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JAST (Journal of Animal Science and Technology) TITLE PAGE

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ARTICLE INFORMATION	Fill in information in each box below
Article Type	Research article
Article Title (within 20 words without abbreviations)	Development of semi-dried goat meat jerky using tenderizers considering the preferences of the elderly
Running Title (within 10 words)	Effects of tenderizers on semi-dried goat meat jerky
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Competing interests	The authors declare no potential conflict of interest.
Funding sources State funding sources (grants, funding sources, equipment, and supplies). Include name and number of grant if available.	This study was supported by the Rural Development Administration's research project (No. PJ0161792023), and we appreciate it.
Acknowledgements	No applicable
Availability of data and material	Upon reasonable request, the datasets of this study can be available from the corresponding author.
Authors' contributions Please specify the authors' role using this form.	Conceptualization: Nam KC, Aung SH, Formal analysis: Aung SH, Md. Altaf Hossain, Park JY Methodology: Aung SH, Md. Altaf Hossain Software: Aung SH, 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 Suncheon National University Institutional Review Board (1040173-202107-HR-010-02) approved the sensory evaluation.

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12 **preferences of the elderly**

13

14

Abstract

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

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

38

Introduction

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

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

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

63 appealing to the elderly.

64 Among the ingredients, synthetic nitrites and nitrates are widely used in meat products
65 since they enhance the red color characteristics of cured meats, provide flavor, prevent
66 microbial growth, and act as antioxidants [17]. However, people who care about their health
67 expect foods made from natural sources and free of chemicals [18]. Therefore, many food
68 producers have investigated the applicability of nitrites derived from natural plant nitrates, as
69 an alternative to synthetic nitrites [19]. Among the various plant-derived nitrate sources, Swiss
70 chard (*Beta vulgaris L. var. cicla*) is a rich source of nitrate and also acts as an antibacterial
71 agent and antioxidant component [20, 21]. However, a nitrate-reducing starter culture is needed
72 when natural nitrate sources are used to generate the typical cured meat qualities [22]. Starter
73 culture converts nitrate into nitrite; this is the most promising approach to incorporating natural
74 sources of nitrite into processed meats [23]. An initial heat treatment at 40 ± 2 °C for about 30-
75 60 min is required for converting natural nitrates to nitrites with a starter culture [24].

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

82 Recently, beef jerky has become more popular than jerky obtained from other meat sources
83 due to its versatility. The popularity of jerky produced from pork, poultry, and other meats is
84 also growing. When compared to other meats, the popularity of goat jerky is hindered because
85 of its distinctive. Additionally, the number of elderly consumers is on the rise nowadays, and
86 ingesting jerky is difficult for them; as a result, texture modification is necessary. On the other

87 hand, food-related diseases are exponentially increasing due to the addition of synthetic
88 additives, making organic food production very challenging for the food industry. This study
89 desired to explore the potential benefits of using Swiss chard powder as a natural curing agent.
90 The ultimate goal of this study was to improve the texture profile as well as the nutritional
91 composition of goat meat jerky by adding natural tenderizers. In addition, the effects of natural
92 tenderizers on the goaty flavor of jerky were also taken into consideration.

93

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 4°C, and stored at a temperature of -18°C 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°C. 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 4°C for 3 h after grinding.

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

129

130 **Analytical methods**

131 **Processing yields**

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

$$134 \quad \text{Processing yields (\%)} = \frac{\text{jerky weight after drying}}{\text{cured meat weight before drying}} \times 100$$

135

136 **Rehydration capacity**

137 The rehydration capacity was determined by the method described by Kim et al. [28].
138 The samples were sliced into (1.0 × 1.0 × 1.0) cm³ volumes. Fifty milliliters of distilled
139 water was added to a 100 mL beaker. The jerky was weighed before and after rehydration for
140 15, 30, 45, and 60 min at room temperature. The following formula was used to compute the
141 percentage of rehydration capacity:

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

143

144 **Moisture, water activity, and fat content**

145 The moisture content was measured based on the weight loss of semi-dried jerky after
146 12 h at 105°C in a drying oven [29]. Samples used to measure water activity were chopped into
147 pieces with sharp scissors and analyzed with a water activity meter (rotronic Hygromer, AWC,
148 USA). The amount of fat in 5 g of jerky sample was assessed using a chloroform/methanol (2:1)
149 ratio as earlier described by Folch and Lees [30].

150 **Color and pH**

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

160 **Microbiological analysis**

161 The filter bag contained a 10 g sample of minced jerky that had been diluted with 90
162 mL of sterile saline solution (0.85% NaCl). After that, it was stomached for 2 min in a blender
163 (LED Embossing Stomacher, Bnf Kore, Gimpo, Korea). After homogenizations, serial decimal
164 dilutions of the homogenate were prepared. For determining the total plate count and detecting
165 the presence of *Salmonella spp.*, each appropriate dilution was immediately inoculated onto

166 the surface of dry film culture medium (Aerobic Count Plate; 3M Petrifilm) and XLT4 (Merck,
167 Darmstadt, Germany). After drying the plates, they were incubated at 37°C for 24 h. The total
168 number of bacteria was determined by multiplying the number of red colonies generated by the
169 rate of dilution. The bacteria count is represented as (Log CFU/g) [31].

170 **TBARS (2-thiobarbituric acid reactive substance)**

171 The amount of lipid oxidation was determined by adding 5 g of sample and 15 mL of
172 distilled water in a 50 mL test tube along with 50 μ L of butylated hydroxytoluene (7.2 per cent
173 in ethanol, w/v) and homogenized according to the TBARS (2-thiobarbituric acid-reactive
174 substances) measuring technique [32]. Subsequently, 2 mL of the homogenized sample was
175 transferred into a 15 mL tube, and 4 mL of thiobarbituric acid/trichloroacetic acid solution (20
176 mM TBA/15% TCA, w/v) was added. The mixture was heated in a hot-water bath at 90°C for
177 15 min and then cooled for 15 min with cool water. After cooling, 3 mL of the mixture was
178 centrifuged at 3,000 rpm, 4°C for 15 min, and the absorbance of the supernatant solution was
179 measured at 531 nm. The blank solution was prepared by mixing 1 mL of distilled water with
180 2 mL of TBA/TCA solution and the amount of TBARS was quantified in mg of
181 malondialdehyde (MDA) per kg of the jerky samples.

182 **Fatty acid composition analysis**

183 A minimally altered method was used to assess the fatty acid composition of semi-dried
184 jerky [33]. Each sample weighing 1 g was combined with 0.7 mL of 10 N KOH and 6.3 mL of
185 methanol for the separation of fatty acid methyl esters. This mixture was then put into a water
186 bath that was maintained at a constant temperature of 55°C. During heating, the samples were
187 vigorously shaken every 30 min. The product was then treated with 0.58 mL of (24 N) H₂SO₄
188 after cooling it in ice-cold water for two minutes. The mixture was heated once more using the
189 same steady temperature and a similar procedure. After adding 3 mL of hexane, the mixture
190 was centrifuged at 3,000 rpm for 5 minutes (HANIL Combi-514R, Inchon, Korea), and then it

191 was transferred to a vial with a Pasteur pipette. The mixture was then run through a gas
 192 chromatography-flame ionization detector (Agilent 7890 series, Wilmington, USA), which had
 193 the following settings. The injector was a split mode injector with a split ratio of 25:1, the
 194 temperature was maintained at 250°C, and the detector was a flame ionization detector. High-
 195 purity air, H₂, and He were used as the carrier gas, and the flow rate was 40 mL/min for H₂ and
 196 400 mL/min for air. The column for analysis was HP-88 (60 m × 250 μm × 0.2 mm). The
 197 fatty acid composition was expressed in terms of percentage.

