Journal of Scientific Research and Reports

Volume 30, Issue 7, Page 496-506, 2024; Article no.JSRR.119287
ISSN: 2320-0227

Development of Low Fat Gujarati Traditional Snack "Ganthiya" Using Hydrophilic Polymers and Modified Natural Polysaccharides

Ashish Dixit [a++*], Manoj Kumar Jaipal [a++] and Nirav Tejani [a#]

[a] *Department of Food Processing Technology, College of Food Technology, SDAU, Sardarkrushinagar, Banaskantha, Gujarat, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jsrr/2024/v30i72165

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here:
https://www.sdiarticle5.com/review-history/119287

Original Research Article

Received: 20/04/2024
Accepted: 25/06/2024
Published: 27/06/2024

ABSTRACT

In order to create the Gujarati traditional snack Ganthiya with less oil, the production parameters were optimized and hydrophilic polymers and modified natural polysaccharides were used. For the goal of optimization, design expert software was utilized. Two processing variables, frying temperature and frying duration, were used to create ganthiya. Frying time ranged from 90 to 150 seconds and the lowest and maximum frying temperatures were 140 to 180 °C. All the trial were conducted in the campus of Food Technology College, SDAU, Sardarkrushinagar, Gujarat during

[++] *Assistant Professor;*
[#] *Junior Research Fellow;*
**Corresponding author: E-mail: anshul_2809@yahoo.com;*

Cite as: *Dixit, Ashish, Manoj Kumar Jaipal, and Nirav Tejani. 2024. "Development of Low Fat Gujarati Traditional Snack 'Ganthiya' Using Hydrophilic Polymers and Modified Natural Polysaccharides". Journal of Scientific Research and Reports 30 (7):496-506. https://doi.org/10.9734/jsrr/2024/v30i72165.*

2020-2021. There were total four responses (moisture content, oil content, oil uptake ratio and overall acceptability). Ganthiya were developed using optimized conditions (180 ^{0}C of frying temperature and 90 seconds of frying time) and effect of carboxymethyl cellulose, methylcellulose, guar gum and gum tragacanth were observed in respect of oil uptake reduction in Ganthiya. A significant decrease in oil absorption was noted in 0.5% methyl cellulose, which was subsequently followed by 0.5% guar gum, 1% carboxymethyl cellulose, 0.5% gum tragacanth, and 0.75 % carboxymethyl cellulose added Ganthiya.

Keywords: Ganthiya; optimization; frying; traditional snack; polysaccharides, polymers.

1. INTRODUCTION

The Gujarati snack market is evidence of the people's love of fried snacks. Gujarati snack market account for approximately 20% of all of India's snack markets. It is anticipated that the snack market would grow at a rate of 2.8% worldwide until 2030 [1].

Frying is the most traditional method of creating crispy food, requiring the creation of a crust on the meal's surface [2]. Deep fat frying involves the transfer of mass and heat. Convection and conduction modes in food and oil facilitate heat transfer, whereas moisture evaporation in fried food products forms holes and facilitates mass transfer [3-6].

Hydrophilic polymers are hydrocolloids that originate from microbial, animal, or vegetable sources and include hydroxyl groups. Hydrogels are the examples of hydrophilic polymers. Due to dual characteristics as polymers and electrolytes (salts), hydrophilic polymers are occasionally referred to as polyelectrolytes [7]. Many hydrophilic polymers are being used as fat replacer [8].

Modification in natural polysaccharides improve the hydrolysis mainly in cellulose and derivatives [9]. These modified natural polysaccharides are used to reduce oil uptake in deep-fat fried food products [10].

It is necessary to reduce the fat level of fried food due to people's growing awareness of healthier diet options. As a result, there is now a greater need of these edible polymers (hydrophilic polymers and modified natural polysaccharides) to enhance quality characteristics and increase shelf life [11].

The RSM is a crucial tool for formulating novel products, designing experiments and optimizing automated settings. It is used to statistically analyze the data and cut down on the numerous experiments to the minimum number that is practically feasible [12,13].

Gujarat is known for its traditional fried snacks, which include khakhra, chevra, dhokhla, khandavi, fafda, patra, thepla, muthia, gujarati chakri, gathiya, and so on. Since most of them include a significant amount of oil, the study was carried out to create low-fat gathiya without compromising its original sensory qualities.

