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## Development and optimization of shelf stable ready to eat palak paneer

RS Thakur and DC Rai

### Abstract

A convenient ready to eat thermally processed *palak paneer* has been developed using retort processing. The processing parameters like temperature and time 110 to 125°C for 10 to 25 min respectively optimized on the basis of descriptive sensory evaluation and thermal parameter  $F_0$ . The processing temperature and time of 116.9 °C for 10 min was considered to be the most appropriate for retorting the *palak paneer* with overall acceptability of 7.81 and desirability 0.719. The developed product was subjected to various chemical, microbial and sensory analyse 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.

**Keywords:** *Palak Paneer*, retort processing, sensory quality, RSM, free fatty acid, thiobarbituric acid value, peroxide value, sensory quality

### Introduction

India is the second largest producer of vegetables in the world (rank next to China) and accounts for about 15% of the world's production of vegetables. The current production level is over 146.55 million tonnes and the total area under vegetable cultivation is around 8494 thousand hectares, which is about 3% of the total area under cultivation in the country (National Horticultural database 2011) [24]. The diverse agro climatic zones of the country make it possible to grow almost all varieties of vegetables in India. Although India is the largest producer of vegetables in the world, the production per capita 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) [15]. 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.

Thermal processing is an important method of food preservation in the manufacture of shelf stable canned foods, and has been the cornerstone of the food processing industry for more than a century (Teixeira, 1992) [29]. In thermal processing, specifically retort processing, has long been used as a common preservation technique in food industry for shelf stable foods. Retort processing also used to produce microbiologically safe products having acceptable eating quality. The commercial retort processing ensures a reduction or inactivation of spore-forming microorganisms sufficient to guarantee commercial sterility (Awuah *et al.* 2007; Uhler, 1997) [4, 31]. However, there are losses of food product quality during thermal processing and storage.

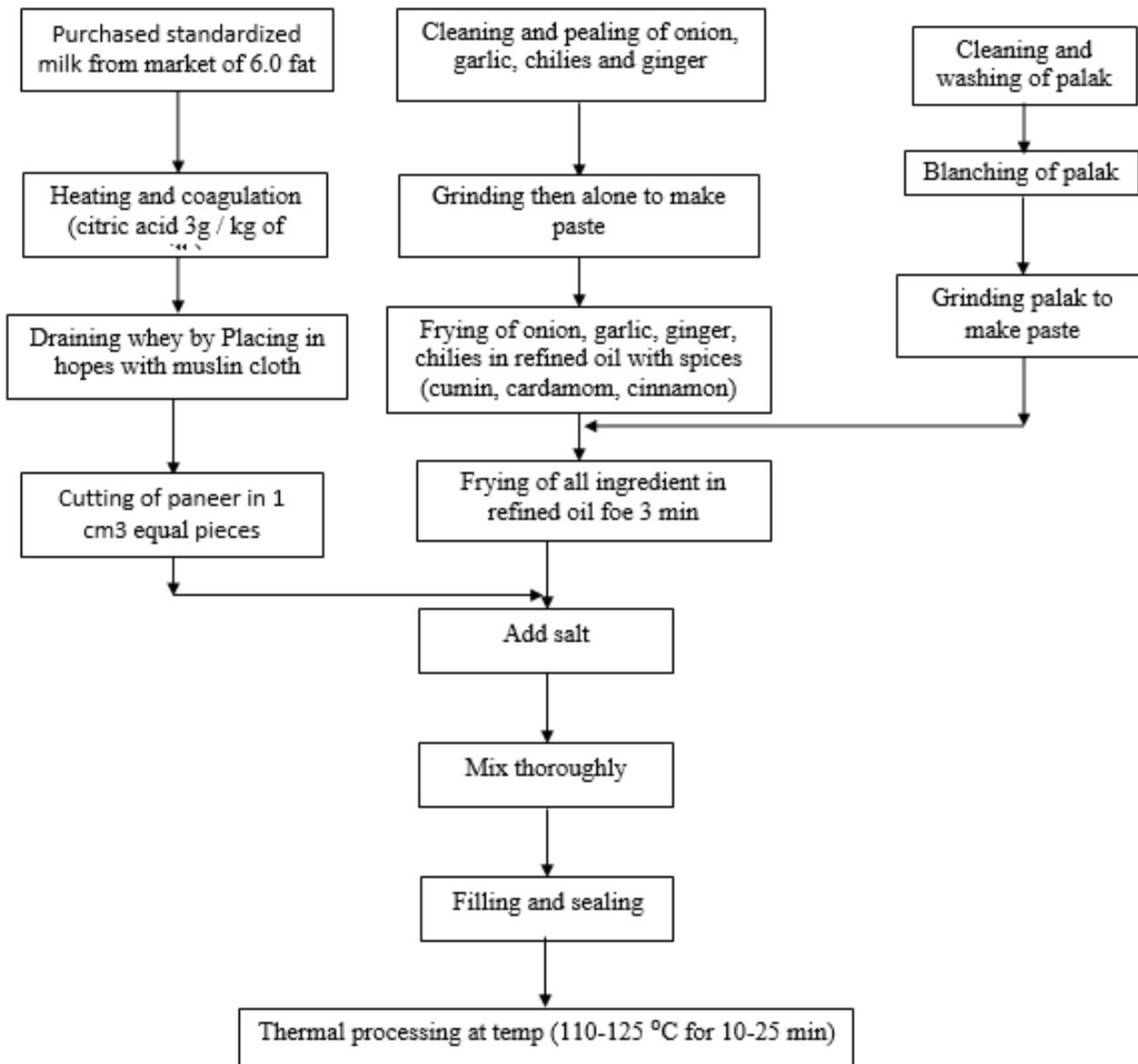
Thermally processed food has been the focus of research studies in recent years. In view of the immense possibilities, the retort processing using retortable pouches offers long-shelf-life food products. The proposed investigation is to optimize the processes in terms of quality while meeting all the safety requirements. In keeping the above points in present study, attempt was made to develop shelf stable ready to eat *palak paneer*.

