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Evaluation of physical, chemical, and microbiological characteristics of retort pouch packaged Malbi from Palembang under different storage conditions

[Evaluasi karakteristik fisik, kimia, dan mikrobiologi Malbi khas Palembang dalam kemasan retort pouch pada berbagai kondisi penyimpanan]

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ABSTRACT

Malbi, a traditional beef dish from Palembang, was packaged using retort pouches to maintain its quality during storage. This study aimed to evaluate the physicochemical characteristics (pH value and texture profile), antioxidant activity, malondialdehyde (MDA) content, and microbiological quality of Malbi stored under different temperatures (room, refrigerated, and frozen) and times (5, 10, and 15 days). The product was sterilized at 110°C for 5 minutes. The results showed that storage time significantly affected ($p<0.05$) antioxidant activity, malondialdehyde (MDA) content, and total plate count (TPC), while temperature only significantly affected TPC. No interaction was found between storage temperature and time. Antioxidant capacity fluctuated on day 10 of storage but increased again on day 15. All Malbi samples remained within acceptable safety limits for MDA and microbe still had MDA content and TPC values below the safe limit for consumption. These findings indicate that retort pouch packaging effectively preserves the overall quality and stability of Malbi for up to 15 days storage.

Keywords: Malbi, retort pouch, storage time, storage temperature

ABSTRAK

Malbi, salah satu olahan daging asal Palembang, dikemas menggunakan pengemas *retort pouch* untuk menjaga kualitasnya selama penyimpanan. Tujuan dari penelitian adalah mengevaluasi sifat fisikokimia (nilai pH dan profil tekstur), aktivitas antioksidan, kandungan malondialdehida (MDA), serta kualitas mikrobiologi produk Malbi yang disimpan pada suhu berbeda (suhu ruang, dingin, dan beku) dan lama penyimpanan (5, 10, dan 15 hari). Produk disterilisasi pada suhu 110°C selama 5 menit. Hasil penelitian menunjukkan bahwa lama penyimpanan berpengaruh signifikan ($p<0.05$) terhadap aktivitas antioksidan, kandungan MDA, dan nilai total plate count (TPC), sedangkan suhu penyimpanan hanya berpengaruh signifikan terhadap nilai TPC. Tidak terdapat interaksi signifikan antara suhu dan lama penyimpanan pada seluruh parameter yang diamati. Kapasitas antioksidan mengalami fluktuasi pada hari ke-10 penyimpanan, namun meningkat kembali pada hari ke-15. Seluruh sampel Malbi tetap berada dalam ambang batas aman untuk kandungan MDA dan TPC, sehingga layak dikonsumsi. Temuan ini menunjukkan bahwa kemasan *retort pouch* efektif dalam mempertahankan kualitas dan kestabilan Malbi hingga 15 hari penyimpanan.

Kata kunci: Malbi, kantong *retort*, waktu penyimpanan, suhu penyimpanan

Introduction

Beef constitutes one of the primary sources of animal-derived protein in Indonesia, and its consumption continues to increase every year. National beef consumption per capita between 2018 and 2022 showed fluctuations but tended to increase with an average growth of 0.28%, reaching its peak in 2022 at 2,67 kg per capita per year. During the same period, household beef consumption increased by 3.36% annually. The ratio of household consumption to total consumption is 19%, which means that meat processed at home is only around 20%, and the remaining 80% comes from processed or ready-to-eat (RTE) meat (Kementan, 2023). This situation indicates a growing consumer preference for practical processed meat

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products and highlights the potential for further innovation in packaged RTE products that are not only convenient but also shelf-stable and nutritionally valuable. One of the popular Palembang beef dishes is Malbi, a kind of beef stew resulting from the acculturation of Arab, Indian, and Palembang Malay cultures. Malbi is often served as a side dish with a distinctive taste of a blend of herbs and spices, such as ginger, pepper, brown sugar, soy sauce, and coconut milk (Oktaria et al., 2022).

