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Static Retort Thermal Processing for Shelf-Life Extension of Traditional Rendang: Preliminary Study of Quality Attributes and Consumer Acceptance

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A B S T R A C T

Rendang, a traditional Indonesian meat dish with significant cultural and economic value, faces distribution challenges due to its short shelf life. This study evaluated static retort thermal processing to improve rendang's physicochemical properties, microbiological safety, and consumer acceptance. Rendang samples were sterilized at 125 °C for 0, 5, 10, 15, and 20 minutes, then analyzed for composition, Total Plate Count (TPC), and sensory properties. Sterilization affected product composition, with moisture, ash, and protein showing biphasic trends, while fat content increased steadily with increasing processing time. Microbiological analysis showed that TPC dropped from 70 CFU/g in untreated samples to 15 CFU/g or below-detectable levels (<10 CFU/g) after retort processing, confirming effective sterilization. Sensory evaluation found that all treatments maintained acceptable colour, aroma, and flavour. Consumer acceptance was high for up to six months of storage, but declined for longer shelf lives, suggesting psychological factors may influence acceptability. Overall, static retort processing at 125 °C for 10–15 minutes offers an optimal balance of safety and quality, making it suitable for extending rendang's shelf life.

Contribution of This Research to the Sustainable Development Goals (SDGs)
SDG 2 – Zero Hunger.
SDG 3 – Good Health and Well-being.
SDG 9 – Industry, Innovation, and Infrastructure.
SDG 12 – Responsible Consumption and Production.

1. INTRODUCTION

1.1. Background

Traditional rendang, a distinctive Southeast Asian meat dish, holds immense cultural and culinary significance, particularly in Indonesia, Malaysia, and Brunei. However, like many traditional meat-based products with high moisture and fat content, rendang faces significant challenges related to microbial spoilage and limited shelf life, which restricts its commercial viability and market accessibility [1]. The perishable nature of rendang makes it susceptible to the growth of both pathogenic and spoilage microorganisms, necessitating effective preservation strategies to maintain food safety and product quality [2].

Food preservation represents a critical concern in modern food production, particularly for traditional dishes that consumers increasingly demand with fresh-like characteristics and extended shelf life [3]. Consumers today show heightened awareness of food safety and nutritional value, driving demand for foods processed with technologies that maintain quality while ensuring microbial safety [4]. Traditional meat products often face rapid deterioration due to enzymatic activity, microbial growth, and lipid oxidation, which significantly compromise both sensory appeal and nutritional integrity [1].

Retort processing, specifically static retort thermal processing, has been established as a reliable sterilization technique capable of achieving commercial sterility in hermetically sealed containers, thereby ensuring microbiological safety and prolonged storage stability [5]. This thermal technology has been applied successfully to various ready-to-eat (RTE) food products to overcome microbial spoilage challenges while extending shelf life [3]. However, the application of static retort processing to traditional rendang remains under-explored, presenting an opportunity to develop shelf-stable products that meet contemporary safety and quality standards while preserving cultural food heritage.

1.2. *Literature Review*

Emerging research demonstrates that thermal processing technologies play a pivotal role in extending the shelf life of meat and meat products while maintaining acceptable quality standards [4]. Advances in thermal technologies, including static retort processing, have improved nutrient retention and optimized the organoleptic and nutritional quality of meat products by enabling precise control of temperature and exposure time [4]. Thermal sterilization processes, such as retort processing, have been shown to effectively eliminate viable pathogenic microorganisms, including spores, and achieve commercial sterility in RTE food products [3].

The challenge of balancing food safety with quality preservation has prompted an an investigation into the effects of thermal processing on multiple quality attributes. Studies on thermally processed food products reveal that quality loss occurs across several dimensions: physicochemical properties (color, viscosity, total soluble solids), sensory characteristics (taste, aroma, texture), and microbial stability [5]. Research on retort-processed Thai ready-to-eat desserts demonstrated that retort processing at different temperatures (114°C, 118°C, and 121°C) with controlled sterilization units (Fo value of 3) achieved acceptable microbiological limits while exhibiting acceptable physicochemical characteristics, with products retorted at 121°C showing the highest consumer acceptability [5].

