Original Research Article

Optimizing the Process Parameters for Carrot Pulp Cake Development Using Response Surface Methodology

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ABSTRACT

Carrots (*Daucus carota* L.) are rich in vitamins B1, B2, B6, β-carotene, and dietary fibers, having nutritional benefits such as, antioxidant, and anticancer properties. Carrot pulp offers a valuable nutritional boost for enhancing bakery products. Incorporating carrot pulp into cake preparation not only adds a unique flavor and moist texture but also boosts the nutritional value with additional vitamins and fiber. The research systematically examines the effects of varying process parameters such as carrot pulp, condensed milk, and whey protein concentrate (WPC) on specific volume, springiness, and overall acceptability of carrot pulp cake using Central Composite Design (CCD) of Response Surface Methodology (RSM). The optimal formulation for carrot pulp cake consisted of 70.8 g of carrot pulp, 200 g of condensed milk, and 4.2 g of WPC. This combination resulted in a high-quality carrot pulp cake with a specific volume of 2.58 cm^3/g, a springiness measurement of 1.049 mm, and an overall acceptability rating of 8.3. The findings contribute to the development of healthier and more sustainable bakery products. This approach not only enhances product quality but also supports waste reduction by valorizing carrot pulp, aligning with sustainable food processing practices.

Keywords: Carrot pulp cake, response surface methodology, condensed milk, whey protein powder.

1. INTRODUCTION

The Indian bakery market crossed $7.22 billion in 2018 globally and is projected to reach $12 billion by 2024, with cakes expected to reach $882 million. The industry includes traditional and modern products like breads, biscuits, and cakes. Increasing consumer demand for convenient, nutritious, and functional baked goods is responsible driving force for industrial growth [1].

The bakery industry can grow by developing fortified, nutritionally enhanced products. Enriching bakery foods, mainly made from wheat flour, with health-promoting ingredients like omega-3 oils and dietary fiber. They can help prevent heart problems like atherosclerosis and irregular heartbeats. They also contribute to lower blood pressure and may be beneficial for individual with diabetes. They may also help with mental health issues like depression and bipolar disorder [2].

Diseases like type II diabetes are linked to low-fiber diets. Dietary fiber can positively regulate blood glucose and cholesterol levels and promote gut health. European Food Safety Authority recommends 25g of fiber daily, while other guidelines suggest higher amounts. In the United States, people typically consume only about 10 to 15 g of fiber on average [3].

Carrots (*Daucus carota* L.) the esteemed root vegetable of the *Apiaceae* family. Presently, Asia leads in carrot production at 61% [4]. In recent years, the consumption of carrot and its related products have increased consistently due to recognition of antioxidant and anticancer activities of β-carotene in carrot, which is also a precursor of vitamin A [5].

Carrot pulp contains substantial nutrients such as proteins, lipids, sugars, vitamins, and minerals. Apart from being high in carotenoids and dietary fiber [6].

2. MATERIAL AND METHODS

2.1 Materials

The raw materials used in the production of carrot pulp cake like refined wheat flour (all-purpose flour), carrot (*Pusa yamdagni*), sweetened condensed milk, whey protein concentrate (WPC), ghee (shortening), oil (sunflower oil), baking soda, baking powder, vinegar, essence, cake gel, skimmed milk powder (SMP), sugar, and PET container were procured from the local market of Anand, Gujarat. The raw materials were of good quality and from the same reputable brand. They were purchased in one or as few instances as possible, stored in a cool, dry place, and used as required.

2.2 Methods

The methods for standardization of carrot pulp cake are discussed in the following sections.

2.2.1 Preparation of carrot pulp

The raw carrots were cleaned, peeled, and grated. After that steam blanched at 90°C for 3 min. Following blanching the samples were chilled in a refrigerator at 5°C for 15min after which the core temperature of the carrot slices was 5°C, grinded and packed in PE pouches, frozen and stored at -24°C [7].

