

# Retort Processing of Indian Traditional Rice Dumpling



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**Abstract:** Indian rice dumpling is a traditional and nutritious south Indian snack with a shorter shelf life. In the study, retort processing has been explored to increase the shelf life of the rice dumpling. Retort processing provides microbiologically safer products. But the use of high temperature for longer processing period results in loss of nutritional and sensory qualities of the rice dumpling. The main objective of the present study is to optimize the process parameters of retort processing to maintain the sterility and retain the nutritional quality of rice dumpling. The experiments were redesigned using central composite design and the optimum value for the retort processing was obtained by response surface methodology. The optimum values of retort processing temperature and time were 115°C and 25 minutes respectively. Rice dumpling produced at the optimum conditions has a shelf life of four weeks when stored at ambient temperature. The sensory analysis was done using hedonic scale, the heat penetration study was calculated by Ball's formula. The  $F_0$  value was found to be 3 minutes. Therefore the shelf life of the Indian traditional rice dumpling could be increased from one day to four weeks by using retort processing technique.

**Keywords:** Retort processing, rice dumpling, Optimization, Central composite design, Shelf life.

## I. INTRODUCTION

There are lots of traditional Indian food items prepared and consumed for various occasions. These traditional foods have shelf life of one or two days. The South Indian traditional food rice dumpling which is otherwise called "KOLUKATTAI" is prepared for the festive occasion. This item has very less shelf life. Microbial contamination is the primary cause of spoilage. It is made from rice flour, jaggery, and Bengal gram, which is rich in carbohydrates and protein.

Retorting is being mainly used for thermal sterilization of low acidic food materials. It is also known as canning and is extensively used as food preservation method. Retorting process yields a food product with extended shelf-life and it need not be refrigerated [1].

Retort pouches are a flexible packaging material that consist of laminates or bounded layers of different packaging films of Polyester-Nylon-Aluminium-polypropylene that can withstand high process temperature & pressure. Their most important feature is that they are made of heat resistant plastics, unlike the usual flexible pouches.

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This makes the retort pouches unique and suitable for the processing of food contents including kolukattai at temperatures around 121°C. That is the kind of ambient temperature prevalent in the thermal sterilization of foods [2, 3].

A pure steam retort involves the introduction of pressurized steam through a series of perforated pipes, called steam spreaders, and located near the bottom of the retort chamber. The retort is vented through a valve at the top of the retort until the complete chamber volume is saturated in steam and the retort has reached its processing temperature. One variation of this type of retort utilizes a high volume fan located in the rear of the retort chamber. The fan forces the steam throughout the retort chamber, providing more even heat distribution. This type of retort is referred to as a steam-air retort. Steam retorts are characteristically difficult to maintain uniform overpressure due to the regular introduction of steam into the vessel [4].

Retort processing has been widely used as a food processing technique to produce microbiologically safe products having acceptable eating quality. However, exposure to higher temperatures for long time results in the loss of nutritional and organoleptic qualities of foods [5].

The objective of the present study is to optimize the time and temperature for the retort processing of Kolukattai to enhance the shelf life of the product and without the degradation of the food quality. This will lead to the possible commercialization of the product with longer shelf life.

## II. MATERIALS AND METHODS

### A. Materials

The raw materials such as rice flour, Bengal gram, jaggery, and cardamom were purchased from the local market. The retort pouch used for this study was 106 microns thick. The pouch was four layered with cast polypropylene - 70 microns, nylon - 15 microns, aluminum - 9 microns, polyester - 12 microns.

The chemicals potassium sulfate, sodium thiosulphate, methyl red, boric acid, petroleum ether of 99% purity and n-Hexane of 99% were purchased from Nice chemicals Pvt. Ltd., Kochi, India. The Nutrient agar and Rose Bengal agar were obtained from HiMedia Laboratories Pvt. Ltd., Mumbai, India.

### B. Product standardization

Product standardization is a major step in food processing. Standardization of kolukattai was carried out by varying the amount of rice flour, jaggery and Bengal gram followed by sensory evaluation.

### C. Product preparation

The rice flour was mixed with the hot water (95°C), salt and mixed well to make the dough. It was left for 2 to 3 minutes for setting.

