

Quality characteristics of duck jerky: combined effects of collagen and konjac

Tae-Kyung Kim,^{*,1} Hyun-Wook Kim,^{†,1} Yun-Yeol Lee,^{*} Hae Won Jang,^{*} Young-Boong Kim,^{*} and Yun-Sang Choi^{*,2}

^{*}Research Group of Food Processing, Korean Food Research Institute, Wanju 55365, Republic of Korea; and

[†]Department of Animal Science & Biotechnology, Gyeongsang National University of Science and Technology, Jinju 52725, Republic of Korea

ABSTRACT The effects of curing solution prepared using various ratios of a combination of collagen and konjac (100/0, 80/20, 60/40, 40/60, 20/80, and 0/100) on the quality characteristics of duck jerky were investigated. The moisture, processing yield, water activity, tenderness score, and overall acceptability score of duck jerky were the highest when the ratio of added collagen and konjac was 60/40. The rehydration ratio of duck jerky increased due to the addition of collagen and konjac combinations in curing solution, and was higher for the 60/40 and 40/60 combinations than for the others. The shear force of duck jerky

was the highest for the untreated jerky, and the lowest for the jerky formulated with the 60/40 combination of collagen and konjac solution. No significant differences were observed in lightness and yellowness between jerky treated with combinations of collagen and konjac. Taken together, our results indicate that addition of a combination of collagen and konjac at a 60/40 ratio results in good quality characteristics of duck jerky. Thus, we suggest that the use of combinations of collagen and konjac in duck jerky processing is beneficial for improving the quality characteristics of the jerky.

Key words: duck, jerky, collagen, konjac, shear force

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INTRODUCTION

Jerky, which is an intermediate moisture food (IMF), is rich in nutrients, with a high protein and low fat content. Moreover, it can be distributed without refrigeration as it has low water activity (Choi et al., 2008). Jerky production is carried out by hurdle technology (Leistner, 1987). Drying and salting of meat products is the oldest preservation method (Choi et al., 2007; Ha et al., 2019). Conventionally, sliced whole muscles of beef that have been cured and dried are used to make jerky (Kim et al., 2008b). Currently, the types of jerky available are few and include those formulated using beef, pork, and chicken; in addition, only a few studies on duck jerky have been reported (Changling et al., 2009; Triyannanto and Lee, 2016). Thus, it is necessary to develop various types of jerky that use different kinds of raw meat such as duck meat.

Global production and demand of duck meat has steadily increased (Kim et al., 2014; An et al., 2017). Duck meat contains a small amount of saturated fats and cholesterol and a large amount of unsaturated

fats compared with that in other meats (Kim et al., 2017; Shin et al., 2019). Muhlisin et al. (2013) reported that duck meat represents a nutritious alkaline protein source with abundant essential amino acids, peptides, and antioxidants (Shim et al., 2018). Most duck meat is generally processed as smoked duck ham, and whole duck meat is utilized in this process. However, during the production of smoked duck ham, duck tenderloin is separated during marinade via tumbling. Most of the separated duck tenderloin is discarded, which is wasteful; thus, the use of duck tenderloin in food products is desirable.

Hydrocolloids are valuable food additives that enhance the textural characteristics, water binding ability, emulsion stability, and external surface of processed meat products (Choi et al., 2010, 2015). In jerky, hydrocolloids generally act as a humectant to increase tenderness and decrease water activity (Han et al., 2008). According to Allen et al. (2007), the water activity of jerky can be lowered to 0.75 or less to improve stability during storage. Some researchers have reported that the addition of humectant can improve the textural properties and sensory characteristics of jerky (Kim et al., 2010; Han et al., 2011; Sorapukdee et al., 2016). However, most previous studies have focused on the addition of one type of humectant; therefore, studies reporting the addition of a combination of humectants are limited. It is necessary to study the quality characteristics of jerky

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¹These authors contributed equally to this work.

²Corresponding author: kcys0517@kfri.re.kr

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following the addition of a combination of humectants that are known to have excellent effects.

Collagen is the major structural protein that makes up approximately one-third of the total proteins in the body. It has been extensively used in the food, pharmaceutical, and cosmetic industries (Song et al., 2014). According to Wang et al. (2014), the addition of collagen to food enhances water retention capacity due to water-binding, gelling, and film-forming properties. The addition of collagen to meat products may improve their biological value and sensory properties (Sousa et al., 2017; Choe and Kim, 2019). Konjac (glucomannan) is a high molecular weight (200 to 2,000 KDa) polysaccharide derived from the dried tuber of *Amorphophallus konjac*. Glucomannan is composed of glucose and mannose in a molar ratio of 1.6:1, linked with the β 1–4 linkage (Chin et al., 2009; Han et al., 2011). Chin et al. (2009) reported that konjac has a strong water-binding ability and exerts a synergistic effect on protein gelation and water binding in meat products when combined with other polysaccharides (Han et al., 2008). However, little information is available regarding the combined effect of collagen and konjac on jerky.

