Original Research Article

APPLICATION OF RSM TO OPTIMIZE PROCESS CONDITIONS FOR THE DEVELOPMENT OF GHEWAR

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ABSTRACT

RSM was performed for the optimization of processing conditions to develop ghewar, traditional sweetmeat of India. Shelf stability of optimized ghewar sample was evaluated at ambient temperature for 30 days. Three variables i.e. frying oil temperature (160-180 ^{0}C), batter temperature (5-10 ^{0}C) and frying oil time (4-6 minute) were taken to investigate the effect on ghewar responses viz., oil content, moisture content, texture and sensory attributes (OA). The optimum conditions were 160 ^{0}C frying oil temperature, 5^{0}C batter temperature and 4 minute frying oil time. The ghewar was shelf stable for 30 days in metallised foil pouches during storage.

Keywords: Ghewar, traditional sweets, optimization, RSM, shelf life, texture

1. INTRODUCTION

Traditional sweets of different types are made in India. They are classified on the basis of different ingredients i.e. dairy, cereals, pulses, fruits or combinations thereof. Most popular traditional sweets are Peda, Barfi, Laddoo, Jalebi, Emarti, Gulabjamun, kalajam, Rasgulla, Soanpapdi, Ghewar, Mysore pak, Kajukatli, Rasmalai, Sandesh, Kalakand**,** Puranpoli, Malpua, Phirnee,Chikki etc. These traditional sweets depend on regional preferences and practices. Indian traditional sweets are also known as 'Mithai'. They are more intense and sweeter than western sweets and desserts and quite a bit heavier because of having ghee or clarified butter. Many researchers have worked on development of different Indian traditional sweets like Pinni [1], Jalebi[2], Khoa jalebi [3], Chiroti [4], Inderse [5], Dodaburfi[6], Ghewar [7] and Coconut Barfi [8] etc., but it is important to optimize the process conditions to standardize the making process of Indian traditional sweets for popularization in India as well as abroad through entering in organized food processing sector. It is also a big challenge to provide the safe and quality product with increased shelf life. Process standardization of Indian traditional sweets may also overcome the problem of getting safe and quality sweets with enhanced shelf life.

Ghewar is a round shaped Indian traditional sweet, prepared using refined wheat flour, ghee and sugar solution. It has honey-comb porous pattern and crispy texture. Batter of refined wheat flour is fried in butter and dipped in sugar solution of measured consistency. It is famous in northern region of India and given as a token of gift in the festivals. Ghewar is prepared by deep frying in oil. Deep frying provides the crispy quality and delicious flavour to the ghewar because of physico chemical changes throughout interaction of fat-food at higher frying oil temperatures [9]. It also enhances the shelf life due to removal of water from the final product [10].

The Response Surface Methodology is used in designing and formulation of new scientific studies. New product can also be developed and analysed using the RSM approach [11, 12].

The study was conducted to standardize the making process of Ghewar under controlled processing conditions. Standardization of Ghewar making process will open the new avenue to bring the age old traditional knowledge into the organized food processing sector. Sustained focus on enhancing organized food processing and increasing exports may boost the Indian economy many folds.

2. MATERIALS AND METHODOLOGY

2.1 Preparation of Indian traditional sweet (Ghewar)

In this method, clarified butter (35g) and ice cubes were creamed together. Ice cubes were removed after getting cream like consistency. Then, refined wheat flour (100 g) is added gradually continuing the creaming process. When adequate aeration is achieved, small amount of milk (20 ml) is added and mixed thoroughly. Then, water is (200 ml) added into the mixture to achieve batter of thin consistency. Then, ghewar mould is placed in an open iron pan and poured melted ghee (clarified butter) in it. The clarified butter is heated at optimized temperature and time in a fryer. Then, one spoonful of batter is poured into mould in thin stream and fried. Another spoonful batter is poured in the centre in a thin stream when froth subsides. Process was repeated 6-7 times by making hole in the centre of ghewar by wooden skewer stick while pouring batter each time in the centre. The frying oil time and temperature were maintained according to optimized conditions by RSM. When the centre gets firm and fried, the ghewar was pulled out gently from the fat. Then, ghewar samples were cooled at room temperature and poured sugar syrup on it and again allowed for cooling.

2.2 Experimental design for optimization of Ghewar

A central composite rotatable design (CCRD) was employed. The independent variables considered for optimization of ghewar making process were frying oil temperature (160-180^{0}C), batter temperature (5-10^{0}C) and frying oil time (4-6 minute).

