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Evaluation of the Quality of Chicken Sausages Resulting from the Addition of Chicken Feet Skin

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ABSTRACT

The research aimed to examine the potential of chicken feet skin in chicken sausages from the chemical-physical, sensory, texture, color profile, amino acid profile, and microstructure aspects. Chicken meat and feet skin were distributed in treatment formulations C_0 (without chicken feet skin), C_1 (5% chicken feet skin), C_2 (10% chicken feet skin), and C_3 (15% chicken feet skin). The chicken feet skin in the sausage mixture did not significantly increase the pH, protein, and ash content; however, it significantly increased the cooking loss, fat content, and antioxidant capacity of sausages ($P<0.05$) and decreased water content in sausages ($P<0.05$). The texture profile related to the hardness, stickiness, gel strength, and chewing power of the sausage significantly decreased ($P<0.05$), but the level of chewiness was not significantly different. The brightness level of sausages (CIE L*) and yellowness level (CIE b*) of sausages in the C_3 treatment were significantly higher ($P<0.05$). Meanwhile, the level of redness (CIE a*) of sausages significantly decreased ($P<0.05$). The level of sausage color preference at the 5% level (C_1) has no significant influence on C_0. However, the effect was significant ($P<0.05$) on C_1-C_3. The flavor and taste of chicken sausage were not affected by the presence of the chicken feet skin. The total amino acid content of sausages was 10.02-12.89% and the dominant amino acids were glutamate, aspartic acid, proline, glycine, alanine, valine, leucine, phenylalanine, lysine and arginine. SEM observations did not show any visual differences, especially in the distribution of fat globules in the sausage emulsion. The research conclusion is that the addition of 5–15% chicken feet skin is able to provide positive functional value, especially on the antioxidant capacity of chicken sausage, as an effect of the collagen content of the chicken feet skin.

Keywords: Chicken sausage, Chicken feet skin, Sausage characteristics, Antioxidant capacity.

INTRODUCTION

Chicken meat and processed products are generally very familiar because they are an important source of essential protein. Therefore, their consumption will continue to increase (Kang et al. 2024). Chicken sausage is one of the most popular processed chicken meat products in the world. Sausage is a product resulting from the meat restructuring method and meat restructuring is one of the downstream processing technologies in an effort to maximize the potential of meat and improve the quality of processed meat (Samad et al. 2024).

Chicken sausages generally contain 20-35% fat and this fat plays an important role in determining the quality of the texture, juiciness, and taste of the sausage (Choe and Kim 2019). In recent years, the consumer has been aware of sausage products with the characteristics of low saturated fatty acid and cholesterol content, so the studies on the innovations in chicken sausage products have experienced an improving trend toward this consumer interest. Various research studies related to downstream technology have been developed in an effort to improve the quality of sausages, such as fat reduction or fat replacement treatments, nitrite-reducing or replacing agents, and the use of by-products (Kang et al. 2014; Lee et al. 2015; Lim et al. 2017; Han and Bertram 2017; Yoo and Kim 2017; Lim and Chin 2018).

Chicken feet skin is a poultry by-product and it has so far been underused, and its price is also relatively cheap. In general, the characteristics of livestock skin such as collagen

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which can bind water and improve the texture of the product have been studied deeply (Song et al. 2014; Miwada et al. 2024). Liu et al. (2012) stated that more than 40% of claw protein is composed of poorly soluble protein (collagen protein), and this protein potential to produce hydrophobic amino acids which are able to donate hydrogen ions in reducing free radicals (Lin et al. 2010; Lee et al. 2012). This study showed that consuming chicken feet with high collagen content can have a positive effect on skin rejuvenation and various other health benefits. Kim et al. (2017) also stated that the skin can be used as a food additive, especially as a gel and film or microencapsulation form (Kim et al. 2016; Mulyani et al. 2017; Miwada et al. 2023).

The advantages of collagen in the skin have been developed by Kim et al. (2020), especially in the use of duck skin and its combination with carrageenan in processed jerky products. Likewise, pork skin is used as a source of collagen in low-fat sausage products (Choe and Kim 2016; Alves et al. 2016). Furthermore, Choe and Kim (2019) stated that the high collagen content in the skin and the functional gel properties of collagen hydrolyzate showed its potential to be used as a fat substitute. However, the research on the use of chicken feet skin to enrich the quality of chicken sausage products is still limited. Therefore, this study interested to present. The data obtained in this research can be used as a basic data needed for the development of processed chicken meat products.

