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Effect of Ginger (*Zingiber officinale*) Extract on the Physicochemical and Microbiological Characteristics of Rote Sheep *Se'i*

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Abstract

Se'i is a traditional smoked meat product from East Nusa Tenggara that may be susceptible to microbial contamination during processing and storage. Ginger (Zingiber officinale) contains bioactive compounds and proteolytic enzymes that may influence the physicochemical characteristics of meat and inhibit microbial growth. This study aimed to evaluate the effects of ginger extract supplementation on the physicochemical and microbiological characteristics of Rote sheep se'i. A completely randomized design was used with four concentrations of ginger extract: 0% (control), 3%, 6%, and 9%. The parameters measured were moisture content, hardness, pH, Total Plate Count (TPC), coliforms, and Escherichia coli. Data were analyzed using analysis of variance (ANOVA). The results showed that increasing ginger extract concentration decreased moisture content and pH, while increasing hardness (P<0.01). The addition of ginger extract also reduced TPC, coliforms, and E. coli (P<0.01). In conclusion, ginger extract has potential as a natural ingredient for improving the microbiological quality of Rote sheep se'i. However, its concentration should be optimized because higher concentrations resulted in a harder product.

Keywords: ginger extract, microbiological quality, physicochemical characteristics, Rote sheep meat se'i.

INTRODUCTION

In 2025, Rote sheep were officially recognized as an Indonesian local livestock breed through the Decree of the Minister of Agriculture No 642/Kpts./HK.150/M/08/2025. This recognition reinforces the importance of conserving Rote sheep, improving their productivity, and promoting downstream development through value-added processed products that reflect the distinctive characteristics of the region.

One potential approach to diversifying the utilization of Rote sheep meat is its processing into *se'i*, hereafter referred to as Rote sheep *se'i*. *Se'i* is a traditional smoked meat product originating from East Nusa Tenggara and is commonly produced from beef or pork. The processing of *se'i* generally involves cutting the meat into long strips, curing it with salt and other ingredients, and smoking it until fully cooked and a characteristic smoky aroma develops (Malelak and Jelantik, 2022).

Smoking not only contributes to the characteristic color, aroma, and flavor of the product but also reduces moisture content and may inhibit microbial growth through the combined effects of heat and antimicrobial compounds present in smoke. Despite undergoing heating and smoking, *se'i* may still be susceptible to quality deterioration due to microbial contamination. Therefore, controlling microbial populations is essential for ensuring the safety and quality of *se'i.* Microbiological quality can be evaluated using parameters such as Total Plate Count (TPC), coliforms, and *Escherichia coli*. TPC provides an estimate of the overall population of viable aerobic microorganisms, whereas coliforms and *E. coli* are commonly used as indicators of hygienic conditions and potential fecal contamination during food processing and handling.

Moisture content, hardness, and pH are important parameters for determining the physicochemical characteristics and stability of meat products. A relatively high moisture content may create conditions that favor microbial growth, although the availability of water for microbial growth is more accurately described by water activity. Therefore, controlling pH, microbial populations, and moisture content is important for maintaining the quality of Rote sheep *se'i.* Low moisture content may also affect the hardness of *se'i*. An appropriate pH may contribute to inhibiting the growth of certain spoilage microorganisms, whereas an increase in pH during storage may be associated with microbial activity and the formation of compounds resulting from protein degradation. Moisture content also influences the texture, yield, and stability of meat products.

The use of natural ingredients with antimicrobial activity represents a promising approach to improving the quality and safety of meat products. One potential natural ingredient is ginger (*Zingiber officinale*). Ginger contains various bioactive compounds, particularly gingerols, shogaols, paradols, flavonoids, and phenolic compounds. These compounds have been reported to possess antimicrobial and antioxidant activities. The active components of ginger may disrupt microbial cell membrane permeability, interfere with enzyme activity, and inhibit cellular metabolic processes, thereby potentially suppressing bacterial growth in food products (Shaukat et al., 2023).

The application of ginger extract in meat products has been reported to influence both microbiological and physicochemical characteristics. The addition of ginger extract to several meat products has resulted in lower microbial populations compared with products without ginger extract. However, its effects on pH and moisture-related properties are not always consistent, as they depend on extract concentration, product type, ingredient composition, heating method, and storage conditions. (Karpi´nska-Tymoszczyk et al., 2022) demonstrated that ginger supplementation could affect the pH and stability of meat products during storage, although the magnitude of these effects depended on the concentration of ginger used. Ginger extract may also influence moisture content through interactions between its components and meat proteins, as well as through changes in the ability of muscle tissue to retain water during heating.