198 **Nutritional quality indexes**

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

207

$$208 \quad AI = \frac{[C12:0 + 4 \times (C14:0) + C16:0]}{[\sum MUFA + \sum PUFA]}$$

209

$$210 \quad TI = \frac{[C14:0 + C16:0 + C18:0]}{[0.5 \times (\sum MUFA + \sum n6) + 3 \times \sum n3 + \frac{\sum n3}{\sum n6}]}$$

211

$$212 \quad HH = \frac{[C18:1cis9 + C18:2n6 + C20:4n6 + C18:3n3 + C20:5n3 + C22:5n3 + C22:6n3]}{[C14:0 + C16:0]}$$

213

214 **Warner-Bartzler Shear Force (WBSF)**

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

222 **Residual nitrite content**

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

238

239 **Myofibrillar fragmentation index (MFI)**

240 The myofibrils were obtained according to the method described by Olson and Stromer
241 [37], using an MFI buffer (0.1M KCl, 0.02M KH₂PO₄, 0.001M EDTA, 0.001M MgCl, and
242 0.001M NaN₃). Two grams of sample were mixed with 20 mL of ice-cold MFI buffer and
243 homogenized at 15000 rpm for 30 sec. The mixture was centrifuged at 1000×g for 15 min
244 before the supernatant was decanted. The sediment was re-mixed in 20 mL of cool ice MFI
245 buffer and the procedure was repeated. The resulting residue was re-suspended in 10 mL MFI
246 buffer, and the homogenate was filtered through an 18 mesh filter to remove fat and connective
247 tissue after vortexing. The extracted liquid will be used to determine the protein content at 540
248 nm by the biuret method. MFI values were recorded as absorbance of units per 0.5 mg/mL
249 myofibril protein concentration multiplied by 200 [38].

250 **SDS-polyacrylamide gel electrophoresis (SDS-PAGE)**

251 The protein denaturation of semi-dried goat meat jerky treated with tenderizers was
252 analyzed using sodium dodecyl sulfate-polyacrylamide gel (SDS-PAGE), as described by
253 Green and Sambrook [39]. The jerky samples were lyophilized using a freeze dryer (Lyoph-
254 Pride, LP03; Ilshin BioBase Co., Ltd., Korea). The lyophilized samples were mixed with the
255 sample loading buffer (0.25 M Tris-HCl pH 6.8, 4% SDS, 20% glycerol, 10% 2-
256 mercaptoethanol, and 1% bromophenol blue) at a 1:1 (v/v) ratio, and the mixture was heated
257 in the heat blot for 15 min. Each sample (1mg/ml) was loaded using sodium dodecyl sulfate-
258 polyacrylamide gel (5% stacking and 15% separating gels) on the mini-gel electrophoresis
259 (SDS-PAGE) under reduced conditions using Mini Protein Gels (Mini-PROTEAN Precast
260 Gels, Ready Gel® Precast Gels, Bio-Rad). After gel electrophoresis, the gels were stained with
261 0.25% Coomassie blue, 10% standard acetic acid, 50% methanol, and 40% distilled water. A
262 standard broad-range protein marker (Precision Plus Protein Unstained Standards) after de-
263 staining (5% standard acetic acid, 25% methanol, and 70% distilled water) was used for the

264 calculation of the molecular weight of the protein bands.

265 **Sensory evaluation**

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

276 **Statistical analysis**

277 The SAS program (Version 9.3 SAS Institute Inc., NC, USA) was used for statistical
278 analysis of the experimental data from three replications. When significant differences were
279 discovered following a one-way ANOVA, the significance test between the mean values ($p <$
280 0.05) was conducted. The boxplot of the outcomes was produced using the R statistical
281 program (version 4.2.1). Results were presented in terms of the mean value and standard error
282 of the means (SEM), which is the standard error of the treatment interval.

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

288

289

Results and Discussion

290 Processing yields (%)

291 One of the key elements influencing processing yields was the meat product additives
292 because the amount of moisture that evaporates during the drying of jerky significantly impacts
293 its processing yield. Figure 2 illustrates how tenderizers affect the processing yields of semi-
294 dried goat meat jerky. In the present results, the highest processing yield of semi-dried goat
295 meat jerky was found in T1, followed by T2, NC, and PC, with yields varying between 47.1%,
296 45.9%, 43.9%, and 40.8%. The yields demonstrated by the tenderizer-treated jerky (T1, T2)
297 were significantly higher than those of the non-treated jerky ($p < 0.05$). Song [11] had
298 postulated that humectants may be better at holding water because beef jerky treated with
299 humectants had higher processing yields than the control. In this investigation, tenderizers were
300 observed to have a good impact on the processing yields of semi-dried goat meat jerky due to
301 their potential for water retention. As a result, the pineapple powder was more successful in
302 terms of increasing product yield.

303 Rehydration capacity (%)

304 Rehydration capacity depends on the capillaries and cavities near the surface of dried
305 foods, a crucial component influencing sensory qualities including tenderness and smoothness
306 during chewing [40]. The rehydration capacity of semi-dried goat meat jerky is displayed in
307 Figure 3. The rehydration capacity of the goat jerky of the tenderizer-treated groups was found
308 to increase with increased rehydration time after soaking in distilled water. Especially, T1 and
309 T2 underwent faster rehydration as compared to NC and PC, showing 25.42% and 25.21%
310 rehydration respectively after 60 min. This outcome may be a result of the various water-
311 binding abilities and structural stabilities of the constituents. Kim et al. [41] reported that
312 restructured jerky analogue treated with TVB (textured vegetable protein) observed higher
313 rehydration capacity, Kim et al. [42] concluded that this may be because of the components'

314 strong water-binding capability and structural stabilities. Therefore, tenderizers (pineapple and
315 tomato powder in this study) are likely to improve the rehydration capacity of T1 and T2 due
316 to their fixed structure and high porosity. In contrast, NC and PC (without tenderizers)
317 demonstrated weak water-binding capabilities and interaction strengths.

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

319 The moisture content, water activity, and shear force of semi-dried goat meat jerky
320 samples are shown in Table 2. Moisture content is one of the most critical characteristics of
321 jerky because it can alter its texture and shelf life. The higher moisture content of the meat
322 products provides desirable tenderness, however, which also results in rapid deterioration of
323 the product due to greater microbial proliferation [43]. Therefore, moisture levels in the semi-
324 dried jerky should range from 30% to 50%, and water activity should be between 0.82 and 0.90
325 [44]. In our study, the moisture content of the semi-dried goat meat jerky ranged from 35.67%
326 to 39.33%. The pineapple-treated jerky (T1) had the highest moisture content, which was
327 considerably greater than PC ($p < 0.05$) but did not significantly vary from T2 and NC ($p >$
328 0.05). Probably, the pineapple and tomato powder may have an ability to retain water, so the
329 addition of these tenderizers enhanced the moisture content of the jerky. Kim et al. [44] reported
330 that humectants and tenderizers can enhance water absorption and retention, leading to higher
331 moisture content in jerky. After being stored for 15 days, the moisture content in the jerky
332 samples receiving all treatments increased. One possible reason for this could have been that
333 the jerky's moisture distribution was unequal when it was first drying, but equilibration may
334 have taken place in storage time and resulted in a more consistent moisture distribution.
335 However, the moisture content in samples receiving all treatments was found to dramatically
336 decrease following 30 days of storage because through natural evaporation and dispersion
337 throughout the course of prolonged storage, the jerky may have continued to lose moisture.

