a}	0.43^{c}	0.42^{c}	0.002
20:2	0.04^{d}	0.05^{c}	0.08^{b}	0.12^{a}	0.002
20:3	0.22^{c}	0.26^{b}	0.26^{b}	0.28^{a}	0.002
20:4	3.16^{d}	3.83^{b}	3.77^{c}	4.06^{a}	0.01
20:5	0.11^{c}	0.14^{a}	0.13^{b}	0.14^{a}	0.002
22:5	0.34^{d}	0.39^{c}	0.44^{b}	0.47^{a}	0.004
22:6	0.05^{a}	0.03^{c}	0.03^{c}	0.04^{b}	0
24:1	0.37^{d}	0.42^{c}	0.43^{b}	0.45^{a}	0.002
SFA	37.16^{a}	35.79^{b}	34.31^{c}	33.84^{d}	0.06
UFA	59.58^{d}	60.77^{c}	62.19^{b}	62.65^{a}	0.02
MUFA	48.02^{c}	47.70^{d}	49.18^{a}	48.67^{b}	0.02
PUFA	11.56^{c}	13.07^{b}	13.02^{b}	13.98^{a}	0.01
UFA/SFA	1.60^{d}	1.70^{c}	1.81^{b}	1.85^{a}	0.003
n-6/n-3	8.44^{c}	8.55^{c}	9.07^{b}	9.44^{a}	0.03
n-6	10.34^{c}	11.70^{b}	11.72^{b}	12.64^{a}	0.01
n-3	1.23^{b}	1.37^{a}	1.29^{b}	1.34^{a}	0.01
AI	0.65^{a}	0.60^{b}	0.50^{c}	0.49^{c}	0.002
TI	1.11^{a}	1.04^{a}	0.99^{b}	0.96^{b}	0.002
P/S	0.31^{c}	0.37^{b}	0.38^{b}	0.41^{a}	0.002
HH	2.03^{c}	2.19^{b}	2.52^{a}	2.58^{a}	0.01

$^{a\text{-}d}$ Means within each jerky sample with different letters are significantly different ($p < 0.05$).

$^{1)}$Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers; T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato powder

$^{2)}$SEM: Standard error of the mean ($p < 0.05$)

