

Original Research Article

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## Process Optimization and Shelf-Life Evaluation of Retort Processed Shelf Stable Ready to Eat Rice Pulav

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### ABSTRACT

#### Keywords

Rice Pulav, Free fatty acid, Thiobarbituric acid value, Peroxide value, Sensory quality, Response surface methodology

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A ready to eat thermally processed *rice pulav* were developed using retort processing. The *rice pulav* processing parameters like temperature and time 115 to 125°C for 15 to 25 min respectively on the basis of descriptive sensory evaluation. The processing temperature and time of 117.67°C for 22.4 min was considered to be the most appropriate for retorting the *rice pulav* with overall acceptability of 7.46 and desirability 0.79. The developed product was subjected to various chemical, microbial and sensory analyses during storage for 180 days at ambient temperature (17 -37°C). Free fatty acid (FFA), thiobarbituric acid (TBA) value and Peroxide value (PV) increased significantly ( $p < 0.01$ ) after 180 days of storage. And the product has good sensory and microbiological profile up to 180 day of storage.

### Introduction

India is largest producer and consumer of rice in world after China with production of 104.92 million tonnes (Anonymous, 2015). Rice is major staple food of India, in the form of boiled rice and pulav. Ready to eat *rice pulav* is ideally suitable for Indian army operational situations where cooking become limited or impossible. Although India is the largest producer of vegetables in the world, the production per capital is only about 100 g per day. However, it is estimated that around 20–25% of total vegetables are lost due to poor

post-harvesting practices. Less than 2% of the total vegetables produced in the country are commercially processed as compared to 70% in Brazil and 65% in USA (Sandhya, 2010). Today the demand for processed foods goes beyond the fundamental requirements of safety and shelf life stability. This has resulted in many ready-to-eat items becoming popular during last few years. Ready-to-eat food is one such item, which is gaining popularity in urban areas. Retort processed technology is extensively used for production of long life ready-to-eat products of various types – vegetables, vegetable products, dairy products,

food products, fruits etc. Retort processing has been widely used as a food processing technique to produce microbiologically safe products having acceptable eating quality (Kumar *et al.*, 2011). The objective of this study is to develop a shelf stable ready to eat *rice pulav* and determine its shelf-life.

## Materials and Methods

### Raw materials and preparation

*Rice pulav* was prepared using rice, carrot, green peas, onion, green chilies, spices (cloves, black cardamom, green cardamom, cumin, cinnamon, black pepper, Indian bay leaf, mace) and refined oil. Indigenous multilayer laminated retort pouches (Pradeep Laminators, Pune, India) of 20 cm × 15 cm dimension having 4 layer configuration and thickness of 106.0 µm (aluminium foil 9.0 µm, cast poly propylene 70.0 µm, polyester layer 12.0 µm and biaxially oriented nylon 15.0 µm) were used for this study. A semi – automatic paddle objected sealing machine (Sun Ray industries Pvt. Ltd., Mysore, India) was used for sealing of pouches. Flow chart (Fig. 1) illustrates the method of preparation and retort processing.

### Retort processing

The pilot-scale horizontal stationary retorting system (Lakshmi Engineering, Chennai, India) located at the Centre of Food Science and Technology, Banaras Hindu University (BHU), Varanasi (India) was used. For thermal processing, the retort temperature were maintained at 115- 125 °C for 15-25 min. Pressure was maintained at 20 ± 1 psi throughout the process, using steam- air mixture while heating and water - air mixture was used while cooling. Rapid cooling was accomplished by re-circulating cooling water. The numbers of experimental units were decided using Response Surface Methodology

software (Design expert 9x). Central compound rotatable design (CCRD) provided 13 number of trial, which are conducted to obtain combination of selected temp-time for production of best quality of product.

### Generation of heat penetration data

For every production trial one of the pouch, transferred to the retort was fitted with thermocouples for measurement of the product temperature every minute during the process. A Cu/CuNi thermocouple (Lakshmi Engineering, Chennai, India) which was capable of measuring temperature in the range of 45 °C to + 135 °C with an accuracy of + 0.1 °C. Thermocouple was placed inside the pouch and the retort was linked to a precision data logging device (Factory Talk ® View Site Edition Client software) which was capable of converting the temperature input data into corresponding process lethality values. These process lethalties values were expressed as  $F_0$  values.

### Optimization of product

Product is evaluated on the basis of  $F_0$  (given by thermal data analogue) and descriptive sensory quality, judged by panel of 10 judges consisting scientists and research scholars of Centre of Food Science and Technology, BHU, Varanasi. The samples of each trial were evaluated for descriptive sensory analysis on 10 point scale grading intensity of parameter 0-10.

### Storage study

The optimized product was stored under ambient temperature (19-39°C). The samples were analyzed at an interval of 15 days for free fatty acid (FFA) and peroxide value (PV) as per AOAC, 1990 and thiobarbituric acid value (TBA) as per Tarledgis *et al.*, (1960). The sensory evaluation was done at 25±2°C

temperature. The sensory quality of product evaluated at an interval of 30 days on the basis of 9 point hedonic scale (9- like extremely, 1- dislike extremely) for colour and appearance, aroma, taste, texture, mouth feel and overall acceptability (Amerine *et al.*, 1965).

The optimized product was also analyzed for microbiological tests at an interval of 15 days. Total plate count (TPC) and coliform count were determined using plate count agar (HiMedia, Mumbai, India) and violet red bile agar (HiMedia, Mumbai, India), respectively, after incubation for 48 h at 30°C. Yeast and molds were estimated with the help of potato dextrose agar (PDA, HiMedia, Mumbai, India) after incubation at 30°C for 4-5 days by the method of Speck (1992). Spore formers were determined after killing the vegetative cells by keeping the sample in boiling water bath for 10–20 min and subsequently incubated at 37°C and 55°C for 48 h after inoculation by method of Food and Drug Administration (1992). Pathogen *Escherichia coli* was also analyzed by the method of Speck (1992).

### Statistical analysis

The data obtained during present investigation were suitably analyzed by using response surface software (RSM design expert 9x) that was used to optimize the temperature and time combinations. ANOVA was performed to validate the RSM optimization. The experimental data obtained from RSM design were analyzed by the response surface regression procedure using the following second order polynomial equation:

$$Y_i = \beta_0 + \sum \beta_i X_i + \sum \beta_j X_j + \sum \beta_{ii} X_i^2 + \sum \beta_{jj} X_j^2 + \sum \beta_{ij} X_i X_j$$

Where,  $Y_i$  was the predicted response,  $\beta_0$  was a constant,  $\beta_i$  was the  $i^{\text{th}}$  linear coefficient,  $\beta_j$  was the  $j^{\text{th}}$  linear coefficient,  $\beta_{ii}$  was the  $i^{\text{th}}$  quadratic coefficient,  $\beta_{jj}$  was the  $j^{\text{th}}$  quadratic

coefficient and  $\beta_{ij}$  was  $ij^{\text{th}}$  interaction coefficient, and  $X_i X_j$  were independent variables.

The second order polynomial coefficients were calculated using the package design expert version 9.0.3 to estimate the responses of the dependent variable. The second order polynomial equation was employed to fit the experimental data.

## Results and Discussion

### Optimization of parameters

Using a CCRD, level of variable viz, temperature and time were selected through 13 experiments. The sensory scores and  $F_0$  as influenced by different levels of temperature and time are presented in Table 1.

### Effect of variables on sensory properties of ready-to-eat rice pulav

#### Effect on colour

The average colour score varied from 5.85 to 7.95 (Table 1). Figure 2 clearly depicts that with an increase in retort process time and temperature, sensory score of colour increased. Effect of time and temperature on sensory score of colour could be described by the following equation:

$$\text{Colour} = +7.08 - 0.043 * A + 0.14 * B - 0.74 * AB - 5.250E-003 * A^2 - 0.16 * B^2 \dots\dots (1)$$

ANOVA F-value was determined to examine the goodness of fit for the developed model (Table 2). The F-value for colour and appearance was significant ( $P < 0.0229$ ). The Model F-value of 5.47 implies that the model is significant.  $R^2$  was found to be 0.7961, indicating that 79.61 % of the variability in the response could be explained by the model. The 'Pred R-squared' of- 0.1975 is in

reasonable agreement with the 'Adj R - squared' of 0.6505.

