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Physicochemical Quality of Lamb *Se'i* Treated with Kusambi (*Schleichera oleosa*) Liquid Smoke

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ABSTRACT: This study aimed was to determine the effect kusambi (*Schleichera oleosa*) wood liquid smoke on the physicochemical quality of Lamb *se'i* (*smoked meat*). A Completely Randomized Design (CRD) with a 4 x 4 layout was employed, consisting of four treatments: P_0: control/no liquid smoke, P_1: 0.5% liquid smoke, P_2: 1.0% liquid smoke, and P_3 : 1.5% liquid smoke with four replications. The parameters measured were: moisture, protein, fat content, pH and yield. Data were analyzed using Analysis of Variance (ANOVA). The results showed that the use of *kusambi* wood liquid smoke at levels of 0.5%–1.5% did not affect yield ($P>0.05$), however, it increased moisture and protein content while pH and fat content ($P<0.01$). Yield ranged from 54.30% to 59.41%. The highest moisture and protein contents were observed with the 1.5% liquid smoke treatment (58.59% and 25.65%, respectively), while the lowest pH value and fat content was 5.37 and 4,60% respectively. In conclusion, the use of *kusambi* liquid smoke at levels of 0.5%–1.5% increased the moisture and protein content of the *se'i* and lowered the pH value and fat content, whereas the yield remained unchanged.

KEYWORDS: *Se'i*, *kusambi* liquid smoke, chemical characteristics, pH

INTRODUCTION

Rote sheep have been officially designated by the Ministry of Agriculture of the Republic of Indonesia as a national indigenous livestock breed, recognizing their importance as a valuable genetic resource and a superior local breed from East Nusa Tenggara. These sheep are characterized by their relatively small body size, high adaptability to the hot and dry environmental conditions of Rote Island, and excellent carcass quality, with approximately 75% of the population classified as premium grade. Despite their recognized genetic and production potential, the utilization of Rote lamb meat remains limited, with most of the meat being marketed as fresh meat and only a few traditional products being developed. The lack of diversification in processed lamb meat products has limited its added value and market competitiveness. Therefore, the development of innovative culinary products based on Rote lamb meat is essential to increase consumer acceptance, extend product shelf life, and enhance the economic value of this indigenous livestock resource.

Se'i is a ready-to-eat smoked meat product traditionally prepared from boneless beef, pork, or venison. In recent years, however, other meat sources, including lamb and mutton, have also been utilized to diversify se'i products. The production process begins by cutting the meat longitudinally into long strips approximately 3 cm thick, resulting in a characteristic rope-like shape. The meat strips are then seasoned with salt and potassium nitrate (KNO_3) and cured for approximately 12 hours to allow the curing ingredients to penetrate the muscle tissue. After curing, the meat is suspended or arranged above a smoldering fire and slowly smoked until fully cooked, producing the distinctive flavor, aroma, and texture characteristic of *se'i* (Malelak and Jelantik, 2022)

However, the harvesting of *Schleichera oleosa* trees has been prohibited because their natural populations have become increasingly scarce, raising concerns about their conservation. Consequently, *Schleichera oleosa* liquid smoke has been developed as an alternative smoking agent to replace conventional wood smoke. Compared with traditional smoke generated by burning wood, liquid smoke offers several advantages, including a more consistent smoke composition, easier application and process control, reduced environmental pollution through the elimination of direct combustion, and a lower risk of contamination by harmful compounds such as polycyclic aromatic hydrocarbons (PAHs). Furthermore, the use of liquid smoke can impart the characteristic smoky flavor and aroma of traditional *se'i* while supporting the sustainable conservation of *Schleichera oleosa* resources. These findings highlight the potential of liquid smoke as an effective alternative for *se'i* production.

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Previous studies have demonstrated the successful application of *Schleichera oleosa* liquid smoke in beef *se'i* as an alternative to conventional smoking. The use of liquid smoke reduced the formation of polycyclic aromatic hydrocarbons (PAHs), particularly benzo(a)pyrene, while improving meat tenderness compared with the traditional smoking (Malelak *et al*., 2020) Despite these promising findings, the application of *Schleichera oleosa* liquid smoke in lamb se'i, particularly using Rote sheep meat, has not yet been investigated. Considering the compositional and structural differences between beef and lamb, the response of lamb se'i to liquid smoke may differ. Therefore, the present study evaluated the effect of *Schleichera oleosa* liquid smoke on the physicochemical characteristics of lamb se'i, with particular emphasis on moisture, protein, fat content, pH, and yield.