MATERIALS AND METHODS

Ethics statement

An approval from the Institutional Animal Ethics Committee was not required to conduct this study as no live animals were used.

Material

The main ingredients for this research were chicken meat and chicken feet skin obtained from traditional markets in Bali, Indonesia. Other supporting ingredients consist of ice water (10%), salt (1.5%), STTP (0.3%), ground spices (1.5%) and garlic (1.5%) in the same amount for each treatment.

Chicken feet skin preparation

The preparation of chicken feet skin was carried out according to the method of Susanto et al. (2018), namely that chicken feet were aged for 8 hours at a temperature of 16ºC. Sorting and skinning chicken feet involve cleaning the nails, outer skin and dirt attached to the feet to get clean raw materials. Next, the foot skin was skinned by heating in a pressure cooker for 5min, followed by grinding the foot skin before mixing into the meat mixture.

Sausage formulation

Broiler chicken meat and chicken feet skin were ground. Mixed the meat formula, chicken feet skin and other supporting ingredients for 7min. The sausage dough formed was kept for 5min at a dough temperature below 10ºC. The sausage mixture emulsion was then put into the sausage casing. The raw sausage dough was boiled at 70-75ºC for 30min in a water bath, then cooled at room temperature for 15min and stored in the freezer and the sausages were ready to be tested. This activity was repeated 4 times. The research used a completely randomized design (CRD) with 4 treatments and 4 repetitions to obtain 16 treatment combinations. Treatments for adding chicken feet skin are named as mentioned below:

C_0 = Control (500g of chicken meat)
C_1 = Addition 5% feet skin (475g of chicken meat and 25g of feet skin)
C_2 = Addition 10% feet skin (450g of chicken meat and 50g of feet skin)
C_3 = Addition15% feet skin (425g of chicken meat and 75g of feet skin)

Variable Measurement

Determination of sausage texture profile (TA)

The texture of chicken sausage was analyzed using the Texture Profile Analyzer (TPA) TXT 32. Sausage samples with the additional feet skin with a size of 3x3x3cm^3 were taken and then pressed with probe (6mm diameter) twice. The probe speed was set at 5mm/s, and the sample was pressed to 30% of its initial height. The parameters observed include hardness, springiness, cohesiveness, gumminess, and chewiness.

Quantitative determination of color and organoleptics

Color measurement was done using PCE-CSM Colorimeter using the CIE L*a*b* formula. Value of L* for lightness, a* for greenness (-) and redness (+), and b* for blueness (-) and yellowness (+). To determine the level of consumer liking, a hedonic test with a range of 1-5 values was used with 20 semi-trained panelists (Yusop et al. 2010).

pH test

The pH value of each sample was measured in homogeneous conditions prepared with 5g of sample and 20mL of distilled water and measured using a pH meter.

Cooking loss

The fresh weight of the sausage was weighed and then heated at 75ºC for 30min. The samples were then coolled and weighed as the final weigh. The difference between the initial weight and the final weight was calculated as the cooking loss weight.

Proximate analysis

Proximate analysis was carried out according to the AOAC method (2005). Determination of antioxidant capacity was done using the DPPH method (Baliyan et al. 2022).

SEM (Scanning Electron Microscopy)

The samples were attached to the SEM slices with double-sided tape coated with a layer of gold with a thickness of 10nm. All samples were observed at an acceleration voltage of 10kV with a magnification level of 500x.

Amino acid test

Amino acid testing was done according to the AOAC method (2005). Amino acids were analyzed using HPLC.

The principle of amino acid analysis is that amino acids of the protein are liberated by hydrolysis with HCl 6N. The hydrolyzate was dissolved with sodium citrate buffer, and each of these amino acids was separated using HPLC. The protein extraction with Kjeldahl method was done before the hydrolysis process was carried out.

Statistical Analysis

The research data were expressed as mean±SD data. To compare the results, a one-way analysis of variance was carried out followed by Duncan's test if the results showed significant differences (P<0.05) in a SPSS version 25 system.