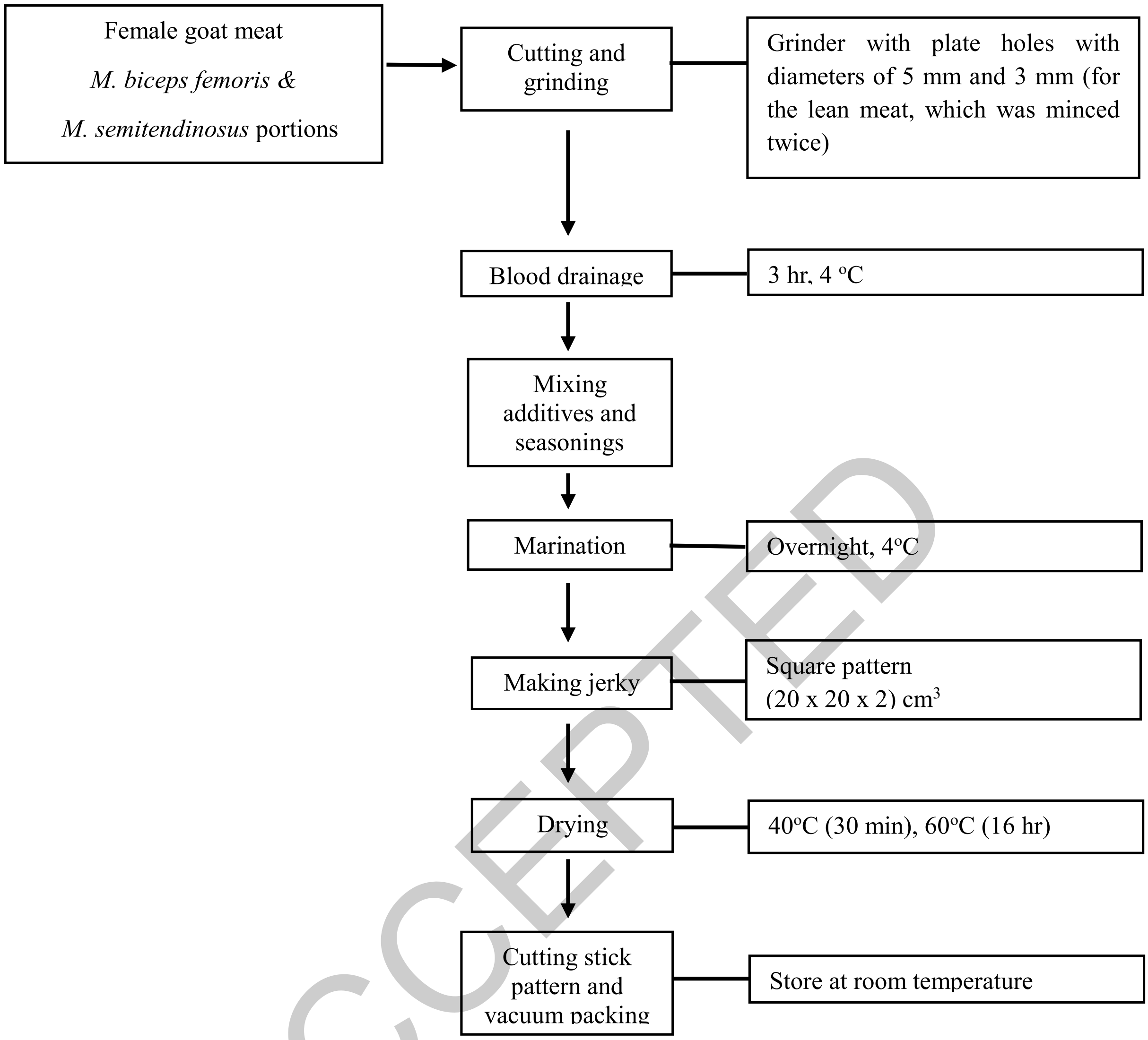


Figure 1. The diagram for manufacturing of semi-dried jerky containing tenderizers.

