TITLE PAGE
- Food Science of Animal Resources -
Upload this completed form to website with submission

ARTICLE INFORMATION	Fill in information in each box below
Article Type	Original article
Article Title	Changes in Physicochemical Characteristics of Goat Meat Emulsion-type Sausage According to the Ratio of Fat and Water Contents
Running Title (within 10 words)	Changes on Physicochemical Characteristics of Low-Fat Goat Meat Sausages
Author	Jeong-Ah Lee[1,2,†], Kyu-Min Kang[1,†], and Hack-Youn Kim[1,3,*] †These authors contributed equally to this work.
Affiliation	[1] Department of Animal Resources Science, Kongju National University, Yesan 32439, Korea [2] Animal Products Utilization Division, National Institute of Animal Science, Rural Development Administration, Wanju-gun 55365, Korea [3] Resource Science Research Institute, Yesan 32439, Korea
Special remarks – if authors have additional information to inform the editorial office	Not applicable.
ORCID (All authors must have ORCID) https://orcid.org	Jeong-Ah Lee (https://orcid.org/0000-0003-3019-8321) Kyu-Min Kang (https://orcid.org/0000-0002-4904-1976) Hack-Youn Kim (https://orcid.org/0000-0001-5303-4595)
Conflicts of interest List any present or potential conflict s of interest for all authors. (This field may be published.)	The authors declare no potential conflict of interest.
Acknowledgements State funding sources (grants, funding sources, equipment, and supplies). Include name and number of grant if available. (This field may be published.)	This research was supported by Cooperative Research Program for Agriculture Science & Technology Development (Project No. PJ016217) Rural Development Administration, Republic of Korea.
Author contributions (This field may be published.)	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 (IRB/IACUC) (This field may be published.)	The sensory evaluation was approved by the Ethics Committee of Kongju National University, South Korea (Authority No: KNU_IRB_2021-75).

CORRESPONDING AUTHOR CONTACT INFORMATION

For the <u>corresponding</u> author (responsible for correspondence, proofreading, and reprints)	Fill in information in each box below
First name, middle initial, last name	Hack-Youn Kim
Email address – this is where your proofs will be sent	kimhy@kongju.ac.kr
Secondary Email address	
Postal address	Department of Animal Resources Science, Kongju National University, Chungnam 32439, Korea
Cell phone number	
Office phone number	+82-41-330-1241
Fax number	+82-41-330-1249

Optimization of Goat Meat Emulsion-type Sausage: Effect of Formulation Ratio of Fat and Water Contents

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 well-being (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 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., 2019; Hwang et al., 2017). 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 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., 2016A). 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 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 & Methods

Preparation of sausage samples

The whole process of sample preparations is shown in Figure 1. Goat meat (Gaon, Gang-jin, Republic of Korea) was diced and ground using a 3mm 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, Barcelona, Spain). After stuffing, the samples were cooked for 40 min at 80℃ chamber (10.10ESI/SK, Alto Shaam, Menomonee Falls, WI, USA) and cooled at 10℃ for 30 min.

Proximate compositions

Association of Official Analytical Chemists (AOAC) guidelines (AOAC, 2010) were used to determine the proximate compositions and each composition used the following methods: Drying samples in 105℃ 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℃ (AOAC 920.153) for ash content.

pH

The samples were mixed with distilled water (DW) (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 Co.) at 80℃ for 30 min and then cooled at room temperature (20℃) for 30 min. The amounts of water and fat that were exuded were measured to determine the emulsion stability.

$$\text{Water loss (\%)} = \frac{\text{exuded water (mL)}}{\text{emulsion weight (g)}} \times 100$$

$$\text{Fat loss (\%)} = \frac{\text{exuded fat (mL)}}{\text{emulsion weight (g)}} \times 100$$

Cooking yield

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

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

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℃. And then centrifuged at 4,032×g at 4℃ 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, USA), and calculated according to the following formula:

Total protein & sarcoplasmic protein = absorbance × sample dilution factor × buffer dilution factor × a value (protein concentrate)

Myofibrillar protein = total protein - sarcoplasmic protein

Water holding capacity (WHC)

The water holding capacity (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, IL, USA) and placing it in a 50 mL conical tube. The prepared sample was centrifuged at 109 × g at 4℃ 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.