Consumer acceptance represents a critical factor in the successful market introduction of processed traditional foods, as sensory perception and quality retention directly influence purchasing decisions and product viability [6]. The preservation of meat products remains crucial not only for extending their shelf life but also for reducing environmental impact through more sustainable practices and maintaining nutritional value [4]. Protein aggregation during thermal processing is a major concern for food quality, as thermal treatments disrupt protein structure, leading to changes in texture, juiciness, and water-holding capacity [7]. Additionally, thermal processing may influence nutrient retention differently across nutrient classes and food matrices, with minerals generally showing greater stability than water-soluble vitamins [8].

The integration of thermal processing with quality monitoring represents an essential approach in developing shelf-stable traditional meat products [9]. Recent advances in analytical techniques and processing methodologies have enabled more precise control and monitoring of thermal treatment effects on food products, allowing for optimization of processing parameters that balance microbial inactivation with quality preservation [9]. Infrared technology and other modern thermal approaches have demonstrated potential to improve heating uniformity and reduce processing time while maintaining product quality [10].

1.3. *Objective*

This study evaluates the effectiveness of static retort thermal processing in enhancing the shelf life, physicochemical quality, microbiological safety, and consumer acceptance of traditional rendang. It examines the impact of various sterilization holding times at 125 °C (0, 5, 10, 15, and 20 minutes) on key physicochemical parameters, Total Plate Count (TPC), sensory characteristics, and consumer perceptions of shelf-life. The study also aims to determine the optimal processing condition that ensures microbiological safety while preserving product quality and acceptability.

2. MATERIALS AND METHODS

2.1. *Materials*

The materials used included the main ingredients and chemicals for analysis. The main ingredients used in rendang preparation included beef (sirloin), coconut milk from mature coconuts, and spice seasonings such as cumin, nutmeg, and cloves, as well as turmeric leaves, bay leaves, kaffir lime leaves, and lemongrass stalks.

The chemicals used for analysis were as follows: for protein determination—concentrated H_2SO_4, 30% NaOH, phenolphthalein (pp) indicator, 2% boric acid, and 0.01 N HCl; for fat determination—hexane

2.2. *Equipment*

The equipment used in this study included a complete set of utensils for cooking rendang; a static retort thermal processing unit with a capacity of 22 L sealer and instruments used in analysis.

a. Static Retort b. Sealer

Figure 1. Retort and Sealer Used in This Study

2.3. *Research Methods*

2.3.1. *Procedure for Rendang Preparation*

Rendang was prepared using conventional slow cooking until a thick brown paste formed. The product was cooled and packaged in multilayer retort pouches:

a. All spices were finely ground, except galangal, which was coarsely ground, while leafy ingredients were added whole.

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b. The coconut milk and all spices were then cooked with continuous stirring until thick and oily (±1 hour 30 minutes) at 90–93°C.
c. The beef, cut into pieces (approximately 40 g each), was added to the heated mixture of coconut milk and spices.
d. Heating was continued until the mixture reached the *kalio* stage, where the meat became tender and the coconut milk thickened and turned brown (the thick coconut milk–spice mixture is referred to as *dedak*). This heating process lasted approximately 1 hour 30 minutes. A portion of the *kalio* produced was packaged for chemical and physical analyses.
e. The remaining *kalio* was further heated by reducing the temperature to 80–85°C and continuously stirred until it turned dark brown to blackish (approximately 3 hours); the product at this stage is referred to as rendang.
f. The heat was turned off, and the rendang was allowed to cool naturally.
h. The rendang was then properly packaged using retort pouches and subjected to the retort process.

2.3.2. *Packaging*

The beef rendang used as the research sample was packaged in retort pouches, with portions weighed and prepared according to a formulation developed in a previous study [2], consisting of 60 g of meat and 60 g of sauce. The pouch size was 18 cm × 13 cm. The rendang in the retort pouches was then thermally processed in a retort machine using the sterilization method for flexible packaging.

