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Influence of sterility values and retort temperature on the physicochemical and sensory attributes of *kawah*-style meat curry

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Abstract

This study examined the physicochemical, microbiological and sensory properties of *kawah*-style meat curry, a traditional dish from Malaysia's Eastern Coastal region, prepared using the retort process. Portions of *kawah*-style meat curry (180 g, with 60 g of partially cooked meat and 120 g of curry gravy) were packed in two types of retort pouches: RCPP/Nylon/Al/PET (Al) and Nylon/RCPP (T). These pouches underwent processing in a retort machine at 121 °C with F_0 values of 8, 10 and 12. Subsequent analysis encompassed physicochemical, microbiological and sensory evaluations. The results showed that increasing F_0 values reduced the total soluble solids (TSS) and pH values of the curry gravy in both pouch types, while the Al pouch maintained better colour (L*, a* and b*) values. Notably, the absence of harmful bacteria including aerobic and anaerobic species, yeast, mould, coliforms (*Escherichia coli)* and *Salmonella* spp. affirmed the safety of the retorted samples for consumption. Sensory evaluation indicated high acceptability, with F_0 8 achieving the highest overall scores (5.95 for Al and 5.89 for T), although the differences were not statistically significant. F_0 8 was selected for further storage studies due to its superior acceptability and safety.

Keywords: *kawah-style meat curry, retort pouches, quality evaluation, sensory acceptance*

Introduction

Kawah-style meat curry is a beloved dish rooted in the culinary heritage of the Eastern Coastal regions of Peninsular Malaysia, particularly in the states of Kelantan and Terengganu. Celebrated for its bold flavours, spiciness and rich umami notes, this dish delivers a deeply satisfying taste experience. It is often paired with plain or biryani rice, creating a harmonious balance of textures and aromas. The market for easily accessible foods has seen significant growth, particularly in the ready-to-eat (RTE) meal segment, which is widely available through retail and single-portion food delivery services. According to Howard et al. (2012), RTE meals are pre-prepared main courses that require no additional ingredients and can be reheated in a container within 15 min. The demand for ready-to-eat meals packaged in retort pouches has exhibited a consistent upward trend in recent years, driven by consumer preferences for convenience, extended shelf-life and minimal preservative use (Chua et al. 2023). In today's fast-paced environment, modern consumers increasingly turn to ready meals and convenience foods to save time and simplify their routines. Recent data from Innova Market Insights (2024) reports that over 60% of global consumers now use convenience foods at least weekly, substituting them for traditional meals due to time constraints. Hence, in response to this trend, the food industry has prioritised the development of RTE meals as a practical solution.

Retort processing is a common thermal sterilisation method for RTE meals, ensuring commercial sterility and extended shelf life in packaging such as cans, pouches, and flexible laminates. The process involves exposing food to high temperatures in a steam chamber for a specific time to eliminate harmful microorganisms and enzymes that could compromise its quality. The advantages of retort processing include maintaining food quality without refrigeration, preserving nutritional value and offering long shelf life for RTE meals. However, the process can affect the food's texture, flavour, and appearance, i.e.,

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challenges that can be addressed through careful recipe formulation and the selection of suitable packaging materials (Lee et al. 2014 a, b).

Retort pouches, a popular type of flexible packaging, are constructed from multiple layers of materials, such as polyester, aluminium foil and polypropylene. These layers render the pouches durable, flexible and resistant to punctures and leaks. Compared to traditional glass or metal cans, retort pouches offer several advantages, including lighter weight, greater visual appeal and enhanced convenience. Additionally, the high surface area-to-volume ratio of retort pouches reduces cooking times, improving nutritional retention and minimising moisture loss. Retort-pouched products are convenient, ready-to-eat, and have a long shelf life, making them appealing to consumers (Rajkumar et al. 2010; Chua et al. 2023).