338 The rate of microbial development and the shelf life of the jerky are both significantly

339 influenced by water activity. Extreme drying of the jerky to reduce the water activity gives it a
340 gritty texture and makes it too dry [14]. Therefore, while manufacturing jerky, controlling water
341 activity below a certain level is a crucial consideration since it contributes to a good texture,
342 inhibits microbial growth, and lengthens shelf life. The water activity of samples receiving all
343 treatments was observed lower than 0.9, although T2 demonstrated the lowest water activity
344 (0.87) compared to other treatments ($p < 0.05$). In addition, there were no noticeable changes
345 in the water activity in any type of jerky after 30 days of storage. Yamaguchi et al. [45]
346 mentioned that jerky needs to possess steady water activity in order to prevent deterioration in
347 quality during storage. Labuza [46] reported that this is a useful approach to characterize the
348 thermodynamic equilibrium of the jerky.

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

364 (3.12 kgf). Most likely, the shear force value is affected by the increased moisture value during
365 storage. However, the shear force value of all the treatments was observed to have increased
366 again after 30 days of storage period, but the increase was not significant. As a result, jerky that
367 has been treated with tenderizers like pineapple and tomato powders is suitable for the geriatric
368 population, because it is more tender and they can easily enjoy the dried meat product. Probably,
369 the dietary fiber present in tenderizers enables the physical trapping of protein and water, which
370 then enhances the water-holding capacity and modifies its texture. In addition, the pattern of
371 jerky plays an important role in achieving the desirable tenderness for elderly persons.

372 **Color, pH, and TBARS**

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

389 limitations of residual nitrite content (70 ppm).

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

401 Kim et al. [48] reported that the addition of tenderizers or humectants positively affects
402 the redness (a^*) of jerky. Similar results were observed in our study, T1 (pineapple) and T2
403 (pineapple and tomato) had significantly higher redness (a^*) values as compared to PC ($p <$
404 0.05). The pigments present in the tenderizers are most likely responsible for the impact on the
405 color. In the case of T2, which contained pineapple and tomato, the pigment lycopene is present
406 in tomato powder and has a higher redness value, which may be responsible for the impact on
407 color improvement. Similarly to this, tomato peel positively impacted all color parameters for
408 sausages which had been treated with a dry fermentation process [55]. Additionally, Østerlie
409 and Lerfall [56] postulated that a combination of minced meat and lycopene could possibly
410 reduce the nitrite demand. The redness (a^*) color of the tenderizer-treated jerky did not undergo
411 major change over the first 15 days of storage. After 30 days of storage, however, a significant
412 drop in the redness (a^*) value was observed, which may be a result of higher levels of
413 metmyoglobin (MMb) production [57]. The addition of tenderizers (T1 and T2) produced

414 greater yellowness (b^*) compared with the control (PC) sample ($p < 0.05$). In addition, the
415 yellowness (b^*) was found to increase significantly during the storage periods. Similarly, Kim
416 et al. [27] revealed that kiwi-tenderized pork jerky showed a greater yellowness (b^*) value.
417 Also, pork jerky that contained tomato powder had a greater yellowness (b^*) rating than jerky
418 without tomato powder [48].

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

431 Lipid oxidation significantly affected the shelf life of the jerky throughout the drying
432 process. Malondialdehyde (MDA) is a byproduct of secondary lipid oxidation and is frequently
433 observed as an oxidation marker [60]. TBARS is a common technique used to measure lipid
434 oxidation by determining the MDA concentration in meat products [61]. The TBARS values
435 of semi-dried goat meat jerky are depicted in Table 3. Regardless of the treatments, TBARS
436 readings for the jerky belonging to every group showed a considerable increase throughout the
437 storage period compared to the initial day. The reason for this may be the decrease in pH values,
438 which was the main reason for the rising water-solubility and enhanced activity of iron in acidic

439 environments [62]. The natural nitrate group (PC) was observed to have a higher TBARS value
440 as compared to NC (synthetic nitrite) ($p < 0.05$). However, tenderizer-treated jerky (T1 and T2)
441 showed significantly decreased TBARS values than the control groups (NC and PC) ($p < 0.05$).
442 Most likely, ingredients such as phenolic compounds and flavonoids present in pineapples are
443 instrumental in the prevention of oxidation during storage. According to Hossain and Rahman
444 [63], pineapple has a high concentration of phenolics, making it a rich source of antioxidants.
445 Additionally, lycopene also suppresses the lipid oxidation of jerky by exerting antioxidative
446 activity.

447 **Microbial analysis**

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

464 **Fat content**

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

482 **Fatty acid analysis**

483 Semi-dried goat meat jerky was evaluated for sixteen fatty acids and their concentrations. Table
484 4 displays the evaluated fatty acid composition. In the current study, jerky demonstrated
485 significant amounts of MUFAs, which made up 49.18% - 47.70% of the total full acids, SFAs
486 came in next highest with 37.16% - 33.84% and PUFAs were from 13.9% to 11.56%. Saturated
487 fatty acids (SFAs) such as lauric acid (C12:0), myristic acid (C14:0), and palmitic acid (C16:0)
488 are present in significantly higher quantities in controls (NC and PC), as compared to T1 and

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

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

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

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

514 0.4. According to our findings, the PUFA: SFA ratio in goat meat jerky ranged from 0.41 to
515 0.31, with T2 having the highest ratio and NC having the lowest. WHO/FAO has recommended
516 that the ratio of n-6/n-3 (omega 6:omega 3) should be lower than 5 [75]. Our study indicated
517 that n-6/n-3 levels in the goat meat jerky were greater than advised. However, the AI, TI, and
518 HH indices indicate that jerky treated with tenderizers has a good nutritional value and can be
519 used in the diet of the elderly population as a supplement.