Therefore, this study was conducted to raise the effective value of discarded duck tenderloin using hydrocolloids and collagen. Furthermore, enhancement of the quality characteristics of duck jerky manufactured with the addition of a combination of collagen and konjac was evaluated.

MATERIALS AND METHODS

Duck Preparation

Fresh duck (Pekin, Cherry Valley, England; 8 wk of age, approximately 3.8 kg live weight) tenderloin (protein, 20.32%; moisture, 71.03%; fat, 2.98%) was purchased from a local processor.

Duck Jerky Processing

Seven different duck jerky preparations were made (weight of each duck jerky batch, 10 kg). Collagen (Italgel Fast, Italgelatine S.p.A., Zona mellea, Italy) and konjac powder (Konjac, Hubei Yizhi Konjac Biotechnology Co. Ltd., Yichang, China) were not added in control. The ratios of the added collagen and konjac were 100/0, 80/20, 60/40, 40/60, 20/80, and 0/100, and total collagen and konjac powder were added at 0.1% (w/v) to the curing solution. The composition of the duck jerky curing solution was based on the duck tenderloin meat weight (w/w); this solution contained cold water (10%), D-sorbitol (8.0%), garlic powder (2.8%), salt (0.7%), black pepper powder (0.05), onion powder (0.4%), beef seasoning (0.4%), monosodium glutamate (0.06%), ascorbic acid (0.05%), ginger powder (0.02%), and natural nitrite from spinach (0.013%), with pH 5.48

± 0.06 , and these ingredients were obtained from a local market. The duck tenderloin was manually mixed with the curing solution for 3 min. The cured duck tenderloin was then continuously tumbled using a tumbler at 4°C and 25 rpm for 30 min. The drying conditions for the marinated duck tenderloin were those reported by Choi et al. (2008): step 1, 55°C (180 min); step 2, 65°C (180 min); step 3, 75°C (60 min) using a convection dry oven in a pilot plant.

Proximate Analysis

Proximate analysis of the duck jerkies was performed using AOAC (2000). The moisture content (950.46B), protein content (981.10), fat content (960.69), and ash content (920.153) were determined by the oven air-drying method, Kjeldahl method using a nitrogen analyzer (Kjeltec 2300 Analyzer Unit, Foss Tecator AB, Höganäs, Sweden), the Soxhlet method, and the dry ashing method using a muffle furnace.

Processing Yield Measurement

The percentage of weight changes of the duck jerkies after drying was used to calculate a processing yield (Kim et al., 2010).

pH Measurement

The pH values of homogenate with duck jerkies (5-g samples) and 20 mL distilled water by an ultra-turrax (T-25, Janke & Kunkel, Staufen, Germany) for 60 s at 1,000 rpm were determined by a pH meter (Model 340, Mettler-Toledo GmbH, Schwerzenbach, Switzerland).

Water Activity Measurement

The duck jerky samples were first ground to approximately 1-mm size. Water activity value of samples was then obtained in duplicate using a water activity meter (BT-RS1, Rotronic Ag., Bassersdorf, Switzerland).

Color Determination

The CIE $L^*a^*b^*$ of the duck jerky samples were measured using a colorimeter (Minolta Chroma meter CR-200, Minolta Ltd., Japan) that was calibrated using a white plate (Illuminate C) with the following values: CIE L^* (lightness) = +97.83, CIE a^* (redness) = -0.43, and CIE b^* (yellowness) = +1.98.

Rehydration Capacity Measurement

The rehydration capacity was obtained using the method reported by Kim et al. (2008a), with appropriate modification. In glass beakers, the cut duck jerky samples into 3.0 × 3.0 × 3.0 mm size and 100 mL distilled water were placed. Weights of samples were measured after swelling at 30°C for 15, 30, 45, and 60 min.

Table 1. Effect of combination of collagen and konjac on compositional properties of duck jerky.