### **Effect on gloss**

The average gloss score varied from 5.85 to 7.55 (Table 1). Figure 3 clearly depicts that sensory score of gloss is increasing with an increase in retort process time and temperature. Effect of time and temperature on sensory score of colour could be described by the following equation:

$$\text{Gloss} = +6.97 - 0.14*A + 0.22*B - 0.55*AB + 4.375E-003*A^2 - .025*B^2 \dots\dots\dots (2)$$

ANOVA F-value was determined to examine the goodness of fit for the developed model (Table 2). The F-value for colour and appearance was significant ( $P < 0.0401$ ). The Model F-value of 4.36 implies that the model is significant.  $R^2$  was found to be 0.7571, indicating that 75.71 % of the variability in the response could be explained by the model. The 'Pred R-squared' of- 0.2301 is in reasonable agreement with the 'Adj R - squared' of 0.5836.

### **Effect on spicity**

The average effect on spicity score varied from 6.10 to 7.27 (Table 1). Figure 4 shows that with increase in processing temp-time there was an increase in sensory score of spicity and slightly decrease further increase with time and temperature. Effect of time and temperature on sensory score of spicity could be described by the following equation:

$$\text{Spicity} = +6.95 - 0.071*A - 0.016*B - 0.38*AB - 0.24*A^2 - 0.36B^2 \dots\dots\dots (3)$$

The F-value for spicity was significant ( $P < 0.0396$ ) (Table 2). The model F-value of 4.39 implies that the model is significant.  $R^2$  was found to be 0.7581, indicating that 75.81

% of the variability in the response could be explained by the model. The "The "Pred R-Squared" of 0.1585 is in reasonable agreement with the "Adj R-Squared" of 0.5853.

### **Effect on cooked**

The average effect on cooked score varied from 5.15 to 7.99 (Table 1). Figure 5 shows that with increase in processing time and temperature, there was increases in sensory score of cooked and decrease with processing time. Effect of time and temperature on sensory score of cooked could be described by the following equation:

$$\text{Cooked} = + 6.87 + 0.23*A + 0.041*B - 0.49*AB + 0.18* A^2 - 0.77* B^2 \dots\dots\dots (4)$$

The F-value for cooked was significant ( $P < 0.0417$ ) (Table 2). The model F-value of 4.29 implies that the model is significant.  $R^2$  was found to be 0.7541, indicating that 75.41 % of the variability in the response could be explained by the model. The "The "Pred R-Squared" of 0.5243 is in reasonable agreement with the "Adj R-Squared" of 0.5784.

### **Effect on grain separation**

The average effect on grain separation score varied from 5.12 to 7.50 (Table 1). Figure 6 shows that sensory score of grain separation increases with increase in processing time and temperature. Effect of time and temperature on sensory score of grain separation could be described by the following equation:

$$\text{Grain Separation} = +7.15 - 0.087* A + 0.33* B - 1.04* AB - 0.14* A^2 - 0.50* B^2 \dots\dots\dots (5)$$

The F-value for grain separation was significant ( $P < 0.0177$ ) (Table 2). The model F-value of 6.05 implies that the model is significant.  $R^2$  was found to be 0.8120, indicating that 81.20 % of the variability in the

response could be explained by the model. The "The "Pred R-Squared" of -0.0850 is in reasonable agreement with the "Adj R-Squared" of 0.6777.

### **Effect on softness**

The average effect on softness score varied from 5.35 to 7.91 (Table 1). Figure 7 shows that with increase in processing temperature and time there was an increase in sensory score of Softness. Effect of time and temperature on sensory score of Softness could be described by the following equation:

$$\text{Softness} = +7.03 - 0.36*A + 0.021*B - 0.66*AB + 0.095*A^2 - 0.47*B^2 \dots\dots\dots (6)$$

The F-value for softness was significant ( $P < 0.0317$ ) (Table 2). The model F-value of 4.80 implies that the model is significant.  $R^2$  was found to be 0.7743, indicating that 77.43 % of the variability in the response could be explained by the model. The "The "Pred R-Squared" of 0.2493 is in reasonable agreement with the "Adj R-Squared" of 0.6131.

### **Effect on ease of spread**

The average effect on ease of spread score varied from 5.12 to 7.50 (Table 1). Figure 8 shows that sensory score of ease of spread increase with increase in processing temperature and time. Effect of time and temperature on sensory score of ease of spread could be described by the following equation:

$$\text{Ease of spread} = +7.04 - 0.17*A - 0.033*B - 0.85*AB + 0.071*A^2 - 0.65*B^2 \dots\dots\dots (7)$$

The F-value for ease of spread was significant ( $P < 0.0177$ ) (Table 2). The model F-value of 6.05 implies that the model is significant.  $R^2$  was found to be 0.8120, indicating that 81.20 % of the variability in the response could be explained by the model. The "The "Pred R-

Squared" of -0.0850 is in reasonable agreement with the "Adj R-Squared" of 0.6777.

### **Effect on hardness**

The average effect on hardness score varied from 5.94 to 7.52 (Table 1). Figure 9 shows that there was an increase in sensory score of hardness with increase of processing temperature and time and then decrease with time. Effect of time and temperature on sensory score of hardness could be described by the following equation:

$$\text{Hardness} = +7.16 + 5.110E-003*A - 7.411E-003*B - 0.46*AB - 0.044*A^2 - 0.54*B^2 \dots\dots (8)$$

The F-value for grain separation was significant ( $P < 0.0431$ ) (Table 2). The model F-value of 4.23 implies that the model is significant.  $R^2$  was found to be 0.7515, indicating that 75.15 % of the variability in the response could be explained by the model. The "The "Pred R-Squared" of 0.3504 is in reasonable agreement with the "Adj R-Squared" of 0.5740.

### **Effect on dryness**

The average effect on dryness score varied from 5.85 to 7.92 (Table 1). Figure 10 shows that with increase in processing temperature and time there was an increase in sensory score of dryness. Effect of time and temperature on sensory score of dryness could be described by the following equation:

$$\text{Dryness} = +6.87 - 0.023*A + 0.13*B - 0.62*AB + 2.750E-003*A^2 - 0.18*B^2 \dots\dots\dots (9)$$

The F-value for dryness was significant ( $P < 0.0056$ ) (Table 2). The model F-value of 9.16 implies that the model is significant.  $R^2$  was found to be 0.8674, indicating that 86.74 % of the variability in the response could be explained by the model.