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Bengal gram was boiled and ground into granules. Then, the jaggery and cardamom were ground and mixed well with the Bengal gram. The sweet stuff was prepared and stuffed into dough and folded to make kolukattai. The kolukattai was steamed in cooker for 15 minutes. The kolukattai was packed in the retort pouches and sealed.

### D. Retort processing

The food product was prepared and it was packed in retort pouch aseptically. The pouch was sealed hermetically by removing the air in the pouch manually. The sealed pouches were placed into the metal sleeves and placed inside the retort. The machine was closed and process was started by applying pressure and temperature for required time. Then pouches were removed from the metal sleeves and stored at ambient temperature (Figure 1). The packaging cost together with cost of energy in sterilization could be justified by the extended shelf life of the RTE product at ambient conditions without any refrigeration [3]. There has been little work done in comparing the effect of retort pouch barrier materials on the shelf life of shelf-stable food products [5]. It is recommended that pouches with GaengPhed Gai are heat-treated to process



**Fig. 1:** Storage of retort processed pouches at 115°C for 25 minutes, a. 1<sup>st</sup> week, b. 2<sup>nd</sup> week, c. 3<sup>rd</sup> week and d. 4<sup>th</sup> week.

lethality ( $F_0$ ) of 10 minutes, as this would guarantee consumer safety and low levels of economical spoilage. An  $F_0$  as low as 6 minutes can be used if the initial levels of heat resistant spores in the raw materials are proven to be low by practical tests. The storage condition was about 25°-30°C which is closer to room temperature. Retort processing has been widely used as a food processing technique to produce microbiologically safe products having acceptable eating quality. However, exposure to higher temperatures for long time results in the loss of nutritional and organoleptic qualities of foods [6].

### E. Experimental design

The experiments were designed based on central composite design by taking time (10-25 min.) and temperature (105°-115°C) as the variables and the shelf life of the product as the response (Table I). All the experiments were performed according to standard procedure and conducted in triplicates. According to the study of obtained data, it can be argued that the selected product processing technology and packaging materials could be applied to

provide the safety and security during four-month storage period [7].

**Table I: Factors and their values at various levels**

| Factors          | - $\alpha$ | -1  | 0    | 1   | + $\alpha$ |
|------------------|------------|-----|------|-----|------------|
| Temperature (°C) | 102.93     | 105 | 110  | 115 | 117.07     |
| Time (min.)      | 6.89       | 10  | 17.5 | 25  | 28.11      |

### F. Microbial analysis

The thermally processed retort pouches were stored at room temperature for shelf-life studies. Microbial analysis of the product was carried out at regular intervals in order to ensure the safety of the product for consumption. Bacterial and fungal growth was checked using Nutrient agar and Rose bengal agar respectively [8, 9].

### G. Nutritional analysis

The nutritional analysis of the product was done to check the changes and contents in the nutrition. The analysis was done on a weekly basis [10]. Total carbohydrate was estimated by phenol sulphuric acid method, Protein content by Kjeldahl method. Crude fiber content was estimated by the method described by Lund, 1975 [11]. The total fat content was estimated by gravimetric method after extracting the sample with n-hexane.

### H. Sensory analysis

The sensory evaluation was done based on a 9 point hedonic scale. The analysis was done on weekly basis. Ten trained panel members evaluated the kolukattai for sensory attributes.

### I. Statistical analysis of the regression model

Optimization of retort pouching was done by taking temperature and time as the variables and the shelf life as the response. The experimental trials were conducted as per the central composite. The design standard order is shown in Table II.

**Table II: Experimental Trials and the Response**

| Experiment No. | Factor 1<br>A:<br>Temperature (°C) | Factor 2<br>B: Time (minutes) | Shelf life |
|----------------|------------------------------------|-------------------------------|------------|
|                |                                    |                               | (weeks)    |
| 1              | 105                                | 10                            | 1          |
| 2              | 115                                | 10                            | 2          |
| 3              | 105                                | 25                            | 2          |
| 4              | 115                                | 25                            | 4          |
| 5              | 102.93                             | 17.5                          | 1          |
| 6              | 117.07                             | 17.5                          | 3          |
| 7              | 110                                | 6.89                          | 1          |
| 8              | 110                                | 28.11                         | 2          |
| 9              | 110                                | 17.5                          | 1          |
| 10             | 110                                | 17.5                          | 1          |
| 11             | 110                                | 17.5                          | 1          |
| 12             | 110                                | 17.5                          | 1          |
| 13             | 110                                | 17.5                          | 1          |

Design-Expert 7.0.0 (State Ease Inc., Minneapolis, MN, USA) software was used to analyse the variance (ANOVA).