In this study, a retort pressure of 1.3 bar and a holding time of 40 minutes were selected to sterilize the samples. After sterilization, the samples were quarantined for 2 weeks to ensure stability and achieve commercial sterility. To study reaction rates, the samples were stored at three different temperatures in an incubator (35, 45, and 55 °C). Microbiological analyses were conducted using a colony counter, micropipettes, an inoculating loop, a microscope, Petri dishes, test tubes, and other supporting equipment.

2.3.3. *Retort Thermal Processing*

Samples were sterilized using a static retort system at 125 °C with different holding times (0, 5, 10, 15, and 20 min). The retort pressure was maintained at approximately 1.3 bar. After processing, samples were cooled and stored under controlled conditions prior to analysis. The experimental treatments are summarized in Table 1.

Table 1. Experimental Treatments Applied in the Study

Treatment Code	Processing Method	Temperature (°C)	Holding Time (min)	Description
Control	No retort processing	–	–	Traditional rendang without thermal sterilization
T1	Retort sterilization	125	5	Rendang processed using retort at 125 °C for 5 min
T2	Retort sterilization	125	10	Rendang processed using retort at 125 °C for 10 min
T3	Retort sterilization	125	15	Rendang processed using retort at 125 °C for 15 min
T4	Retort sterilization	125	20	Rendang processed using retort at 125 °C for 20 min

Note: All treatments were evaluated for physicochemical characteristics, sensory attributes, and

Figure 2 . Retort Pouch Packaging Equipment Used in the Study.

2.3.4. *Physicochemical Analysis*

Physicochemical analysis was conducted to evaluate compositional changes associated with retort processing. The parameters analyzed included carcass weight (yield), moisture, ash, fat, and protein. Moisture content was determined using the oven-drying method, ash content by dry ashing, fat content by Soxhlet extraction, and protein content by the Kjeldahl method. All analyses were performed in triplicate, and the results were expressed as mean values

2.3.5. *Total Plate Count (TPC) Analysis*

Microbiological quality was evaluated using the Total Plate Count (TPC) method. Approximately 10 g of sample was aseptically homogenized with 90 mL sterile diluent to obtain a 10^{-1} dilution, followed by serial dilutions as required. Aliquots (1 mL) were plated using the pour plate method with Plate Count Agar (PCA) and incubated at 35–37 °C for 48 h. Plates containing 25–250 colonies were counted, and results were expressed as CFU/g. All analyses were conducted in triplicate

2.3.6. *Sensory Evaluation*

Sensory evaluation was conducted to assess the organoleptic quality of rendang subjected to different retort treatments. The evaluated attributes included colour, aroma, and flavour, which are key quality indicators for traditional rendang products. Observations were conducted across all treatments to determine the effect of sterilization on sensory quality

2.3.7. *Consumer Acceptance Study*

Consumer perception of shelf life was evaluated by assessing respondents' willingness to consume rendang at different labeled shelf-life durations (0, 2, 4, 6, 12, 18, and 24 months). The percentage of respondents willing to consume the product was recorded and analyzed to determine acceptance trends.

2.3.8. *2.8 Statistical Analysis*

All experiments were conducted in triplicate, and results were expressed as mean values. Data were analyzed descriptively to evaluate trends across treatments.

3. RESULTS AND DISCUSSION

3.1. *Effect of Sterilization Time on the Physicochemical Properties of Rendang*

Retort sterilization significantly affected the physicochemical characteristics of rendang. Changes were observed across ash, moisture, protein, and fat contents, reflecting the combined effects of thermal concentration, structural modification, and degradation mechanisms during processing.

3.1.1. *Effect of Retort Sterilization Time on Ash Content*

The sterilization treatments using the retort were 0, 5, 10, 15, and 20 minutes. The data showed that the ash contents corresponding to each treatment were 4.24%, 5.05%, 3.57%, 3.64%, and 3.04%, respectively (Figure 3). The results indicate an increase in ash content after heating or sterilization. However, this trend was followed by a decrease in ash content as sterilization time increased.