RESULTS

The results of physical and chemical analysis of chicken sausages with the addition of feet skin (C_1; C_2 and C_3) are presented in Table 1. The pH value, protein content, and ash content with the addition of feet skin to the sausage dough did not have a significant effect (P>0.05) compared with control (C_0). However, the effect of treatment was significant on cooking loss, water content, and antioxidant capacity (P<0.05).

Moreover, the study in Table 2 regarding the texture profile of chicken sausage with the addition of feet skin (C_1; C_2 and C_3) significantly reduced the level of hardness, guminess, cohesiveness, and chewiness (P<0.05) compared to the control (C_0). However, the springiness values between the C_0 treatment; C_1; C_2, and C_3 have no significant differences (P>0.05). Color instrumentation on CIE L*; CIE a* and CIE b* values were significantly different in treatment C_1; C_2 and C_3 compared to the control (C_0).

The sensory evaluation of chicken sausages with the addition of feet skin is presented in Table 3. The impact of adding feet skin (C_1; C_2 and C_3) to the sausage mixture had a significant effect on color, texture, and overall acceptability (P<0.05) compared to the control (C_0). However, taste and flavor had no significant influence (P>0.05).

The study of the amino acid profile of chicken sausage with the addition of feet skin is presented in Table 4. It was found that 18 types of amino acids were found in the chicken sausage product and the addition of feet skin to the sausage mixture had a significant impact (P>0.05) on 15 types of amino acids, except 3 types of amino acids which include methionine, tyrosine and arginine. The microscopic appearance using the SEM test, as presented in Fig. 1, shows a uniform emulsion system related to the fat and water emulsion between treatment C_0 and treatment C_1; C_2, and C_3.

Table 1: Physical and chemical analysis of chicken sausages resulting from the addition of chicken feet skin

Variables	Addition of Chicken Feet Chicken			
	C_0	C_1	C_2	C_3
pH	6.13±0.68	6.07±0.59	6.57±0.65	6.34±0.33
Cooking loss(%)	5.38±0.84a	6.40±0.61ab	6.84±1.53b	8.34±0.60c
Water content (%)	58.48±0.43a	57.65±0.98ab	56.23±1.23b	56.14±1.53b
Protein content (%)	11.37±0.16	11.05±0.89	11.20±0.66	11.11±0.60
Fat content (%)	15.39±1.10a	17.36±0.79b	17.48±0.73b	19.25±0.59c
Ash content (%)	2.19±0.35	2.23±0.14	2.20±0.09	2.21±0.23
Antioxidant capacity (mg/L GAEAC)	8.34±1.00a	14.18±1.00c	11.22±0.76b	16.57±1.00d

Values (mean+SD) bearing different letters in a row differ significantly (P<0.05). C_0: control; C_1: addition of 5% feet skin; C_2: addition of 10% feet skin; and C_3: addition of 15% feet skin.

Table 2: Texture and color attributes of chicken sausages with chicken feet skin

Variables	Addition of Chicken Feet Skin			
	C_0	C_1	C_2	C_3
Hardness (kg)	15.15±14.90a	10.56±11.71b	10.19±30.53b	8.55±1.24c
Guminess (kg mm^{-2})	6.61±0.78a	4.44±0.76b	4.29±1.36b	3.32±0.55c
Cohesiveness (ratio)	0.44±0.03a	0.42±0.04a	0.42±0.03a	0.39±0.02b
Springiness (mm)	0.76±0.06	0.74±0.08	0.76±0.05	0.78±0.28
Chewiness (kg mm^{-1})	5.03±0.61a	3.31±0.78b	3.25±1.06b	2.56±0.85c
CIE L*	24.90±0.46a	25.80±0.27b	26.12±0.20b	26.55±0.30c
CIE a*	3.33±0.20a	3.30±0.23a	2.60±0.20b	2.76±0.20b
CIE b*	12.81±0.26a	13.05±0.24ab	13.31±0.17b	13.14±0.19b

Values (mean+SD) bearing different letters in a row differ significantly (P<0.05). C_0: control; C_1: addition of 5% feet skin; C_2: addition of 10% feet skin; and C_3: addition of 15% feet skin.

Table 3: Sensory analysis of chicken sausages with chicken feet skin.

