



# Quality Evaluation of Spent Hen Sausage with Banana Blossom Flour (*Musa paradisiaca*) Addition During Refrigerated Storage Periods

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**Abstract:** The development of functional meat products has gained increasing attention, particularly through the incorporation of dietary fibers to enhance nutritional value while maintaining product quality. This study aimed to evaluate the effect of adding 3% banana blossom flour (BBF) on the quality characteristics of spent hen meat sausages subjected to refrigeration at a temperature of 4°C over periods of 0, 7, 14, and 21 days. The experiment was arranged in a completely randomized design, with storage duration as the treatment factor and five replications. The parameters observed included moisture content, pH, texture, color (L, a\*, b\*), microbial counts, peroxide value, and sensory attributes during cold storage. The results showed that storage periods of spent hen meat sausages with BBF addition exerted a statistically significant effect ( $P < 0.01$ ) on all parameters. During storage, pH value, redness, yellowness, total microorganism, and peroxide value increased, whereas moisture content, lightness, and sensory quality decreased. In conclusion, BBF addition extended the shelf life of sausages, allowing to remain acceptable until 21 days of cold storage, despite a gradual decline in sensory quality associated with increased peroxide values. Moreover, the utilization of BBF facilitates the enhancement of agricultural by-products as part of sustainable food innovation.

**Keywords:** Banana blossom flour; Cold storage; Filler; Spent hen sausage

## Introduction

Poultry meat has become an increasingly important source of animal protein in recent years. Spent hens are laying hens that have passed their productive egg laying stage. Their utilization remains limited, and they are often sold at low prices (Çimen et al., 2024). The meat derived from spent hens is characterized by a high concentration of protein, vitamins, minerals, and omega-3 fatty acids, all of which provide considerable health advantages (Barido & Lee, 2021). However, the meat of spent hens is characterized by high collagen content, which contributes to its tough texture, while the presence of unsaturated fatty acids makes the fat more susceptible to oxidation. These factors reduce the overall

processing quality and consumer acceptability of spent hen meat (Qin et al., 2025). To increase its value and consumer acceptance, preservation and processing innovations are needed. One promising approach is restructured meat technology, which improves texture through mincing, mixing with additional ingredients, and reforming the meat (Evanuarini et al., 2024). Through the application of this technology, spent hen meat can be developed into spent hen meat sausages with improved quality and market competitiveness.

Sausages are widely recognized as processed meat products consumed globally. Chicken sausage, in particular, is one of the most popular types, appreciated for its taste, convenience, and versatility in different dishes (Mukhlisah et al., 2023). Due to the inherent high

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lipid content within sausages, lipid oxidation is inclined to occur during both the storage and processing phases. An overabundance of lipid oxidation results in the development of rancidity and undesirable flavor profiles, which significantly compromise the quality and storage stability of sausages (Fu et al., 2022). Synthetic antioxidants, including butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA), have been employed in the preservation of meat products. However, the use of synthetic chemicals as antioxidants is often associated with negative health effects (Fardani et al., 2025). Therefore, natural antioxidants are strongly recommended (Honrado et al., 2022). Local ingredients such as banana blossom, which is rich in natural antioxidants, have the potential to delay rancidity and add value to meat products (Lau et al., 2020).

The banana blossom represents an underutilized agricultural by-product with diverse therapeutic attributes. Its bioactive compounds, including phenolics, flavonoids, tannins, and alkaloids, provide antioxidant, antidiabetic, and antimicrobial properties (Ravindran et al., 2021). Flavonoids in banana blossom exhibit antimicrobial activity, which is highly relevant for maintaining sausage quality during refrigerated storage. In addition, banana blossom contains a remarkably high dietary fiber content, reaching up to 70.07% (Ramu et al., 2017), and a balanced mineral composition dominated by potassium, calcium, and magnesium (Basumatary & Nath, 2018). When incorporated into spent hen sausage formulations, BBF simultaneously acts as a natural antioxidant to suppress lipid oxidation and rancidity, while also enhancing fiber content, improving texture, and delivering health benefits (Mishra et al., 2023). The evaluation of sausages throughout refrigerated storage is important to determine their shelf life.

