



ENSURING STABILITY OF BEEF LIVER-MEAT PASTE QUALITY DURING ITS STORAGE

Shafa N. Hayati, Tuti Suryati*, Astari Apriantini
IPB University, Bogor, Indonesia

Keywords: Antioxidant, malondialdehyde, microbiological, beef liver paste, storage

Abstract

Beef liver-meat paste was a diversified ready-to-eat food product. Packaging, storage temperature, and storage duration were important factors to consider in assessment of ready-to-eat food products quality. The study was aimed to analyze the stability of malondialdehyde (MDA) content, antioxidant activity, and microbiological quality of beef liver-meat paste packaged in retort pouches during its storage. The spices used in this study is stew seasoning spices mixture with the addition of apple. The liver and meat are cooked with stew spices for 20 minutes at 70–75 °C, then pureed with the apples for 5 minutes in a food processor, and then packaged in a retort pouch, sterilized using an autoclave at 110 °C for 5 minutes. The product was stored at chilled and frozen temperatures for 14 days. This study was designed using a completely randomized design (CRD) with a 2×3 factorial pattern, consisting of two different temperatures and three different storage durations, with three production periods. Using of antioxidant-rich spice seasonings in beef liver-meat paste products in retort pouch packaged and stored under chilled and frozen conditions effectively ensures food product quality stability; this is evidenced by MDA content that remains below the rancidity threshold, sustained high antioxidant activity, and microbiological quality remaining within safe limits throughout the storage period.

For citation: Hayati, S. N., Suryati, T., Apriantini, A. (2026). Ensuring stability of beef liver-meat paste quality during its storage. *Theory and Practice of Meat Processing*, 11(3), 287–297. <https://doi.org/10.21323/2414-438X-2026-11-3-287-297>

Acknowledgements:

The authors express sincere appreciation and gratitude to the Division of Animal Products Technology, Department of Animal Production and Technology, Faculty of Animal Science, IPB University for providing laboratory facilities and assistance during the research.

Introduction

In general, the nutritional content of beef liver does not significantly differ from that of beef. 100 g of beef contains 19 g of protein and 2.5 g of fat, while 100 g of beef liver contains 19.8 g of protein and 4.2 g of fat. Beef is a source of high-quality animal protein and contains a complete range of essential amino acids. Beef liver contains many vitamins such as vitamin B complex, vitamin A, vitamin B12, and folic acid [1]. Beef liver and meat contain iron that can cover human iron needs to prevent anemia. Anemia is a disease caused by a lack of iron in the body. The form of iron that is easily absorbed by the body is found in animal protein, namely heme iron [2]. Therefore, consuming beef liver and meat can help prevent anemia. However, not everyone likes beef liver because of its bitterish taste.

Processing beef liver into pasta is one way to diversify beef liver products and attract public interest to consuming beef liver. Pasta is a processed food product made from finely or coarsely chopped meat and fat along with various herbs and spices added. It can be served as a main dish or side dish [3]. Beef liver-meat pasta can be prepared using various types of spices, including stew seasoning and curry seasoning as used in this study. Spices are used to enhance the flavor of the beef liver-meat pasta and thus mask the bitterish taste of beef liver. The addition of beef meat and fruits to pasta improves the texture of the pasta. Pasta fea-

tures a variety of textures, ranging from smooth and soft to coarse and dense. Diversification of beef liver pasta products has the potential to become a food product with high nutritional value. Beef liver pasta can be served as a side dish for the toddlers and adults. Its smooth texture makes it easy for toddlers to chew and digest, and it can be served as a spread on bread. For people with anemia, consuming beef liver-meat pasta can help meet the body's iron needs.

The processing of beef liver-meat paste involves high temperatures, which can trigger lipid oxidation reactions that produce MDA, a toxic compound. Lipid oxidation can occur during both processing and storage. Factors such as temperature, storage duration, and exposure to light and oxygen can accelerate the oxidation process. Extensive lipid oxidation can alter texture, flavor, and color, thereby reducing product quality. MDA content directly correlates with the degree of rancidity in a food material. The higher the MDA content, the greater the degree of rancidity [4,5]. MDA content levels in a product serve as indicators of the intensity of lipid oxidation, product rancidity, and overall product quality and safety [6]. According to [4], factors influencing the rate of oxidation reactions in food products include the chemical structure of the lipids included, the amount and type of oxygen under storage conditions, storage temperature, packaging material properties, and the presence of antioxidant compounds. Antioxidant

compounds can prevent the formation of free radicals in lipid oxidation. Therefore, the presence of antioxidant compounds is crucial in food products, but antioxidant compounds can also act as pro-oxidants. Processing and storage can also affect antioxidant activity [7]. Natural sources of antioxidant compounds are found in spices such as cinnamon, star anise, cloves, nutmeg, garlic, turmeric, and bay leaf [8].

Processed meat products are classified as highly perishable foods, which means that they are exposed to high risk of spoilage. Changes in and the deterioration of product quality can be influenced by storage temperature. Higher storage temperatures accelerate microbial growth and chemical reactions, whereas lower temperatures reduce the rate of quality degradation, thereby extending the product's shelf life [9,10]. Optimal storage temperatures for meat and meat products are within from 0°C to 5°C for a three-day storage period up to one week long. Storage at freezing temperatures (−18°C) prevents microbiological spoilage and slows down the rates of enzymatic and chemical reactions [11]. Although low storage temperatures can inhibit microbial growth and extend shelf life, hygiene and safety standards must still be maintained during the product processing stage.

In addition to storage temperature, packaging methods can also reduce product damage during storage. Food product packaging is used to extend the product's shelf life and prevent damage, thereby maintaining product safety [12]. Retort pouches are flexible, pouch-shaped packaging which are commonly used for packaging the ready-to-eat food products. Retort pouch packaging has a layered structure with an outer layer made of polyethylene terephthalate (PET), a middle layer of nylon, an aluminum foil barrier layer, and a polyolefin as a sealing layer [13].

Beef liver paste packaged in retort pouches is one way of diversification of ready-to-eat food products. Storage temperature and duration are important factors to consider in ready-to-eat food products. Several studies on processed pasta have been conducted abroad, such as [14] using beef liver; [15] using pork liver; [16] using a mixture of beef liver, meat, pork heart, and pork meat; and [17] using lamb liver and fat, but these studies only conducted sensory, physicochemical, and microbiological analyses of the processed pasta. Research on processed pasta in Indonesia is not yet widely reported. This study analyzed the stability of beef liver-meat paste product packaged in retort pouches during storage at various temperatures by examining MDA content, antioxidant activity, and microbiological quality.

Objects and methods

Materials

Liver and meat in this study were obtained from the knuckles of Brahman cross-breed cattle and were bought from a meat supplier in Bogor, West Java. The ingredients

used for the production of stew seasoning were bought from a local market in Indonesia.

Materials and seasoning preparation

The stew and curry seasoning formula used was the result of a trial-and-error method on the pre-research stage using a limited number of panelists; each ingredient was weighed in ratio based on the weight of liver and meat used. The spicy stew seasoning is made by grinding garlic, shallots, galangal, and brown sugar with a blender (Phillips, PT. Phillips Indonesia) until everything is mixed together. The curry seasoning is made by grinding garlic, shallots, red chili, turmeric, and candlenut. The liver is boiled in water with bay leaves for 5–10 minutes to remove the blood and the fishy smell. Further the liver and meat are cut and weighed into 175 grams each. The composition of the spice seasoning ingredients used is shown in Table 1.

