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# ARTICLE Changes in Physicochemical Characteristics of Goat Meat Emulsion-type Sausage According to the Ratio of Fat and Water Contents

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**Abstract** The study aimed to determine the optimal fat and water level for goat meat emulsion-type sausage. Proximate composition, pH, emulsion stability, cooking yield, protein solubility, water holding capacity (WHC), texture profile analysis, and sensory evaluation were performed on goat meat sausages with water additions of 5%, 10%, 15%, 20%, and 25%. Cooking yield tended to decrease as the water addition level increased, while water loss showed an increase. However, myofibrillar protein solubility and WHC showed the highest values on 15% water addition treatment. Hardness, gumminess, and chewiness tended to decrease as the moisture content increased. Sensory evaluations showed that when considering appearance, tenderness, and overall acceptability, the most superior treatment was 15%. In conclusion, it is concluded that adding 15% water would be most suitable for the production of goat meat emulsion-type sausage.

**Keywords** goat meat, emulsion-type, physicochemical characteristics, water content, low fat

## Introduction

The contemporary food industry has seen a shift toward the consumption of low-fat, high-protein foods, spurred by growing concerns regarding consumer health and wellbeing (Manzoor et al., 2022). Goats have been recognized as an excellent source of meat to meet this demand, because of their low fat content, high digestibility, and high protein content (Madruga et al., 2009). As the benefit of goat meat revealed, consumption in 2013–2019 has been raised ten times higher than in 2005–2012 (Mechesso et al., 2021). Consequently, goat meat consumption is projected to continue to increase. Various studies have been conducted to promote goat meat consumption, focusing on aspects such as the nutritional properties of different cuts (Kim et al., 2019), the physicochemical

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properties associated with various slaughter ages (Choi et al., 2023; Kawęcka and Pasternak, 2022), and the changes in nutritional and textural properties depending on the cooking method (Lee et al., 2022).

The forequarters and hindquarters of goats constitute 45% of the total meat yield (Webb, 2014), and devising utilization strategies for these parts will be effective in increasing goat meat consumption. However, these parts are reported to have a lower fat content and higher shear force than other parts (Hwang et al., 2017; Hwang et al., 2019). This is similar to the reason for the imbalance observed in pork consumption (Kameník et al., 2018). This implies that, despite the expected increase in goat meat consumption, the preference for the forequarters and hindquarters may decrease (Kim et al., 2019; Lee et al., 2017).

Emulsion-type sausages are innovative meat products capable of mitigating the issues of high shear force evident in the forequarters and hindquarters of goat meat through integrated processes of grinding, fat incorporation, and emulsification (Choi et al, 2010). During the manufacture of emulsion-type sausages, the addition of water is crucial because it enhances the solubilization of myofibrillar proteins via salt-mediated mechanisms (Dickinson, 2012). Therefore, it is necessary to find the optimal content for each raw meat by considering ingredients that can affect the emulsifying power, such as the moisture content and water holding capacity (WHC) of the meat (Karakaya et al., 2006). Solubilized myofibrillar proteins are instrumental in the emulsification of water and lipids, and in the establishment of a matrix structure upon heating and denaturation, which effectively secures water within the tissue (Flores et al., 2007). This functionality improves the final product's water-holding capacity, tenderness, and juiciness, thereby augmenting its quality (Choi and Chin, 2021). Nonetheless, the excessive addition of water has been reported to provoke phase separation in emulsions, leading to a decline in cooking yield and a compromise in textural attributes (Johnson et al., 1977). Additionally, insufficient water content during emulsification can negatively influence the solubilization of myofibrillar proteins and the subsequent formation of the matrix structure (Yang et al., 2016b). It is necessary to find the optimal content for each raw meat by considering ingredients that can affect the emulsifying power, such as the moisture content and WHC of the meat (Karakaya et al., 2006).

Although various studies have been conducted on sausages made from goat meat (Madruga and Bressan, 2011), studies analyzing the characteristics of goat meat sausages about different water levels are limited. Therefore, in this study, we analyzed the effects of varying levels of fat (5%, 10%, 15%, 20%, and 25%) and replaced the rest of the percentages with water on the physicochemical properties of emulsion-type sausages made from goat meat.