Along with the development of the food industry, various traditional processed ingredients have begun to be developed in the form of RTE foods, including Malbi, to reach a wider market (Yamin et al., 2021). As demonstrated by Sugiarto et al. (2024), retort pouches—composed of polyester, aluminium foil, and polypropylene laminates—are capable of withstanding high-temperature sterilization and maintaining product integrity during long-term storage at ambient temperature. Food packaging is not only a method for transporting food safely, but also serves to extend shelf life and provide protection against bacteria, contamination, and harmful degradation (Kusumaningrum et al., 2023). Retort pouches have been shown to preserve product quality, significantly extend shelf life, and offer advantages in weight, convenience, and cost compared to traditional canned packaging, while also serving as a practical packaging for ready-to-eat processed food products (Sugiarto et al., 2024). However, processed meat products remain susceptible to the risk of quality damage due to lipid oxidation, microbial contamination, and enzymatic activity that can reduce quality during storage (Dabasso et al., 2021). A comprehensive review by Zouharova et al. (2023) highlights that shelf life of meat products is primarily governed by packaging technology, such as modified atmosphere or active packaging, cold chain integrity, hygienic handling, and storage temperature, which all critically influence product appearance, flavor, odor, and texture. In addition, the nutritional quality of meat products, including their antioxidant capacity and micronutrient stability, is strongly affected by these preservation strategies, making packaging and storage conditions decisive factors for consumer acceptance. In this context, retort pouch technology has been increasingly recognized as promising approach for extending the stability of traditional meat-based foods while ensuring safety and maintaining sensory quality.

Research by Putra et al. (2024) showed that the use of retort pouch packaging has demonstrated effectiveness in preserving the physical, chemical, antioxidant, and microbiological quality of Sate Padang, a traditional meat dish originating from Padang, Indonesia. However, compared to other traditional meat products that have been studied in retort packaging systems such as Sate Padang (Putra et al., 2024) and Beef Rendang (Praharasti et al., 2019), scientific research on Malbi, particularly regarding its physicochemical stability, antioxidant activity, lipid oxidation, and microbiological safety, remains very limited. This lack of information represents a significant obstacle to optimizing Malbi's potential as a RTE product with extended shelf life. Therefore, this study was conducted to evaluate the characteristics of Malbi in terms of physical quality, chemical composition, antioxidant capacity, malondialdehyde (MDA) content, and microbiological quality when packaged in retort pouches and stored under different temperature conditions, namely room temperature (28-30°C), refrigeration (4°C), and frozen storage (-18°C), for varying storage periods. The outcomes of this study are expected to fill the existing research gap and provide valuable scientific insights for the advancement of Malbi as a standardized, high-quality, and shelf-stable RTE product.

Materials and methods

Materials and equipment

The main raw material used in this research was tenderloin beef, sourced from a certified meat supplier in Bogor, Indonesia. Other ingredients included traditional Malbi seasoning (Table 1) and retort pouches measuring 12 x 17 cm, used for packaging. Reagents and chemicals used for sample testing included distilled water (aquadest), propyl gallate/PG (Sigma-Aldrich), ethylenediaminetetraacetic acid/EDTA (Sigma-Aldrich), 4 N hydrochloric acid/HCl (Merck), saturated sodium chloride/NaCl solution (Merck),

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ascorbic acid (LabChem), sodium carbonate reagent (Merck), DPPH solution (Sigma-Aldrich), thiobarbituric acid (TBA) solution (Merck), tetraethoxypropane/TEP (Sigma-Aldrich), antifoaming agent (Able Westchem), pure methanol (Merck), buffered peptone water/BPW (Oxoid), and plate count agar/PCA (Oxoid). The equipment used in this study included beef processing tools, an analytical balance, blender, chiller, refrigerator, and thermometer. Instruments employed for sample analysis comprised petri dishes, distillation tubes, food sterilization autoclave (Getra, Indonesia), vacuum sealer V-403G (Tosei, Japan), pH meter (Ionix, India), texture analyzer TVT 6700 (Perten Instruments, Sweden), and UVms2 spectrophotometer (SAFAS, Monaco).

Research methodology

This study was conducted using a randomized complete block design (RCBD) with a 3 x 3 factorial arrangement, consisting of two factors and three blocks, resulting in a total of 27 experimental units. The first factor was storage temperature, with three levels: room temperature (28-30°C), refrigerated (4°C), and frozen conditions (-20°C). The second factor was storage duration, with three time intervals: 5, 10, and 15 days. As a baseline reference, measurements were also taken on day 0 at room temperature before storage; however, these values were not included in the statistical analysis. The collected data were analyzed using analysis of variance (ANOVA). If a significant effect was observed, the analysis was followed by Tukey's Honestly Significant Difference (HSD) test to determine the differences between treatment means.

Preparation of beef Malbi

Beef was first cleaned thoroughly and cut into 2 x 2 x 2 cm portions. Grated coconut was dry-roasted until golden brown, then ground using a blender to achieve fine texture. The spice paste was prepared by blending all ingredients according to the formulation presented in Table 1. The blended spices were sautéed in a pan until aromatic and oil separation occurred. Subsequently, the beef pieces, water, salt, beef stock, and seasoning agents were added. The mixture was cooked over medium-low heat until the beef became tender and the flavors were fully absorbed. Once cooking was complete, the beef Malbi was allowed to cool at room temperature before further processing.

