International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(4): 949-954

Received: 13-05-2018
Accepted: 17-06-2018

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Heat penetration characteristics and physico-chemical properties of retort processed shelf stable ready to eat palak paneer

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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 ^{0}C for 10 to 25 min respectively optimized on the basis of sensory evaluation and thermal parameters. Palak paneer were packed in retortable pouches and processed in a horizontal stationary air–steam retort. The product was characterized by a short lag period for the heating curve jh (from 0.25 to 1.939), small heating rate index fh (3.43-16.22 min) and a short lag factor for the cooling curve, jc (0.65 to 1.31) implying essentially convective heating regime. The total process time (B') was 7.9 to 32.5 min for F_0 value of 2.81-55.19 min. Process time of 10 min at 116 °C yielded a product that was microbiologically safe as well as sensorily acceptable.

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). 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 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.

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.*

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. 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.

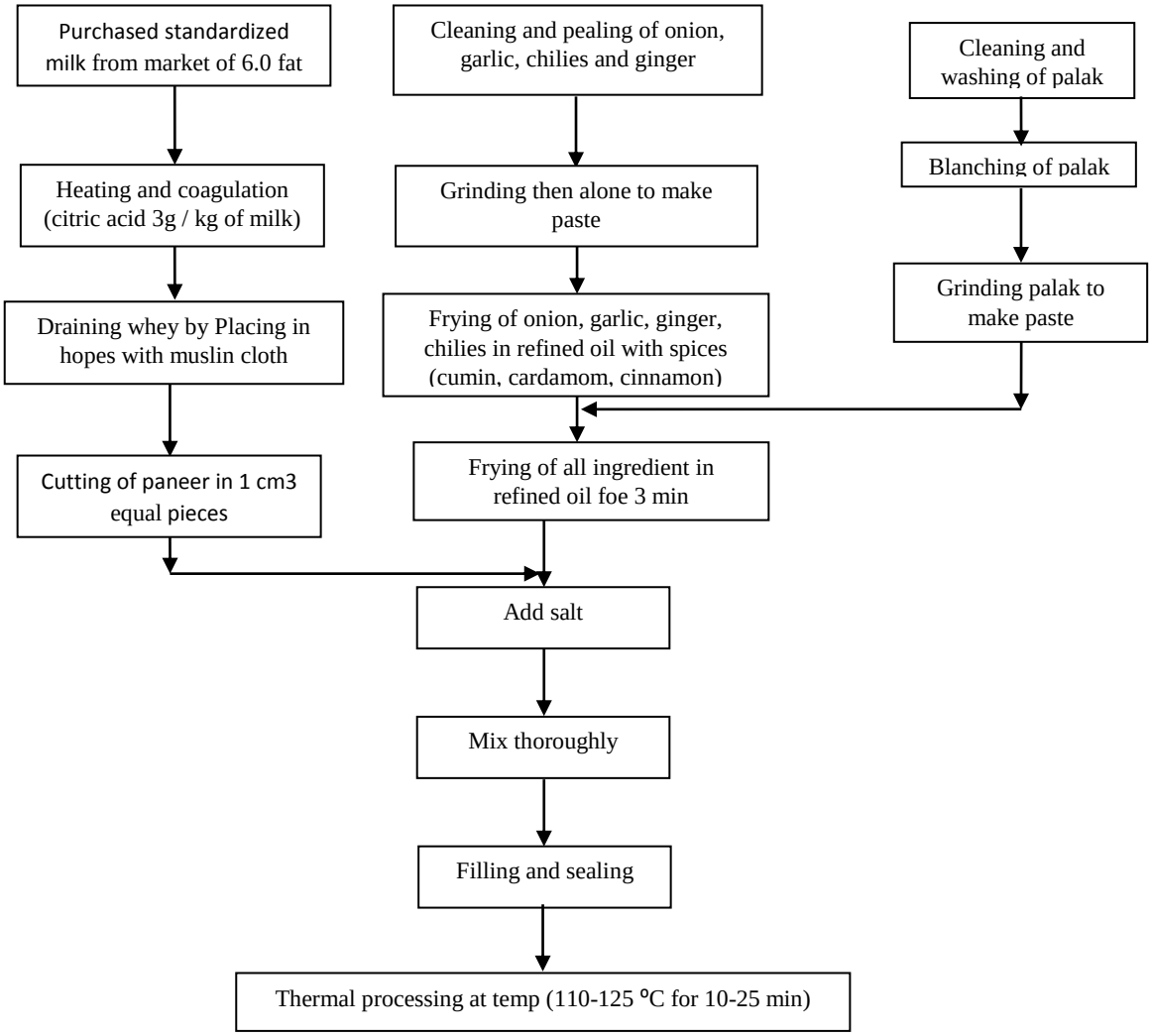

Fig 1: Flow chart for the preparation of ready to eat *palak paneer*

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 ºC for 10-25 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 ºC to 135 ºC with an accuracy of $\pm$ 0.1 ºC. 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 lethalities values were expressed as F_o 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.

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 Hedonic scale			
	Process Temperature ^{0}C	Process Time Minute	Colour	Taste	Texture	Overall Acceptability
1	110	10	6.15	6.11	6.87	9.19
2	125	10	7.14	8.18	7.51	6.01