2. MATERIALS AND METHODOLOGY

2.1 Determination of Moisture content

Moisture content of ganthiya samples was calculated using following formula [14];

$$MC\ (\%\ wb) = (W_1 - W_2) / W_1 \times 100 \quad (1)$$

Where,

W_1= Initial weight of the sample before drying (g)

W_2= Final weight of sample after drying (g)

2.2 Determination of Oil Content

Oil content of control and fried Ganthiya s amples was determined by soxhlet method using soxplus instrument. Percentage oil content was calculated using following formula [15];

$$\%\ \text{Oil content} = (\text{wt. of extract}) / (\text{wt. of sample}) \times 100 \quad (2)$$

2.3 Determination of Oil Uptake Ratio

Oil uptake ratio was determined using following formula:

$$\text{Oil uptake ratio} = (\text{Oil content of product}) / (\text{Moisture content of dough} - \text{Moisture content of product}) \times 100 \quad (3)$$

Table 1. Coded and non-coded values of variables and their levels for Ganthiya

Independent Variables	Non- coded Value	Coded variable				
		-2	-1	0	+1	+2
Frying oil temperature (^{0}C)	A	131.72	140	160	180	188.28
Frying oil time (Sec.)	B	77.57	90	120	150	162.43

2.4 Determination of Oil Uptake Reduction in Snack

Following formula was used to compute the reduction in oil uptake [16].

Oil uptake reduction (%) = (Oil, control sample – Oil, experimental sample) / (Oil, control sample)× 100

2.5 Optimization of Frying Parameters

Using response surface methodology, the frying process parameters (frying oil temperature and frying time) have been adjusted for Ganthiya, a typical traditional Gujarati snack.

2.6 Experimental Design

The program Design Expert was used to create the experiments. The experimental results were statistically analyzed using the same program. A central composite rotatable experimental design (CCRD) with three variables (five levels for each variable) was used. Table 1 presents the outline of Ganthiya's experimental design with coded and non-coded variable levels.

3. RESULTS AND DISCUSSION

3.1 Design of Experiments for Ganthiya and its Corresponding Results

Thirteen different experiment combinations were developed by using a central composite rotatable design (CCRD) using two factors: frying temperature and frying time. To improve the process parameters for the creation of snack (Ganthiya), the outcomes of these combinations of tests were used. Table 2 displays the general layout of the experimental design and the associated data.

3.2 The Fitted Model and Surface Plots for Different Responses

3.2.1 Process variables' effects on moisture content

An essential component of deep-fried snack is moisture. The deep-fried snack known as Ganthiya had measured moisture ranging from 2.85 to 9.0 (Table 2). Tables 3 and 7 present the moisture's statistical characteristics. A regression model fitted to the moisture experimental results indicates that the model is significant, as indicated by the model's F-value of 9.71. Noise has a mere 0.47% probability of producing a "Model F-Value" of this magnitude. The "Lack of Fit F-value" of 0.50 indicates that, with respect to the pure error, the Lack of Fit is not significant. A "Lack of Fit F-value" this large could be the result of noise with a 70.31% possibility. The model's fit was further demonstrated by the coefficient of determination R^2 (0.874), which suggests that the model could account for 87.40% of the response's variability. There is a fair amount of agreement between the "Pred R-Squared" of 0.613 and the "Adj R-Squared" of 0.784 (Table 7). This approach can be utilized to navigate the design space because a ratio larger than 4 is desirable. After taking into account all of the aforementioned factors, the model (Eq. 1) was chosen to depict the variance in moisture. In terms of the coded levels of the variables, the quadratic model derived via regression analysis for moisture analysis looked like this:

$$\text{Moisture} = 6.29 - 1.28\,A - 1.53\,B - 0.27A^2 - 9\times10^{-3}\,B^2 + 5\times10^{-3}\,AB \quad (1)$$

Where,

A= Frying oil temperature (^{0}C)
B= Frying time (seconds)

The frying oil temperature (A) and frying time (B) exhibited a highly significant negative linear effect on the moisture content of fried Ganthiya, according to equation (1), with a 95% confidence level. It was discovered that the quadratic terms for frying oil temperature (A^2) and frying duration (B^2) were not significant. Interaction term was not significant.

The Fig. 1 illustrates how oil temperature and frying time affect moisture. It has been noted that moisture values significantly decrease as temperature and time increase. Similar outcomes were also noted by various researchers [17,18].