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## Materials and methods

### Raw material and preparation

Palak paneer was prepared using palak, paneer, onion, garlic, ginger, green chilies, cloves, cardamom, cumin, cinnamon, and refined oil. All the ingredients were purchased from local market. For preparation of paneer standardized milk from Parag Dairy was purchased of 6% Fat. Flow chart (Fig. 1) illustrates the method of preparation and retort processing.



**Fig 1:** Flow chart for the preparation of ready to eat *palak paneer*

### 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 110- 125 °C for 10-25 min. Pressure was maintained at  $20 \pm 1$  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  $\pm 0.1$  °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 lethaliies 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 [28]. 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) [1].

**Table 1:** Experimental runs and actual values of factors used in central composite rotatable design of *Palak paneer*

Trial Number	Variables		Sensory attributes scored on 10-point descriptive scale									$F_0$	
	Process Temperature °C	Process Time Minute	Appearance				Flavour		Texture		Taste	Overall Acceptability	
			Colour	Uniformity	Surface Texture of curry	Smoothness	Spicy	Cooked	Texture	Ease of spread			
1	110	10	6.15	6.45	6.69	8.05	7.52	6.49	6.87	5.85	6.11	9.19	2.81
2	125	10	7.14	7.12	6.52	4.72	7.39	5.35	7.51	7.75	8.18	6.01	43.14
3	110	25	6.55	5.29	6.26	5.01	6.83	5.33	7.21	6.45	7.46	6.89	6.29
4	125	25	6.47	5.95	6.15	6.98	5.46	6.34	5.78	5.57	6.32	6.24	42.34
5	106.893	17.5	6.27	6.28	6.59	6.24	7.64	6.42	7.29	6.02	6.44	7.14	7.68
6	128.107	17.5	6.54	6.26	6.32	6.28	4.51	5.15	6.18	6.12	6.76	5.71	55.19
7	117.5	6.8934	7.49	6.12	7.39	7.27	7.63	7.59	6.38	7.57	7.52	7.19	6.16
8	117.5	28.1066	6.51	6.12	6.54	7.37	7.47	7.16	5.91	6.19	7.39	7.65	22.25
9	117.5	17.5	7.93	7.91	6.28	6.28	7.47	7.14	7.44	7.46	7.19	7.87	10.58
10	117.5	17.5	7.17	7.39	6.27	6.36	7.24	6.56	7.23	7.66	7.76	7.98	10.33
11	117.5	17.5	7.19	7.52	6.22	6.23	6.16	6.93	7.39	6.36	6.48	6.76	11.149
12	117.5	17.5	7.5	7.22	6.28	7.56	7.17	6.38	7.29	7.38	7.29	7.43	14.81
13	117.5	17.5	6.9	7.14	6.49	7.52	7.27	6.69	6.48	6.27	7.88	7.88	11.31

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) [26]. 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) [9]. Pathogen Escherichia coli was also analyzed by the method of Speck (1992) [26].

### 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:

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

Where,  $Y_i$  was the predicted response,  $\beta_0$  was a constant,  $\beta_i$  was the  $i^{th}$  linear coefficient,  $\beta_{ii}$  was the  $i^{th}$  quadratic coefficient and  $\beta_{ij}$  was  $ij^{th}$  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.X to estimate the

responses of the dependent variable. The second order polynomial equation was employed to fit the experimental data. All the experiments were performed in quadruplicate and analysis of variance calculated using Statistical Software SAAS.

### 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.

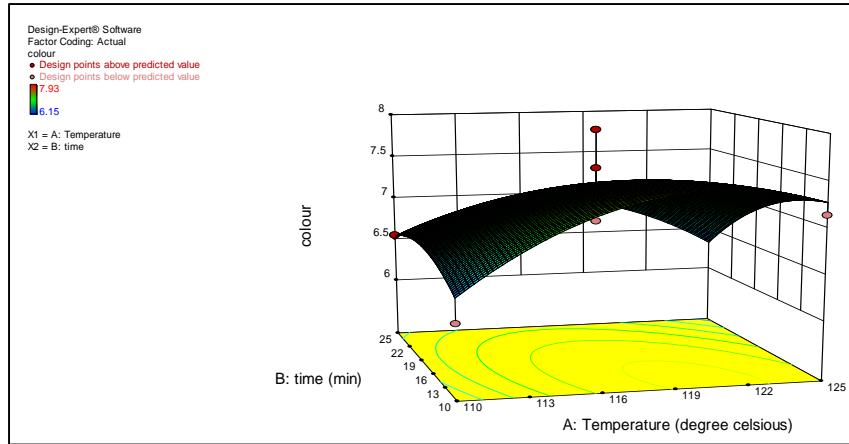
#### Effect of variables on sensory properties of ready-to-eat palak paneer

##### Effect on colour

The average effect on Colour score varied from 6.15 to 7.93 (Table 1). Fig 2 shows that with increase in processing temperature and time there was an increase in sensory score of colour and then slight decrease in score in further increase in time and temperature. Effect of time and temperature on sensory score of Colour could be described by the following equation:

$$\text{Colour} = +7.34 + 0.16*A - 0.21*B - 0.27*AB - 0.50A^2 - 0.20B^2 \dots \dots \dots (1)$$

The F-value for Colour was significant ( $P < 0.0376$ ) (Table 2). The model F-value of 4.48 implies that the model is significant.  $R^2$  was found to be 0.7620, indicating that 76.20 % of the variability in the response could be explained by the model. The "The "Pred R-Squared" of 0.2796 is in reasonable agreement with the "Adj R-Squared" of 0.5920.