The addition of sorghum bran to beef sausages has been shown to significantly affect physicochemical and microbiological properties during refrigerated storage (Xiong et al., 2022). Similarly, incorporating 1.5% andaliman flour effectively maintained sausage quality for up to 21 days under cold storage, whereas sausages without andaliman flour were acceptable for only 7 days (Julianti & Lubis, 2023). BBF offers a unique combination of exceptionally high crude fiber, abundant phenolic compounds with antioxidant activity, and a mineral profile dominated by potassium that may help stabilize sausage emulsions. However, research on its application in spent hen meat sausages remains very limited. Therefore, this study was conducted to evaluate the effect of BBF addition on the quality and shelf life of spent hen meat sausages during cold storage.

## Method

### *Materials*

The materials consisted of spent hen chicken meat as the main ingredient obtained from farm in Malang. The strain used was Lohmann Brown laying hens and were 75 weeks old. The BBF was produced independently from the kepok banana (*Musa paradisiaca*) cultivars purchased from traditional markets in Malang. The blossoms were selected based on suitable physical characteristics, including uniform size, optimal maturity, fresh color, and freedom from damage or contamination. Other ingredients included canola oil, tapioca flour, ice cubes, sugar, salt, ginger powder, pepper powder, garlic, and egg white.

### *Preparation of Banana Blossom Flour*

Freshly harvested banana blossoms were thoroughly washed following the removal of 3–4 outer fibrous bracts. The blossoms were subsequently cut into slices of approximately 3 mm and immersed in 0.2% citric acid (1 liter) for 30 minutes. The slices were drained on trays and dried at 50°C for 12 hours with a cross-flow hot air dryer. The dried product was ground and sieved through 100 mesh (Shekhara, 2023).

### *Preparation of Spent Hen Meat Sausage*

Chicken meat was prepared by trimming off skin, fat, and bones, cutting into small pieces (60%), ground in a meat grinder with added salt (2%) and ice cubes (10%). Tapioca flour (8%), canola oil (10%), garlic (3%), sugar (2%), egg white (4.5%), pepper powder (0.25%), ginger powder (0.25%), and BBF were subsequently mixed into the batter (3%). The mixture was ground again until homogeneous and smooth in texture. The sausage batter was then stuffed into collagen casings using a sausage stuffer. Cooking was carried out by boiling the sausages at 80±2°C for 20 minutes and then soaked in cold water for 10 minutes. The cooked sausages were stored at 4°C.

### *Research Design*

The research was conducted as a laboratory trial using a completely randomized design (CRD) followed by Duncan's multiple range test (DMRT) when significant differences were observed. Four distinct storage treatments were implemented at a temperature of 4°C, with replicated five times. The treatments were defined by varying storage durations: W0: sausage with 3% BBF stored for 0 days (control); W1: sausage with 3% BBF stored for 7 days; W2: sausage with 3% BBF stored for 14 days; W3: sausage with 3% BBF stored for 21 days

### *Moisture Content*

According to AOAC (2005), moisture content was assessed using the oven drying technique. Petri dishes

were pre-dried at  $105\text{ }^{\circ}\text{C} \pm 2$  for 30 minutes, put into desiccator, and weighed ( $B_0$ ). Approximately 2–5 g of sample was added to the dish, and the total weight noted ( $B_1$ ). The dishes were subsequently dried at  $105\text{ }^{\circ}\text{C}$  for 3–5 hours, cooled again in a desiccator, and reweighed ( $B_2$ ). Moisture content was calculated using the formula:

$$\text{Moisture Content (\%)} = \frac{B_1 - B_2}{B_1 - B_0} \times 100 \quad (1)$$

Where:

$B_0$  = the weight of the empty dish

$B_1$  = the weight of the dish plus sample before drying

$B_2$  = the weight of the dish plus sample after drying

#### pH Value

pH measurement followed AOAC (2005) using a calibrated pH meter. 1 g sample was finely ground and subsequently diluted with 10 ml of distilled water and calibrated against buffers at pH 7 and 4. The electrode was immersed in the diluted sample, and after the display stabilized within 1 minute the pH value was recorded.