### III. RESULTS AND DISCUSSION

The preparation of kolukattai was standardized by optimizing the amount of ingredients followed by sensory evaluation. 150g of rice flour, 50g of jaggery, 2g of salt and 1g of cardamom and 250 to 270 ml of water is needed to produce 12 pieces of 40g each of good quality kolukattai.

#### 3.1 Heat penetration study:

The heat penetration data was collected followed by cold spot for each product in the sample container[1, 2]. The products were heated through conductive, convective and broken curve methods shown in Figure 2.

Time and Temperature profile for Retort processing

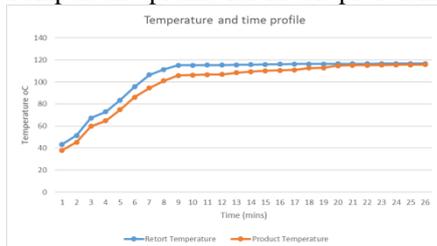


Fig. 2: Heat penetration characteristics of Kolukattai.

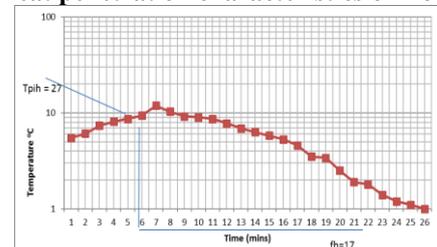


Fig. 3: Time temperature profile of retort processed Kolukattai at 115°C

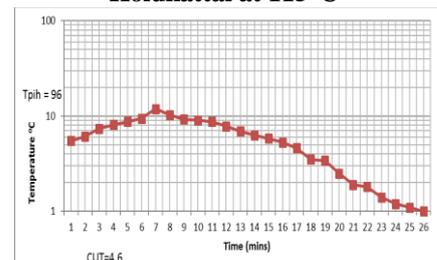


Fig.4: Time temperature profile and determination of new  $T_{pih}$  value after shifting Y-axis to 42% CUT

From the graph,  $f_h$ ,  $J_{ch}$ ,  $I_h$ , cook value, etc., were determined and given below.

$T_{ih}$  = Initial temperature of the product during retort processing, 37.9°C.

$T_{ri}$  = Initial temperature of the retort, 43.4 °C.

$T_r$  = Proposed retort processing temperature, 115 °C.

$T_{rpt}$  = Retort temperature at any time, t.

$T_w$  = Cooling water temperature, 27 °C

$I_h = T_r - T_{ih}$ , °C (115 - 37.9°C = 77.1°C).

$f_h$  = Heating rate index (time taken by the retort to pass one log cycle intertemperature), 17 min.

$l$  = Come Up Time (CUT), 8 min

$T_{pih}$  = Pseudo initial temperature of the product during heating, 27°C (from the graph after extrapolation).

$J_{ch}$  = Lag factor,  $(T_r - T_{pih}) / (T_r - T_{ih}) = 1.141$ .

#### 3.2 Thermal process time calculation

The temperature and duration of the cooking process of kolukattai have an adverse effect on the quality of the

product. The correct process time required for thermal processing of kolukattai in retort pouches was estimated by following Ball's formula method. The retort temperature and product temperature recorded during retort processing are presented in Table 3.

In the present study, Total process time, Ball's process time and Operator's process time for retort processing of packaged Kolukattai were calculated as described. The total process time was obtained by adding 42% of the come up time to the Ball's process time, while the Operator's process time was obtained by deducting 42% of the come up time from the Ball's process time (Figure 3).