Traits	Control	Treatments (collagen/konjac) ¹					
		100/0	80/20	60/40	40/60	20/80	0/100
Moisture content (%)	27.39 ± 0.16 ^{b,c}	29.73 ± 0.56 ^a	30.43 ± 0.62 ^a	29.66 ± 0.79 ^a	26.82 ± 0.76 ^{b,c}	27.63 ± 0.39 ^b	25.81 ± 0.94 ^c
Protein content (%)	43.93 ± 0.40	44.13 ± 0.81	42.21 ± 0.59	42.79 ± 0.63	42.59 ± 0.66	44.20 ± 1.01	44.93 ± 0.62
Fat content (%)	2.07 ± 0.03 ^c	2.09 ± 0.01 ^c	1.85 ± 0.05 ^d	1.48 ± 0.12 ^e	2.81 ± 0.07 ^a	3.00 ± 0.09 ^a	2.44 ± 0.04 ^b
Ash content (%)	5.34 ± 0.03 ^c	5.60 ± 0.12 ^b	5.56 ± 0.07 ^b	5.69 ± 0.05 ^{a,b}	5.81 ± 0.08 ^{a,b}	5.59 ± 0.15 ^b	6.06 ± 0.19 ^a

All values are the mean ± standard error of 3 replicates.

^{a-e} Means within a row with different letters are significantly different ($P < 0.05$).

¹Control, no added collagen and konjac. Ratio of collagen and konjac in water was adjusted to 100/0, 80/20, 60/40, 40/60, 20/80, 0/100, and total concentration of collagen and konjac powder was 0.1% (w/v) in curing solution.

The rehydration capacity was calculated using the following equation:

$$\text{Rehydration capacity (\%)} = \left[\frac{\text{weight of the duck jerky after swelling (g)}}{\text{weight of the duck jerky before swelling (g)}} \right] \times 100$$

Shear Force Measurement

The shear force data were collected and analyzed using a texture analyzer (TA-XT2i, Stable Micro Systems Ltd., Surrey, UK) to determine the maximum force required to shear each cross section of duck jerky sample. After cut sample into $1 \times 3 \times 0.5 \text{ cm}^3$ across the fibers, duck jerky was used in experiments. The shear force condition was set at 2 mm/s of test speeds with Warner–Bratzler shear attachment.

Measurement of Free Amino Acid Content

First, 0.5 g of the duck jerky samples, together with collagen and konjac, was placed in a 20-mL ampoule and mixed with 10 mL of 6 mol/L HCl. After sealing the ampoule, the duck jerky samples were hydrolyzed under nitrogen at 105°C for 24 h. The hydrolysate was then evaporated to dryness under vacuum at 40°C, and the dried sample was dissolved in 3 to 5 mL of 0.02 mol/L HCl, which was then filtered through a 0.20- μm membrane filter (Sterlitech, Kent, WA, USA). The amino acid content was determined on a Hitachi L-8800 amino acid analyzer (Tokyo, Japan), using an ion-exchange resin column (4.6 mm *i.d.* \times 60 mm). All the HPLC ninhydrin and buffers reagents were obtained from Wako (Osaka, Japan). The amino acid standards were purchased from Sigma–Aldrich Chemical Co. (St. Louis, MO, USA).

Sensory Evaluation

Sensory evaluation of the duck jerky samples was performed as described by Bergara–Almeida et al. (2002), and carried out using the Hedonic test. A total of 12 panel members comprising researchers from the

Research Group of Food Processing at KFRI (Korean Food Research Institute, South Korea) evaluated the sensory properties of the duck jerky samples with different treatments. Each duck jerky sample was given scores for appearance, flavor, tenderness, juiciness, and overall acceptability, using a 9-point (1 = extremely undesirable, 9 = extremely desirable) descriptive scale. The trained panel members were asked to cleanse their palates between sampling the duck jerkies using warm water. Sensory evaluation was performed under fluorescent light.

Statistical Analysis

All experimental data were analyzed using the SAS statistical package (1999) as a completely randomized design. One-way analysis of variance was conducted to determine the significant differences ($P < 0.05$) among the treated groups, using Duncan's multiple range tests to analyze the physicochemical properties and sensory characteristics of the duck jerkies. Data are expressed as the mean ± standard error, and all experiments were conducted in triplicate. There was no significant difference between the replicates ($P > 0.05$).