Although the potential application of ginger extract as a natural ingredient in meat products has been widely investigated, information regarding its use in *se'i* produced from Rote sheep meat remains limited. The characteristics of the raw material, curing process, smoking temperature, and heating duration involved in *se'i* processing may result in responses to ginger extract that differ from those observed in other meat products. Furthermore, the appropriate concentration of ginger extract required to achieve a desirable balance among physicochemical properties and microbiological quality in Rote sheep *se'i* has not been established. Investigation of these aspects is therefore necessary to provide a scientific basis for the development of using natural ingredients while maintaining desirable physicochemical and microbiological characteristics.

Based on these considerations, this study aimed to evaluate the effects of different concentrations of ginger (*Zingiber officinale*) extract on the moisture content, hardness, pH, Total Plate Count (TPC), coliforms, and *Escherichia coli* of Rote sheep *se'i*. The findings are expected to provide information on the effectiveness of ginger extract as a natural additive and to support the development and value addition of Rote sheep meat into a distinctive processed meat product.

MATERIALS AND METHODS

Materials and experimental design

Twenty four Kg of Sirloin lamb was took from Roteness sheep (local breed). Ginger (*Zingiber officinale*) **was** purcchaged in local market**.** The ingredients used for *se'i* processing included, salt (Natrium chloride/NaCl) and saltpeter.

The experiment was arranged in a completely randomized design (CRD): 4x4 with four treatments such as; G_0 = lamb *se'i* without ginger extract (control); G_3 = lamb *se'i* added 3% ginger extract (v/w); G_6 = lamb *se'i* added 6% (ginger extract v/w); and G_9 = lamb *se'i* added 9% ginger extract (v/w).

Preparation of Ginger Extract

The procedure for preparing ginger extract begins with taking 1 kg of ginger, peeling and cut in small size, and washing it thoroughly. After washing, the ginger was blended with 1 liter of water and then squeezed to obtain the extract.

Se'i processing

Remove visible fat from sirloin then sliced longitudinally into rope-shaped strips approximately 3 cm thick. The meat was then randomly divided into four treatment groups, with each treatment consisting of 6 kgs of meat. Each treatment was further divided into four replications,

Each experimental unit was mixed with 2% (w/w) sodium chloride and 350 mg potassium nitrate (KNO_3). Extract ginger was subsequently added according to the respective treatment levels (0, 3, 6, or 9%, v/w), was thoroughly mixed and marinated for approximately 12 h at refrigerated temperature. After marination, the meat was smoked until fully cooked (well done). The meat was subsequently smoke using *Schleichera oleosa* wood as fuel and the smoke source, at 70–80°C for 45–60 min until the internal temperature reached 72°C. After smoking, the *se'i* products were cooled to room temperature, after which samples were send to laboratory to determine of moisture, pH, and TPC.

Parameters Measured

pH Value

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A 10-gram meat sample was manually pulverized using a mortar and mixed with 10 ml of distilled water. The pH meter probe/tip was calibrated with buffer solutions 4 and 7. Dip the electrode of the Hanna H 199192 pH meter into the meat extract. Allow the pH meter to stabilize and record the pH value. Each sample was read in duplicate.

Water content

Water content measurement followed the dried at 125°C for 1 hour. (Indonesian Standar Nasional, 2009).

Water content (%) =

$$\frac{\text{Initial weight} - \text{weight after drying}}{\text{Initial weight}} \times 100\%$$

Tekstur r **(hardness)**

Hardness values were determined using the Texture Profile Analysis (TPA) method with a Geni DTA-5 analyzer.

Procedure measured: Cut the meat into uniform pieces, for example **2 × 2 × 2 cm**, Allow all samples to reach the same temperature before analysis then place the sample on the texture analyzer platform. Use a **flat-ended cylindrical compression probe**, for example 35–50 mm diameter then Compress the sample **twice**, commonly to **50% of its original height**. A typical test speed is around **1–2 mm/s**, although the exact conditions should be standardized for your study. Record the force–time or force–distance curve. Hardness is defined as the maximum force recorded during the first compression cycle.

Hardness=F max,first compression (**N (Newton)**.