Table 2. Experimental central composite design and result of responses for Ganthiya

Run	Variables		Responses			
	Frying Temperature (°C)	Frying Time (Sec.)	Moisture Content (%, W_b)	Oil Content (%)	Oil Uptake Ratio	Sensory Attributes (OAA)
1	140	90	9	33.38	1.78	6.5
2	180	90	6.65	29.71	1.41	7.7
3	140	150	5.18	32.56	1.32	7.5
4	180	150	2.85	28.19	1.13	6.5
5	131.7157	120	7.8	36.6	1.84	5.5
6	188.2843	120	3.88	28.29	1.19	6.3
7	160	77.57359	8	31.67	1.61	7.2
8	160	162.4264	4.72	34.48	1.5	7.9
9	160	120	6.3	32.32	1.51	7.15
10	160	120	6.66	33.39	1.59	7.7
11	160	120	7.1	34.5	1.67	7.2
12	160	120	6.66	32.32	1.59	7.3
13	160	120	4.72	33.39	1.5	7.4

Table 3. ANOVA for moisture content of Ganthiya obtained from RSM approach of design expert software

Source	Sum of Squares	DF	Mean Square	F -Value	Prob> F	
Model	32.36	5	6.47	9.71	0.0047	significant
A-Temperature	13.07	1	13.07	19.61	0.0031	
B-Time	18.78	1	18.78	28.19	0.0011	
A^2	1.0×10^{-4}	1	1.0×10^{-4}	1.501×10^{-4}	0.9906	
B^2	0.50	1	0.50	0.76	0.4135	
AB	5.635×10^{-4}	1	5.635×10^{-4}	8.457×10^{-4}	0.9776	
Residual	4.66	7	0.67			
Lack of Fit	1.27	3	0.42	0.50	0.7031	not significant

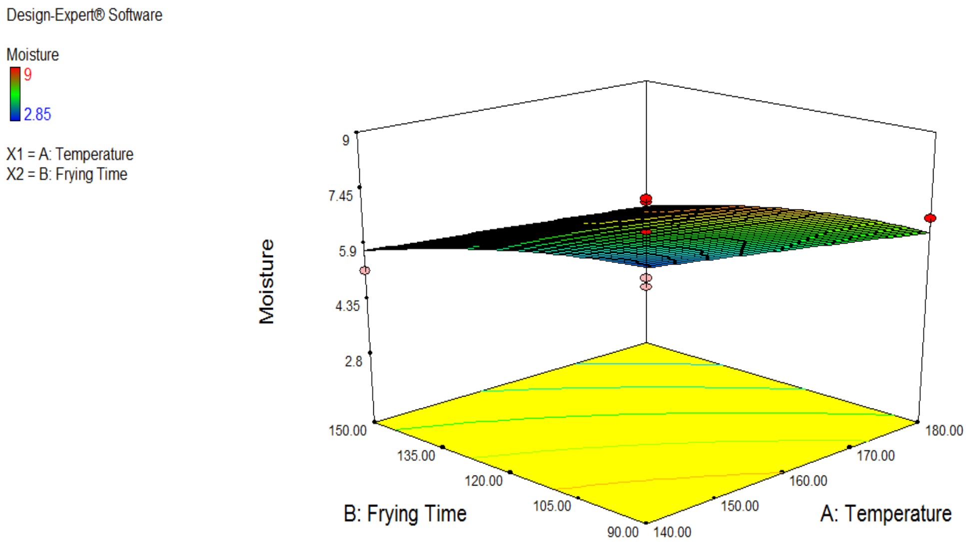

Fig. 1. Response surface plot illustrating how the temperature of the oil and the frying time affect moisture

3.2.2 Process variables' effects on oil content

A crucial consideration for deep-fried foods is their oil content. Table 2 shows that the oil content of the deep-fried snack, Ganthiya, ranged from 28.19 to 34.50%. The oil content statistics parameters are displayed in Table 7. The oil content experimental results were fitted with a regression model, and the model's F-value of 4.69 indicates significance. A significant "Model F-Value" has a 3.37% probability of occurring owing to noise. With respect to the pure error, the "Lack of Fit F-value" of 5.31 indicates that the Lack of Fit is not significant. A "Lack of Fit F-value" this large could be the result of noise with a 7.02% possibility. Non-significant lack of fit is good.

The coefficient of determination (R^2) i.e. 0.77, was also used to express the fit of the model. This means that 77% of the response's variability could be explained by the model. When the "Pred R-Squared" is negative, it means that the current model is not as good at predicting our reaction as the overall mean.

Table 7 shows that the signal was deemed satisfactory with a precision of 6.710. A ratio that is higher than 4 is preferred. This model can be utilized to navigate the design space because the ratio here shows a sufficient signal. The model (Eq. 2) was chosen to reflect the variance in oil content after taking into account all of the previously mentioned factors. The following quadratic model, which represented the coded levels of the variables, was derived via regression analysis for the oil uptake analysis:

$$\text{Oil Content} = 33.18 - 2.47A + 0.20B - 0.82A^2 - 0.50B^2 - 0.17AB \quad (2)$$

Where,

A= Frying oil temperature (^{0}C)
B= Frying time (seconds)

Equation (2) yields the following conclusions: at a 95% confidence level, the oil content of fried Ganthiya exhibited a significant negative linear effect of the frying oil temperature (A). The results showed that the quadratic terms for frying time (B^2) and frying oil temperature (A^2) were not significant. It was also discovered that the interaction term was not significant.