RESULTS AND DISCUSSION

Proximate Analysis of Duck Jerky

The effects of addition of combinations of collagen and konjac on the proximate analysis of duck jerky are shown in Table 1. The moisture content of duck jerky was increased when collagen powder was added to the curing solution at over 0.06 to 0.1% (ratios of collagen and konjac powder used were 60/40 to 100/0). The moisture content was similar to that of the control ($P > 0.05$) when the konjac over the ratio of collagen. Similar results were obtained by Han et al. (2008), who found that the moisture content of pork jerky marinated with konjac did not differ significantly from that of the control. Furthermore, Song et al. (2014) noted that the moisture content of semi-dried chicken jerky increased with the addition of collagen. In general, the moisture content of IMF ranges from 20 to 40% (Jose et al., 1994; Kim et al., 2010); in our study, duck jerky was classified

as an IMF with a moisture content of approximately 24 to 30%. The protein content of duck jerky treated with different combinations of collagen and konjac ranged from 42.21 to 44.93%, and there was no significant ($P > 0.05$) difference between the control and all the treatments. The moisture to protein ratio (MPR) has been used as an index of microbial safety of jerky-type products whose MPR does not exceed 0.75 (Konieczny et al., 2007). The fat content of duck jerky treated with the combination of collagen and konjac at a ratio of 60/40 was the lowest ($P < 0.05$); this was likely affected by the water content of the jerky. The ash content of duck jerky treated with combinations of collagen and konjac was higher ($P < 0.05$) than that of the control, and this difference was likely due to the addition of collagen and konjac. The compositional properties of jerky were reported to differ because of differences in raw meat, muscle type, drying process, additive, and vacuum difference in packaging (Yang, 2006).

Processing Yield, Water Activity, pH, and Color of Duck Jerky

Table 2 shows the changes in processing yield, water activity, and color of duck jerky treated with combinations of collagen and konjac. The duck jerky treated with collagen and konjac had a higher ($P < 0.05$) processing yield than that of the control. The processing yield of duck jerky was the highest ($P < 0.05$) when treated with a combination of collagen and konjac at a ratio of 60/40. Choi et al. (2008) reported that the jerky processing yield is mainly affected by moisture evaporation during the drying process, and it is one of the most significant factors influencing the processing yield. Han et al. (2008) reported that jerky treated with humectants had a higher drying yield than that of the control, and konjac treatment produced the highest drying yields in comparison to other humectant treatments. Han et al. (2011) indicated that chicken jerky prepared with 0.1% konjac showed higher processing yield enhancement than that prepared by other treatments. Song (1997) showed that treatment with humectants resulted in a higher processing yield than that of control, as the humectants have a higher water retention capacity. Moreover, Song et al. (2014) indicated that the processing yield of the chicken jerky with collagen increased with the increasing amount of collagen added. Collagen has widely been used to improve the cooking yield and textural properties in some meat products owing to its gelling ability. The insoluble collagen is generally converted into gelatin at temperatures above 45°C during thermal processing. In our study, the processing yield was improved by the addition of collagen and konjac. The highest processing yield was obtained with the 60/40 combination of collagen and konjac.

Water activity of duck jerky marinated with different combinations of collagen and konjac ranged from 0.734 to 0.799. When water activity does not exceed 0.80, jerky products can be classified as IMF (Konieczny

Table 2. Effect of combination of collagen and konjac on processing yield, water activity, pH, and color of duck jerky.

Traits	Control	Treatments (collagen/konjac) ¹					
		100/0	80/20	60/40	40/60	20/80	0/100
Processing yield (%)	55.97 ± 0.91 ^c	57.24 ± 0.50 ^b	56.60 ± 0.64 ^b	59.68 ± 0.42 ^a	58.50 ± 0.71 ^{a,b}	57.59 ± 0.66 ^b	56.82 ± 0.72 ^b
Water activity	0.775 ± 0.001 ^{b,c}	0.786 ± 0.004 ^{a,c}	0.789 ± 0.006 ^{a,b}	0.799 ± 0.005 ^a	0.783 ± 0.009 ^{b,c}	0.771 ± 0.001 ^c	0.734 ± 0.003 ^d
Raw							
pH	5.96 ± 0.02 ^b	5.91 ± 0.02 ^c	5.95 ± 0.02 ^b	5.99 ± 0.02 ^a	5.98 ± 0.02 ^a	5.96 ± 0.01 ^b	5.98 ± 0.01 ^a
L* -value	36.68 ± 0.69	36.20 ± 0.41	37.05 ± 0.80	35.95 ± 1.09	37.41 ± 0.67	36.73 ± 0.36	35.62 ± 1.25
a* -value	12.47 ± 0.49 ^{c,d}	13.13 ± 0.57 ^{b,c}	11.62 ± 0.55 ^d	13.93 ± 0.24 ^{a,b}	12.57 ± 0.50 ^{c,d}	12.11 ± 0.31 ^{c,d}	14.69 ± 0.26 ^a
b* -value	10.47 ± 0.41	10.33 ± 0.62	11.38 ± 1.01	10.60 ± 0.99	10.46 ± 0.49	12.62 ± 1.87	11.50 ± 0.59
Cooked							
pH	6.03 ± 0.02	6.04 ± 0.04	6.03 ± 0.02	6.05 ± 0.03	6.06 ± 0.02	6.04 ± 0.02	6.03 ± 0.02
L* -value	27.55 ± 0.60	27.16 ± 0.95	29.27 ± 1.03	28.51 ± 0.98	26.52 ± 0.94	25.90 ± 0.41	26.67 ± 1.38
a* -value	10.98 ± 0.37	10.58 ± 1.21	9.65 ± 0.42	11.10 ± 0.40	9.74 ± 0.33	9.67 ± 0.26	9.29 ± 0.33
b* -value	8.58 ± 0.63	7.81 ± 0.81	8.75 ± 0.55	9.12 ± 0.52	7.36 ± 0.81	6.93 ± 0.28	7.31 ± 1.19

