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QUALITY ATTRIBUTES OF LAMB SATAY AND THEIR CORRELATION WITH CONSUMER PREFERENCE IN TEGAL REGENCY, INDONESIA

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Abstract
Sheep commodities holds significant potential for the development of the livestock sector in Tegal Regency, especially for lamb satay, which is a local culinary icon. However, the red meat industry faces food safety issues that affect consumer acceptance and satisfaction. This study aims to evaluate the quality of lamb satay from various producers in Tegal Regency and its correlation with consumer satisfaction. Samples of satay and sheep meat were collected from three selected producers. Laboratory analysis included microbiological analysis, nutritional content analysis, and physicochemical properties analysis, each with three replicates. Consumer satisfaction was measured using a questionnaire given to 32 consumers, consisting of 15, 8, and 9 respondents for producers A, B, and C, respectively. The results showed no statistically significant differences ($p > 0.05$) in microbiological quality, including TPC, E. coli, and S. aureus. Nutritional and physicochemical parameters such as protein, fat, ash, water, carbohydrates, pH, and water activity also showed no differences between producers, indicating consistent quality. A total of 18 fatty acids were identified in lamb satay. A positive relationship ($p < 0.01$) was found between consumer satisfaction and protein, moisture, ash, pH, and water activity levels, while fat and carbohydrates showed a negative correlation ($p > 0.01$). In addition, all sensory attributes had a significant effect ($p < 0.01$) on consumer satisfaction. In conclusion, lamb satay in Tegal Regency has consistent quality among producers. Higher levels of moisture, ash, pH, water activity, and sensory attributes increase consumer satisfaction, while higher fat and carbohydrate content decrease it.

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Introduction

Sheep commodity holds significant potential for the development of the livestock sector in Indonesia, particularly in Tegal Regency. This region is among the regencies with the highest sheep population in Central Java. This is also supported by ideal geographical conditions, such as the availability of abundant forage land, a favorable climate, and the presence of a community with a long-standing tradition of sheep farming. According to data from the Central Statistics Agency or Badan Pusat Statistik (BPS), sheep population in Tegal Regency reached 189,094 heads in 2023 [1]. The sheep commodity plays an important role in supporting the local economy, both as a source of income and as raw material for processed culinary products, especially the traditional lamb satay of Tegal Regency. With its abundant sheep population, Tegal Regency has great potential to develop local culinary products based on lamb meat.

Tegal lamb satay has become a culinary icon that represents a deeply rooted local tradition. The uniqueness of this satay lies in its main ingredient, which is young lamb meat known as "balibul" (under five months old), due to its more tender texture compared to older sheep. Lamb from younger sheep is more tender than that from older ones due to differences in muscle fiber size and structure [2]. The satay-making process generally involves grilling over charcoal at a temperature of approximately 200–220 °C. The culture of consuming lamb satay in Tegal is rooted not only in flavor preferences but also in the social habits of the community. This dish is often served at various events, ranging from family gatherings to business meetings.

Lamb meat is a popular source of protein in Indonesia and has the high nutritional value. According to previous studies, lamb meat has approximately 19 % protein [3], and 4.6–5.5 % fat [4]. These favorable nutritional contents make lamb meat an important source of nutrients in the dietary patterns of the population. The quality of lamb meat generally consists of three main aspects, namely physical, chemical, and sensory characteristics. Physical and chemical attributes such as pH, water activity (a_w), fat content, protein, moisture, and other components affect meat tenderness, juiciness, and flavor.

Chemical and nutritional attributes, such as fat content in food, provide a complex sensory experience and play a critical role in influencing consumer preferences [5]. The presence and amount of fat significantly affect key sensory attributes such as juiciness, texture, mouthfeel, and overall flavor, all of which are central to consumer satisfaction and product acceptance [6]. Based on previous research, fat is closely associated with desirable sensory qualities such as creaminess, richness, and palatability, which enhance the overall enjoyment of meat products. These positive sensory effects make fat an important component in many meat products [7]. However, recent dietary trends have shifted toward healthier food choices, with increasing emphasis on reducing fat consumption. This shift is driven by mounting evidence linking excessive fat intake with negative health outcomes, including obesity, cardiovascular diseases, and even cancer [8]. The interplay between different types of dietary fat, metabolic responses, and disease mechanisms is complex, suggesting that fat content in food must be carefully managed, not only to preserve sensory quality but also to promote better health outcomes.

In addition to nutritional and sensory aspects, the safety of lamb meat is another essential factor affecting its overall quality and consumer trust. *Escherichia coli, Salmonella* spp., and *Staphylococcus aureus* are common indicators of potential food safety hazards [9]. Such microbial contamination impacts food safety, consumer health, and acceptance of products [10]. Food safety issues in the red meat industry pose a major threat to public health and has become an increasing global concern [11]. Such contamination can trigger outbreaks of foodborne zoonotic diseases. Most serious food safety cases affect consumer health and often result in product recalls and the removal of contaminated meat products from the food supply chain. Food safety problems are most frequently caused by microbiological factors, especially pathogenic bacteria [12]. These issues can also influence consumer satisfaction with meat and meat-based products.