The retort technology is used for a wide range of meat curry products, including '*gulai-besar*' (Tayeh et al. 2019), Rogan josh (Ahmad Shah et al. 2017), Chettinad-style goat meat curry (Rajkumar et al. 2010), *kaoyuk* (Nakban et al. 2020) and others. While prior studies have explored the retort processing of various meat curries, limited research has examined the physicochemical, microbiological and sensory properties of meat curry with varying F_0 values and pouch types. Therefore, this study aims to evaluate the physicochemical characteristics, microbiological and sensory acceptability of retorted *kawah*-style meat curry packaged in different pouch types.

Materials and method

Preparation of the kawah-style meat curry

The *k*awah-style meat curry was fully prepared and cooked by Saudagar Rasa Sdn. Bhd. (Selangor, Malaysia) using a standardised recipe. Upon delivery to MARDI's laboratory, only weighing and packaging were performed. The partially cooked meat chunks were separated from the curry gravy prior to packing. The curry gravy was made using fresh onions, *k*awah-style meat curry spices, cooking oil, tamarind, brown sugar, garlic, *rustle*, salt, ginger, galangal, coconut milk and chicken stock.

Retort processing

Retort processing was performed using a horizontal water immersion clutch retort (Model H60, Type C50, Japan). A total of 180 g of product (60 g of half-cooked meat and 120 g of curry gravy) was manually filled into different types of retort pouches (12 × 16.5 cm): RCPP/Nylon/Al/PET (Al) and Nylon/RCPP (T). All pouches were sealed by an impulse sealing machine (Automatic Impulse Sealer, Japan) after residual air was removed. The hermetically sealed pouches were put on a tray and loaded into the retort machine. To ensure the adequacy of the thermal process, sample pouch was fixed with thermocouple glands, through which the thermocouple was inserted into the meat pieces to record the core temperature during heat processing. The filled and sealed pouches (along with sample pouches) were subjected to thermal processing at 121 °C with different F_0 values of 8, 10 and 12. The F_0 meter probe was mounted with the sample and pouch system exactly in its slowest heating zone (SHZ). The vessel was then turned on together with the data logger. The F_0 result was then printed on thermal paper. The pressure remained constant at 15 psi throughout the process, while the temperature was then swiftly dropped to 55 °C during the cooldown process. After the sterilisation process, the products were incubated for two weeks at ambient temperature (35 ± 2 °C) to ensure the products' stability in achieving commercial sterility prior to distribution.

Physicochemical analysis

pH

The pH value of the *kawah*-style meat curry gravy was determined using a pH meter (Metler Toledo, Switzerland). The analysis was performed in triplicates, and was reported.

Total soluble solid (°Brix)

The total soluble solid of the *kawah*-style meat curry gravy was measured using a digital refractometer (Model HI 96801, Hanna Instrument, USA). The analysis was performed in triplicates, and was reported.

Water activity (a_w)

The water activity of the retorted *kawah*-style meat curry gravy was determined using a water activity meter (LabMaster-aw, Novasina, Switzerland) according to the manufacturer's instructions. Values were recorded after constant readings were obtained. The analysis was performed in triplicates and the average value was reported.

Colour

The colour of the *kawah*-style meat curry gravy was evaluated using a chroma meter (Model CR-400/410, Konica Minolta, Japan) by measuring the colour parameters of the gravy: L* = 0 (black) and L* = 100 (white), +a* indicates red and –a* = green and +b* indicates yellow and –b* = blue. The analysis was performed in triplicates on the surface of each sample and the average value was reported.

Microbiological quality assessment

Total plate count, yeast and mould, coliform (Escherichia coli) and anaerobic bacteria

The meat chunks in the curry were cut using a sterile knife and then mixed with the gravy. Approximately 10 g of the mixture was aseptically weighed and homogenised with 90 mL of Ringer's solution (Oxoid, Hampshire, England) using a stomacher lab blender (Seward Model 400, London, UK) for 60 s. Serial dilutions were prepared using the same diluent and duplicate counting plates were prepared with the corresponding dilutions. For the pour plate test, 1 mL of the appropriate dilution was mixed with molten (45 °C) media and poured into plates. The inoculum was evenly mixed by gently swirling the plates six times in each direction (six clockwise, six anti-clockwise directions). Then, the agar with the inoculum in the plate was allowed to solidify. Total mesophilic aerobic bacteria and total anaerobic bacteria were counted by plating the sample on a plate count agar (PCA, Difco, USA). Yeast and mould counts were performed on potato dextrose agar (PDA, Difco, USA). Microbial colonies were counted after 72 h incubation at 31 ± 1 °C for both PCA and PDA (ICMSF, 1978). Total anaerobic bacteria were incubated in an anaerobic jar with a gas pack pouch to create an anaerobic environment. *E.coli and* other *coliforms* were determined using a compact dry EC (Nissui Pharmaceutical, Japan) and incubated at 37 °C for 48 h according to the manufacturer's instructions. All microbial enumeration results were expressed as log colony-forming units (CFU/g).