## **Materials and Methods**

#### Preparation of sausage samples

The whole process of sample preparations is shown in Fig. 1. Goat meat (Gaon, Gangjin, Korea) was diced and ground using a 3 mm plates equipped grinder (PA-82, Mainca, Barcelona, Spain). Ground goat meat was mixed with 5 different ratios (T1: water 5% and fat 25%; T2: water 10% and fat 20%; T3: water 15% and fat 15%; T4: water 20% and fat 10%; T5: water 25% and fat 5%) of ice and water using a bowl-cutter (K-30, Talsa, Valencia, Spain). Salt (1.2%), sugar (1%), and mixed spice (0.3%) were added to each mixture as the subsidiary material. The goat meat emulsions were stuffed into natural pig casings (Woosing Foodtec, Seoul, Korea) using a stuffer (EM-12, Mainca). After stuffing, the samples were cooked for 40 min at 80°C chamber (10.10ESI/SK, Alto Shaam, Menomonee Falls, WI, USA) and cooled at 10°C for 30 min.

#### **Proximate compositions**

Association of Official Analytical Chemists (AOAC) guidelines (AOAC, 2010) were used to determine the proximate

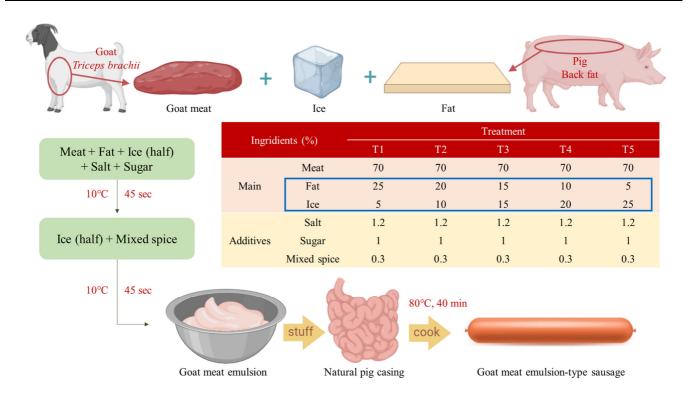


Fig. 1. Formulation of goat meat emulsion-type sausage with various levels of added water and fat.

compositions and each composition used the following methods: Drying samples in 105°C oven (AOAC 950.46) for moisture content, Soxhlet method (AOAC 991.36) for fat content, Kjeldahl method (AOAC 928.08) for protein content, dry-ashing method at 550°C (AOAC 920.153) for ash content.

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The samples were mixed with distilled water (1:4, w/v) at 6,991×g for 1 min using an ultra turrax homogenizer (HMZ-20DN, Pooglim Tech, Seongnam, Korea). And the sample mixtures were analyzed with a pH meter (Model S220, Mettler-Toledo, Schwerzenbach, Switzerland).

#### **Emulsion stability**

The emulsion stability was determined by inserting a wire mesh into the centrifuge tube, filling it with the goat meat emulsion, and sealing the entrance. The centrifuge tube was heated in a chamber (10.10ESI/SK, Alto Shaam) at 80°C for 30 min and then cooled at room temperature (20°C) for 30 min. The amounts of water and fat that were exuded were measured to determine the emulsion stability.

Water loss (%) = 
$$\frac{\text{Exuded water (mL)}}{\text{Emulsion weight (g)}} \times 100$$
 (1)

Fat loss (%) = 
$$\frac{\text{Exuded fat (mL)}}{\text{Emulsion weight (g)}} \times 100$$
 (2)

#### **Cooking yield**

The prepared samples were cooked in an 80°C chamber (10.10 ESI/SK, Alto Shaam). At this point, the cooking time was 40 min and the internal temperature reached 75°C. And the cooked samples were cooled at room temperature (20°C) for 30 min and the cooking yield was calculated as a percentage by substituting the following formula.