#### Texture

Texture was determined using a force gauge setup. Sausage samples ( $2.5 \times 1.5\text{ cm}$ ) were removed from the casing prior to testing, and the peak force (N) required to cut through the sample was recorded as an indicator of hardness.

#### Color Analysis

Color evaluation of samples was conducted with a Colorimeter CR 10 Plus (Konica Minolta, Osaka, Japan) using the CIE LAB approach in line with AOAC (2005). The indices recorded were  $L^*$  (lightness),  $a^*$  (redness), and  $b^*$  (yellowness). Evaluations were performed at three separate sites on every samples, and the average values were recorded.

#### Total Microorganism

Total microbial counts were determined using the TPC method (AOAC, 2005). A 1 g sample was diluted in 9 mL of sterile saline (0.85% NaCl) to prepare a  $10^{-1}$  dilution, followed by serial dilutions. One milliliter from each dilution was plated with Plate Count Agar, incubated at  $37\text{ }^{\circ}\text{C}$  for 24–48 h, and colonies between 25–250 were enumerated as log CFU/g.

#### Peroxida Value

Peroxide values were determined following AOAC (2005). A 10 g sample was reacted with glacial acetic acid–chloroform (3:2, v/v), followed by the addition of potassium iodide. After standing in the dark for one minute, distilled water was added, and the released

iodine was titrated with sodium thiosulfate. The peroxide value was calculated using the formula.

$$\text{Peroxide Value (meq/kg)} = \frac{(V \times N)}{W} \times 10 \quad (2)$$

V = titration volume

N = normality of sodium thiosulphate

W = weight of sample

#### Sensory Evaluation

Spent hen meat sausages were evaluated by 30 panelists, consisting of 15 males and 15 females in healthy condition. Each sample was assessed for aroma, color, texture, and overall acceptability. The sausages were prepared by heating at  $75\text{ }^{\circ}\text{C}$  for 15 minutes, cooled to approximately  $45\text{ }^{\circ}\text{C}$ , cut into four pieces, and served randomly to the panelists. Each sample was assigned a randomly generated three-digit identifier. The evaluation was conducted using a 5-point descriptive hedonic scale (1 = dislike very much; 5 = like very much) (Evanuarini et al., 2023). The flowchart of the research is shown in Figure 1.

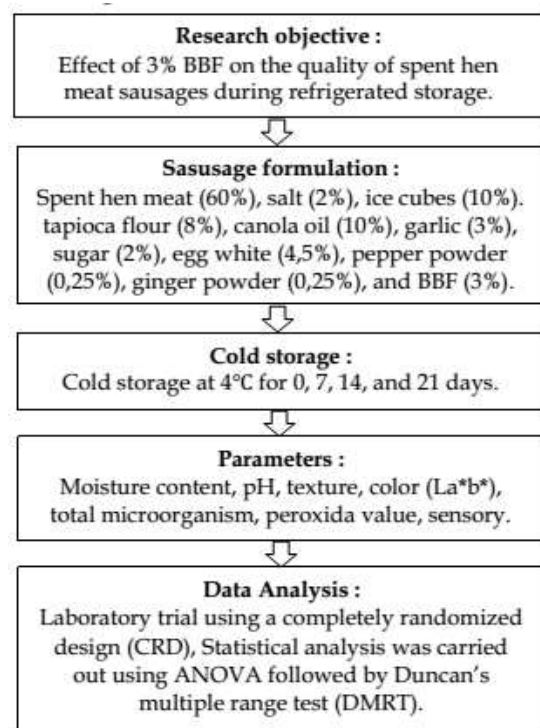


Figure 1. Flowchart of research

## Result and Discussion

### The Effect of Different Storage Periods on the Moisture Content of Sausages

Table 1 presents the moisture content of spent hen meat sausages with added BBF at different storage periods. A significant effect was observed ( $P < 0.01$ ).