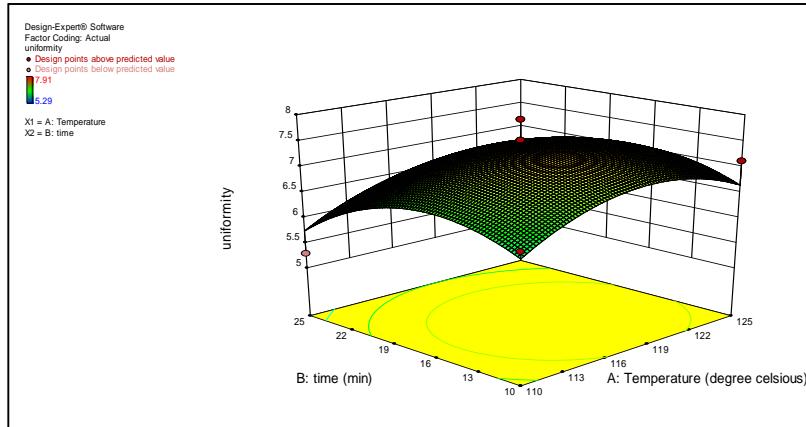
**Fig 2:** Effect of temp-time on colour of ready-to-eat palak paneer.

## Effect on Uniformity

The average effect on Uniformity score varied from 6.12 to 7.91 (Table 1). Fig 3 shows that sensory score of uniformity increases with increase in processing temperature and time and then decrease in sensory score of uniformity. Effect of time and temperature on sensory score of Uniformity could be described by the following equation:

$$\text{Uniformity} = +7.44 + 0.16A - 0.29B - 2.500E-003AB - 0.58A^2 - 0.66B^2 \dots \dots \dots (2)$$

The F-value for Uniformity was significant ( $P < 0.0168$ ) (Table 2). The model F-value of 6.16 implies that the model is significant.  $R^2$  was found to be 0.8149, indicating that 81.49 % of the variability in the response could be explained by the model. The "Pred R-Squared" of - 0.0204 is in reasonable agreement with the "Adj R-Squared" of 0.6826.

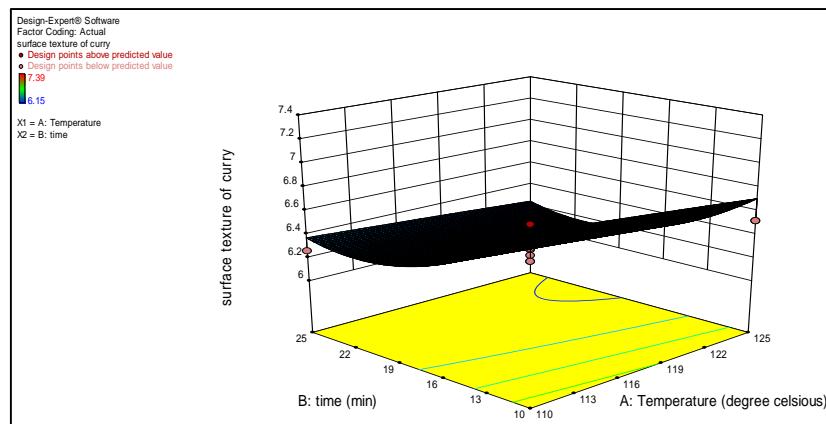


**Fig 3:** Effect of temp-time on uniformity of ready-to-eat palak paneer.

### **Effect of Surface texture of curry**

The average effect on Surface texture of curry score varied from 6.15 to 7.39 (Table 1). Fig 4 shows that with increase in processing temperature and time there was a decrease in

sensory score of Surface texture of curry. Effect of time and temperature on sensory score of Surface texture of curry could be described by the following equation:



**Fig 4:** Effect of temp-time on surface texture of curry of ready-to-eat palak paneer

$$\text{Surface texture of curry} = +6.31 - 0.083*A - 0.25*B + 0.015*AB - 2.750E-003*A^2 + 0.25*B^2 \dots (3)$$

The F-value for Surface texture of curry was significant ( $P<0.0214$ ) (Table 2). The model F-value of 5.61 implies that the model is significant.  $R^2$  was found to be 0.8004, indicating that 80.04 % of the variability in the response could be explained by the model. The "The "Pred R-Squared" of – 0.2260 is in reasonable agreement with the "Adj R-Squared" of 0.6678.

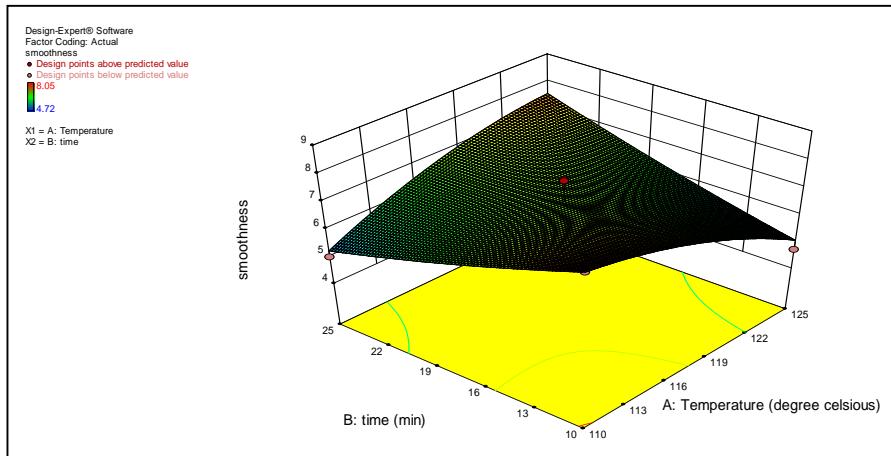
### Effect on Smoothness

The average effect on Smoothness score varied from 5.01 to 8.05 (Table 1). Fig 5 shows that sensory score of Smoothness

decrease with increase in processing temperature and time. Effect of time and temperature on sensory score of Smoothness could be described by the following equation:

$$\text{Smoothness} = +6.79 - 0.16*A - 0.080*B + 1.33*AB - 0.42*A^2 + 0.12*B^2 \dots (4)$$

The F-value for Smoothness was significant ( $P<0.0463$ ) (Table 2). The model F-value of 4.11 implies that the model is significant.  $R^2$  was found to be 0.7458, indicating that 74.58% of the variability in the response could be explained by the model. The "The "Pred R-Squared" of 0.0897 is in reasonable agreement with the "Adj R-Squared" of 0.5642.