Overall, the ash content data demonstrate two main trends: an increase in ash content during the early stage of sterilization, followed by a decline at longer sterilization durations

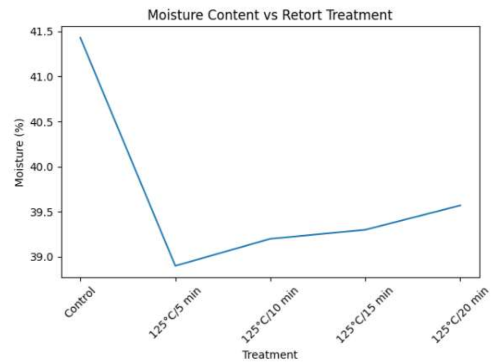

Figure 3. Effect of Sterilization Time on Ash

The observation of biphasic changes in ash content during retort sterilization of rendang (an initial increase followed by a decline) reflects the complex thermal interactions specific to this traditional meat-based product. Rendang, a rich, spice-infused meat preparation with a characteristic fat matrix, exhibits unique behaviour during high-temperature processing compared to simpler meat systems. The initial increase in ash content from 4.24% to 5.05% at 5 minutes of sterilization can be attributed to the concentration effect resulting from moisture loss during the early heating phase [11]. As water evaporates from the rendang matrix, the relative proportion of mineral components increases, a phenomenon well-documented in meat processing operations [2]. This rapid initial change indicates that rendang's complex formulation—comprising beef, coconut-derived fats, spices (such as galangal, garlic, and turmeric), and salt—undergoes significant compositional changes even during brief exposure to sterilization.

The subsequent decline in ash content observed at 10, 15, and 20 minutes of sterilization (3.57%, 3.64%, and 3.04%, respectively) suggests that extended thermal exposure initiates mechanisms beyond simple moisture loss. This pattern is particularly significant for rendang, which naturally contains substantial mineral-binding compounds from its spice ingredients and the Maillard reaction products formed during traditional slow cooking [3]. The progressive decline may be attributed to the thermal degradation of mineral-organic complexes formed between ash components and proteins, fats, and organic compounds characteristic of rendang [4]. Additionally, volatilization of lighter mineral compounds during extended sterilization, combined with the decomposition of certain ash constituents under sustained high-temperature exposure, contributes to the observed reduction in total measurable ash content.

3.2. *Effect of Retort Sterilization Time on Moisture Content*

The sterilization treatments using the retort were 0, 5, 10, 15, and 20 minutes. The data showed that the moisture contents corresponding to each treatment were 41.43%, 38.90%, 39.20%, 39.30%, and 39.77%, respectively (Figure 4). The results indicate a decrease in moisture content after initial heating or sterilization. However, this trend was followed by an increase in moisture content as sterilization time increased.

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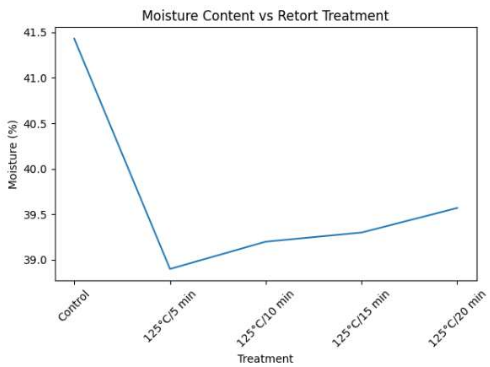

Figure 4. Effect of Retort Treatment on Moisture Content

The biphasic pattern in moisture content during retort sterilization of rendang provides important insights into how this traditional meat-based product responds to thermal processing. The initial decrease in moisture content from 41.43% at 0 minutes to 38.90% at 5 minutes of sterilization indicates substantial water loss during the early heating phase. This phenomenon is characteristic of thermal processing in meat products, where elevated temperatures cause rapid denaturation of proteins and disruption of the protein matrix, leading to moisture migration and evaporation [15]. For rendang specifically, this initial moisture loss is significant because the product's characteristic texture and flavor depend on a balance between the protein-fat matrix and bound moisture. The coconut-based fat component and spices in rendang create a complex system in which water is retained through multiple binding mechanisms, including hydrogen bonding with proteins and incorporation into the fat emulsion [16].