Cooking yield (%) = 
$$\frac{\text{Sample weight after cooking (g)}}{\text{Sample weight before cooking (g)}} \times 100$$
 (3)

#### **Protein solubility**

The protein solubility of the samples was determined by a modified method based on Choe et al. (2017). To determine the total protein content, 2 g of the samples were mixed with 20 mL of 1.1 M potassium iodide in 0.1 M potassium phosphate (pH 7.4). For the sarcoplasmic protein, 2 g of the samples were mixed with 20 mL of 0.025 M potassium phosphate (pH 7.4). For both methods, the mixtures were homogenized for 2 min and overnight at 2°C. And then centrifuged at 4,032×g at 4°C for 15 min and filtered. The absorbance of the sample was measured at 540 nm using the Spectra-photometer (SpectraMax iD3, Molecular Devices, San Jose, CA, USA), and calculated according to the following formula:

Myofibrillar protein = Total protein – Sarcoplasmic protein (5)

#### Water holding capacity

The WHC was measured by applying the centrifugal method (Jin et al., 2007). The sample was prepared by wrapping 5 g of the sausage in a filter paper (Whatman No. 1, GE Healthcare, Chicago, IL, USA) and placing it in a 50 mL conical tube. The prepared sample was centrifuged at 109×g at 4°C for 10 min using a centrifuge (Supra R22, Hanil Science, Daejeon, Korea), and the WHC was measured by comparing the weight of the sample before and after centrifugation. The formula used for calculation is as follows.

WHC (%) = 
$$\frac{A - B}{A}$$
 (6)

$$A = \frac{\text{Weight before centrifugation (g) \times Moisture content (\%)}}{100}$$
(7)

B = Weight before centrifugation – Weight after centrifugation

#### **Texture profile analysis**

The texture profile analysis (TPA) was performed on sausages which were cut into cubes measuring 2.0 cm in width,

(8)

length, and height. The analysis was carried out using a texture analyzer (TA 1, Lloyd, Delray Beach, FL, USA) equipped with a 10 cm cylinder probe. The analysis parameters were set as follows: pre-test speed 2.0 mm/s, post-test speed 5.0 mm/s, maximum load 2 kg, head speed 2.0 mm/s, distance 8.0 mm, force 5 g.

#### Viscosity

The viscosity of the goat meat emulsion was measured using a rotational viscometer (MerlinVR, Rheosys, Hamilton Township, NJ, USA) equipped with a 30 mm parallel plate and 2.0 mm gap. An appropriate amount of the sausage emulsion was placed on a plate set at 20°C and tested. The head speed was set at 20 rpm and measured for 60 s.

#### **Sensory evaluation**

The sensory evaluation was conducted with the approval of the Ethics Committee of Kongju National University (authority No: KNU\_IRB\_2021-75). Each sausage, after being cooked and cooled, was cut to a consistent thickness. Fifteen trained individuals, both male and female and aged between 20 and 30, were randomly selected to rate the color, flavor, tenderness, juiciness, goaty odor, appearance, and overall acceptability. Each category was evaluated on a 10-point scale, with the mean score being calculated for comparison. For the categories of color, flavor, appearance, and goaty odor, the most desirable state was represented by 10, and the least desirable state was represented by 1. Tenderness was represented by 10 for the most tender state and 1 for the toughest state. For juiciness, a score of 10 indicated the highest level of moisture and 1 indicated the lowest.

#### Statistical analysis

All data in this study were obtained by conducting experiments at least 3 times. All data were presented as the mean value and SD, and one-way analysis of variance (ANOVA) using the General Linear Models procedure in the SAS program (version 9.4 for window, SAS Institute, Cary, NC, USA). Significant differences between data were analyzed using Duncan's multiple range test with a significance level of p<0.05.