3	110	25	6.55	7.46	7.21	6.89
4	125	25	6.47	6.32	5.78	6.24
5	106.893	17.5	6.27	6.44	7.29	7.14
6	128.107	17.5	6.54	6.76	6.18	5.71
7	117.5	6.8934	7.49	7.52	6.38	7.19
8	117.5	28.1066	6.51	7.39	5.91	7.65
9	117.5	17.5	7.93	7.19	7.44	7.87
10	117.5	17.5	7.17	7.76	7.23	7.98
11	117.5	17.5	7.19	6.48	7.39	6.76
12	117.5	17.5	7.5	7.29	7.29	7.43
13	117.5	17.5	6.9	7.88	6.48	7.88

Sensory Study

Ssensory evaluation was done at 25±2 ^{0}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].

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:

$$Yi = \beta o + \sum \beta i\, X_i + \sum \beta_{ii}\, X_i^2 + \sum \beta_{ij} X_i X_j$$

Where, Yi was the predicted response, βo was a constant, βi was the ith linear coefficient, βii was the ith quadratic coefficient and βij was ijth interaction coefficient, and XiXj 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.

Physico-chemical analysis

Product were optimized by using Response Surface Methodology (RSM) with two parameters viz., temperature and time. The developed products were tested for physico-chemical parameters viz., moisture content, fat, protein, carbohydrates, TBA value, FFA content, Peroxide value and textural parameters viz., consistency, cohesiveness and index of viscosity for *Palak Paneer*.

Results and Discussion

Optimization for retorting

Optimization of retort process time and temperature for the development of palak paneer was based on sensory using RSM. Out of 5 suggested solutions, the solution No.1 had better overall acceptability of 7.79 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 117^0 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, 6.99 for texture, 7.41 for taste and 7.79 for overall acceptability.

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

Source	Degree of Freedom	F value			
		Colour	Texture	Taste	Overall Acceptability
Model	5	4.48	4.52	4.27	4.74
A-temp	1	1.74	4.51	1.31	12.42
B-time	1	2.85	3.42	0.33	0.73
AB	1	2.38	6.94	14.17	4.64
A^2	1	14.35	0.59	5.03	5.87
B^2	1	2.32	7.57	0.16	0.036
Residual	7				
Lack of Fit	3	0.48	1.01	0.045	1.79