Moisture content decreased by approximately 7.1% during 21 days of refrigerated storage. According to the Indonesian National Standard (SNI), sausages should not exceed 67% moisture. The result of this study between 58.66%-63.14%, indicate compliance with the standards of acceptability.

**Table 1.** The Effect of Different Storage Periods on the Moisture Content of Sausages

Treatment	Moisture content (%)
W0	63.14±0.58 <sup>b</sup>
W1	62.40±1.11 <sup>b</sup>
W2	60.14±0.92 <sup>a</sup>
W3	58.66±0.63 <sup>a</sup>

\*Note: a,b Different notations in the same column indicate a highly significant difference (P<0,01).

Moisture content plays a key role in determining the storage stability of processed meat products. During refrigerated storage, the moisture content of spent hen meat sausages with BBF decrease due to dehydration and fluid exudation in vacuum packaging (Song et al., 2020). Water loss was also affected by pectin degradation in BBF, which weakens cell walls and increases porosity (Frempong et al., 2022). This result consistent with the reduction in water-holding capacity of processed meat products, which results in liquid being released from the sausage matrix. (Wattanachant & Ungkusonmongkol, 2025). Similar trends have been reported in sausages supplemented with tomato powder (Qiu & Chin, 2020) and eggplant (Sembring & Chin, 2021), which showed a decline in moisture content during storage.

*The Effect of Different Storage Periods on pH Value of Sausages*

The pH value represents the degree of acidity or alkalinity of a product. The pH values of spent hen meat sausages with added BBF at different storage periods are shown in Table 2 (P < 0.01). During storage up to 21 days, the pH increased gradually.

**Table 2.** The Effect of Different Storage Periods on the pH value of sausages

Treatment	pH value
W0	6.30±0.04 <sup>a</sup>
W1	6.34±0.02 <sup>a</sup>
W2	6.49±0.02 <sup>b</sup>
W3	6.54±0.04 <sup>c</sup>

\*Note: a,b,c Different notations in the same column indicate a highly significant difference (P<0,01).

The slight increase in pH from 6.30 to 6.54 observed during storage of spent hen meat sausages with BBF may be associated with protein degradation and the release of alkaline metabolites. Microbial activity and residual enzymatic reactions can contribute to deamination

processes, resulting in minor pH elevation (Wang et al., 2022). Such pH changes may also enhance lipase activity, thereby accelerating lipid hydrolysis and rancidity (Othón Díaz et al., 2023). Rani et al. (2024) reported that pH values increased in chicken meat nuggets enriched with pumpkin seed powder and chia seed powder. In contrast, Lishianawati et al. (2022) observed a decrease in pH during storage, which they attributed to the proliferation of lactic acid bacteria under refrigerated conditions. The slight increase in pH observed in this study suggests that lactic acid bacteria did not proliferate significantly.

*The Effect of Different Storage Periods on the Texture of Sausages*

Statistical analysis of the texture values of spent hen meat sausages with BBF addition showed in Table 3 (P < 0.01). During storage up to 21 days, texture values decreased gradually. Average texture values varied between 13.69 N - 15.25 N, which indicate a degradation of the product's texture as a result of storage duration.

**Table 3.** The Effect of Different Storage Periods on the Texture of Sausages

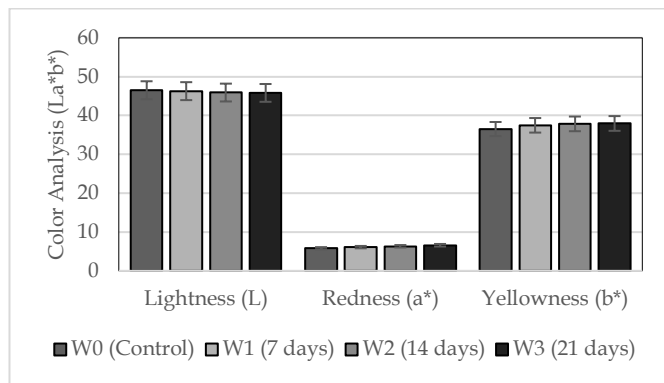
Treatment	Texture (N)
W0	15.25±0.14 <sup>d</sup>
W1	15.04±0.11 <sup>c</sup>
W2	14.45±0.08 <sup>b</sup>
W3	13.69±0.10 <sup>a</sup>

\*Note: a,b,c Different notations in the same column indicate a highly significant difference (P<0,01).

