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# Optimizing Process Conditions for Ghewar Development Using Response Surface Methodology

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author AD and MKJ designed the study, analysed the data statistically, wrote the protocol, wrote the first draft of the manuscript. Authors HB, RH and KV performed analyses of the study. Authors MKJ and RV managed the literature searches, and manuscript checking. All authors read and approved the final manuscript.*

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## ABSTRACT

RSM was performed for the optimization of processing conditions to develop ghewar, traditional sweetmeat of India. Three variables i.e. frying temperature (160-180 ºC), batter temperature (5-10 ºC) and frying 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 ºC frying temperature, 5ºC batter temperature and 4 minute frying time. Upon optimization, the

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ghewar yielded the following results: 45.33% oil content, 4.65% moisture, 15.2 N texture (hardness), 54.89 L value, 15.16 a value, 24.97 b value, 58.73 hue value, 29.21 chroma value, 48.07 total color difference, and 0.24 water activity. Storage study of optimized ghewar was also carried out and found shelf stable for 30 days in metallised foil pouches. Hardness values were found to progressively drop from 15.2-9.40 N during the storage period, whereas moisture content, FFA, and peroxide value were found to gradually increase from 3.70-5.12%, 0.33-0.54 %, and 4.8-7.6 meq/kg, respectively.

*Keywords: Ghewar; traditional sweet; optimization; RSM; shelf life; texture.*

## 1. INTRODUCTION

India produces a wide variety of traditional sweets. They are categorized according to various constituents, such as dairy, grains, 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 have ghee or clarified butter, which makes them considerably heavier and more intense and sweeter than western sweets and desserts. The development of various Indian traditional sweets, such as Pinni [1], Jalebi [2], Khoa jalebi [3], Chiroti [4], Inderse [5], Dodaburfi [6], Ghewar [7], and Coconut Barfi [8], has been the focus of numerous researches. However, in order to popularize Indian traditional sweets both domestically and internationally, it is crucial to standardize the process conditions. Increasing the shelf life of a high-quality, traditional sweet is another formidable task. Standardizing the manufacturing process for traditional Indian sweets could potentially solve the issue of obtaining safe, high-quality sweets with longer shelf life.

Ghewar is famous in northern region of India. This classic Indian dessert has a spherical shape and is made from refined wheat flour, ghee, and sugar solution. Its texture is crunchy and its design is honeycomb porous. Ghewar is prepared by deep frying in oil. The crispy texture and mouthwatering flavour of deep-fried ghewar are a result of the physical and chemical changes that occur during the fat-food interaction at higher temperatures in the frying oil [9]. Deep frying 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. Processing parameters are scientifically optimized and new product can be developed using response surface approach [11, 12]. Statistical parameters are analysed and significance of model can also be checked using the RSM approach.

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 sector may boost the Indian economy many folds.

## 2. MATERIALS AND METHODOLOGY

### 2.1 Preparation of Indian Traditional Sweet (Ghewar)

In this method, ice cubes and 35g of clarified butter were creamed together. When the ice cubes started to resemble cream, they were removed. Subsequently, 100 grams of refined wheat flour is added gradually to continue the creaming process. A tiny amount of milk (20 ml) is added and well blended when sufficient aeration has been reached. Next, 200 ml of water is added to the mixture to create a thin-consistency batter. Then, melted ghee, or clarified butter, is added to an open iron pan containing a ghewar mold. In a fryer, the clarified butter is heated to the ideal temperature and time. After that, a single spoonful of batter is streamed into the mold and deep-fried. When froth subsides, pour another spoonful of batter into the center in a narrow stream. The process was done six or seven times, each time pouring batter into the center after poking a hole with a wooden skewer stick. The frying time and temperature were maintained according to optimized conditions by RSM. The ghewar was carefully removed from the fat once the center became solid and cooked. The ghewar samples were then allowed to cool at ambient temperature before being covered with sugar syrup and left to cool once more.

### 2.2 Experimental Design for Optimization of Ghewar

A central composite rotatable design (CCRD) was employed. The frying temperature (160–180°C), batter temperature (5–10°C), and frying time (4-6 minutes) were the independent variables taken into account for the optimization of the ghewar making process.