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

$$A = \frac{\text{weight before centrifugation (g)} \times \text{moisture content (\%)}}{100}$$

$$B = \text{weight before centrifugation} - \text{weight after centrifugation}$$

Texture profile analysis (TPA)

The texture profile analysis (TPA) was performed on sausages which were cut into cubes measuring 2.0 cm in width, length, and height. The analysis was carried out using a texture analyzer (TA 1, Lloyd Co., 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, 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℃ and tested. The head speed was set at 20 rpm and measured for 60 sec.

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 standard deviation (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 Figure 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., 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 T4 and T5 samples, indicating the formation of a relatively stable emulsion ($P < 0.05$).

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 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 (WHC)

The functional characteristics of the emulsion, such as emulsion stability and water holding capacity, 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 water holding capacity (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, revealing results opposite 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., 2016B). We 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 (TPA) 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., 2016B). 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 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.

Figure 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 et al., 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 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 emulsion-type 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 water holding capacity 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.

Conflict of interest

The authors declare that they have no conflict of interest to this work.

Acknowledgments

This research was supported by Cooperative Research Program for Agriculture Science & Technology Development (Project No. PJ016217) Rural Development Administration, Republic of Korea.

Author contribution

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, South Korea (Authority No: KNU_IRB_2021-75).

References

Aaslyng MD, Bejerholm C, Ertbjerg P, Bertram HC, Andersen HJ. 2003. Cooking loss and juiciness of pork in relation to raw meat quality and cooking procedure. Food Qual Preference 14:277-288.

Aktaş N, Genccelep H. 2006. Effect of starch type and its modifications on physicochemical properties of bologna-type sausage produced with sheep tail fat. Meat Sci 74:404-408.

Amiri A, Sharifian P, Soltanizadeh N. 2018. Application of ultrasound treatment for improving the physicochemical, functional and rheological properties of myofibrillar proteins. Int J Biol Macromol 111:139-147.

AOAC. 2010. Official methods of analysis. 16th ed. Association of Official Analytical Chemists, Washington, DC, USA.

Broucke K, Van Poucke C, Duquenne B, De Witte B, Baune MC, Lammers V, Terjung N, Ebert S, Gibis M, Weiss J, Van Royen G. 2022. Ability of (extruded) pea protein products to partially replace pork meat in emulsified cooked sausages. Innovative Food Sci Emerg Technol 78:102992.

Cengiz E, Gokoglu N. 2007. Effects of fat reduction and fat replacer addition on some quality characteristics of frankfurter-type sausages. Int J Food Sci Technol 42:366-372.

Charmpi C, Van Reckem E, Sameli N, Van der Veken D, De Vuyst L, Leroy F. 2020. The use of less conventional meats or meat with high pH can lead to the growth of undesirable microorganisms during natural meat fermentation. Foods 9:1386.

Choe J, Kim HW, Farouk MM, Kim YHB. 2017. Impacts of post-mortem ageing prior to freezing on technological and oxidative properties of coarse ground lamb sausage in a model system. Asian-Australas J Anim Sci 30:1021.

Choe JH, Kim HY, Lee JM, Kim YJ, Kim CJ. 2013. Quality of frankfurter-type sausages with added pig skin and wheat fiber mixture as fat replacers. Meat Sci 93:849-854.

Choi DM, Kang KM, Kang SM, Kim HY. 2023. Physicochemical Properties of Black Korean Goat Meat with Various Slaughter Ages. Animals 13:692.

Choi JS, Chin KB. 2021. Structural changes of meat protein of chicken sausages with various levels of salt and phosphate and their effects on in vitro digestion. Int J Food Sci Technol 56:5250-5258.

Choi YS, Choi JH, Han DJ, Kim HY, Lee MA, Jeong JY, Chung HJ, Kim CJ. 2010. Effects of replacing pork back fat with vegetable oils and rice bran fiber on the quality of reduced-fat frankfurters. Meat Sci 84:557-563.

Choi YS, Choi JH, Han DJ, Kim HY, Lee MA, Lee ES, Jeong JY, Paik HD, Kim CJ. 2008. Effects of rice bran fiber on quality of low-fat tteokgalbi. Food Sci Biotechnol 17:959-964.

Claus JR, Hunt MC, Kastner CL. 1990A. Effects of substituting added water for fat on the textural, sensory, and processing characteristics of bologna 1. J Muscle Foods 1:1-21.