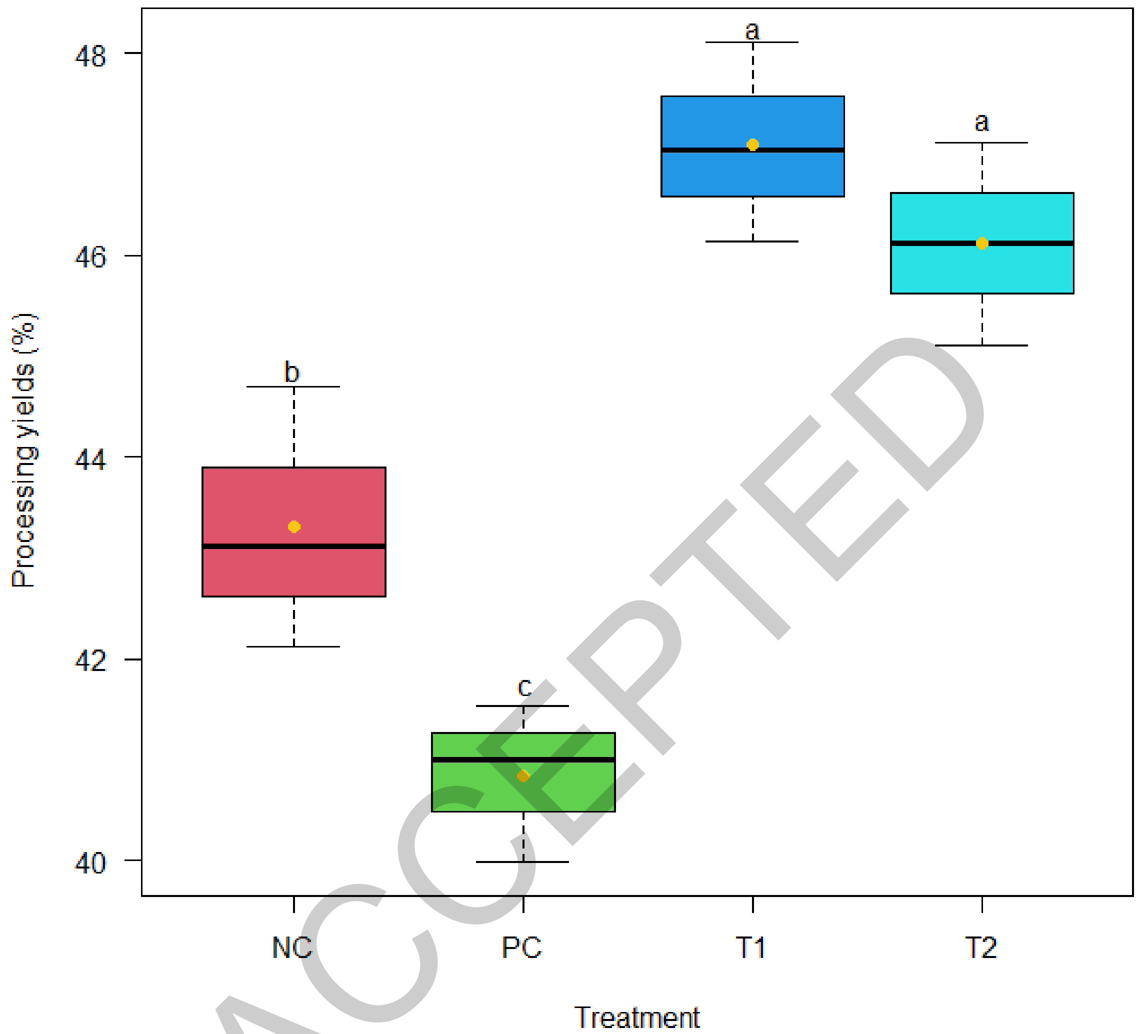


Figure 2. Effects of tenderizers on processing yields of semi-dried goat meat jerky. Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers; T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato powder

[a-c] Different letters differ significantly between treatments ($p < 0.05$)

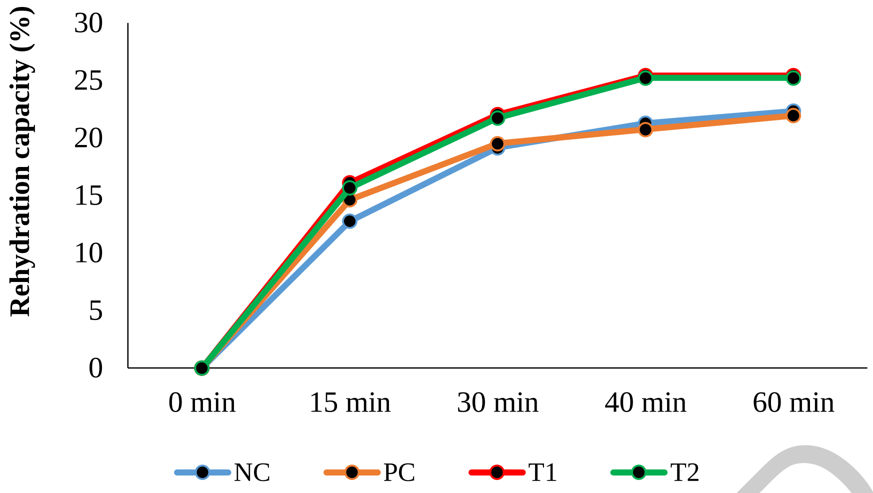


Figure 3. Effects of tenderizers on rehydration capacity of semi-dried goat meat jerky. Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers; T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato powder