Table 1. Malbi seasoning formulation (designed for 500 grams of beef)

Seasoning Ingredient	Composition (g)	Composition (%)
Tamarind	30	4.76
Onion	140	22.20
Garlic	70	11.10
Cloves	1	0.16
Salt	2	0.32
Brown sugar	60	9.52
Granulated sugar	10	1.59
Ginger	2	0.32
Sweet soy sauce	110	17.45
Toasted coconut	100	15.86
Pepper	2.5	0.40
Oil	100	15.86
Nutmeg	2	0.32
Flavoring	1	0.16
Total	628	100.00

Packaging and sample analysis

After reaching ambient temperature, the beef Malbi and its gravy were filled into retort pouches at a 1:1 ratio, with a total weight of 100 grams per package. Air was removed from the pouches using a vacuum sealer, and the sealed packages were subjected to thermal sterilization in an autoclave at 110°C for 5 minutes. The sterilized products were then stored under three temperature conditions: room temperature, refrigerated, and frozen for periods of 0 (baseline data), 5, 10, and 15 days.

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pH value measurement

The pH measurement was performed according to the AOAC method (2023) using a pH meter (Ionix, India). The pH electrode was calibrated using buffer solutions of pH 4.0 and 7.0, then gently washed with distilled water, dried properly, and subsequently used for sample measurement. Readings are taken after a stable value is obtained.

Texture profile analysis

Texture profile analysis (TPA) was conducted following the method of Turcu et al. (2020) with modifications. Prior to measurement, samples stored under refrigeration and frozen conditions were thawed at room temperature for approximately 30-60 minutes, and all samples were equilibrated at room temperature. Malbi beef was cut into cubes (1 x 1 x 1 cm) and analyzed using a TVT 6700 texture analyzer (Perten Instruments, Sweden) connected to a computer for data acquisition. Texture parameters measured included hardness, springiness, cohesiveness, gumminess, and chewiness. Each blocks was analyzed to obtain texture parameters.

DPPH radical scavenging activity and antioxidant capacity

Antioxidant activity was assessed according to the method described by Tangkanakul et al. (2009), utilizing the DPPH assay. The sample extract was obtained by extracting the meat and spices using 100% methanol, then filtered and stored in the freezer. The extract (0.15 mL) was added to 0.9 mL of the 0.1 mM methanolic DPPH solution. After 20 minutes, the absorbance of the mixture was recorded at 517 nm using a UVms2 spectrophotometer (SAFAS, Monaco). The percentage of free radical scavenging activity (%SA) was calculated using the formula (1-X/C) x 100, where X represents the absorbance of the extract and C the absorbance of the standard. Antioxidant capacity was quantified by comparing results to a vitamin C standard curve, prepared at concentrations of 0; 0.5; 1; 1.5; 2, and 2.5 mg per 100 mL, and reported as milligrams of vitamin C equivalent (VCE) per gram of sample (mg VCE/100 g).

Malondialdehyde analysis content

The malondialdehyde (MDA) content was measured by the thiobarbituric acid reactive substances (TBARS) assay, following the procedure outlined by Sorensen & Jorgensen (1996). Samples weighing 10 g were ground and subsequently mixed with a distillation solution comprising 0.1% propyl gallate and 0.1% EDTA. The solution was added with 2.5 mL of 4 M HCl, boiling stones, and antifoaming agent, then distilled to collect 50 mL of distillate. Afterward, 5 mL of distillate was mixed with 5 mL of TBA solution, heated at 100°C for 35 minutes, then cooled before measuring the absorbance at 528 nm using a UVmc2 spectrophotometer (SAFAS, Monaco). Calculation of the MDA value was performed using the TEP standard curve with a concentration of 0; 2; 4; 6; 8; and 10 µM/25 mL of distilled water, using the formula :

$$TBARS = (CMDA \times Vdis)/Ms$$

Total plate count

Total plate count (TPC) analysis was conducted following the procedure of SNI 2897:2008. The Malbi sample was serially diluted in 0.85% NaCl solution up to 10^{-5}. From each dilution, 0.5 mL was inoculated into sterile plate count agar (PCA) using the pour plate method, then incubated at 30±1°C for 48±2 hours in an inverted position. Colonies ranging from 30 to 300 CFU per plate were enumerated, and the results were expressed as CFU/g sample.

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Results and discussion

pH value

The result of ANOVA indicated no significant interaction effect between storage temperature and storage duration on the pH value of beef Malbi packaged in retort pouches. The pH values of Malbi measured over 15 days of storage at various temperatures ranged from 5.19 to 5.52 (Table 2).