The subsequent increase in moisture content observed at 10, 15, and 20 minutes of sterilization (39.20%, 39.30%, and 39.77%, respectively) represents a critical shift in the product's thermal dynamics. This reversal pattern, in which moisture content begins to increase after an initial decline, suggests that extended sterilization duration triggers mechanisms distinct from those during the initial heating phase. One explanation for this moisture reabsorption may be the progressive gelation and structural reorganization of the protein matrix during sustained high-temperature exposure [17]. As proteins denature more completely and reorganize, they may create new hydration sites or enhance water-holding capacity by altering their quaternary structure. Additionally, the cooling phase following sterilization may allow moisture from the retort environment to reabsorb into the product, particularly if the product's internal structure has been modified to accommodate greater water retention [18]. For rendang, this reversible moisture trend is particularly important because texture quality in this traditional product is heavily dependent on proper moisture content—excessive dryness compromises palatability and sensory appeal, while excessive moisture can lead to product deterioration and reduced shelf stability.

3.3. *Effect of Retort Sterilization on Protein Content*

The sterilization treatments using the retort were 0, 5, 10, 15, and 20 minutes. The data showed that the protein contents corresponding to each treatment were 60.94%, 73.46%, 72.63%, 71.97%, and 70.06%, respectively (Figure 5). The results indicate an increase in protein content after heating or sterilization. However, prolonged sterilization led to a decline in protein content. These findings demonstrate two main patterns:

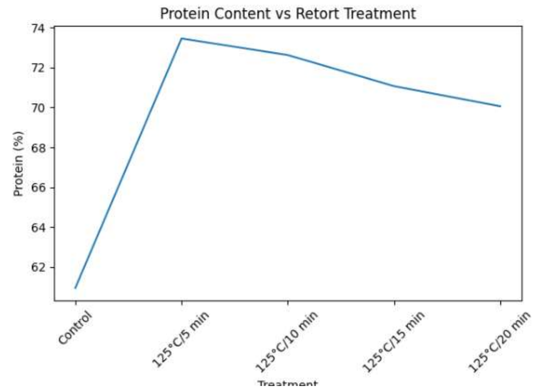

Figure 5. Effect of Retort Treatment on Protein Content

. These findings reflect two principal mechanisms governing protein behavior during thermal processing: concentration effects during early heating and degradation during prolonged exposure.

The initial increase in protein content is primarily attributed to moisture loss during early retort treatment. Elevated temperatures induce protein denaturation and structural contraction, which expel water from the meat matrix and increase the relative proportion of solids, including proteins. This concentration effect has been widely reported in thermally processed meat products and accounts for the sharp rise observed within the first 5 min of sterilization [19], [20]. In addition, early-stage denaturation may enhance protein extractability in analytical procedures, contributing to higher measured protein values.

In contrast, prolonged sterilization resulted in a gradual decline in protein content, indicating progressive thermal degradation. Extended exposure to high temperature promotes protein aggregation, cross-linking, and oxidation, leading to the formation of insoluble complexes that may not be fully detected by conventional analytical methods [20], [21]. Furthermore, heat-sensitive amino acids such as lysine and cysteine may degrade or participate in Maillard reactions, thereby reducing measurable protein levels and potentially affecting nutritional quality [3]. Similar trends have been reported in thermally processed meat systems, where excessive heating reduces protein availability and alters functional properties [19].