MATERIALS AND METHODS

Materials and experimental design

Fresh lamb loin (*Longissimus dorsi*) (16 kg) was purchased from a local butcher in Kupang, East Nusa Tenggara, Indonesia. The meat obtain from Roteness sheep (local breed). *Schleichera oleosa* liquid smoke was available in university laboratorium. The ingredients used for se'i processing included, salt (Natrium chloride/NaCl) and potassium nitrate (KNO_3, saltpeter).

The experiment was arranged in a completely randomized design (CRD) consisting of four treatments with four replications. The treatments were as follows: L_0 = lamb se'i without liquid smoke (control); L_1 = lamb se'i with 0.5% (v/w) *Schleichera oleosa* liquid smoke; L_2 = lamb se'i with 1.0% (v/w) *Schleichera oleosa* liquid smoke; and L_3 = lamb se'i with 1.5% (v/w) *Schleichera oleosa* liquid smoke. Each treatment was replicated four times, resulting in 16 experimental units.

Se'i processing

The lamb loin was trimmed to remove visible fat and connective tissue before being 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 4 kg of meat. Each treatment was further divided into four replications, resulting in 16 experimental units of one kg each.

Each experimental unit was mixed with 2% (w/w) sodium chloride and 350 mg potassium nitrate (KNO_3). *Schleichera oleosa* liquid smoke was subsequently added according to the respective treatment levels (0, 0.5, 1.0, or 1.5%, v/w). The seasoned meat was thoroughly mixed and marinated for approximately 12 h at refrigerated temperature. After marination, the meat was smoked until fully cooked (well done). The control treatment (L_0) was prepared using the conventional se'i smoking process with *Schleichera oleosa* wood as the smoke source. For treatments L_1–L_3, conventional smoking was replaced by the application of S. oleosa liquid smoke, and the meat was subsequently cooked in an electric oven at 70–80°C for 45–60 min until the internal temperature reached 72°C. This approach allowed the effects of liquid smoke to be evaluated without interference from additional smoke generated during traditional smoking. After smoking, the *se'i* products were cooled to room temperature, after which samples were collected for the determination of moisture, protein, fat content, pH, and processing yield.

Parameters Measured

Yield

Yield is obtained by comparing the final weight resulting from the process with the initial weight before processing.

$$\text{Yield} = \frac{\text{Final Weight}}{\text{Initial Weight}} \times 100\%.$$

pH Value

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 (National Standardization Agency of Indonesia, 2013) procedure. The samples were oven dried at 125°C for 1 hour.

$$\text{Water content (\%)} = \frac{\text{Initial weight – weight after drying}}{\text{initial weight}} \times 100\%$$

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Protein content

Protein content was determined following the (National Standardization Agency of Indonesia, 2013) procedure. The sample was extruded to release nitrogen from the protein as ammonium salts. These ammonium salts were broken down into NH3 during distillation using NaOH. The liberated NH3. bound to boric acid. produced ammonium phosphate. which was quantitatively titrated with a standard acid solution to obtain total nitrogen. Protein content was obtained from N x 6.25.

Lipid content

Lipid content was determined following the (National Standardization Agency of Indonesia, 2013) procedure. The sample was treated with HCl and then extracted with petroleum ether. The resulting petroleum ether extract was evaporated to dryness. and the lipid content was calculated gravimetrically.

$$\text{Lipid content (\%)} = \frac{\text{Weight of empty flask+lipid)-weight of empty lipid}}{\text{sample weight}} \times 100\%$$

Data analysis

Data were analyzed using one-way analysis of variance (ANOVA) if there was a significant difference between treatments ($p<0.05$) (SPSS 25).

RESULTS AND DISCUSSION

Yield of *Se'i*

Product yield is defined as the percentage of the final product weight relative to the initial raw meat weight and is an important indicator of processing efficiency and economic value. As shown in Table 1, the application of *Schleichera oleosa* liquid smoke at level of 0.5, 1.0, and 1.5% had no change on the yield of lamb *se'i* ($p>0.05$). It was indicated that the replacement of traditional smoking with liquid smoke did not alter the proportion of weight retained after processing. The yield ranged from 54.30 to 59.40%. nilai rendemen ini sama dengan rendemen *se'i* kambing yang diolah menggunakan asap cair daun kusambi yaitu 54.25-58.42% (Taek et al., 2025).