2.3 Estimation of fat and moisture content

Fat and moisture content of ghewar samples were analysed as described by Ranganna [13] and official methods of analysis [14], respectively.

2.4Texture analysis

Texture analyser (Stable Micro System) was used to analyse the hardness of ghewar sample as described by Bourne [15]. Knife blade cut with slotted insert probe (HDP/BS) made of stainless steel was used throughout the experiments. HDP/90 platform was used to place the Ghewar samples. Load cell of 5 kg was used to measure the force for texture analysis.

2.5Colour analysis

A colour measuring instrument Chroma Meter CR-400 with 8mm aperture size (Konica Minolta, JAPAN) was used to determine the colour values of ghewar samples in terms of L, a and b values. Hue angle, chroma and total colour difference were also computed [16].

3. RESULTS AND DISCUSSION

3.1 Response surface modeling and 3-D graphs for oil content of ghewar

Oil values in ghewar samples were found from 44 to 60.42 (Table 1). The Ghewar prepared using 180 ^{0}C of frying oil temperature, 10 ^{0}C of batter temperature and 6 minute of frying oil time having the maximum oil values 60.42. The minimum oil value in ghewar sample was obtained for experiment having 160 ^{0}C of frying oil temperature, 10 ^{0}C of batter temperature and 4 minute of frying oil time.

The different statistical characteristics of oil values are shown in Table 2. The relationship between frying oil temperature, batter temperature, frying oil time and oil values of ghewar shows the significant F value of model, 9.30. A non-significant Lack of Fit F value (3.69) was obtained (Table 3). The observed R^2 value (0.8933) indicates that 89.33% of data fits in the model. The Adj R^2 (0.7973) and Adequate Precision (10.735) show the model accuracy and signal to noise ratio, respectively (Table 4). Eq. (2) represents the effect of independent variables on the oil content of ghewar:

Oil content = $54.81 + 3.05\alpha_1 - 0.038\alpha_2 + 4.22\alpha_3 + 0.43\alpha_1\alpha_2 + 0.68\ \alpha_1\alpha_3 + 0.010\alpha_2\alpha_3 - 0.78\alpha_1^2 - 0.14\alpha_2^2 - 1.13\alpha_3^2$

3.2 Influence of independent variables on oil content of developed ghewar

The influence of frying oil temperature, batter temperature and frying oil time on the oil content of ghewar is illustrated in the form of 3-D surface graph (Fig 1). It is observed from the equation (2), that oil content of ghewar had significant positive linear effect of frying oil temperature (α1) and frying oil time (α3). The quadratic and interaction terms were observed non-significant. Figure 1 shows the significant effect on the oil absorption of ghewar. Increased oil absorption was observed during increased frying oil temperature and frying oil time. Similar observations have been reported by various researchers [17, 18].

Table 1. Experimental central composite design and result of responses for Ghewar

Run	Variables			Responses			
	Frying Temp. (°C)	Batter Temp. (°C)	Frying Time (Minute)	Oil content	Moisture Content	Overall Acceptability	(Hardness) N
1	160.00	5.00	4.00	45.33	4.65	8.0	15.2
2	180.00	5.00	4.00	48.33	3.68	7.3	7.91
3	160.00	10.00	4.00	44.00	4.23	8.2	16.84
4	180.00	10.00	4.00	49.00	3.57	7.6	12
5	160.00	5.00	6.00	54.00	3.05	4.0	15.67
6	180.00	5.00	6.00	60.00	2.40	2.0	15.63

7	160.00	10.00	6.00	53.00	3.34	4.0	22.56
8	180.00	10.00	6.00	60.42	2.33	2.0	16.98
9	153.50	7.50	5.00	48.00	4.11	6.0	24.96
10	186.00	7.50	5.00	60.00	2.02	4.5	19.8
11	170.00	3.50	5.00	55.60	3.03	5.0	6.5
12	170.00	11.50	5.00	56.03	2.68	5.0	16.6
13	170.00	7.50	3.50	48.00	3.13	6.0	11.2
14	170.00	7.50	6.50	58.00	2.66	4.0	20.5
15	170.00	7.50	5.00	55.35	2.69	7.75	15.12
16	170.00	7.50	5.00	53.00	2.85	7.0	13.8
17	170.00	7.50	5.00	53.50	2.97	7.3	12.25
18	170.00	7.50	5.00	56.50	2.32	6.0	14.1
19	170.00	7.50	5.00	56.00	2.67	8.0	13.05
20	170.00	7.50	5.00	54.00	2.32	7.5	16.89