Production of beef liver paste

The ground spices are sautéed using 28 g of cooking oil for 5 minutes, and then 300 ml of water is added. Next, the liver and meat are seasoned with bay leaves and star anise for stew seasoning; and bay leaves, lime leaves, cardamom, and lemongrass for the curry formula and cooked until the 10th minute. Other complementary ingredients, such as powdered spices and sweet soy sauce are added gradually until the 15th minute. The liver and meat are stirred periodically until the 20th minute, so that the stew spices are completely absorbed into meat and liver, and cooked with them. Overall, the liver and meat along with the spices are cooked for 20 minutes until cooked at an internal temperature of 70–75°C. The liver and meat are cooled at a chilled temperature (in refrigerator) for 10 minutes. The liver and meat along with the spices and added apple are pureed using a food processor for 5 minutes.

Packaging and storage

The beef liver paste was packaged in retort pouches (7×10 cm; RCPP, PA, PET, aluminium foil; 240 µm thickness) (Retort Packaging Store, Jakarta, Indonesia) and sterilized using an autoclave Hirayama HVE50 (Hirayama Manufacturing Corporation) at 110°C for 5 minutes. The product was stored at chilling (5°C) and freezing (−21°C) temperatures for 14 days. Sample analysis was conducted every 7 days for 14 days long, starting from day 0, day 7, and day 14.

Organoleptic test

Organoleptic testing comprised hedonic assessment and hedonic quality tests involving 30 semi-trained panelists-individuals who had received basic training or gained knowledge regarding organoleptic properties testing and who had prior experience in such evaluations. The panelists were briefed on the sample attributes to be assessed and the testing procedures. Beef liver-meat paste samples were served in tasting booths in the containers labeled with random numerical codes, and the paste was spread onto bread. The booths were also equipped with coffee powder and mineral water to neutralize odors and flavors

Table 1. Formula composition for beef liver-meat paste using stew seasoning and curry seasoning

Ingredients	Formulas							
	SA		SN		CA		CN	
	g	%	g	%	g	%	g	%
Malang apple	105	32.42	—	—	105	30	—	—
Honey pineapple	—	—	105	32.42	—	—	105	30
Garlic	16.8	5.19	16.8	5.19	80	22.86	80	22.86
Shallot	56	17.29	56	17.29	24	6.86	24	6.86
Salt	4	1.23	4	1.23	3	0.86	3	0.86
Galangal	17.6	5.43	17.6	5.43	—	—	—	—
Cinnamon powder	4.2	1.30	4.2	1.30	—	—	—	—
Star anise	3	0.93	3	0.93	—	—	—	—
Cloves powder	0.2	0.06	0.2	0.06	—	—	—	—
Palm sugar	10.5	3.24	10.5	3.24	—	—	—	—
Nutmeg powder	1.6	0.49	1.6	0.49	—	—	—	—
Pepper	1	0.31	1	0.31	—	—	—	—
Sweet soy sauce	102	31.49	102	31.49	—	—	—	—
Bay leaves	2	0.62	2	0.62	2	0.57	2	0.57
Lime leaves	—	—	—	—	2	0.57	2	0.57
lemongrass	—	—	—	—	10.5	3	10.5	3
Red chili	—	—	—	—	23	6.57	23	6.57
Turmeric	—	—	—	—	21	6	21	6
Coriander powder	—	—	—	—	17.5	5	17.5	5
Candlenut	—	—	—	—	41	11.71	41	11.71
Cumin powder	—	—	—	—	17.5	5	17.5	5
Cardamom	—	—	—	—	3.5	1	3.5	1
Total	323.9	100	323.9	100	350	100	350	100

Note: SA = stew seasoning with apple; SN = stew seasoning with pineapple; CA = curry seasoning with apple; CN = curry seasoning with pineapple. Formula composition for 175 g of beef liver and 175 g of beef meat. Percentages are calculated based on the total weight of ingredients used in each formula.

perception. The hedonic test was conducted by evaluating samples based on the panelists' degree of liking. The attributes assessed included color, texture, aroma, taste, and overall appearance, using a numerical scale of 1 to 4, where: 1 = strongly dislike; 2 = dislike; 3 = like; 4 = strongly like. The hedonic quality test was performed to evaluate the intensity of specific quality attributes of the samples, while the parameters of hedonic quality scales were assessed as follows:

Color	: 1) light grayish-brown, 2) light yellowish-brown, 3) moderately dark brown, 4) dark brown
Texture	: 1) very coarse, 2) moderately coarse, 3) smooth, 4) very smooth
Spices aroma	: 1) very weak, 2) weak, 3) strong, 4) very strong
Fishy aroma	: 1) very weak, 2) weak, 3) strong, 4) very strong
Iron-like aroma	: 1) very weak, 2) weak, 3) strong, 4) very strong
Taste of liver	: 1) very weak, 2) weak, 3) strong, 4) very strong
Spreadability	: 1) very difficult, 2) difficult, 3) easy, 4) very easy

Analysis of MDA content

MDA content analysis was carried out using the thio-barbituric acid reactive substances (TBARS) content. A 10 g sample was homogenized with 50 mL of distilled water containing 0.1% propyl gallate (PG) and 0.1% ethylenediamine tetraacetate (EDTA) for 1 minute. The mixed solution was transferred into a distillation tube by washing with the previous mixed solution and adding 47.5 mL of

distilled water containing 0.1% PG and 0.1% EDTA. The mixed solution was acidified with 2.5 mL of HCl solution with a ratio of 1:2 of HCl solution, and 5 drops of anti-foaming agent were added. The mixture was then distilled until the volume reached 50 mL in each distillation. A total of 5 mL of distillate was mixed with 5 mL of 0.02 M TBA solution, incubated at 100 °C for 40 minutes and then cooled down to room temperature. Absorbance was measured using a spectrophotometer (UV-Vis 8453, Agilent, USA) at a wavelength of 532 nm in duplicate for each sample. TBARS values were expressed in mg of MDA content per one kg of the sample using TEP as a standard.

Analysis of antioxidant activity and antioxidant capacity

A 1 g sample was placed in a test tube and extracted using 2.5 mL of 100% methanol at room temperature for 24 hours. The sample solution was then filtered. The filtrate was separated in another tube and 2.5 mL of methanol was added. The first filtrate was stored for 24 hours at –25 °C in a closed tube. After 24 hours, the filtrate from the second filtration was separated and mixed with the previous day's filtrate in a 10 mL volumetric flask and methanol was added until the volume of the volumetric flask reached 10 mL. The extract was stored at –25 °C before analysis. A total of 0.15 mL of the sample extract was mixed with 0.9 mL of 0.1 mM DPPH (2,2-diphenyl-1-picrylhydrazyl) solution and placed in a microtube to react for 2 minutes at room

temperature. The standard reference absorbance was obtained from the reaction of 0.9 mL of DPPH solution in 0.1 mM methanol with 0.15 mL of vitamin C, which was left for 20 minutes at room temperature. The absorbance of the standard reference and sample solutions was measured using a spectrophotometer (UV-Vis 8453, Agilent, USA) at a wavelength of 517 nm. Antioxidant capacity was assessed from the conversion results of %SA (scavenging activity) based on the standard curve. The antioxidant capacity was expressed in units of mg equivalent of vitamin C 100 g⁻¹ of beef liver-meat paste (mgEVC 100 g⁻¹).