These findings suggest that moderate sterilization durations offer the best balance between microbial safety and protein preservation. Excessive heating beyond 10–15 min may not significantly enhance safety but can contribute to nutritional and structural deterioration. Overall, the biphasic protein response highlights the importance of optimizing retort conditions to maintain both safety and nutritional quality in shelf-stable rendang

3.3.1. *Effect of Retort Sterilization Time on Fat Content*

The sterilization treatments using the retort were 0, 5, 10, 15, and 20 minutes. The data showed that the fat contents corresponding to each treatment were 16.98%, 21.01%, 22.58%, 23.71%, and 28.17%, respectively (Figure 6). The results indicate an increase in fat content after heating or sterilization. This trend was followed by a further increase in fat content with longer sterilization durations. Overall, the data demonstrate a consistent upward trend in fat content as sterilization time increased. The following analysis is based on these results:

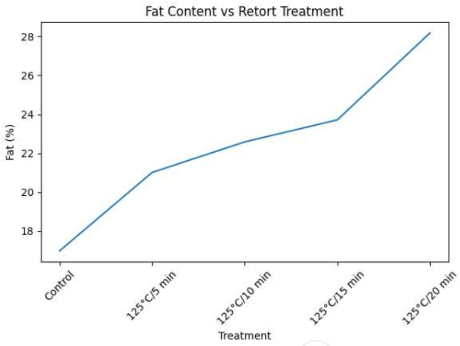

Figure 6. Effect of Retort Treatment on Fat Content

Fat concentration increased progressively with longer retort times. This apparent increase is primarily associated with moisture reduction rather than lipid synthesis. Similar concentration effects have been reported in thermally processed meat products, where dehydration leads to higher relative lipid percentages. However, excessive fat concentration at extended heating (20 min) may accelerate lipid oxidation and negatively influence shelf stability.

The data reveal a consistent and progressive increase in fat content during retort sterilization of rendang, ranging from 16.98% at baseline (0 minutes) to 28.17% at 20 minutes of sterilization. This substantial increase, representing approximately 66% elevation in fat content over the treatment period, is primarily attributable to the concentration effect resulting from moisture loss during thermal processing. Thermal treatment of meat products causes substantial water loss, which increases the relative proportion of all dry matter components, including lipids [22]. For rendang specifically, this phenomenon is particularly pronounced because the product is inherently high in fat content from both the beef component and the coconut-based sauce matrix that characterizes this traditional Indonesian dish. The progressive fat accumulation across all sterilization durations (16.98% → 21.01% → 22.58% → 23.71% → 28.17%) demonstrates that moisture loss continues throughout the 20-minute sterilization cycle, with accelerated fat concentration at longer treatment times.

The observed increase in apparent fat content is not primarily due to actual fat generation or oxidation, but rather reflects the concentration of existing lipids as the water matrix is progressively removed [22]. During retort sterilization at 121°C, the moisture content of the rendang decreases through both evaporation and structural reorganization of the protein-fat-water matrix. As water migrates through the sterilization product interior toward the surface and evaporates into the retort chamber, the proportion of high-quality fat compounds increases proportionally. This concentration effect is amplified in rendang compared to lean meat products due to its inherently high fat content (derived from beef fat, coconut milk, and coconut cream), which is foundational to the product's traditional composition and organoleptic properties.

The observed progressive increase in fat content during retort sterilization of rendang reflects the inherent characteristics of this fat-rich product undergoing thermal processing. The concentration of lipids through moisture loss is both expected and, to a degree, beneficial for maintaining rendang's traditional sensory properties. However, optimizing the sterilization duration to achieve both microbiological safety and desirable product characteristics suggests that treatments in the 10-15 minute range represent the most practical approach for commercial rendang production, balancing the desired flavour and lipid concentrations with the avoidance of excessive moisture loss and potential lipid degradation.

3.3.2. Sensory Evaluation

Sensory evaluation indicated that all treatments maintained acceptable color, aroma, and flavor characteristics Table 2)

Table 2. Sensory Profile of Rendang Subjected to Different Retort Sterilization Treatments

Sensory Attribute	Control	125 °C/5 min	125 °C/10 min	125 °C/15 min	125 °C/20 min
Color	Brown	Brown	Brown	Brown	Brown
Aroma	Normal	Normal	Normal	Normal	Normal
Flavor	Normal	Normal	Normal	Normal	Normal

These findings highlight the suitability of static retort processing for preserving traditional sensory characteristics while ensuring product safety. The absf noticeable sensory deterioration across all sterilization timesuniform concentrationin holding timsterilisationdo not significantly influence consumer-perceived quality. Overall, the results confirm that retort sterilization at 125 °C can be successfully applied to rendang production without negatively affecting its organoleptic attributes

3.3.3. Total Plate Count (TPC)

The Total Plate Count (TPC) results demonstrated a substantial reduction in microbial load in rendang after retort sterilization compared with the control (Figure 7).