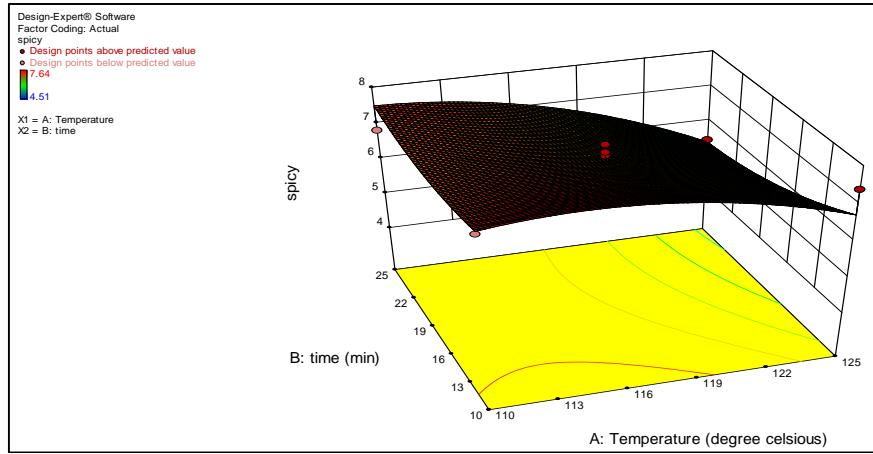
**Fig. 5** Effect of temp-time on smoothness of ready-to-eat palak paneer.

### Effect on Spicy

The average effect on Spicy score varied from 4.51 to 7.64 (Table 1). Fig 6 shows that with increase in processing temperature and time there was a decrease in sensory score of Spicy. Effect of time and temperature on sensory score of Spicy could be described by the following equation:

$$\text{Spicy} = +7.06 - 0.74*A - 0.36*B - 0.31*AB - 0.50*A^2 + 0.24*B^2 \dots (5)$$

The F-value for Spicy was significant ( $P<0.0490$ ) (Table 2). The model F-value of 4.01 implies that the model is significant.  $R^2$  was found to be 0.7410, indicating that 74.10% of the variability in the response could be explained by the model. The "The "Pred R-Squared" of – 0.3047 is in reasonable agreement with the "Adj R-Squared" of 0.5560.



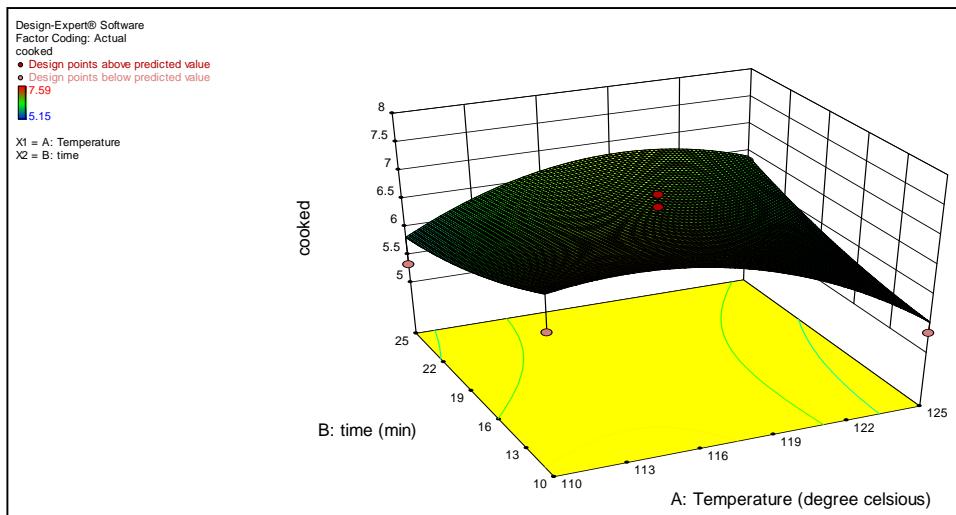
**Fig 6:** Effect of temp-time on spicy of ready-to-eat palak paneer.

### Effect on Cooked

The average effect on Cooked score varied from 5.15 to 7.59 (Table 1). Fig 7 shows that with increase in processing time there was a decrease in sensory score of cooked and there was an increase with increase in processing temperature then

slight decrease in sensory score of cooked. Effect of time and temperature on sensory score of Cooked could be described by the following equation:

$$\text{Cooked} = +6.74 - 0.24*A - 0.097*B + 0.54*AB - 0.65*A^2 + 0.14*B^2 \dots (6)$$

**Fig 7:** Effect of temp-time on cooked of ready-to-eat palak paneer.

The F-value for Cooked was significant ( $P<0.0466$ ) (Table 2). The model F-value of 4.10 implies that the model is significant.  $R^2$  was found to be 0.7452, indicating that 74.52% of the variability in the response could be explained by the model. The "Pred R-Squared" of -0.5150 is in reasonable agreement with the "Adj R-Squared" of 0.5633.