Total Plate Count (TPC)

Total Plate Count (ALT) in accordance with the Indonesian National Standard (2009).

$$N = \frac{\Sigma C}{(n_1 + 0,1n_2) \times d}$$

where:

N = number of colonies, expressed as colony-forming units per gram (CFU/g) or per milliliter (CFU/mL);

ΣC = total number of colonies counted on all selected plates;

n_1 = number of plates counted at the first selected dilution;

n_2 = number of plates counted at the second selected dilution;

d = dilution factor corresponding to the first selected dilution.

For enumeration, Petri dishes containing 25–250 colonies were selected. Colony counts from the selected plates were calculated by considering the corresponding dilution factors, and the final results were expressed to two significant figures as CFU/g for solid samples or CFU/mL for liquid samples.

Isolation of Coliform and E. coli

Each sample (25 g) was aseptically weighed and homogenized in 225 mL of Buffered Peptone Water (BPW; Merck, Germany) to obtain a 10^{-1} dilution. Serial ten-fold dilutions were subsequently prepared to obtain 10^{-2} and 10^{-3} dilutions. Following the presumptive test, tubes showing gas production were considered positive and subjected to further confirmation for *Escherichia coli*. One loopful of culture from each gas-positive tube was streaked onto Eosin Methylene Blue Agar (EMBA; Merck, Germany) and incubated at 37°C for 24 h. Presumptive *E. coli* colonies were identified based on their characteristic appearance on EMBA. The analysis was performed according (Indonesian Standar Nasional, 2009).

Data analysis

Data were analyzed using one-way analysis of variance (ANOVA) if there was a significant difference between

RESULTS AND DISCUSSION

Moisture Content of Lamb *Se'i* Treated with Ginger Extract

The moisture content of lamb *se'i* decreased significantly with increasing concentrations of ginger extract ($P < 0.01$), with the lowest moisture content (51.82%) observed in the 9% ginger extract treatment (Table 1). This finding is consistent with that reported by (Rovida et al., 2020), who found that the addition of ginger extract reduced the moisture content of chicken meat.

Ginger contains zingibain, a proteolytic enzyme capable of hydrolyzing myofibrillar proteins and connective tissue (Moon, 2018). At higher concentrations of ginger extract, increased proteolytic activity may promote more extensive degradation of muscle structural proteins, including proteins involved in water retention within the muscle tissue. Disruption of the myofibrillar structure may reduce the water-holding capacity of the meat, allowing water to be released more readily during heating. Consequently, greater moisture loss during thermal processing may contribute to the lower moisture content observed in lamb *se'i* treated with higher concentrations of ginger extract.

The decrease in moisture content may also be associated with the reduction in the pH of *se'i* as the concentration of ginger extract increased. A decrease in pH toward the isoelectric point of meat proteins reduces the net charge of the proteins and the space between myofibrillar filaments, thereby decreasing their ability to bind and retain water. Consequently, more water may be released from the muscle tissue during heating. During *se'i* processing, heat-induced denaturation and shrinkage of myofibrillar proteins, together with the contraction of connective tissue, may further promote water loss from the meat.

Tabel 1. Physicochemical characteristics of lamb *se'i* treated with different concentrations of ginger extract

Parameters	Ginger extract				
	Control (0%)	Ginger (3%)	Ginger (6%)	Ginger (9%)	p-value
Water (%)	67.87±0,15^{d}	63.83± 0,30^{c}	61.27±046^{b}	51.82±0,07^{a}	0.001
Hardnes(N)	548.23±20,65^{a}	653.99±9,87^{b}	669.8±49,49^{b}	861.3±27,75^{c}	0.001
pH	6.61±0.02^{d}	6.21±0.02^{c}	6.08±0.01^{b}	5.90±0.02^{a}	0.001

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Different superscript letters within the same row indicate significant differences (P < 0.05).

The reduction in moisture content may have beneficial implications for the quality of lamb *se'i*. Lower moisture content may contribute to reduced water availability for microbial growth and, consequently, improved product stability and potentially longer shelf life. However, moisture content should not be considered equivalent to water activity (aw); therefore, the effect on microbial stability would need to be confirmed by direct measurement of aw. On the other hand, excessive moisture loss may result in a harder and denser *se'i* texture, thereby reducing tenderness.