From the heat penetration graph, it is observed that

$$\log (T_r - T_{ih}) = 1.887^\circ\text{C}$$

$$\log (T_r - T_{pih}) = 1.94^\circ\text{C}$$

$f_h$  = time to pass one log cycle (in temperature) in the retort

= heating rate index = 17 min

$$(T_r - T_{pih})$$

$$\text{Lag factor, } J_{ch} = \frac{(T_r - T_{ih})}{(T_r - T_{pih})}$$

$$= \frac{1.887}{1.94}$$

$$\text{Lag factor, } J_{ch} = \frac{1.887}{1.89} = 1.03$$

We know that,

$$\log J_{ch} (T_r - T_{ih}) = \log (T_r - T_{pih})$$

$$\log J_{ch} (T_r - T_{ih}) = \log (T_r - T) + t/f_h$$

$$\log J_{ch} (T_r - T_{ih}) = \log J_{ch} (T_r - T_{ih}) - t/f_h \dots 1$$

$$\log J_{ch} (T_r - T_{ih}) = \log (T_r - T) + t/f_h$$

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$$\log J_{ch} (T_r - T_{ih}) = \log (T_r - T) + t/f_h$$

$$\log J_{ch} (T_r - T_{ih}) = \log (T_r - T) + t/f_h$$

iii. Come-up-time (CUT) effectiveness = 42 %  
 However, to calculate Ball's process time,  $B_B$ , the heating curve is sufficient.

**3.3 Ball's process time,  $B_B$**

From equation 3.,  
 $B_B = f_h [\log (J_{ch} I_h) - \log g_c]$   
 Ball determined  $\log g_c$  values for different values of  $f_h/U$ . In the present experiment, it was found that  $f_h/U = 16/3 = 5.33$   
 For the value of  $f_h/U = 6$ ,  $\log g_c = 0.805$ .

Ball's process time,  
 $B_B = f_h [\log (J_{ch} I_h) - \log g_c]$   
 $= 17 \{ \log [(1.03) \times (77.1)] - 0.805 \}$   
 $= 18.6 \text{ min}$

By considering the sterilization effect obtained during Come-Up-Time (CUT) and shifting the Y axis from 0 to 4.6 min (i.e. 42% of CUT), the new  $T_{pih}$  value was determined. Using this new  $T_{pih}$ , new  $J_{ch}$  value was determined (Figure 4.). Hence, the new  $J_{ch}$  value is,

$$\text{Lag factor, } J_{ch} = \frac{(T_r - T_{pih})}{(T_r - T_{ih})}$$

$$\text{Lag factor, } J_{ch} = \frac{106}{77.1} = 1.37$$

New  $J_{ch} = 1.37$   
 New Ball's process time (after considering 42% of Come-Up-Time as effective heating time),  
 $B_B = f_h [\log (J_{ch} I_h) - \log g_c]$   
 $= 17 [\log (1.37) \times (77.1)] - 0.805$   
 $= 21.88 \text{ min.}$

The canning process was effectively determined using Ball formula and this formula has been in use for a long time. It is also broadly applied in canning process. Over the years many scientists contributed for the corrections toward its limitations [10].

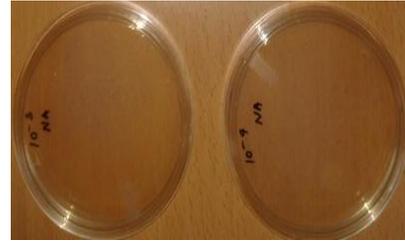
**3.4 Estimation of Ball's Process Time**

From the graph (Figure 4.) the following parameters were determined, calculated, and reported.

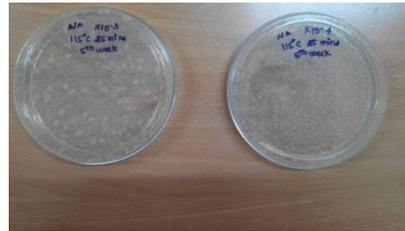
| Process Parameters                  | Value           |
|-------------------------------------|-----------------|
| $f_h$                               | 17 min          |
| $J_{ch}$                            | 1.37            |
| Retort temperature, $T_r$ °C        | 115 °C          |
| Initial temperature, $T_i$ °C       | 43.4 °C         |
| $I_h = T_r - T_i$                   | 77.1 °C         |
| $J_{ch} I_h$                        | (1.37) x (77.1) |
| $\log J_{ch} I_h$                   | 1.03            |
| $\log g_c$                          | 0.805           |
| $B_B = f_h \log (J_{ch} I_h / g_c)$ | 21.88 min       |
| Operator's process time             | 17 min          |
| Total process Time                  | 26.76 min       |

**3.5 Microbial study**

The microbial study was done to determine the shelf life and the quality of the product. It will determine whether the product is fit for consumption are not. Serial dilution was done for each sample at different combinations of trials made. The pour plate technique was used to determine microbial growth. The trial with temperature 115°C and time 25 minutes showed maximum shelf life of 4 weeks. The nutrient agar was used for testing the growth of the bacteria and Potato Dextrose agar was used for testing the fungal growth (Figure 5).



a.



b.