Variables	Addition of Chicken Feet Skin			
	C_0	C_1	C_2	C_3
Color	4.15±0.88a	4.30±0.57a	3.70±0.80b	3.50±0.69b
Flavor	4.05±0.76	4.10±0.55	4.20±0.77	3.95±0.83
Texture	4.25±0.79a	4.30±0.66a	3.70±0.57b	3.55±0.51b
Taste	4.05±0.76	4.35±0.75	4.20±0.89	4.05±0.76
Overall acceptance	4.20±0.62a	4.40±0.60a	4.15±0.67a	3.75±0.44b

Values (mean+SD) bearing different letters in a row differ significantly (P<0.05). C_0: control; C_1: addition of 5% feet skin; C_2: addition of 10% feet skin; and C_3: addition of 15% feet skin.

Table 4: Amino acid profile of chicken sausages with chicken feet skin

Amino Acid (%)	Addition of Chicken Feet Skin			
	C_0	C_1	C_2	C_3
Aspartic acid	0.84±0.01a	1.15±0.11b	0.69±0.04c	0.75±0.13d
Threoninne	0.41±0.01a	0.39±0.01b	0.36±0.15c	0.37±0.31cb
Serine	0.40±0.02a	0.41±0.01a	0.36±0.12b	0.39±0.02ab
Glutamate	3.27±0.01a	4.68±0.43b	2.86±0.01c	2.95±0.05c
Proline	0.54±0.01a	0.48±0.11b	0.56±0.02a	0.63±0.01c
Glycine	0.47±0.1a	0.58±0.1ab	0.53±0.4b	0.62±0.5c
Alanine	0.55±0.03ab	0.63±0.11b	0.52±0.32a	0.56±0.01c
Cystein	0.10±0.01a	0.08±0.21b	0.09±0.01ab	0.10±0.01a
Valine	0.51±0.03ac	0.52±0.01a	0.43±0.22b	0.47±0.03c
Methionine	0.21±0.03a	0.21±0.03a	0.20±0.01a	0.20±0.02a
Isoleucine	0.47±0.01a	0.46±0.01a	0.41±0.16b	0.42±0.22b
Leucine	0.81±0.03a	0.84±0.01a	0.70±0.01b	0.74±0.03c
Tyrosine	0.22±0.02a	0.24±0.01a	0.24±0.01a	0.23±0.02a
Penilalanine	0.59±0.01a	0.56±0.21b	0.51±0.11c	0.51±0.02c
Histidine	0.36±0.02a	0.32±0.11b	0.30±0.15b	0.30±0.12b
Lycin	0.69±0.01a	0.72±0.11b	0.63±0.22c	0.64±0.02c
Arginine	0.49±0.01a	0.50±0.01a	0.51±0.02a	0.49±0.01a
Tryptophan	0.14±0.01ab	0.11±0.31a	0.12±0.02ab	0.15±0.13b
Amino Acid Total	11.05±0.22a	12.89±0.97b	10.02±0.21a	10.52±0.57a

Values (mean+SD) bearing different letters in a row differ significantly ($P<0.05$). C_0: control; C_1: addition of 5% feet skin; C_2: addition of 10% feet skin; and C_3: addition of 15% feet skin.