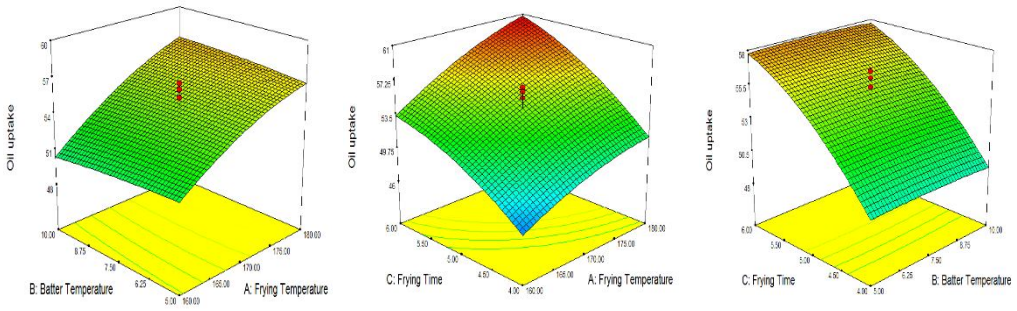

Fig. 1. 3-D surface graph showing the effect of process variables on oil uptake of Ghewar

TABLE 2. ANOVA for different responses (Quadratic Mo

	Coefficient Estimate					
	Oil Uptake	Moisture	Overall Acceptability	Hardness (Texture)	Oil Uptake	Mo
Model	54.81	2.62	7.24	14.25	9.30	4
α_1	3.05	-0.50	-0.57	-1.94	26.55	1(
α_2	-0.038	-0.066	0.039	2.27	4.098E-003	0
α_3	4.22	0.42	-1.64	2.53	50.86	1:
$\alpha_1\alpha_2$	0.43	-6.250E-003	0.016	-0.39	0.31	1.5
$\alpha_1\alpha_3$	0.68	-3.750E-003	-0.33	0.81	0.77	5.6
$\alpha_2\alpha_3$	0.010	0.094	-0.066	0.31	1.676E-004	0
α_1^2	-0.78	0.25	-0.62	2.60	1.84	4
α_2^2	-0.14	0.17	-0.71	-1.23	0.058	2
α_3^2	-1.13	0.19	-0.71	0.29	3.88	2

Table 3.ANOVA for response surface quadratic model of different responses of Ghewar

Responses	Source	Sum of Square	Mean Square	F Value	P Value
Oil Uptake	Lack of fit	37.56	7.51	3.69	0.0889
	Pure error	10.17	2.03		
Moisture	Lack of fit	1.65	0.33	4.56	0.0607
	Pure error	0.36	0.072		
Overall Acceptability	Lack of fit	11.38	2.28	4.55	0.0610
	Pure error	2.50	0.50		
Hardness	Lack of fit	21.47	4.29	1.61	0.3081
	Pure error	13.38	2.68		

Table 4.Model statistical attributes for different responses of Ghewar

	Responses			
Parameters	**Oil Uptake**	**Moisture**	**Overall Acceptability**	**Hardness**
Std. Dev.	2.18	0.45	1.18	1.87
Mean	53.40	3.04	5.86	15.38
C.V %	4.09	14.76	20.12	12.14
PRESS	299.07	13.08	90.04	194.62
R^2	0.8933	0.7888	0.8094	0.9085
Adj R^2	0.7973	0.5988	0.6379	0.8261
Pred R^2	0.3316	-0.3763	-0.2359	0.4888
Adeq Precision	10.735	6.379	6.631	13.558

3.3 Response surface modeling and 3-D graphs for moisture content of ghewar

Values of moisture of ghewar prepared from different experimental conditions were in the range of 2.02 to 4.65 (Table 1). The ghewar prepared using 160 ^{0}C of frying oil temperature, 5 ^{0}C of batter temperature and 4 minute of frying oil time got the highest score of moisture content (4.65 %). The lowest value of moisture content (2.02 %) was found for Ghewar prepared using process parameter 186 ^{0}C of frying oil temperature, 7.50 ^{0}C batter temperature and 5 minute of frying oil time.