Several studies on the quality of processed lamb meat have been conducted, namely analyses of proximate composition and sensory characteristics of lamb sausage [13], as well as of the physicochemical, microbiological, and organoleptic characteristics of fermented sausages from premium IPB lamb with varying proportions of jack bean flour [14]. However, information and studies regarding the quality of lamb meat and processed lamb satay products, particularly in Tegal Regency, remain very limited. Therefore, this study aims to comprehensively evaluate the microbiological, nutritional, physicochemical, and sensory quality of lamb satay in Tegal Regency and analyze their correlation with consumer satisfaction, thereby contributing to the improvement of local food product development strategies.

Objects and methods

Sample and sampling technique

The study was conducted in Tegal Regency using a survey method and purposive sampling approach. Lamb satay producers were deliberately selected based on specific criteria, namely their willingness to participate in the study and having operated their business for at least one year. A total of three different producers were selected and interviewed, originating from three different districts, including Adiwerna (Producer A), Lebaksiu (Producer B), and Slawi (Producer C). Interviews were conducted with each satay producer to obtain detailed information on their production workflow, including production steps, grilling practices, the type of sheep used, and the seasoning formulations. Additionally, samples of satay and raw lamb meat were collected from each of these producers. Samples were collected from thin-tailed sheep (*domba ekor tipis*), which is the most commonly used breed among satay producers in Tegal Regency.

The raw lamb meat and lamb satay samples were transported to the laboratory in a cooling box at a controlled temperature of ±4 °C to ensure safe and aseptic conditions during transport. Analyses were conducted immediately upon arrival to minimize quality changes. Satay samples from producers A, B, and C (Figure 1) were analyzed for microbiological parameters, nutritional composition, and physicochemical properties.

Consumer satisfaction survey

Questionnaire was designed to measure consumers' perceptions, preferences, and satisfaction levels regarding the lamb satay they consume. This questionnaire was ad-

(a) (b) (c)

Figure 1. Lamb satay from producer A (a), producer B (b), and producer C (c) (Source: personal documentation, 2024)

ministered to 32 consumers, consisting of 9, 8, and 15 respondents for producers A, B, and C, respectively. These respondents were consumers who had purchased and consumed satay products from each producer. Respondents were selected using purposive sampling with specific criteria, namely willing to complete the questionnaire, at least 17 years of age, currently and previously having consumed satay from one of the selected sellers at least once, and being in good health at the time of completing the questionnaire. In addition, consumer demographic data including age, gender, education level, occupation, monthly income, and region of origin, were also recorded as supplementary information for the study [15].

The sensory evaluation of the satay products was conducted directly at the producers' location by consumers who purchased and consumed the products. Consumer satisfaction was assessed based on five main attributes including flavor, aroma, texture, color, and product piece size, immediately after consumption, using the 5-point Likert scale, where 1 = very dissatisfied, 2 = dissatisfied, 3 = neutral, 4 = satisfied, and 5 = very satisfied. Each sensory attribute and the overall satisfaction score were rated accordingly.

Microbiological analysis

Microbiological analysis included total plate count (TPC), *Escherichia coli* (*E. coli*), and *Staphylococcus aureus* (*S. aureus*), following the Indonesian National Standard (SNI) methods [16]. The analysis consisted of two main stages, namely dilution and inoculation. In the dilution stage, a 10^{-1} dilution was prepared by mixing 25 g of the sample with 225 mL of Buffered Peptone Water (BPW, Oxoid Ltd., UK), which served as both the solvent and diluent. In the inoculation stage, 1 mL of the diluted sample from the 10^{-2}, 10^{-3}, and 10^{-4} dilutions was transferred into sterile petri dishes containing 20 mL of Plate Count Agar (PCA, Oxoid Ltd., UK) for TPC analysis. Additionally, 1 mL of the diluted sample from the 10^{-1}, 10^{-2}, and 10^{-3} dilutions was poured into petri dishes along with 20 mL of molten agar media. Eosin Methylene Blue Agar (EMBA, Oxoid Ltd., UK) was used for *E. coli* and Baird-Parker Agar (BPA, Oxoid Ltd., UK) for *S. aureus*. Homogenization was performed using a figure-eight motion, and the plates were left to set. The inoculated plates were then incubated in an inverted position at 34–36 °C for 24–48 hours.

Nutritional and physicochemical content

Nutritional analysis included the content of moisture, protein, fat, ash, and carbohydrates, conducted in accordance with standard procedures indicated in [17], while fatty acids were determined according to [18]. The moisture content was determined by oven drying (WTB Binder GmbH, Germany), ash content by dry combustion in a muffle furnace Vulcan 3–550 (Dentsply Sirona, USA), protein content was analyzed using the Kjeldahl method, while the fat content was determined by Soxhlet extraction with petroleum ether solvent, and the carbohydrate content was calculated using the difference method. Fatty acid analysis was carried out by converting triglycerides and free fatty acids in the samples into fatty acid methyl esters (FAMEs), which were then analyzed using gas chromatography-mass spectrometry (GC–MS) Thermo Trace 1310 (Thermo Scientific, USA).