Analysis of total microbes

25 grams of the sample was weighed and then placed into a sterile container. 225 mL of 0.1% buffered peptone water (BPW) solution was added to the sterile container and then homogenized by vortex for 1 minute to achieve a 10⁻¹ dilution. A total of 1 mL of the 10⁻¹ dilution suspension was transferred into 9 mL of BPW solution to achieve 10⁻² dilution. Dilution was carried out up to achieving 10⁻⁵. A total of 1 mL of suspension from each dilution from 10⁻³ to 10⁻⁵ was put into a petri dish in duplicate, and 15 mL of plate count agar (PCA) that had been cooled to 45°C was added to each petri dish. The suspension solution and PCA media were mixed by rotating the petri dish (Oxoid, Oxoid Ltd.) in 8-shaped movement trajectory and then left to settle down and solidify. The petri dish was incubated at 37°C for 48 hours by placing the dish in an inverted position.

Analysis of *Staphylococcus aureus*

25 grams of the prepared sample was weighed and taken, then put into 225 mL of 0.1% BPW solution to obtain a dilution of 10⁻¹. A total of 1 mL of suspension from the 10⁻¹ dilution was transferred into 9 mL of BPW for a dilution of 10⁻². Dilution was carried out up to 10⁻³. All dilution samples were taken 1 mL each and placed into a petri dish in duplicate, then added 15 mL of bisphenol A (BPA) media (Oxoid CM0275, Oxoid Ltd.) containing 5% egg yolk (Himedia, HiMedia Laboratories Pvt. Ltd.). The suspension solution and media were homogenized by rotating them in 8-shaped movement trajectory and left to settle down and solidify. The Petri dish was incubated at 37°C in an inverted position for 24 hours. *S. aureus* colonies were colored gray to blackish with a white colony edge and surrounded by a bright area.

Analysis of *Escherichia coli*

25 grams of the prepared sample was weighed and taken, then put into 225 mL of 0.1% BPW solution to obtain a dilution of 10⁻¹. A total of 1 mL of suspension from the 10⁻¹ dilution was transferred into 9 mL of BPW for achieving a dilution of 10⁻². Dilution was carried out up to 10⁻³. All dilution samples were taken 1 mL each and put into a petri dish in duplicate, then added 15 mL of EMBA (Himedia, HiMedia Laboratories Pvt. Ltd.) liquid media. The suspension solution and EMBA media were homogenized by rotating them in 8-shaped movement trajectory and left

to settle down and solidify. The Petri dish was incubated at 37°C in an inverted position for 24 hours. Colonies that appeared metallic green in EMBA media were counted as *Escherichia coli* colonies.

Analysis of *Salmonella*

25 grams of the prepared sample was weighed and taken, then put into 225 mL of 0.1% BPW solution to obtain a dilution of 10⁻¹. A total of 1 mL of suspension from the 10⁻¹ dilution was transferred into 9 mL of BPW for a dilution of 10⁻². Dilution was carried out up to achieving 10⁻³. All dilution samples were taken 1 mL each and placed into a petri dish in duplicate, then 15 mL of XLDA (Himedia, HiMedia Laboratories Pvt. Ltd.) liquid media was added. The suspension solution and XLDA media were homogenized by rotating them in 8-shaped figure movement trajectory and left to settle down and solidify. The Petri dishes were incubated at 37°C in an inverted position for 24 hours. Colonies that appeared red with a blackish center were counted as *Salmonella* sp. colonies.

Experimental design and data analysis

The study was designed using a completely randomized design (CRD) with a 2×3 factorial pattern consisting of two different temperatures (chilled and frozen) and three different storage times (0 day, 7 days, and 14 days) with three production periods. The data were analyzed using analysis of variance (ANOVA) to determine the effect of the combined factor, and the differences in means were analyzed using the Tukey test.

Results and discussion

Optimization of beef liver-meat paste properties

Organoleptic testing was conducted to evaluate food product characteristics using human senses. The organoleptic characteristics of beef liver-meat paste were assessed through a hedonic test. The hedonic test was performed to measure the panelists' degree of liking for the product based on the sensory attributes evaluated. The results of the hedonic test for beef liver-meat paste indicated that the use of different formulas had a significant effect ($p \leq 0.05$) on the sensory attributes (Table 2).

Table 2. The hedonic test scores of beef liver-meat paste using different formulas

Parameters	Formulas			
	SA	SN	CA	CN
Color	3.3 ± 0.71 ^a	2.7 ± 0.84 ^{bc}	2.4 ± 0.72 ^{bcd}	2.3 ± 0.69 ^{cd}
Texture	3.1 ± 0.57 ^a	2.9 ± 0.80 ^a	2.4 ± 0.81 ^{bc}	2.7 ± 0.96 ^{ac}
Aroma	3.1 ± 0.48 ^a	2.9 ± 0.87 ^{ab}	3.2 ± 0.89 ^a	2.6 ± 0.97 ^b
Flavor	3.2 ± 0.66 ^a	2.8 ± 0.89 ^a	2.9 ± 0.82 ^a	2.0 ± 0.81 ^b
Overall appearance	3.1 ± 0.68 ^a	2.8 ± 0.81 ^{ab}	2.5 ± 0.86 ^{bc}	2.2 ± 0.83 ^c

Note: SA = stew seasoning with apple; SN = stew seasoning with pineapple; CA = scurry seasoning with apple; CN = curry seasoning with pineapple. The scale for variable tested ranged from 1 to 4 (1 = strongly dislike, 2 = dislike, 3 = like, 4 = strongly like). Values within the same row followed by different superscripts indicate significant differences ($p \leq 0.05$).

The beef liver-meat paste formulated with stew seasoning and added apple achieved the highest hedonic test scores across all sensory attributes compared to the other formulations, thus making it the most preferred beef liver-meat paste among the panelists. Hedonic quality testing was conducted to identify the intensity of the product's sensory characteristics. The results of the hedonic quality test on beef liver-meat paste indicated that the use of different formulas had a significant effect ($p \leq 0.05$) on the attributes of color, texture, spice aroma, iron aroma, characteristic liver flavor, and spreadability, but did not significantly affect the fishy aroma attribute (Table 3).

Table 3. The hedonic quality test scores for beef liver-meat paste using different formulas

Parameters	Formulas			
	SA	SN	CA	CN
Color	3.3 ± 0.64 ^a	3.7 ± 0.61 ^b	2.1 ± 0.52 ^{cd}	2.0 ± 0.49 ^{cd}
Texture	2.3 ± 0.75 ^a	3.1 ± 0.73 ^{bd}	1.8 ± 0.68 ^c	3.3 ± 0.64 ^{bd}
Spice aroma	2.7 ± 0.76 ^a	2.7 ± 0.98 ^{abc}	3.4 ± 0.68 ^c	3.2 ± 0.76 ^{bc}
Fishy aroma	2.4 ± 0.89	2.2 ± 0.82	1.9 ± 1.03	2.0 ± 0.76
Iron-like aroma	2.4 ± 0.89 ^a	2.3 ± 0.99 ^a	1.8 ± 0.87 ^{bc}	1.9 ± 0.78 ^{ac}
Taste of liver	3.1 ± 0.64 ^a	3.2 ± 0.81 ^a	2.2 ± 0.73 ^{bc}	2.2 ± 0.89 ^{bc}
Spreadability	2.7 ± 0.66 ^a	3.4 ± 0.73 ^{bd}	1.6 ± 0.77 ^c	3.4 ± 0.81 ^{bd}

Note: SA = stew seasoning with apple; SN = stew seasoning with pineapple; CA = curry seasoning with apple; CN = curry seasoning with pineapple. The scale for each tested variable ranges from 1 to 4. Color: 1) light grayish-brown, 2) light yellowish-brown, 3) moderately dark brown, 4) dark brown; Texture: 1) very coarse, 2) moderately coarse, 3) smooth, 4) very smooth; Spice aroma: 1) very weak, 2) weak, 3) strong, 4) very strong; Fishy aroma: 1) very weak, 2) weak, 3) strong, 4) very strong; Iron-like aroma: 1) very weak, 2) weak, 3) strong, 4) very strong; Taste of liver: 1) very weak, 2) weak, 3) strong, 4) very strong; Spreadability: 1) very difficult, 2) difficult, 3) easy, 4) very easy. Values within the same row followed by different superscripts indicate significant differences ($p \leq 0.05$).