Effect of Ginger Extract on the Texture of Lamb *Se'i*

The texture of lamb *se'i* became progressively harder as the concentration of ginger extract increased (P < 0.01). The highest hardness value (861.33 N) was recorded in *se'i* treated with 9% ginger extract, whereas the lowest value (548.23 N) was observed in the control treatment (Table 1).

Several studies have reported that ginger extract can improve meat tenderness (Moon, 2018; Rovida et al., 2020; Febrianta, 2022; Dwiloka et al, 2024) due to the presence of zingibain, a proteolytic enzyme capable of hydrolyzing myofibrillar proteins and connective tissue (Moon, 2018). However, the present study showed a different response. Increasing the concentration of ginger extract increased the hardness of lamb *se'i* from 548.23 N in the control to 861.33 N in the 9% ginger extract treatment. This contrasting result suggests that the effect of ginger extract on *se'i* texture is not determined solely by the proteolytic activity of *zingibain* but also by changes in the physicochemical properties of the meat during processing.

The increase in hardness was likely associated with the reduction in pH and changes in the water-holding capacity of meat proteins (Khalid et al., 2023). In the present study, increasing the concentration of ginger extract decreased the pH of *se'i* from 6.61 in the control to 5.90 in the 9% ginger extract treatment. A decrease in pH can alter the net charge of myofibrillar proteins and reduce the space between protein filaments, thereby decreasing the ability of the muscle tissue to retain water during heating. The resulting loss of water during thermal processing can promote muscle fiber shrinkage and increase the density of the protein matrix. This more compact structure requires greater force to deform, resulting in higher hardness values.

In addition, the heating process involved in *se'i* production may limit the proteolytic activity of zingibain. Although zingibain can hydrolyze meat proteins during the preheating and early heating stages, further increases in temperature may lead to enzyme denaturation and inactivation. Cooking duration has also been reported to influence meat tenderness (Naqvi et al., 2021). Once proteolytic activity is reduced, heat-induced denaturation of myofibrillar proteins, tissue shrinkage, and moisture loss may become more dominant factors in determining the final texture of the product. Therefore, at higher concentrations of ginger extract, the effects associated with pH reduction and changes in water retention during heating may outweigh the tenderizing effect of zingibain. This mechanism may explain why increasing ginger extract concentration in the present study resulted in progressively higher hardness values in lamb *se'i.*

Effect of Ginger Extract on the pH of Lamb *Se'i*

The addition of ginger extract significantly decreased the pH of lamb *se'i* as the concentration of ginger extract increased (P < 0.01). The pH decreased from 6.61 in the control to 5.90 in *se'i* treated with 9% ginger extract (Table 1).

The progressive decrease in pH with increasing ginger extract concentration may be attributed to the presence of various organic acids in ginger, including citric, malic, oxalic, succinic, and tartaric acids (Yeh et al., 2014). As the concentration of ginger extract increased, greater amounts of these organic acids were incorporated into the meat, thereby contributing to the reduction in product pH. Similar effects have been reported in other meat products, where the addition of ginger reduced the pH of chicken meat (Muhialdin et al., 2020) and minced meat (Terefe, 2017).

Gingerols and shogaols, which are among the major bioactive compounds in ginger, contain phenolic hydroxyl groups that can exhibit acidic properties (Yapıcı and Gülçin, 2026). The increasing incorporation of these compounds, together with organic acids from the ginger extract, may therefore contribute to the observed reduction in the pH of lamb *se'i.*

A lower pH may create less favorable conditions for the growth of some spoilage and pathogenic microorganisms and may therefore contribute to lower microbial counts. However, the antimicrobial effect of ginger should not be attributed to pH reduction alone because its bioactive compounds may also exert direct antimicrobial activity. Furthermore, changes in pH influence the water-holding capacity of meat proteins and may consequently contribute to the observed changes in moisture content and texture of the product.

Effect of Ginger Extract on Total Plate Count (TPC), Coliforms, and *Escherichia coli*

The addition of ginger extract significantly reduced Total Plate Count (TPC) and coliform counts in lamb *se'i* as the concentration of ginger extract increased (P < 0.01), whereas *Escherichia coli* was same for all sampes. TPC values ranged from 3.14 to 4.16 log CFU/g and coliform ranged from 1.02 to 1.91 log CFU/g The highest TPC and coliform was recorded in samples control 4.16 log CFU/g and 1.91 log CFU/g respectively, while the lowest was found in the 9% ginger 3.14 log CFU/g for tpc and 1.02 log CFU/g respectively. The numbers of TPC and coliform all *se'i* sample showed lower than the fixed to standard limit of SNI 7388:2009 for TPC 1×10^5 CFU/g and Coliform 1×10^2 CFU/g.