Physicochemical analyses of the samples were conducted based on methods indicated in [17], including measurements of pH and water activity (a_w). The pH was measured three times for each sample using a portable pH meter Ionix PC60 (Apera Instruments, USA) equipped with a penetration probe and automatic temperature compensation. Prior to measurement, the instrument was calibrated using two buffer solutions with pH 4.0 and pH 7.0. The electrode was then inserted into the sample, and the pH value was recorded directly from the display. Water activity was measured using an a_w meter Novasina MS1 (LabMaster-aw neo, Swistzerland) by activating the device, allowing the reading to stabilize, and recording the water activity value automatically.

Statistical analysis

Lamb satay samples from each producer were analyzed in the laboratory in three repetitions, except for the fatty acid analysis, which was performed in a single repetition. The raw lamb samples were also analyzed in a single repetition. Consumer demographic profile was analyzed using descriptive analysis. Data from the laboratory were analyzed using one-way analysis of variance (ANOVA) to determine differences in lamb satay quality among producers. Consumer perception data were analyzed using Spearman's correlation analysis to assess the relationship between consumer satisfaction and laboratory quality parameters. Principal component analysis (PCA) was also used to reduce data dimensions and identify patterns or groups among producers based on objective quality parameters and consumer perceptions. Furthermore, multiple regression analysis was conducted to evaluate the influence of sensory attributes (flavor, aroma, texture, color, and product piece size) on consumer satisfaction. Statistical analysis was performed using R-studio 2025.05.1–513 (Boston, USA).

Results and discussion

Consumer demographic profile

Understanding consumer demographics is essential for identifying the factors that influence food preferences and purchasing behavior. Variations in age, gender, education, occupation, and income levels can shape consumers' perceptions of product quality and their willingness to buy ready-to-eat meat products [19]. The demographic profile of the respondents is presented in Table 1.

Most of the satay consumers in this study were from Tegal Regency (75 %) and were predominantly male (68.75 %). The age group of 21–30 years represented the largest segment (53.13 %), indicating that satay consumers were mainly young and within the productive age group.

This finding is consistent with the previous study [20], which demonstrated that individuals of productive age tend to show higher consumption levels toward developing products, including ready-to-eat foods. The majority of respondents also held a bachelor's degree (53.13 %), suggesting that consumers possessed adequate knowledge and awareness regarding food quality and safety.

Table 1. Lamb satay consumer demographics

Parameter	Frequency (n)	Percentage (%)
Region		
Tegal	24	75.00
Purwakarta	2	6.25
Rembang	1	3.13
South Halmahera	1	3.13
Pemalang	2	6.25
Demak	1	3.13
Bogor	1	3.13
Gender		
Female	10	31.25
Male	22	68.75
Age (years)		
>50	6	18.75
41–50	3	9.38
31–40	6	18.75
21–30	17	53.13
Education Level		
High school or below	11	34.38
Bachelor's degree	17	53.13
Graduate degree or higher	4	12.50
Occupation		
Civil servant	8	25.00
Entrepreneur	15	46.88
Self-employed	4	12.50
Other	5	15.63
Monthly Income		
< IDR 2 million (> USD 120)	3	9.38
IDR 2–4 million (USD 120–240)	15	46.88
IDR 5–8 million (USD 300–480)	5	15.63
> IDR 8 million (> USD 480)	9	28.13

Note: IDR = Indonesian Rupiah, USD = United States Dollar.

In terms of occupation and income, nearly half of the respondents were self-employed (46.88 %) with a monthly income ranging from IDR2–4 million (46.88 %). This condition reflected that satay consumers generally came from the middle-income group, who maintained a relatively stable purchasing power for ready-to-eat meat products. According to [21], economic factors and social characteristics such as age and education level play a significant role in determining consumer preferences for meat. In the context of this study, most satay consumers were young, educated individuals and were able to evaluate products not only based on price but also by considering aspects of quality, flavor, and overall consumption experience.

Total microbes and pathogenic bacteria of lamb satay

Microbiological analysis was conducted to assess the quality and safety of lamb satay produced by three different producers. The raw lamb used as the main ingredient for satay was also analyzed to provide information on its raw material quality. This analysis was considered crucial to ensure that the products meet food safety standards, as meat products are highly susceptible to contamination by pathogenic microorganisms, such as *S. aureus* [22] and *E. coli*, which may pose risks to consumer health [23]. The measurements were performed by counting the number of colonies grown on selective media, and the results were expressed in Log CFU/g.

Table 2. Microbiological load of raw lamb used for satay

Parameter	Producers		
	A	B	C
Total plate count (Log CFU/g)	5.95	5.92	5.91
E. coli (Log CFU/g)	2.02	2.22	2.14
S. aureus (Log CFU/g)	2.19	2.16	2.29

Note: Log CFU/g = $\log_{10}$ of colony forming units per gram; Data are presented as mean.