All values are the mean ± standard error of 3 replicates.

^{a-d}Means within a row with different letters are significantly different ($P < 0.05$).

¹Control, no added collagen and konjac in water was adjusted to 100/0, 80/20, 60/40, 40/60, 20/80, 0/100, and total concentration of collagen and konjac powder was 0.1% (w/v) in curing solution.

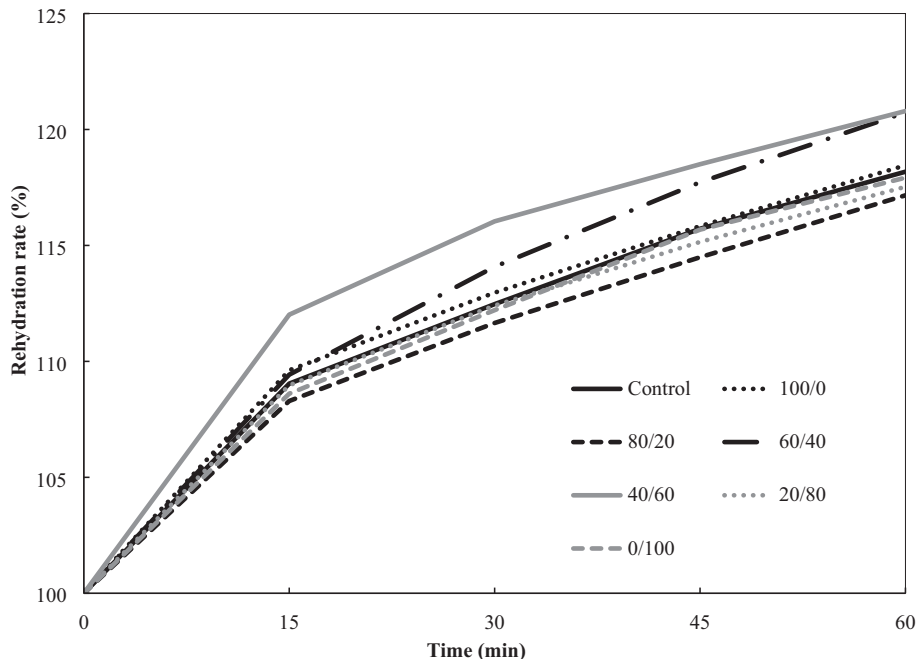


Figure 1. Effect of combination of collagen and konjac on rehydration ratio of duck jerky. Treatments: In control, no added both collagen and konjac powder in curing solution. Ratio of collagen and konjac powder in curing solution was adjusted to 100/0, 80/20, 60/40, 40/60, 20/80, 0/100, and total concentration of collagen and konjac powder was 0.1% (w/v) in curing solution.

et al., 2007). The water activity did not exceed 0.80 across all treatments and the control in this study. Furthermore, the water activity of jerky has a close relationship with the moisture content (Han et al., 2011). In this study, water activity had a similar trend with moisture content. The water activity of duck jerky was decreased when the ratio of konjac powder was increased and that of collagen powder was decreased in the curing solution.

The pH and color values of raw and cooked duck jerky treated with different combinations of collagen and konjac are shown in Table 2. The pH of raw and cooked duck jerky ranged from 5.91 to 5.98 and 6.03 to 6.06, respectively. Han et al. (2011) reported that the pH values of chicken jerky increased at higher konjac concentrations. Song et al. (2014) reported that the collagen level had no effect on the pH value of the chicken jerky. The color values of duck jerky showed a significant ($P < 0.05$) difference only in the redness of raw duck jerky meat (before drying); no significant difference was observed for dried duck jerky ($P > 0.05$). There was no significant difference ($P > 0.05$) in the lightness and yellowness of raw and cooked duck jerky treated with a combination of collagen and konjac. Han et al. (2008) reported that there was no difference in color values between the control and jerky samples to which konjac was added, and no difference in color values was observed when the amount of added konjac was increased. Song et al. (2014) reported that the redness and yellowness of the jerky slightly decreased when the levels of added collagen were increased, and no significant difference in lightness was shown. Thus, our study shows

that the addition of different combinations of collagen and konjac does not affect the color of jerky.