### 2.3 Estimation of Fat and Moisture Content

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

### 2.4 Texture Analysis

The hardness of the ghewar sample was examined using a texture analyzer (Stable Micro System), in accordance with Bourne's method [15]. Stainless steel knife blade with slotted insert probe (HDP/BS) was used for all of the experimentation. HDP/90 platform was used to place the ghewar samples. A 5 kg load cell was used to measure the force for texture analysis.

### 2.5 Colour Analysis

The color values of the ghewar samples were measured using a Chroma Meter CR-400 with an 8mm aperture size (Konica Minolta, Japan) to calculate the L, a, and b values. Calculations for hue angle, chroma, and total color difference were also made [16].

## 3. RESULTS AND DISCUSSION

### 3.1 Response Surface Modeling and 3-D Graphs for Oil Content of Ghewar

The oil percentage of the ghewar samples ranged from 44.42% to 60.42% (Table 1). The ghewar that was developed with a frying temperature of 180 $^0$C, a batter temperature of 10 $^0$C, and a frying time of 6 minutes produced a maximum oil value. The minimum oil value was obtained for experiment having 160 $^0$C of frying temperature, 10 $^0$C of batter temperature and 4 minute of frying time.

**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 |

**Table 2. ANOVA for different responses (quadratic model) for ghewar**

| | Coefficient Estimate | | | | F Value | | | | Prob>F | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oil Uptake | Moisture Content | Overall Acceptability | Hardness (Texture) | Oil Uptake | Moisture Content | Overall Acceptability | Hardness (Texture) | Oil Uptake | Moisture Content | Overall Acceptability | Hardness (Texture) |
| **Model** | 54.81 | 2.62 | 7.24 | 14.25 | 9.30 | 4.15 | 4.72 | 4.78 | 0.0009 | 0.0183 | 0.0118 | 0.0112 |
| $\alpha_1$ | 3.05 | -0.50 | -0.57 | -1.94 | 26.55 | 16.89 | 3.25 | 6.54 | 0.0004 | 0.0021 | 0.1015 | 0.0285 |
| $\alpha_2$ | -0.038 | -0.066 | 0.039 | 2.27 | 4.098E-003 | 0.29 | 0.015 | 3.44 | 0.9502 | 0.5992 | 0.9055 | 0.0932 |
| $\alpha_3$ | 4.22 | 0.42 | -1.64 | 2.53 | 50.86 | 12.27 | 26.54 | 1.50 | <0.0001 | 0.0057 | 0.0004 | 0.02495 |
| $\alpha_1\alpha_2$ | 0.43 | -6.250E-003 | 0.016 | -0.39 | 0.31 | 1.557E-003 | 1.522E-003 | 1.97 | 0.5921 | 0.9693 | 0.9697 | 0.1909 |
| $\alpha_1\alpha_3$ | 0.68 | -3.750E-003 | -0.33 | 0.81 | 0.77 | 5.604E-004 | 0.64 | 3.46 | 0.4010 | 0.9816 | 0.4417 | 0.0925 |
| $\alpha_2\alpha_3$ | 0.010 | 0.094 | -0.066 | 0.31 | 1.676E-004 | 0.35 | 0.025 | 21.77 | 0.9899 | 0.5671 | 0.8768 | 0.0009 |
| $\alpha_1^2$ | -0.78 | 0.25 | -0.62 | 2.60 | 1.84 | 4.36 | 3.97 | 3.79 | 0.2048 | 0.0635 | 0.0742 | 0.0800 |
| $\alpha_2^2$ | -0.14 | 0.17 | -0.71 | -1.23 | 0.058 | 2.13 | 5.19 | 0.53 | 0.8142 | 0.1756 | 0.0459 | 0.4815 |
| $\alpha_3^2$ | -1.13 | 0.19 | -0.71 | 0.29 | 3.88 | 2.49 | 5.19 | 0.093 | 0.0771 | 0.1457 | 0.0459 | 0.7666 |