### **Results and Discussion**

#### Proximate compositions and pH

The provision of protein is one of the primary roles of meat products (Williams, 2007); a higher protein content enables the production of high-quality processed meat (Youssef and Barbut, 2010). Table 1 presents the proximate composition and pH of goat meat emulsion-type sausage according to the changes in water and fat contents. As the water content increased from 5% to 25%, the moisture content of the sausages significantly increased (p<0.05), whereas the fat content significantly decreased (p<0.05). No significant differences were found in protein or ash content among the treatments. The changes in the moisture and fat contents of the sausages in this study are believed to be influenced by the ratios of water and fat added, as presented in Fig. 1 (Gregg et al., 1993). In a study by Jin et al. (2016) on the physicochemical properties of emulsion-type pork sausages according to the ratio of raw materials, variations in water and fat content did not affect the protein content. This is similar to the results of the present study, suggesting that, even with varying amounts of water added during the manufacturing process, it is possible to produce products that provide an equivalent amount of protein.

The pH of meat products is a crucial factor influencing their water-holding capacity and microbial growth (Charmpi et al.,

Traits		Treatments				
		T1	T2	Т3	T4	T5
Moisture (	%)	57.98±0.50 <sup>e</sup>	$61.88{\pm}0.15^{d}$	65.14±0.59°	$71.34{\pm}0.91^{b}$	75.99±0.35ª
Protein (%	b)	15.49±0.32ª	15.62±0.22ª	15.85±0.52ª	15.76±0.64ª	15.50±0.49ª
Fat (%)		24.97±0.31ª	$20.11 \pm 0.09^{b}$	16.91±0.03°	$10.87{\pm}0.30^{d}$	$6.42{\pm}0.14^{e}$
Ash (%)		1.88±0.01ª	$1.91{\pm}0.04^{a}$	1.86±0.05ª	$1.89{\pm}0.05^{a}$	1.92±0.05ª
pН	Uncooked	6.45±0.01	6.46±0.02	6.44±0.01	6.44±0.01	6.45±0.01
	Cooked	$6.67 \pm 0.02$	6.66±0.01	6.66±0.01	6.65±0.01	6.65±0.01

Table 1. Proximate compositions and pH of goat meat emulsion-type sausage with various levels of added water and fat

All values represented as mean±SD.

<sup>a-e</sup> Means in the same row marked with different letters denote significant differences (p<0.05).

T1, water 5% and fat 25%; T2, water 10% and fat 20%; T3, water 15% and fat 15%; T4, water 20% and fat 10%; T5, water 25% and fat 5%.

2020; Feng and Arai, 2022). There were no significant differences in the pH among the treatments before or after cooking. However, the pH was significantly higher after cooking than before cooking (p<0.05). In a study by Muguerza et al. (2002), in which emulsion-type pork fermented sausages were prepared with 10%, 20%, and 30% fat, no significant differences in pH were observed, indicating that the ratio of raw materials did not affect pH. Similarly, in this study, changes in fat and moisture content did not affect the pH of the emulsion or the sausages. The pH of pork back fat is between 6.5 and 6.7 (Paneras and Bloukas, 1994), which is close to neutral. Therefore, variations in moisture and fat content did not significantly impact the pH of the emulsion. The increase in pH after heating is associated with the release of basic amino acids due to the denaturation of proteins (Oz and Celik, 2015). Imidazole, the base of histidine, is released in the form of imidazolium during the heating of meat products, causing an increase in pH (Choi et al., 2008). In conclusion, it is feasible to produce goat meat emulsion-type sausage with stable and uniform pH, regardless of the amount of water and fat added.

#### Emulsion stability and cooking yield

Table 2 shows the emulsion stability and cooking yield of goat meat emulsion-type sausage according to the changes in water and fat contents. Among all treatments, the emulsion stability was lowest at T1 sample (p<0.05) and exhibited an increasing trend with an increase in moisture addition across treatments. Fat loss was significantly higher in treatments with T1 and T2 samples than in those with T3, T4, and T5 samples (p<0.05). Claus et al. (1990a) reported that during the preparation of emulsion-type pork sausages with fat substituted by water, water loss increased as the moisture content increased. Similarly, the study by Colmenero et al. (1997) on the emulsion stability of emulsified sausages based on fat content found that a higher fat content resulted in higher fat loss, which aligns with the findings of this study. In conclusion, a decrease in emulsion stability was observed when the amount of water or fat exceeded 20%. T3 sample resulted in significantly lower fat loss compared to the T1 and T2 samples (p<0.05), and significantly lower water loss compared to the T1 and T2 samples (p<0.05), and significantly lower water loss compared to the T1 and T2 samples (p<0.05).