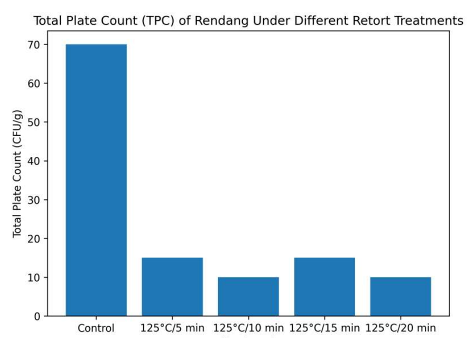

Figure 7. Effect of Retort Treatment on Total Plate Count (TPC)

The control sample showed the highest count (70 CFU/g), whereas retort-treated samples exhibited markedly lower values, namely 15 CFU/g at 125 °C for 5 min, <10 CFU/g at 10 min, 15 CFU/g at 15 min, and <10 CFU/g at 20 min. These findings confirm that retort processing effectively suppresses microbial populations, thereby enhancing the microbiological safety of rendang.

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The observed decrease in TPC is consistent with the established principles of thermal sterilization, in which high-temperature treatment leads to protein denaturation, membrane disruption, and enzyme inactivation in microorganisms. Thermal processing above 121 °C is widely recognized as sufficient to destroy most vegetative cells and significantly reduce spore-forming microorganisms in low-acid foods [23,24] Similar reductions in microbial load have been reported in retort-processed meat products, where TPC values typically decrease to very low or undetectable levels following adequate thermal treatment [21].

Among the treatments evaluated, processing at 125 °C for 10 and 20 min resulted in counts below the detectable limit, indicating near-complete microbial inactivation. These results are comparable to previous studies on retort-processed ready-to-eat meat products, which reported significant reductions in microbial counts and improved shelf stability under similar thermal conditions [24]. The slight fluctuation observed between treatments (e.g., similar counts at 5 and 15 min) may be attributed to normal variability in microbiological enumeration rather than differences in processing efficiency.

In addition to thermal lethality, product composition may also contribute to microbial stability. Rendang typically has relatively low moisture content and high fat levels, which may reduce water activity and inhibit microbial growth during storage. Such compositional factors have been recognized as important contributors to the microbiological stability of thermally processed foods [21].Overall, the findings confirm that retort sterilization at 125 °C is highly effective in reducing microbial contamination in rendang. The results align well with previous literature on retort-processed meat products and support the application of retort technology as a reliable preservation method for extending shelf life while maintaining product safety

3.3.4. Effect of Storage Duration on Respondents' Acceptance of Rendang Sterilized at 125°C

The results showed that the storage duration of sterilized rendang influenced respondents' acceptance as determined by sensory evaluation. At storage periods of 0, 2, 4, and 6 months, the overall acceptance scores were 4.96, 4.94, 4.89, and 4.87, respectively (on a 0–5 scale). The data indicate a slight decline after storage; however, the scores for all treatments were still classified as "highly liked" by respondents (Figure 7).

After up to 2 months of storage, the overall acceptance score declined only slightly from 4.96 to 4.94, indicating that the product remained highly acceptable. This suggests that the physicochemical characteristics of rendang, such as texture, aroma, taste, and color, remained stable during this period.

A more noticeable decline appeared during storage from 4 to 6 months, with acceptance scores decreasing from 4.89 to 4.87. This decline may be associated with changes in sensory quality, such as aroma and flavour deterioration, caused by chemical reactions during storage.

Despite the downward trend in acceptance scores, all values remained within the "highly liked" category. These findings indicate that sterilization at 125°C for 10 minutes is effective in maintaining product quality during storage for up to 6 months. The sterilization treatment can inactivate spoilage microorganisms and enzymes, thereby slowing the deterioration of quality during storage.