Table 2 displays the many statistical features associated with oil values. The model for oil content of ghewar shows the significant F-value (9.30). A non-significant Lack of Fit F-value (3.69) was also obtained for same model (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. (1) represents the effect of independent variables on the oil content of ghewar:

$$\text{Oil content} = 54.81 + 3.05\alpha_1 - 0.038\alpha_2 + 4.22\alpha_3 + 0.43\alpha_1\alpha_2 + 0.68\,\alpha_1\alpha_3 + 0.010\alpha_2\alpha_3 - 0.78\alpha_1^2 - 0.14\alpha_2^2 - 1.13\alpha_3^2 \quad (1)$$

## 3.2 Influence of Independent Variables on Oil Content of Developed Ghewar

The influence of frying temperature, batter temperature and frying 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 (1), that oil content of ghewar had significant positive linear effect of frying temperature ($\alpha_1$) and frying time ($\alpha_3$). The quadratic and interaction terms were observed non-significant. Fig. 1 shows the significant effect on the oil absorption of ghewar. Raising the frying temperature and length of time was found to increase oil absorption. Similar observations have been reported by various researchers [17, 18].

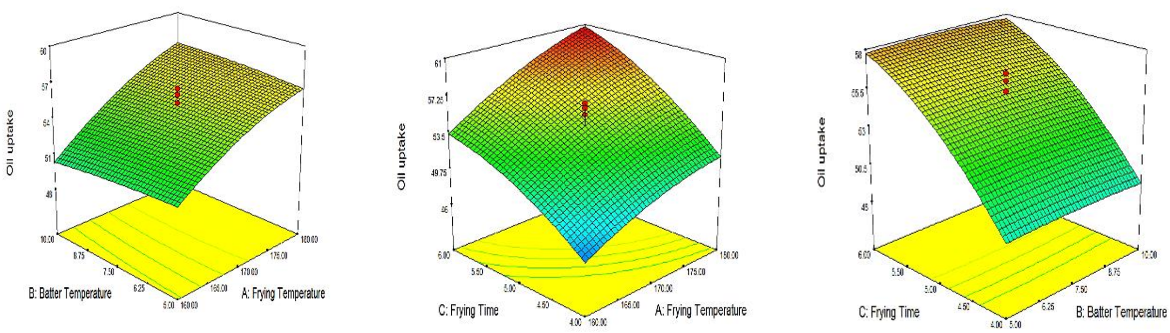


**Fig. 1. 3-D surface graph showing the effect of process variables on oil uptake of ghewar**

**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 Content** | 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**

| Parameters | Responses | | | |
|---|---|---|---|---|
| | Oil Uptake | Moisture Content | 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

The moisture content of ghewar developed under various experimental conditions ranged from 2.02 to 4.65 (Table 1). The Ghewar that was developed with a frying temperature of 160 $^0$C, a batter temperature of 5 $^0$C, and a frying time of 4 minutes produced a highest score of moisture content (4.65 %). The lowest value of moisture content (2.02 %) was obtained for ghewar sample prepared using 186 $^0$C of frying temperature, 7.50 $^0$C batter temperature and 5 minute of frying time.

Table 2 displays the various statistical attributes of moisture content. The model for moisture content of ghewar shows the significant F value (4.15). A non-significant Lack of Fit F-value (4.56) was also obtained for same model (Table 3). The value of $R^2$ (0.7888) and adjusted $R^2$ (0.5988) indicate the model accuracy. The adequate precision value (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. (2) represents the effect of independent variables on the moisture content of ghewar:

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

### 3.4 Influence of Independent Variables on the Moisture Content of Developed Ghewar

The interaction effect of frying temperature, batter temperature and frying 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 (2), moisture content of fried Ghewar had significant positive linear effect of frying temperature ($\alpha_1$) and frying time ($\alpha_3$) at 95 % confidence level. The quadratic and interaction terms were observed non-significant. Fig. 2 depicts the significant effect on the moisture values of ghewar. It has been noted that moisture values dramatically decrease as temperature and time increase. Quite Similar results were also recorded by various researchers [19, 20]. Because water vaporizes quickly after it reaches its boiling point, the moisture content decreases as the frying temperature and time increase [21].