Microbiological analysis of raw lamb used for satay production (Table 2) showed that total plate count (TPC) ranged from 5.91 to 5.95 log CFU/g, indicating that the microbial load of the raw meat was still within the acceptable limit for raw meat, which is 10^5 CFU/g or 5 log CFU/g according to international guidelines [23]. The presence of Escherichia coli was detected at levels between 2.02 and 2.22 log CFU/g, while Staphylococcus aureus ranged from 2.16 to 2.29 log CFU/g. These results indicate a slight level of microbial contamination, which may have originated from handling during slaughtering, transportation, or storage. The acceptable limits for E. coli and S. aureus in raw meat should be below 10^2 CFU/g or 2 log CFU/g [24,25]. In addition, the total microbial count and the presence of pathogens decreased after the grilling process, as shown in Table 3. This reduction is likely attributed to the exposure to high temperatures during grilling, which can destroy microbial cell structures and reduce their viability.

The results of microbiological analysis of lamb satay show that there are no significant differences ($p > 0.05$) in all microbiological parameters between the three different producers. This indicates that the products from producers have similar microbiological quality and meet equivalent

Table 3. Microbiological load of lamb satay from different producers

Parameter	Producers			p-value
	A	B	C	
Total plate count, Log CFU/g	3.65 ± 0.06	3.74 ± 0.11	3.56 ± 0.09	0,142
E. coli, Log CFU/g	1.12 ± 0.10	1.39 ± 0.21	1.26 ± 0.07	0,139
S. aureus, Log CFU/g	1.62 ± 0.26	1.60 ± 0.05	1.49 ± 0.15	0,632

Note: Log CFU/g = $\log_{10}$ of colony forming units per gram; Data are presented as mean ± standard deviation.

food safety standards. The absence of significant differences in TPC values suggests comparable levels of cleanliness and sanitation in their production facilities. Similarly, the statistically non-significant levels of *E. coli* and *S. aureus* presence indicate that the risk of pathogen contamination in products from the three different producers is relatively the same.

The TPC of lamb satay samples in Tegal Regency was below the acceptable limit recommended by Good Manufacturing Practice (GMP) guidelines, specifically ≤5 log CFU/g [24]. The presence of S. aureus was also within the satisfactory limit for ready-to-eat food products, including cooked meat products, which is <2 log CFU/g (100 CFU/g) [26]. However, E. coli counts exceeded the recommended satisfactory limit of <1 log CFU/g (<10 CFU/g) for such products [26]. This suggested potential for cross-contamination or inadequate pre or post-cooking hygiene practices, such as the use of cutting tools, serving containers, or insufficient sanitation [27]. Although it does not directly indicate a high risk of disease, the presence of *E. coli* above the satisfactory limit remains an important indicator in food safety evaluation, particularly for ready-to-eat products like lamb satay. Therefore, enhanced sanitation oversight and education on hygienic practices are essential for both producers and sellers to minimize the risk of microbial contamination.

Nutritional and physicochemical content of lamb satay

The analysis of the nutritional content (fatty acids and proximate composition) as well as physicochemical properties in food products is essential to comprehensively assess the quality and characteristics of the product. The fatty acid profile and proximate composition affect sensory quality and provide an overview of the main nutritional content, which serves as a quality indicator [28]. Physicochemical properties contribute to the stability of the product during storage and processing [29].

The results showed that the three samples of lamb satay from different producers contained 18 fatty acids (Table 4). The fatty acid profile of the lamb satay samples showed variations among producers, particularly in the proportions of saturated and unsaturated fatty acids. These variations may reflect differences in meat sources, feed composition, and fat metabolism among the animals used by each producer. The fatty acid composition was dominated by saturated fatty acids (SFAs), followed by monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs). Animal fats, such as those found in lamb satay, are generally dominated by three main fatty acids, namely palmitic acid (C16:0) and stearic acid (C18:0), which belong to the SFA group, and oleic acid (C18:1n9c), which belongs to the MUFA group. The combination of these three fatty acids contributes to a characteristic property known as plasticity. This property allows animal fats to retain their solid form at room temperature, while becoming soft and malleable at higher temperatures, such as during grilling [30].

Table 4. Fatty acid content of lamb satay from different producers

Fatty acid	Content, %w/w		
	A	B	C
Saturated fatty acids (SFAs)			
Butyric acid (C4:0)	0.07	0.11	0.06
Caproic acid (C6:0)	0.07	0.06	0.04
Caprilic acid (C8:0)	0.11	0.09	0.18
Capric acid (C10:0)	0.29	0.21	0.28
Lauric Acid (C12:0)	0.96	0.52	0.91
Myristic Acid (C14:0)	3.80	2.79	3.04
Pentadecanoic Acid (C15:0)	0.49	0.73	0.42
Palmitic Acid (C16:0)	20.25	20.86	24.74
Heptadecanoic Acid (C17:0)	1.15	1.65	1.47
Stearic Acid (C18:0)	16.62	26.20	23.28
Arachidic Acid (C20:0)	0.09	0.17	0.13
Monounsaturated fatty acids (MUFAs)			
Myristoleic Acid (C14:1)	0.06	0.28	0.04
Palmitoleic Acid (C16:1)	1.53	1.36	1.65
Cis-10-Heptadecanoic Acid (C17:1)	0.36	0.29	0.38
Elaidic Acid (C18:1n9t)	2.50	1.21	3.22
Oleic Acid (C18:1n9c)	25.93	18.02	32.00
Polyunsaturated fatty acids (PUFAs)			
Linoleic Acid (C18:2n6c)	0.94	0.39	1.33
Linolenic Acid (C18:3n3)	0.12	0.03	0.05
Total fatty acids	75.34	74.96	93.22
Total saturated fatty acids (SFAs)	43.90	53.39	54.55
Total unsaturated fatty acids (UFAs)	31.44	21.58	38.67
Total polyunsaturated fatty acids (PUFAs)	1.06	0.42	1.38
Total monounsaturated fatty acids (MUFAs)	30.38	21.16	37.29
Ratio SFAs/UFAs	1.39	2.47	1.41