The Fig. 2 illustrates how oil uptake is affected by frying time and oil temperature. Increased oil absorption was seen with lowest frying oil temperature. Many researchers have observed similar findings [19,20].

3.2.3 Process variables' effects on oil uptake ratio

The deep-fried Ganthiya's oil uptake ratio ranged from 1.13 to 1.84, as indicated by Table 2. The statistical features of the oil uptake ratio are displayed in Tables 7. The regression model's F-value of 5.30 indicates significance when it comes to the oil uptake ratio experimental data (Table 5). A "Model F-Value" of this magnitude has a 2.48% probability of occurring as a result of noise. In comparison to the pure error, the "Lack of Fit F-value" of 6.23 indicates that the Lack of Fit is not significant. A "Lack of Fit F-value" of this magnitude has a 5.47% probability of being the result of noise. Non-significant lack of fit is desirable.

The model's fit was further demonstrated by the coefficient of determination R^2 (0.7910), which suggests that the model could account for 79.10% of the response's variability. If the "Pred R-Squared" value is negative, it suggests that the overall mean predicts our reaction more accurately than the existing model. A sufficient signal was indicated by the adequate precision of 7.341 (Table 7). A ratio that is higher than 4 is preferred. In this case, the ratio of 7.341 denotes a sufficient signal, hence navigating the design space using this model is possible. The model (Eq. 3) was chosen to reflect the change in the oil.

$$\text{Oil uptake ratio} = 1.57 - 0.18A - 0.11B - 0.060A^2 - 0.040B^2 + 0.045AB \quad (3)$$

Where,

A= Frying oil temperature (^{0}C)
B= Frying time (seconds)

The oil uptake ratio of fried Ganthiya had a significant negative linear effect of frying oil temperature (A) and a significant negative linear effect of frying time (B), according to equation (3). The results showed that the quadratic terms for frying time (B^2) and frying oil temperature (A^2) were not significant. It was also discovered that the interaction term was not significant.

Fig. 2 illustrates how oil uptake is affected by frying time and oil temperature. With an increase in frying temperature, the oil uptake ratio first increased and subsequently decreased. Numerous investigators have noted comparable results [21,22].

Table 4. ANOVA for oil content of *Ganthiya* obtained from RSM approach of design expert software

Source	Sum of Squares	DF	Mean Square	F- Value	Prob> F	
Model	55.21	5	11.04	4.69	0.0337	significant
A-Temperature	48.97	1	48.97	20.78	0.0026	
B-Time	0.33	1	0.33	0.14	0.7178	
A^2	0.12	1	0.12	0.052	0.8262	
B^2	4.67	1	4.67	1.98	0.2019	
AB	1.77	1	1.77	0.75	0.4148	
Residual	16.50	7	2.36			
Lack of Fit	13.19	3	4.40	5.31	0.0702	not significant

Table 5. ANOVA for oil uptake ratio of Ganthiya obtained from RSM approach

Source	Sum of Squares	DF	Mean Square	F- Value	Prob> F	
Model	0.41	5	0.083	5.30	0.0248	significant
A	0.27	1	0.273	17.51	0.0041	
B	0.10	1	0.100	6.42	0.0390	
A^2	8.1×10^{-3}	1	8.1×10^{-3}	0.52	0.4948	
B^2	0.025	1	0.025	1.59	0.2478	
AB	0.011	1	0.011	0.70	0.4293	
Residual	0.11	7	0.016			
Lack of Fit	0.090	3	0.030	6.23	0.0547	not significant