Fig.5: a. 4-week sample, b. 15-week sample

**3.6 Statistical analysis of the regression model**

The interaction term (AB) in quadratic regression model was selected based on coefficient of determination ( $R^2 - 0.9218$ ) and the adjusted coefficient of determination (adj.  $R^2 - 0.8659$ ). The prediction of response by the model depends on  $R^2$  and if the value is closer to unity, then better the prediction. The  $R^2$  value indicated that the statistical model explained 92.18% of the variability in the response. The terms with the  $p$ -value of  $>0.05$  were not significant and excluded from the regression model (Table 3). This leads to reduction in the  $R^2$  value generally, and the adjusted  $R^2$  value increases after excluding the insignificant terms from the model. In this study it was found that the interaction term AB was insignificant and it can not be excluded since it resulted in the reduction of  $R^2$  and adjusted  $R^2$  values.  $R^2$  is a popular way of assessing the best fit of the model. It failed to predicts the outcomes of experiments. If the response is smaller relative to noise,  $R^2$  will be small no matter how many replicates are run. The final quadratic regression model for optimizing the process variables for shelf life is given by equation as follows

$$\text{Shelf life} = +1.04 + 0.55xA + 0.73xB + 0.25AB + 0.35A^2 + 0.6B^2$$

Where,

A is the temperature in terms of the coded unit given by equation as follows

$$A = \frac{(\text{Temperature in } ^\circ\text{C}) - 110}{5}$$

B is the time in terms of the coded unit given by equation as follows



$$B = \frac{(\text{Time in min.}) - 17.5}{7.5}$$

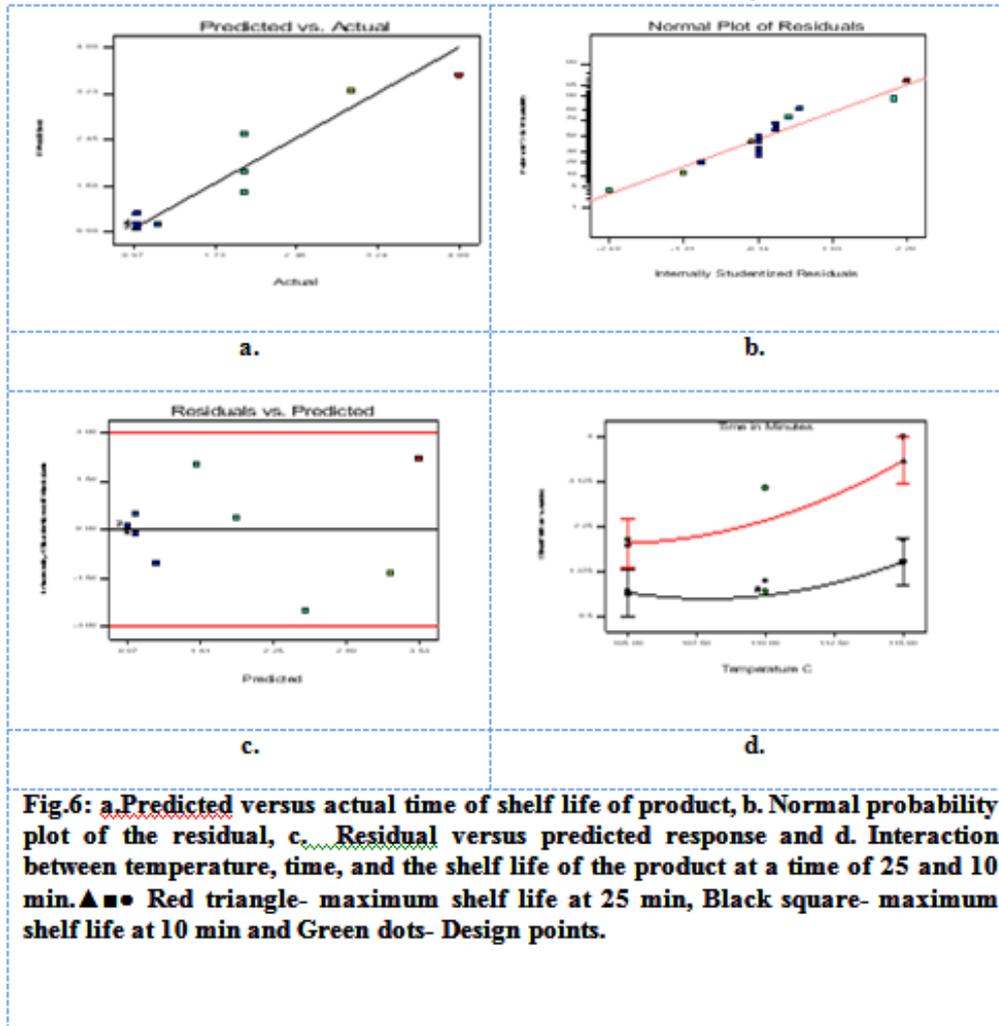
The overall model showed a significant difference at  $p < 0.05$  (Table III). Lack of fit of model was found insignificant at  $p > 0.05$ .