**Table.1** Experimental runs and actual values of factors used in central composite rotatable design of *Rice pulav*

| Trial Number | Variables             |                     | Sensory attributes scored on 10-point descriptive scale |       |         |        |                  |          |                |          |         |       |                       | F <sub>0</sub> |
|--------------|-----------------------|---------------------|---------------------------------------------------------|-------|---------|--------|------------------|----------|----------------|----------|---------|-------|-----------------------|----------------|
|              | Process Temperature°C | Process Time Minute | Appearance                                              |       | Flavour |        | Texture          |          |                |          |         | Taste | Overall Acceptability |                |
|              |                       |                     | Colour                                                  | Gloss | Spicy   | Cooked | Grain Separation | Softness | Ease of spread | Hardness | Dryness |       |                       |                |
| 1            | 115                   | 15                  | 6.12                                                    | 6.16  | 6.02    | 5.53   | 5.12             | 6.25     | 5.64           | 5.94     | 5.85    | 5.47  | 5.72                  | 3.22           |
| 2            | 125                   | 15                  | 7.34                                                    | 6.82  | 6.89    | 7.17   | 7.07             | 6.84     | 7.38           | 7.14     | 7.11    | 7.26  | 7.55                  | 24.953         |
| 3            | 115                   | 25                  | 7.6                                                     | 7.41  | 6.75    | 6.52   | 7.4              | 7.4      | 6.85           | 6.8      | 7.25    | 7.10  | 7.44                  | 4.395          |
| 4            | 125                   | 25                  | 5.85                                                    | 5.85  | 6.1     | 6.2    | 5.19             | 5.35     | 5.2            | 6.15     | 6.05    | 5.75  | 5.85                  | 45.442         |
| 5            | 112.929               | 20                  | 7.19                                                    | 7.21  | 6.66    | 6.96   | 7.34             | 7.91     | 7.90           | 7.32     | 7.09    | 7.10  | 7.18                  | 2.68           |
| 6            | 127.071               | 20                  | 7.32                                                    | 7.07  | 6.1     | 7.34   | 7.03             | 6.93     | 6.87           | 6.96     | 6.92    | 7.18  | 7.14                  | 44.74          |
| 7            | 120                   | 12.9289             | 6.55                                                    | 6.1   | 6.15    | 5.15   | 5.67             | 6.12     | 5.7            | 6.12     | 6.38    | 6.25  | 6.23                  | 10.06          |
| 8            | 120                   | 27.0711             | 7.35                                                    | 7.15  | 6.1     | 5.37   | 7.27             | 6.48     | 6.2            | 6.17     | 6.89    | 6.41  | 7.11                  | 18.162         |
| 9            | 120                   | 20                  | 7.23                                                    | 6.82  | 7.21    | 7.99   | 7.09             | 7.09     | 6.83           | 7.49     | 6.77    | 7.11  | 7.69                  | 12.85          |
| 10           | 120                   | 20                  | 7.23                                                    | 7.26  | 6.85    | 6.78   | 7.5              | 7.56     | 7.41           | 7.52     | 6.93    | 7.09  | 7.33                  | 12.89          |
| 11           | 120                   | 20                  | 7.17                                                    | 7.04  | 7.27    | 6.53   | 6.66             | 6.39     | 7.58           | 6.51     | 6.64    | 6.84  | 7.10                  | 14.1725        |
| 12           | 120                   | 20                  | 6.8                                                     | 6.61  | 6.9     | 6.86   | 7.2              | 6.75     | 6.5            | 6.9      | 6.90    | 6.95  | 7.00                  | 14.966         |
| 13           | 120                   | 20                  | 6.96                                                    | 7.12  | 6.51    | 6.19   | 7.31             | 7.36     | 6.89           | 7.38     | 7.12    | 7.20  | 7.55                  | 13.538         |

**Table.2** ANOVA for different predicted models for responses

| Source         | DF | F value    |            |       |        |                  |          |                |            |            |       |                       |                |
|----------------|----|------------|------------|-------|--------|------------------|----------|----------------|------------|------------|-------|-----------------------|----------------|
|                |    | Colour     | Gloss      | Spicy | Cooked | Grain separation | Softness | Ease of Spread | Hardness   | Dryness    | Taste | Overall Acceptability | F <sub>0</sub> |
| Model          | 5  | 5.47       | 4.36       | 4.39  | 4.29   | 6.05             | 4.80     | 4.93           | 4.23       | 9.16       | 16.53 | 8.78                  | 174.70         |
| A-temp         | 1  | 0.16       | 1.48       | 0.50  | 1.53   | 0.26             | 5.48     | 0.93           | 1.526E-003 | 0.098      | 0.82  | 0.043                 | 714.31         |
| B-time         | 1  | 1.68       | 3.81       | 0.026 | 0.049  | 3.80             | 0.019    | 0.034          | 3.208E-003 | 3.41       | 0.32  | 2.03                  | 52.43          |
| AB             | 1  | 23.62      | 12.07      | 7.04  | 3.41   | 18.56            | 9.44     | 11.44          | 6.25       | 36.60      | 52.76 | 29.69                 | 35.65          |
| A <sup>2</sup> | 1  | 2.053E-003 | 1.304E-003 | 4.77  | 0.78   | 0.60             | 0.34     | 0.14           | 0.097      | 1.273E-003 | 0.17  | 1.71                  | 70.85          |
| B <sup>2</sup> | 1  | 1.85       | 4.37       | 11.27 | 14.54  | 7.43             | 8.15     | 11.56          | 14.88      | 5.59       | 28.70 | 11.34                 | 0.35           |
| Residual       | 7  |            |            |       |        |                  |          |                |            |            |       |                       |                |
| Lack of Fit    | 3  | 4.64       | 2.28       | 0.70  | 0.096  | 4.19             | 0.62     | 1.65           | 0.31       | 1.64       | 4.04  | 1.37                  | 6.23           |
| Pure Error     | 4  |            |            |       |        |                  |          |                |            |            |       |                       |                |

**Table.3** Predicted score of the suggested formulation of ready-to-eat *Rice pulav* by design Expert 9.0.3

| S. No. | Temperature°C | Time Min | Colour | Gloss | Spicy | Cooked | Grain separation | Softness | Ease of spread | Hardness | Dryness | Taste | Overall acceptability | F <sub>0</sub> | Desirability |
|--------|---------------|----------|--------|-------|-------|--------|------------------|----------|----------------|----------|---------|-------|-----------------------|----------------|--------------|
| 1      | 117.673       | 22.443   | 7.297  | 7.208 | 6.921 | 6.749  | 7.442            | 7.265    | 7.159          | 7.120    | 7.044   | 7.093 | 7.466                 | 8.701          | 0.792        |
| 2      | 125.000       | 16.430   | 7.379  | 6.947 | 6.736 | 7.209  | 7.174            | 6.988    | 7.242          | 7.181    | 7.104   | 7.379 | 7.494                 | 27.908         | 0.742        |
| 3      | 125.000       | 16.425   | 7.379  | 6.947 | 6.736 | 7.208  | 7.174            | 6.988    | 7.242          | 7.181    | 7.104   | 7.379 | 7.495                 | 27.900         | 0.742        |

**Table.4** Changes in chemical characteristics of ready to eat *rice pulav* during storage period under room temperature (14-35°C)

| Storage Period | FFA            | TBA             | PV            |
|----------------|----------------|-----------------|---------------|
| 0 days         | 0.102±0.0018   | 0.1013± 0.0001  | 2.632±0.387   |
| 15 days        | 0.214±0.0069   | 0.1028± 0.0002  | 4.992±0.204   |
| 30 days        | 0.320±0.0025   | 0.1041± 0.00022 | 5.955±0.136   |
| 45 days        | 0.414±0.0034   | 0.1054± 0.00029 | 7.115±0.120   |
| 60 days        | 0.522±0.015607 | 0.1070±8.16E-05 | 8.11±0.081    |
| 75 days        | 0.671±0.013699 | 0.108±0.000129  | 9.01±0.120    |
| 90 days        | 0.747±0.005852 | 0.110±0.000129  | 9.78±0.0802   |
| 105 days       | 0.860±0.004163 | 0.111±0.000129  | 10.61±0.0860  |
| 120 days       | 0.937±0.004646 | 0.122±0.000993  | 11.65±0.0648  |
| 135 days       | 1.062±0.009574 | 0.134±0.001214  | 12.78±0.0704  |
| 150 days       | 1.107±0.0035   | 0.143±0.001482  | 13.36±0.0732  |
| 165 days       | 1.22±0.008165  | 0.151±0.001343  | 14.92±0.0519  |
| 180 days       | 1.33±0.01291   | 0.161±0.001291  | 16.117±0.1123 |

n=4

**Table.5** Microbiological profile of retort processed ready to eat *rice pulav* during storage period

| Storage days | Total plate count | Yeast & Mould | <i>E. coli</i> | Spore formers |           |
|--------------|-------------------|---------------|----------------|---------------|-----------|
|              |                   |               |                | 37° C         | 55° C     |
| 0 days       | Nil               | Nil           | -ve            | No growth     | No growth |
| 15 days      | Nil               | Nil           | -ve            | No growth     | No growth |
| 30 days      | Nil               | Nil           | -ve            | No growth     | No growth |
| 45 days      | Nil               | Nil           | -ve            | No growth     | No growth |
| 60 days      | Nil               | Nil           | -ve            | No growth     | No growth |
| 75 days      | Nil               | Nil           | -ve            | No growth     | No growth |
| 90 days      | Nil               | Nil           | -ve            | No growth     | No growth |
| 105 days     | Nil               | Nil           | -ve            | No growth     | No growth |
| 120 days     | Nil               | Nil           | -ve            | No growth     | No growth |
| 135 days     | Nil               | Nil           | -ve            | No growth     | No growth |
| 150 days     | Nil               | Nil           | -ve            | No growth     | No growth |
| 165 days     | Nil               | Nil           | -ve            | No growth     | No growth |
| 180 days     | Nil               | Nil           | -ve            | No growth     | No growth |