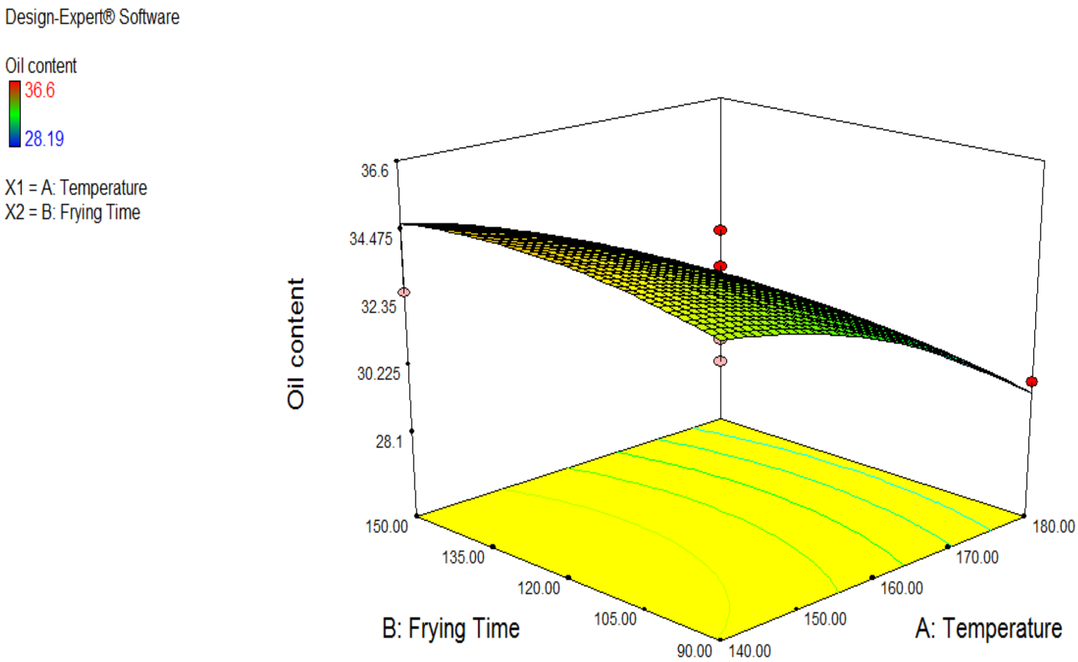

Fig. 2. Response surface plot illustrating the impact of oil temperature and frying duration on oil absorption

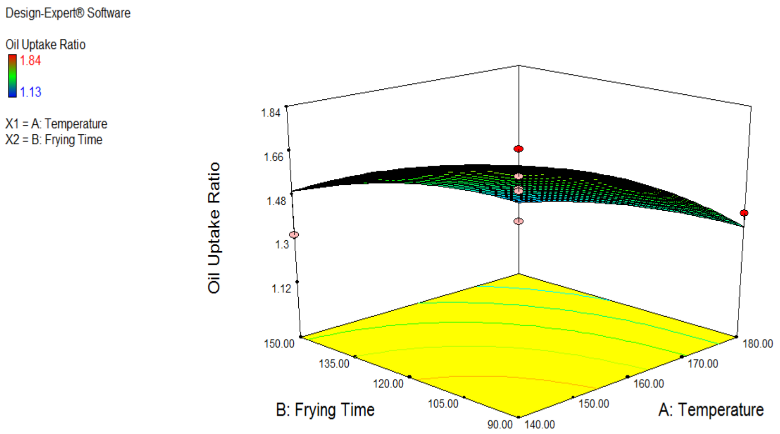

Fig. 3. Response surface plot illustrating how oil temperature and frying time affect the oil uptake ratio

3.2.4 Process variables' effects on overall acceptability

The deep-fried Ganthiya's assessed overall acceptability ranged from 5.5 to 7.9 (Table 2). The other statistical characteristics of overall acceptability are displayed in Table 7. The overall acceptability of the regression model fitted to the experimental results (Table 6) demonstrates that the model's F-value of 9.97 is significant. Noise has a mere 0.44% possibility of producing a "Model F-Value" of this magnitude. With respect to the pure error, the "Lack of Fit F-value" of 3.49 indicates that the Lack of Fit is not significant. A "Lack of Fit F-value" this significant could be the result of noise with a 12.95% possibility.

The model's fit was further demonstrated by the coefficient of determination R^2 (0.8769), which shows that the model could account for 87.69% of the response's variability. Table 7 shows that the signal was deemed satisfactory with adeq precision of 9.517. A ratio that is higher than 4 is preferred. The model (Eq. 4) was chosen to reflect the variance in overall acceptability after taking into account all of the aforementioned factors. For the overall acceptability analysis, the quadratic model derived from regression analysis looked like this in terms of the coded levels of the variables:

$$\text{Overall Acceptability} = 7.35 + 0.17A + 0.099B - 0.64A^2 + 0.18B^2 - 0.55AB \quad (4)$$

Where,

A= Frying oil temperature (^{0}C)
B= Frying time (seconds)

Equation (4) yields the following conclusions: at a 95% confidence level, the overall acceptability of fried Ganthiya was significantly ($P < 0.05$) impacted negatively by the temperature of the frying oil (A) and positively by the frying duration (B). Interaction term was not found significant.