Note: Fatty acid contents are expressed in% w/w (percentage weight per weight).

The three major fatty acids commonly found in animal fats (palmitic acid, stearic acid, and oleic acid) have also been investigated for their potential health benefits in humans. Oleic acid is known to play a role in lowering low-density lipoprotein (LDL) cholesterol and increasing high-density lipoprotein (HDL) cholesterol levels, both of which are important indicators of heart health [31]. Previous studies have also found that stearic acid shows potential as an anticancer agent through its mechanism of inhibiting key control points in the cell cycle and its ability to selectively induce apoptosis in malignant breast cancer cells without affecting normal cells. These findings suggest that stearic acid may play a role in preventing cancer cell proliferation [32].

Palmitic acid acts as an energy source and an important component in the formation of cell membranes and the body's lipid metabolism. However, excessive palmitic acid has been linked to an increased risk of metabolic syndrome, cardiovascular disease, cancer, neurodegenerative disorders, and chronic inflammatory conditions through mechanisms involving disruption of molecular signaling pathways [33]. However, the fatty acid analysis of raw lamb meat was not carried out in this study. The fatty acid analysis focused on determining the total fatty acid content in the lamb satay product. For future studies, it is

recommended to include fatty acid profiling of both raw and grilled samples to better understand the effect of the grilling process on lipid composition and nutritional quality. Additionally, the proximate composition and physicochemical parameters were also analyzed to find variations among different raw lamb and satay producers.

Table 5. Nutritional and physicochemical quality of raw lamb used for satay

Parameter	Producers		
	A	B	C
Protein (%)	18.39 ± 0.25	21.94 ± 0.08	19.91 ± 0.19
Fat (%)	4.73 ± 0.17	3.70 ± 0.14	6.05 ± 0.03
Ash (%)	1.02 ± 0.03	1.25 ± 0.03	1.23 ± 0.01
Moisture (%)	74.07 ± 0.12	71.57 ± 0.19	71.37 ± 0.38
Carbohydrate (%)	1.80 ± 0.28	1.55 ± 0.10	1.46 ± 0.23
pH	5.76 ± 0.03	5.86 ± 0.04	5.87 ± 0.01
Water activity	0.97 ± 0.01	0.95 ± 0.01	0.96 ± 0.01

Note: Data are presented as mean ± standard deviation.

The nutritional and physicochemical characteristics of raw lamb used for satay are shown in Table 5. Compared to the raw satay samples (Table 5), several compositional changes were observed after grilling (Table 6). In general, the moisture content decreased, while the fat content increased after grilling. The reduction in moisture is mainly attributed to water evaporation due to high grilling temperatures. The decrease in water content during barbecuing occurs as a result of the high temperature, which causes shrinkage of the myofibrillar proteins and the perimysial connective tissue, thereby reducing the water-holding capacity of meat [34]. This phenomenon is also related to an increase in the fat content observed in the lamb satay after grilling in the present study, as the loss of moisture leads to a relative concentration of lipids in the final product. According to [35], the water content in charcoal-grilled lamb patties decreased significantly, while the protein and fat contents increased at each cooking interval.

Table 6. Nutritional and physicochemical parameters of lamb satay from different producers

Parameter	Producers			*p*-value
	A	B	C	
Protein (%)	17.98 ± 0.37	18.10 ± 1.64	19.55 ± 2.85	0.425
Fat (%)	28.26 ± 3.71	30.40 ± 1.76	27.42 ± 1.44	0.155
Ash (%)	0.94 ± 0.16	0.68 ± 0.07	0.95 ± 0.15	0.071
Moisture (%)	50.46 ± 3.07	47.83 ± 1.80	50.40 ± 0.32	0.365
Carbohydrate (%)	2.41 ± 1.44	2.97 ± 2.09	1.07 ± 0.77	0.362
pH	6.15 ± 0.03	6.11 ± 0.05	6.16 ± 0.03	0.272
Water activity	0.85 ± 0.02	0.84 ± 0.01	0.84 ± 0.01	0.751

Note: Data are presented as mean ± standard deviation.