Rehydration of Duck Jerky

The effect of different combinations of collagen and konjac on the rehydration ratio of duck jerky is shown in Figure 1. Generally, the rehydration ability demonstrates hysteresis during rehydration because of structural and cellular disruption, which occurs during drying. The rehydration ratio of duck jerky treated with different combinations of collagen and konjac was observed to increase markedly with an increase in holding times. The rehydration ratio of duck jerky treated with combinations of collagen and konjac (60/40 and 40/60) was higher ($P < 0.05$) than that of other treatments. Song et al. (2014) reported that the rehydration capacity of the jerky treated with 3% collagen increased with an increase in holding time; however, there was no difference between the jerky samples treated with up to 2% collagen. Kim et al. (2012) reported that semi-dried jerky prepared with a combination of chicken feet gelatin and wheat fiber did not show alterations in rehydration. Our results agree with those of Kim et al. (2008a), who observed that the rehydration capacity of jerky showed a tendency to increase with increasing rehydration times.

Shear Force of Duck Jerky

One of the most important characteristics of jerky products is tenderness. Shear force values for duck jerky

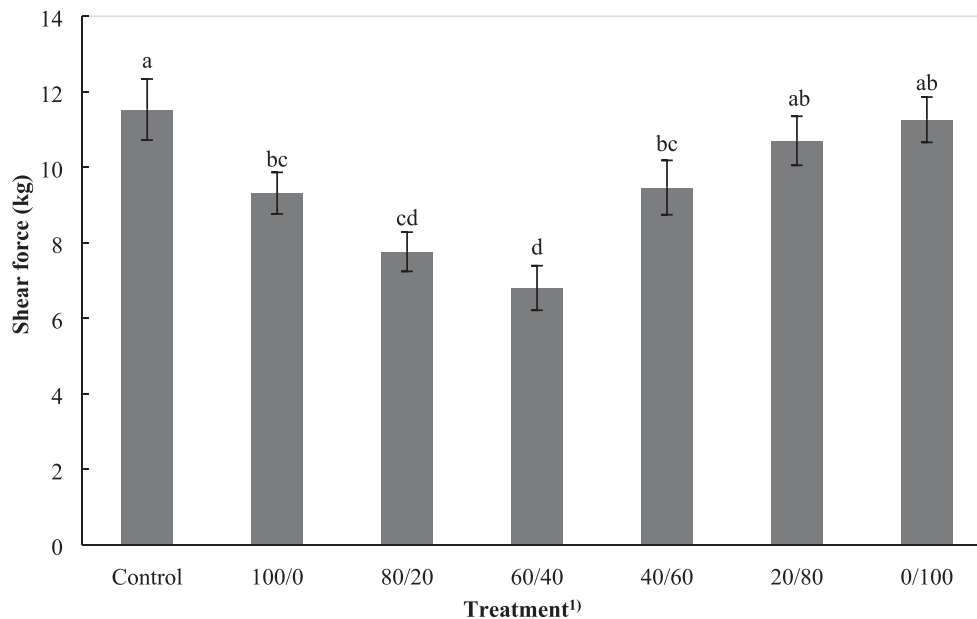


Figure 2. Effect of combination of collagen and konjac on shear force of duck jerky. ^{a-d} Columns with different letters are significantly different ($P < 0.05$). ¹⁾ Treatments: In control, no added both collagen and konjac powder in curing solution. Ratio of collagen and konjac powder in curing solution was adjusted to 100/0, 80/20, 60/40, 40/60, 20/80, 0/100, and total concentration of collagen and konjac powder was 0.1% (w/v) in curing solution.

prepared with combinations of collagen and konjac are given in Figure 2. According to previous studies (Han et al., 2011; Song et al., 2014), collagen enables higher levels of moisture retention in jerky than that by konjac. The moisture content of a meat product is a critical factor that decreases the shear force of the meat product (Choi et al., 2010). Yang et al. (2009) proposed that the higher shear force might be related to the lower moisture content and muscle fiber composition of the jerky. The shear force of duck jerky was the highest for the control, and the lowest ($P < 0.05$) for jerky treated with a 60/40 combination of collagen and konjac. A similar result was reported by Kim et al. (2012), who found that the shear force of chicken jerky decreased with an increase in chicken feet gelatin levels. They suggested that the reduced shear force due to the addition of gelatin positively affects the textural properties of the dry meat products. This reduction in shear force indicated that the gel structure improved the water-holding capacity by the addition of collagen (Doerscher et al., 2004). These results agree with those of Han et al. (2011), who indicated that the chicken jerky prepared with konjac had a significantly lower shear force. Therefore, the addition of collagen and konjac to jerky represents an effective method for improving its tenderness.