Salmonella spp.

The meat chunks in the curry were cut using a sterile knife and mixed with the gravy. The ISO 6579 enrichment procedure was used for the recovery of *Salmonella* from foods. Approximately 25 g of the mixture was aseptically weighed and homogenised with 225 mL of buffered peptone water (Oxoid, Hampshire, England) using a stomacher lab blender (Seward Model 400, London, UK) for 60 s. The samples were then incubated at 37 °C for 16 to 20 h. After incubation, the samples were gently shaken and transferred as follows: a) 0.1 mL into 10 mL *Rapport-Vassiliadis Soya Peptone broth* (RVS) and (b) 1.0 mL into 10 mL Selenite Cystine (SC) broth. All tubes were vortexed and mixed well before being incubated at 41.5 ± 1 °C for 24 ± 3 h (RVS broth) and at 37 ± 1 °C for 24 ± 3 h (SC broth). Approximately 3 mm loopfull of incubated RVS medium were streaked onto selective enrichment plates of Xylose Lysine Deoxycholate (XLD) agar (Oxoid, Hampshire, England) and Brilliance Salmonella Agar (Oxoid, Hampshire, England). The procedure was repeated for the SC broth, and the plates were re-incubated at 37 ± 1 °C for 24 ± 3 h. If the growth is minimal or if no typical colonies of *Salmonella* are present, the plates were re-incubated for an additional 24 h and re-examined for typical colonies of *Salmonella*. *Salmonella* spp. is considered present when purple colonies are observed on Brilliance *Salmonella* agar and red colonies with black centre on XLD agar.

Sensory evaluation of retorted kawah-style meat curry

Two coded samples of retorted *kawah*-style meat curry, packed in Al and transparent pouch, were served together with gravy and evaluated by 40 semi-trained panellists. The samples were warmed before serving. The panellists were asked to evaluate the products for their colour, odour, taste, texture (meat), viscosity (gravy) and overall acceptability using a 7-point hedonic scale. The scale points are as follows: 1 = dislike very much, 2 = dislike moderately, 3 = dislike, 4 = neither like nor dislike, 5 = like, 6 = like moderately and 7 = like very much. Drinking water was provided to clean the palate after testing each sample.

Statistical analysis

The statistical software Minitab 19 (Minitab Inc., State College, PA, USA) was used to perform a two-way analysis of variance (ANOVA) with the Tukey test (p <0.05) to compare differences among treatments for physicochemical data. For sensory evaluation data, which were collected using a 7-point hedonic scale and treated as ordinal, the Mann–Whitney test was applied to assess differences between groups. This nonparametric test was chosen as the data did not meet the assumptions of normality and homogeneity of variance. Differences were considered statistically significant at (p <0.05).