### 3.5 Response Surface Modeling and Surface Plots for Overall Acceptability

Overall acceptability is measured using our sense organs [22,23]. The ghewar's overall acceptability ranged from 2 to 8.2 across the several trial runs (Table 1). The ghewar developed using frying temperature of 160 $^0$C, a batter temperature of 10 $^0$C, and a frying time of 4 minutes received the highest possible grade for overall acceptability (8.2). Two experimental runs, with 180 $^0$C of frying temperature, 5 $^0$C of batter temperature, and 6 minutes of frying time, and 180 $^0$C of frying temperature, 10 $^0$C of batter temperature, and 6 minutes of frying time, yielded the lowest minimum score.

The different statistical characteristics of overall acceptability are shown in Table 2. The model for overall acceptability of ghewar shows the significant F value (4.72). A non-significant Lack of Fit F-value (4.55) was also obtained for same model (Table 3). 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:

$$\text{Overall Acceptability} = 7.24 - 0.57\alpha_1 + 0.039\alpha_2 - 1.64\alpha_3 + 0.016\,\alpha_1\alpha_2 - 0.33\alpha_1\alpha_3 - 0.066\,\alpha_2\alpha_3 - 0.62\alpha_1^2 - 0.71\alpha_2^2 - 0.71\alpha_3^2 \quad (3)$$

### 3.6 Influence of Independent Variables on the Overall Acceptability of Developed Ghewar

The interaction effect of frying temperature, batter temperature and frying 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 (3), overall acceptability of fried ghewar had significant negative linear effect of frying time ($\alpha_3$) at 95 % confidence level. The interaction term were observed non-significant. The batter temperature ($\alpha_2^2$) and frying time ($\alpha_3^2$) having significant negative quadratic effect.

Fig. 3 shows that when the frying temperature rises, overall acceptability first rises and subsequently falls. Reason may be the development of crispiness when temperature increases. Further increase of frying temperature, develop intermediate chemicals as a result of browning reaction. Fig. 3 showed that overall acceptance decreased as frying time increased. The reason might be excess frying that produces off flavour, taste and colour.

### 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 temperature, 7.5 $^0$C batter temperature and 5 minute of frying time got the highest score of hardness (24.96 N). The lowest score of 6.5 was observed for 170$^0$C of frying temperature, 3.3$^0$C batter temperature and 5 minute of frying time.

The different statistical characteristics of hardness are shown in Table 2. The model for hardness of ghewar shows the significant F-value (11.03). A non-significant Lack of Fit F-value (1.61) was also obtained for same model (Table 3). 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. (4) represents the effect of independent variables on the textural attribute (hardness) of ghewar:

$$\text{Hardness} = 14.25 - 1.94\alpha_1 + 2.27\alpha_2 + 2.53\alpha_3 - 0.39\alpha_1\alpha_2 + 0.81\alpha_1\alpha_3 + 0.31\alpha_2\alpha_3 + 2.60\alpha_1^2 - 1.23\alpha_2^2 + 0.29\alpha_3^2 \quad (4)$$

### 3.8 Influence of Independent Variables on the Textural Attribute (Hardness) of Developed Ghewar

The interaction effect of frying temperature, batter temperature and frying 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 temperature have significant impact on hardness of ghewar sample. Significant effect on hardness of gulabjamun were also observed during frying [25]. As frying temperature is raised and batter temperature is lowered, the hardness value drops, as seen in Fig. 4. 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 Min also supported the similar results in his study [30].

### 3.9 Optimization of Process Parameters and Result Verification

The development of ghewar was based on the minimum oil uptake, minimum batter temperature (°C), in range frying temperature (°C), in range frying time (minute), and in range overall acceptance. Based on these factors, the ideal process parameters for the creation of ghewar were determined to be 160 °C for the frying temperature, 5 °C for the batter temperature, and 4 minutes for the frying time. The result of responses were 46.64% of oil uptake, 4.30% of moisture, 7.0 of overall acceptability and 13.48 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 process parameters of the optimized ghewar, which are shown in table 5, were nearly identical between the experimental and predicted values.

### 3.10 Colour Characteristics and Water Activity of Optimized Ghewar Sample

Table 4 displays the color values and water activity results of the optimized ghewar samples. The optimized Ghewar sample yielded L, a, and b values of 54.89, 15.16, and 24.97, respectively (Table 6). The L, a, and b values were found to be substantially closer to the ghewar market sample [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).