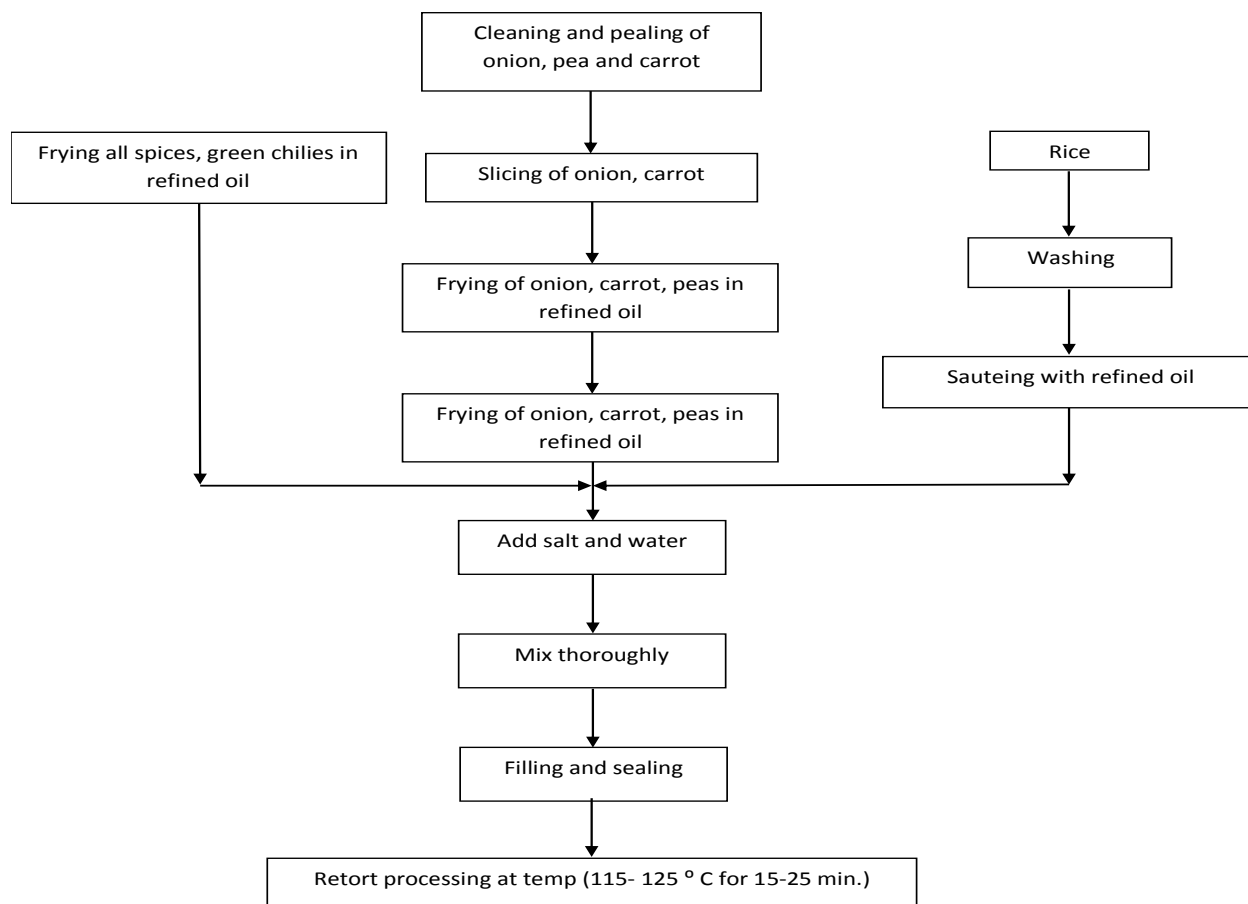
-ve, not detected; n=3

**Table.6** Sensory attributes of shelf stable ready to eat *rice pulav* during storage at ambient temperature (17-37°) on 9-point hedonic scale

| Days                  | 0 day      | 30 day     | 60 day     | 90 day     | 120 day    | 150day     | 180 day    |
|-----------------------|------------|------------|------------|------------|------------|------------|------------|
| Colour & Appearance   | 8.79±0.12  | 8.22±0.085 | 7.83±0.095 | 7.42±0.159 | 6.93±0.089 | 6.48±0.111 | 6.12±0.050 |
| Aroma                 | 8.44±0.152 | 7.97±0.190 | 7.43±0.184 | 6.95±0.127 | 6.43±0.089 | 6.20±0.093 | 6.05±0.369 |
| Taste                 | 8.66±0.097 | 7.96±0.117 | 7.49±0.135 | 7.12±0.171 | 6.62±0.102 | 6.16±0.103 | 5.84±0.064 |
| Texture               | 8.62±0.230 | 7.92±0.158 | 7.50±0.132 | 6.92±0.112 | 6.45±0.126 | 6.05±0.132 | 5.83±0.209 |
| Mouth feel            | 8.80±0.117 | 8.43±0.053 | 8.13±0.100 | 7.71±0.161 | 7.22±0.090 | 6.77±0.100 | 6.40±0.055 |
| Overall acceptability | 8.88±0.074 | 8.43±0.079 | 8.06±0.126 | 7.65±0.169 | 7.15±0.103 | 6.68±0.113 | 6.34±0.074 |

Mean ± SD, n= 10

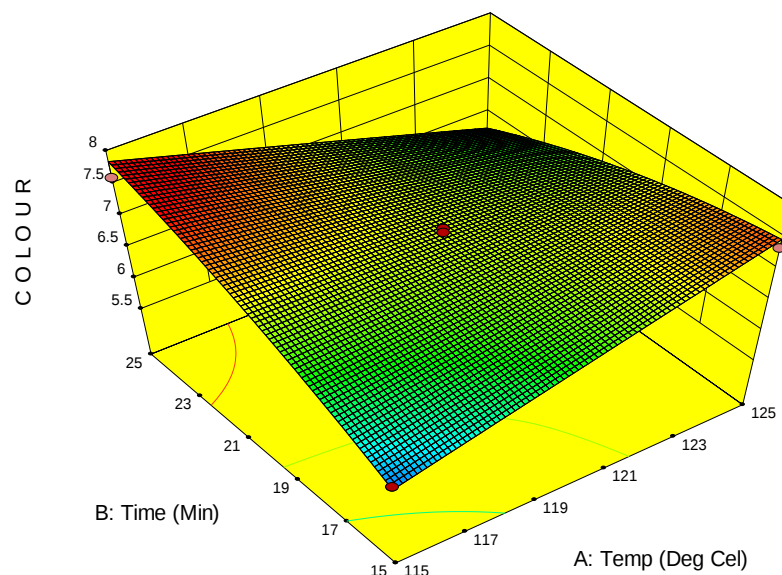
**Fig.1** Flow chart for the preparation and processing of ready to eat *rice pulav*