The results also show that parameters of nutritional content (Table 6), namely protein, fat, ash, moisture, and carbohydrate content, had no significant differences between the three different producers ($p > 0.05$). These findings indicate that the lamb satay products from the three producers had relatively uniform nutritional compositions, reflecting consistency in raw material selection, such as the type of lamb used, as well as in basic processing techniques including the meat cut types and grilling methods applied. This consistency is important for ensuring product quality stability in the market, including attributes such as flavor, aroma, texture, and juiciness, which collectively determine the overall eating experience and consumer satisfaction [36]. It also plays a role in maintaining consumer preferences for distinctive sensory and organoleptic characteristics, as well as preserving the identity of Tegal lamb satay as a widely recognized regional culinary icon. Sensory attributes have consistently been shown to serve as strong predictors of consumer purchase intention and repeat buying behavior [37].

The physicochemical parameters (pH and water activity) showed no significant differences among the three producers ($p > 0.05$). Despite the lack of significance, this uniformity indicates that similar handling and processing practices were applied, contributing to product consistency. The pH is a key determinant of meat quality, influencing attributes such as tenderness, juiciness, color, and shelf life. The relatively stable pH values among samples helped maintain water holding capacity (WHC) and supported favorable sensory characteristics [38]. Meanwhile, the water activity values ranged from 0.84 to 0.85, indicating sufficient free water availability to support microbial growth. Although slightly below the threshold for pathogenic bacteria (≥0.91), these values fall within the optimal range for yeast (0.87–0.91) and mold (0.80–0.87) [39].

Correlation of lamb satay quality and consumer satisfaction

The correlation analysis between lamb satay quality attributes (nutritional and physicochemical) and consumer satisfaction was conducted to identify specific quality parameters that could influence sensory characteristics and could subsequently affect consumer acceptance or satisfaction [40]. The evaluation included chemical and physical characteristics that potentially influenced the flavor, aroma, and texture of the meat, which were then correlated with the satisfaction scores of each consumer from the respective producers. The results were expected to provide an overview of the key factors influencing consumer preferences, serving as a guide for improving product quality and competitiveness.

Table 7. Average satisfaction of consumer toward lamb satay from three different producers

Producers	Number of respondent/consumer (n)	Average consumer satisfaction
A	9	4.22
B	8	3.64
C	15	4.30

Consumer satisfaction with lamb satay varied among producers (Table 7). Overall, all producers were rated within the "High" category on a 1–5 Likert scale, although a clear difference in mean scores was evident between pro-

ducer B and the other two producers. This variation can be an indication of differences in consumer satisfaction based on the quality of lamb satay, which were subsequently analyzed through correlation analysis and principal component analysis (PCA). The PCA method was appropriate for this study as it involved multiple quality assessment attributes that were intercorrelated, thereby facilitating the identification of the main factors influencing consumer satisfaction [41].

Table 8. Correlation levels of lamb satay quality and consumer satisfaction

Variable	Coefficient (ρ)	Correlation	*p*-value
Protein	0.2145	No correlation	0.2384
Fat	–0.5941	Negative	0.0003**
Ash	0.5941	Positive	0.0003**
Moisture	0.5014	Positive	0.0033**
Carbohydrate	–0.5941	Negative	0.0003**
pH	0.5010	Positive	0.0034**
Water activity	0.5010	Positive	0.0034**

Note: ** indicate highly significant correlation ($p < 0.01$)

The Spearman correlation analysis (Table 8) showed a significant positive correlation ($p < 0.01$) between moisture content, pH, and water activity with consumer satisfaction levels. The coefficient values indicated that higher levels of these variables were significantly associated with increased consumer or panelist acceptance. In contrast, protein content showed a non-significant correlation ($p > 0.01$). Conversely, fat and carbohydrate contents exhibited a significant negative correlation ($p < 0.01$) with consumer satisfaction scores, meaning that higher fat and carbohydrate levels tended to result in lower consumer satisfaction scores.

Principal component analysis (PCA) was also performed to reduce data dimensionality and identify the main physicochemical attributes associated with consumer satisfaction levels. The biplot visualization (Figure 2) showed that samples with very high satisfaction levels were located close to the vectors of variables such as moisture, ash, pH, and water activity. In contrast, samples with low to moderate satisfaction levels were positioned closer to the vectors of fat and carbohydrate variables.

Table 9. Variable loadings on the first three dimensions of PCA

Variable	Loading value	
	Dim 1	Dim 2
Protein	0.260	–0.606
Moisture	0.433	0.096
Fat	–0.430	0.129
Ash	0.434	0.080
Carbohydrate	–0.354	0.441
pH	0.301	0.547
Water activity	0.393	0.328

Note: Dim = Dimension, represents the principal components (PC1, PC2).

Additionally, the loading values (Table 9) indicated that the vectors of ash (0.434), moisture (0.433), and fat (–0.430) contributed the most to Dim 1, whereas pH (0.547) and carbohydrate (0.441) were the dominant contributors to Dim 2. Interestingly, the protein vector pointed toward the lower-right quadrant, in a different direction from most of the other vectors. This distribution pattern suggests potential differences in how each attribute is associated with the underlying components represented by the two dimensions.