Claus JR, Hunt MC, Kastner CL, Kropf DH. 1990B. Low-fat, high-added water bologna: effects of massaging, preblending, and time of addition of water and fat on physical and sensory characteristics. J Food Sci 55:338-341.

Colmenero FJ, Carballo J, Fernández P, Barreto G, Solas MT. 1997. High-pressure-induced changes in the characteristics of low-fat and high-fat sausages. J Sci Food Agric 75:61-66.

Dickinson E. 2012. Emulsion gels: The structuring of soft solids with protein-stabilized oil droplets. Food Hydrocolloids 28:224-241.

Farouk MM, Wieliczko K, Lim R, Turnwald S, MacDonald GA. 2002. Cooked sausage batter cohesiveness as affected by sarcoplasmic proteins. Meat Sci 61:85-90.

Feng CH, Arai H. 2022. Evaluation of hesperidin on sausages stuffed in a new modified casing during long-term storage—A preliminary study. Sustainability 14:9071.

Flores M, Giner E, Fiszman SM, Salvador A, Flores J. 2007. Effect of a new emulsifier containing sodium stearoyl-2-lactylate and carrageenan on the functionality of meat emulsion systems. Meat Sci 76:9-18.

Gregg LL, Claus JR, Hackney CR, Marriott NG. 1993. Low-fat, high added water bologna from massaged, minced batter. J Food Sci 58:259-264.

Herrero AM, De la Hoz L, Ordóñez JA, Herranz B, De Á vila MR, Cambero MI. 2008. Tensile properties of cooked meat sausages and their correlation with texture profile analysis (TPA) parameters and physico-chemical characteristics. Meat Sci 80:690-696.

Hwang YH, Bakhsh A, Lee JG, Joo ST. 2019. Differences in muscle fiber characteristics and meat quality by muscle type and age of Korean native black goat. Food Sci Anim Resour 39:988.

Hwang YH, Joo SH, Bakhsh A, Ismail I, Joo ST. 2017. Muscle fiber characteristics and fatty acid compositions of the four major muscles in Korean native black goat. Korean J Food Sci Anim Resour 37:948.

Jin SK, Ha SR, Hur SJ, Choi JS. 2016. Effect of the ratio of raw material components on the physico-chemical characteristics of emulsion-type pork sausages. Asian-Australas J Anim Sci 29:263.

Jin SK, Kim IS, Jung HJ, Kim DH, Choi YJ, Hur SJ. 2007. The development of sausage including meat from spent laying hen surimi. Poult Sci 86:2676-2684.

Johnson HR, Aberle ED, Forrest JC, Haugh CG, Judge MD. 1977. Physical and chemical influences on meat emulsion stability in a model emulsitator. J Food Sci 42:522-531.

Jung DY, Lee HJ, Shin DJ, Kim CH, Jo C. 2022. Mechanism of improving emulsion stability of emulsion-type sausage with oyster mushroom (Pleurotus ostreatus) powder as a phosphate replacement. Meat Sci 194:108993.

Kameník J, Saláková A, Kašpar L. 2018. Characteristics of selected pork muscles 45 min and 24 h post mortem. Acta Vet Brno 87:173-180.

Kawęcka A, Pasternak M. 2022. The Effect of Slaughter Age on Meat Quality of Male Kids of the Polish Carpathian Native Goat Breed. Animals 12:702.

Karakaya M, Saricoban C, Yilmaz MT. 2006. The effect of mutton, goat, beef and rabbit-meat species and state of rigor on some technological parameters. J Muscle Foods 17:56-64.

Kim HJ, Kim HJ, Jang A. 2019. Nutritional and antioxidative properties of black goat meat cuts. Asian-Australas J Anim Sci 32:1423.

Lee HJ, Lee JJ, Jung MO, Choi JS, Jung JT, Choi YI, Lee JK. 2017. Meat quality and storage characteristics of pork loin marinated in grape pomace. Korean J Food Sci Anim Resour 37:726.

Lee JA, Kim HW, Seol KH, Cho S, Kang SM. 2022. Effect of Cooking Method on the Nutritional Composition and Tenderness of Loin from Korean Black Goat Crossbreed. Resour Sci Res 4:105-114.

Lee SH, Kim GW, Choe J, Kim HY. 2018. Effect of buckwheat (Fagopyrum esculentum) powder on the physicochemical and sensory properties of emulsion-type sausage. Korean J Food Sci Anim Resour 38:927.