2.2.2 Standardization of process parameters for carrot pulp cake

Table 1: Recipes for manufacturing of carrot pulp cake

Ingredients	Amount
Refined flour (g)	100
Ghee (g)	25
Oil (g)	25
Condensed milk(g)	50, 100, 150, 200, 250
WPC (g)	2, 4, 6, 8, 10
Carrot pulp (g)	0, 25, 50, 75, 100
Water (mL)	0, 25, 50, 75, 100
Baking soda (g)	1
Baking powder (g)	2
Vinegar (mL)	6
Essence (mL)	0.5
Cake gel (g)	3

2.2.3 Experimental design for carrot pulp cake

A central composite design (CCD) was carried out to examine the effects of various responses influenced by three independent variables namely carrot pulp (A), condensed milk (B), and whey protein concentrate (C) having 5 levels. The dependent variables were specific volume, springiness, and overall acceptability. Table 2 provides the variation levels of the independent and dependent variables. The levels were determined using coded values of -2, -1, 0, +1, and +2. The actual and coded values for each experimental combination were detailed in Table 3.

Table 2: Actual and coded values of three independent variables and dependent variables used in CCD

Independent variables	**Coded levels**				
	-Alpha -2	**Low -1**	**Centre 0**	**High +1**	**+Alpha +2**
Carrot pulp (g)	0	25	50	75	100
Condensed milk (g)	50	100	150	200	250
Whey protein concentrate (g)	2	4	6	8	10
Dependent variables	**Observations**				
Physical properties	Specific volume				
Textural characteristics	Springiness				
Sensory properties	Overall acceptability				

Table 3: Experimental design matrix for optimization of carrot pulp cake using CCD of RSM

Run No.	Carrot pulp (g)	Condensed milk (g)	WPC (g)
1	25	100	8
2	75	200	8
3	75	100	4
4	50	150	6
5	75	200	4
6	0	150	6
7	75	100	8
8	50	150	6
9	50	50	6
10	50	150	6
11	50	250	6
12	50	150	2
13	25	200	8
14	50	150	10
15	100	150	6
16	50	150	6
17	25	100	4
18	50	150	6
19	25	200	4
20	50	150	6

The carrot pulp cake was prepared according to the procedure and the trials suggested by the software (Table 3). The optimization of independent variables was conducted using advanced statistical software, Design Expert 13.0.5.0. All 20 trials were executed and the results were statistically analyzed. Each of the 20 carrot pulp cake samples were prepared with varying compositions as per the design and evaluated for physical, textural, and sensory properties.

The data was analyzed using response surface methodology (RSM) and the optimization of independent variables was performed based on the recommended results by the software.

2.2.4 Process for manufacture of carrot pulp cake

The manufacturing process of carrot pulp cake was carried out using necessary ingredients including the mixture of condensed milk, whey protein concentrate (WPC), and cake gel. Furthermore, addition of essence was performed and the mixture was blended using oil and ghee. Then water was incorporated into the mixture. Subsequently, the refined wheat flour was mixed with baking powder and baking soda and added into prepared mixture. Further, vinegar was mixed and carrot pulp was incorporated into the batter. Lastly, the batter was poured into a cake mold and baked at 175°c for 50-55 minutes. Upon completion of process, the cake was cooled for 1-1.5 h and packed.

2.2.5 Analytical methods for proximate composition

The moisture, protein, fat, ash, crude fiber, and carbohydrates content of carrot pulp cake was analyzed [8, 9, and 10].

3. RESULTS AND DISCUSSION

3.1 Optimization of Process Parameters for Manufacturing of Carrot Pulp Cake Using RSM

This experiment aims to standardize the process parameters for manufacturing of carrot pulp cake. The independent variables/ factors selected for optimization of the process parameters were carrot pulp, condensed milk, and whey protein concentrate (WPC). The experimental design matrix was suggested by the Design Expert (v.13.0.5.0) using CCD of RSM. The suggested matrix consisting of 20 runs with different combinations of factors and three responses *viz.* specific volume, springiness, and overall acceptability is illustrated in Table 4. All the 20 runs were conducted according to the procedure shown in section 2.2.2 and evaluated for specific volume, springiness, and overall acceptability.