Color is the first sensory attribute observed by the panelists when evaluating a product and can attract consumer interest. The use of different formulas had a significant effect ($p \leq 0.05$) on the panelists' preference for the color of beef liver-meat paste (Table 2). The color of beef liver-meat paste made with stew seasoning formula was preferred over that made with the curry seasoning formula. Based on the hedonic quality test, the use of different formulas also had a significant effect ($p \leq 0.05$) on the color of beef liver-meat paste (Table 3). Beef liver-meat paste using stew seasoning with the addition of apple or pineapple exhibits a moderately dark brown color. The use of cinnamon, palm sugar, and sweet soy sauce triggers a Maillard reaction involving reducing sugars and amino acids from meat proteins during heating which results in emerging a dark brown color [18,19]. Beef liver-meat paste using curry seasoning with the addition of apple or pineapple displays a light yellowish-brown color. This is attributed to the curcumin compound in turmeric, which provides a yellow pigment [20], thereby influencing the color of beef liver-meat paste.

Texture can indicate a product's characteristic and influence the level of consumer's acceptance. Using of various formulations provided a significant effect ($p \leq 0.05$) on

panelists' preference for the color of beef liver-meat paste (Table 2). Regarding texture, beef liver-meat paste using stew seasoning spices with added apple or pineapple, and curry seasoning spices with added pineapple was preferred by panelists over the meat paste version with curry seasoning and added apple. Based on the hedonic quality test, using of various formulas also provided a significant effect ($p \leq 0.05$) on the texture of beef liver-meat paste (Table 3). The addition of fruit into the seasoning formula provides for distinct textural characteristics. Adding apple to stew or curry seasoning results in a slightly coarser texture, whereas adding pineapple ensures a smooth texture. Apple fiber is rich in pectin, which binds water more stably, helps maintain structure through gel formation, and reinforces the protein network; this results in a paste product with a texture that is slightly coarse, dense, and stable [21]. Pineapple contains bromelain, a proteolytic enzyme capable of degrading myofibrillar proteins and collagen in meat. Bromelain hydrolyzes myofibrillar proteins such as myosin and actin as well as connective tissue into small-molecule peptides and amino acids, thereby increasing tenderness and reducing meat toughness [22].

Aroma is a key factor in determining consumer's acceptance of a product. A pleasant aroma can attract consumer's attention. Using of various formulations provided a significant effect ($p \leq 0.05$) on the panelists' liking scores for the aroma of beef liver-meat paste (Table 2). Beef liver-meat paste cooked with using stew and curry seasonings with added apple obtained higher liking scores than the formulations with added pineapple. Based on the hedonic quality test, using of various formulas also had a significant effect ($p \leq 0.05$) on the spice aroma and iron-like aroma of beef liver-meat paste, though no significant difference was observed regarding the fishy aroma (Table 3). The beef liver-meat paste exhibited a faint fishy aroma, a strong spice aroma, and a faint iron-like aroma. The strong spice aroma in all seasoning formulas effectively masked the fishy aroma of the beef liver. Curry seasoning with the addition of either apple or pineapple produced a spice aroma rated as stronger than the stew seasoning. This result may be attributed to the greater variety of spices used in the curry seasoning compared to the stew seasoning, such as lime leaves, lemongrass, cardamom, coriander, cumin, and turmeric. These spices contain essential oils and volatile compounds that impart a strong spice aroma capable of masking fishy and iron-like odors [23]. The characteristic aromas of lime leaves, lemongrass, coriander, cardamom, and cumin are derived from essential oil constituents such as citronellal, citronellol, linalool, geraniol, α -terpineol, and β -pinene. These compounds volatilize readily at room temperature, thereby generating a stronger and more distinctive aroma during processing [23–25].

Flavor is perceived through oral stimulation. Changes in the texture or viscosity of a food product can alter its flavor by affecting the stimulation of receptor cells. Using of various formulations provided a significant effect

($p \leq 0.05$) on the panelists' liking scores for the flavor of the beef liver-meat paste (Table 2). The stew seasoning formula with added apple and pineapple, as well as the curry seasoning formula with added apple obtained liking scores that did not differ significantly from the "like" score; however, they differed significantly from the curry seasoning formula with added pineapple, which received a "dislike" score. Based on the hedonic quality test, using of various formulas also provided a significant effect ($p \leq 0.05$) on the taste of liver of beef liver-meat paste (Table 3). The stew seasoning differed significantly from the curry seasoning. The stew seasoning exhibited a strong characteristic liver flavor, whereas the curry formula displayed a weaker one. According to [26], liver possesses savory, metallic, and slightly bitter flavor notes derived from its iron and high lipid content, which can influence consumer's acceptance. This taste of liver can be mitigated by incorporating spices into the seasoning formula. The stew seasoning imparts a sweetness derived from palm sugar and sweet soy sauce. In contrast, the curry formula offers a more complex flavor profile due to the use of a wider variety of spices, thus resulting in a stronger spiced taste that effectively reduces the intensity of the peculiar liver flavor. The use of spices and the addition of fruit help reduce the peculiar flavor of liver and improve consumer's acceptance.

Spreadability refers to the ease with which beef liver-meat paste can be spread onto the food surface, such as the bread used in the testing. Based on the hedonic quality test, using of various formulas also provided a significant effect ($p \leq 0.05$) on the spreadability of beef liver-meat paste (Table 3). Beef liver-meat pastes that were cooked using stew seasoning and curry seasonings with the addition of pineapple exhibited high spreadability properties, as they were easy to spread, whereas formulas with the same seasonings but containing apple exhibited low spreadability, thus making them difficult to spread. The spreadability of beef liver-meat paste can be influenced by the type of fruit added to the formula; the addition of pineapple to the paste made it easier to spread due to the fruit's higher water content which is 90 % [27] compared to apple 84 % [28]. Furthermore, pineapple contains bromelain, an enzyme that breaks down connective tissue, thereby reducing the meat's water-binding capacity and this way resulting in a more tender, easily disintegrated texture [22]. In contrast, apples contain pectin, which enhances the meat's water-binding capacity and helps maintain structural integrity through gel formation, this way resulting in a denser meat texture [21].

Overall appearance is an attribute that characterizes the general quality of the product. The results indicate that using the various formulations significantly influenced ($p \leq 0.05$) panelists' preferences regarding the overall appearance of beef liver-meat paste (Table 2). Overall, the stew seasoning formulations whether with added apple or pineapple, received higher scores (indicator "like") compared to the curry seasoning formulations with added ap-

ple or pineapple, which received scores indicating "dislike." These findings suggest that the stew seasoning formulations, with either apple or pineapple additions, successfully enhanced panelists' appeal regarding the sensory attributes in question, thus resulting in product acceptance. This aligns with the hedonic test results showing that beef liver-meat paste that was cooked with using stew seasoning along with added apple or pineapple also achieved higher scores for other sensory attributes, such as color, texture, aroma, and taste.

Beef liver-meat paste

Based on the hedonic test results, beef liver-meat paste cooked with using stew seasoning with added apple exhibited the highest hedonic scores compared to the other formulations (Table 2). This specific formulation was selected as the best and was subsequently used for the packaging stage where retort pouches were used, and was put for storage under chilled and frozen conditions for 14 days. A retort pouch is a flexible package commonly used for ready-to-eat food products. The packaging features a multi-layered structure consisting of an outer polyethylene terephthalate (PET) layer, a nylon middle layer, an aluminum foil barrier layer, and a polyolefin sealing layer. This layered structure enables a shelf life of up to three years for the packaged food when stored at 27 °C [13].