**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)*

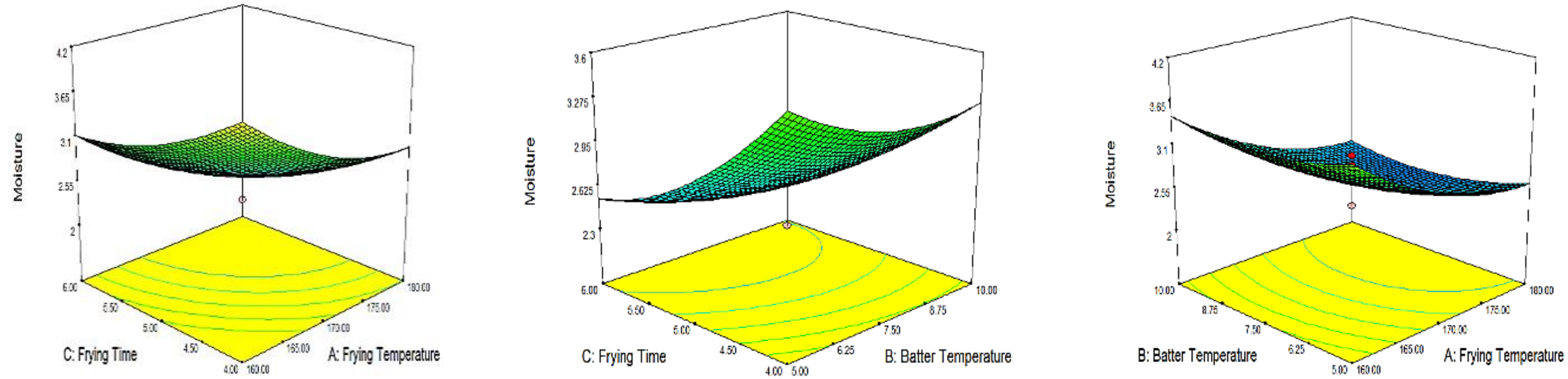


**Fig. 2. 3-D surface graph showing the effect of process variables on moisture content of Ghewar**

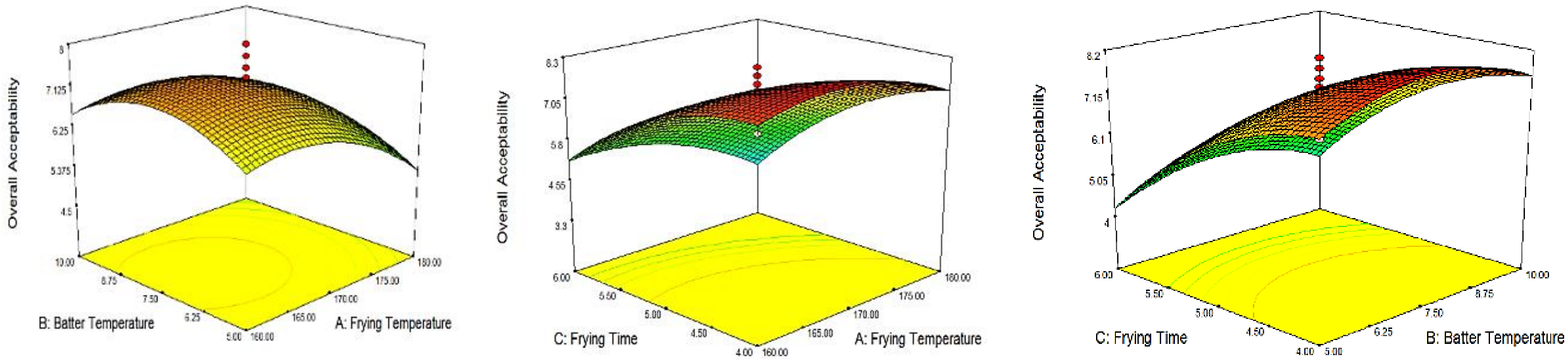


**Fig. 3. 3-D surface graph showing the effect of process variables on overall acceptability of Ghewar**

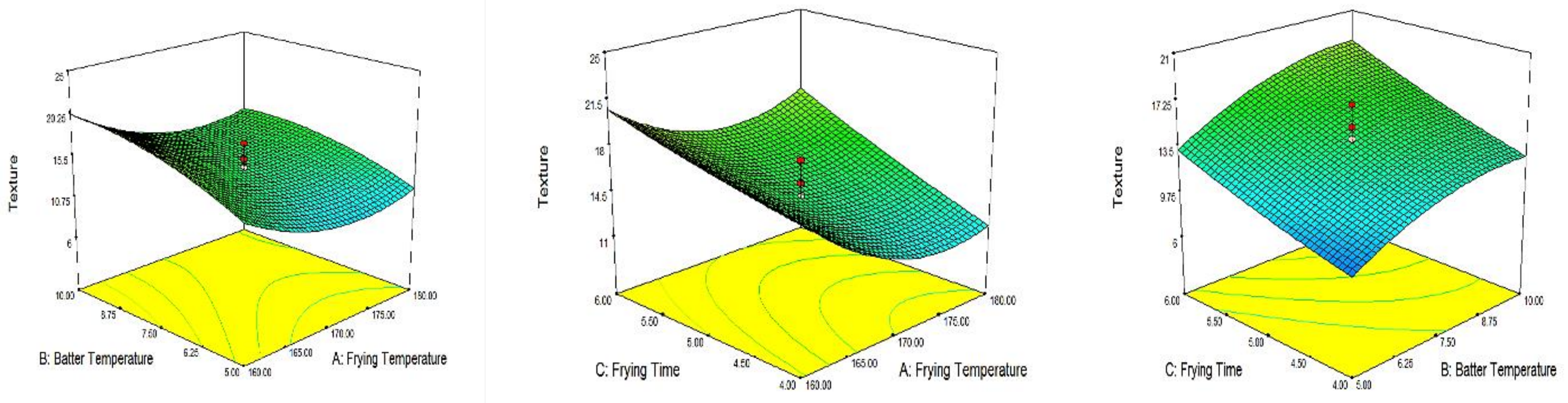


**Fig. 4. 3-D surface graph showing the effect of process variables on hardness (texture) of Ghewar**

**Table 6. Instrumental colour values and water activity of ghewar**

| **Optimized ghewar Sample** | **Colour Attributes** | | | | | | **Water activity** |
|---|---|---|---|---|---|---|---|
| | 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)*

**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 |
| **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 |

Water activity is an important parameter to ensure shelf life of developed ghewar. The ghewar sample's water activity was found to be 0.24, which was significantly lower than that of the ghewar market samples. [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.

### 3.11 Storage 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 and monitored after every10 days.

The optimized ghewar's moisture content rose marginally throughout the course of the 30-day storage period, from 3.70% to 5.12%. (Table 7). The metalized polyester bag and aluminum foil reduced moisture absorption over the course of the storage period. This might be due to their superior water vapour barrier qualities. Various researchers identified the similar outcome during storage studies of Indian traditional sweets [31,7].