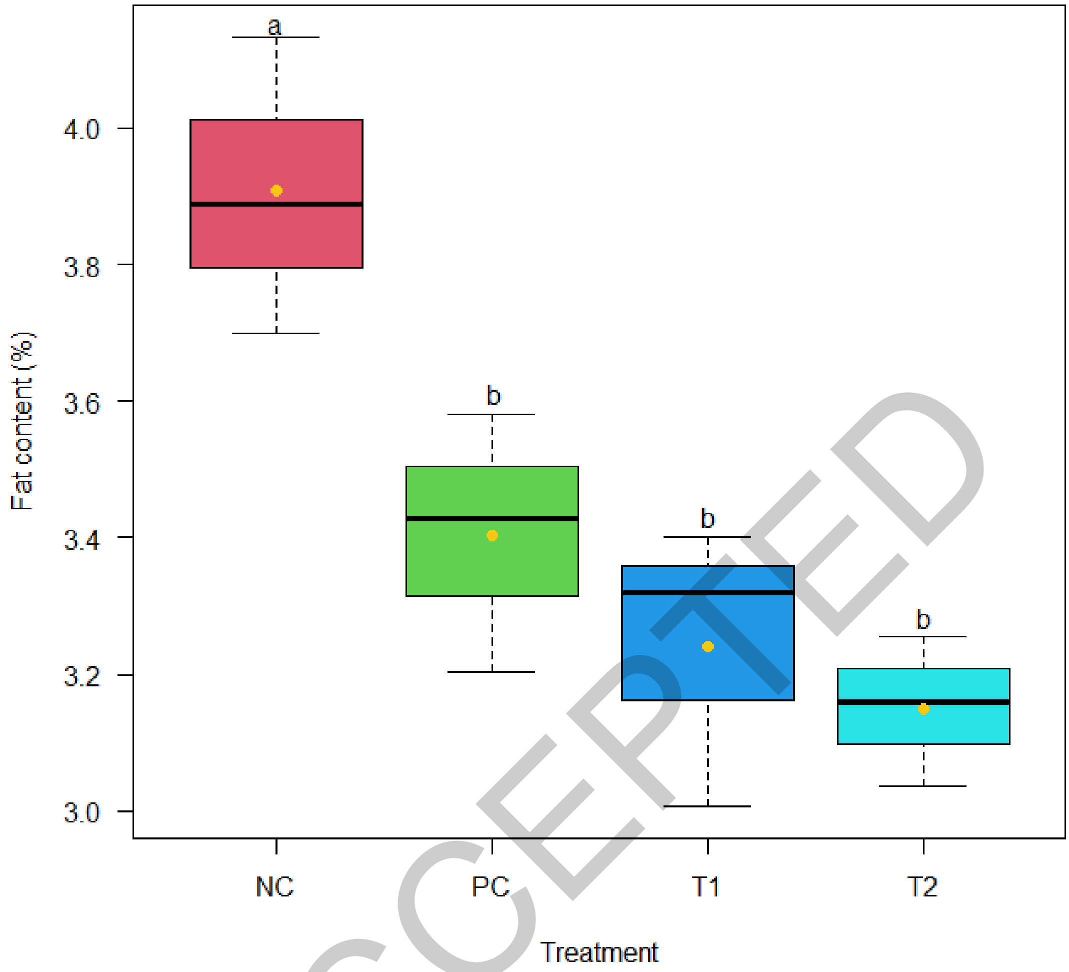