Beef liver-meat paste is prepared using a stew seasoning spice formula with the addition of apples. It features a dark brown color and a coarse, dense texture (Figure 1). The stew seasoning spice contributes to the dark brown color through brown sugar, cinnamon, and sweet soy sauce in the seasoning. During cooking, brown sugar reacts with heat, and a Maillard reaction occurs between the carbonyl groups of reducing sugars and the amino groups of meat proteins and amino acids, thus resulting in a dark brown color [19]. Cinnamon contains cinnamaldehyde components that enhance aroma, color, and flavor. Cinnamon bark is rich in antioxidant compounds, sugars, and coumarins that can produce a brown color, so more cinnamon makes the food color darker [18]. Apples are a source of fiber containing cellulose, hemicellulose, lignin, and pectin



Figure 1. Appearance of beef liver-meat paste using stew seasoning with the addition of apple

that improve texture. Apple fiber, which is rich in pectin, increases water-binding capacity, strengthens the structure through gelation, and stabilizes the protein network, thus resulting in a denser paste [21].

MDA content of beef liver-meat paste during storage

Malondialdehyde is a by-product of lipid oxidation that is used as a marker of lipid oxidation level in meat [29]. Lipid oxidation results in rancidity and a deterioration in nutritional quality, color, flavor, texture, and food safety. Liver paste is considered a product susceptible to oxidation due to its high fat and iron content, while the manufacturing processes such as grinding and heating can also affect lipid oxidation in the product [30]. The beef liver — meat paste in retort pouch packaging showed that the storage temperature and storage duration treatments did not provide a significant effect on the MDA content (Table 4). The MDA content during storage tended to decrease from 0.80 mg kg⁻¹ to 0.33 mg kg⁻¹ at chilled temperature and 0.43 mg kg⁻¹ at frozen temperatures.

Table 4. MDA content of beef liver-meat paste during storage (mg kg⁻¹)

Storage temperature	Storage duration (days)		
	0*	7	14
Chilled (5 °C)	0.80 ± 0.08	0.59 ± 0.13	0.33 ± 0.06
Frozen (-21 °C)		0.51 ± 0.10	0.43 ± 0.16

Note: *) Day 0 measurement result was taken as an initial reference value.

Research by [31] reported that the threshold level of MDA associated with detectable rancid odor is less than 2.28 mg kg⁻¹. The MDA content of beef liver–meat paste during storage (Table 4) remained below 0.80 mg kg⁻¹, so no rancid odor was produced. The stability of MDA content in beef liver–meat paste during its storage up to the 14th day may be attributed to the various spices used in the stew seasoning formulation and the addition of apples, which provide antioxidant compounds. Spices are the natural antioxidant sources rich in phenolic acids, flavonoids, alkaloids, and tannins that can inhibit lipid oxidation [16]. Antioxidant compounds in processed products also play a crucial role in maintaining quality stability by protecting against oxidation reactions during the sterilization process [32]. Research by [33], reported that processed meat products such as sausages enriched with senduduk leaves exhibited MDA contents ranging from 1.01 to 2.10 mg kg⁻¹ when stored at room temperature for up to 10 hours. These low MDA contents are attributed to the phenolic compounds in the senduduk leaf extract, which act as antioxidants and thereby prevent increased oxidation.

Another factor contributing to the stability of MDA content in beef liver-meat paste product is the using of retort pouch packaging, which helps inhibit oxidation reactions by reducing oxygen concentration and light exposure. Retort pouches utilize a vacuum system to inhibit oxidation by lowering oxygen levels, while aluminium foil layer protects the product from light exposure. During the propaga-

tion phase of oxidation, oxygen reacts with alkyl radicals to form peroxy radicals and acts as a source of reactive oxygen species, whereas light promotes the initiation phase via photo-oxidation. The use of vacuum packaging and aluminium foil as barrier layer helps maintain lipid oxidation stability [4]. These findings align with the research by [32], reported that MDA contents of buffalo meat packed in retort pouches ranged from 0.24–0.98 mg kg⁻¹ during storage. The three-layer structure of the retort pouch inhibits oxygen permeability, and vacuum sealing slows down the oxidation process. Additionally, antioxidant compound within the processed product contribute to oxidation stability during food sterilization [32].

Antioxidant activity of beef liver — meat paste during storage

Antioxidants are the compounds that can inhibit or prevent the oxidation process in food so that it does not cause rancidity/damage. DPPH radical scavenging activity measures the ability of the formulas ingredients to inhibit oxidation during the processing of beef liver-meat paste. Antioxidant capacity measures the overall antioxidant potential of the compounds within the sample being analyzed. A higher percentage of DPPH radical scavenging activity indicates a higher antioxidant capacity, signifying a greater ability of the formula to inhibit oxidation. Using of antioxidant-rich spices in the seasoning helps prevent the formation of MDA content resulting from lipid oxidation. The beef liver-meat paste in retort pouch packaging showed that the storage temperature and storage duration treatments did not provide a significant effect on DPPH radical scavenging activity and antioxidant capacity (Table 5), meaning that the antioxidant activity of beef liver-meat paste remained stable during its storage.

Table 5. Antioxidant activity of beef liver-meat paste during its storage

Storage temperatures	Storage duration (days)	Parameters	
		DPPH radical scavenging activity (%)	Antioxidant capacity (mgEVC 100 g ⁻¹)
Chilled (5 °C)	0*	71.67 ± 1.60	459.74 ± 15.35
	7	68.72 ± 2.50	450.02 ± 17.22
	14	63.66 ± 5.24	413.16 ± 30.43
Frozen (-21 °C)	0*	71.67 ± 1.60	459.74 ± 15.35
	7	70.71 ± 7.45	457.52 ± 46.42
	14	66.49 ± 8.34	439.11 ± 51.47

Note: *) Day 0 measurement result was taken as an initial reference value.

Based on [34], antioxidant capacity is divided into four categories, in particular: very high (>500 mg EVC g⁻¹), high (>200–500 mg EVC g⁻¹), moderate (100–200 mg EVC g⁻¹), and low (<100 mg EVC g⁻¹). The antioxidant capacity of beef liver paste during storage until the 14th day is included in the high category, at chilled temperatures ranging from 459–413 mgEVC g⁻¹ and frozen temperatures ranging from 459–439 mgEVC g⁻¹. The relation of the antioxidant activity data of beef liver-meat paste to

the levels of MDA formed indicates that the antioxidant components within the paste effectively inhibit lipid oxidation during the product heat treatment process. The quality stability of beef liver-meat paste during storage is effectively ensured by the retort pouch packaging, storage temperature, and the antioxidant components present in the product. These findings align with research by [35], reported that using the natural antioxidants in chicken meatballs significantly reduced lipid oxidation and kept MDA content level below 1 mg kg^{-1} . Using the natural antioxidants is an effective strategy for preventing oxidative deterioration, preserving product quality, and inhibiting rancidity development. The spices used in stew seasoning contain antioxidant compounds such as quercetin and allicin in garlic and shallots, pinene and eugenol in star anise, myricetin and catechin in nutmeg, eugenol and gallic acid in cloves, catechin and tannins in cinnamon, and piperine in pepper [8]. Stew spices with added apples contain various phenolic and flavonoid compounds that act as natural antioxidants. Phenolic compounds interact with reactive free radicals seeking partners by attacking and binding to the surrounding electrons, then donating electrons to the reactive free radicals, thus forming stable molecules. Therefore, MDA content depends on the concentration of phenolic compounds in the spices [36]. Research [37] also noted that light-impermeable vacuum retort pouch packaging helps maintain the stability of antioxidant activity and the product's nutritional quality.