The exudates lost during the heating of emulsions predominantly comprise internal liquids and soluble substances, with the majority of these constituents being water, as reported by Aaslyng et al. (2003). Jung et al. (2022) reported a significant negative correlation between cooking yield and water loss in pork emulsion-type sausages. In this study, the highest cooking yield was observed in the T1 sample (p<0.05), which decreased as the amount of added water increased. The decline in ionic strength due to increased water addition has been reported to reduce water-binding capacity (Claus et al., 1990b). Therefore, a

Traits (%)		Treatments				
		T1	T2	Т3	T4	T5
Emulsion stability	Water loss	3.41±0.38°	4.79±0.33°	$7.95{\pm}1.17^{b}$	$11.87{\pm}0.54^{a}$	13.58±1.34ª
	Fat loss	3.89±0.60ª	$3.41{\pm}0.68^{a}$	$1.34{\pm}0.38^{\rm b}$	$1.34{\pm}0.26^{b}$	$0.83{\pm}0.13^{\circ}$
Cooking yield		92.72±0.97 <sup>a</sup>	92.24±0.60ª	90.49±0.69 <sup>b</sup>	87.71±0.93°	87.01±0.46°

Table 2. Emulsion stability and cooking yield of goat meat emulsion-type sausage with various levels of added water and fat

All values represented as mean±SD.

 $a^{-c}$  Means in the same row marked with different letters denote significant differences (p<0.05).

T1, water 5% and fat 25%; T2, water 10% and fat 20%; T3, water 15% and fat 15%; T4, water 20% and fat 10%; T5, water 25% and fat 5%.

lower cooking yield indicates the unstable binding of water, protein, and fat within the emulsion, which can lead to a decrease in the hardness, cohesiveness, and external quality of meat products (Zhang et al., 2022). Generally, a cooking yield greater than 90% is reported to indicate ideal quality in meat products (Choe et al., 2013), In this experiment, the T4 and T5 samples showed cooking yields below this standard. Consequently, it is not recommended to exceed 20% water content when manufacturing goat meat emulsion-type sausages.

#### Protein solubility and water holding capacity

The functional characteristics of the emulsion, such as emulsion stability and WHC, are formed by muscle fiber proteins, such as myosin and actin (Amiri et al., 2018). This action ultimately enhances the textural characteristics of the product (Farouk et al., 2002); thus, the solubility of muscle fiber proteins can be used as an indicator to assess the quality of sausages (Petracci et al., 2013). Table 3 shows the protein solubility and WHC of goat meat emulsion-type sausage according to the changes in water and fat contents. Total protein solubility was not significantly different among the treatment groups. The solubility of myofibrillar proteins did not show significant differences in T1, T2, and T3 samples. However, myofibrillar proteins showed significantly lower solubility in the T4 and T5 samples than in the T3 samples (p<0.05). In contrast, the solubility of sarcoplasmic proteins was significantly lower in T1, T2, and T3 samples (p<0.05). However, it significantly increased in the T4 and T5 samples to those for the solubility of myofibrillar proteins (p<0.05). The solubility of myofibrillar proteins is influenced by ionic strength (Sun and Holley, 2011). The ionic strength increases with the amount of cations (Na+) and anions (Cl-) generated by the dissolution of salts (Wu et al., 2016). Therefore, the results are influenced by the exposure of sulfhydryl groups and hydrophobic of myofibrillar proteins (Yang et al., 2016a). We

Table 3. Protein solubility and water holding capacity (WHC) of goat meat emulsion-type sausage with various levels of added water
and fat

Traits (mg/mL)		Treatments					
	T1	T2	Т3	T4	T5		
Total protein	355.52±8.36ª	354.44±6.40ª	356.17±10.49ª	353.79±8.71ª	356.82±2.55ª		
Sarcoplasmic protein	$119.01{\pm}0.97^{b}$	$119.23 \pm 3.18^{b}$	$119.88 {\pm} 2.73^{b}$	129.18±2.19ª	129.40±2.78ª		
Myofibrillar protein	$236.51 \pm 8.49^{ab}$	235.21±4.30 <sup>ab</sup>	$242.93{\pm}7.62^{a}$	$224.61 \pm 6.40^{b}$	$227.42 \pm 3.69^{b}$		
WHC (%)	91.32±0.41ª	91.17±1.82ª	$92.07{\pm}0.98^{a}$	$87.40{\pm}0.28^{b}$	$87.79 {\pm} 0.59^{b}$		

All values represented as mean±SD.