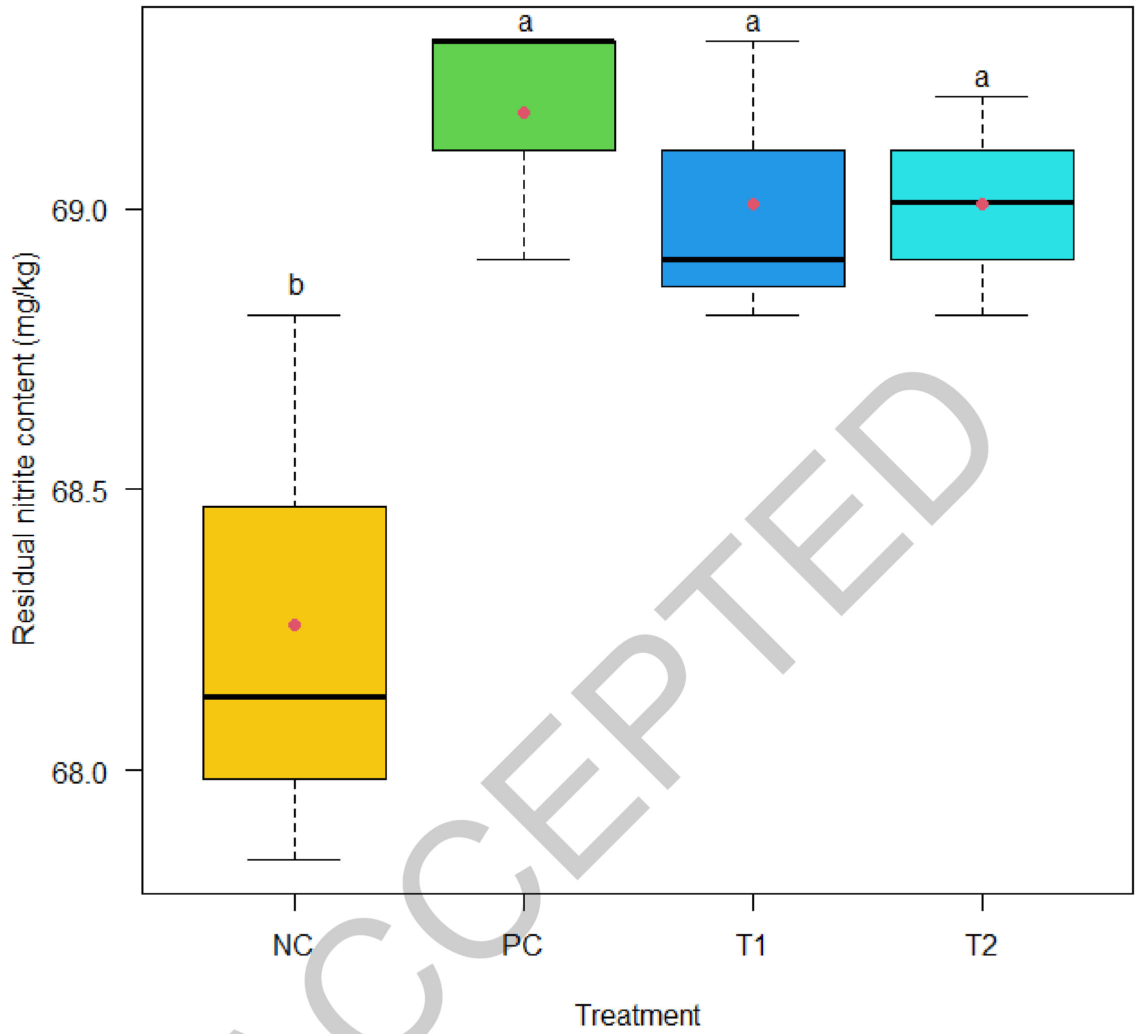