The different statistical characteristics of moisture are shown in Table 2. The relationship between frying oil temperature, batter temperature, frying oil time and moisture values of ghewar shows the significant F value of model, 4.15. A non-significant Lack of Fit F value (4.56) was obtained (Table 3). The value of R^2 (0.7888) and adjusted R^2 (0.5988) indicate the model accuracy. The adequate precision value of 6.379 is a signal to noise ratio which indicate the adequate model discrimination (Table 4). A ratio more than 4 is appropriate. The model Eq. (3) represents the effect of independent variables on the moisture content of ghewar:

$$\textbf{Moisture} = 2.62 - 0.50\alpha_1 - 0.066\alpha_2 - 0.42\alpha_3 - 6.250\times10^{-3}\alpha_1\alpha_2 - 3.750\times10^{-3}\alpha_1\alpha_3 + 0.094\alpha_2\alpha_3 + 0.25\alpha_1^2 + 0.17\alpha_2^2 + 0.19\alpha_3^2 \quad (3)$$

3.4 Influence of independent variables on the moisture content of developed ghewar

The interaction effect of frying oil temperature, batter temperature and frying oil time on the moisture content of ghewar is shown in the form of 3-D surface graph (Fig. 2). It is observed from the equation (3), moisture content of fried Ghewar had significant positive linear effect of frying oil temperature (α1) and frying oil time (α3) at 95 % confidence level. The quadratic and interaction terms were observed non-significant. Figure 2 depicts the significant effect on the moisture values of ghewar. It was observed that moisture values are decreasing significantly with increasing temperature & time. Quite Similar results were also recorded by various researchers [19, 20]. The reason of decreasing the moisture content with increasing the frying oil temperature and time is due to the water vaporizes rapidly after reaching to its boiling point [21].

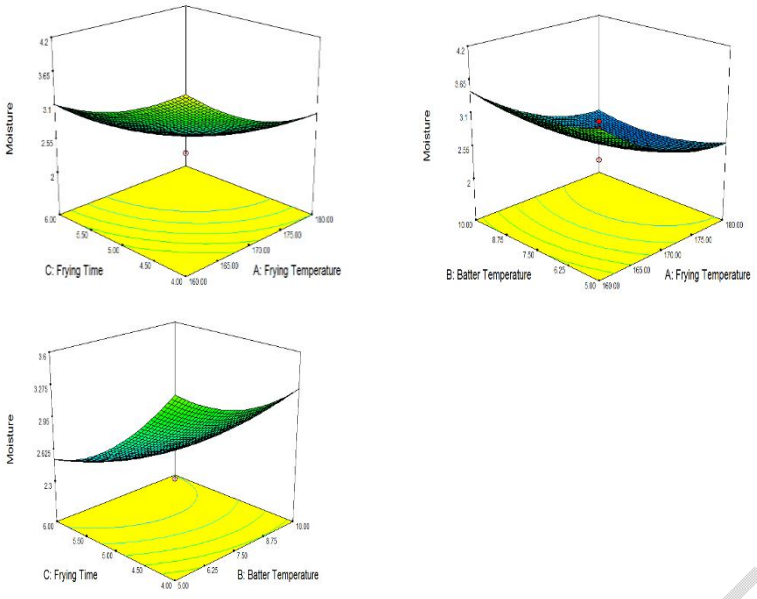

Figure 2. 3-D surface graph showing the effect of process variables on moisture content of Ghewar

3.5 Response surface modeling and surface plots for overall acceptability

Overall acceptability is measured using our sense organs [22,23]. The range of overall acceptability of the ghewar in the different experimental runs were 2 to 8.2 (Table 1). The Ghewar made using 160 ^{0}C of frying oil temperature, 10 ^{0}C batter temperature and 4 minute of frying oil time got the maximum score of overall acceptability (8.2). Minimum score was found for two experimental runs i.e. 180 ^{0}C of frying oil temperature, 5 ^{0}C batter temperature and 6 minute of frying oil time and 180 ^{0}C of frying oil temperature, 10 ^{0}C batter temperature and 6 minute of frying oil time.

The different statistical characteristics of overall acceptability are shown in Table 2. The relationship between frying oil temperature, batter temperature, frying oil time and overall acceptability of ghewar shows the significant F value of model, 4.72. The value of R^2 (0.8094) and adjusted R^2 (0.6379) indicate the model accuracy. The adequate precision value (6.631) indicate adequate model discrimination (Table 4). Signal to noise ratio greater than 4 is appropriate. Below mentioned quadratic model of overall acceptability achieved from statistical analysis in term of coded levels:

$$\text{Overall Acceptability} = 7.24 - 0.57\alpha_1 + 0.039\alpha_2 - 1.64\alpha_3 + 0.016\,\alpha_1\alpha_2 - 0.33\alpha_1\alpha_3 - 0.066\,\alpha_2\alpha_3 - 0.62\alpha_1^2 - 0.71\alpha_2^2 - 0.71\alpha_3^2 \quad (4)$$

