

Optimisation of retort process parameters and evaluation of heat penetration characteristics of the traditional shrimp dish, *Iral kootu*

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Abstract

The main objective of this study was to optimise the retort process parameters and evaluate the heat penetration characteristics at the optimised time-temperature for the shrimp dish *Iral kootu*. Three varieties of shrimps were used for the study: white (*Penaeus indicus*), tiger (*Penaeus monodon*) and flower shrimp (*Penaeus semisulcatus*). The dishes were prepared and packed in retort pouches and processed to different time-temperature combinations. Preliminary optimisation was done for processing temperatures of 115 and 121°C for 5, 10 and 15 min. Based on sensory evaluation, 115 and 121°C for 10 min were selected for further optimisation. Commercial sterility tests and sensory evaluations of the products from the second trial indicated that both products are commercially sterile, but the product processed at 121°C for 10 min secured a higher sensory score for all the attributes. Heat penetration characteristics were determined using Ball's graphical and mathematical methods, at 121°C for 10 min. The estimated total process time (B) was 36 min, with a corresponding lethality value (F_0) of 8.89 min and a cook value (C) of 59.35 min.

Introduction

Traditional foods play a vital role in defining local identity, shaping consumer behaviour, preserving cultural heritage for future generations, and fostering interaction between heritage and the global community (Albayrak and Gunes, 2010). "*Iral kootu*" is a traditional South Indian dish prepared from shrimps that occupies a special place in the culinary heritage of Tamil Nadu, particularly in the southern districts of Madurai, Tirunelveli and Thanjavur. It is typically a "prepare, cook and serve" type of dish with limited shelf-life (Anusha *et al.*, 2025).

Shrimps constitute a major component of tropical and subtropical fisheries and represent an important economic resource globally (Hossain *et al.*, 2012). They are rich in various nutritional and bioactive compounds - including high quality proteins, essential amino acids, vitamins, calcium, fatty acids and minerals like copper, iron, zinc, iodine, manganese and selenium (Temgire *et al.*, 2021). Fish and seafood-based ready-to-eat food products are widely accepted food commodity in the food market. However, rising demand and globalisation, have intensified concerns regarding food safety and quality, particularly for highly perishable products. These products are highly sensitive to microbial

and biochemical spoilage, causing undesirable changes in flavour, odour, and sensory attributes. Further, lipid oxidation is also a major factor contributing to quality deterioration during processing and storage (Nikmaram *et al.*, 2018).

Ready-to-eat (RTE) food products comprise packaged products meant for direct consumption without further cooking (Temgire *et al.*, 2021). RTE food products are highly acceptable and popular food commodities for consumers due to convenience. The main reasons for consumer interest for these food products include attractiveness, reasonable price, taste, appearance and texture (Patel and Rathode, 2017). Retort pouch processing is widely used for these types of food products. Retort pouch processing involves application of high-temperature thermal treatment to food products in hermetically sealed flexible retort pouches to destroy all pathogenic and spoilage organisms of concern (Girish *et al.*, 2018). Retort pouches have been successfully utilised for different shrimp or prawn products like prawn kuruma (Mohan *et al.*, 2008), shrimp in curry medium (Mallick *et al.*, 2010), shrimp soup (Shashidhar *et al.*, 2016), freshwater prawn (*Macrobrachium rosenbergii*) in curry medium (Majumdar *et al.*, 2017), shrimp in water (Dixon *et al.*, 2020) and shrimp in masala (Dasan *et al.*, 2021).

The objective of this study was to optimise the retort process parameters (time and temperature) and to evaluate the heat penetration characteristics at the optimised time-temperature for *Iral kootu*.

Materials and methods

Preparation of shrimps

The shrimp varieties (white shrimp, *Penaeus indicus*, tiger shrimp, *Penaeus monodon* and flower shrimp, *Penaeus semisulcatus*) procured for the study were transported under hygienic, refrigerated conditions (0-4°C) to the Meat, Poultry and Fish Processing Unit, Department of Food Processing Technology, College of Food and Dairy Technology, Koduveli, Chennai. Shrimps were cleaned using potable water, deshelled and deveined and then washed thoroughly with chilled water 2-3 times. The dressed shrimps were stored under frozen conditions (-18 to -20°C) before processing. Frozen deveined shrimps were thawed to room temperature and pre-cooked at 80°C for 1 min, prior to cooking.