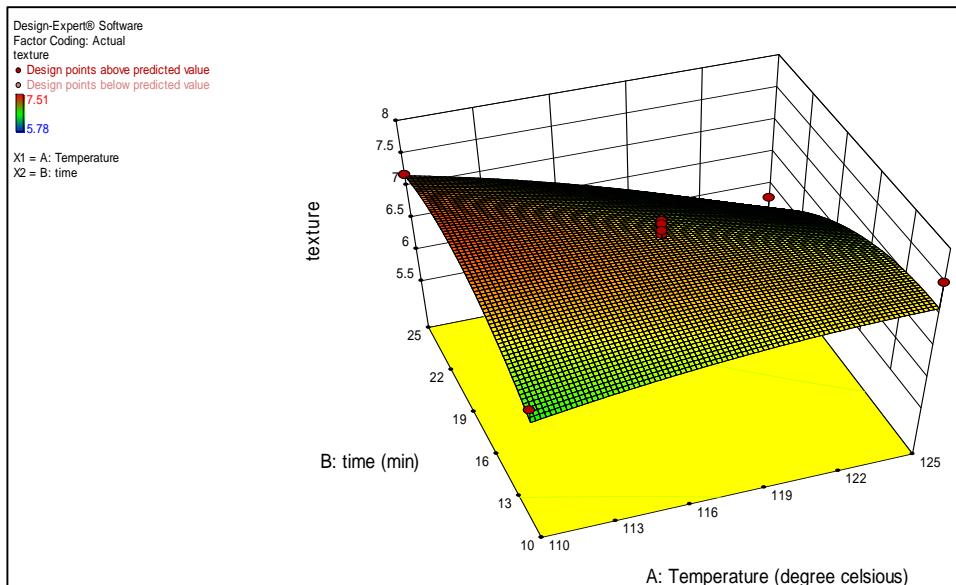
#### Effect on Texture

The average effect on Texture score varied from 5.78 to 7.51 (Table 1). Fig 8 shows that with increase in processing time there was an increase in sensory score of cooked then decrease with further increase and there was an increase in

sensory score with increase in processing temperature then constant in sensory score of cooked with further increase in temperature. Effect of time and temperature on sensory score of Texture could be described by the following equation:  

$$\text{Texture} = +7.17 - 0.29*A - 0.26*B - 0.52*AB - 0.11*A^2 - 0.41*B^2 \dots\dots\dots(7)$$

The F-value for Texture was significant ( $P<0.0368$ ) (Table 2). The model F-value of 4.52 implies that the model is significant.  $R^2$  was found to be 0.7631, indicating that 76.31% of the variability in the response could be explained by the model. The "Pred R-Squared" of 0.0651 is in reasonable agreement with the "Adj R-Squared" of 0.5946.

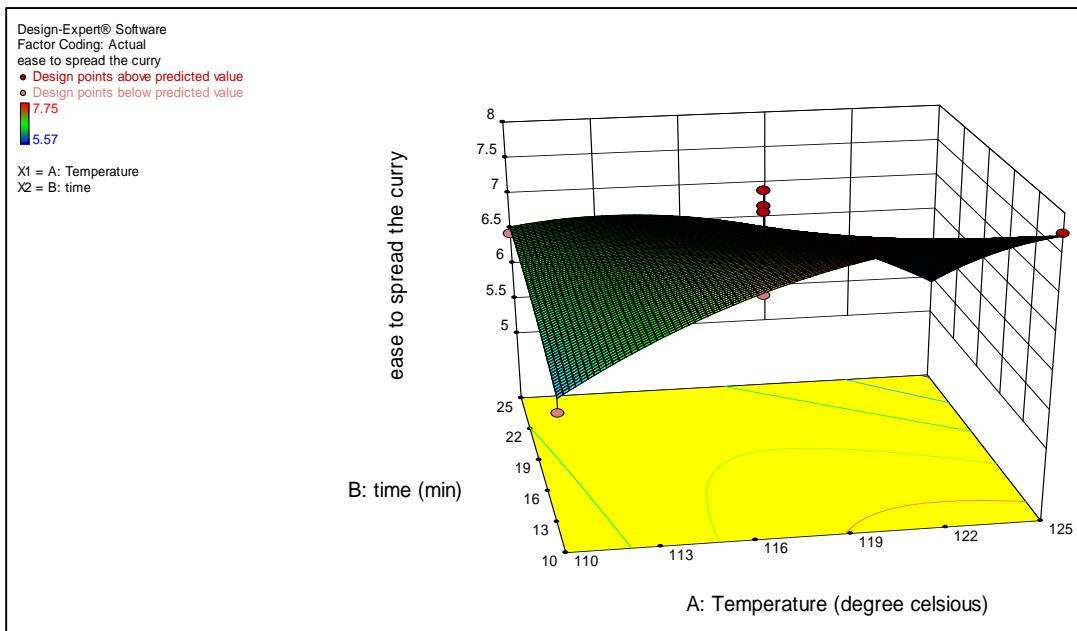
**Fig 8:** Effect of temp-time on texture of ready-to-eat palak paneer.

#### Effect on ease of spread of curry

The average effect on Ease to spread the curry score varied from 5.57 to 7.71 (Table 1). Fig 9 shows that with increase in processing time there was a slight increase in sensory score of Ease to spread the curry and major increase due to increase in processing temperature. Effect of time and temperature on sensory score of Ease to spread the curry could be described by the following equation:

$$\text{Ease to spread the curry} = + 7.03 + 0.15*A - 0.44*B - 0.70*AB - 0.50*A^2 - 0.090*B^2 \dots\dots\dots(8)$$

The F-value for Ease to spread the curry was significant ( $P<0.0476$ ) (Table 2). The model F-value of 4.06 implies that the model is significant.  $R^2$  was found to be 0.7434, indicating that 74.34% of the variability in the response could be explained by the model. The "Pred R-Squared" of 0.5042 is in reasonable agreement with the "Adj R-Squared" of 0.5601.