**Table III: Analysis of variance for the full quadratic regression model**

| Source         | Sum of squares | Degree of freedom | Mean square | F-value | p-value prob > F | Remarks     |
|----------------|----------------|-------------------|-------------|---------|------------------|-------------|
| Model          | 10.02          | 5                 | 2           | 16.5    | 0.0009           | Significant |
| A-temperature  | 2.44           | 1                 | 2.44        | 20.06   | 0.0029           |             |
| B-time         | 4.25           | 1                 | 4.25        | 34.97   | 0.0006           |             |
| AB             | 0.25           | 1                 | 0.25        | 2.06    | 0.1945           |             |
| A <sup>2</sup> | 0.88           | 1                 | 0.88        | 7.22    | 0.0312           |             |

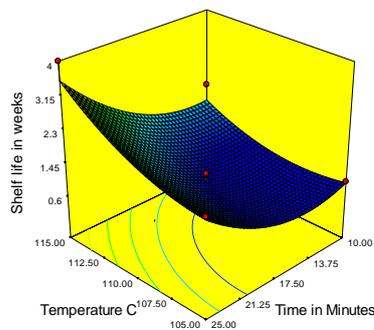
|                |       |    |       |       |        |                 |
|----------------|-------|----|-------|-------|--------|-----------------|
| B <sup>2</sup> | 2.55  | 1  | 2.55  | 20.97 | 0.0025 |                 |
| Residual       | 0.85  | 7  | 0.12  |       |        |                 |
| Lack of fit    | 0.82  | 3  | 0.27  | 34.08 | 0.0628 | Non-significant |
| Pure error     | 0.032 | 4  | 0.008 |       |        |                 |
| Cor total      | 10.87 | 12 |       |       |        |                 |

There are different trails carried out during the research, but the most desirable and acceptable was found to be at temperature 115°C processed for 25 minutes. The shelf life was found to be 3.5 weeks according to RSM. The Model F-value of 16.50 implies the model is significant. There is only a 0.09% chance that a “Model F-value” this large could due to noise. Values of “Prob>F” less than 0.0500 indicate model terms significantly. In this case A, B, A<sup>2</sup>, B<sup>2</sup> are significant model terms. Values greater than 0.1000 indicate the model terms model reduction may improve our model. The Lack of Fit F- value of 34.08 implies the Lack of Fit is not significant. There is only a 0.62% chance that a “Lack of Fit F- value” this large could occur due to noise.



**Fig.6: a. Predicted versus actual time of shelf life of product, b. Normal probability plot of the residual, c. Residual versus predicted response and d. Interaction between temperature, time, and the shelf life of the product at a time of 25 and 10 min. ▲ ■ ● Red triangle- maximum shelf life at 25 min, Black square- maximum shelf life at 10 min and Green dots- Design points.**

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**Fig. 7: 3D graph represents the relationship between temperature (°C), Time (minutes) and shelf life of the product**

A positive linear correlation was obtained between predicted and observed values (Figure 8). To determine model adequacy residual analysis was performed. It showed normal distribution of errors as straight line (Figure 6). The structureless pattern was observed for the plot of residuals vs predicted response. It indicates the adequacy of the model.