Preparation of shrimp gravy (*Iral kootu*)

The ingredients used for gravy preparation included condiments, spice mix, tomato, refined sunflower oil, water and salt. Preparation of *Iral kootu* followed Anusha *et al.* (2025) and the recipe is given in Table 1. Chopped condiments were added to hot refined sunflower oil and sautéed for 1 min. To this, chopped tomato was added and sautéed for 1 min. Spice mix, salt and water were added to the above mixture and mixed well at a low flame. The gravy was cooled and ground into a paste form.

Thermal processing

About 64±2 g of pre-cooked shrimps, along with 36±2 g of gravy

Table 1. Recipe for *Iral kootu*

Ingredients	Quantity
Shrimp	100 g
Condiments	20 g
Tomato	10 g
Spice mix	7.5 g
Water	10 ml
Refined sunflower oil	10 ml
Salt	2.5 g

were filled into 15x20 cm pouches to maintain an equal pack weight of 100±2 g. Thermocouples were inserted into the meat part to record the data. Residual air was removed, pouches were sealed, and thermal processing was carried out in a pilot-scale horizontal stationary water-spray retorting system (Lakshmi Engineering Works, Chennai, India) using various time-temperature combinations. After completing the heating process, the pouches were rapidly cooled to room temperature by spraying water under pressure. The cooled pouches were then dried, labeled and stored at ambient temperature.

Optimisation of retort process parameters (time and temperature)

To study the heat penetration, a thermocouple probe (4.3 mm dia) was carefully introduced into the core of the shrimp sample. The cold point temperatures were monitored by retort digital display to study process parameters and control the temperature distribution throughout the retort processing. The data were collected at an interval of 1 min. The packed and sealed pouches were thermally processed for different time-temperature combinations as shown in Table 2. The time-temperature combination of retort processing used in this study was adopted from Gokhale and Lele (2014), Shashidhar *et al.* (2016) and Sarifudin *et al.* (2022). The shrimp gravies processed were stored at room temperature and sensory analysis was conducted to determine the optimum time-temperature combination of retort processing. Accordingly, two-time temperature combinations representing 115 and 121°C were determined.

Subsequently, *Iral kootu* was individually prepared using the selected time-temperature combinations and subjected to commercial sterility tests and sensory evaluation to identify an optimum time-temperature combination for retort processing. Heat penetration characteristics were also calculated for the selected optimum time-temperature combination.

Table 2. Thermal processing parameters

Treatments	Process temperature (°C)	Holding time (min)
T1	115	5
T2	115	10
T3	115	15
T4	121	5
T5	121	10
T6	121	15

Commercial sterility test

For commercial sterility test, the pouches were incubated at 37°C for 15 days and at 55°C for a minimum of 5 days to observe any survivors of mesophilic and thermophilic bacteria. After the stipulated time interval, the incubated pouches were opened aseptically in a clean laminar flow chamber. Then 1–2 g samples were taken using sterile forceps and inoculated into the sterile fluid thioglycolate broth in test tubes. Sterile liquid paraffin was overlaid on top of the broth to create anaerobic conditions. The samples were then incubated at 37°C for 48 h and at 55°C for 4 days, respectively to assess the commercial sterility of the product (Dasan *et al.*, 2021).

Sensory analysis

The sensory quality of the products was evaluated by a semi-trained panel of fifteen members according to Mohan *et al.* (2008) with slight modifications. Thermally processed shrimp gravy pouches were selected from three varieties of shrimps and heated in boiling water for 5 min. The contents of the sample, including the gravy, were placed in coded plates and served warm to panellists. Water was provided to restore taste sensitivity. A 9-point hedonic scale was used for scoring the samples. Panellists were asked to assign a score of 1 to 9 (1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like nor dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; 9 = like extremely) to each sample for colour, flavour, firmness, succulence and overall acceptability, where 1 was least desirable and 9 was most desirable. A score of 6 was the limit of acceptability.

Evaluation of heat penetration characteristics

The heat penetration through the sample was studied at 121°C for 10 min, which was selected based on the sensory analysis. The heating lag factor (J_h), heating rate index (f_h), cooling lag factor (J_c), lethality value (F_0), cook value (C_0), total process time and thermal death time at retort temperature (U) were calculated graphically. The parameters f_h/U , temperature deficit (g) and Ball's process time (B) were calculated by the mathematical method. The parameters were determined by plotting temperature deficit ($Tr - Tc$) on semi-log paper where Tr is the retort temperature and Tc is the product

core temperature. These heat penetration characteristics of shrimp gravy were calculated according to Girish *et al.* (2018).