The reduction in sausage texture during storage is primarily associated with proteolytic degradation of muscle proteins and weakening of the extracellular matrix triggered by microbial activity and endogenous enzyme systems, along with microstructural changes (Cheng, 2020). Such deterioration continues even under cold storage, mainly due to lipid oxidation, protein breakdown, and microbial growth (Gu et al., 2023). Meat proteins are initially cleaved into polypeptides by proteolytic enzymes from both muscle and microbes, and subsequently hydrolyzed into smaller peptides by peptidases (Triki et al., 2018). This process weakens the protein gel network, reducing elasticity and lowering texture values in processed meat products. Kandil et al. (2020) reported that beef sausages with chickpea addition exhibited decreased hardness after 15 days of cold storage, likely due to microbial proteolysis. Zhang et al. (2024) demonstrated that natural antioxidants can mitigate texture deterioration by reducing emulsion destabilization and suppressing protein cross-link formation through inhibition of protein oxidation.

*The Effect of Different Storage Periods on the Color of Sausages*

As shown in Figure 2, the CIE LAB color indices (L, a\*, b\*) of spent hen meat sausages varied significantly during storage (P < 0.01). Mean color values showed increased redness (a\*) and yellowness (b\*), accompanied by decreased lightness (L) as storage progressed.



**Figure 2.** Color analysis of spent hen sausage during different storage periods

Spent hen sausages exhibited a significant reduction in lightness (P < 0.01) throughout storage. This reduction may be due to moisture loss caused by dehydration during storage (Song et al., 2020), resulting in a darker product appearance (Mishra et al., 2017). The decrease in the lightness value causes the sausage to appear dark and be less acceptable to the panelists. According to Mantihal et al. (2021), who observed that the lower lightness values in chicken burgers with 6% cabbage flour compared to controls during storage. In contrast, redness (a\*) increased significantly (P < 0.01) during storage, ranging from 5.81 in the control to 6.59 during 21 days. This augmentation may be associated with oxidative alterations in the pigments of meat, which could be modulated by the antioxidant characteristics inherent in BBF (Koishybayeva & Korzeniowska, 2024). Guliyeva et al. (2021) also reported increased redness in patties with 3% pennyroyal powder during cold storage. Yellowness (b\*) values in spent hen meat sausages fortified with BBF exhibited statistically significant elevations (P < 0.01) during the entirety of the storage. The increase in yellowness may be linked to rancidity, which enhances yellow color intensity (Das et al., 2025). This trend continued during storage and aligned with the observations made by Lishianawati et al. (2022), found that duck meat nuggets with 2% black garlic powder exhibited higher yellowness.

*The Effect of Different Storage Periods on the Total Plate Count of Sausages*

Table 4 shows the average total plate count of spent hen meat sausages with BBF during storage (P < 0.01). The colony counts ranged from 1.43 log CFU/g to 1.87

log CFU/g. According to the (SNI 3820:2015) for chicken sausage quality, the maximum allowable microbial count is 1×10<sup>5</sup> CFU/g.

**Table 4.** The Effect of Different Storage Periods on the Total Plate Count of Sausages

Treatment	Total Plate Count (log CFU/g)
W0	1.43±0.07 <sup>a</sup>
W1	1.59±0.07 <sup>b</sup>
W2	1.78±0.09 <sup>c</sup>
W3	1.87±0.05 <sup>c</sup>

\*Note: a,b,c Different notations in the same column indicate a highly significant difference (P < 0,01).