Results and discussion

Physicochemical properties evaluation

The pH of the kawah-style meat curry gravy plays a pivotal role in determining its quality during the retort process. *Table 1* reveals that the pH of the gravy exhibits a slight but significant reduction (p <0.05) from 5.47 to 5.43 as the F_0 values increase from 8 to 12 in the Al pouches. Conversely, the pH of the curry in the T pouches shows no significant changes (p <0.05). Notably, the pH values of the curry in the T pouches are higher than those in the Al pouches at F_0 values of 8 and 12. This discrepancy can be attributed to the differences in the permeability of the packaging materials to oxygen and water vapour, with T pouches generally having higher permeability. Such permeability variations may influence the pH of the curry during retorting. Moreover, pH changes could result from the degradation of proteins and the liberation of free amino acids, which affect the curry′s acidity (Girish et al. 2018). A decrease in pH value has been reported in various retorted meat-based products. For instance, Kim et al. (2020) observed a reduction in pH from 6.45 to 6.32 in soy sauce-flavoured *samgyetang* after retorting at an F_0 value of 8. Similarly, Ariyana et al. (2023) reported a pH decline from 6.17 to 5.58 in *satay rembiga* as the sterilisation time increased from 3 to 18 minutes. In addition, the decrease in pH is linked to the breakdown of organic acids naturally present in food, leading to the formation of acidic compounds that further lower the overall pH (Mutma'innah et al. 2022).

The total soluble solids (TSS) are a key quality indicator for the *kawah*-style meat curry, reflecting the concentration of dissolved solids in the gravy. Changes in TSS significantly impact the flavour, texture and overall quality of the product. The TSS of the curry in both Al and T pouches decreased significantly (p <0.05) from 9.27 to 8.53 and 11.33 to 8.00, respectively, as F_0 values increased from 8 to 12 (*Table 1*). This reduction is likely due to moisture loss during the retort heating process, which alters the concentration of soluble solid components in the gravy (Noor Zainah et al. 2023).

Water activity is another critical parameter in the retorting process, as it directly affects microbial growth and shelf life. Higher water activity levels increase the risk of microbial growth and spoilage, while lower levels help extend shelf life (Juneja et al. 2016). Despite the variations in retorting conditions, the water activity of the curry remained relatively stable in both Al and T pouches as the F_0 values increased. However, a slight decrease in water activity was observed in the T pouch samples. Additionally, the water activity of the curry in T pouches was higher than in Al pouches for samples processed at F_0 values of 8 and 10. According to Usawakesmanee et al. (2024), this is attributed to the superior moisture barrier properties of Al foil, which better preserves internal moisture content and limits vapor diffusion. By contrast, T pouch laminates allow higher moisture permeability, resulting in greater retention (or absorption) of water and thus elevated water activity levels in the *kawah*-style meat curry.

Colour is a vital quality attribute of the kawah-style meat curry gravy, influencing its visual appeal and consumer acceptance. *Table 1* outlines the colour changes in the gravy across different F0 values. The lightness (L*) of the curry in both Al and T pouches increase significantly (p <0.05) as F_0 values rise. This trend may be due to the effect of pH on the colour of gravy, as higher pH levels often lead to darker hues. In contrast, Ahmad Shah et al. (2017) observed a decrease in L* values of rogan josh with higher F0 values, likely due to prolonged heat exposure. Similarly, Muhlisin et al. (2013) noted a decline in L* values for Chuncheon dakgalbi (a Korean dish) with extended cooking times. The redness (a*) and yellowness (b*) of the curry increase with the rising F_0 values in samples packed in Al pouches, from 11.89 to 14.86 and 36.14 to 36.59, respectively. Conversely, both a* and b* values decrease in samples packed in T pouches as F_0 values increase. The increase in L* values and the reduction in a* values at higher F_0 values may be linked to the Maillard reactions between sugars and amino acids, causing the colour changes (Starowicz and Zieliński 2019). The rise in b* values in the Al pouches can be attributed to the unique properties of the packaging material and the thermal effects on the curry's colour.

Microbiological quality assessment

The absence of microbial growth in the *kawah*-style meat curry samples after retorting serves as a critical indicator of the process's success in achieving commercial sterilisation. This is essential to ensure food safety and quality, as the presence of residual microorganisms could lead to spoilage or potential health risks for consumers. Post-retort processing, microbial parameters, including total plate count, yeast and mould, coliform (*E. coli)*,

Table 1. Effect of different F_0 value on the physical properties of retorted *kawah*-style meat curry