Table 2. The pH value of retort pouch packaged beef Malbi with different temperatures and storage times

Temperature	Storage (d)			
	0	5	10	15
Room (28-30°C)	5.52±0,03*	5.27±0,05[a]	5.25±0,07[a]	5.25±0,06[a]
Refrigerated (4°C)		5.28±0,10[a]	5.19±0,07[a]	5.24±0,08[a]
Frozen (-18°C)		5.32±0,14[a]	5.20±0,15[a]	5.25±0,05[a]

Note: Data are presented as mean ± standard deviation. Data at day 0 (room temperature) were used as baseline for comparison.

The initial pH value on day 0 (baseline) at room temperature was recorded at 5.52. This value is the initial reference for monitoring pH changes during storage. This pH stability indicates good chemical resistance to the product during storage. According to Triyannanto et al. (2020), products in retort pouch packaging that undergo high-temperature sterilization tend to maintain pH stability. The pH change observed during storage may be attributed to protein degradation and the release of free amino acids, as well as lipid oxidation triggered by residual oxygen inside the packaging, and the breakdown of carbohydrates, glucose, and lipid components (Shah et al., 2017). Storage in closed or vacuum packaging also minimizes oxygen exposure, thus supporting the formation of lactic acid from glycogen, which also affects the decrease in pH (Triyannanto et al., 2020).

Texture profile analysis

The result of ANOVA showed that the interaction between temperature treatment and storage time did not significantly affect the texture profile of beef Malbi in retort pouch packaging (Table 3). Texture is one of the main indicators of the quality of processed meat products because it plays an important role in sensory characteristics when chewed.

Table 3. Texture profile of retort pouch packaged beef Malbi with different temperatures and storage times

Parameters	Temperature	Storage (d)			
		0	5	10	15
Hardness (g)	Room (28-30°C)	2399.30±20.66*	2408.50±56.00[a]	2407.13±23.42[a]	2389.80±29.19[a]
	Refrigerated (4°C)		2434.73±9.26[a]	2421.47±10.23[a]	2391.17±13.11[a]
	Frozen (-18°C)		2228.73±323.45[a]	2368.77±21.31[a]	2401.80±24.29[a]
Springiness (mm)	Room (28-30°C)	0.88±0.15*	0.73±0.10[a]	0.74±0.15[a]	0.84±0.11[a]
	Refrigerated (4°C)		0.74±0.08[a]	0.83±0.19[a]	0.87±0.07[a]
	Frozen (-18°C)		0.87±0.28[a]	0.79±0.11[a]	0.91±0.09[a]
Cohesiveness	Room (28-30°C)	0.48±0.01*	0.47±0.08[a]	0.51±0.01[a]	0.51±0.06[a]
	Refrigerated (4°C)		0.45±0.05[a]	0.49±0.07[a]	0.47±0.03[a]
	Frozen (-18°C)		0.50±0.02[a]	0.51±0.03[a]	0.51±0.05[a]
Gumminess (g)	Room (28-30°C)	1150.15±42.71*	1143.05±208.57[a]	1226.49±39.48[a]	1215.02±162.37[a]
	Refrigerated (4°C)		1089.68±114.81[a]	1185.90±165.02[a]	1131.51±78.10[a]
	Frozen (-18°C)		1115.39±210.64[a]	1213.48±60.38[a]	1225.25±125.66[a]
Chewiness (g /mm)	Room (28-30°C)	1437.53±210.55*	1326.78±377.01[a]	1380.92±235.36[a]	1446.78±345.30[a]
	Refrigerated (4°C)		1320.02±305.26[a]	1606.74±558.02[a]	1600.72±111.94[a]
	Frozen (-18°C)		1332.60±411.04[a]	1411.48±240.82[a]	1421.01±262.59[a]

Note: Data are presented as mean ± standard deviation. Data at day 0 (room temperature) were used as baseline for comparison.

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The observation results showed that relatively small changes in the texture profile values, indicating stable texture quality throughout the storage period. This stability may be influenced by the nature of the retort pouch packaging, which is able to withstand high-temperature sterilization, thereby reducing significant physical changes. Changes in hardness, gumminess, and chewiness values were still observed, which were most likely associated with protein denaturation caused by heat treatment. Heat treatment triggers myofibril protein contraction, protein aggregation, and coagulation (Ariyana et al., 2023), as well as changes in the structure and modification of protein segments (Khalid et al., 2023).