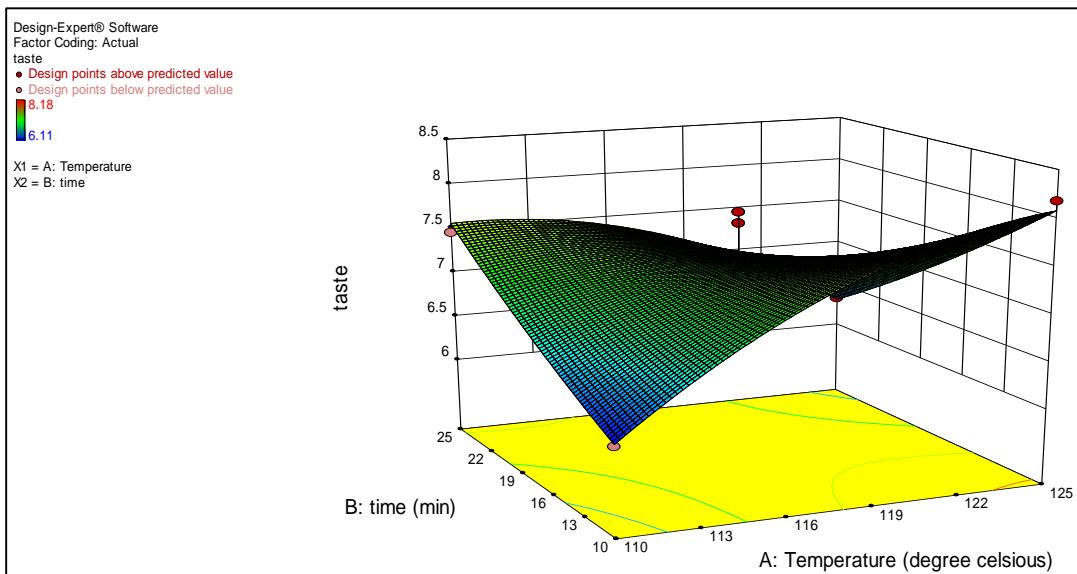
**Fig 9:** Effect of temp-time on ease of spread of curry of ready-to-eat palak paneer.

### Effect on Taste

The average effect on Taste score varied from 6.11 to 8.11 (Table 1). Fig 10 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:

$$\text{Taste} = +7.32 + 0.17 * \text{A} - 0.087 * \text{B} - 0.80 * \text{AB} - 0.36 * \text{A}^2 + 0.065 * \text{B}^2 \dots \dots \dots (9)$$

The F-value for Taste was significant ( $P < 0.0423$ ) (Table 2). The model F-value of 4.27 implies that the model is significant.  $R^2$  was found to be 0.7529, indicating that 75.29% of the variability in the response could be explained by the model. The "Pred R-Squared" of 0.5687 is in reasonable agreement with the "Adj R-Squared" of 0.5765.

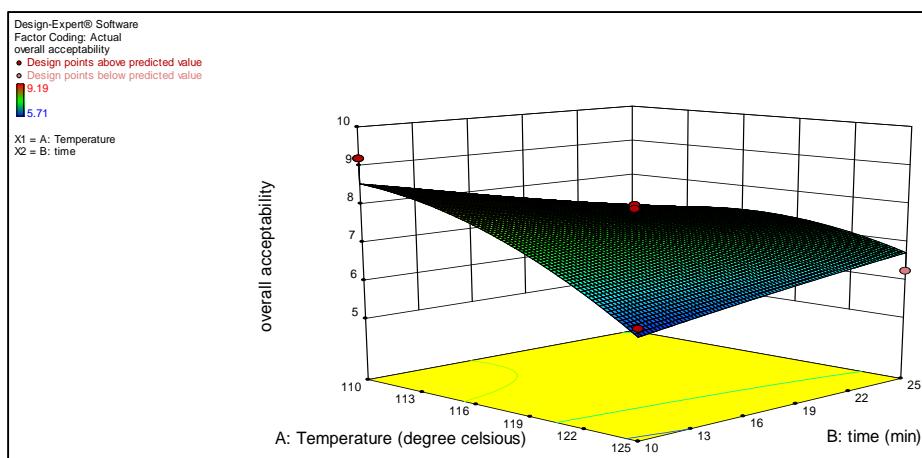
**Fig 10:** Effect of temp-time on taste of ready-to-eat palak paneer.

### Effect on Overall acceptability

The average effect on Overall acceptability score varied from 6.01 to 9.19 (Table 1). Fig 11 shows that there was a decrease in overall acceptability score 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:

$$\text{Overall acceptability} = +7.58 - 0.73 * \text{A} - 0.18 * \text{B} + 0.63 * \text{AB} - 0.54 * \text{A}^2 - 0.042 * \text{B}^2 \dots \dots \dots (10)$$

The F-value for Overall acceptability was significant ( $P < 0.0329$ ) (Table 2). The model F-value of 4.74 implies that the model is significant.  $R^2$  was found to be 0.7718, indicating that 77.18% of the variability in the response could be explained by the model. The "Pred R-Squared" of 0.0830 is in reasonable agreement with the "Adj R-Squared" of 0.6088.