Table 6. ANOVA for sensory attributes (OAA) of *Ganthiya* obtained from RSM approach

Source	Sum of Squares	DF	Mean Square	F- Value	Prob> F	
Model	4.890	5	0.978	9.970	0.0044	significant
A	0.222	1	0.222	2.259	0.1766	
B	0.078	1	0.078	0.795	0.4022	
A^2	1.21	1	1.21	12.335	0.0098	
B^2	2.883	1	2.882	29.388	0.0010	
AB	0.229	1	0.229	2.330	0.1708	
Residual	0.687	7	0.098			
Lack of Fit	0.497	3	0.166	3.485	0.1295	not significant

Table 7. Statistical parameters for different responses of Ganthiya

Parameters	Responses			
	Moisture Content	Oil Uptake	Oil Uptake Ratio	Sensory Attributes (OAA)
Std. Dev.	0.81626	1.5350	0.1250	0.3132
Mean	6.11692	32.369	1.5108	7.0654
C.V %	13.3444	4.7424	8.2733	4.4329
PRESS	14.3294	98.936	0.6707	3.8288
R^2	0.87402	0.7699	0.7910	0.8769
Adj R^2	0.78404	0.6056	0.6418	0.7889
Pred R^2	0.61295	-0.3797	-0.2816	0.3135
Adeq. Precision	10.1355	6.709815	7.340908	9.51685

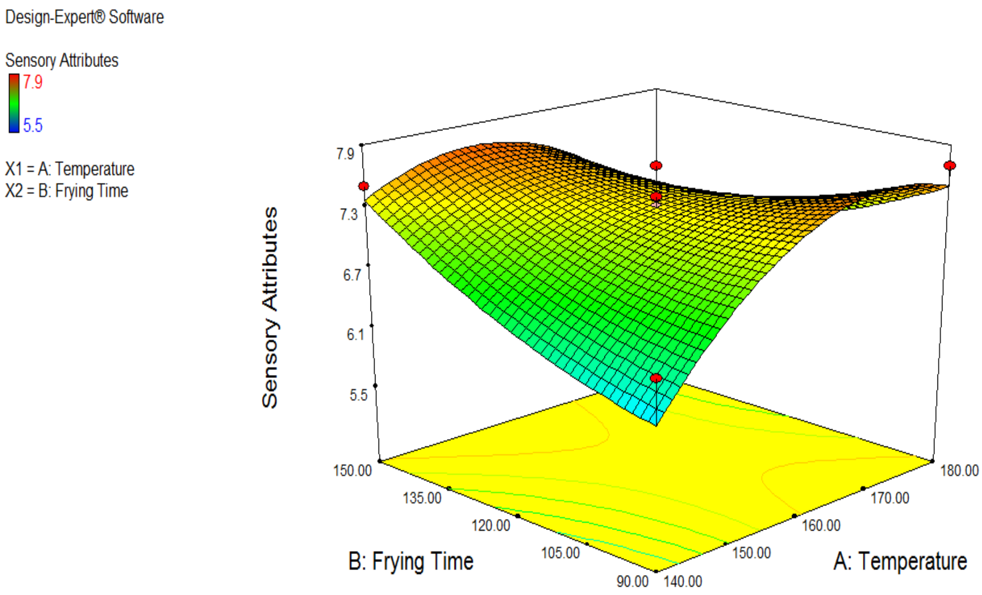

Fig. 4. Response surface plot showing the effect of frying time and oil temperature on overall acceptability

Fig. 4 shows the effect of frying time and oil temperature on overall acceptability. It is evident that with increasing the temperate and time overall acceptability increases. Similar outcomes were also seen by Fofandi et al. [23].

3.3 Compromised Optimum Condition for Experiment

In order to obtain market acceptability, minimum oil content, minimum frying time, and maximum frying oil temperature, attempts were made to design a deep-fried snack (Ganthiya) with a minimum fat content and an acceptable score in sensory attributes. These characteristics were therefore tried to be maintained across all replies, while other factors (moisture and oil uptake ratio) were kept within range.

Based on these parameters, the uncoded ideal circumstances for Ganthiya development were 180 ^{0}C for the temperature of the frying oil and 90 seconds of cooking time. The design expert software projected the following responses for these ideal process conditions: 6.25 % moisture, 29.36% oil content, 1.35 % oil uptake ratio and 7.50 % overall acceptance value.

3.4 Verification of Results

In addition to being used to assess experimental and predicted response values, the applicability of the model built for predicting the optimal response values was verified using the suggested optimum conditions of the variables.