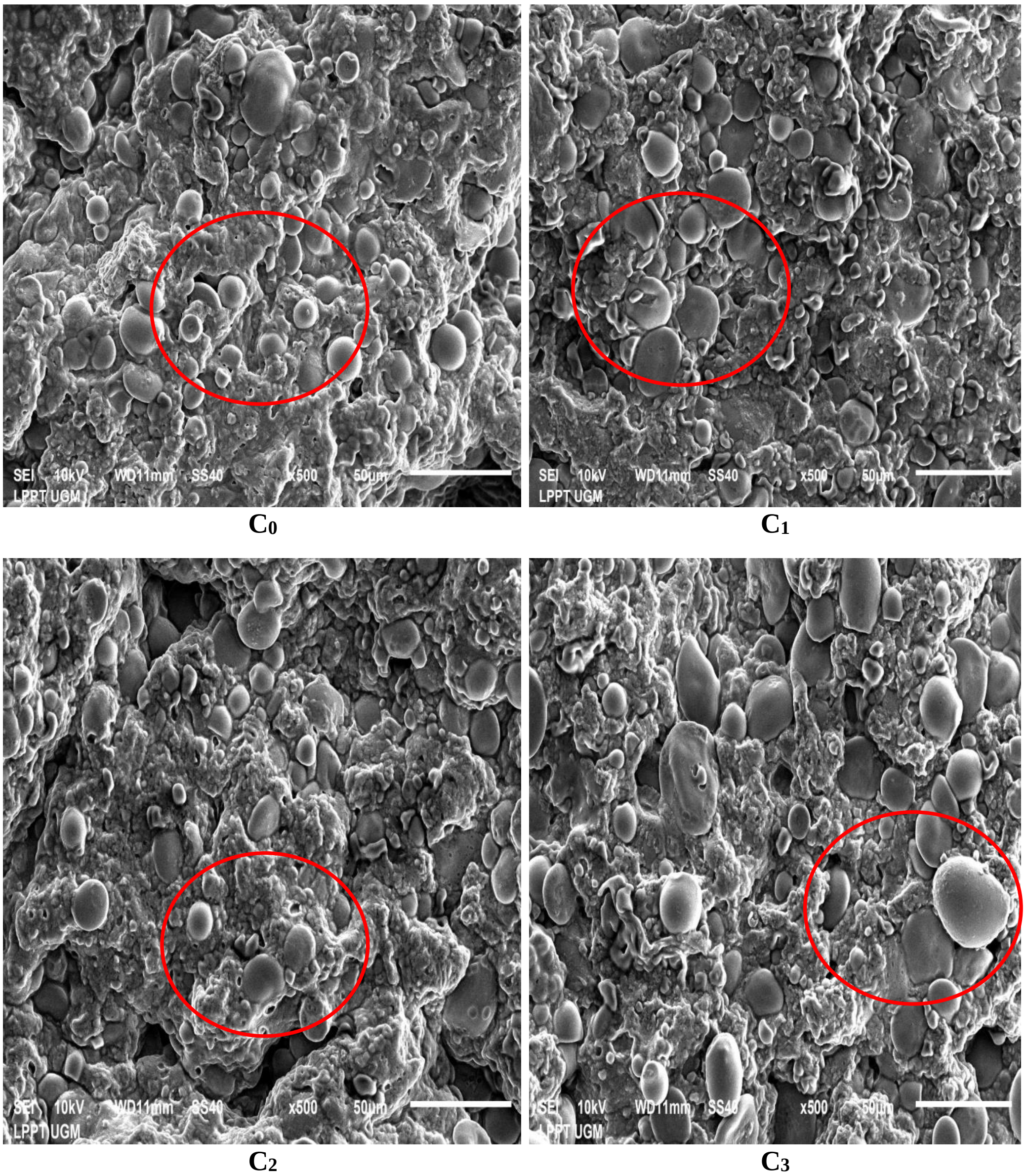

Fig. 1: Scanning electron microscopy of sausage with 500 x magnification: C_0: control; C_1: addition of 5% feet skin; C_2: addition of 10% feet skin; and C_3: addition of 15% feet skin. Fat globules (○)