The total plate count serves as a critical microbiological parameter utilized to evaluate the durability of product shelf life (Karwacka et al., 2024). Water activity is the main factor influencing microbial growth rate, the higher the water activity, the faster microorganisms proliferate (Jin et al., 2019). Products with higher pH values also tend to support microbial growth, as such conditions favor cell metabolism, enzyme activity, and nutrient availability (Alp & Bulantekin, 2021). In addition, product quality depends on the condition of raw materials, which must be controlled throughout processing, since initial contamination from raw materials or the production environment can serve as a source of microbial growth during storage (Sánchez-Aldana et al., 2020). Sausages with 2% cocoa seed coat flour stored for 15 days showed an increase in total microorganism (Choi et al., 2019).

An increased microbial population negatively impacts product attributes and reduces its preservation period. The addition of natural antioxidants can slow microbial growth. Banana blossom extract has been shown to contain phenolic and flavonoid compounds with antioxidant and multiple bioactive functions (Rodrigues et al., 2020). Previous studies reported that sausages without additives showed higher total plate counts than those containing mosambi peel powder during storage, which was attributed to antimicrobial compounds such as polyphenols present in mosambi peel powder (Younis et al., 2021).

*The Effect of Different Storage Periods on the Peroxide Value of Sausages*

The analysis showed that the peroxide value increased (P < 0.01) up to day 21, as shown in Table 5. The minimum value was documented on day 0 at 1.91 meq/kg, whereas the maximum was noted on day 21 at 2.49 meq/kg. The peroxide values recorded in this work were far below 10 meq/kg, which is generally considered the threshold at which rancidity becomes evident (Adzitey et al., 2021).

**Table 5.** The Effect of Different Storage Periods on the Peroxide Value of Sausages

Treatment	Peroxide value (meq/kg)
W0	1.91±0.10 <sup>a</sup>
W1	2.26±0.09 <sup>b</sup>
W2	2.38±0.05 <sup>bc</sup>
W3	2.49±0.11 <sup>c</sup>

\*Note: a,b,c Different notations in the same column indicate a highly significant difference ( $P < 0,01$ ).

Rancidity in spent hen meat sausages with BBF was indicated by the increase in peroxide values, which if exceeding the standard, can cause undesirable odor, taste, and color. The rise in peroxide values is attributed to lipid oxidation producing ketones and aldehydes as major products (Śmiecińska & Daszkiewicz, 2021). Lipid oxidation affects the sensory characteristics of meat products, thereby diminishing consumer acceptance (Wattanachant & Ungkusonmongkol, 2025). This process is modulated by intrinsic factors encompassing the fatty acid profile, lipid classification, and compositional elements, in addition to extrinsic factors such as humidity, temperature, illumination, oxygen levels, and the existence of metallic ions. The quality of the product is directly influenced by these determinants (Abeyrathne et al., 2021). Banana blossom extract demonstrated a marked ability to suppress lipid oxidation during storage, due to its antioxidant content (Rodrigues et al., 2020).

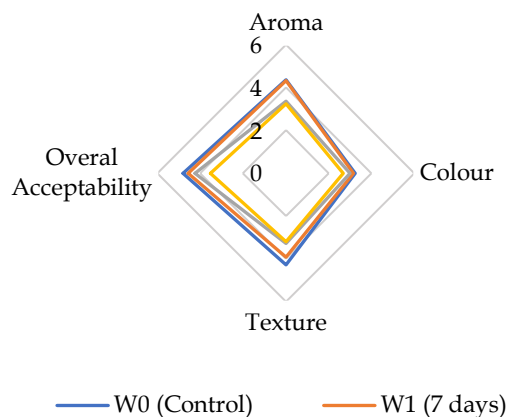
The peroxide values in sausages with cinnamon powder exhibited a substantial elevation after a duration of six days under cold storage, indicating lipid oxidation through hydroperoxide formation (Wattanachant & Ungkusonmongkol, 2025). Similarly, chicken sausages with a mixture of plant-based additives demonstrated a progressive elevation in peroxide values until the fifteenth day of storage (Das et al., 2025). Duck meat nuggets with 2% black garlic powder also exhibited increasing peroxide values during 30 days of storage, due to the oxidation of lipid within the meat, microbial activity, and oxidative rancidity (Lishianawati & Yusiati, 2022).