Microbiological quality of beef liver-meat paste during storage

The beef liver-meat paste packed in retort pouch packaging showed that the storage temperature and storage duration treatments did not provide a significant effect in all microbiological parameters (Table 6). That indicates that beef liver-meat paste has stable microbiological quality during 14 days of storage under chilled (5°C) and frozen (-21°C) temperatures. Based on Food Standards Australia New Zealand (FSANZ)¹, the total plate count (TPC) of beef liver-meat paste indicates that the product maintained a microbiological status within an acceptable range for ready-to-eat (RTE) foods. The absence of *E. coli* and *Salmonella*, as well as *S. aureus* levels below the threshold limit ($< 2 \log \text{CFU g}^{-1}$), falls into the 'satisfactory' category according to FSANZ microbiological criteria for RTE food. The satisfactory category means the results are within expected microbiological levels (lower range) and present no food safety concern.

Total count of microbes and *S. aureus* in beef liver-meat paste decreased during storage, while *E. coli* and *Salmonella* were not detected at all. This proves that low-temperature storage can inhibit microbial growth and extend the prod-

uct's shelf life [38]. However, total microbes were still detected on the day 0 following the sterilization process. This may be attributed to heat-resistant thermophilic bacteria; consequently, the product requires rapid cooling after its sterilization to prevent bacterial re-growth [39]. According to [9], vacuum packaging can inhibit bacterial growth at as low temperatures as 4°C ; however, when the temperature reaches the optimum range of $30\text{--}37^{\circ}\text{C}$, microorganisms—particularly mesophilic bacteria can grow again.

Table 6. Microbiological quality of beef liver-meat paste during storage

Storage temperatures	Storage duration (days)	Parameters			
		TPC	<i>E. coli</i>	<i>S. aureus</i>	<i>Salmonella</i>
		(log CFU g ⁻¹)			
Chilled (5°C)	0*	5.40 ± 0.47	$<3/\text{g}$	2.62 ± 0.25	Negative/25 g
	7	5.03 ± 0.55	$<3/\text{g}$	2.61 ± 0.22	Negative/25 g
	14	4.74 ± 0.36	$<3/\text{g}$	2.41 ± 0.03	Negative/25 g
Frozen (-21°C)	0*	5.40 ± 0.47	$<3/\text{g}$	2.62 ± 0.25	Negative/25 g
	7	4.95 ± 0.96	$<3/\text{g}$	2.56 ± 0.28	Negative/25 g
	14	4.63 ± 0.41	$<3/\text{g}$	2.49 ± 0.16	Negative/25 g

Note: *) Day 0 measurement result was taken as an initial reference value.

Beef liver-meat paste packaged in the retort pouches under both chilled and frozen storage conditions showed no presence of *E. coli* and *Salmonella* throughout the 14-day storage period (Table 6). Sterilization was performed to ensure microbiological safety and storage stability. The sterilization process applied to food products packaged in the sealed pouches is effective in inactivating pathogenic bacteria and thus extending food shelf life [13]. The barrier properties of the aluminum foil layer and the sealing capabilities of the polyolefin in retort pouch packaging help maintain product sterility during storage time [40]. Research by [41], reported that goshtaba meatballs packaged in retort pouches maintained stable microbiological-safe quality during three months of their storage at 25°C after their sterilization at 121°C for 15 minutes, thus demonstrating the effectiveness of sterilization in extending the shelf life of meat and meat products.

In addition, spices and the addition of apples in beef liver-meat paste formulation also helped inhibit bacterial growth. Spices used in stew seasoning, such as garlic, shallots, bay leaves, nutmeg, cinnamon, and star anise, contain antibacterial compounds including flavonoids, saponins, tannins, quercetin, allicin, myristicin, and pectin [42–45]. Flavonoid compounds are able to inhibit microbial growth because they can form complex compounds with proteins, thereby disrupting bacterial cell membranes [46]. Cloves contain flavonoids, phenols, and eugenol, which exhibit antibacterial activity against *S. aureus*. Eugenol, a hydrophobic compound, can inhibit both Gram-positive and Gram-negative bacteria by penetrating the lipopolysaccharide layer of the cell membrane and this way damaging the cell structure [47]. Pepper contains antimicrobial

¹ Food Standards Australia New Zealand (FSANZ) 2025 «Compendium of Microbiological Criteria for Food». Canberra: Food Standards Australia New Zealand. Retrieved from <https://www.foodstandards.gov.au/sites/default/files/2025-08/Compendium%20of%20Microbiological%20Criteria%202025.pdf>. Accessed Sept 6, 2026.

compounds such as piperine, which is capable of lysing bacterial cells [48].

Conclusion

Beef liver-meat paste formulated with stew seasoning spices and apple was the most preferred food formulation based on its hedonic score, and was selected for its storage. Beef liver-meat paste packed in retort pouches during its storage maintained oxidative, antioxidant, and microbiological stability under both chilled (5 °C) and frozen (−21 °C) conditions. MDA content remained below the rancidity

threshold (<2.28 mg kg^{−1}). Antioxidant capacity remained in the high category (400–500 mg EVC 100 g^{−1}), ranging from 413–459 mg EVC 100 g^{−1} under chilled conditions storage and 439–459 mg EVC 100 g^{−1} under frozen conditions storage. Microbiological quality remained within safe limits regarding microbial contamination throughout the storage period. Using of antioxidant-rich seasonings in beef liver-meat paste products packed in retort pouch packaged and stored under chilled and frozen conditions effectively maintained the oxidative and microbiological quality of the food product for 14 days of its storage.