DISCUSSION

The pH value and proximate analysis of chicken sausage with the addition of chicken feet skin is presented in Table 1. Increasing the level of chicken feet skin addition to the sausage mixture does not significantly increase the pH of chicken sausage, although it has increased descriptively. The pH of chicken meat is known to be 5.89-5.93., and the pH value of the sausage becomes higher, influenced by the additional of ingredients provided (Sinambela et al. 2023). An increase in pH indicates the increased activity by microorganisms. This activity can also occur due to the high water content of the product (Salsabila et al. 2023). The cooking loss of chicken sausage with increasing chicken feet skin content significantly increased. This increase is thought as the result of the high-fat content in the chicken feet and its interaction with the meat protein during heating, which causes elution between the water component of the sausage dough and the fat component of the sausage. The results of this study are consistent with those reported by Kim et al. (2016), who found that chicken nuggets with the addition of chicken skin also show higher cooking losses than those without the addition of chicken skin. The heating process in making sausages causes collagen fibers to shrink and results in compression by myofibrils, which have been denatured due to heating. This causes mass instability and causes cooking losses to increase (Rocha et al. 2019). Increasing the chicken feet' skin content significantly reduced the water content in the sausage; however, the protein content and ash content were not significantly different. The sausage moisture content is known to be 56.14-58.48%. Commercial sausages are reported to have a water content of around 56.48–71.30% (Huda et al. 2010). High water content can accelerate damage due to increased microbial activity and accelerate fat oxidation by unsaturated fatty acids with mineral content (Salsabila et al. 2023). The control sausage had the lowest water content, while the lowest value was owned by the sausage with the addition of 15% chicken feet skin. Chicken feet are known to be extracted to produce gelatin. Previous studies showed that the addition of chicken feet skin gelatin in different amounts did not have a significant impact on protein levels. Additionally, the known fat content does not change much when gelatin is added to sausages (Sompie and Siswosubroto 2021). The results showed that sausages with the addition of chicken feet skin did not have a significant effect on sausage protein levels. The protein content in sausages in this study ranged from 11.05 to 11.37%. The protein levels detected were lower than the provisions, namely a minimum of 12% protein content in sausages (Rocha et al. 2019). Sausages with the addition of chicken feet skin in different percentages have an ash content of 2.19-2.23%. The statistical value of ash content that is not different is thought to be due to chicken feet having a low ash content, namely 1.07–1.10%, and this value is lower than the ash content in breast meat (Lukasiewicz et al. 2014). The presence of other materials, such as minerals and residual inorganic substances from burning organic materials, causes increased ash content in the product. Natural food ingredients have an organic matter and water content of around 96%, and the rest are mineral elements; therefore, each food ingredient can definitely influence the amount of ash content. (Evanuarini et al. 2023; Salsabila et al. 2023). The high-fat content of chicken feet skin had a significant effect on increasing the fat content of sausages. The fat content of sausages in this study was 15.39-19.25%. High-fat content has the potential to go rancid if not stored properly because it can undergo oxidation. Rancid products can reduce quality and nutritional value (Salsabila et al. 2023). The use of duck skin in duck ham products significantly increases the fat content (Kim et al. 2017). Chicken skin in processed products actually increases the fat content of the processed meat products (Choe and Kim 2016). This research sausage still contains below 30% fat, so it is safe (Rocha et al. 2019). The fat content of commercial chicken sausages has been reported between 7.79-18.48% (Huda et al. 2010). The antioxidant capacity of chicken sausage with the addition of chicken feet skin increased significantly. The antioxidant potential of chicken feet skin is thought to occur as a result of enzymatic hydrolysis producing different sizes of biopeptides and producing high antioxidant capacity, especially in the amino acid components lysine and glycine, which are known to be types of amino acids that have hydrophobic amine groups, so they can easily reduce DPPH free radicals in their activity. The antioxidant (Siow and Gan 2013). This antioxidant capacity can prevent oxidative damage to product amino acids (Evanuarini et al. 2023).

Increasing the addition of chicken feet skin to sausages significantly reduces the level of hardness. This reduction in the level of hardness is caused by the interaction of the chicken feet skin protein with the meat protein, which maintains the strength of the sausage emulsion. Hassan et al. (2020) stated that emulsion stability determines the amount of water and fat provided by meat protein. The bond of meat protein with the water component determines the level of hardness (Okuskhanova et al. 2017). As fat increases, it can reduce the amount of water in the sausage, which functions as a plasticizer, making the product softer. Hardness texture is also influenced by the fat content of the sausage (Famenin et al. 2019). The level of hardness decreased and was also followed by the level of stickiness and gel strength, which significantly decreased. However, the level of chewiness was not significantly different, while chewing power actually decreased. A decrease in cohesiveness, followed by a decrease in hardness and elasticity values, can be expected to also occur at the emulsion level (Rigdon et al. 2021). A decrease in hardness is always accompanied by a decrease in gumminess. This value is lower than the texture of the control sausage in this study. The characteristic texture of chicken sausage is thought to be caused by the high-fat content in the chicken feet skin. There are reports that duck skin reduces the emulsion capacity and protein solubility of duck ham products (Kim et al. 2017). Analysis of the sausage brightness level (CIE L*) in the C_3 treatment was significantly higher compared to other treatments. Increasing the addition of chicken feet skin significantly increased the brightness level of sausages but significantly reduced the redness level of chicken sausages (CIE a*). Even though the addition of chicken feet skin in treatment C_1 (5%) was not significantly different from the control treatment (C0), likewise, the level of yellowness (CIE b*) of chicken sausages with the addition of 5% chicken feet skin was still the same as the control. Protein binding with added fat increases the brightness of the product. Increasing duck skin increases the brightness of duck hams (Kim et al. 2017). High-fat content can increase the yellowish, as seen with the addition of 10-15% chicken feet.