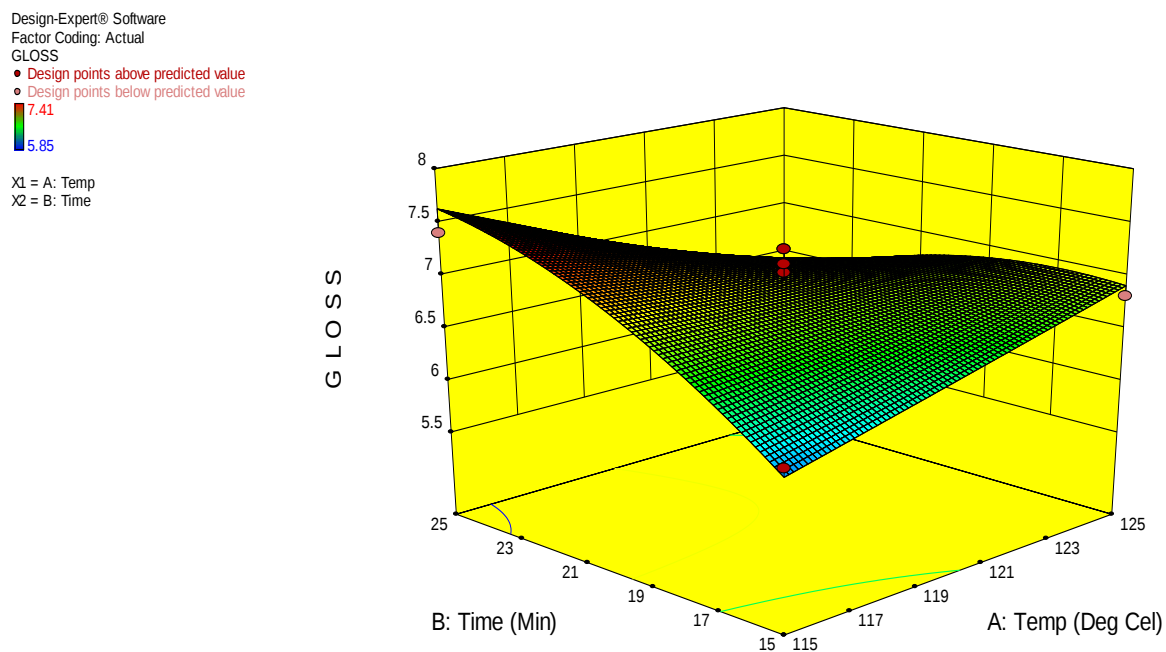
**Fig.2** Effect of temp-time on colour of ready-to-eat *Rice pulav*

Design-Expert® Software  
Factor Coding: Actual  
COLOUR  
● Design points above predicted value  
● Design points below predicted value  
7.6  
5.85

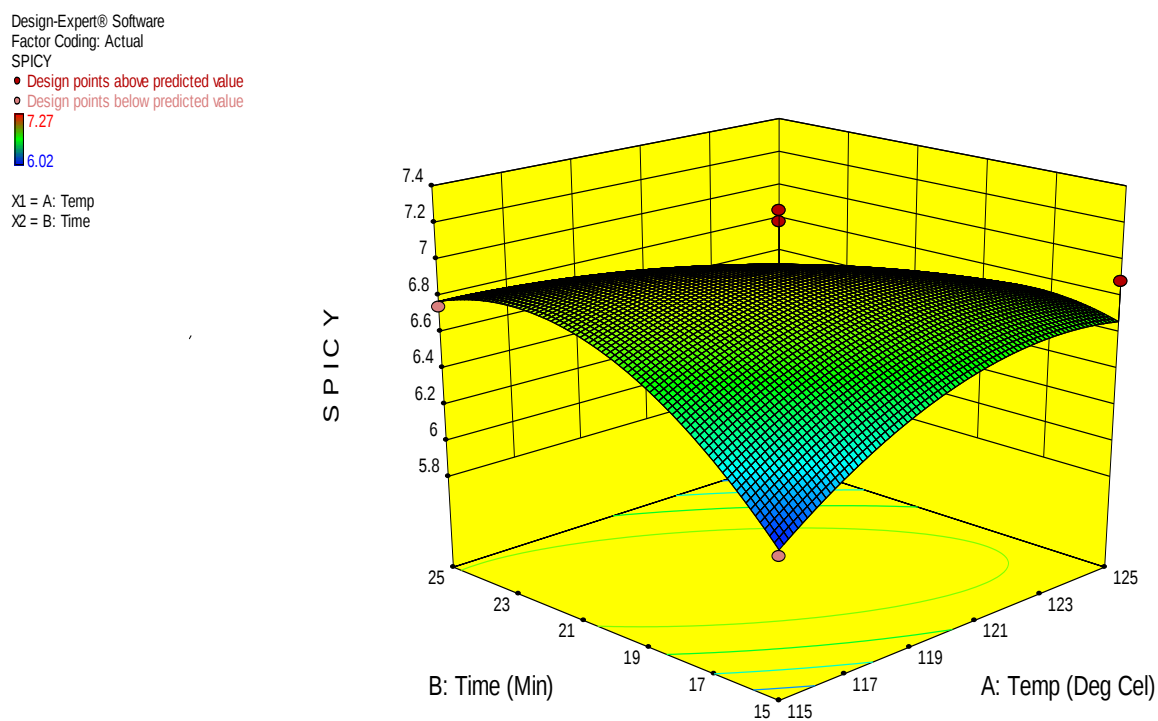
X1 = A: Temp  
X2 = B: Time



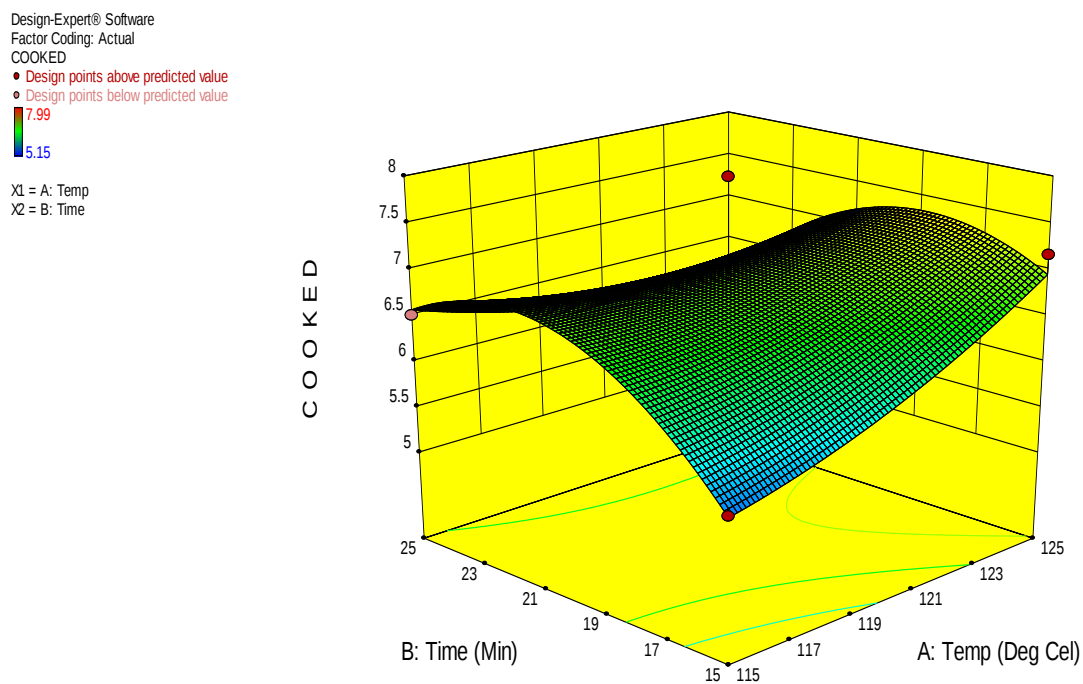
**Fig.3** Effect of temp-time on Gloss of ready-to-eat *Rice pulav*