<sup>a,b</sup> Means in the same row marked with different letters denote significant differences (p<0.05).

T1, water 5% and fat 25%; T2, water 10% and fat 20%; T3, water 15% and fat 15%; T4, water 20% and fat 10%; T5, water 25% and fat 5%.

observed that an increase in moisture led to a decrease in the salt concentration of the emulsion, resulting in a decrease in the solubility of myofibrillar proteins. Simultaneously, the solubility of sarcoplasmic proteins, which indicates water solubility, was found to increase. Therefore, it was determined that the optimal moisture addition level that minimizes the addition of fat without decreasing the solubility of myofibrillar proteins was 15%.

WHC was significantly higher in T1, T2, and T3 samples than in T4 and T5 samples (p<0.05). Muscle fiber proteins dissolved in salt exhibit hydrophilic characteristics at one end and hydrophobic characteristics at the opposite end, forming protein-encapsulated oil-in-water emulsions (Choi and Chin, 2021). Furthermore, the matrix structure formed by protein gelation during heating immobilizes moisture within the tissue (Flores et al., 2007), enhancing the resilience, juiciness, and tenderness of the final product (Choi and Chin, 2021). Therefore, the significantly higher viscosity in T1, T2, and T3 samples compared to the T4 and T5 samples is attributed to the solubility of muscle fiber proteins (p<0.05). The T4 and T5 samples showed a significantly lower cooking yield and viscosity than all other treatment groups (p<0.05), and the moisture content was significantly higher in T1, T2, and T3 samples than in T4 and T5 samples (p<0.05; Zhang et al., 2022). It has been reported that moisture with weak internal binding capacity may lead to a potential decline in the structural characteristics of the final product (Zhang et al., 2022). In conclusion, in this study, a moisture addition of 15% emerged as the optimal level to ensure high solubility of muscle fiber proteins and resilience in the synovial fluid.

#### Texture profile analysis and viscosity

TPA is a prominent method used to represent the textural characteristics of sausages and is employed as an indicator to determine the quality of sausages (Herrero et al., 2008). Table 4 presents the results of TPA for goat meat emulsion-type sausage according to the changes in water and fat contents. Hardness, gumminess, and chewiness exhibited a decreasing trend with increasing moisture content of the sausages, and significantly lower values were observed in T4 and T5 samples (p<0.05). There were no significant differences in springiness among the treatment groups, whereas cohesiveness was significantly lower in T5 sample than in the other treatment groups (p<0.05). A stronger binding force of the protein matrix formed in the emulsion results in greater hardness and cohesiveness of the sausages (Broucke et al., 2022). However, the decrease in cohesiveness in T5 sample is due to the lack of solubility of myofibrillar proteins and over-added water contents and it leads to undeveloped matrix formation of emulsion-type sausage (Yang et al., 2016a). The experimental results of the proximate composition, cooking yield, and viscosity in this study indicate that in treatment groups with high moisture content, moisture did not sufficiently bind to the fat globules and protein molecules but remained in a free-water form within