Table 8. Effect of CMC, methyl cellulose, guar gum and gum tragacanth on oil uptake of snack (Ganthiya)

	Oil Uptake (%)			
Experimental Samples	**CMC**	**GG**	**GT**	**MC**
0.5 %	17.81±0.1	15.03±0.2	16.14±0.1	14.48±0.2
0.75 %	16.58±0.2	18.20±0.3	18.91±0.2	20.53±0.1
1.0 %	15.33±0.1	20.53±0.1	21.61±0.3	22.26±0.2
CV (%)	7.48	15.40	14.48	21.39
SE(d)	0.72	1.59	1.58	2.36

Table 9. Effect of CMC, methyl cellulose, guar gum and gum tragacanth on oil uptake reduction of snack (Ganthiya)

	Reduction in Oil Uptake (%)			
Experimental Samples	**CMC**	**GG**	**GT**	**MC**
0.5 %	40.05 ±0.1	49.41±0.2	45.67±0.1	51.26±0.2
0.75 %	44.19±0.2	38.74±0.3	36.35±0.2	30.89±0.1
1.0 %	48.40±0.1	30.89±0.1	27.26±0.3	25.07±0.2
CV (%)	9.44	23.43	25.27	28.48
SE(d)	2.41	5.37	5.31	7.94

In the testing sample, the ideal ingredient circumstances produced the following results: moisture: 6.65%, oil content: 29.71%, oil uptake ratio: 1.41 and overall acceptability: 7.7.

3.5 Hydrocolloids' Impact on Ganthiya's Decreased Oil Uptake

Data on absolute oil uptake during frying and relative oil uptake reduction in fried Ganthiya with hydrocolloid addition compared to control sample are displayed in Tables 8 and 9. It was discovered that the ranges of absolute oil uptake and relative oil uptake reduction with different hydrocolloids at different concentrations were 14.48 to 22.26% and 24.18 to 50.68%, respectively.

The oil content of the optimized (control) Ganthiya was found to be 29.71 %, however the oil uptake in the Ganthiya was found to be significantly reduced upon the addition of hydrocolloids. The maximum reduction in Ganthiya 's oil uptake was seen to be 51.26%, 49.41%, 48.40%, 45.67% and 44.19% in samples with 0.5 % carboxymethyl cellulose, 0.5 % guar gum, 1% carboxymethyl cellulose, 0.5 % gum tragacanth and 0.75 % carboxymethyl cellulose, added respectively.

Various researchers also documented comparable outcomes, which align with our findings [24-26].

4. CONCLUSION

The first part of the study used the response surface approach to optimize the temperature and time of the frying process in order to create low-fat fried Ganthiya. The perfect parameters were found to be 180 ^{0}C for the frying oil temperature and 90 seconds for the frying time. In the second part of the study, which comprised creating snacks (Ganthiya) at the previously mentioned optimal conditions, the effects of different polymers on the snack's decreased oil uptake were investigated. The greatest reduction in oil uptake was noted in 0.5% methyl cellulose containing Ganthiya, which was followed by 49.41% in 0.5% guar gum containing Ganthiya, 48.40% in 1% carboxymethyl cellulose containing Ganthiya, 45.67% in 0.5% gum tragacanth containing Ganthiya, and 44.19 % in 0.75% carboxymethyl cellulose containing Ganthiya.