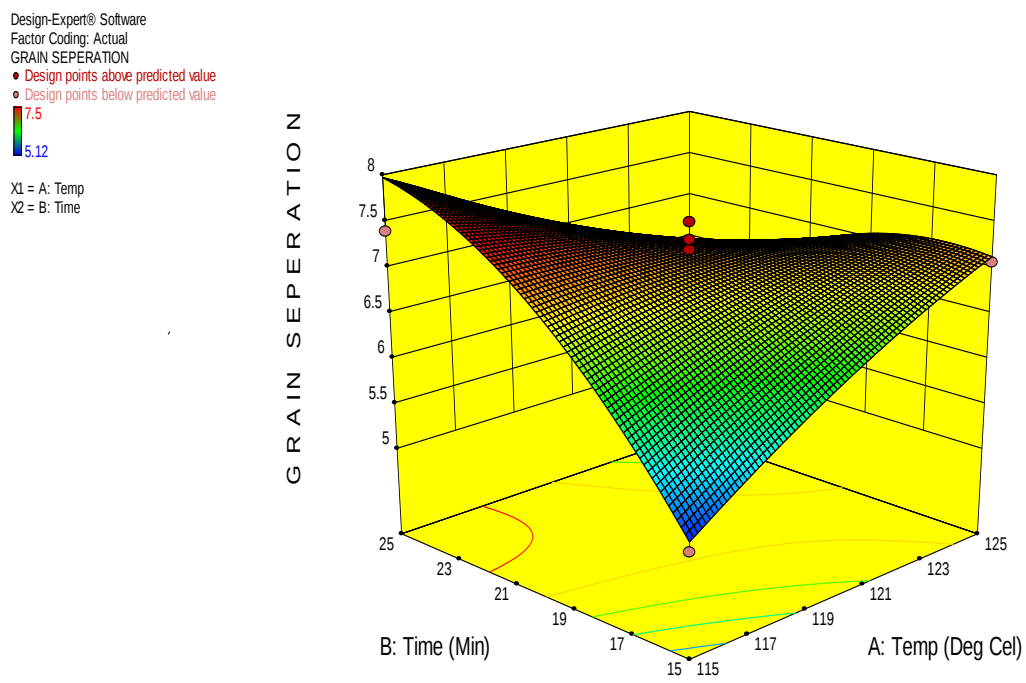
**Fig.4** Effect of temp-time on spicy of ready-to-eat *Rice pulav*



**Fig.5** Effect of temp-time on cooked of ready-to-eat *Rice pulav*



**Fig.6** Effect of temp-time on grain separation of ready-to-eat *Rice pulav*



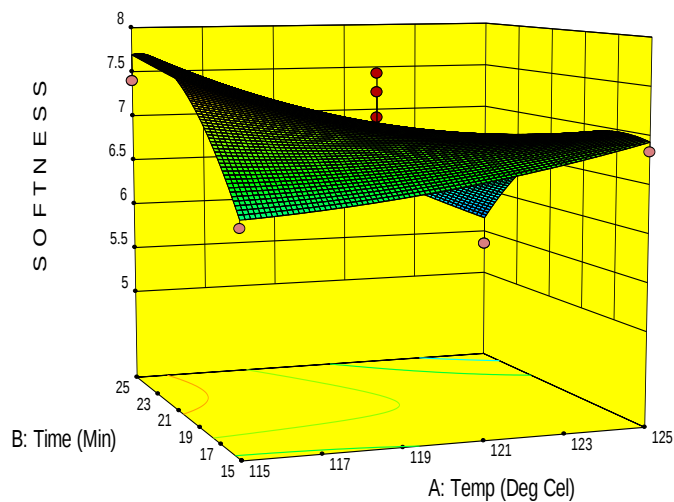
**Fig.7** Effect of temp-time on softness of ready-to-eat *Rice pulav*

Design-Expert® Software  
Factor Coding: Actual  
SOFTNESS

- Design points above predicted value
- Design points below predicted value

7.91  
5.35

X1 = A: Temp  
X2 = B: Time



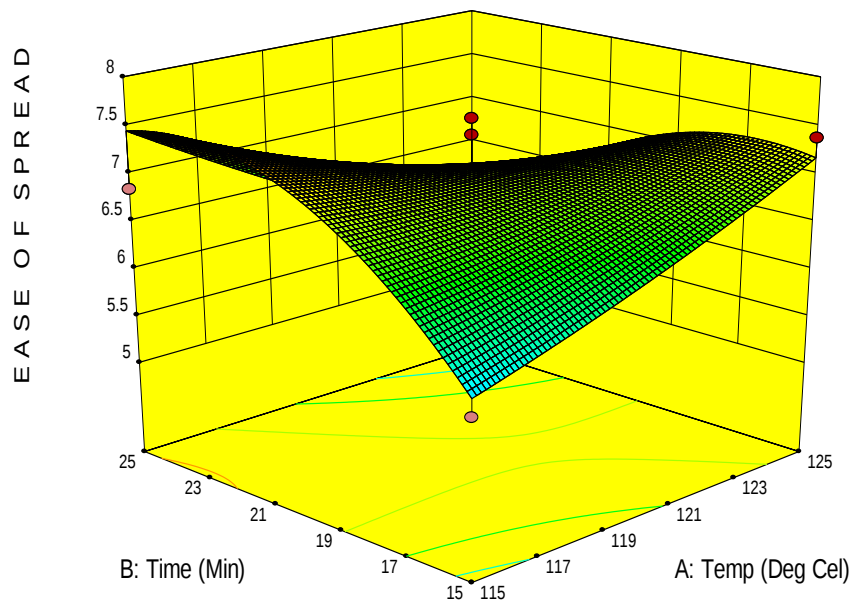
**Fig.8** Effect of temp-time on ease of spread of ready-to-eat *Rice pulav*