Figure 4. Effects of tenderizers on the fat content of semi-dried goat meat jerky. Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers; T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato powder

[a,b] Different letters differ significantly between treatments ($p < 0.05$)

Figure 5. Residual nitrite content of semi-dried goat meat jerky.



Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers; T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato powder

[a,b] Different letters differ significantly between treatments ($p < 0.05$)

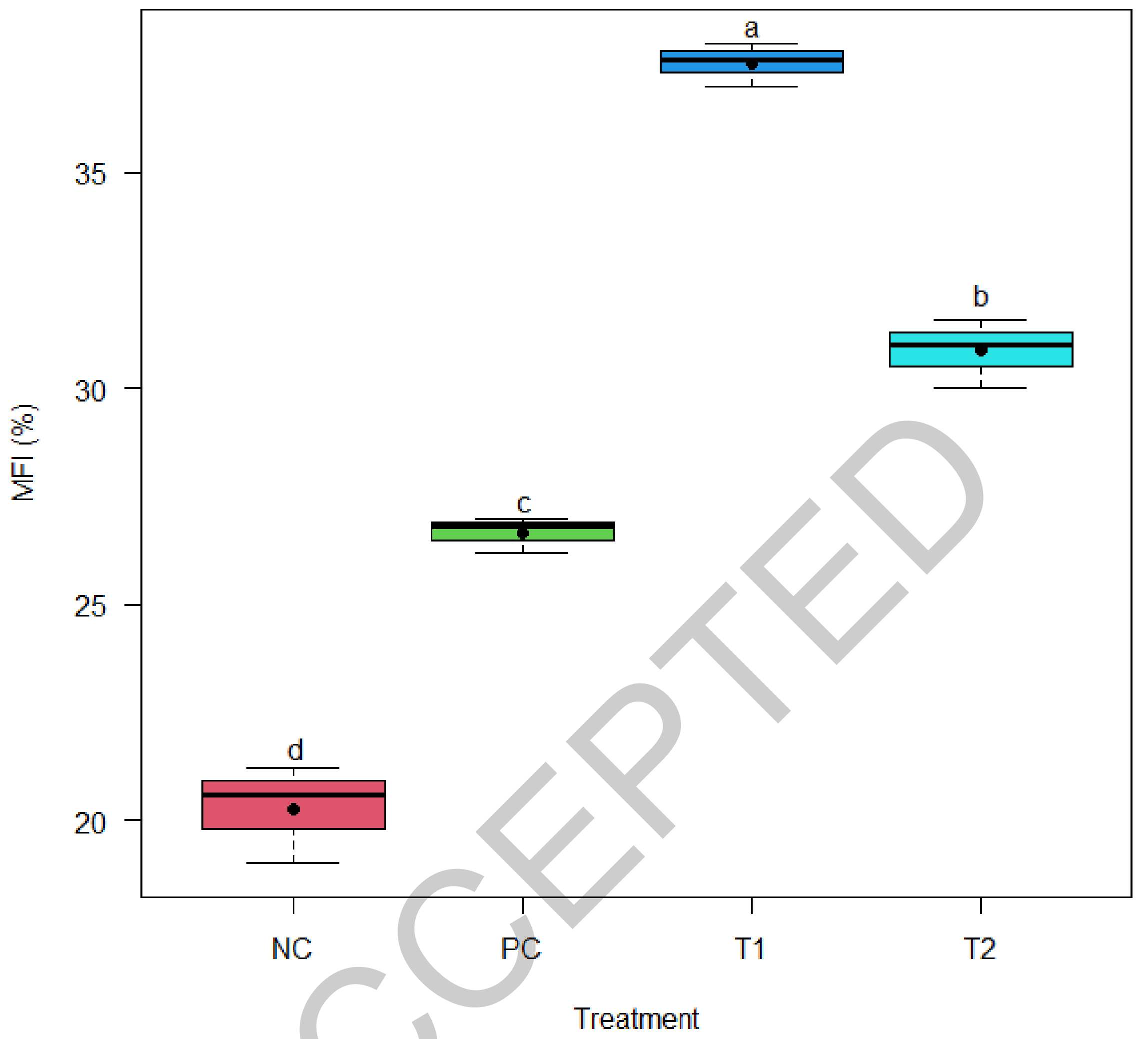


Figure 6. Effects of tenderizers on the MFI of semi-dried goat meat jerky.

Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers; T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato powder

[a-d] Different letters differ significantly between treatments ($p < 0.05$)