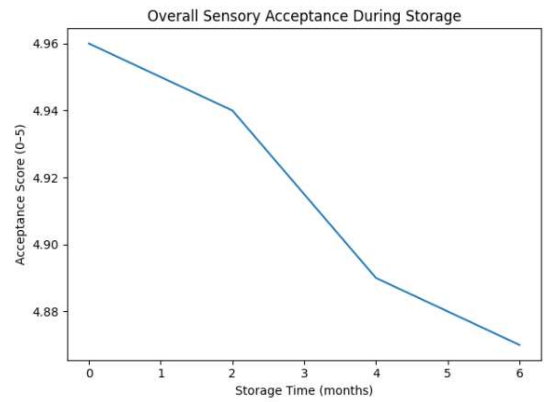

Figure 7. Sensory Acceptance During Storage

Overall sensory acceptance declined only slightly over six months of storage. The acceptance score remained within the "highly preferred" range (>4.8 on a 5-point scale), indicating strong sensory stability of retort-processed rendang. The linear downward trend suggests gradual quality changes rather than abrupt deterioration, supporting the conclusion that shelf life up to six months is technologically and sensorially justified.

3.3.5. Consumer Perception of Rendang Shelf Life

This study also examined consumer perceptions regarding their intention to consume rendang with varying shelf-life durations of 0, 2, 4, 6, 12, 18, and 24 months. The percentage of respondents willing to consume the product declined steadily. The data were as follows: 100%, 98%, 97%, 92%, 75%, 42%, and 31%, respectively.

Over a 6-month shelf life, the number of respondents willing to consume rendang decreased, but the difference was not statistically significant. After that, a significant decline occurred at shelf lives of 12, 18, and 24 months (Figure 8).

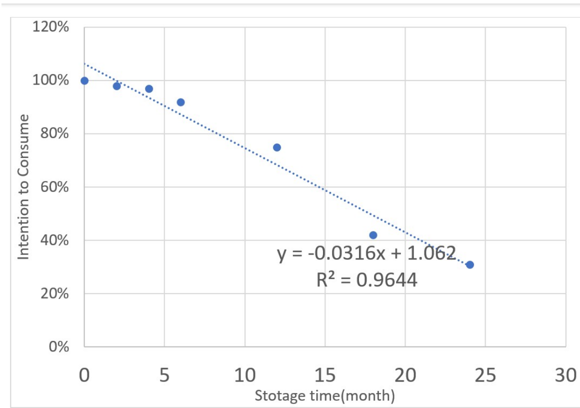

Figure 8. Respondents' Perception (Expressed as Intention to Consume) at Different Shelf-Life Durations

Consumer perception data reveal a statistically significant threshold in acceptance of shelf-stable rendang at 12 months of shelf-life. The results demonstrate that consumer willingness to consume the product remains relatively stable at high levels up to 6 months (declining only from 100% to 92%, a non-significant change), but exhibits a dramatic and statistically significant decline beyond this point (75% at 12 months, 42% at 18 months, and 31% at 24 months). This pattern indicates that consumers perceive a critical boundary at approximately the 12-month mark, beyond which their confidence in product safety, quality, and acceptability deteriorates substantially. The perceived level of risk associated with a food product can significantly influence purchase and consumption decisions [25], and the sharp decline observed at 12 months suggests that consumers may begin to question the safety and sensory quality of shelf-stable rendang when shelf-life extends beyond one year.

4. CONCLUSION

Static retort thermal processing significantly improved microbiological safety while maintaining the quality of traditional rendang. Sterilization affected the physicochemical composition, showing biphasic trends in moisture, ash, and protein content, while fat content increased due to concentration effects. Total Plate Count (TPC) decreased markedly in all treated samples, confirming effective microbial inactivation. Sensory evaluation indicated stable color, aroma, and flavor across treatments, demonstrating preservation of the traditional organoleptic profile. Consumer acceptance remained high up to six months but declined at longer declared shelf lives. Overall, sterilization at 125 °C for 10–15 min provided the best balance between safety, stability, and acceptability.

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