*The Effect of Different Storage Periods on the Sensory Quality of Sausages*

The sensory attributes of spent hen meat sausages incorporating BBF across various storage durations statistically significant impact ( $P < 0.01$ ) on all sensory parameters, delineated in Figure 3. During 21 days of storage, the average sensory scores decreased significantly, as indicated by reduced aroma intensity, lower color scores, weakened texture, and declining panelist acceptance with longer storage duration.

A significant reduction in aroma scores ( $P < 0.01$ ) was observed in sausages stored for 21 days. This

decline may be due to lipid oxidation, which produces aldehydes and ketones that negatively affect product aroma (Śmiecińska et al., 2021). Similar reductions in aroma were reported by Santos et al. (2022), meat products with pumpkin flower powder showed decreased aroma during cold storage due to rancidity. Beef patties containing clove extract exhibited no significant changes throughout the storage period (Zahid et al., 2018).



**Figure 3.** Sensory quality of spent hen sausage during different storage periods

Color scores of spent hen meat sausages were also significantly lower ( $P < 0.01$ ) during 21 days of storage, with average values ranging from 2.68 to 3.24. This reduction may be linked to the presence of anthocyanin pigments, which impart a darker color to sausages (Kaewjumpol et al., 2021) but are unstable during processing and storage (Nthimole et al., 2024). Moreover, the decline in color quality is associated with lipid oxidation and microbial processes (Wang et al., 2021), resulting in darker sausage appearance that lowers panelist preference. Fu et al. (2022) observed a decrease in color scores of Jiangsu-type sausages supplemented with cherry powder during storage, and Maillard-Berdeja et al. (2022), who observed reduced color intensity in sausages with pomegranate peel flour due to pigment degradation and matrix changes.

A significant reduction ( $P < 0.01$ ) in texture scores was observed in spent hen meat sausages during storage, with values ranging from 3.20 to 4.28. This reduction may be attributed to the deterioration of the extracellular muscle matrix, instigated by microbial and endogenous enzymatic activity, which compromise the integrity of the protein gel structure and render the texture increasingly fragile (Cheng, 2020). Consequently, panelists rated texture less favorably. Comparable findings were presented by Choton et al. (2021), the decreased texture scores in meat nuggets with

chickpea flour and green leaf powder during storage, and Habib et al. (2018), who observed reduced texture in buffalo meat nuggets with pomegranate peel powder due to water loss, protein denaturation, and muscle fiber degradation during cold storage.

Storage duration significantly affected the overall acceptance of spent hen meat sausages ( $P < 0.01$ ). Panelists considered sausages stored up to 7 days acceptable, while those stored for 21 days were rated less favorably. This was attributed to increasingly fragile texture, darker and less fresh color, and noticeable aroma deviations in sausages stored. Fu et al. (2022), who reported decreased overall acceptance scores in Jiangsu-type sausages with cherry powder during 30 days of storage.

## Conclusion

Addition of 3% BBF allowed spent hen sausages to remain safe for consumption up to 21 days of cold storage, with total plate counts ( $< 1.87 \log \text{CFU/g}$ ) and peroxide values ( $< 2.5 \text{ meq/kg}$ ) still meeting SNI standards. However, physical and sensory qualities (texture softening, color darkening, aroma decline) deteriorated over time, with the best sensory acceptance observed at 7 days. Thus, BBF extended shelf life within safety limits, although quality gradually decreased.

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## Author Contributions

Conceptualization, H.E. and A.S.; methodology, I.W.N.; software, M.R.; validation, H.E., and A.S.; formal analysis, M.R.; investigation, P.P.R.; resources, M.R.; data curation, P.P.R.; writing—original draft preparation, M.R.; writing—review and editing, M.R.; visualization, I.W.N.; supervision, H.E.

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## Conflicts of Interest

The authors declare no conflict of interest.

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