Madruga MS, Bressan MC. 2011. Goat meats: Description, rational use, certification, processing and technological developments. Small Ruminant Res 98:39-45.

Madruga MS, Medeiros EJLD, Sousa WHD, Cunha MDGG, Pereira Filho JM, Queiroga RDCRDE. 2009. Chemical composition and fat profile of meat from crossbred goats reared under feedlot systems. Revista Brasileira de Zootecnia 38:547-552.

Manzoor MF, Hussain A, Naumovski N, Ranjha MMAN, Ahmad N, Karrar E, Xu B, Ibrahim SA. 2022. A narrative review of recent advances in rapid assessment of anthocyanins in agricultural and food products. Front Nutr 9:901342.

Mechesso AF, Moon DC, Ryoo GS, Song HJ, Chung HY, Kim SU, Kang HY, Na SH, Yoon SS, Lim SK. 2021. Resistance profiling and molecular characterization of Staphylococcus aureus isolated from goats in Korea. Int. J. Food Microbiol 336:108901.

Muguerza E, Fista G, Ansorena D, Astiasarán I, Bloukas JG. 2002. Effect of fat level and partial replacement of pork backfat with olive oil on processing and quality characteristics of fermented sausages. Meat Sci 61:397-404.

Oz F, Celik T. 2015. Proximate composition, color and nutritional profile of raw and cooked goose meat with different methods. J Food Process Preserv 39:2442-2454.

Paneras ED, Bloukas JG. 1994. Vegetable oils replace pork backfat for low-fat frankfurters. J Food Sci 59:725-728.

Petracci M, Bianchi M, Mudalal S, Cavani C. 2013. Functional ingredients for poultry meat products. Trends Food Sci Technol 33:27-39.

Sun XD, Holley RA. 2011. Factors influencing gel formation by myofibrillar proteins in muscle foods. Compr Rev Food Sci Food Saf 10:33-51.

Totosaus A, Perez-Chabela ML. 2009. Textural properties and microstructure of low-fat and sodium-reduced meat batters formulated with gellan gum and dicationic salts. LWT Food Sci Technol 42:563-569.

Webb EC. 2014. Goat meat production, composition, and quality. Anim Front 4:33-37.

Williams P. 2007. Nutritional composition of red meat. Nutr Diet 64:S113-S119.

Wu L, Wu T, Wu J, Chang R, Lan X, Wei K, Jia X. 2016. Effects of cations on the “salt in” of myofibrillar proteins. Food Hydrocolloids 58:179-183.

Yang H., Khan MA, Han M, Yu X, Bai X, Xu X, Zhou G. 2016B. Optimization of textural properties of reduced-fat and reduced-salt emulsion-type sausages treated with high pressure using a response surface methodology. Innovative Food Sci Emerg Technol 33:162-169.

Yang H, Zhang W, Li T, Zheng H, Khan MA, Xu X, Sun J, Zhou G. 2016A. Effect of protein structure on water and fat distribution during meat gelling. Food Chem 204:239-245.

Youssef MK, Barbut S. 2010. Physicochemical effects of the lipid phase and protein level on meat emulsion stability, texture, and microstructure. J Food Sci 75:S108-S114.

Zhang Y, Wang X, Chen H, Ren F, Liu Z, Wang P, Liu X. 2022. Application of gel-in-oil-in-water double emulsions as a pork oil replacer in emulsified sausage. J Food Process Preserv 46:e16333.

Zhao Y, Hou Q, Zhuang X, Wang Y, Zhou G, Zhang W. 2018. Effect of regenerated cellulose fiber on the physicochemical properties and sensory characteristics of fat-reduced emulsified sausage. LWT Food Sci Technol 97:157-163.

Tables and figures

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

Traits		Treatments				
		T1	T2	T3	T4	T5
Moisture (%)		57.98±0.50^{e}	61.88±0.15^{d}	65.14±0.59^{c}	71.34±0.91^{b}	75.99±0.35^{a}
Protein (%)		15.49±0.32^{a}	15.62±0.22^{a}	15.85±0.52^{a}	15.76±0.64^{a}	15.50±0.49^{a}
Fat (%)		24.97±0.31^{a}	20.11±0.09^{b}	16.91±0.03^{c}	10.87±0.30^{d}	6.42±0.14^{e}
Ash (%)		1.88±0.01^{a}	1.91±0.04^{a}	1.86±0.05^{a}	1.89±0.05^{a}	1.92±0.05^{a}
pH	Uncooked	6.45±0.01	6.46±0.02	6.44±0.01	6.44±0.01	6.45±0.01
	Cooked	6.67±0.02	6.66±0.01	6.66±0.01	6.65±0.01	6.65±0.01

All values represented as mean±SD.