The ability to detect, recognize, differentiate, compare, and express feelings of like or dislike are included in sensory tests. Quality is assessed with a hedonic test, which receives a score between 1 and 5 (Tharukliling et al. 2021). Table 3 shows the sensory analysis of chicken sausages with chicken feet skin. The level of sausage color preference with the addition of chicken feet skin at the 5% level had no significant effect on the control treatment. The effect is significant if the addition of chicken feet skin is increased to 5-15%. The flavor and taste of chicken sausage are not affected by the addition of the chicken feet skin.

In this study, 18 types of amino acids were observed in chicken sausages that were given the addition of chicken skin. The total amino acid content in each treatment ranged from 10.02-12.89% (Table 4) and there was a significant change in amino acid concentration in each treatment. The dominant types of amino acids in the treatment of chicken sausage with the addition of chicken feet skin include glutamate, aspartic acid, proline, glycine, alanine, valine, leucine, phenylalanine, lysine, and arginine. The amino acid profile of chicken sausage is important in determining nutritional content and its impact on health. The collagen contained in chicken feet skin, in its degradation, produces amino acids characteristic of sausages such as glycine, proline, and hydroxyproline (Liu et al. 2023). The amino acid profile of sausages can vary and depends on factors such as the manufacturing method and ingredients used (Bar et al. 2020). The amino acid profile in the chicken patty was also reported to contain the same type of amino acids as in the sausage, with the addition of chicken feet skin in this study (Evanuarini et al. 2023). The amino acids detected in sausages benefit the human body (Bulang et al. 2021). The amino acid profile also plays an important role in sensory characteristics, such as glutamic acid and aspartic acid contributing to freshness; glycine and alanine contributing to sweetness; arginine, leucine, valine, and phenylalanine contributing to the bitter taste and lysine contributing to the bitter and sweet tastes (Berisha et al. 2023).

SEM recording data can be used as supporting data in identifying sensory quality, especially for texture parameters of processed meat products, because it can show an overview of the relationship between topography, surface texture appearance, and the level of hardness of the sample. The surface texture of the sausage in this study looks rough and contains a large number of small lumps; this makes the appearance look hard and dense. This texture condition is caused by the process of making sausages using heat, which can change the protein structure of the meat myofibrils (Tharukliling et al. 2021). The increase in the addition of chicken feet skin to sausages did not show any visual differences, especially in the distribution of fat globules in the sausage emulsion. However, there was a tendency to increase the size of fat globules with the increasing addition of chicken feet skin. In general, all sausage treatments visually show that they consist of the same microstructure, namely consisting of a protein gel matrix and fat granules that form a porous network structure. The protein and fat components of the chicken feet skin were observed and integrated into the sausage meat protein matrix and were visually the same as the control treatment. The structure of the sausage network has the same level of density (emulsion distribution) and resembles a honeycomb. Fat granules with an increased addition of chicken feet skin make the sausage structure softer and chewier (Ahmad et al. 2020; Kim et al. 2021). This emulsion activity is hydrophobic because it is able to prevent the release of liquid in the dough. This can also influence the level of panelists' liking for juice (Tharukliling et al. 2021).

Conclusion

Increasing the addition of chicken feet skin to chicken sausage dough can provide additional functional value to chicken sausage products, especially by increasing antioxidant capacity. The chicken feet skin collagen can reduce the hardness of the sausage without changing its elasticity. The addition of chicken feet skin up to 15% can be done to diversify the quality of chicken sausages, and up to this level, there is no difference in the SEM visualization of fat globules in the sausage emulsion. Likewise, the sensory aspect can improve quality, with sausage's total amino acid content ranging from 10.02 to 12.89%.

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Author's contribution: INSM: Data conceptualization and curation. INSS: Data curation, IWW: Formal analysis. IWS: Physical, chemical, SEM and sensory analysis, AS: Texture profile analysis and writing editor.

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