Table 1. Physical Characteristics of Sheep *Se'i* Treated with Kusambi (*Schleichera oleosa*) Liquid Smoke

Parameters	*Schleichera oleosa* Liquid Smoke				p Value
	Control	0,5%	1,0%	1,5%	
Yield (%)	56,21±1,67	54,30±2,46	59,4 ±8,86	58,52±1,28	0,569
pH value	5,76± 0,01^{d}	5,52± 0,01^{c}	5,46 ±0,01^{b}	5,37± 0,02^{a}	0,0001

Note: Different superscripts in the same row indicate a significant difference (P<0.05). ± standard deviation.

Yield served as a core indicator of water-holding capacity in muscle tissue, where a higher value reflected superior moisture retention during heating (Benede et al., 2024). The similar yield values among treatments suggest that the addition of *Schleichera oleosa* liquid smoke did not substantially affect moisture evaporation or the water-holding capacity of the meat during heating. Because all treatments were cooked under identical temperature (70–80°C) and endpoint internal temperature (72°C) conditions, the extent of moisture and fat loss during processing was likely comparable among treatments. Therefore, the concentration of liquid smoke used in this study did not influence processing yield, so that liquid smoke can replace traditional smoking without affecting yield.

Product yield represents the percentage of the final product obtained relative to the initial raw material weight. A high yield indicates that the processing method effectively retains product weight, thereby offering economic benefits and production efficiency. In the processing of Rote sheep *se'i*, the use of liquid smoke can influence yield due to factors such as changes in moisture content, fluid loss during heating, and the meat's water-holding capacity.

pH Se'i

The pH of lamb se'i was significantly affected ($P < 0.05$) by the addition of *Schleichera oleosa* liquid smoke. The control treatment exhibited the highest pH value (5.76), while increasing the concentration of liquid smoke resulted in a gradual decrease

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in pH by approximately 0.24–0.39 point, with the lowest value (5.73) observed in the 1.5% liquid smoke treatment (Table 1). This trend indicates that the addition *of Schleichera oleosa* liquid smoke increased the acidity of the product, most likely due to the presence of organic acids in *Schleichera oleosa* liquid smoke.

The acid content of *Schleichera oleosa* liquid smoke ranges from 0.72% to 3.44%, with a pH value of 4.0 to 5.50, depending on the pyrolysis temperature (Malelak G E M, Ratu M R D, Lestari G A Y, Benu I, 2020). (Malelak *et al.*, 2015) reported that liquid smoke also reduced pH of beef *se'i* as many as 0,04 point (5.63 to 5.59). All se'i samples had pH values well below the critical limit of 7.0, indicating that the product remained within a pH range unfavorable for the growth of most spoilage and pathogenic bacteria. Therefore, the reduction in pH following the application of Schleichera oleosa liquid smoke may have contributed to improved microbial stability and extended shelf life.

Water content

Water content differed significantly among treatments ($P < 0.05$), ranging from 36.48 to 43.64%. The highest moisture content was observed in the 0.5% liquid smoke treatment, whereas higher concentrations (1.0 and 1.5%) resulted in lower moisture contents. This finding suggests that a low concentration of liquid smoke enhanced water retention during processing, while higher concentrations promoted greater moisture loss. The reduction in moisture content at higher liquid smoke levels may be associated with the increased concentration of organic acids and phenolic compounds, which can alter muscle protein structure, reduce water-holding capacity, and facilitate water release during heating.

Table 2. Chemical characteristics of *Se'i* lamb treated with Kusambi (*Schleichera oleosa*) Liquid Smoke

Parameter	Perlakuan				Nilai p
	Kontrol	Asap cair 0,5%	Asap cair 1,0%	Asap cair 1,5%	
Water (%)	41,62±0,10^{b}	43,64±0,17^{c}	36,48±0,49^{a}	38,59±0,85^{a}	0,0001
Protein (%)	20,81±0,12^{a}	22,47±0,004^{b}	24,80±0,05^{c}	25,65±0,27^{d}	0,0001
Lemak (%)	5,85±0,15^{d}	5,38 ± 0,17^{c}	5,07±0,06^{b}	4,65±0,03^{a}	0,0001

Note: Different superscripts in the same row indicate a significant difference (P<0.05). ± standard deviation.