Statistical analysis

The statistical analysis was done using SPSS software package for Windows (IBM SPSS Statistics, Version 20.00). The data were analysed using one-way analysis of variance ANOVA and means were separated using Duncan's multiple range test and statistical significance was determined at a 95% confidence level ($p < 0.05$). All determinations were made in sextuplicate and data are expressed as mean \pm standard errors.

Results and discussion

Retort process parameters

Ready-to-eat *Iral kootu* prepared according to the standardised recipe and retort processed at 121 and 115°C for 5, 10 and 15 min. During retort processing, the core temperature of the products, measured by a thermocouple, was found to increase gradually with the increase of processing time. The retort process parameters were standardised based on sensory evaluation. The sensory scores obtained for each variety of shrimp are given in Tables 3, 4 and 5. The mean of colour, flavour, firmness, succulence and overall acceptability scores of *Iral kootu* prepared from white shrimp were 8.10 ± 0.16 , 8.10 ± 0.16 , 8.30 ± 0.12 , 7.97 ± 0.11 and 8.17 ± 0.10 at 115°C for 10 min, and 8.13 ± 0.13 , 8.20 ± 0.14 , 8.00 ± 0.13 , 7.73 ± 0.12 and 8.02 ± 0.09 at 121°C for 10 min, respectively.

The sensory scores of *Iral kootu* prepared from white shrimp at 115°C for 10 min and 121°C for 10 min were significantly higher for all the attributes studied, compared to those of the other treatments. Similar trends were also observed for *Iral kootu* prepared from tiger as well as flower shrimps. Therefore, gravies from all three shrimp varieties processed at 115 and 121°C for 10 min were subjected to comparative sensory analysis to select a time-temperature combination for retort processing. *Iral kootu* from three varieties of shrimp were subjected to a second thermal processing at selected time-temperature combinations of 115 and 121°C for 10 min., after which commercial sterility test and sensory evaluation were conducted to aid in the final selection.

Table 3. Effect of retort process parameters on sensory scores of *Iral kootu* prepared from white shrimp

Treatments	Sensory characteristics				
	Colour	Flavour	Firmness	Succulence	Overall acceptability
T ₁	7.70 \pm 0.11 ^a	7.87 \pm 0.12 ^a	7.83 \pm 0.15 ^a	7.37 \pm 0.15 ^a	7.69 \pm 0.11 ^a
T ₂	8.10 \pm 0.16 ^b	8.30 \pm 0.15 ^b	8.30 \pm 0.12 ^b	7.97 \pm 0.11 ^b	8.17 \pm 0.10 ^b
T ₃	8.03 \pm 0.20 ^b	7.63 \pm 0.22 ^a	7.60 \pm 0.16 ^a	7.13 \pm 0.17 ^a	7.60 \pm 0.17 ^a
T ₄	7.57 \pm 0.12 ^a	7.20 \pm 0.15 ^a	7.67 \pm 0.16 ^a	7.00 \pm 0.14 ^a	7.36 \pm 0.12 ^a
T ₅	8.13 \pm 0.13 ^b	8.20 \pm 0.14 ^b	8.00 \pm 0.13 ^b	7.73 \pm 0.12 ^b	8.02 \pm 0.09 ^b
T ₆	7.97 \pm 0.07 ^a	7.60 \pm 0.15 ^a	7.47 \pm 0.19 ^a	7.37 \pm 0.12 ^a	7.59 \pm 0.13 ^a
F value	2.225 ^{NS}	6.578 ^{**}	3.807 ^{**}	7.128 ^{**}	5.870 ^{**}

Sextuplicate; Mean \pm SE; NS - Non-significant ($p \geq 0.05$) at intervals; **-Highly significant ($p \leq 0.01$) at intervals. Superscripts in lowercase letters (a and b) indicate significant differences ($p < 0.05$) column-wise.