520 **Residual nitrite content**

521 Nitrate and nitrite are frequently utilized in meat processing because they have
522 beneficial effects on antimicrobials, lipid oxidation, flavor, and especially the development of
523 red color in cured meat [76]. While curing, nitrite generates a large number of nitrosated
524 reaction chemicals, some of which persist in the final product, in the form of unreacted residual
525 nitrite content. This unreacted nitrite content has been found to cause cancer and is associated
526 with an enhanced risk of leukemia in consumers [77]. Therefore, reducing the residual nitrite
527 content in meat products is crucial and the recommended acceptable daily intake for nitrite is
528 between zero and 0.07 mg/kg body weight per day [78]. In this study, Swiss chard powder
529 (*Beta vulgaris var. cicla*) (0.2%) was utilized as a substitute for synthetic nitrite in PC, T1, and
530 T2 groups, and pickling salt (synthetic nitrite) (0.06%) was treated as the NC to ensure that the
531 residual nitrite level was less than 70 ppm, as determined by the pre-test (data not shown). The
532 results of our investigations (Figure 5) demonstrated that the 0.06% pickling salt used as the
533 NC had the lowest residual nitrite concentration (68.26 ppm), but it was unable to provide the
534 desired red color for the semi-dried goat meat jerky as mentioned color. However, PC, T1, and
535 T2 contained 0.2% Swiss chard powder (natural nitrate), which not only provided the desired
536 red color for our semi-dried goat meat jerky but also had a residual nitrite content lower than
537 70 ppm. PC, T1, and T2 did not differ substantially from one another ($p > 0.05$), however, T1

538 and T2 had lower residual nitrite content than PC. Most likely, the dietary fiber present in
539 pineapples lowers the levels of residual nitrite content. In essence, nitrites possibly react with
540 the dietary fiber and bioactive substances in the product in which tenderizers have been added
541 (pineapple and tomato powder), thereby reducing the residual nitrite level in T1 and T2.
542 Fernández-López et al. [79] also observed a lower residual nitrite content in dried-cured
543 products containing orange dietary fibre (ODF) than those without ODF. Thus, the replacement
544 of synthetic nitrite with 0.2% Swiss chard powder will result in eye-catching jerky and will
545 also ensure food safety.

546 **Myofibrillar fragmentation index (MFI)**

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

563 (pineapple and tomato) cause physical disruption of myofibrillar protein and contribute to
564 enhanced proteolysis that positively impacts the tenderness of semi-dried goat meat jerky.

565 **SDS-polyacrylamide gel electrophoresis (SDS-PAGE)**

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

579 **Sensory Evaluation**

580 The sensory panels evaluated how the color, flavor, typical goaty flavor, tenderness,
581 juiciness, and overall acceptability of semi-dried goat meat jerky changed after being treated
582 with tenderizers (Figure 8). The three main sensory qualities are tenderness, flavor, and color,
583 and they may vary based on the raw materials and processing formulas [83]. Sensory evaluation
584 results in the current study, indicate that the tenderizer positively affects color, texture, flavor,
585 and overall acceptance. Regarding the restrictions of residual nitrite concentration, the sensory
586 color score of PC was significantly higher than NC ($p < 0.05$). The color score of the T2 sample
587 was the highest among all treatments ($p < 0.05$). Additionally, the panelists preferred the T2

588 flavor over the other treatments ($p < 0.05$), but there was no noticeable difference in the T1
589 flavor ($p > 0.05$), however, the flavor scores of NC and PC were lower due to the typical goaty
590 smell which the panelists found unpleasant. Jerky (T2) treated with pineapple and tomato flavor
591 was preferred over the other groups since it had a lower goaty flavor. In addition, one of the
592 most crucial sensory characteristics in meat products for the elderly that influence pleasure and
593 acceptability is the texture of the jerky. According to the sensory attributes, the overall
594 tenderness scores of the semi-dried goat meat jerky ranged from 7.2 to 5, and jerky treated with
595 tenderizers (T2 and T1) had the greatest tenderness scores ($p < 0.05$). T2 and T1 were also
596 judged to be juicier as compared to NC and PC ($p < 0.05$). The overall acceptability scores
597 varied from 7.3 to 5, with T2 achieving the highest approval. The reason for this may be
598 improved textural properties. Mori et al. [84] mentioned that tenderness is the first factor that
599 influences the overall quality of meat and meat products. Therefore, tenderizers used in jerky
600 may improve the quality traits, including flavor, tenderness, juiciness, and overall acceptance.

601 **Multivariate analysis**

602 Multivariate analysis was carried out on samples of the different experimental
603 treatments to classify the semi-dried goat meat jerky according to its quality features. PCA
604 (principal component analysis) and PLS-DA (partial least squares-discriminant analysis) of
605 different treatments (NC, PC, T1, and T2) were performed. Each group was geographically
606 isolated from the others, with PC1 accounting for 87.6% and Component 1 for 82.8% of the
607 total variation (Figure 9a, b). Additionally, the six quality attributes (MFI, moisture, a^* , shear
608 force, PUFA, and n-6) were represented by the variable importance in projection (VIP) score,
609 which illustrates the significance of the variables for group discrimination in PLS-DA (Figure
610 9c). Group T1 had the highest MFI, moisture, and redness (a^*) values, indicating that
611 myofibrillar breakdown and redness color attributes were enhanced in the jerky made with
612 pineapple and natural nitrate. The jerky is made without tenderizers, NC and PC had the highest

613 shear force. In addition, PUFA and n-6 fatty acids were higher in T2 (pineapple and tomato).

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

619 **Conclusion**

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

638 a long time at room temperature as it has low water activity and microbial growth.

639 **Funding sources**

640 This study was supported by the Rural Development Administration's research project
641 (No. PJ0161792023), and we appreciate it.

642 **Acknowledgements**

643 No applicable.

644 **Competing Interests**

645 The authors declare no potential conflict of interest.

646 **Author's Contributions**

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

652 **Ethics approval and consent to participate**

653 The Sunchon National University Institutional Review Board (1040173-202107-HR-
654 010-02) approved the sensory evaluation.

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864 **Tables and Figures**865 **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

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868 Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers;

869 T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato

870 powder

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872

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

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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	

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876 ^{a-c} Means with a column with different letters are significantly different ($p < 0.05$).

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

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

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

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883 **Table 3. Effects of tenderizers on colour attributes, pH, microbial safety, and oxidation of**
 884 **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		