3.6 Influence of independent variables on the overall acceptability of developed Ghewar

The interaction effect of frying oil temperature, batter temperature and frying oil time on the overall acceptability of Ghewar is shown in the form of 3-D surface graph (Fig 3). It is observed from the equation (4), overall acceptability of fried Ghewar had significant negative linear effect of frying oil time (α3) at 95 % confidence level. The interaction term were observed non-significant. The batter temperature ($\alpha 2^2$) and frying oil time ($\alpha 3^2$) having significant negative quadratic effect.

It can be observed from the figure 3 that overall acceptability first increases then decreases with increase in frying oil temperature. Reason may be the development of crispiness when temperature increases. Further increase of frying oil temperature, develop intermediate chemicals as a result of browning reaction. It was observed from the figure 3, overall acceptability is decreasing as frying oil time increasing. The reason might be excess frying that produces off flavour, taste and colour.

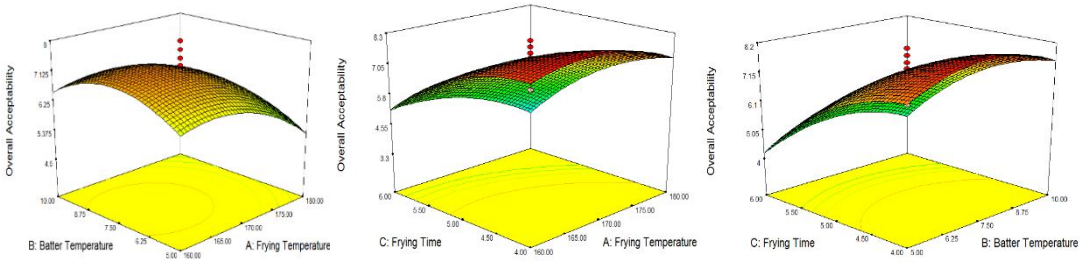

Figure 3. 3-D surface graph showing the effect of process variables on overall acceptability of Ghewar

3.7 Response surface modelling and surface plots for texture (hardness)

The range of the textural attribute (hardness) of the Ghewar in the different experimental runs were found from 6.5 N to 24.96 N (Table 1).The Ghewar made using 153.18 ^{0}C of frying oil temperature, 7.5 ^{0}C batter temperature and 5 minute of frying oil time got the highest score of hardness (24.96 N). The lowest score of 6.5 was observed for Ghewar made using process parameters 170^{0}C of frying oil temperature, 3.3^{0}C batter temperature and 5 minute of frying oil time.

The different statistical characteristics of textural attribute (hardness) are shown in Table 2. The relationship between frying oil temperature, batter temperature, frying oil time and textural attribute (hardness) of ghewar shows the significant F value of model, 11.03. The observed R^2 value (0.9085) indicates that 90.85% of data fits in the model. The Adj R^2 (0.8261) and Adequate Precision (13.558) show the model accuracy and signal to noise ratio, respectively (Table 4). Eq. (5) represents the effect of independent variables on the textural attribute (hardness) of ghewar:

$$\text{Hardness} = 14.25 - 1.94\alpha_1 + 2.27\alpha_2 + 2.53\alpha_3 - 0.39\alpha_1\alpha_2 + 0.81\alpha_1\alpha_3 + 0.31\alpha_2\alpha_3 + 2.60\alpha_1^2 - 1.23\alpha_2^2 + 0.29\alpha_3^2 \quad (5)$$

3.8 Influence of independent variables on the textural attribute (hardness) of developed Ghewar

The interaction effect of frying oil temperature, batter temperature and frying oil time on the hardness of Ghewar is shown in the form of 3-D surface graph (Fig 4). Texture of the food can be measured mechanically, which indicate the structural conversion in the product during frying [24]. Frying oil temperature have significant impact on hardness of Ghewar sample. Significant effect on hardness of Gulabjamun were also observed during frying [25]. It was observed from the Figure 4, that hardness value decreases with increased frying oil temperature and reduced batter temperature. Market Ghewar samples have similar results of hardness values [26]. Honeycomb texture and special shape of Ghewar is developed due to the binding effect of refined wheat flour [27-29]. Hardened ghewar is obtained when fried

at higher temperature range for longer time. Choe and Minalso supported the similar results in his study [30].