REFERENCES

1. Suryaningsih, L., Gumilar, J., Pratama, A. (2017). Response of beef liver percentageto beef sausage protein content, fat content and cooking suspension. *Jurnal Ilmu Ternak*, 17(2), 77–81. <https://doi.org/10.24198/jit.v17i2.15274> (In Indonesian)
2. McManus, L., Veras, K., Faria, V. S., Manninen, M., Egan, B. (2025). Effect of increasing red meat intake on iron status in adults with normal and suboptimal iron status: A systematic literature review and meta-analysis of intervention studies. *Nutrition Reviews*, 83(8), 1389–1401. <https://doi.org/10.1093/nutrit/nuaf016>
3. Porto-Fett, A. C. S., Shoyer, B. A., Shane, L. E., Osoria, M., Henry, E., Jung, Y. et al. (2019). Thermal inactivation of *Salmonella* in pâté made from chicken liver. *Journal of Food Protection*, 82(6), 980–987. <https://doi.org/10.4315/0362-028X.JFP-18-423>
4. Domínguez, R., Pateiro, M., Gagaoua, M., Barba, F. J., Zhang, W., Lorenzo, J. M. (2019). A comprehensive review on lipid oxidation in meat and meat products. *Antioxidants*, 8(10), Article 429. <https://doi.org/10.3390/antiox8100429>
5. Reddy, D. M., Reddy, G. V. B., Mandal, P. K. (2018). Application of natural antioxidants in meat and meat products — A review. *Food and Nutrition Journal*, 7(3), Article FDNJ-173. <https://doi.org/10.29011/2575-7091.100073>
6. Andre, Apriantini, A., Budiman, C. (2021). The effect of propolis extract as edible coating on chemical characteristics and antioxidant activity in beef during room temperature storage. *Jurnal Ilmu Produksi dan Teknologi Hasil Peternakan*, 9(2), 72–78. <https://doi.org/10.29244/jipthp.9.2.72-78> (In Indonesian)
7. Subroto, E., Cahyana, Y., Tensiska, Mahani, Filianty, F., Lembong, E. et al. (2021). Bioactive compounds in garlic (*Allium sativum* L.) as a source of antioxidants and its potential to improve the immune system: A review. *Food Research*, 5(6), 1–11. [https://doi.org/10.26656/fr.2017.5\(6\).042](https://doi.org/10.26656/fr.2017.5(6).042)
8. Yashin, A., Yashin, Y., Xia, X., Nemzer, B. (2017). Antioxidant activity of spices and their impact on human health: A review. *Antioxidants*, 6(3), Article 70. <https://doi.org/10.3390/antiox6030070>
9. Maulidina, R., Marlina, E. T., Utama, D. T. (2022). Microbiological quality of processed meat products sold online from MSMEs in Bandung City. *Jurnal Teknologi Hasil Peternakan*, 4(2), 83–100. <https://doi.org/10.24198/jthp.v4i2.47313> (In Indonesian)
10. Anggraeni, W., Lukman, H., Pramusintha, B. (2022). The effect of long storage and packaging methods on the physical properties of chicken meatballs in refrigerator (± 5 °C). *Jurnal Ilmiah Ilmu-Ilmu Peternakan*, 25(1), 91–99. <https://doi.org/10.22437/jiip.v25i1.12471> (In Indonesian)
11. Coombs, C. E. O., Holman, B. W. B., Friend, M. A., Hopkins, D. L. (2017). Long-term red meat preservation using chilled and frozen storage combinations: A review. *Meat Science*, 125, 84–94. <https://doi.org/10.1016/j.meatsci.2016.11.025>
12. Ropikoh, S., Widjayanti, W., Idris, M., Nuh, G. M., Fanani, M. Z. (2024). The development of food product packaging and storage technology. *Jurnal Ilmiah Pangan Halal*, 6(1), 30–38. <https://doi.org/10.30997/jiph.v6i1.12668> (In Indonesian)
13. Tripathi, S., Candlen, K., Froio-Blumsack, D., Ratto, J. A., Chen, W.-T., Peterson, A. M. (2026). Effect of food items and retort processing on the properties of multilayer packaging films. *Food Packaging and Shelf Life*, 55, Article 101758. <https://doi.org/10.1016/j.fpsl.2026.101758>
14. Shen, R., Yang, D., Zhang, L., Yu, Q., Ma, X., Ma, G. et al. (2023). Preparation of complementary food for infants and young children with beef liver: Process optimization and storage quality. *Foods*, 12(14), Article 2689. <https://doi.org/10.3390/foods12142689>
15. Pětová, M., Polášek, Z., Lapčíková, B., Lapčík, L., Buňková, L., Pospíech, M. et al. (2024). Evaluation of the viscoelastic properties of pork liver pâté during sterilisation observed *in situ*. *LWT*, 191, Article 115614. <https://doi.org/10.1016/j.lwt.2023.115614>
16. Chernukha, I., Kupaeva, N., Khvostov, D., Bogdanova, Y., Smirnova, J., Kotenkova, E. (2023). Assessment of antioxidant stability of meat pâté with allium cepa husk extract. *Antioxidants*, 12(5), Article 1103. <https://doi.org/10.3390/antiox12051103>
17. Almeida da Silva, B., de Castro, V. C. G., da Silva Araújo, C., Joele, M. R. S. P., Maciel e Silva, A. G., Rodrigues da Silva, J. A. et al. (2024). Optimization of the process of preparation of liver pâtés and omental fat of lambs fed with lipid cakes. *PLOS ONE*, 19(7), Article e0304532. <https://doi.org/10.1371/journal.pone.0304532>
18. Andriyani, S., Zainuri, Nofrida, R. (2024). The influence of adding cinnamon powder (*Cinnamomum burmanii*) on the chemical, physical and organoleptic properties of moringa leaf herbal tea (*Moringa oleifera* L.). *EduFood*, 2(1), 93–106. (In Indonesian)
19. de Oliveira Santos, L., Ribeiro, A. L. S., de Oliveira Lima, K. M., dos Santos, I. R. P., de Almeida, B. S., de Matos, M. F. R. et al. (2025). Critical factors associated with maillard reaction products in different meats: An integrative review. *Food Control*, 168, Article 110960. <https://doi.org/10.1016/j.foodcont.2024.110960>
20. Augustyńska-Prejsnar, A., Topczewska, J., Ormian, M., Saletnik, A., Sokołowicz, Z., Lechowska, J. (2022). The effect of the addition turmeric on selected quality characteristics of duck burgers stored under refrigeration. *Applied Sciences*, 12(2), Article 805. <https://doi.org/10.3390/app12020805>
21. Manoliu, D.-R., Ciobotaru, M. C., Ciobanu, M.-M., Boișteanu, P.-C. (2025). Development and characterization of meat-based pasta enriched with apple and sugar beet fibers. *Foods*, 14(22), Article 3837. <https://doi.org/10.3390/foods14223837>