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

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

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

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

891 **Table 4. Effects of tenderizers on the fatty acid composition of semi-dried goat meat jerky**
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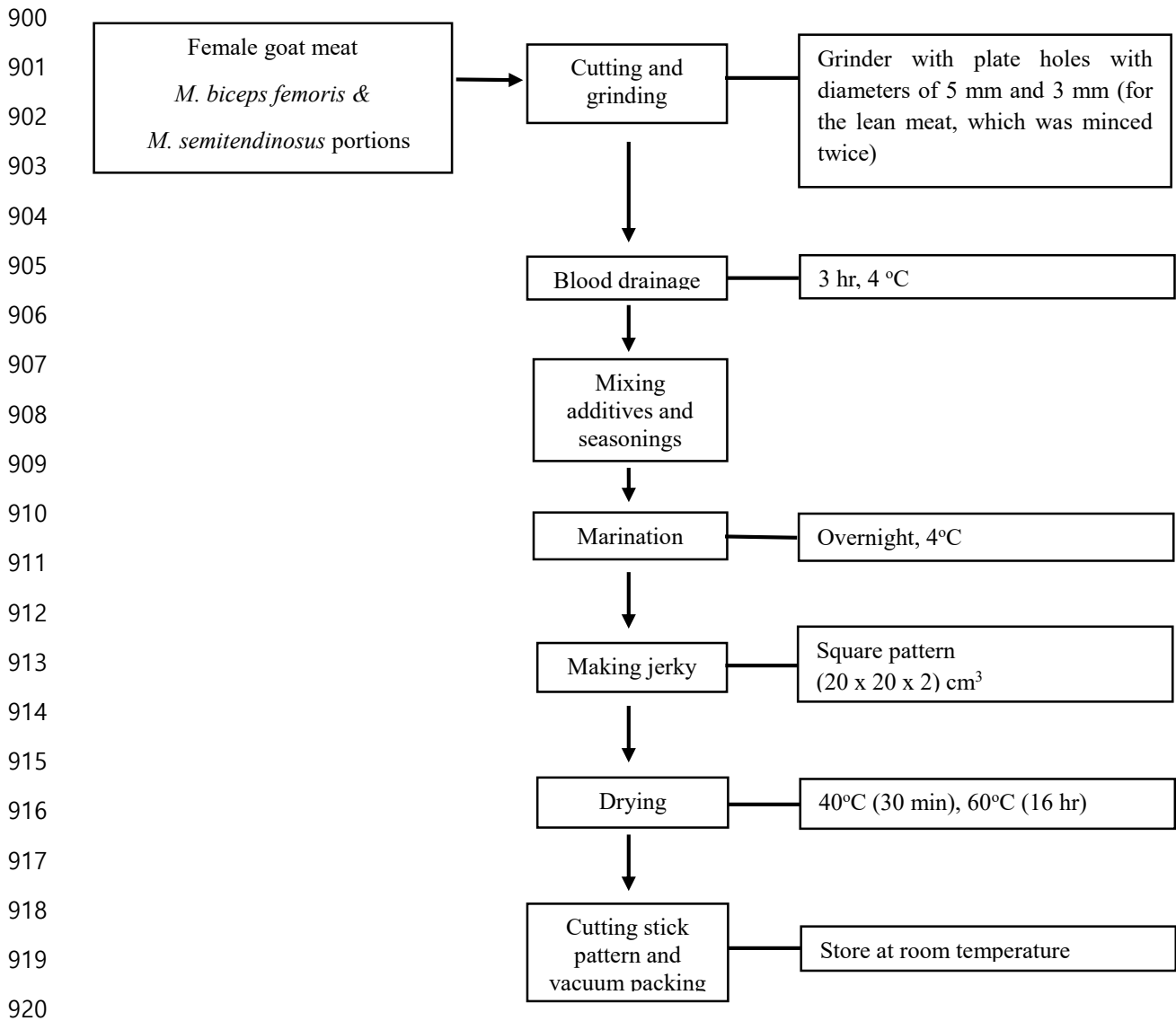
Items (%)	Treatments ¹⁾				SEM ²⁾
	NC	PC	T1	T2	
10:0	0.05 ^b	0.04 ^b	0.06 ^a	0.06 ^a	0.002
12:0	0.53 ^a	0.46 ^b	0.29 ^c	0.29 ^c	0.002
14:0	3.71 ^a	3.31 ^b	2.49 ^c	2.42 ^d	0.02
16:0	23.59 ^a	22.60 ^b	20.91 ^c	20.59 ^d	0.03
16:1	3.42 ^a	3.30 ^a	2.54 ^b	2.55 ^b	0.03
18:0	9.29 ^a	9.37 ^a	10.56 ^b	10.48 ^c	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

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

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

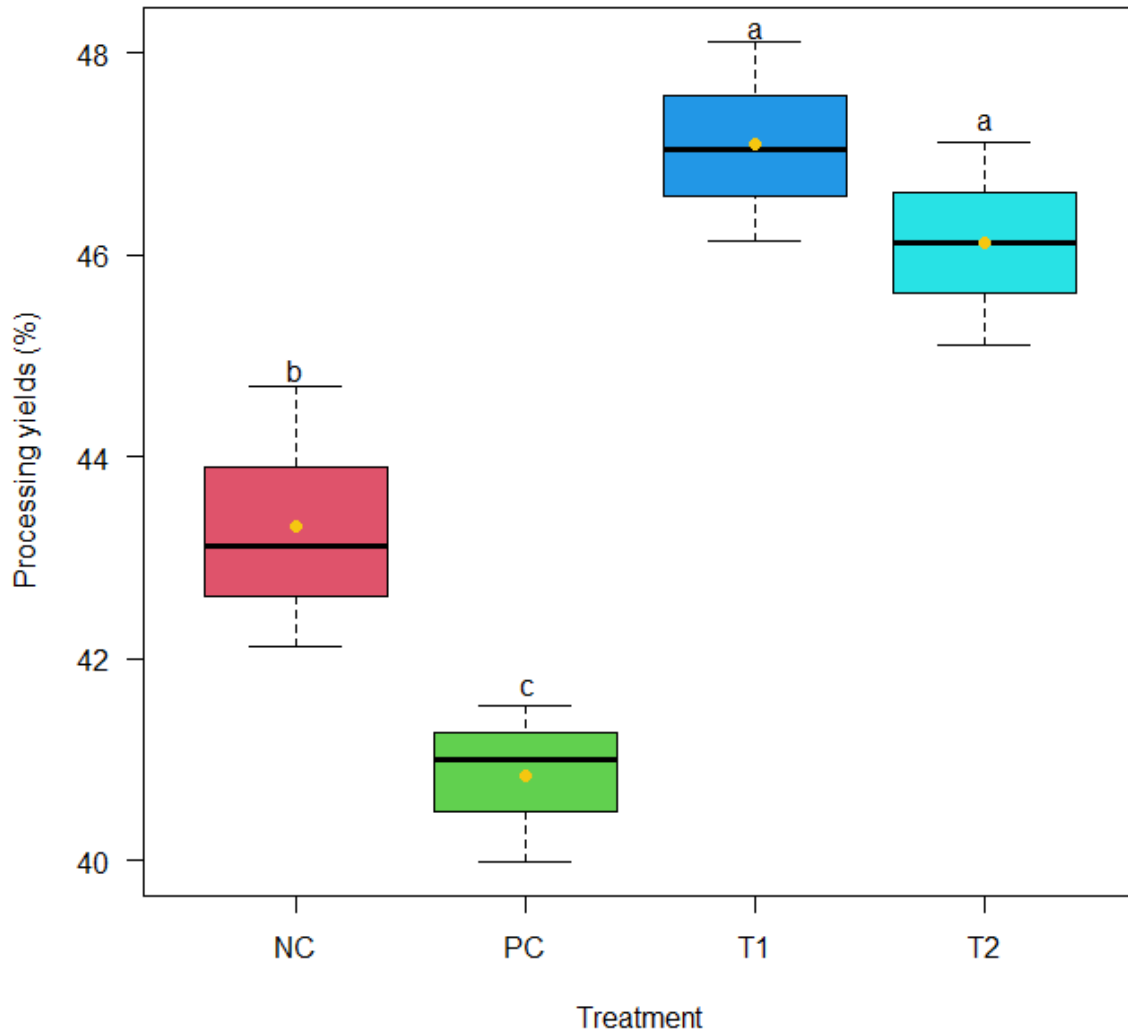
898 ²⁾SEM: Standard error of the mean ($p < 0.05$)

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

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

929 ^{a-c} Different letters differ significantly between treatments ($p < 0.05$)