Table 4. Effect of retort process parameters on sensory scores of *Iral kootu* prepared from tiger shrimp

Treatments	Sensory characteristics				
	Colour	Flavour	Firmness	Succulence	Overall acceptability
T ₁	7.70±0.11 ^a	7.97±0.19 ^a	7.73±0.20 ^a	7.53±0.23 ^a	7.73±0.15 ^a
T ₂	8.13±0.17 ^b	8.47±0.17 ^b	8.13±0.21 ^b	8.13±0.19 ^b	8.22±0.15 ^b
T ₃	8.03±0.20 ^b	7.57±0.20 ^a	7.57±0.21 ^a	7.43±0.28 ^a	7.65±0.19 ^a
T ₄	7.57±0.12 ^a	7.20±0.09 ^a	7.80±0.10 ^a	7.33±0.12 ^a	7.48±0.08 ^a
T ₅	8.13±0.13 ^b	8.67±0.11 ^b	8.23±0.13 ^b	8.03±0.03 ^b	8.27±0.08 ^b
T ₆	7.97±0.19 ^a	7.67±0.12 ^a	7.70±0.11 ^a	7.30±0.12 ^a	7.66±0.06 ^a
F value	2.251 ^{NS}	13.623 ^{**}	2.463 ^{**}	4.076 ^{**}	6.575 ^{**}

Sextuplicate; Mean±SE; NS - Non-significant ($p \geq 0.05$) at intervals; ** - Highly significant ($p \leq 0.01$) at intervals. Superscripts in lowercase letters (a and b) indicate significant differences ($p < 0.05$) column-wise.

Table 5. Effect of retort process parameters on sensory scores of *Iral kootu* prepared from flower shrimp

Treatments	Sensory characteristics				
	Colour	Flavour	Firmness	Succulence	Overall acceptability
T ₁	7.63±0.11 ^a	7.13±0.09 ^a	7.80±0.11 ^a	7.07±0.07 ^a	7.41±0.06 ^a
T ₂	8.10±0.16 ^b	8.33±0.13 ^b	8.13±0.09 ^b	8.00±0.00 ^b	8.14±0.05 ^b
T ₃	7.90±0.22 ^a	7.87±0.09 ^a	8.00±0.00 ^b	7.53±0.13 ^a	7.83±0.08 ^a
T ₄	7.57±0.12 ^a	7.20±0.11 ^a	7.80±0.10 ^a	7.20±0.11 ^a	7.44±0.06 ^a
T ₅	8.13±0.13 ^b	8.47±0.13 ^b	8.07±0.07 ^b	8.00±0.00 ^b	8.17±0.05 ^b
T ₆	7.97±0.19 ^a	7.87±0.09 ^a	8.00±0.00 ^b	7.33±0.13 ^a	7.79±0.07 ^a
F value	2.178 ^{NS}	26.485 ^{**}	3.225 ^{**}	19.474 ^{**}	26.025 ^{**}

Sextuplicate; Mean±SE; NS - Non-significant ($p \geq 0.05$) at intervals; ** - Highly significant ($p \leq 0.01$) at intervals. Superscripts in lowercase letters (a and b) indicate significant differences ($p < 0.05$) column-wise.

Sensory scores for three shrimp varieties at 115 and 121°C for 10 min are given in Tables 6 to 8. Although, no significant difference was noticed in colour, firmness, succulence and overall acceptability, slightly higher scores were secured by treatment at 121°C for 10 min. A highly significant difference ($p \leq 0.01$) was observed in flavour. A similar tendency was observed for all three varieties studied. The overall acceptability for white, tiger and flower shrimp gravies at 121°C were 8.04±0.11, 8.17±0.09 and 8.11±0.12, respectively. *Iral kootu* processed at 121°C for 10 min ranked highest in all sensory attributes for each shrimp variety. The results obtained in this study are consistent with work done by Shashidhar et al. (2016) and Kamaleeswari (2025).

The processed pouches of all three shrimp varieties after thermal processing and incubation under two different conditions (37°C for 48 h and at 55°C for 4 days) showed no turbidity in the thioglycolate broth indicating that the thermal processing given

was sufficient for commercial sterility. Though both samples were commercially sterile, *Iral kootu* processed at 121°C for 10 min was found to be superior in sensory evaluation. The studies conducted by Sreelakshmi et al. (2013) and Shashidhar et al. (2016) are in agreement with the present study. Even though, retort processing at 115 and 121°C for 10 min were commercially sterile, based on both commercial sterility and sensory analysis, 121°C for 10 min was chosen for subsequent studies.