Traits	Treatments					
	T1	T2	Т3	T4	T5	
Hardness (kgf)	3.28±0.26ª	$2.90{\pm}0.16^{b}$	$2.71 \pm 0.18^{b}$	1.92±0.17°	$1.98{\pm}0.14^{\circ}$	
Springiness	0.49±0.03ª	$0.48{\pm}0.03^{a}$	$0.46{\pm}0.04^{a}$	$0.48{\pm}0.02^{a}$	$0.47{\pm}0.03^{a}$	
Gumminess (kgf)	2.43±0.17ª	$2.16{\pm}0.14^{b}$	$2.06{\pm}0.18^{b}$	1.47±0.11°	1.37±0.09°	
Chewiness (kgf)	1.21±0.13ª	$1.03{\pm}0.10^{b}$	$0.94{\pm}0.12^{b}$	$0.71 \pm 0.06^{\circ}$	$0.65{\pm}0.07^{\circ}$	
Cohesiveness	$0.74{\pm}0.05^{ab}$	$0.74{\pm}0.03^{a}$	$0.76{\pm}0.02^{a}$	0.76±0.03ª	$0.68{\pm}0.03^{\rm b}$	

All values represented as mean±SD.

<sup>a-c</sup> Means in the same row marked with different letters denote significant differences (p<0.05).

T1, water 5% and fat 25%; T2, water 10% and fat 20%; T3, water 15% and fat 15%; T4, water 20% and fat 10%; T5, water: 25% and fat 5%.

the tissue (Claus et al., 1990a; Zhang et al., 2022). Residual moisture negatively affects the binding capacity of the emulsion and leads to a reduction in the hardness, gumminess, and chewiness of sausages (Johnson et al., 1977). Therefore, it is advisable to avoid adding moisture at 20% or higher to prevent a decline in the structural characteristics of goat meat emulsion-type sausages.

Fig. 2 depicts the viscosity measurement results of goat meat emulsion-type sausage according to the changes in water and fat contents. The initial viscosities of the T1, T2, and T3 samples were 118.60 Pa·s, 114.64 Pa·s, and 113.69 Pa·s, respectively, showing little difference, and the viscosity reduction graph also exhibited a gradual curve. However, the initial viscosities of the T4 and T5 samples were relatively low compared to the other treatment groups, measuring 91.77 Pa·s and 65.61 Pa·s, respectively. Furthermore, the viscosity exhibited a sharp decline during the measurement period. Gregg et al. (1993) reported that an increase in the moisture content of emulsion leads to a reduction in viscosity owing to a decrease in friction on the internal particle surfaces. In this study, we observed that viscosity differences occurred based on the moisture contents. The high viscosity of emulsion indicates strong interactions and binding forces among moisture, fat, and proteins that constitute the emulsion (Aktaş and Gençcelep, 2006). Therefore, an emulsion with high viscosity indicates the minimal separation between moisture and fat, exhibits excellent cohesiveness and binding forces and allows for the production of sausages of stable quality (Lee et al., 2018). Therefore, it was inferred that adding moisture to the emulsion at levels exceeding 20% may lead to a decrease in hardness, gumminess, chewiness, and viscosity, potentially causing a decline in the quality of the goat meat emulsion-type sausages.

#### Sensory evaluation

Table 5 presents the sensory evaluation results of goat meat emulsion-type sausage according to the changes in water and fat contents. Variations in moisture and fat content did not have a significant impact on the color, flavor, or goat odor of goat meat emulsion-type sausages. Similar to the results of the present study, Cengiz and Gokoglu (2007) reported no significant

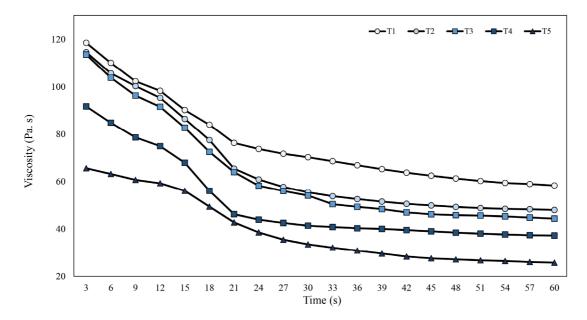


Fig. 2. Viscosity (Pa.s) of goat meat emulsion-type sausage with various levels of added water and fat. T1, water 5% and fat 25%; T2, water 10% and fat 20%; T3, water 15% and fat 15%; T4, water 20% and fat 10%; T5, water 25% and fat 5%.