Analysis of Free Amino Acids in Duck Jerky

Free amino acids are related to the taste of meat products, for e.g., glutamic acid has a salty taste and phenylalanine and isoleucine confer acidity. Results of the analysis of the free amino acid content of duck jerky

treated with different combinations of collagen and konjac are shown in Table 3. In the duck jerky samples, among the free amino acids, the content of glutamic acid was the highest, followed by that of aspartic acid, leucine, and lysine. The free amino acid content did not differ significantly ($P > 0.05$) between the control and jerky treated with various combinations of collagen and konjac. Liu et al. (2007) reported that the most abundant free amino acids detected in the cooked duck were glutamic acid and alanine. Our results are similar to those reported by Heo et al. (2013), who noted that duck meat contains glutamic acid, aspartic acid, leucine, and lysine. In general, collagen is composed of various kinds of amino acids. However, the addition of low amounts of collagen, not exceeding a maximum of 0.01% of the meat weight, probably had little to no impacts on the amino acid composition of duck jerky samples in this study. Thus, the addition of collagen and konjac to duck jerky does not affect the free amino acid composition of the final meat products.

Sensory Evaluation of Duck Jerky

Table 4 shows the effects of the addition of collagen and konjac combinations on the sensory properties of duck jerky. The appearance and juiciness scores of duck jerky were not affected ($P > 0.05$) by the addition of collagen and konjac. The flavor scores of duck jerky treated with only collagen were the highest ($P < 0.05$) among those of all treated samples. The tenderness and overall acceptability scores of duck jerky treated with a 60/40 combination of collagen and konjac were the highest ($P < 0.05$) among the sensorial

Table 3. Effect of combination of collagen and konjac on free amino acid analysis (g/100 g) of duck jerky.

Traits	Control	Treatments (collagen/konjac) ¹					
		100/0	80/20	60/40	40/60	20/80	0/100
Asp	3.67 ± 0.09	3.48 ± 0.21	3.43 ± 0.14	3.62 ± 0.04	3.56 ± 0.05	3.39 ± 0.06	3.56 ± 0.05
Thr	1.85 ± 0.03	1.72 ± 0.11	1.70 ± 0.07	1.81 ± 0.02	1.79 ± 0.03	1.69 ± 0.03	1.74 ± 0.03
Ser	1.65 ± 0.04	1.58 ± 0.09	1.56 ± 0.06	1.64 ± 0.02	1.55 ± 0.02	1.50 ± 0.04	1.62 ± 0.01
Glu	7.66 ± 0.14	7.41 ± 0.21	7.35 ± 0.10	7.54 ± 0.07	7.58 ± 0.09	7.31 ± 0.15	7.75 ± 0.09
Pro	1.54 ± 0.08	1.59 ± 0.13	1.46 ± 0.04	1.44 ± 0.03	1.46 ± 0.01	1.34 ± 0.01	1.50 ± 0.06
Gly	1.76 ± 0.14	1.95 ± 0.14	1.69 ± 0.09	1.74 ± 0.05	1.72 ± 0.02	1.60 ± 0.01	1.84 ± 0.12
Ala	2.29 ± 0.08	2.30 ± 0.07	2.24 ± 0.03	2.31 ± 0.02	2.25 ± 0.01	2.15 ± 0.03	2.31 ± 0.01
Val	1.77 ± 0.01	1.64 ± 0.03	1.61 ± 0.03	1.71 ± 0.01	1.92 ± 0.04	1.80 ± 0.01	1.88 ± 0.04
Met	0.89 ± 0.01	1.16 ± 0.02	1.18 ± 0.02	1.12 ± 0.08	0.95 ± 0.03	1.26 ± 0.01	1.29 ± 0.02
Ile	1.68 ± 0.01	1.55 ± 0.03	1.54 ± 0.02	1.62 ± 0.01	1.83 ± 0.04	1.67 ± 0.02	1.74 ± 0.04
Leu	3.17 ± 0.03	3.02 ± 0.08	3.02 ± 0.02	3.10 ± 0.03	3.14 ± 0.07	2.98 ± 0.01	3.12 ± 0.06
Tyr	1.26 ± 0.09	1.25 ± 0.03	1.28 ± 0.06	1.27 ± 0.05	1.10 ± 0.01	1.24 ± 0.08	1.33 ± 0.04
Phe	1.63 ± 0.02	1.55 ± 0.05	1.55 ± 0.02	1.58 ± 0.01	1.61 ± 0.03	1.60 ± 0.01	1.69 ± 0.06
Lys	3.01 ± 0.03	2.84 ± 0.12	2.79 ± 0.01	2.98 ± 0.02	2.92 ± 0.08	2.78 ± 0.07	2.84 ± 0.08
His	1.08 ± 0.01	1.04 ± 0.02	1.03 ± 0.01	1.08 ± 0.01	1.09 ± 0.01	1.02 ± 0.01	1.06 ± 0.02
Arg	2.43 ± 0.09	2.10 ± 0.12	2.31 ± 0.03	2.41 ± 0.03	2.36 ± 0.03	2.18 ± 0.04	2.28 ± 0.01