Antioxidant capacity

The result of ANOVA showed no significant interaction effect between storage temperature and time on the DPPH radical scavenging activity or antioxidant capacity of Malbi in retort pouch packaging. However, storage time significantly influenced both parameters ($p<0.05$) (Table 4). The values of DPPH radical scavenging activity and antioxidant capacity on day 0 at room temperature were 65.85% and 207.22 mg EVC/100g, respectively. An increase in DPPH inhibition was observed on days 5 and 15 with an average of 78.42% and 70.26%, respectively. Conversely, a decrease occurred on day 10 with an average of 56.53%, indicating fluctuations during storage. This finding is in line with Putra et al. (2024), who stated that antioxidant compounds have an important role in protecting biological molecules from oxidative reactions that trigger the formation of malondialdehyde (MDA) compounds.

The highest average antioxidant capacity was recorded on the fifth day, with a value of 244.21 mg EVC/100g across all storage temperatures. Based on the classification of Tangkanakul et al. (2009), the antioxidant capacity of Malbi is mostly in the high category (200–500 mg EVC/100g), except on the 10th day, which is classified as moderate. The reduction observed on the 10th day corresponds with the decline in DPPH radical scavenging activity, suggesting a parallel pattern between the two parameters. This decline is likely associated with the degradation or transformation of phenolic and other antioxidant compounds during storage, which temporarily lowered the antioxidant potential before increasing again on day 15.

Table 4. DPPH scavenging activity and antioxidant capacity of retort pouch packaged beef Malbi with different temperatures and storage times

Variable	Temperature	Storage (d)			
		0	5	10	15
Scavenging Activity (%)	Room (28-30°C)	65.85±10.48*	71.83±19.06^{a}	46.93±10.16^{c}	68.96±10.82^{b}
	Refrigerated (4°C)		83.29±9.50^{a}	60.93±8.12^{c}	69.39±8.58^{b}
	Frozen (-18°C)		80.14±10.04^{a}	61.73±11.83^{c}	72.44±4.66^{b}
Antioxidant Capacity (mgEVC/100g)	Room (28-30°C)	207.22±30.83*	224.81±56.08^{a}	151.56±29.89^{c}	216.39±31.84^{b}
	Refrigerated (4°C)		258.55±27.94^{a}	192.73±23.89^{c}	217.64±25.26^{b}
	Frozen (-18°C)		249.26±29.55^{a}	195.11±34.81^{c}	226.61±13.72^{b}

Note: Data are presented as mean ± standard deviation. Different superscript letters in the same row indicate significant differences ($p<0.05$) among storage temperatures (main effect) at the same storage day. Data at day 0 (room temperature) were used as baseline for comparison.

Spices function as natural antioxidants and are recognized for enhancing DPPH radical scavenging activity due to their rich content of phenolic compounds, including tocopherols, flavonoids, and phenolic acids (Ithnin et al., 2023). In Malbi, flavonoid compounds in spices such as allicin from garlic act as antioxidants by suppressing the synthesis of reactive oxygen species (ROS), inhibiting the activity of specific enzymes, and functioning as metal chelating agents to prevent free radical formation (Ajanaku et al., 2022). Furthermore, melanoidin compounds formed through Maillard reactions involving amino acids and reducing sugars during the cooking process exhibit antioxidant properties. This is facilitated by reductones, which can disrupt free radical chains by donating hydrogen atoms (Fajri et al., 2023). The presence of lipophilic compounds from spices, such as eugenol (cloves), gingerol (ginger), and myristicin

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(nutmeg), also contributes to stabilizing free radicals and inhibiting lipid peroxidation (Liu et al., 2025). The synergistic interaction between these compounds is able to form a stable complex structure, thereby increasing the total antioxidant activity of the product (Chen et al., 2022).

Malondialdehyde content

The result of ANOVA showed no significant interaction between storage temperature and storage time on MDA levels in Malbi in retort pouch packaging. However, the duration of storage significantly ($p<0.05$) influenced the variation in MDA levels (Table 5). The MDA content of the control Malbi sample on day 0 at room temperature was recorded at 0.55 mg/kg. MDA content tends to increase with increasing storage time, reflecting lipid oxidation.

Table 5. MDA content of retort pouch packaged beef Malbi with different temperatures and storage times (mg/kg)

Temperature	Storage (d)			
	0	5	10	15
Room (28-30°C)	0.55±0,02*	0.57±0.01^{c}	0.67±0.07^{b}	0.74±0.08^{a}
Refrigerated (4°C)		0.61±0.07^{c}	0.74±0.12^{b}	0.70±0.06^{a}
Frozen (-18°C)		0.71±0.06^{c}	0.64±0.03^{b}	0.71±0.04^{a}

Note: Data are presented as mean ± standard deviation. Different superscript letters in the same row indicate significant differences ($p<0.05$) among storage temperatures (main effect) at the same storage day. Data at day 0 (room temperature) were used as baseline for comparison.