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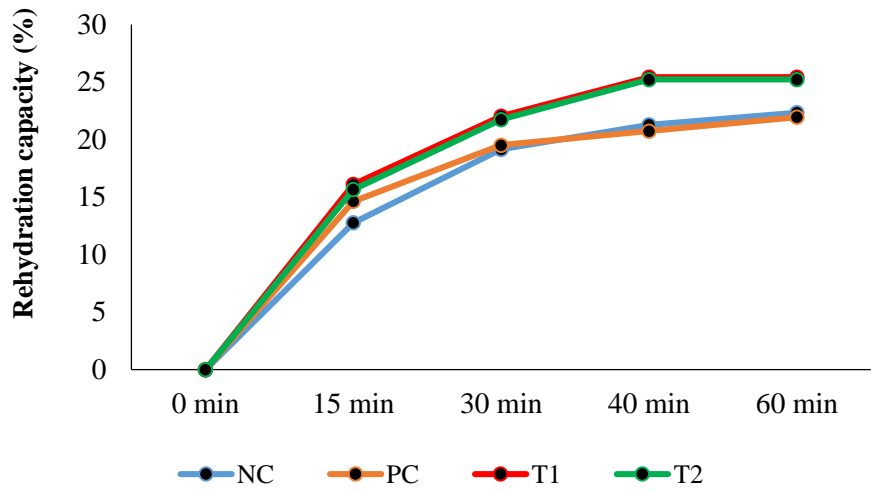
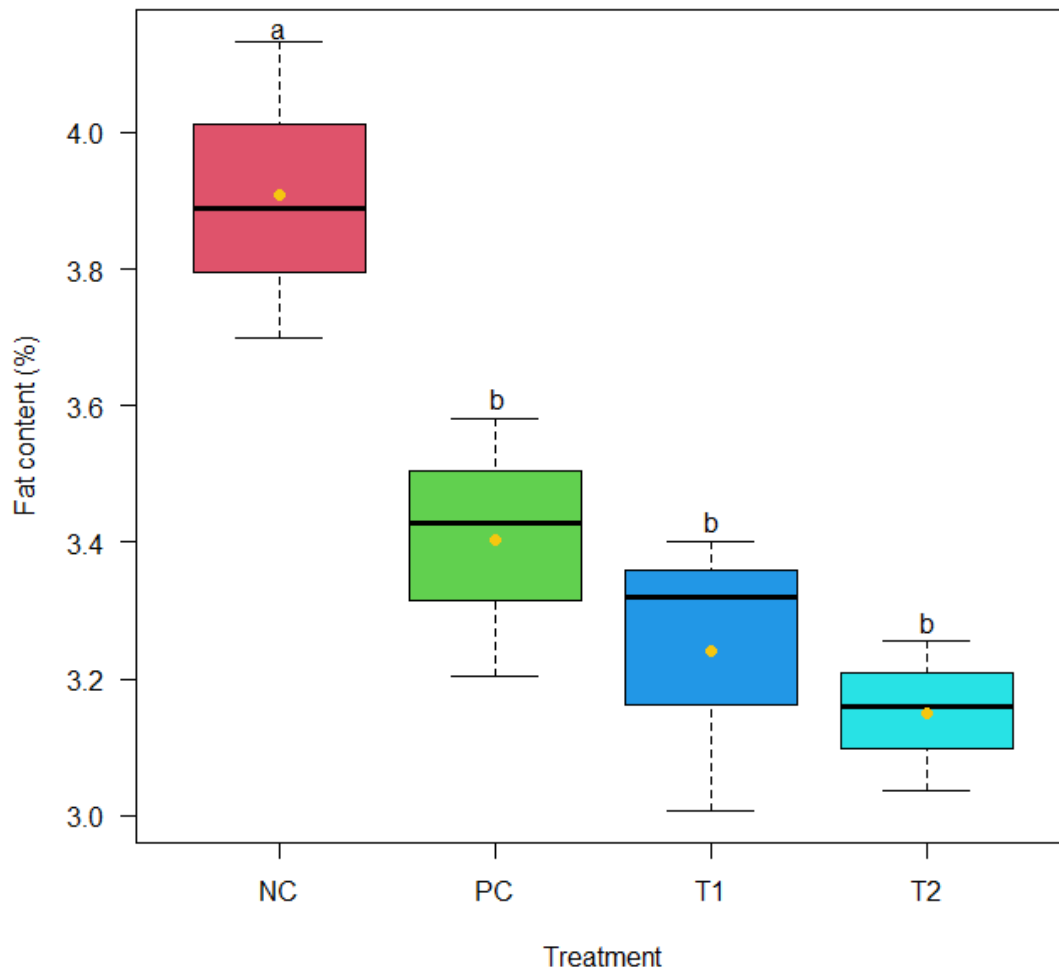


Figure 3. Effects of tenderizers on rehydration capacity of semi-dried goat meat jerky.
Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers;
T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato
powder



948 **Figure 4. Effects of tenderizers on the fat content of semi-dried goat meat jerky.**

949 Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers;

950 T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato

951 powder

952 ^{a,b} Different letters differ significantly between treatments ($p < 0.05$)

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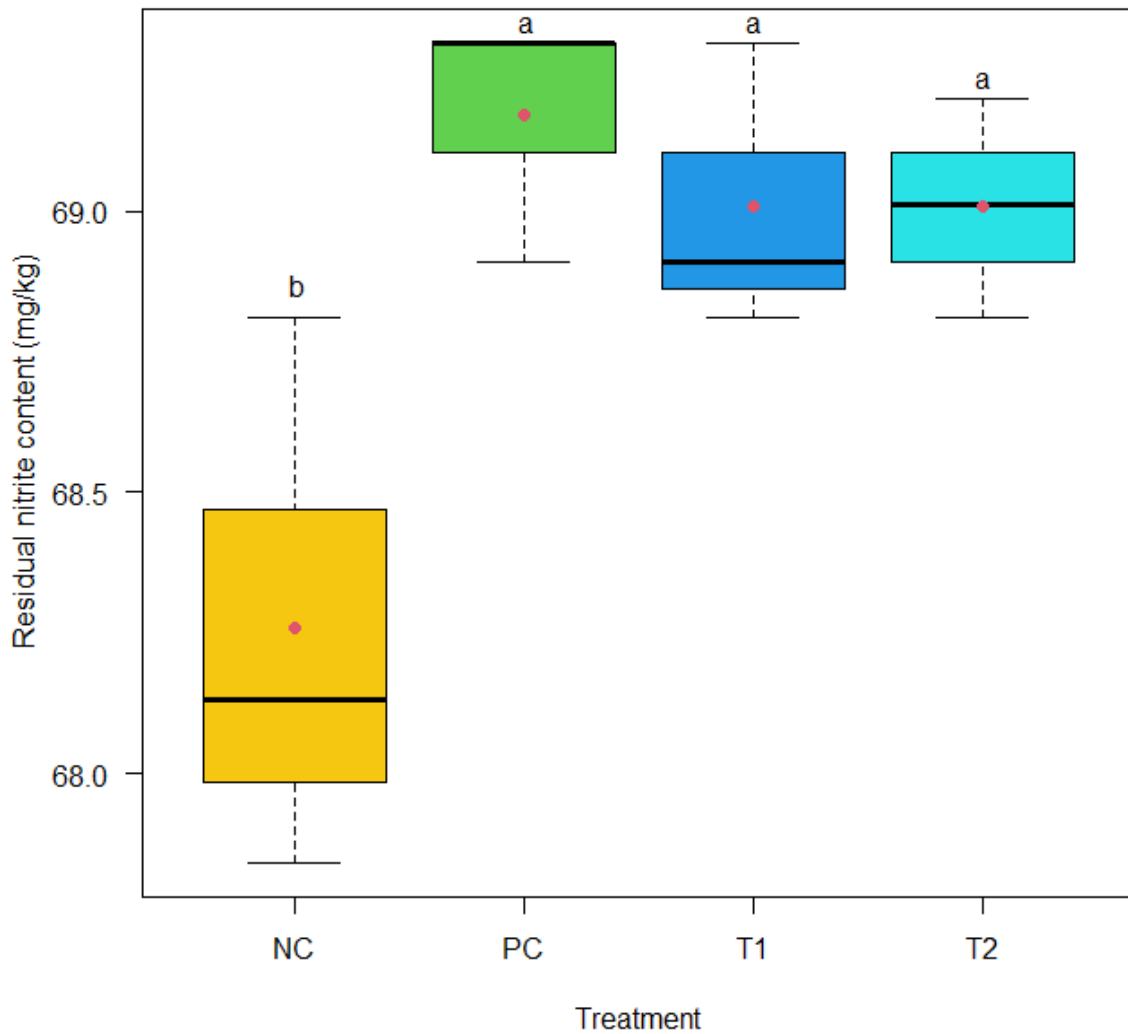
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962 **Figure 5. Residual nitrite content of semi-dried goat meat jerky.**