In addition, the presence of second-order terms ( $A^2$  and  $B^2$ ) confirmed the curvature effects and indicated that the optimal conditions were located within the design space. Interaction between temperature and shelf life at a time of 10 and 25 minutes the effect of temperature and time on shelf life not significant at lower temperatures and time (Figure 7). But, the effect of temperature and time on shelf life was significant at higher temperature of 115°C and time of 25 minutes. Thus the Higher temperature of 115°C and time of 25 minutes favored the shelf life of the product. The interaction between temperature and time on the shelf life reveals that the higher time and temperature had synergistic effect on shelf life.

Figure 6: shows the three-dimensional interaction of the temperature, time and shelf life. As the temperature and time increase the shelf life of the food product also increases. The predicted shelf life of the product was 3.5 week but the actual shelf life was 4 weeks which was denoted as red circle on the graph along the y-axis (Figure 9). The maximum shelf life of kolukattai predicted by the product was about 3.5 weeks at 115°C for 25 minutes.

### 3.7 Nutritional analysis

Nutritional analysis were done during the storage period of four weeks. As the microbial study was done every week for quality and stable shelf purpose alike nutritional analysis was also done to determine the changes in the nutritional content of the product stored for 4 weeks. Total Carbohydrate, Protein, Fat, and Fiber of the product were estimated. The result of nutritional analysis shows that there is little amount of degradation of total carbohydrate, fat, protein and crude fiber (Table 4).

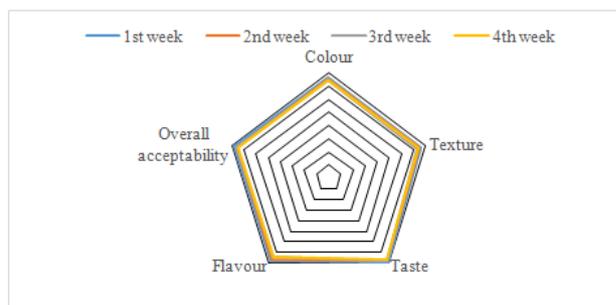
**Table 4: Nutritional content in kolukattai**

| Parameters               | 0 <sup>th</sup> day | 1 <sup>st</sup> week | 2 <sup>nd</sup> week | 3 <sup>rd</sup> week | 4 <sup>th</sup> week |
|--------------------------|---------------------|----------------------|----------------------|----------------------|----------------------|
| Total Carbohydrate /100g | 63.75g              | 61.87g               | 61.25g               | 60.96g               | 60.73g               |
| Fat /100g                | 0.09g               | 0.09g                | 0.08g                | 0.08g                | 0.08g                |
| Protein /100g            | 8.22g               | 7.68g                | 6.96g                | 6.61g                | 6.25g                |
| Crude fiber /100g        | 0.85g               | 0.80g                | 0.80g                | 0.80g                | 0.80g                |

### 3.8 Sensory analysis

The sensory analysis was done for the product processed at 115°C for 25 minutes which showed the maximum shelf life. At the end of 4<sup>th</sup> week, the pouch was heated in boiling water bath for 15 minutes, and the pouch was cut opened and sensory analysis was done by panelists with 10 members. The 9 points Hedonic scale was used for determining the acceptability of the product. The 9 point hedonic has the range like

9. Like extremely.
8. Like very much.
7. Like moderately.
6. Like slightly.
5. Neither like nor dislike.
4. Dislike slightly.
3. Dislike moderately.
2. Dislike very much.
1. Dislike extremely.



**Fig. 8: Spider web chart for sensory analysis**

Figure 8, spider web chart shows that the results of the sensory analysis were found to be good. The lines lie near the outer range which scored out of 9 using 9 points hedonic scale.



a.

b.



c.

**Fig. 9: a. Product before steaming, b. packing of steamed product and c. Retort processing machine.**

There slight variation in the results for 4 weeks but the overall acceptability of the product was good.

#### IV. CONCLUSION

According to the Central Composite design, the quadratic regression model was determined to predict the shelf life of the product. This revealed that the predicted shelf life of the product is exceeded by the obtained actual shelf life when the product is retort packaged in optimum conditions having temperature and time at 115°C for 25 minutes respectively. This increases the shelf life of kolukattai to 4 weeks resulted in little degradation of its nutrition.



machine designing.

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