Traits	Treatments				
	T1	T2	Т3	T4	T5
Color	$9.22{\pm}0.58^{a}$	9.33±0.62ª	9.21±0.63ª	$9.28{\pm}0.48^{a}$	9.28±0.53ª
Tenderness	$8.46{\pm}0.60^{b}$	$8.69{\pm}0.36^{ab}$	$9.04{\pm}0.48^{a}$	$9.07{\pm}0.38^{a}$	9.09±0.43ª
Juiciness	$8.63 \pm 0.40^{b}$	$8.64{\pm}0.35^{b}$	$8.74{\pm}0.47^{b}$	$9.12{\pm}0.44^{ab}$	$9.38{\pm}0.57^{a}$
Flavor	8.78±0.55ª	$8.91{\pm}0.56^{a}$	$9.04{\pm}0.69^{a}$	$9.04{\pm}0.55^{a}$	$8.88{\pm}0.75^{a}$
Goaty odor	$8.30{\pm}0.78^{b}$	$8.53{\pm}0.80^{ab}$	9.03±0.56ª	$8.96{\pm}0.53^{ab}$	$8.61{\pm}0.44^{ab}$
Appearance	$8.52{\pm}0.39^{ab}$	$8.81{\pm}0.57^{a}$	$9.20{\pm}0.56^{a}$	$8.17{\pm}0.58^{b}$	$8.17 \pm 0.62^{b}$
Overall acceptability	7.99±0.52°	$8.54{\pm}0.39^{b}$	9.18±0.33ª	$8.59{\pm}0.40^{b}$	$8.42 \pm 0.60^{bc}$

Table 5. Sensory evaluation of goat meat emulsion-type sausage with various levels of added water and fat

All values represented as mean±SD.

 $a^{-c}$  Means in the same row marked with different letters denote significant differences (p<0.05).

T1, water 5% and fat 25%; T2, water 10% and fat 20%; T3, water 15% and fat 15%; T4, water 20% and fat 10%; T5, water 25% and fat 5%.

differences in the sensory characteristics of emulsified sausages with different moisture and fat ratios. In the TPA, the evaluation scores for juiciness and tenderness showed an increasing trend as hardness, gumminess, and chewiness decreased (Table 4). Results of appearance showed that the T3 sample scored significantly higher than the other treatment groups (p<0.05). This is considered to be a result of the positive impact of the high resilience and solubility of muscle fiber proteins on the appearance of sausages compared with that in other treatment groups (Choi and Chin, 2021). Zhao et al. (2018) reported that replacing fat with moisture in emulsified sausages may compromise the texture and appearance. In this study, the overall acceptability of T1 and T3 samples significantly increased (p<0.05), whereas the T4 and T5 samples showed a decreasing trend in acceptability. In conclusion, a decrease in the appearance and overall acceptability scores was observed when moisture was added to goat meat emulsion-type sausages at levels exceeding 20%. The optimal moisture addition level for the sensory quality of goat meat emulsion-type sausages was found to be 15%.

## Conclusion

We analyzed the effects of the changes in water and fat contents on the physicochemical properties of goat meat emulsiontype sausages to determine the optimal water addition level for their production. The experiments show the expected results following the water addition levels. However, the T3 sample showed the highest WHC and myofibrillar protein solubility. These results show that the species of livestock and their nutritional contents, particularly water content, do not significantly affect the structures of emulsion-type meat products. Therefore, in industrial manufacturing of goat meat emulsion-type sausage, adding 15% water and 15% fat is the appropriate ratio.

## **Conflicts of Interest**

The authors declare no potential conflicts of interest.

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## **Author Contributions**

Conceptualization: Lee JA, Kim HY. Data Curation: Lee JA. Formal analysis: Kang KM. Methodology: Lee JA, Kim HY. Software: Kang KM. Validation: Lee JA. Investigation: Kang KM, Kim HY. Writing - original draft: Lee JA, Kang KM. Writing - review & editing: Lee JA, Kang KM, Kim HY.

## **Ethics Approval**

The sensory evaluation was approved by the Ethics Committee of Kongju National University, Korea (Authority No: KNU\_IRB\_2021-75).

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