Oxidation of lipids represents a primary factor contributing to chemical deterioration in meat products, as it generates free radicals that may initiate pigment oxidation, lead to the development of off-odors, and result in the production of harmful compounds (Shah et al., 2017). The phenomenon of fluctuations in MDA levels is in line with the reports of Praharasti et al. (2019) and Amdani et al. (2023), which explain that the red complex in the TBA test may also come from reactions with other aldehydes from non-lipid breakdown, thus affecting measurement accuracy. Beef and roasted coconut, as the main ingredients of Malbi, contain lipids, which during heat processing will react with TBA reagent to produce malondialdehyde (Amdani et al., 2023). MDA compounds are also formed during heating. Based on Zhang et al. (2019), the limit of MDA content that can cause rancid odor is 2-2,5 mg/kg, and all Malbi samples were recorded as still below this safe threshold. This shows that beef Malbi in retort pouch packaging has relatively good oxidative stability during storage.

Total plate count

The result of ANOVA showed that storage temperature and storage time independently exerted significant effects ($p<0.05$) on the TPC value of Malbi, although the interaction between the two was not significant (Table 6). The total number of Malbi microbes on day 0 at room temperature was recorded at 4.90 Log CFU/g. In general, the number of microbes decreased during storage, especially at frozen temperatures, with the total microbes dropping to 2.00 Log CFU/g on day 15. This indicates that lower temperatures suppress the proliferation of contaminant microbes and native meat microflora (Praktiknya et al., 2023). Shah et al. (2017) also stated that thermal heating in retort pouch packaging is effective in killing microorganisms. The packaging's barrier characteristics contribute to prolonging the product's microbiological stability.

However, the presence of microbes was still detected on day 0 post-sterilization, possibly due to thermophilic bacteria that are resistant to high heat (Triyannanto et al., 2020) or the potential for recontamination if cooling is not carried out quickly (Watson et al., 2023). Guragain et al. (2020) reported that the native microflora of beef does have a certain resistance to extreme heat. A slight increase in microbial counts was observed on day 5 compared to subsequent storage periods. This phenomenon may be associated with the temporary survival and limited proliferation of heat-resistant microorganisms at the early stage of storage, which were later inhibited by the combined effects of low temperature and the

antimicrobial properties of spices. The decrease in microbial counts during further storage suggests that the synergistic effect of packaging, storage conditions, and spices contributes to maintaining microbiological stability. Based on SNI (2009), the maximum limit for total microbial contamination in ready-to-eat processed meat products is 5.00 Log CFU/g (Maulidina et al., 2023). The results of this study indicate that all Malbi samples remained below this safe limit, supporting the effectiveness of retort pouch packaging in maintaining microbiological quality during storage.

Table 6. TPC value of retort pouch packaged beef Malbi with different temperatures and storage times (Log CFU/g)

Temperature	Storage (d)			
	0	5	10	15
Room (28-30°C)	4.90±0.54*	4.38±0.86^{a}	3.02±1.21^{c}	3.65±0.60^{b}
Refrigerated (4°C)		4.21±1.02^{a}	2.80±0.72^{c}	3.35±0.16^{b}
Frozen (-18°C)		4.00±0.89^{a}	2.00±0.00^{c}	2.00±0.00^{b}

Note: Data are presented as mean ± standard deviation. Different superscript letters in the same row indicate significant differences ($p<0.05$) among storage temperatures (main effect) at the same storage day. Data at day 0 (room temperature) were used as baseline for comparison.

Conclusion

Retort pouch packaging proved effective in preserving the physicochemical and microbiological quality of beef Malbi throughout 15 days of storage under various temperature conditions, including ambient, refrigerated, and frozen. The stability of pH and texture profile indicated good chemical and physical integrity. Storage at lower temperatures was particularly effective in suppressing microbial growth, supporting the microbiological safety of the product. In addition, antioxidant capacity remained relatively high, helping to inhibit oxidative reactions. The consistently low malondialdehyde (MDA) levels during storage also reflected the oxidative stability of the product. These findings confirm that retort pouch packaging plays an important role in supporting the overall quality and extending the shelf life of Malbi during 15 days storage.