Physical analysis	Type of pouch	F_0 value		
		8	10	12
pH	Al	5.47 ± 0.00^{aB}	5.48 ± 0.01^{aA}	5.43 ± 0.01^{bB}
	T	5.54 ± 0.01^{aA}	5.37 ± 0.02^{bB}	5.53 ± 0.01^{aA}
Total soluble solid (°Brix)	Al	9.27 ± 0.06^{aB}	9.40 ± 0.10^{aB}	8.53 ± 0.06^{bA}
	T	11.33 ± 0.12^{aA}	10.40 ± 0.10^{bA}	8.00 ± 0.00^{cB}
Water activity (a_w)	Al	0.96 ± 0.01^{aA}	0.96 ± 0.00^{aB}	0.96 ± 0.00^{aA}
	T	0.98 ± 0.01^{aA}	0.99 ± 0.00^{aA}	0.96 ± 0.00^{bA}
Color				
L*	Al	28.26 ± 0.35^{bA}	28.56 ± 0.02^{bA}	29.75 ± 0.04^{aA}
	T	24.94 ± 0.07^{cB}	27.76 ± 0.03^{aB}	26.77 ± 0.03^{bB}
a*	Al	11.89 ± 0.03^{cA}	15.27 ± 0.06^{aA}	14.86 ± 0.05^{bA}
	T	10.43 ± 0.15^{bB}	14.30 ± 0.07^{aB}	10.26 ± 0.07^{bB}
b*	Al	36.14 ± 0.17^{cA}	37.76 ± 0.14^{aA}	36.59 ± 0.23^{bA}
	T	29.30 ± 0.35^{bB}	33.47 ± 0.05^{aB}	28.71 ± 0.24^{cB}

Values are expressed as mean ± standard deviation.
Different lowercase in the same row are significant differences (p <0.05)
Different uppercase letters in the same column are significant differences (p <0.05)
Al = RCPP/Nylon/Al/PET; T = Nylon/RCPP

anaerobic plate count and Salmonella spp., were examined. No microbial growth was detected in any sample across the different F_0 values tested (*Table 2*). This result highlights the effectiveness of the recommended thermal processing conditions in achieving commercial sterilisation for the *kawah*-style meat curry packed in various retort pouches. Before thermal processing, the microbial counts for the curry were recorded as 4.98×10^7 CFU/g for total plate count, 4.64×10^6 CFU/g for yeast and mould, and 6.1×10^6 CFU/g for anaerobic plate count. The complete absence of microbial growth after retorting confirms the efficacy of the process in significantly reducing the microbial load of the product. Comparable outcomes were reported in pork curry samples retorted at 121 °C and an F_0 value of 11.81, where no growth of microorganisms including *E. coli*, Salmonella spp., Clostridium spp. and Staphylococci spp., was observed in the total plate counts during storage according to Girish et al. (2018). Similarly, Rajkumar et al. (2010) reported the absence of microorganisms after processing of *rogan josh* in retort pouches at 121 °C with F_0 values ranging from 7 to 11. In conclusion, the retorted *kawah*-style meat curry processed using various F_0 values and packaging materials is safe for consumption, meeting the required standards for commercial sterilisation.

Sensory evaluation

Sensory evaluation is inherently subjective and influenced by individual preferences. Hence, it is essential to collect feedback from a diverse group of panellists to obtain results representative of the general population. The sensory evaluation outcomes for kawah-style meat curry packed in Al and T pouches are summarised in *Table 3*. Sensory evaluation showed that most sensory attributes including colour, taste, texture, viscosity and overall acceptability received similar median scores of 6.00 across pouch types (Al and T) and F_0 values (8, 10, and 12), indicating good consumer acceptance for all treatments. However, statistically significant differences (p <0.05) were observed for specific attributes. Notably, the odour of T pouch samples at F_0 8 and 12 achieved higher scores (7.00 ± 0.77 and 7.00 ± 0.90) respectively, indicating a more favourable aroma perception. Similarly, the colour score for T pouch at F0 12 was slightly higher (6.50 ± 0.71), possibly due to improved visual appeal from Maillard reactions at higher thermal intensity. These findings align with previous reports highlighting the impact of thermal intensity and packaging on sensory attributes. For instance, Wan Nur Zahidah et al. (2024) reported significant changes in the colour of grilled beef packed in retort pouches when processed at different F_0 values, demonstrating that thermal treatment can markedly influence sensory perception. Similarly, Majumdar et al. (2017) observed noticeable reductions in colour intensity and alterations in texture for retort-processed prawn curry as the F_0 value increased from 6 to 9, underscoring the influence of higher thermal intensity on sensory quality. These studies support the conclusion that retort conditions and packaging type can significantly affect the sensory outcomes of thermally processed foods.