The results of the Spearman correlation and PCA analyses consistently showed that consumers tended to prefer lamb satay with higher moisture, ash, pH, and water activity levels, as well as lower fat and carbohydrate contents. Optimal moisture and water activity play an important role in maintaining the tenderness, juiciness, and texture of meat products, thereby directly influencing consumer evaluations of sensory attributes [42]. A stable pH value

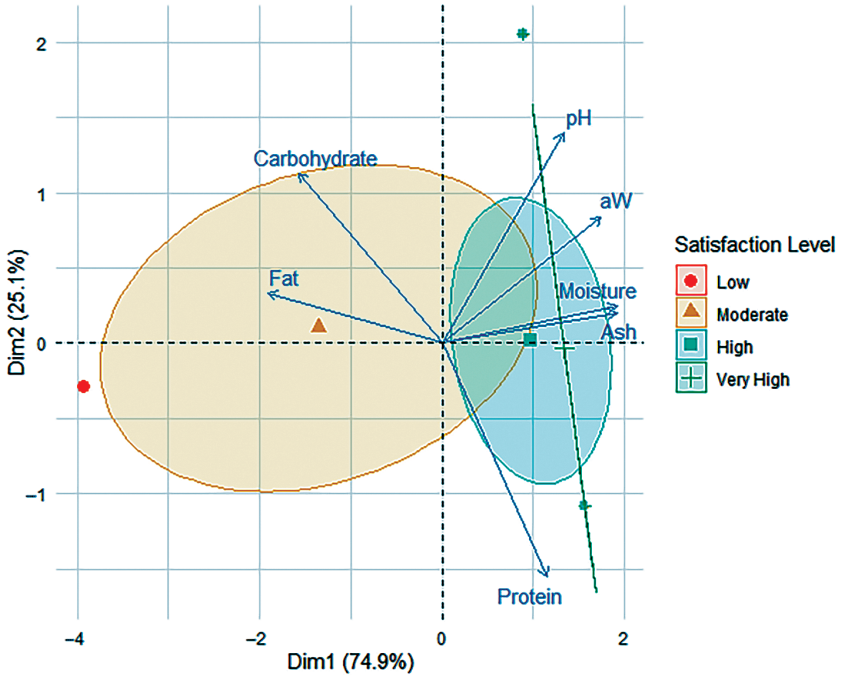

Figure 2. PCA biplot of lamb satay quality attributes and consumer satisfaction

is also believed to have an effect on the texture [43], reduce flavor changes during storage, and maintain the sensory stability of the product [38]. In addition, ash content showed a strong positive correlation, which is assumed to reflect the presence of minerals or other compositional elements that enhanced the perception of sensory attributes. Previous studies reported that ash or certain mineral contents played an important role in shaping flavor [44], and enhancing panelists' perception of quality [45].

Although protein content tended to increase when intramuscular fat was low and water content was high [46], our results showed no significant correlation between protein levels and consumer satisfaction. Interestingly, products with higher fat content were associated with lower consumer satisfaction, suggesting that fat level played a more critical role than protein in influencing consumer preferences, possibly due to perceptions of greasiness. These findings were consistent with previous studies indicating that consumers tended to prefer products with lower levels of fat and carbohydrates, presumably because lamb satay with higher fat content was perceived as too greasy and high in calories [47]. This preference aligned with current consumer trends that favored healthier, lower-calorie options. Supporting evidence includes a study reporting that Polish consumers preferred low-fat cooked meat products and tended to reject meat containing intramuscular fat, as it was perceived to be high in calories and cholesterol [48]. Moreover, excessive fat consumption, commonly observed in Western diets, has been associated with an increased risk of obesity and type-2 diabetes, partly due to ectopic lipid accumulation in skeletal muscle tissue [49]. These findings emphasized the importance of balancing chemical composition to influence sensory quality and consumer acceptance, suggesting that product formulation should consider an optimal balance of chemical, nutritional, and physical characteristics to effectively meet consumer preferences.

The pattern of correlation among variables observed in this study showed relatively consistent and similar trends. This was likely influenced by the limited sample size and the interdependence among the analyzed variables, which resulted in a nearly uniform direction of correlation. Therefore, further studies with a more comprehensive research design and a larger sample size are needed to obtain a more representative and in-depth understanding.

Influence of lamb satay sensory quality on consumer satisfaction

Based on the previous analysis in this study (correlation and PCA), it was necessary to evaluate the influence of sensory quality attributes of lamb satay, such as flavor, aroma, color, texture, and cut size, to understand the factors affecting consumer satisfaction. These sensory attributes play a crucial role in determining consumer acceptance and preference for a product [50]. Furthermore, these attributes contribute significantly to the overall level of consumer satisfaction.

Table 10. Multiple linear regression of the lamb satay sensory attributes on consumer satisfaction

Variable	Coefficient (β)	Standard error (SE)	p-value
Color	20.944	5.519	0.001**
Aroma	14.894	4.569	0.003**
Texture	19.562	3.287	0.000**
Flavor	21.892	3.998	0.000**
Piece size	22.267	3.087	0.000**

Note: ** indicates highly significant effect ($p < 0.01$).