Table 2. Total Plate Count (TPC), coliform, and *Escherichia coli* counts in lamb *se'i* treated with ginger extract.

Parameters	Ginger extract				
	Control (0%)	Ginger (3%)	Ginger (6%)	GGinger (9%)	p Value
TPC (log cfu/g)	**4.16**±0.08^{d}	**3.64**±0.12^{c}	3,3.52±0.1^{b}	**3,14**±0.1^{a}	0.001

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Coliform (log cfu/g)	1.91±0.08[d]	1.47±0.04[c]	1.23±0.3[b]	1.02±0.4[a]	0,02
E Coli (cfu/g)	<3	<3	<3	<3	

Different superscript letters within the same row indicate significant differences ($P < 0.05$).

Ginger (*Zingiber officinale*) is rich in bioactive compounds, including gingerols, shogaols, and α-zingiberene, which have been reported to inhibit the growth of spoilage microorganisms (Asghar et al., 2023). Gingerols and shogaols are phenolic compounds with antimicrobial properties. These compounds may exert their antimicrobial effects by disrupting bacterial cell membranes, interfering with protein and nucleic acid synthesis, and inhibiting enzymes involved in microbial metabolism. As the concentration of ginger extract increases, greater amounts of antimicrobial compounds become available, potentially resulting in stronger inhibition of bacterial growth in the product (Yeh et al., 2014).

The results of the present study also indicate an association between the decrease in moisture content and the reduction in bacterial counts. As shown in Table 1, the control had the highest moisture content (67.87%) and also exhibited the highest TPC (4.16 log CFU/g; Table 2). In contrast, lamb *se'i* treated with 9% ginger extract had the lowest moisture content (51.82%) and the lowest TPC (3.14 log CFU/g). Water availability is an important factor affecting microbial growth because microorganisms require available water for metabolic activity and proliferation. Thus, reduced water availability may contribute to the inhibition of microbial growth. However, moisture content alone does not directly represent the amount of water available to microorganisms; water activity (aw) is a more appropriate indicator of microbial water availability. Therefore, the relationship between the lower moisture content and reduced TPC observed in this study should be interpreted as an association rather than a direct causal relationship unless a_w is also measured.

Another factor that may contribute to the reduction in TPC is the pH of the product. Many spoilage bacteria grow optimally under conditions close to neutral pH. As the pH becomes more acidic, bacterial growth may be progressively restricted. In the present study, the pH decreased to 5.90 in lamb *se'i* treated with 9% ginger extract. This more acidic environment, together with the antimicrobial activity of ginger bioactive compounds and changes in water availability, may have contributed to the lower bacterial counts observed at higher concentrations of ginger extract.

Coliforms are Gram-negative, rod-shaped, non-spore-forming bacteria commonly used as indicators of the microbiological quality and hygienic status of meat products. Their presence, particularly at elevated levels, may indicate inadequate sanitation, improper handling, or contamination during processing. Therefore, routine microbiological assessment of meat products is essential for evaluating processing hygiene and minimizing potential risks to consumers. Monitoring coliform populations can provide useful information on sanitary conditions and may indicate circumstances that favor contamination by foodborne pathogenic microorganisms (Martin et al., 2022).

Escherichia coli bacteria belonging to Coliform group. The detection of *E. coli* in foods indicates that direct or indirect fecal contamination has occurred and that other enteric pathogens may also be present (Çiftçi & Öncül, 2021). *E. coli* in all *se'i* sample showed < 3 CFU/g it was fixed to standard limit of (Indonesian National Standard, 2009).

CONCLUSSION

It can be concluded that addition of 3–9% ginger (*Zingiber officinale*) extract decreased the moisture content and pH of Rote sheep *se'i* while increasing its hardness, resulting in a firmer texture. Ginger extract also reduced Total Plate Count (TPC), coliform, and *Escherichia coli* counts. The TPC, coliform, and *E. coli* counts were within the microbiological limits specified by SNI 7388:2009. Therefore, ginger extract has potential as a natural ingredient in the processing of Rote sheep *se'i* to help control microbial contamination. However, the concentration of ginger extract should be optimized, as higher concentrations may increase product hardness and reduce moisture content.

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