$^{a–e}$ 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%.

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

Traits (%)		Treatments				
		T1	T2	T3	T4	T5
Emulsion stability	Water loss	3.41 ± 0.38^{c}	4.79 ± 0.33^{c}	7.95 ± 1.17^{b}	11.87 ± 0.54^{a}	13.58 ± 1.34^{a}
	Fat loss	3.89 ± 0.60^{a}	3.41 ± 0.68^{a}	1.34 ± 0.38^{b}	1.34 ± 0.26^{b}	0.83 ± 0.13^{c}
Cooking yield		92.72 ± 0.97^{a}	92.24 ± 0.60^{a}	90.49 ± 0.69^{b}	87.71 ± 0.93^{c}	87.01 ± 0.46^{c}

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%.

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	T3	T4	T5
Total protein	355.52±8.36^{a}	354.44±6.40^{a}	356.17±10.49^{a}	353.79±8.71^{a}	356.82±2.55^{a}
Sarcoplasmic protein	119.01±0.97^{b}	119.23±3.18^{b}	119.88±2.73^{b}	129.18±2.19^{a}	129.40±2.78^{a}
Myofibrillar protein	236.51±8.49^{ab}	235.21±4.30^{ab}	242.93±7.62^{a}	224.61±6.40^{b}	227.42±3.69^{b}
WHC (%)	91.32±0.41^{a}	91.17±1.82^{a}	92.07±0.98^{a}	87.40±0.28^{b}	87.79±0.59^{b}

All values represented as mean±SD.

$^{a–b}$ 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%.

Table 4. Texture profile analysis of goat meat emulsion-type sausage with various levels of added water and fat

Traits	Treatments				
	T1	T2	T3	T4	T5
Hardness (kgf)	3.28±0.26^{a}	2.90±0.16^{b}	2.71±0.18^{b}	1.92±0.17^{c}	1.98±0.14^{c}
Springiness	0.49±0.03^{a}	0.48±0.03^{a}	0.46±0.04^{a}	0.48±0.02^{a}	0.47±0.03^{a}
Gumminess (kgf)	2.43±0.17^{a}	2.16±0.14^{b}	2.06±0.18^{b}	1.47±0.11^{c}	1.37±0.09^{c}
Chewiness (kgf)	1.21±0.13^{a}	1.03±0.10^{b}	0.94±0.12^{b}	0.71±0.06^{c}	0.65±0.07^{c}
Cohesiveness	0.74±0.05^{ab}	0.74±0.03^{a}	0.76±0.02^{a}	0.76±0.03^{a}	0.68±0.03^{b}

All values represented as mean±SD.

$^{a\text{–}c}$ 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%.