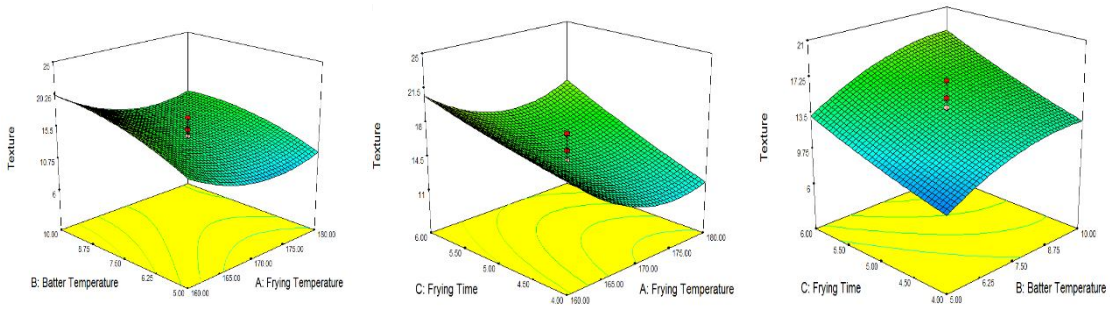

Figure 4. 3-D surface graph showing the effect of process variables on hardness (texture) of Ghewar

3.9Optimization of process parameters and result verification

Process parameters were optimized to develop Ghewar on the basis of minimum oil uptake, minimum batter temperature (^{0}C), in range frying oil temperature (^{0}C), in range frying oil time (minute) and in range overall acceptability. Under these criteria, optimum process parameters for the development of Ghewar were found 160 ^{0}C of frying oil temperature, 5 ^{0}C of batter temperature and 4 minute of frying oil time. The result of responses were 46.64% of oil uptake, 4.30% of moisture, 7.0 of overall acceptability and 13.79 N of texture (hardness) with desirability of 0.916 (Table 5). The Ghewar was prepared using the above mentioned optimized process conditions and the developed Ghewar was again analysed for oil uptake, moisture, overall acceptability and texture (hardness). The predicted and experimental values of process parameters of optimized Ghewar were almost similar and is presented in Table 5.

Table 5. **Predicted and experimental values for different parameters of optimized combination**

Responses	Predicted value	Experimental value
Oil Uptake (%)	46.64	45.33 ± 0.2**
Moisture (%)	4.30	4.65 ± 0.1**
Overall Acceptability	7.0	8.0 ± 0.1*
Hardness (N)	13.48	15.2 ± 0.2*

*Values are mean ± SD of 6 replicates (n=6); **Values are mean ± SD of 3 replicates (n=3)

Table 6.Instrumental colour values and water activity of Ghewar

	Colour Attributes	Water activity

Optimized Ghewar Sample	L Value*	a Value*	b Value*	Hue angle* Tan-1(b/a)	Chroma* ($\sqrt{a^2+b^2}$)	Total Colour Difference * (ΔE)	(*aw)
	54.89 ± 1.74	15.16 ± 1.23	24.97 ± 1.00	58.73 ± 1.72	29.21 ± 1.24	48.07 ± 1.28	0.24 ± 0.01

*Values are mean ± SD of 3 replicates (n=3)

3.10Colour characteristics and water activity of optimized Ghewar sample

The result of colour values and water activity of optimized Ghewar samples are shown in (Table 4). The L, a and b values of optimized Ghewar sample were 54.89, 15.16 and 24.97, respectively (Table 6). It was observed that the L, a and b values are quite closer to market sample of Ghewar [26]. Redness value of optimized Ghewar sample was found to be lowest compared to lightness and yellowness because of the use of optimized temperature. Hue, chroma and total colour difference values of optimized Ghewar sample were 58.73, 29.21 and 48.07, respectively (Table 6).

Water activity is an important parameter to ensure shelf life of developed Ghewar. The water activity of Ghewar sample was found 0.24, which was quite less as compared to market samples of Ghewar [26](Table 6). Lower value of water activity indicates the longer shelf life of Ghewar. The value of water activity of market samples were high because they would have been analysed after the soaking in sugar syrup solution.

3.11Storage study of optimized Ghewar samples

The optimized Ghewar was first rapped in aluminium foil and then packed in metalized polyester pouch. The product was packed and stored at 30 ± 5°C for a period of 30 days for storage study. The optimized Ghewar sample was stored for 30 days and monitored after every10 days.