The moisture content obtained in the present study was lower than that reported by (Aoetpah *et al,* 2023), who found values ranging from 41.18% to 64.64% in traditionally smoked beef se'i. The application of coconut shell liquid smoke at concentrations of 2–10% resulted in beef se'i with moisture content ranging from 28.74% to 42.02%; however, an increase in liquid smoke concentration was not consistently accompanied by a decrease in the se'i moisture content (Dheko, Darmakusuma and Kale, 2017). This discrepancy is likely attributable to differences in processing methods. In the present study, se'i was treated with Schleichera oleosa liquid smoke and cooked in a controlled oven, where consistent heat transfer and continuous hot-air circulation likely enhanced moisture evaporation. In contrast, traditional smoking exposes the meat to smoke and heat under less controlled conditions, which generally produces lower and more variable heating rates and may reduce the extent of moisture loss. Differences in raw materials (lamb versus beef), processing conditions, and smoking duration may also have contributed to the variation in moisture content between studies.

Protein content

Protein content increased significantly ($P < 0.05$) from 20.81% in the control to 25.65% in the 1.5% liquid smoke treatment. The increase in protein concentration is likely associated with the reduction in moisture content at higher liquid smoke concentrations, resulting in a greater proportion of protein in the final product.

Protein structure is significantly affected by heating or smoking. The influence of heat and smoke causes the protein structure to shift from irregular clumps to a compact, rod-like configuration, accompanied by intermolecular protein aggregation (Hu *et al.,*2025). Carton *et al* (2009) found that carbonyl compounds produced during the smoking process react with amino acids, causing structural modifications in myofibrillar proteins, such as significant myofibril shrinkage. Protein structural folding is a fundamental factor influencing the ionization of carboxyl and amino groups, thereby promoting the formation of new intermolecular and

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intramolecular bonds during the processing of smoked fish (Guo *et al.*, 2021). It is likely that a similar phenomenon occurs during the processing of *se'i* in this study, explaining the observed increase in *se'i* protein content.

Lipid content

Conversely, fat content decreased significantly ($P < 0.05$) as the concentration of *Schleichera oleosa* liquid smoke increased, declining from 5.85% in the control treatment to 4.65% in the 1.5% liquid smoke treatment. This reduction is primarily attributed to fat rendering and drip loss during thermal processing. Heating causes adipose tissue to melt, allowing liquefied fat to escape from the meat together with exuded moisture. The application of liquid smoke, combined with oven heating, may have enhanced the release of melted fat, resulting in lower residual fat content in the final product. Although the phenolic compounds present in liquid smoke possess antioxidant properties that inhibit lipid oxidation, the observed reduction in fat content is more likely due to physical fat loss during processing rather than oxidative degradation.

Compared with traditionally smoked beef *se'i*, which contains 5.39–10.24% fat (Aoetpah *et al*, 2023), the fat content of the lamb *se'i* produced in the present study (4.65–5.85%) was comparatively lower. This difference is likely attributable to differences in the animal species and muscle composition. Lamb generally contains a higher proportion of unsaturated fatty acids and has a different fat distribution than beef, both of which influence fat retention during thermal processing. In addition, factors such as breed, age, sex, feeding regime, and genotype are known to influence the lipid content and fatty acid composition of lamb meat (de Smet, 2004). Although lamb is an excellent source of high-quality protein, B vitamins, and essential minerals, it is often perceived as less healthy because of its relatively high proportion of saturated fatty acids (Chikwanha *et al.*, 2017). Nevertheless, the lower fat content observed in the present study may represent a nutritional advantage by reducing the overall lipid content of the final product.

CONCLUSSION

The use of *Schleichera oleosa* liquid smoke successfully replaced conventional wood smoking in the production of lamb se'i without affecting processing yield. Liquid smoke significantly altered the chemical characteristics of the product by decreasing pH and fat content while increasing protein content. Although moisture content differed among treatments, all liquid smoke concentrations produced acceptable physicochemical characteristics. Among the treatments evaluated, 1.5% *Schleichera oleosa* liquid smoke produced lamb se'i with the highest protein content (25.65%), the lowest fat content (4.65%), and the lowest pH (5.37), indicating that this concentration is the most effective for improving the physicochemical quality of lamb se'i.

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