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

S. No.	Temperature ^{0}C	Time Min.	Colour	Texture	Taste	Overall acceptability	Desirability
1	117.055	10.000	7.31	6.99	7.41	7.79	0.719
2	116.670	10.000	7.29	6.98	7.35	7.86	0.719
3	117.252	10.000	7.33	7.00	7.43	7.76	0.719
4	117.337	10.000	7.33	7.00	7.450	7.74	0.719
5	117.576	10.000	7.34	7.01	7.48	7.70	0.718

Thermal process parameters of *Palak Paneer*

Lag period for heating curve (j_h)

The above presented Table 4 depicts the thermal process parameter of palak paneer. The j_h value as pseudo-initial temperature deficit (PID) divided by the actual initial temperature deficit (ID) ranged from 0.25 to 1.939 (Table 4). A decreasing trend has been found in the j_h value as processing temperature increase and similar result reported by Gautam *et al*. 2012 [11] and Bisht *et al*. 2013 [7]. Shelf stable dairy dessert *dalia* exhibited a j_h value in the range of 0.40 to 0.85 (Jha *et al*. 2012) [16]. Shelf stable dietetic *chhana kheer* reported j_h value ranged from 0.78 to 1.03 (Gautam *et al*. 2012) [11]. shelf stable *Kodo* millet *Kheer* reported j_h value ranged from 0.12 to 1.05 (Bisht *et al*. 2013) [7].

Heating Rate Index (f_h)

The time taken for a heat penetration curve to traverse one log cycle is referred to as f_h value. In the present study, f_h values were found to be in the range of 3.43-16.22 (Table 4). These values are reported for convective heat transfer in food products, in contrast the f_h value in conductive heat transfer are higher i.e. 30-40 min (Horner 1992) [12]. Heating rate index (f_h) for convective heating products has been reported to be dependent upon temperature of heating medium and condensing surface, steam-air flow rate and direction, surface size and orientation, viscosity, film thickness and stagnant air layer thickness (Tung *et al*. 1990) [30]. The f_h value for long-life *kheer* in retort pouch was found to be in the range of 2.82-8.70 min (Jha *et al*. 2011) [17], Shelf stable *channa kheer* of 2.82-8.70 min (Gautam *et al*. 2012) [11]. When the temperature of processing increases, penetration of heat to the core of the product takes place at a much faster rate, and this in turn reduces the time taken.

Lag factor for cooling curve (j_c)

Lag factor depict the cooling curve due to the fact that the product temperature does not fall as rapidly as the retort temperature falls. The j_c values for convective heating products are reported to be close to 1.0, whereas for conducting heating packs the values could be much higher as the cooling process is much slower for these products. As shown in Table 4, j_c values for the *palak paneer* ranged from 0.65 to 1.31, which were in conformity with the values reported for convective heating liquid products (Horner, 1992). j_c values for retort processed rice based dairy dessert *Kheer* was 1.09-2.31 (Jha *et al*. 2011) [17], shelf stable *kodo kheer* 0.72 to 1.14 (Bisht *et al*. 2013) [7], shelf stable dietetic *channa kheer* 0.76 to 1.06 (Gautam *et al*. 2012) [11] and for shelf stable dairy dessert *dalia* was 0.91- 1.10 (Jha *et al*. 2012) [16].

Total Process Time (*B'*)

The total process time (*B'*) and operator's process time (P_t) depend greatly on f_h and j_h values obtained for each process. Total process time for *palak paneer* ranged from 7.9 to 32.5 min (Table 4) depending on F_o value (2.81-55.19 min) and other related factors such as f_h J_h, g and I_o. Process time (*B*) for long life *Kheer* in retort pouch, (thickness 115 µm) was found to be 14.89-21.52 min for a F_o in the range of 12.4-14.8 min (Jha *et al*. 2011) [17], *Kodo* millet *Kheer* ranged from 7.60 to 45.15 min shelf stable dietetic *channa kheer* 19.13 to 32.98 (Gautam *et al*. 2012 and for shelf stable dairy dessert *dalia* was 10.20- 15.78 (Jha *et al*. 2012) [16].