Design-Expert® Software  
Factor Coding: Actual  
EASE OF SPREAD

- Design points above predicted value
- Design points below predicted value

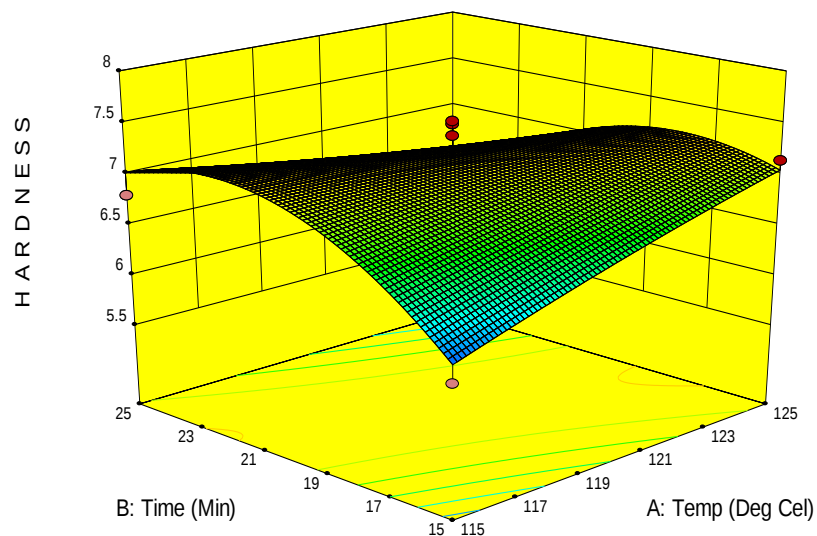
7.9  
5.2

X1 = A: Temp  
X2 = B: Time



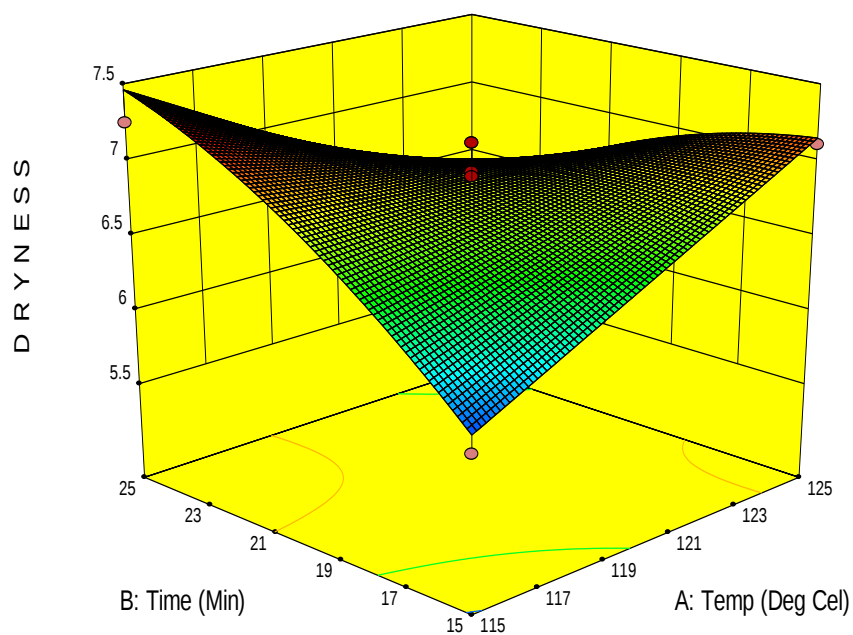
**Fig.9** Effect of temp-time on hardness of ready-to-eat *Rice pulav*

Design-Expert® Software  
Factor Coding: Actual  
HARDNESS  
● Design points above predicted value  
○ Design points below predicted value  
7.52  
5.94  
X1 = A: Temp  
X2 = B: Time



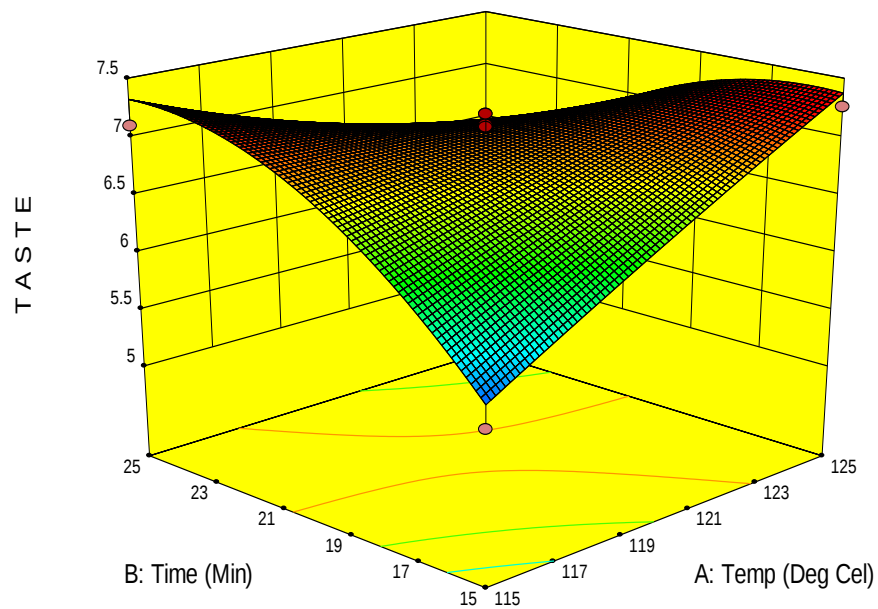
**Fig.10** Effect of temp-time on dryness of ready-to-eat *Rice pulav*

Design-Expert® Software  
Factor Coding: Actual  
DRYNESS  
● Design points above predicted value  
○ Design points below predicted value  
7.25  
5.85  
X1 = A: Temp  
X2 = B: Time



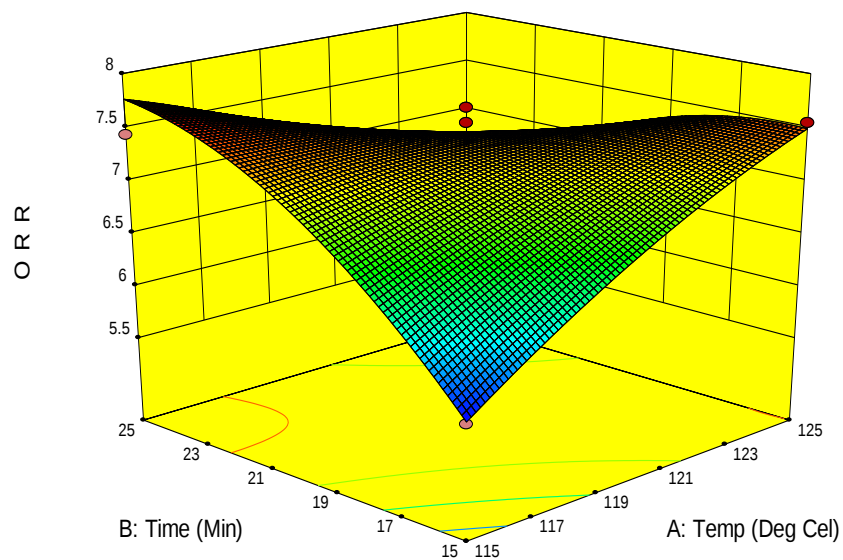
**Fig.11** Effect of temp-time on taste of ready-to-eat *Rice pulav*

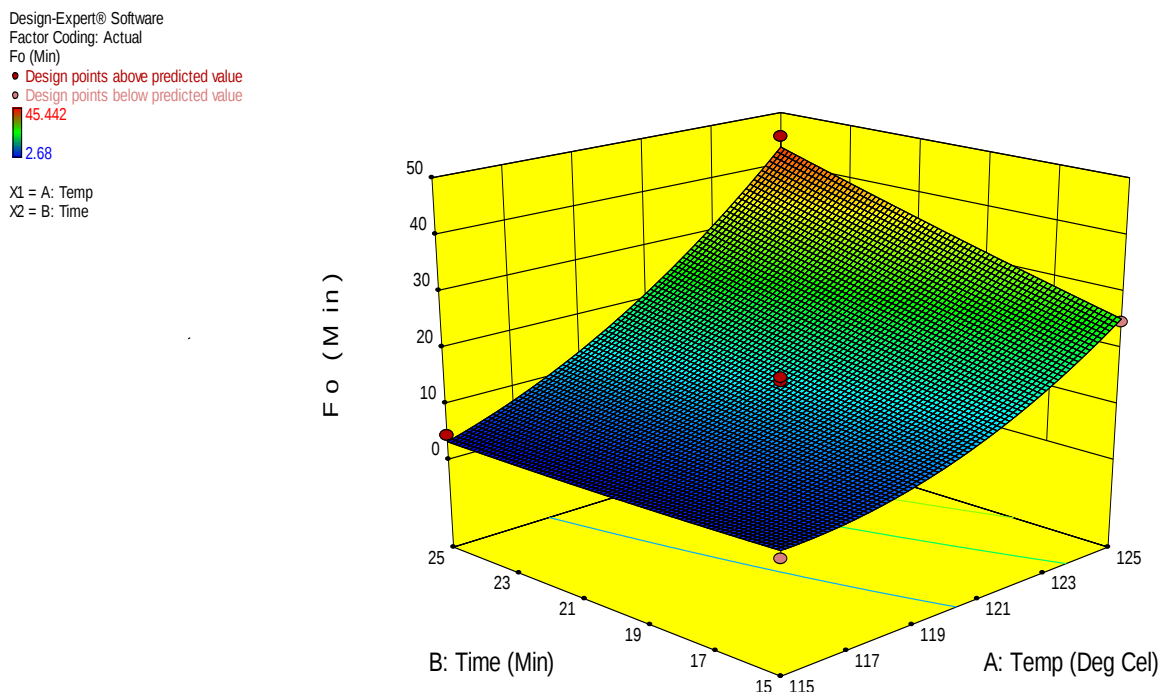
Design-Expert® Software  
Factor Coding: Actual  
TASTE  
● Design points above predicted value  
○ Design points below predicted value  
7.26  
5.47  
X1 = A: Temp  
X2 = B: Time



**Fig.12** Effect of temp-time on overall acceptability of ready-to-eat *Rice pulav*

Design-Expert® Software  
Factor Coding: Actual  
ORR  
● Design points above predicted value  
○ Design points below predicted value  
7.69  
5.72  
X1 = A: Temp  
X2 = B: Time



**Fig.13** Effect of temp-time on  $F_0$  of ready-to-eat *Rice pulav*

The "The "Pred R-Squared" of 0.3875 is in reasonable agreement with the "Adj R-Squared" of 0.7728.