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References

Ajanaku, C. O., Ademosun, O. T., Atohengbe, P. O., Ajayi, S. O., Obafemi, Y. D., Owolabi, A. Y., Akinduti, P. A., & Ajanaku, K. O. (2022). Functional bioactive compounds in ginger, turmeric, and garlic. *Frontiers*, 9, 1-11. https://doi.org/10.3389/fnut.2022.1012023

Amdani, R. Z., Kusumaningrum, A., Amri, A. F., Nurhikmat, A., Susanto, A., Siswoprayogi, S., & Praharasti, A. S. (2023). Evaluating the food properties of canned beef rendang to determine the product quality. *Agritech*, 44, 218-231. https://doi.org/10.22146/agritech.73815

AOAC. (2023). *Association of Official Analytical Chemists*. Official methods of analysis, 22nd edition, Washington, DC, USA.

Ariyana, M. D., Handayani, B. R., Amaro, M., Rahayu, T. I., Afriliya, N.S., Widyastuti, S., Nazaruddin, Perdhana, F. F., Sinaga, Y. M. R., & Nurhikmat, A. (2023). Physicochemical properties of retort pouch packaged rembiga satay with various sterilization times. *International Conference on Food, Agriculture, and Natural Resources (IC-FANRES)*, 370-378. https://doi.org/10.2991/978-94-6463-274-3_34

Chen, X. H., Shang, S. F., Yan, F., Jiang, H., Zhao, G. J., Tian, S., Chen, R., Chen, D. J., & Dang, Y. F. (2023). Antioxidant activities of essential oils and their major components in scavenging free radicals, inhibiting lipid oxidation, and reducing cellular oxidative stress. *Molecules*, 28, 4559. https://doi.org/10.3390/molecules28114559

Dabasso, B. G., Makokha, A. O., Onyango, A.N., Mathara, J. M., & Badake, Q. D. (2021). Effect of temperature, storage containers, and improved hygiene on microbial safety and chemical quality of traditional meat products. *European Journal of Agriculture and Food Sciences*, 3, 71-77. https://doi.org/10.24018/ejfood.2021.3.4.317

Fajri, P. Y., Astawan, M., & Wresdiyati, T. (2023). Evaluasi potensi Rendang dan Kalio Minangkabau sebagai pangan fungsional. *Agroteknika*, 6, 127-137. https://doi.org/10.55043/agroteknika.v6i1.208

Guragain, M., Smith, G. E., King, D. A., & Bosilevac, J. M. (2020). Prevalence of extreme heat-resistant gram-negative bacteria carried by U.S. cattle at harvest. *Journal of Food Protection*, 83,1438–1443. https://doi.org/10.4315/JFP-20-103

Ithnin, N. H., Selamat, J., Murugesu, S., Hew, P. S., Sukor, R., & Karim, S. N. (2023). Effect of cooking time and temperature on extraction yield and antioxidant properties of beef rendang. *Malaysian Journal of Science, Health, and Technology*, 9, 106-111. https://doi.org/10.33102/mjosht.v9i2.317

Kementerian Pertanian. (2023). *Buku Outlook Komoditas Peternakan*. Pusat Data dan Sistem Informasi Pertanian, Jakarta.

Khalid, W., Maggiolino, A., Kour, J., Arshad, M. S., Aslam, N., Afzal, M. F., Meghwar, P., Zafar, K. W., Palo, P., & Korma, S. A. (2023). Dynamic alterations in protein, sensory, chemical, and oxidative properties occurring in meat during thermal and non-thermal processing techniques: a comprehensive review. Frontiers in Nutrition. 9: 1–19. https://doi.org/10.3389/fnut.2022.1057457

Kusumaningrum, A., Febrisiantosa, B., Amri, F. A., Amdani, R. Z., Nurhikmat, A., Prayogi, S., & Dewandaru, B. M. (2023). Pengaruh suhu sterilisasi pada sifat morfologis dan mekanik kemasan fleksibel retort produk empal gentong siap saji. *Jurnal Teknologi dan Industri Hasil Pertanian*, 28(2), 90-98. https://doi.org/10.23960/jtihp.v28i2.90-98

Liu, X., Zheng, Z., & Liu, Y. (2025). Lipophilic antioxidants in edible oils: mechanisms, applications, and interactions. *Elsevier*, 200. https://doi.org/10.1016/j.foodres.2024.115423

Maulidina, R., Marlina, E. T., & Utama, D. T. (2023). Mutu mikrobiologi produk olahan daging yang dijual secara daring di UMKM di Kota Bandung. *JTHP*, 4, 83-100. https://doi.org/10.24198/jthp.v4i2.47313

Oktaria, F. D., Idris, M., & Suriadi, A. (2022). Tinjauan historis akulturasi budaya dalam kuliner Palembang sebagai sumber pembelajaran sejarah. *Kalpataru*, 8, 31-47.