Table 4: Thermal process parameters of *Palak Paneer*

Trial No.	Retort temperature (ºC)	Process time (min)	F_o (min)	f_h (min)	j_h	j_c	B (min)
1	110	10	2.81	3.43	1.939	0.843	7.96
2	125	10	43.14	12.13	0.340	0.83	32.5
3	110	25	6.29	5.1	0.25	1.31	10.64
4	125	25	42.34	7.91	0.76	1.16	26.21
5	106.893	17.5	7.68	5.9	0.29	1.53	11.40
6	128.107	17.5	55.19	12.10	1.05	0.92	7.9
7	117.5	6.8934	6.16	13.60	1.21	0.65	20.65
8	117.5	28.1066	22.25	16.22	1.71	1.92	22.34
9	117.5	17.5	10.58	9.23	0.91	0.89	15.01
10	117.5	17.5	10.33	9.29	0.94	0.78	15.23
11	117.5	17.5	11.149	9.21	0.95	0.69	14.18
12	117.5	17.5	14.81	9.31	0.92	0.72	15.12
13	117.5	17.5	11.31	9.12	0.90	0.75	16.35

Storage Study

Sensory Analysis

Results 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 ± 0.108 for colour and appearance, 8.79±0.106 for aroma, 8.77±0.114 for taste, 8.84±0.115 for texture and 8.82±0.091 for Overall acceptability (Table 5) 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±0.126 for colour and appearance, 6.08±0.150 for aroma, 6.10±0.104 for taste, 6.13±0.108 for texture, and 6.14±0.097 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.

Table 5 Sensory attributes of shelf stable ready to eat *palak paneer* during storage at ambient temperature (17-37^0) on 9-point hedonic scale

Days	0 day	30 day	60 day	90 day	120 day	150day	180 day
Colour & Appearance	8.83±0.108	8.31±0.070	7.86±0.105	7.43±0.111	7.11±0.060	6.66±0.056	6.15±0.126
Aroma	8.79±0.106	8.38±0.128	7.86±0.105	7.44±0.136	7.02±0.112	6.52±0.179	6.08±0.150
Taste	8.77±0.114	8.28±0.102	7.81±0.136	7.35±0.127	7.06±0.120	6.60±0.085	6.10±0.104

Texture	8.84±0.115	8.33±0.097	7.85±0.099	7.42±0.108	7.11±0.056	6.62±0.135	6.13±0.108
Overall acceptability	8.82±0.091	8.32±0.112	7.79±0.139	7.45±0.089	7.08±0.104	6.63±0.101	6.14±0.097

Physico-chemical analysis

Table 6 showed the physico-chemical properties 79.22% moisture content, 11.14 % fat content, 2.81 % protein content, 5.37% carbohydrate content, 1.30 % ash content, 0.143 mg MA/ Kg sample TBA value, 1.632 meq O_2/Kg fat Peroxide value and 0.1242 % oleic acid free fatty acid content of *Palak Paneer* respectively. The developed products were also analyzed for instrumental texture and results were reported in Table 6. The consistency of Palak Paneer is 345.5±0.023 g.s, cohesiveness 21.56±0.011 G and Index of viscosity 18.40±0.104 g.s.

Table 6 Physico-chemical analysis of retort processed palak paneer

Chemical constituent	***Palak Paneer***
Moisture %	79.22 ±1.619
Fat %	11.14 ±0.825
Protein %	2.81 ±0.612
Ash %	1.30 ±0.168
Carbohydrates %	5.37 ±0.457
TBA value	0.143 ±0.002
Peroxide value	1.632 ±0.174
FFA	0.1242 ±0.004
Textural Parameters	
Consistency (g.s)	345.5±0.023
Cohesiveness (G)	21.56±0.011
Index of Viscosity (g.s)	18.40±0.104

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