### Effect on taste

The average effect on taste score varied from 5.47 to 7.26 (Table 1). Figure 11 shows that with increase in processing temperature and time there was an increase in sensory score of taste. Effect of time and temperature on sensory score of taste could be described by the following equation:

$$\text{Taste} = +7.04 + 0.069 * A + 0.043 * B - 0.79 * AB - 0.034 * A^2 - 0.44 * B^2 \dots\dots\dots (10)$$

The F-value for taste was significant ( $P < 0.0009$ ) (Table 2). The model F-value of 16.53 implies that the model is significant.  $R^2$  was found to be 0.9219, indicating that 92.19 % of the variability in the response could be

explained by the model. The "The "Pred R-Squared" of 0.5523 is in reasonable agreement with the "Adj R-Squared" of 0.8662.

### Effect on overall acceptability

The average effect on overall acceptability score varied from 5.85 to 7.69 (Table 1). Figure 12 shows that sensory score of overall acceptability increase with increase in processing temperature and time. Effect of time and temperature on sensory score of overall acceptability could be described by the following equation:

$$\text{ORR} = +7.33 + 0.023 * A + 0.16 * B - 0.85 * AB - 0.16 * A^2 - 0.40 * B^2 \dots\dots\dots (11)$$

The F-value for overall acceptability was significant ( $P < 0.0063$ ) (Table 2). The model F-value of 8.78 implies that the model is

significant.  $R^2$  was found to be 0.8624, indicating that 86.24 % of the variability in the response could be explained by the model. The "The "Pred R-Squared" of 0.3978 is in reasonable agreement with the "Adj R-Squared" of 0.7641.

### Effect on $F_0$

The average effect on  $F_0$  score varied from 3.22 to 45.442 (Table 1). Figure 13 shows that with increase in processing time there was a minor increase in sensory score of  $F_0$  and major increment in score with processing temperature increase. Effect of time and temperature on sensory score of  $F_0$  could be described by the following equation:

$$F_0 = +13.68 + 15.28 * A + 4.14 * B + 4.83 * AB + 5.16 * A^2 + 0.36 * B^2 \dots\dots\dots (11)$$

The F-value for  $F_0$  was significant ( $P < 0.0001$ ) (Table 2). The model F-value of 174.70 implies that the model is significant.  $R^2$  was found to be 0.7419, indicating that 74.19 % of the variability in the response could be explained by the model. The "The "Pred R-Squared" of - 0.5416 is in reasonable agreement with the "Adj R-Squared" of 0.5575.

### Optimization for retorting

Optimization of retort process time and temperature for the development of *rice pulav* was based on sensory score and thermal quality  $F_0$  using RSM. Out of 3 suggested solutions, the solution no.1 had better overall acceptability of 7.46 than all other solutions and also the desirability was 0.79, highest amongst all other solutions (Table 3). Hence the solution with processing temperature and time of 117.67°C for 22.4 min was considered to be the most appropriate for retorting the *rice pulav*. The optimized *rice pulav* was having predicted scores of 7.29 for colour,

7.20 for gloss, 6.92 for spicy, 6.74 for cooked, 7.44 for grain separation, 7.26 for softness, 7.15 for ease of spread, 7.12 for hardness, 7.09 for taste, 7.46 for overall acceptability and 8.70 for  $F_0$  (Table 3). The optimized product thus prepared scored 8.79 for colour and appearance, 8.44 for aroma, 8.66 for taste, 8.62 for texture, 8.80 for mouth feel and 8.88 for overall acceptability (Table 7).

### Storage study

#### Chemical analysis

The ready to eat *rice pulav* was evaluated for the changes in free fatty acid (FFA, % oleic acid) contents, thiobarbituric acid (TBA, mg MA/ Kg sample) values and peroxide value (PV, meqO<sub>2</sub>/Kg fat) periodically given in table 4.

During storage, FFA content increased significantly from 0.1022 to 1.335 % as oleic acid and which was due to the breakdown of long chain fatty acid into short individual fatty acid molecules and also lipid oxidation increased (Table 5). Similar results have been reported in retort processed shelf stable chapatias (Khan *et al.*, 2011), radiated and retort processed vegetable pulav (Kumar *et al.*, 2011), retort processed black clam (Bindu *et al.*, 2007), thermally processed pearl spot fish curry (Jayakumar *et al.*, 2007) and retort processed ready to eat tender jackfruit (Lakshamana *et al.*, 2013). The increase in free fatty acid can be due to hydrolysis of triglyceride, triggered by infusion of moisture from the food into oil followed by oxidation (Fritsch 1981).

Thiobarbituric acid (TBA) and Peroxide values (PV) of *rice pulav* increased gradually during the period of storage. TBA value is key index of secondary lipid oxidation, increased significantly from 0.1013 to 0.1613 mg MA/Kg of sample during storage (Table

5). PV increased significantly from 2.632 to 16.117 meq O<sub>2</sub>/kg fat (Table 5). Similar results of increasing PV and TBA value reported by Bindu *et al.*, (2004) in ready to eat mussel meat, Bindu *et al.*, (2007) in retort processed black clam and shelf stable *chapaties* by Khan *et al.*, (2011). Dhanpal *et al.*, (2010), Jha *et al.*, (2011) and Gautam *et al.*, (2013) have also reported significant increase in TBA values with increase in storage time in ready to eat tilapia fish curry, long life *kheer*, *Chhana kheer* and *chhana* roll respectively.

### Microbiological analysis

The data presented in Table 6 showing microbiological profile of retort processed ready to eat *rice pulav*. The microbiological data showed that no total plate count and yeast mould count in processed product up to 180 days of storage. The pathogen tests of *E. coli* were also found negative in the samples. The data showed on growth on commercial sterility test of spore formers at 37 and 55°C temperature. Khan *et al.*, (2011) reported the similar results on shelf stable *chapaties* and Kumar *et al.*, (2011) on ready to eat vegetable pulav.

### Sensory analysis

The Sensory attributes of ready to eat *rice pulav* analyzed using a 9-point hedonic scale score revealed that the product scored 8.79 ± 0.12 for colour and appearance, 8.44±0.152 for aroma, 8.66±0.097 for taste, 8.62±0.230 for texture, 8.80±0.117 for mouth feel and 8.88±0.074 for Overall acceptability (Table 4.7) during initial day of storage. On storage, there is decreased significant decrease in sensory scores and also with in acceptability limit. The sensory scores decreased to 6.12±0.050 for colour and appearance, 6.05±0.369 for aroma, 5.84±0.064 for taste, 5.83±0.209 for texture, 6.40±0.055 for mouth

feel and 6.34±0.074 for Overall acceptability during storage period of 6 months under ambient (17-37°C) conditions and thus clearly indicating the effect of storage conditions on the quality attributes of the product. However, the samples stored at ambient (17-30°C) were acceptable up to 6 months of storage as the Overall acceptability score of the product remained in good.

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