Praharasti, A. S., Kusumaningrum, A., Khasanah, Y., Nurhayati, R., Nurhikmat, A., Susanto, A., & Suprapedi. (2019). Physicochemical properties and their relations of beef rendang inside retort pouch packaging in various temperature storage conditions. *IOP Conf Ser: Earth Environ Sci,* 251, 1-9. https://doi.org/10.1088/1755-1315/251/1/012043

Praktiknya, D. E., Mahendra I. B. P. O., & Risma. (2023). Pengaruh suhu rendah dan metode vakum pada penyimpanan daging sapi terhadap jumlah koloni bakteri dan organoleptik tekstur, bau, dan warna. *Hang Tuah Med Journal*, 21, 98-113. https://doi.org/10.30649/htmj.v21i1.346

Putra, P. J., Suryati, T., & Wulandari, Z. (2024). Karakteristik sate padang dalam kemasan dengan suhu dan waktu simpan berbeda. *Jurnal Ilmu Pertanian Indonesia*, 29, 573-580. https://doi.org/10.18343/jipi.29.4.573

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. *Elsevier*, 76-82. https://doi.org/10.1016/j.fpsl.2017.04.001

Sugiarto, Muslich, & Widiaputri, F. F. (2024). Design of retort pouch packaging and shelf-life estimation for commercial sterilized Mutton Tongseng by MSMEs. *IOP Conf Ser: Earth Environ Sci,* 1358, 1-9. https://10.1088/1755-1315/1358/1/012018

Suharman, Izzati, N. K., & Himelda, T. A. N. (2023). Analisis cemaran mikroba dalam produk minuman sari kedelai dengan metode *total plate count* (TPC). *JITAP*, 1, 9-13. https://doi.org/10.31316/jitap.vi.5748

Sorensen, S., & Jorgensen, S. (1996). A critical examination of some experimental variables in the 2-thiobarbituric acid (TBA) test for lipid oxidation in meat products. *European Food Research and Technology*, 3, 205-210. https://doi.org/10.1007/BF01263541

Tangkanakul, P., Auttaviboonkul, P., Niyomwit, B., Lowvitoon, N., Charoenthamawat, P., & Trakoonvitakorn, G. (2009). Antioxidant capacity, total phenolic content, and nutritional composition of Asian foods after thermal processing. *International Food Research Journal*, 16, 571-580.

Triyannanto, E., Arizona, A. S., Rusman, Suryanto, E., Sujarwanta, R. O., Jamhari, & Widyastuti, I. (2020). Pengaruh kemasan retorted dan penyimpanan pada suhu ruang terhadap kualitas fisik dan mikrobiologi sate ayam. *Jurnal Sain Peternakan Indonesia*, 15, 265-272. https://doi.org/10.31186/jspi.id.15.3.265-272

Turcu, R. P., Panaite, T. D., Untea, A. E., Soica, C., Iuga, M., & Mironeasa, S. (2020). Effects of supplementing grape pomace to broilers fed polyunsaturated fatty acid enriched diets on meat quality. *Animals*. 10, 1-17. https://doi.org/10.3390/ani10060947

Watson, S. C., Furbeck, R. A., Fernando, S. C., Chaves, B. D., & Sullivan, G. A. (2023). Spoilage *Pseudomonas* survive common thermal processing schedules and grow in emulsified meat during extended vacuum storage. *Journal of Food Science*, 88, 2162–2167. https://doi.org/10.1111/1750-3841.16557

Yamin, M., Jufri, A. J., Jamaluddin, J., & Khairuddin, K. (2021). Makanan siap saji dan dampaknya terhadap kesehatan manusia. *Jurnal Pengabdian Magister Pendidikan IPA*, 4, 116-124. https://doi.org/10.29303/jpmpi.v4i3.936

Zhang, Y., Holman, B. W. B., Ponnampalam, E. N., Kerr, M. G., Bailes, K. L., Kilgannon, A. K., Collins, D., & Hopkins, D. L. (2019). Understanding beef flavour and overall liking traits using two different methods for determination of thiobarbituric acid reactive substances (TBARS). *Meat Sci*, 149, 114-119. https://doi.org/10.1016/j.meatsci.2018.11.018

Zouharova, A., Bartakova, K., Bursova, S., Necidova, L., Harustiakova, D., Klimesova, M., & Vorlova, L. (2023). Meat and fish packaging and its impact on the shelf life –a review. *Acta Veterinaria Brno*, 92, 95-108. https://doi.org/10.2754/avb202392010095