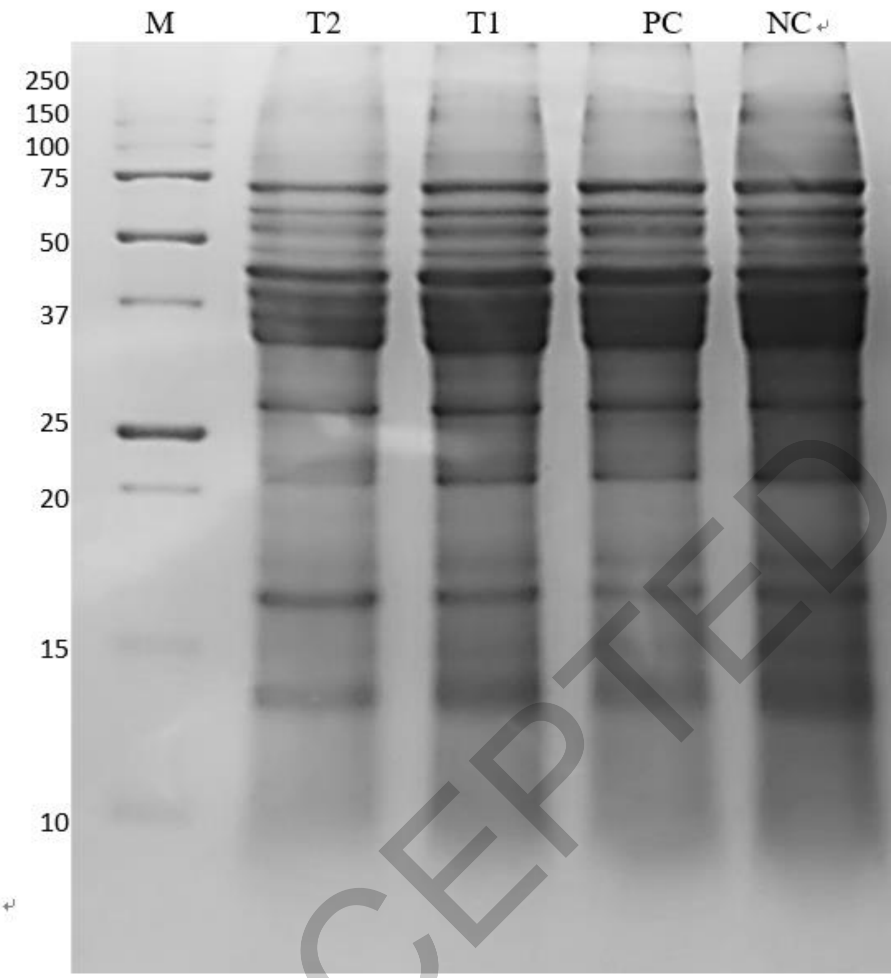


Figure 7. 15% SDS-PAGE gel patterns for protein denaturation of semi-dried jerky.
M: marker, NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers; T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato powder