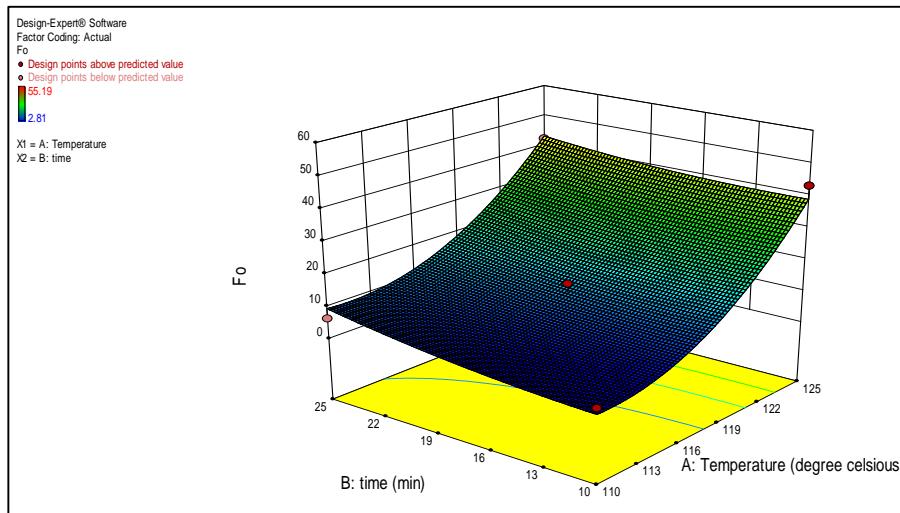


**Fig 11:** Effect of temp-time on overall acceptability of ready-to-eat palak paneer.

### Effect on $F_0$

The average effect on  $F_0$  score varied from 2.81 to 55.19 (Table 1). Fig 12 shows that with increase in processing time there was a slight increase in thermal score of  $F_0$  and major increase due to increase in processing temperature. Effect of time and temperature on sensory score of  $F_0$  could be described by the following equation:

The F-value for  $F_0$  was significant ( $P < 0.0001$ ) (Table 2). The model F-value of 62.51 implies that the model is significant.  $R^2$  was found to be 0.9781, indicating that 97.81% of the variability in the response could be explained by the model. The "Pred R-Squared" of 0.8655 is in reasonable agreement with the "Adj R-Squared" of 0.9621.



**Fig 12:** Effect of temp-time on  $F_0$  of ready-to-eat palak paneer.

## Optimization for retorting

Optimization of retort process time and temperature for the development of palak paneer was based on sensory score and thermal quality  $F_0$  using RSM. Out of 7 suggested solutions, the solution No.1 had better overall acceptability of 7.81 than all other solutions and also the desirability was 0.719, highest amongst all other solutions (Table 3). Hence the solution with processing temperature and time of  $116.9^{\circ}\text{C}$  for 10 min was considered to be the most appropriate for retorting the *palak*

*paneer*. The optimized *palak paneer* was having predicted scores of 7.31 for colour, 7.05 for uniformity, 6.81 for surface texture of curry, 7.09 for smoothness, 7.68 for spicy, 7.03 for cooked, 6.99 for texture, 7.31 for ease of spread, 7.39 for taste, 7.81 for overall acceptability and 8.60 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).

**Table 2:** ANOVA for the different predicted models for responses of *Palak Paneer*

Source	Degree of Freedom	F value										
		Colour	Uniformity	Surface texture of curry	Smoothness	Spicy	Cooked	Texture	Ease of spread of curry	Taste	Overall Acceptability	F <sub>0</sub>
Model	5	4.48	6.16	5.61	4.11	4.01	4.10	4.52	4.06	4.27	4.74	62.51
A-temp	1	1.74	1.16	1.52	0.50	10.77	1.89	4.51	0.64	1.31	12.42	238.78
B-time	1	2.85	3.72	13.95	0.12	2.48	0.31	3.42	5.89	0.33	0.73	7.49
AB	1	2.38	1.370E-004	0.025	16.60	0.94	4.71	6.94	7.29	14.17	4.64	0.42

A <sup>2</sup>	1	14.35	12.87	1.465E-003	2.83	4.21	12.09	0.59	6.45	5.03	5.87	65.84
B <sup>2</sup>	1	2.32	16.41	12.32	0.22	0.99	0.57	7.57	0.22	0.16	0.036	1.43
Residual	7											
Lack of Fit	3	0.48	3.29	6.31	0.76	2.23	5.02	1.01	0.095	0.045	1.79	6.27

**Table 3:** Predicted score of the suggested formulation of ready-to-eat *palak paneer* by design Expert 9.0.3

S. No.	Temperature °C	Time Min.	Colour	Uniformity	Surface texture curry	Smoothness	Spicy	Cooked	Texture	Ease of spread	Taste	Overall acceptability	F <sub>0</sub>	Desirability
1	116.947	10.000	7.310	7.056	6.818	7.092	7.688	7.033	6.996	7.312	7.398	7.817	8.600	0.719
2	116.875	10.000	7.306	7.053	6.819	7.106	7.691	7.039	6.994	7.303	7.388	7.829	8.432	0.719
3	117.055	10.000	7.318	7.059	6.816	7.072	7.682	7.023	6.999	7.325	7.413	7.798	8.855	0.719
4	116.670	10.000	7.291	7.046	6.821	7.144	7.700	7.057	6.987	7.278	7.359	7.864	7.967	0.719
5	117.252	10.000	7.330	7.065	6.814	7.034	7.672	7.004	7.006	7.349	7.439	7.764	9.330	0.719
6	117.337	10.000	7.335	7.067	6.813	7.017	7.668	6.996	7.008	7.358	7.450	7.749	9.539	0.719
7	117.576	10.000	7.349	7.073	6.810	6.970	7.654	6.971	7.015	7.385	7.482	7.706	10.140	0.718

**Storage Study****Chemical analysis**

The ready to eat *palak paneer* 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, meq O<sub>2</sub>/Kg fat) periodically given in table 5.

**Table 5:** Changes in chemical characteristics of ready to eat *Palak paneer* during storage period under room temperature (14–35°C)

Storage Period	FFA	TBA	PV
0 days	0.124±0.004	0.143±0.002	1.632±0.174
15 days	0.340±0.0182	0.285±0.020	2.692±0.167
30 days	0.455±0.020	0.415±0.020	4.055±0.121
45 days	0.537±0.022	0.540±0.029	5.340±0.409
60 days	0.662±0.027	0.720±0.008	7.097±0.060
75 days	0.765±0.007	0.982±0.001	9.045±0.069
90 days	0.935±0.004	1.103±0.001	10.635±0.108
105 days	1.147±0.035	1.221±0.008	12.110±0.037
120 days	1.339±0.010	1.323±0.010	13.590±0.137
135 days	1.555±0.026	1.432±0.015	14.460±0.111
150 days	1.750±0.031	1.615±0.012	16.80±0.119
165 days	1.927±0.0170	1.866±0.032	17.880±0.064
180 days	2.327±0.022	2.125±0.026	19.187±0.038

Each value is represented as the mean ± SD of n=4.