The regression analysis results (Table 10) showed that all sensory attributes, such as color, aroma, texture, flavor, and product piece size, had a significant influence on consumer satisfaction. This is indicated by p-values all below 0.01, demonstrating a very strong relationship. These findings suggest that sensory quality greatly affects the acceptance and satisfaction of consumers toward lamb satay. The highest coefficient (β) values were observed sequentially for piece size, flavor, color, texture, and aroma.

Based on Figure 3, the regression model demonstrates excellent predictive performance for consumer satisfaction. The graph compares the actual consumer satisfaction values on the Y-axis with the predicted values from the model on the X-axis. The red dashed line represents the condition of a perfect prediction, where the predicted value is exactly equal to the actual value. The close proximity of most data points (blue dots) to the red dashed line indicates that the constructed regression model was highly accurate and reliable.

These findings support the perspective that sensory quality is a key factor influencing a level of consumer acceptance and satisfaction of food products [51]. Sensory responses were also strongly influenced by the chemical composition of the product, which determined essential attributes such as flavor and texture [37]. Previous study also stated that the flavor attribute had the greatest influence on consumer liking of game meat products, followed by texture [52]. Innovations, such as fermentation in processed meat products (sausages), enhance both flavor and safety [53]. Therefore, lamb satay producers were strongly advised to pay close attention to the management of sensory attributes or quality throughout the production and product development process. This included the selection of high-quality raw materials, standardization of seasoning formulations, and strict control over cooking techniques (such as temperature and grilling duration) to ensure optimal sensory quality [54]. By prioritizing innovation in these sensory aspects, producers would not only be able to meet consumer expectations but also potentially create a sustainable competitive advantage and build strong brand loyalty in the market. It should be noted that in this study, no specific measurements of the dimensions or average weight of the satay pieces were conducted. Therefore, the evaluation of the "product piece size" was entirely based on

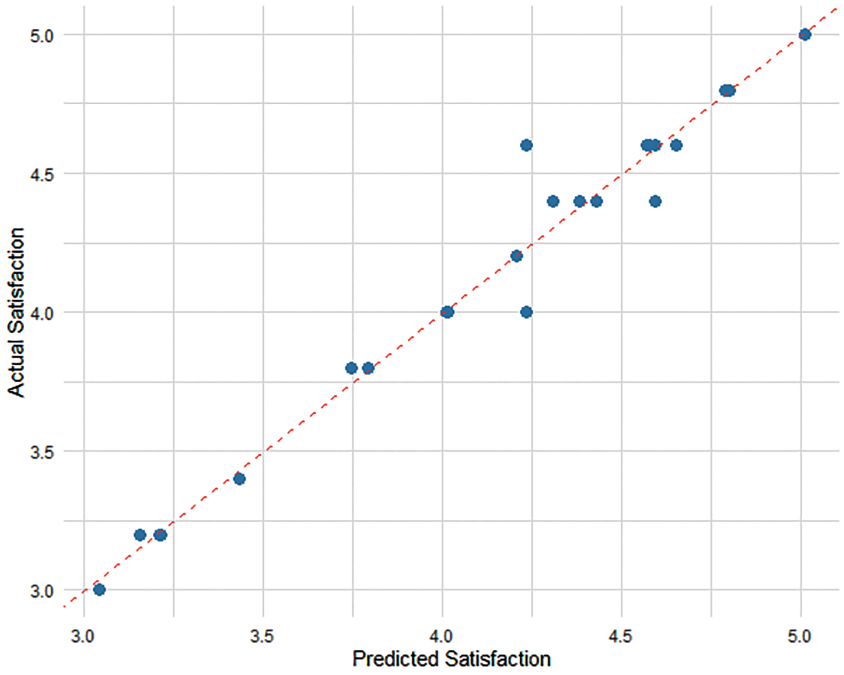

Figure 3. Actual and predicted consumer satisfaction plot

consumers' subjective perception of the appropriateness of the served pieces, as reflected in the 5-point Likert scale. This approach was intended to capture consumers' direct impressions of portion size as a sensory attribute influencing their overall satisfaction.

Conclusion

This study found that the quality of lamb satay from various producers in Tegal Regency showed uniformity in microbiological aspects, nutritional content, and physicochemical characteristics. Total of 18 fatty acids were successfully identified in the product. However, the contamination level of Escherichia coli exceeded the safety threshold for ready-to-eat food. This study also revealed that the physicochemical quality of lamb satay was strongly correlated with consumer satisfaction levels. Higher levels of moisture, ash, water activity, and pH were associated with increased consumer satisfaction and acceptance. Conversely, high fat and carbohydrate contents reduced consumer preference. These findings align with current consumer trends favoring healthier food products. In addition, sensory quality or attributes play a crucial role in shaping consumer satisfaction and acceptance of lamb satay. Based on the findings of this study, it is recommended that lamb satay producers in Tegal Regency enhance the hygiene of their production processes to minimize Escherichia coli contamination and optimize the balance of physicochemical composition in order to improve sensory quality as well as consumer acceptance and satisfaction.

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