The moisture content of optimized Ghewar increased slightly from 3.70% to 5.12 % during 30 days storage period (Table 7). The moisture content for safe storage of Ghewar was maintained during the whole storage period (30 days). The aluminium foil and metalized polyester pouch resulted in lower moisture uptake during whole storage period due to excellent water vapour barrier properties. Various researchers identified the similar outcome during storage studies of indian traditional sweets [31, 7].

FFA values of fried oil were increasing continuously from 0.33 to 0.54% (Table 7). As FFA content is maintained less than 1 % during storage, therefore, Ghewar sample can be considered fit for consumption upto one month. Tiwari et al. also reported the increased FFA content during storage of legume and cereal by-product based snacks[32].

Lipid oxidation is measured using peroxide value. It was observed that peroxide value were increasing continuously from 4.8 to 7.6 meq/kg during the storage period (Table 7). 7.6 meq/kg peroxide value are considered safe for human consumption. Tiwari *et al.* reported the similar trend of increasing the peroxide value during storage of snack[32].

No differences were witnessed in texture of Ghewar during 30 days of storage period. It was observed that, texture value was decreasing from 15.2 N to 9.40 N during storage period. Reason may be the increase of moisture content during storage period. Texture value decreased significantly at 5 % level of significance (Table 7).

Table 7.Physico-chemical and textural changes during storage of Ghewar

Parameter / Days	0 Day	10^{th} Day	20^{th} Day	30^{th} Day
Moisture (%)	3.70	4.13	4.64	5.12
Oil content (%)	45.60	45.01	44.70	43.98
Hardness(N)	15.2	13.90	10.69	9.40
FFA	0.33	0.39	0.45	0.54
Peroxide value (meq/kg)	4.8	5.2	6.8	7.6

4. CONCLUSION

Standardization of age old traditional technique of making process of Indian sweets is very much required to include new food items in organized sector. Ghewar is very popular in Northern India and has a very wide market. Ghewar is becoming very popular due to its honeycomb structure and texture but the making process of Ghewar is very complex which needs the appropriate deep frying under controlled frying oil temperature, frying oil time and batter temperature. Taking all these point into consideration, RSM was adopted for the optimization of processing conditions. The optimized Ghewar (160 ^{0}C of frying oil temperature, 5 ^{0}C of batter temperature and 4 minute of frying oil time) resulted 46.05% of oil content, 3.93% moisture and 13.78 N of texture (hardness) and acceptable sensory score. The developed Ghewar have good structure, soft body, pleasant taste, less oil content and reduced water activity. The developed Ghewar can be stored for 30 days period in metallized foil pouches. The optimized deep fried Ghewar then can be instantly consumed after pouring the hot sugar syrup.

REFERENCES

1. Saxena AK, Kulkarni SG, Berry SK, Sehgal RC, Beerh OP. Preparation, packaging and storage of Pinni- an Indian traditional sweet, Journal of Food Science and Technology. 1996; 33:503-505.

2.Chakkaravarthi A, Punil kumar HN, Bhattacharya S. Jilebi-an Indian traditional sweet: attributes, manufacturing practices and scope for large scale production. Indian Food Industry. 2009; 28:30-36.

3.Pagote CN, Jayaraj RK. Khoa jalebi, a unique traditional product of central India. Indian Journal of Traditional Knowledge. 2012;11: 96-102.

4.Chetana R, Yella Reddy S, Prabhakar JV. Effect of fat and emulsifiers on texture of Chiroti-an Indian traditional sweetmeat. Journal of Food Science and Technology. 1996; 33: 474-478.

5.Saxena AK, Kulkarni SG, Manan JK, Berry SK, Beerh OP. Studies on reparation, packaging and storage of Irderse- an indian traditional sweet, J Food Sci Technol. 1991; 28: 352-355.