Heat penetration characteristics

Heat penetration characteristics were analysed at a retort temperature of 121°C to assess processing efficiency and the results are given in Table 9. At this temperature, the F_0 value obtained for the shrimp gravy was 8.89 min (Fig. 1). The recommended F_0 value for fish and fish products is in the range of 5-20 min (Frott and Lewis, 1994). The study conducted by Majumdar et al. (2015) on the retort processing of Rohu fish in curry medium reported an F_0 value

Table 6. Effect of retort process parameters on sensory scores of *Iral kootu* prepared from white shrimp

Treatments	Sensory characteristics				
	Colour	Flavour	Firmness	Succulence	Overall acceptability
T ₁	8.10±0.16	8.43±0.13	7.97±0.12	7.67±0.13	8.04±0.11
T ₂	8.20±0.18	7.70±0.18	7.90±0.14	7.57±0.15	7.84±0.12
t value	0.427 ^{NS}	3.306 ^{**}	0.357 ^{NS}	0.504 ^{NS}	1.225 ^{NS}

Sextuplicate; Mean±SE; NS - Non-significant ($p \geq 0.05$) at intervals; ** - Highly significant ($p \leq 0.01$) at intervals.

Table 7. Effect of retort process parameters on sensory scores of *Iral kootu* prepared from tiger shrimp

Treatments	Sensory characteristics				
	Colour	Flavour	Firmness	Succulence	Overall acceptability
T	8.37±0.12	8.50±0.12	8.13±0.16	7.67±0.13	8.17±0.09
T ¹	8.27±0.15	7.80±0.17	7.97±0.09	7.60±0.16	7.91±0.11
T ²	8.27±0.15	7.80±0.17	7.97±0.09	7.60±0.16	7.91±0.11
t value	0.507 ^{NS}	3.400 ^{**}	0.915 ^{NS}	0.333 ^{NS}	1.815 ^{NS}

Sextuplicate; Mean±SE; NS - Non-significant ($p \geq 0.05$) at intervals; ** - Highly significant ($p \leq 0.01$) at intervals.

Table 8. Effect of retort process parameters on sensory scores of *Iral kootu* prepared from flower shrimp

Treatments	Sensory characteristics				
	Colour	Flavour	Firmness	Succulence	Overall acceptability
T	8.13±0.19	8.57±0.13	8.07±0.15	7.67±0.13	8.11±0.12
T ¹	8.07±0.18	7.80±0.19	7.93±0.11	7.60±0.16	7.85±0.11
T ²	8.07±0.18	7.80±0.19	7.93±0.11	7.60±0.16	7.85±0.11
t value	0.252 ^{NS}	3.300 ^{**}	0.712 ^{NS}	0.333 ^{NS}	1.536 ^{NS}

Sextuplicate; Mean±SE; NS - Non-significant ($p \geq 0.05$) at intervals; ** - Highly significant ($p \leq 0.01$) at intervals.

of 8.14 min at 121.1°C. Similarly, ready-to-serve mahseer curry in retort pouch (Bindu *et al.*, 2011) and thermal processing of prawn kuruma in retortable pouch (Mohan *et al.*, 2008) also revealed F_0 value of 8.50 and 8.28 respectively at same temperature. This F_0 value is sufficient to obtain a commercially sterile product.

The come-up time (CUT) was 13 min, at which the product core temperature was 106°C and the retort chamber temperature was 115.2°C. The recommended range of come-up time was 5 to 7 min, and it should be as short as possible (Shashidhar *et al.*, 2016). Boneless rohu balls in curry medium processed at 121.1°C to three different F_0 values of 6, 7, and 9 min, showed CUT values of 11, 10, and 11, respectively (Majumdar *et al.*, 2016). The study by Tribuzi *et al.* (2015) on retort processing of chopped mussel meat in retort pouch at three different temperatures of 110, 118 and 121°C reported CUT values of 13, 19 and 22 respectively.

The heating rate index (f_h) was found to be 10 min in the present study. The trials by Mallick *et al.* (2010) on retort processing of shrimp in curry medium at 121.1°C for F_0 values of 5, 7 and 9 min reported f_h values of 9.40, 10.20 and 11.50 min respectively. Likewise, an f_h value of 19 min was obtained for retort-processed shrimp kuruma (Mohan *et al.*, 2008).