22. Huang, W., Geng, L., Fu, H., Wang, D., Jia, D., Wang, A. et al. (2026). Effect of sous vide cooking combined with bromelain on beef tenderness and eating quality. *Food Chemistry: X*, 33, Article 103438. <https://doi.org/10.1016/j.fochx.2025.103438>
23. Pratiwy, A. E., Kusumaningrum, I., Aminullah, A. (2019). Utilization of lemongrass extract (*Cymbopogon citratus*) against the antioxidant content and sensory properties of dark chocolate products. *Jurnal Pertanian*, 10(2), 80–92. <https://doi.org/10.30997/jp.v10i2.1927>
24. Dang, N. H., Anh, L. T. V., Dat, N. T. (2020). Anti-inflammatory effects of essential oils of amomum aromaticum fruits in lipopolysaccharide-stimulated RAW264.7 cells. *Journal of Food Quality*, 2020, Article 8831187. <https://doi.org/10.1155/2020/8831187>
25. Saleh, M. R., Putranto, W. S., Gumilar, J. (2023). The effect of addition of blackseed oil (*Nigella sativa*) with different concentrations in the yoghurt production process on the amount of lactic acid bacteria, pH and acceptability. *Jurnal Teknologi Hasil Peternakan*, 4(1), 12–23. <https://doi.org/10.24198/jthp.v4i1.45086> (In Indonesian)
26. López-Martínez, M., Toldrá, F., Mora, L. (2023). Pork organs as a potential source of flavour-related substances. *Food Research International*, 173, Article 113468. <https://doi.org/10.1016/j.foodres.2023.113468>
27. Nurjannah, I., Utami, C. R. (2022). Characteristics of pineapple flour queen variety (*Ananas comosus* L. Merr) modified foam mat drying method. *Teknologi Pangan: Media Informasi Dan Komunikasi Ilmiah Teknologi Pertanian*, 13(1), 121–133. <https://doi.org/10.35891/tp.v13i1.3008> (In Indonesian)
28. Fitriyah, R. L., Hastuti, U. S., Witjoro, A. (2019). Qualities of nata de apple with different varieties of apples (*Malus sylvestris* mill) and sugar based on thickness, weight and fiber content. *Bioedukasi: Jurnal Pendidikan Biologi*, 12(1), 61–65. <https://doi.org/10.20961/bioedukasi-uns.v12i1.27408>
29. Bertolin, J. R., Joy, M., Blanco, M. (2019). Malondialdehyde determination in raw and processed meat products by UPLC-DAD and UPLC-FLD. *Food Chemistry*, 298, Article 125009. <https://doi.org/10.1016/j.foodchem.2019.125009>
30. Botella-Martínez, C., Pérez-Álvarez, J. Á., Fernández-López, J., Viuda-Martos, M. (2024). Innovative formulation in pâté using a gelled emulsion of hemp oil (*Cannabis sativa* L.) as fat replacer. *LWT*, 206, Article 116630. <https://doi.org/10.1016/j.lwt.2024.116630>
31. Suryati, T., Astawan, M., Lioe, H. N., Wresdiyati, T., Usmiati, S. (2014). Nitrite residue and malonaldehyde reduction in dendeng — Indonesian dried meat — Influenced by spices, curing methods and precooking preparation. *Meat Science*, 96(3), 1403–1408. <https://doi.org/10.1016/j.meatsci.2013.11.023>
32. Devadason, I. P., Anjaneyulu, A. S. R., Mendirtta, S. K., Murthy, T. R. K. (2014). Quality and shelf life of buffalo meat blocks processed in retort pouches. *Journal of Food Science and Technology*, 51(12), 3991–3997. <https://doi.org/10.1007/s13197-012-0895-5>
33. Suharyanto, S., Amrullah, A. H. K., Harahap, A. S. (2023). Reducing oxidation in beef sausage during room temperature storage by adding senduduk (*Melastoma malabathricum* L.) leaf extract. *Jurnal Agripet*, 23(2), 134–141. <https://doi.org/10.17969/agripet.v23i2.22410> (In Indonesian)
34. Tangkanakul, P., Auttaviboonkul, P., Niyomwit, B., Lowviton, N., Charoenthamawat, P., Trakoontivakorn, G. (2009). Antioxidant capacity, total phenolic content and nutritional composition of Asian foods after thermal processing. *International Food Research Journal*, 16, 571–580.
35. Rabby, Md. G., Islam, Md. N., Hasan, Md. S., Hossain, Md. N., Alam, M., Alam, A. et al (2025). Effects of Sesame and Cinnamon extract on physicochemical characteristics, oxidative stability, and antimicrobial activity in fresh poultry meatballs at refrigerated storage. *Poultry Science*, 104(10), Article 105572. <https://doi.org/10.1016/j.psj.2025.105572>
36. Da Silva, J. D. F., Breda, F. C., Ribeiro, L. C., De Lima, J. A., Berretta, A., Prestes, O. D. et al. (2025). Kinetics-thermodynamics of the antioxidant activity of propolis extracts in pork pâté. *Food Research International*, 218, Article 116879. <https://doi.org/10.1016/j.foodres.2025.116879>
37. Mrázková, M., Sumczynski, D., Orsavová, J. (2023). Influence of storage conditions on stability of phenolic compounds and antioxidant activity values in nutraceutical mixtures with edible flowers as new dietary supplements. *Antioxidants*, 12(4), Article 962. <https://doi.org/10.3390/antiox12040962>
38. Hernández-Macedo, M. L., Barancelli, G. V., Contreras-Castillo, C. J. (2011). Microbial deterioration of vacuum-packaged chilled beef cuts and techniques for microbiota detection and characterization: A review. *Brazilian Journal of Microbiology*, 42(1), 1–11. <https://doi.org/10.1590/S1517-83822011000100001>
39. Triyannanto, E., Arizona, A. S., Rusman, Suryanto, E., Sujarwanta, R. O., Jamhari. et al. (2020). Effect of retorted packaging and storage in room temperature on physical and microbiology of chicken meat satay. *Jurnal Sain Peternakan Indonesia*, 15(3), 265–272. <https://doi.org/10.31186/jspi.id.15.3.265-272> (In Indonesian)
40. Shah, M. A., Bosco, S. J. D., Mir, S. A., Sunooj, K. V. (2017). Evaluation of shelf life of retort pouch packaged Rogan josh, a traditional meat curry of Kashmir, India. *Food Packaging and Shelf Life*, 12, 76–82. <https://doi.org/10.1016/j.fpsl.2017.04.001>
41. Rather, J. A., Akhter, N., Rather, S. A., Masoodi, F. A., Dar, B. N. (2023). Effect of xanthan gum treatment on the shelf-life enhancement of retorted meatballs (Goshtaba): A traditional meat product of India. *Measurement: Food*, 13, Article 100127. <https://doi.org/10.1016/j.meafoo.2023.100127>
42. Nurhasanah. (2014). Antimicrobial activity of nutmeg (*Myristica fragrans* houtt) fruit methanol extract against growth *Staphylococcus aureus* and *Escherichia coli*. *Jurnal Bioedukasi*, 3(1), 277–286. <https://doi.org/10.33387/bioedu.v2i1.61> (In Indonesian)
43. Wellyalina. (2017). Identification of phytochemical compounds and antimicrobial activity of extracts of the main spices rendang of *Staphylococcus aureus*. *Jurnal Pertanian UMSB*, 1(2), 29–37. <https://doi.org/10.33559/pertanian> (In Indonesian)
44. Moulia, M. N. (2018). Antimicrobial of garlic extract. *Jurnal Pangan*, 27(1), 55–66. <https://doi.org/10.33964/jp.v27i1.399> (In Indonesian)
45. Marpaung, J. M., Panjaitan, I. M. S., Tobing, J. H. L. (2024). Comparison of effectiveness of clove flower, cinnamon bark, and star anise extract on the growth of *Escherichia coli* bacteria. *Jurnal Biologi Tropis*, 24(4), 1069–1076. <https://doi.org/10.29303/jbt.v24i4.8068>
46. Luo, J., Luo, J., Sheng, Z., Fang, Z., Fu, Y., Wang, N. et al. (2025). Latest research progress on anti-microbial effects, mechanisms of action, and product developments of dietary flavonoids: A systematic literature review. *Trends in Food Science and Technology*, 156(38), Article 104839. <https://doi.org/10.1016/j.tifs.2024.104839>
47. Valarezo, E., Ledesma-Monteros, G., Jaramillo-Fierro, X., Radice, M., Meneses, M. A. (2025). Antimicrobial activity of clove (*Syzygium aromaticum*) essential oil in meat and meat products: A systematic review. *Antibiotics*, 14(5), Article 494. <https://doi.org/10.3390/antibiotics14050494>
48. Zhao, K., Wonta, K. B., Xia, J., Zhong, F., Sharma, V. (2024). Phytochemical profiling and evaluation of antimicrobial activities of common culinary spices: *Syzygium aromaticum* (clove) and *Piper nigrum* (black pepper). *Frontiers in Nutrition*, 11, Article 1447144. <https://doi.org/10.3389/fnut.2024.1447144>

AUTHOR INFORMATION

Shafa N. Hayati, Magister Student, Department of Animal Production and Technology, Faculty of Animal Science, IPB University. 16680, Bogor, Indonesia. E-mail: shafanh2@gmail.com
ORCID: <https://orcid.org/0009-0005-7227-0653>

Tuti Suryati, Doctor, Department of Animal Production and Technology, Faculty of Animal Science, IPB University. 16680, Bogor, Indonesia. E-mail: t-suryati@apps.ipb.ac.id
ORCID: <https://orcid.org/0000-0002-0517-3002>
* corresponding author

Astari Apriantini, Doctor, Department of Animal Production and Technology, Faculty of Animal Science, IPB University. 16680, Bogor, Indonesia. E-mail: astari87@apps.ipb.ac.id
ORCID: <https://orcid.org/0000-0002-4811-5101>

All authors bear responsibility for the work and presented data.

All authors made an equal contribution to the work.

The authors were equally involved in writing the manuscript and bear equal responsibility for plagiarism.

The authors declare no conflict of interest.