All values are the mean ± standard error of 3 replicates.

¹Control, no added collagen and konjac. Ratio of collagen and konjac in water was adjusted to 100/0, 80/20, 60/40, 40/60, 20/80, 0/100, and total concentration of collagen and konjac powder was 0.1% (w/v) in curing solution.

Table 4. Effect of combination of collagen and konjac on sensory evaluation of duck jerky.

Traits	Control	Treatments (collagen/konjac) ¹					
		100/0	80/20	60/40	40/60	20/80	0/100
Appearance ²	6.55 ± 0.31	6.27 ± 0.43	6.73 ± 0.27	6.85 ± 0.41	6.81 ± 0.34	6.73 ± 0.38	6.55 ± 0.49
Flavor	6.18 ± 0.23 ^b	7.45 ± 0.16 ^a	6.09 ± 0.31 ^b	6.18 ± 0.23 ^b	6.18 ± 0.23 ^b	5.55 ± 0.37 ^b	5.55 ± 0.37 ^b
Tenderness	2.55 ± 0.28 ^c	3.18 ± 0.26 ^c	5.18 ± 0.18 ^b	6.27 ± 0.27 ^a	5.36 ± 0.47 ^b	2.73 ± 0.24 ^c	3.18 ± 0.18 ^c
Juiciness	4.09 ± 0.31	4.36 ± 0.34	3.91 ± 0.39	5.18 ± 0.38	4.82 ± 0.48	5.00 ± 0.52	5.09 ± 0.51
Overall acceptability	4.46 ± 0.28 ^b	5.02 ± 0.36 ^b	5.46 ± 0.22 ^b	6.46 ± 0.23 ^a	5.27 ± 0.57 ^b	4.91 ± 0.28 ^b	4.55 ± 0.21 ^b

All values are the mean ± standard error of 3 replicates.

^{a-c}Means within a row with different letters are significantly different ($P < 0.05$).

¹Control, no added collagen and konjac. Ratio of collagen and konjac in water was adjusted to 100/0, 80/20, 60/40, 40/60, 20/80, 0/100, and total concentration of collagen and konjac powder was 0.1% (w/v) in curing solution.

²Appearance, flavor, and overall acceptability (1 = very undesirable, 9 = very desirable), tenderness (1 = very tough, 9 = very tender), and juiciness (1 = very dry, 9 = very moist) were expressed for evaluating sensory attributes.

scores. Some researchers have reported that the tenderness of jerky is the most important factor among the various sensory attributes (Choi et al., 2008; Kim et al., 2012). Our results are in accordance with those of studies by Song et al. (2014), who observed that the tenderness of jerky was highly related to the overall acceptability, and reported that chicken jerky prepared with collagen had higher overall acceptability scores. Han et al. (2011) reported that jerky treated with 0.2% konjac had significantly higher acceptability scores than the control. Han et al. (2011) noted that the former had higher sensory scores due to an increase in moisture content and water-holding capacity. Therefore, in our study, the use of collagen and konjac in combination improved the sensory properties of duck jerky; furthermore, a 60/40 combination of collagen and konjac was the most effective humectant formulation.

CONCLUSION

We studied the physicochemical properties and sensory characteristics of duck jerky formulated with different combinations of collagen and konjac. The mois-

ture content, processing yield, water activity, tenderness score, and overall acceptability score of duck jerky treated with collagen and konjac at a ratio of 60/40 were the highest, whereas shear force was the lowest for jerky treated with this combination. The results of this study revealed that the addition of a combination of collagen and konjac at a ratio of 60/40 results in the best quality characteristics of the duck jerky. Our data indicate that the combination of collagen and konjac may be used to improve the quality of duck jerky products.

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