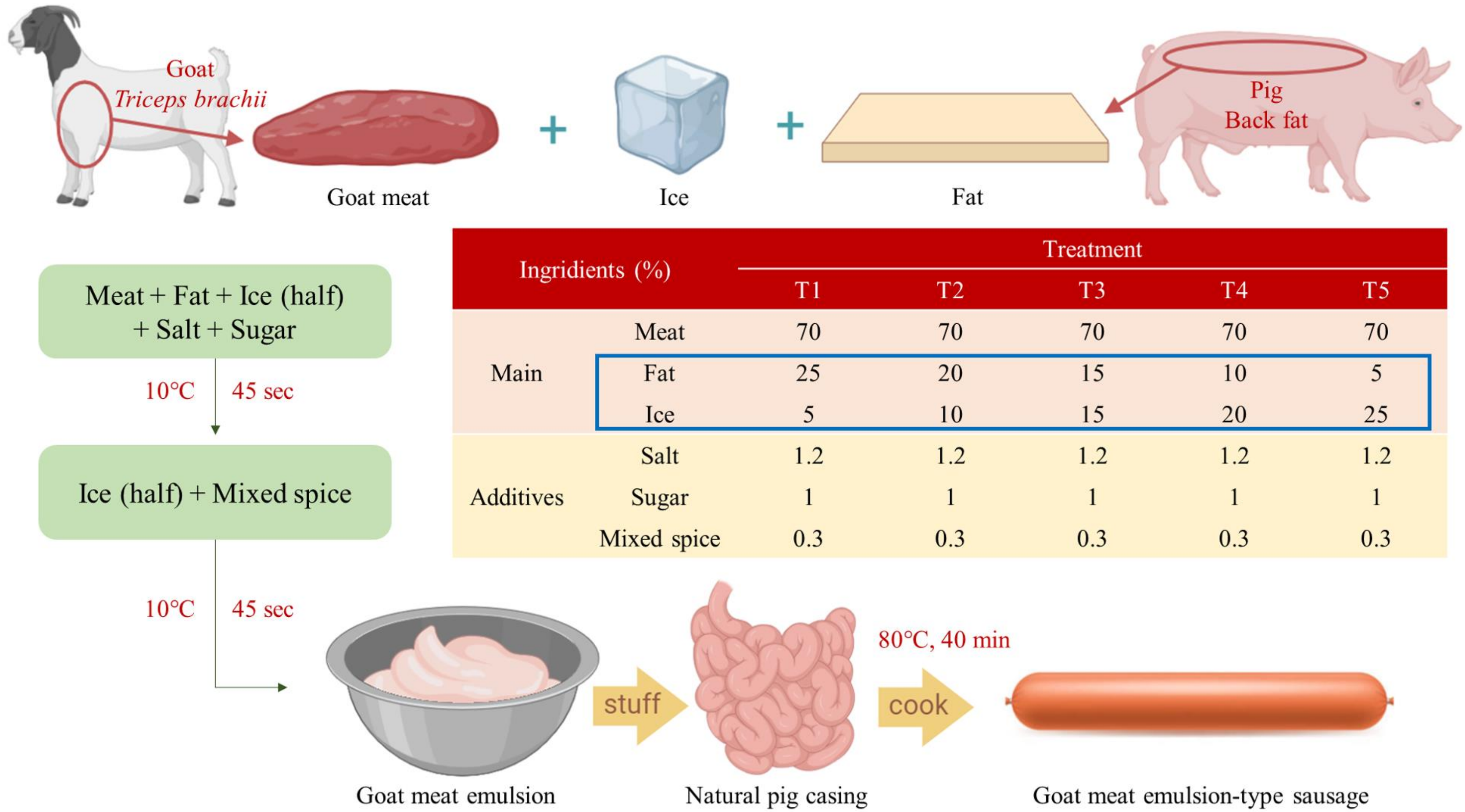
Table 5. Sensory evaluation of goat meat emulsion-type sausage with various levels of added water and fat

Traits	Treatments				
	T1	T2	T3	T4	T5
Color	9.22±0.58^{a}	9.33±0.62^{a}	9.21±0.63^{a}	9.28±0.48^{a}	9.28±0.53^{a}
Tenderness	8.46±0.60^{b}	8.69±0.36^{ab}	9.04±0.48^{a}	9.07±0.38^{a}	9.09±0.43^{a}
Juiciness	8.63±0.40^{b}	8.64±0.35^{b}	8.74±0.47^{b}	9.12±0.44^{ab}	9.38±0.57^{a}
Flavor	8.78±0.55^{a}	8.91±0.56^{a}	9.04±0.69^{a}	9.04±0.55^{a}	8.88±0.75^{a}
Goaty odor	8.30±0.78^{b}	8.53±0.80^{ab}	9.03±0.56^{a}	8.96±0.53^{ab}	8.61±0.44^{ab}
Appearance	8.52±0.39^{ab}	8.81±0.57^{a}	9.20±0.56^{a}	8.17±0.58^{b}	8.17±0.62^{b}
Overall acceptability	7.99±0.52^{c}	8.54±0.39^{b}	9.18±0.33^{a}	8.59±0.40^{b}	8.42±0.60^{bc}

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%.