Fried oil's FFA readings were steadily rising from 0.33 to 0.54% (Table 7). The ghewar sample is safe to consume for up to one month because its FFA concentration is kept at less than 1% throughout storage. Tiwari et al. also reported the increased FFA content during storage of legume and cereal by-product based snacks [32].

Peroxide value is used to quantify lipid oxidation. It was noted that the peroxide value increased steadily from 4.8 to 7.6 meq/kg during the storage period (Table 7). Peroxide values of 7.6 meq/kg are regarded as safe for human consumption. Tiwari *et al.* reported the similar trend of increasing the peroxide value during storage of snack [32].

It was noted that over the storage time, the hardness value decreased from 15.2 N to 9.40 N. The reason could be the moisture content rising throughout the storage time. Hardness value decreased significantly at 5 % level of significance (Table 7).

## 4. CONCLUSION

It is imperative to standardize the age-old traditional method of creating Indian sweets in order to incorporate new food items into the organized food 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 temperature, frying time and batter temperature. Taking all these point into consideration, RSM was adopted for the optimization of processing conditions. The optimized ghewar (160 ºC of frying temperature, 5 ºC of batter temperature and 4 minute of frying time) resulted 45.33% of oil content, 4.65% moisture and 15.2 N of hardness and acceptable sensory score. The developed ghewar had good structure, soft body, pleasant taste, less oil content and reduced water activity. The developed optimized ghewar can be stored for 30 days period in metallized foil pouches.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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