The Ball's processing time (B) and total process time were 21 and 36 min. This processing time was sufficient to achieve commercial sterility of the product. The cook value (C_g) aims to achieve optimal tenderness in the finished product. The C_g was found to be 59.35 min in the present study. The processing time and cook value are interrelated. When processing time increased, the cook value also increased. Shrimp in curry medium was prepared and thermally processed to three different F_0 values of 5, 7 and 9 which, resulted in total process times of 20.09, 24.31 and 28.69 min and cook value

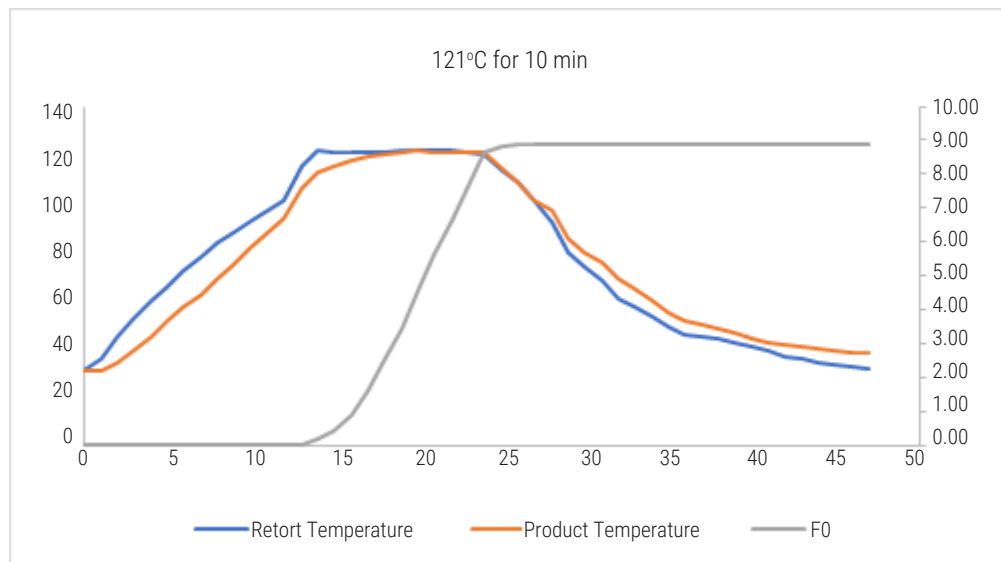
Fig. 1. Heat penetration and F_0 value for finalised retort process parameters

Table 9. Heat penetration characteristics of *Iral kootu* in retort pouch

Parameters	Values
Retort temperature (°C)	121
F ₀ value (min)	8.89
Come up time, CUT (min)	13
Heating time, HT (min)	10
Cooling time, CT (min)	13
Total process time, CUT+HT+CT (min)	36
Heating rate index, f _h (min)	10
Heating lag factor, J _h	0.96
Cooling lag factor, J _c	1.16
Thermal death time, F _i (min)	1.02
Temperature deficit, g (°C)	0.7
Thermal death time at retort temperature, U (min)	9.07
f _h /U	1.10
Internal heating time, I _h (°C)	90.5
Cook value, C _g (min)	59.35
Ball's process time (min)	21

of 59.20, 67.45 and 69.73 min, respectively (Mallick et al., 2010). Majumdar et al. (2016) prepared and processed boneless Rohu fish ball in gravy at 121.1°C to three different F₀ values of 6, 7 and 9 min, which unveiled total process time of 38.84, 42.21 and 44.65 min, and Cg of 59.88, 67.48 and 76.04 min.

Three varieties of shrimps viz., white shrimp (*P. indicus*), tiger shrimp (*P. mondon*) and flower shrimp (*P. semisulcatus*) with medium body size, were selected for the preparation of *Iral kootu*, based on their surplus availability in Tamil Nadu. These were subjected to retort processing at different time-temperature combinations for the optimisation of process parameters. Temperatures of 121 and 115°C for time periods of 5, 10 and 15 min were tested initially. From the primary trials, the combinations of 121 and 115°C for 10 min were chosen based on sensory evaluation. During the secondary trials, these two combinations underwent commercial sterility testing and sensory analysis. Both samples were found commercially sterile, however the sample processed at 121°C for 10 min was selected as optimum based on sensory evaluation. The F₀ value, total process time and cook value for this sample were 8.89 min, 36 min and 59.35 min. The heating rate index, heating lag factor and cooling lag factor were 10 min, 0.96 and 1.16 respectively. The Ball's process time was 21 min and thermal death time at retort temperature was 9.07 min. Therefore, retort processing at 121°C for 10 min was established as the optimum processing condition for *Iral kootu*, ensuring commercial sterility while maintaining superior sensory quality, thereby demonstrating its suitability for the production of safe and ready-to-eat product

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