The free fatty acids (FFA) are the primary products of microbial or enzymatic lipolysis of lipids present in food during storage. During storage, FFA content increased significantly from 0.124 to 2.337 % 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). Increase in FFA in retort processed black clam meat was also observed by Bindu *et al.* (2007) [6]. Similar results have been reported in retort processed shelf stable *chapatis* (Khan *et al.* 2011) [21], radiated and retort processed vegetable pulav (Kumar *et al.* 2011) [22], thermally processed pearl spot fish curry (Jayakumar *et al.* 2007) [13] and retort processed ready to eat tender jackfruit (Lakshamana *et al.* 2013) [23]. 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) [10]. Thiobarbituric acid (TBA) and Peroxide values (PV) of *palak paneer* analyzed periodically over the period of 180 days. The data showed in Table 5 shows a gradual increase during the period of storage of 180 days. TBA value is key index of secondary lipid oxidation, increased significantly from 0.143 to 2.125 mg MA/Kg of sample during storage (Table 5). A significant increase in Peroxide value (PV) from 1.632 to 19.187 meq O<sub>2</sub>/kg fat (Table 5). Similar results of increasing PV and TBA value reported by Bindu *et al.* 2004 [5] in ready to eat mussel meat, Bindu *et al.* 2007 [6] in retort processed black clam and shelf stable *chapatis* by Khan *et al.* 2011 [21]. Dhanpal *et al.* (2010) [8], Jha *et al.* (2011) [17] and Gautam *et al.* (2013) [11] 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 microbiological profile of retort processed ready to eat palak paneer was done at regular interval of 15 day (table 6). 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 during entire period of storage. The data showed on growth on commercial sterility test of spore formers at 37 and 55°C temperature. Khan *et al.* 2011 [21] reported the similar results on shelf stable *chapatis* and Kumar *et al.* 2011 [22] on ready to eat vegetable pulav. Dhanpal *et al.* (2010) [8] reported the similar results of no growth immediately after processing and at the end of storage study of 1 year, which indicates that the thermal processing given was sufficient to attain sterility in thermally processed Tilapia fish curry at 116°C and F<sub>0</sub> value of 7.0. Rajan *et al.* (2014) [27] also reported the similar results of no detection of total bacterial count including *E. coli*, *Salmonella spp.*, *Clostridium spp.*, *Staphylococci spp.*, yeast and mould during storage period of 180 days in retort processed chettinad chicken, corresponding F<sub>0</sub> value of 5.2.

**Table 6:** Microbiological profile of retort processed ready to eat *Palak paneer* 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

### Sensory analysis

Table 7 showed the Sensory attributes of ready to eat *palak paneer* analyzed using a 9-point hedonic scale score revealed that the product scored  $8.83 \pm 0.108$  for colour and appearance,  $8.79 \pm 0.106$  for aroma,  $8.77 \pm 0.114$  for taste,  $8.84 \pm 0.115$  for texture,  $8.79 \pm 0.078$  for mouth feel and  $8.82 \pm 0.091$  for Overall acceptability (Table 4.7) during initial day of storage. On storage, there is significant decrease in sensory scores and also with in acceptability limit. The sensory scores decreased to  $6.15 \pm 0.126$  for colour and

appearance,  $6.08 \pm 0.150$  for aroma,  $6.10 \pm 0.104$  for taste,  $6.13 \pm 0.108$  for texture,  $6.17 \pm 0.088$  for mouth feel and  $6.14 \pm 0.097$  for Overall acceptability during storage period of 6 months under ambient ( $17\text{--}37^\circ\text{C}$ ) conditions and thus clearly indicating the effect of storage conditions on the quality attributes of the product. However, the samples stored at ambient ( $17\text{--}30^\circ\text{C}$ ) were acceptable up to 6 months of storage as the Overall acceptability score of the product remained in good.

**Table 7:** Sensory attributes of shelf stable ready to eat *palak paneer* during storage at ambient temperature ( $17\text{--}37^\circ\text{C}$ ) on 9-point hedonic scale

Days	0 day	30 day	60 day	90 day	120 day	150day	180 day
Colour & Appearance	$8.83 \pm 0.108$	$8.31 \pm 0.070$	$7.86 \pm 0.105$	$7.43 \pm 0.111$	$7.11 \pm 0.060$	$6.66 \pm 0.056$	$6.15 \pm 0.126$
Aroma	$8.79 \pm 0.106$	$8.38 \pm 0.128$	$7.86 \pm 0.105$	$7.44 \pm 0.136$	$7.02 \pm 0.112$	$6.52 \pm 0.179$	$6.08 \pm 0.150$
Taste	$8.77 \pm 0.114$	$8.28 \pm 0.102$	$7.81 \pm 0.136$	$7.35 \pm 0.127$	$7.06 \pm 0.120$	$6.60 \pm 0.085$	$6.10 \pm 0.104$
Texture	$8.84 \pm 0.115$	$8.33 \pm 0.097$	$7.85 \pm 0.099$	$7.42 \pm 0.108$	$7.11 \pm 0.056$	$6.62 \pm 0.135$	$6.13 \pm 0.108$
Mouth feel	$8.79 \pm 0.078$	$8.31 \pm 0.098$	$7.93 \pm 0.120$	$7.41 \pm 0.104$	$7.11 \pm 0.064$	$6.64 \pm 0.186$	$6.17 \pm 0.088$
Overall acceptability	$8.82 \pm 0.091$	$8.32 \pm 0.112$	$7.79 \pm 0.139$	$7.45 \pm 0.089$	$7.08 \pm 0.104$	$6.63 \pm 0.101$	$6.14 \pm 0.097$

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