Table 2. Effect of different F_0 value on the microbiological analysis before and after retorted *kawah*-style meat curry

Treatment	F_0 value	Packaging material	Total plate count, TPC (CFU/g)	Yeast and mould (CFU/g)	Coliform/*E.coli* (CFU/g)	Anaerobic plate count (CFU/g)	*Salmonella* spp. (CFU/g)
Before retort			1.15×10^7	4.98×10^7	4.64×10^6 **E.coli* not detected	4.54×10^7	N.D
After retort	8	Al	N.D	N.D	N.D	N.D	N.D
		T	N.D	N.D	N.D	N.D	N.D
	10	Al	N.D	N.D	N.D	N.D	N.D
		T	N.D	N.D	N.D	N.D	N.D
	12	Al	N.D	N.D	N.D	N.D	N.D
		T	N.D	N.D	N.D	N.D	N.D

Result written as N.D means no growth detected.
Detection of *Salmonella* in food product by the ISO 6579 *Salmonella* culture procedure
Al = RCPP/Nylon/Al/PET; T = Nylon/RCPP

Table 3. Sensory evaluation results of retorted *kawah*-style meat curry products using different packaging materials and F_0 values

Sensory attributes	Type of pouch	F_0 value		
		8	10	12
Color	Al	6.00 ± 0.81^{bA}	6.00 ± 0.96^{aA}	6.00 ± 0.75^{cB}
	T	6.00 ± 0.69^{bB}	6.00 ± 0.69^{cB}	6.50 ± 0.71^{aA}
Odour	Al	6.00 ± 0.85^{cB}	6.00 ± 1.07^{aA}	6.00 ± 0.95^{bB}
	T	7.00 ± 0.77^{bA}	6.00 ± 0.77^{cB}	7.00 ± 0.90^{aA}
Taste	Al	6.00 ± 0.84^{cB}	6.00 ± 1.11^{aA}	6.00 ± 0.92^{bB}
	T	6.00 ± 0.92^{bA}	6.00 ± 0.92^{cB}	6.00 ± 0.95^{aA}
Texture (meat)	Al	6.00 ± 1.03^{bA}	6.00 ± 1.31^{aA}	6.00 ± 0.88^{cB}
	T	6.00 ± 0.99^{bB}	6.00 ± 0.86^{cB}	6.00 ± 1.14^{aA}
Viscosity (gravy)	Al	6.00 ± 0.88^{cA}	6.00 ± 1.08^{aA}	6.00 ± 0.89^{bB}
	T	6.00 ± 0.86^{bB}	6.00 ± 0.86^{cB}	6.00 ± 0.97^{aA}
Overall acceptability	Al	6.00 ± 0.87^{cB}	6.00 ± 0.98^{aA}	6.00 ± 0.95^{bA}
	T	6.00 ± 0.92^{bA}	6.00 ± 0.92^{cB}	6.00 ± 0.95^{aB}

Values are expressed as median ± standard deviation.
Different lowercase in the same row are significant differences (p <0.05)
Different uppercase letters in the same column are significant differences (p <0.05)
Al = RCPP/Nylon/Al/PET; T = Nylon/RCPP

Conclusion

In conclusion, factors such as temperature, duration, pressure, packaging material, and pH level significantly influence the overall quality of retorted *kawah*-style meat curry. A comprehensive evaluation of these parameters is essential to ensure optimal product quality during the planning of the retort process and the selection of appropriate packaging materials. Based on the sensory evaluation results, the *kawah*-style meat curry processed with an F_0 value of 8, which received favourable feedback from the panellists, has been selected for further storage studies to assess its physicochemical stability, microbiological safety and sensory attributes over time. These findings contribute valuable insights into optimising retort processing conditions for improved product acceptability and shelf-life.

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