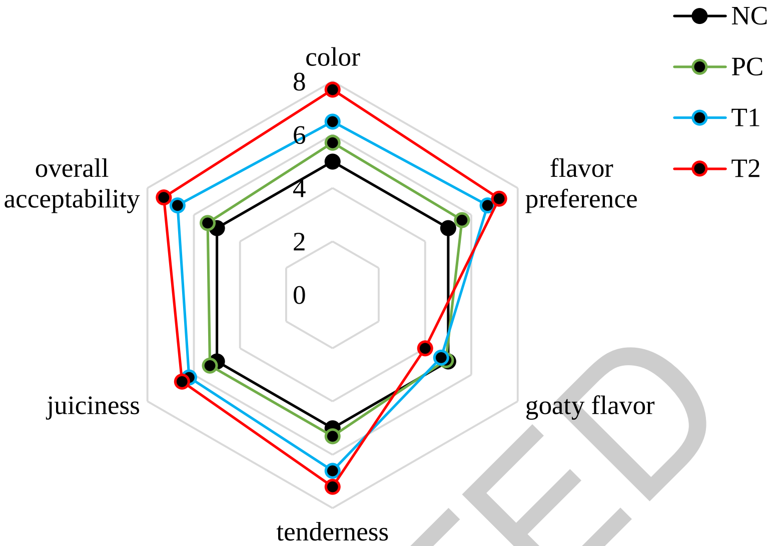
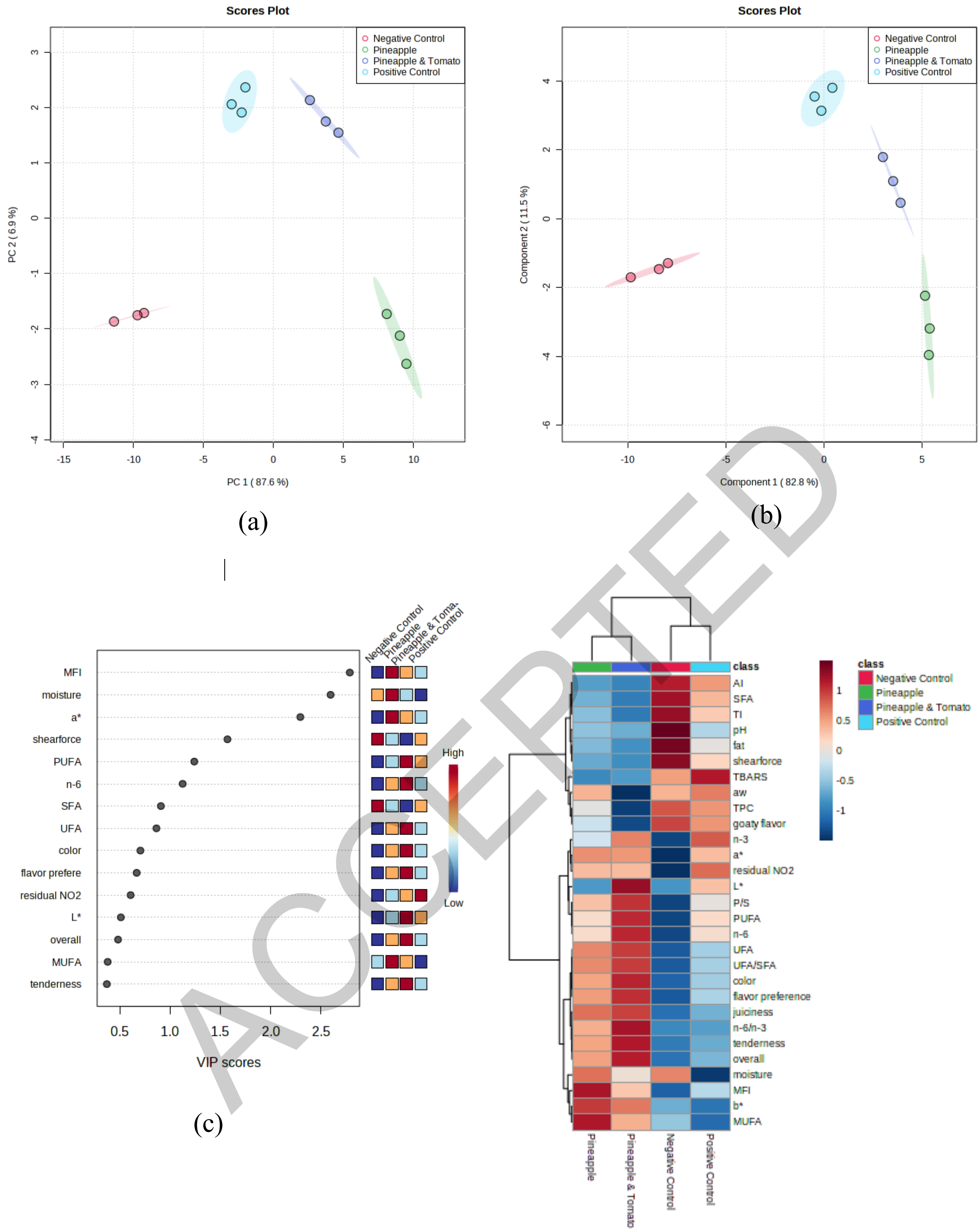


Figure 8. Effects of tenderizers on the sensory properties of semi-dried goat meat jerky. Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers; T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato powder



(d)

Figure 9. Results of (a) PCA, (b) PLS-DA, (c) VIP score, and (d) Heatmap of semi-dried goat meat jerk in the initial day.

NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers; T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato powder