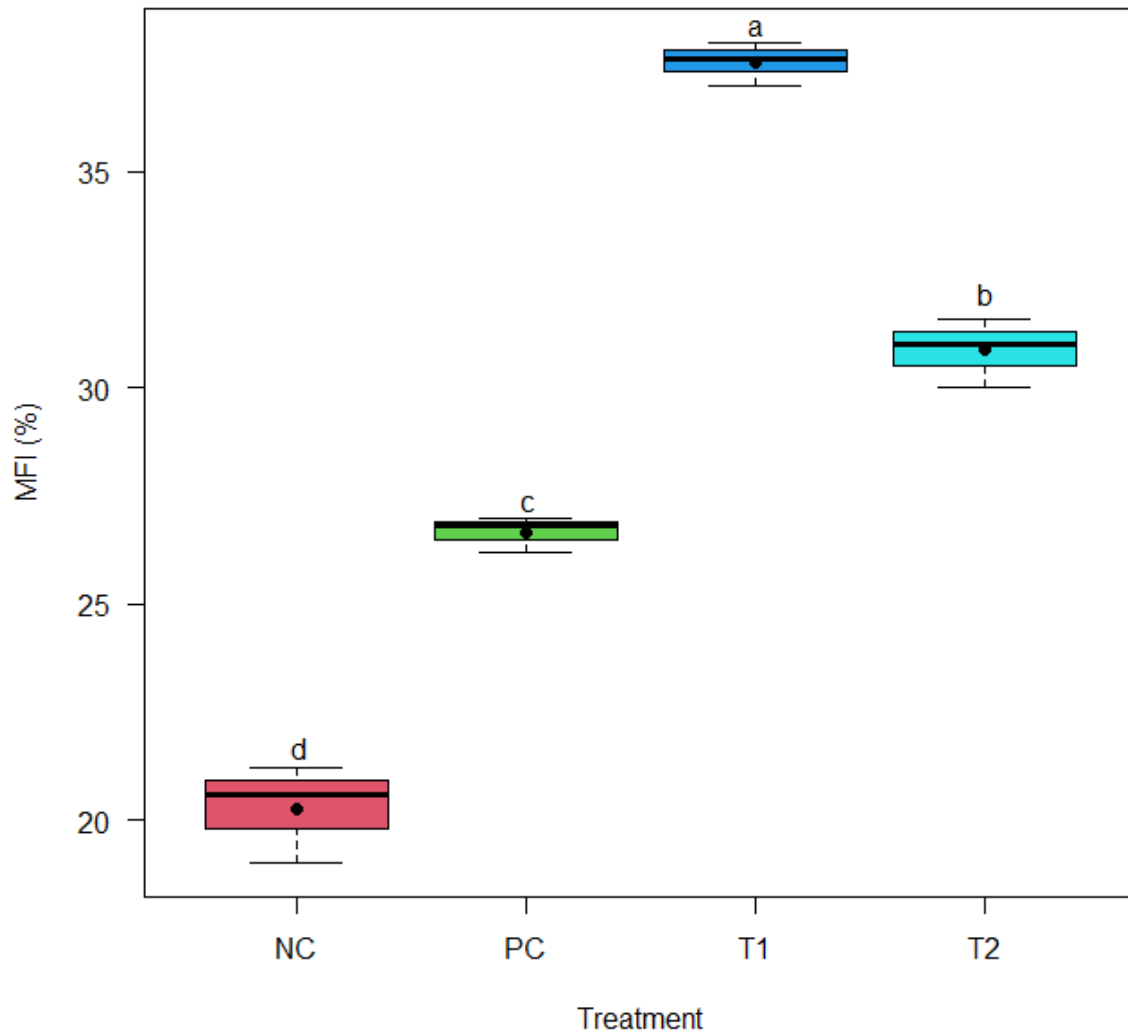


963 Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers;
964 T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato
965 powder

966 ^{a,b} Different letters differ significantly between treatments ($p < 0.05$)

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968



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

971 Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers;

972 T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato

973 powder

974 ^{a-d} Different letters differ significantly between treatments ($p < 0.05$)

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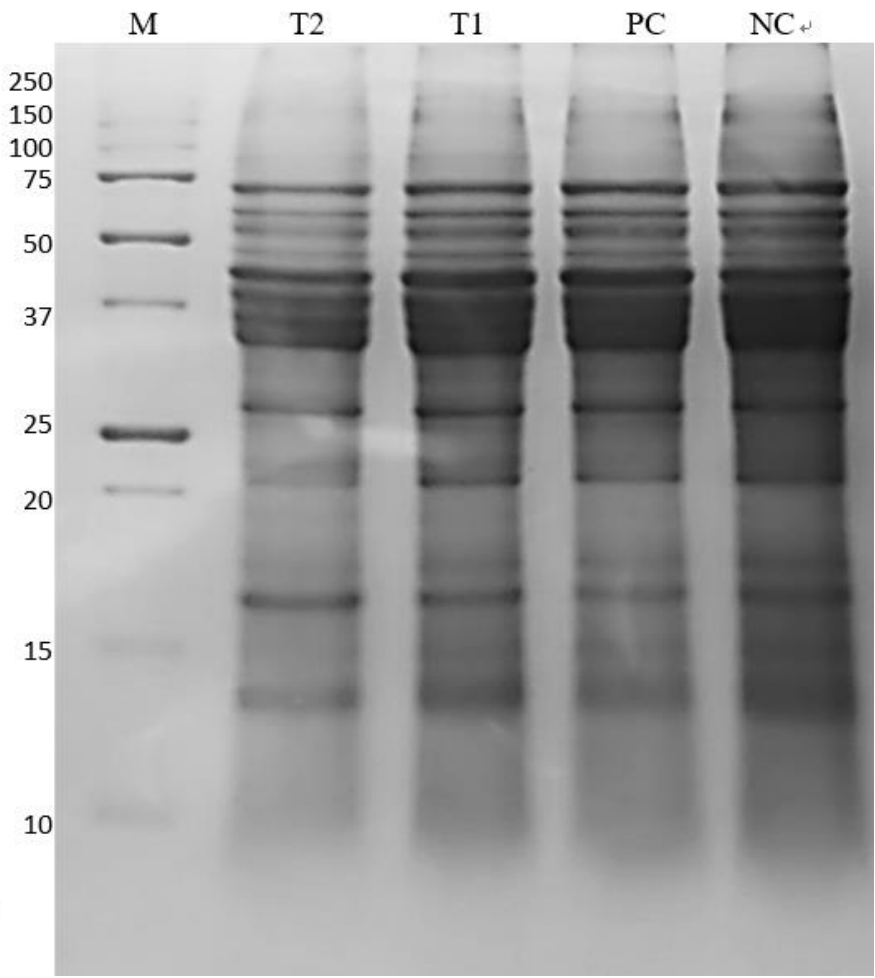