6.Chawla R, Patil GR, Singh AK. Physicochemical and textural attributes of market sample of dodaburfi. Dairy Foods International. 2011; 1: 176-83.
7.Saxena AK, Kulkarni SG, Berry SK, Sehgal RC, Beerh OP. Studies on preparation, packaging and storage of Ghewar: an Indian traditional sweet, Journal of Food Science and Technology. 1996; 33: 407-409.
8.Gupta V, Vijayalakshmi N, Ashwini B, Anbarasu K, Vijayalakshmi G, Prakash M, Indiramma A, Rangarao G, Ramesh B. Shelf life enhancement of coconut burfi – an Indian traditional sweet. Journal of Food Quality. 2010; 33: 329-349.
9.Bordin K, Kunitake MT, Aracava KK, Trindade CS. Changes in food caused by deep fat frying-a review. Arch Latinoam Nutr. 2013; 63(1): 5-13.
10. Dixit A, Upadhyay A, Mishra A. Process optimization for the development of low fat fried Indian traditional snack using response surface approach. Carpathian Journal of Food Science and Technology. 2018; 10(3): 57–71.
11. Kashudhan H, Dixit A, Kumar K. Development of wheatgrass-pomegranate blended therapeutical juice using response surface methodology. Journal of Food Processing and Preservation. 2016; 41(2): e12869.
DOI:10.1111/jfpp.12869.
12. Bradley N, The response surface methodology. Master of Science Thesis, Indiana University of South Bend, Indiana, 2007.
13. Ranganna S, Handbook of analysis and quality control of fruits and vegetables products, Tata McGraw Hill Publ. Co. Ltd., New Delhi, 2007.
14.AOAC, Official methods of analysis. 18th ed. Washington, DC: Association of Official Analytical Chemists, 2006.
15. Bourne MC. Texture profile analysis. Food Technology. 1978; 32:62-66.
16. Hutchings JB. Food colour and appearance. Blackie Academic and Professional, London, 1994.
17. Krokida MK, Oreopoulou V, Maroulis ZB, Water loss and oil uptake as a function of frying oil time, J. Food Eng. 2000; 44: 39-46.
1**8.** Pinthus EJ, Weinberg P, Saguy IS. Criterion for oil uptake during deep-fat frying. J. Food Sci. 1993; 58:204-5.
19. Prakash J, Naik HR, Hussain SZ, Singh B. Effect of processing conditions on the quality characteristics of barley chips. J. Food Sci. Technol. 2015; 52:294–302.
20. Dixit A, Jaipal MK, Tejani N. Development of low fat gujarati traditional snack 'ganthiya' using hydrophilic polymers and modified natural polysaccharides. Journal of Scientific Research and Reports. 2024; 30 (7):496-506.
DOI: 10.9734/jsrr/2024/v30i72165.
21. Achir N, Vitrac O, Trystram G. Heat and mass transfer during frying, in: S. Sahin & S.G. Sumnu (Eds.), Advances in deep fat frying of foods, CRC Press, Canada, 2008, pp. 5-32.
22. Debjani C, Das S, Das H. Aggregation of sensory data using fuzzy logic for sensory quality evaluation of food. J. Food Sci. Technol. 2011; 50:1088-1096.
23. Stone H, Sidel JL. Sensory evaluation practices, 3rd ed. Elsevier, California, 2004.
24. Asokapandian S, Swamy GJ, Hajjul H. Deep fat frying of foods: A critical review on process and product parameters. Critical Reviews in Food Science and Nutrition. 2019; 60:3400–3413.
25. Kumar AJ, Singh RRB, Patel AA, Patil GR. Kinetics of colour and texture changes in Gulabjamun balls during deep-fat frying, LWT - Food Science and Technology. 2006; 39:827–833.
26. Shinde S, Halder K, Kumar N, Meena GS, Pathera AK. Physico-chemical characterization and fuzzy logic modeling of sensory evaluation for market Ghewar, International Journal of Chemical Studies, 2017; 5:1809-1816.
27. Londhe GK, Joglekar NV, Patil GR, Awaz HB, Bhosale AM. Effect of different binders on the sensory attributes of gulabjamun. Indian Journal of Dairy and Biosciences. 2000; 11: 71-74.
28. Ghosh BC, Rao J, Balasubramanyam KBV & Kulkarni S. Process standardization and shelf life evaluation of chhana podo. Indian Journal of Dairy Science. 2007; 60: 322-326.

29. Pandya AJ, Khan MMH. Buffalo milk utilization for dairy products. In Park, Y. W. and Haenlein, G. F. W. (Eds). Handbook of milk of non-bovine mammals, p. 215-256. Oxford: Blackwell Publishing, 2006.
30. Choe E, Min DB. Chemistry of deep-fat frying oils. Journal of Food Science. 2007; 72: 77-86.
31. Geetha P, Arivazhagan R, Periyar SS, Ida IM. Process standardization, characterization and shelf life studies of chhana jalebi-a traditional Indian milk sweet. International Food Research Journal. 2015; 22: 155-162.
32. Tiwari U, Gunasekaran M, Jaganmohan R, Alagusundaram K, Tiwari BK. Quality characteristic and shelf life studies of deep-fried snack prepared from rice brokens and legumes by-product, Food and Bioprocess Technology. 2009; 4: 1172–1178.