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Snacks market size, share & trends analysis report by product (frozen & refrigerated, fruit, bakery), by packaging (bags & pouches, boxes), by distribution channel, by Region, and Segment Forecasts; 2023 – 2030. Accessed 12 February 2024. Available:https://www.researchandmarkets.com/reports/5595801/snacks-market-size-share-and-trends-analysis.
2. Ngadi M, Xue J. Food frying: modifying the functional properties of batters. In: Ahmed J, Ramaswamy HS, Kasapis S, Boye JIB, editors. Novel food processing: effects on rheological and functional properties, CRC Press, Canada; 2009.
3. Chiedu, Udeh Charles, Malomo Sunday Abiodun, Ijarotimi Oluwole Steve, Emojorho Ernest Eguono, Arogundade Toyin Joy. Physicochemical, nutritional and functional properties of composite flour blends from whole wheat, sweet potato, defatted peanut and rice bran. European Journal of Nutrition & Food Safety. 2023; 15(12):41-55. https://doi.org/10.9734/ejnfs/2023/v15i121366.
4. Nassef SL, Hafez HH. Determining quality attributes of cupcakes by watermelon Puree and Stevia Sweetener. Asian Journal of Food Research and Nutrition. 2024;3(1):1–11. Available:https://journalajfrn.com/index.php/AJFRN/article/view/104
5. St-Onge MP, Aban I, Bosarge A, Gower B, Hecker KD, Allison DB. Snack chips fried in corn oil alleviate cardiovascular disease risk factors when substituted for low-fat or high-fat snacks. The American Journal of Clinical Nutrition. 2007;85(6): 1503-10.
6. López-Martínez A, Azuara-Pugliese V, Sánchez-Macias A, Sosa-Mendoza G, Dibildox-Alvarado E, Grajales-Lagunes A. High protein and low-fat chips (snack) made out of a legume mixture. CyTA-Journal of Food. 2019;17(1):661-8.
7. Shit SC, Shah PM. Edible Polymers: Challenges and Opportunities. Journal of Polymers, 2014;1–13. DOI:10.1155/2014/427259
8. Gibis M, Schuh V, Weiss J. Effects of carboxymethyl cellulose (CMC) and microcrystalline cellulose (MCC) as fat replacers on the microstructure and sensory characteristics of fried beef patties. Food Hydrocoll. 2015;45:236–246.
9. Chen T, Sun C, Tian X, Jiang X, Zhang M. Natural polysaccharide: Modification and application. Paper and Biomaterials. 2021;6(2):43-58. DOI: 10.12103/j.issn.2096-2355.2021.02.005.
10. Amboon W, Tulyathan V, Tattiyakul J. Effect of hydroxypropyl methylcellulose on rheological properties, coating pickup, and crude fat of rice flour-based batters. Food and Bioprocess Technology. 2012;5:601-608.
11. Saha D, Bhattacharya S. Hydrocolloids as thickening and gelling agents in food: a critical review. J Food Sci Technol. 2010; 47:587–597.
12. 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.
13. Kumari M, Gupta SK. Response surface methodological (RSM) approach for optimizing the removal of trihalomethanes (THMs) and its precursor's by surfactant modified magnetic nanoadsorbents (sMNP) - An endeavor to diminish probable cancer risk. Sci Rep. 2019;9: 18339. DOI:10.1038/s41598-019-54902-8.
14. AOAC, Official methods of analysis. 18th ed. Washington, DC: Association of official analytical chemists; 2006.
15. Ranganna S, Handbook of analysis and quality control of fruits and vegetables products. Tata McGraw Hill Publ. Co. Ltd., New Delhi; 2007.
16. Dixit A, Mishra N, Upadhyay A, Mishra A. Effect of hydrocolloids coating on fat uptake reduction of tapioca sago chips. Journal of Agricultural Engineering and Food Technology. 2016;3(1):35-39.
17. 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(1):294–302. DOI: 10.1007/s13197-013-0997-8
18. Jothi JS, Le TND, Kawai K. Effects of trehalose and corn starch on the mechanical glass transition temperature and texture properties of deep-fried food with varying water and oil contents. Journal of Food Engineering. 2020; 267:109731.

DOI: 10.1016/j.jfoodeng.2019.109731
19. Dixit A, Upadhyay A, Mishra A. Process optimization for the development of low fat fried Indian traditional snack using response surface approach. Carpathian J Food Sci and Technol. 2018; 10(3): 57–71.
20. Kita A, Lisinska G. The influence of oil type and frying temperatures on the texture and oil content of French fries. Journal of the Science of Food and Agriculture. 2005; 85(15):2600-2604.
DOI: 10.1002/jsfa.2319
21. Li Y, Guo Q, Wang K, Nverjiang M, Wu K, Wang X, Xia X. Monitoring the changes in heat transfer and water evaporation of french fries during frying to analyze its oil uptake and quality. Foods. 2022;11(21): 3473.
DOI: 10.3390/foods11213473.
22. Liu Y, Tian J, Zhang T, Fan, L. Effects of frying temperature and pore profile on the oil absorption behavior of fried potato chips. Food Chemistry. 2021;345:128832.
DOI: 10.1016/j.foodchem.2020.128832
23. Fofandi DC, Bhola DV, Chudasama BG, Tanna PD. Effect of frying time and temperature on physicochemical and sensory quality attributes of batter and breaded Unicorn file (*Aluterus monoceros*) fish fillet. Journal of Entomology and Zoology Studies. 2020;8(4): 1600-1603.
24. Albert S, Mittal GS. Comparative evaluation of edible coatings to reduce fat uptake in a deep-fried cereal product. Food Res. Int. 2002; 35(5):445-458.
DOI:10.1016/S0963-9969(01)00139-9.
25. Sakhale BK, Pahade PK. Effect of blanching and coating with hydrocolloids on reduction of oil uptake in french fries. International Food Research Journal. 2012;19(2): 697-69.
26. Liberty JT, Dehghannya J, Ngadi MO. Effective strategies for reduction of oil content in deep-fat fried foods: A review. Trends in Food Science & Technology. 2019; 92:172–183.
DOI: 10.1016/j.tifs.2019.07.050

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/119287