Figure 7. 15% SDS-PAGE gel patterns for protein denaturation of semi-dried jerky.
M: marker, NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers;
T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato
powder

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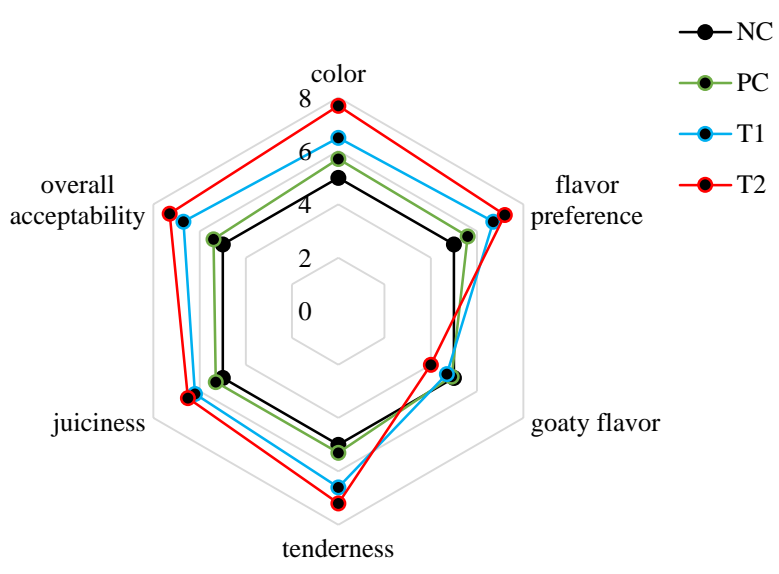
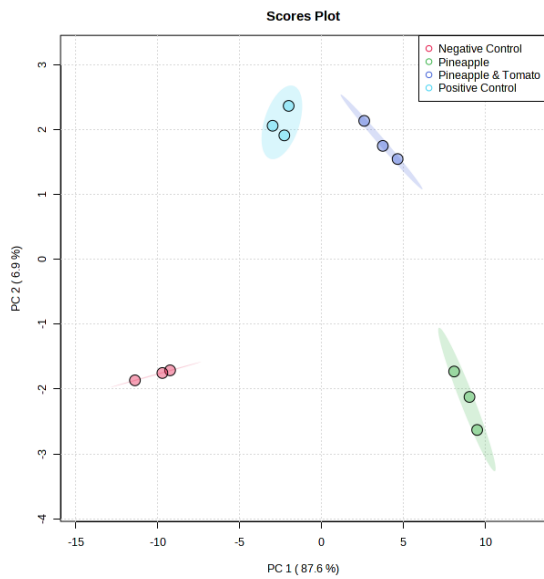
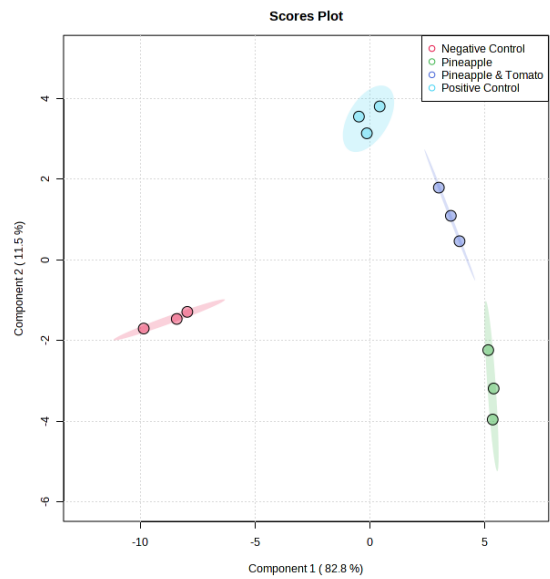


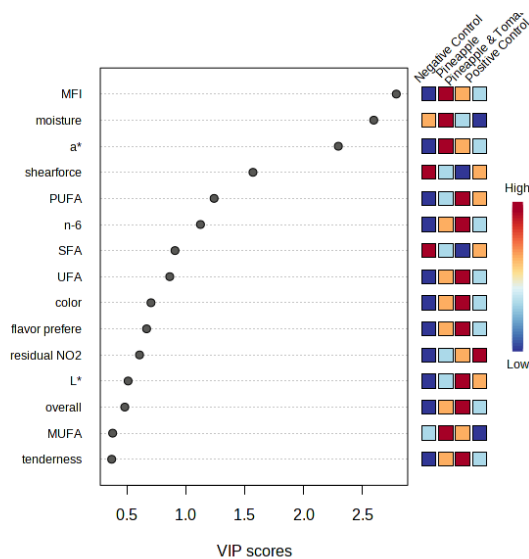
Figure 8. Effects of tenderizers on the sensory properties of semi-dried goat meat jerky.
Treatments: NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers;
T1- natural nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato
powder



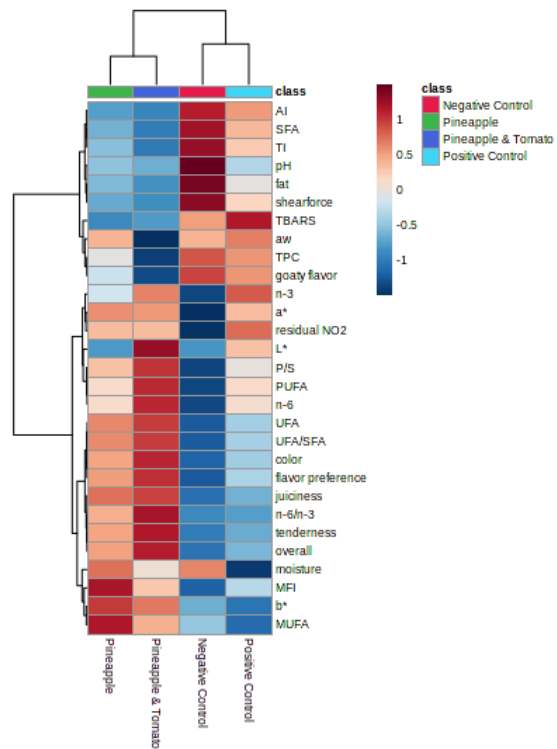
(a)



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(c)



(d)

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1026 **Figure 9. Results of (a) PCA, (b) PLS-DA, (c) VIP score, and (d) Heatmap of semi-dried**
 1027 **goat meat jerk in the initial day.**

1028 NC- synthetic nitrite without tenderizers; PC- natural nitrate without tenderizers; T1- natural
 1029 nitrate with pineapple powder; T2- natural nitrate with pineapple and tomato powder