Ingridients (%)		Treatment				
		T1	T2	T3	T4	T5
Main	Meat	70	70	70	70	70
	Fat	25	20	15	10	5
	Ice	5	10	15	20	25
Additives	Salt	1.2	1.2	1.2	1.2	1.2
	Sugar	1	1	1	1	1
	Mixed spice	0.3	0.3	0.3	0.3	0.3

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

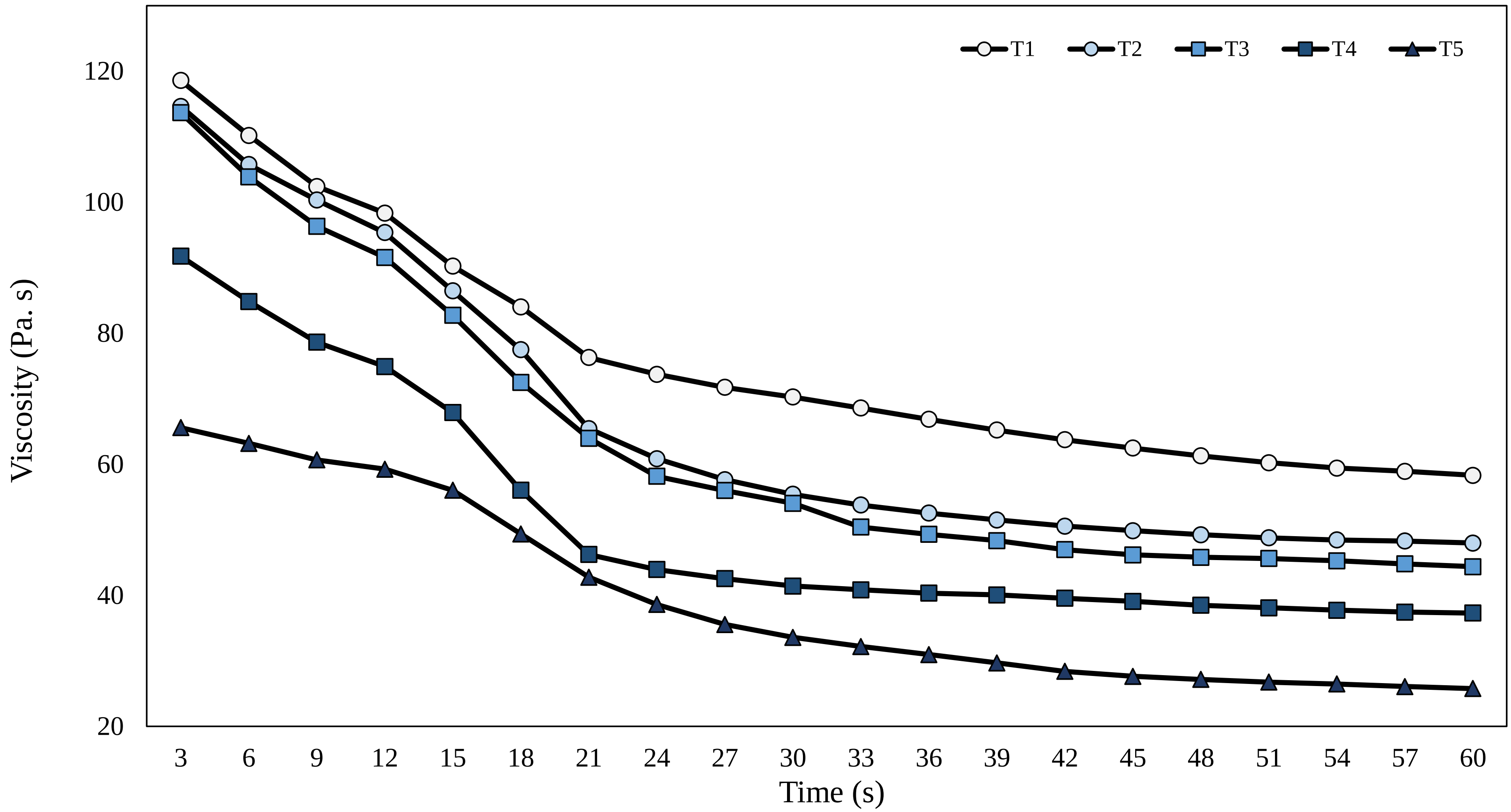


Figure 2. Viscosity (Pa. s) of goat meat emulsion-type sausage with various levels of added water and fat. T1: water 5% and fat 25%; T2: water 10% and fat 20%; T3: water 15% and fat 15%; T4: water 20% and fat 10%; T5: water: 25% and fat 5%.