3.1.1 Influence of independent variables on properties of carrot pulp cake

The responses obtained by conducting 20 runs, as presented in Tables 4, were individually analyzed using the quadratic regression model in the Design Expert software. ANOVA of the model was utilized to assess the significance of the model and the impact of individual factors on the responses. The fitted quadratic regression model for each response and their respective effects are discussed below.

Effect of process variables on specific volume of carrot pulp cake

Specific volume is expressed as the volume per unit mass of a cake. The specific volume of carrot pulp cakes varied within the range of 1.55 to 2.58 cm^3/g as shown in Table 4. The specific volume was observed maximum (2.58 cm^3/g) for the run 11 executed using 50 g carrot pulp, 250 g condensed milk, and 6 g WPC while the minimum (1.55 cm^3/g) for the run 9, with 50 g carrot pulp, 50 g condensed milk, and 6 g WPC in Table 4.

As shown in Table 5, the quadratic model for specific volume achieved an F-value of 80.14 and a *P*-value of < 0.0001 indicating that the model was highly significant. The lack of Fit was not significant compared to the pure error, suggesting that the model was well fitted to the experiment. The multiple regression equation developed to predict the specific volume under the influence of various factors is presented below:

Specific volume (cm^3/g) = 2.45 + 0.1669*A + 0.2356*B – 0.0219*C + 0.1313*AB + 0.0087*AC + 0.0087*BC – 0.0699*A^2 – 0.0886*B^2 + 0.0014*C^2

The values shown in Table 5 and above equation revealed that the linear parameters (A), and (B) shown a highly significant effect ($P<0.01$) on the specific volume while, the effects of parameters (C) were not-significant ($P>0.05$). The quadratic term of the factor represents the impact of the ingredient at its highest level used during product standardization. The interaction effects of factors (AB) was highly significant ($P<0.01$) on the specific volume. The effect of the factor (A^2), and (B^2) was highly significant ($P<0.01$) while the (AC), (BC), and (C^2) parameters shown not-significant ($P>0.05$) effects at quadratic levels.

As indicated in Table 6, the adjusted R^2 and predicted R^2 for the specific volume were 0.97 and 0.91, respectively while the coefficient of determination was 0.98. A higher R^2 values approaching 1.00 indicated a better fit for the quadratic model. The adequate precision value (APV) for specific volume was 26.96, significantly surpassing the minimum desirable APV value of 4.00. This suggests that the model is reliable for predicting the response within the design space.

The three-dimensional response surfaces are plotted to illustrate the interactions among the variables on specific volume are shown in Fig. 1.

Table 4: Factors and responses of experimental carrot pulp cake

Run No.	Factors			Responses		
	A	B	C	Specific volume (cm^3/g)	Springiness (mm)	Overall acceptability (out of 9)
1	25	100	8	1.76	0.869	6.1
2	75	200	8	2.55	1.030	7.8
3	75	100	4	2.40	0.870	7.0
4	50	150	6	2.40	0.985	7.6
5	75	200	4	2.57	1.040	8.3
6	0	150	6	1.80	1.005	6.7
7	75	100	8	2.39	0.834	6.9
8	50	150	6	2.46	0.999	7.5
9	50	50	6	1.55	0.603	5.1
10	50	150	6	2.41	0.988	7.7
11	50	250	6	2.58	1.055	8.1
12	50	150	2	2.48	1.005	7.7
13	25	200	8	2.49	1.038	7.6
14	50	150	10	2.37	0.980	6.5
15	100	150	6	2.48	0.976	7.8
16	50	150	6	2.47	0.987	7.7
17	25	100	4	1.85	0.937	6.7
18	50	150	6	2.41	0.999	7.4
19	25	200	4	2.50	1.050	7.8
20	50	150	6	2.47	0.998	7.6

The effect of condensed milk and carrot pulp on specific volume at constant 6 g WPC is depicted in Fig. 1. The results indicated that as the levels of carrot pulp and condensed milk increased, the specific volume also increased. The impact of condensed milk was more pronounced than that of carrot pulp. The specific volume observed maximum (2.58 cm^3/g) for the run 11 executed using 50 g carrot pulp, and 250 g condensed milk at constant 6 g WPC while the minimum (1.55 cm^3/g) for the run 9 executed with 50 g carrot pulp, and 50 g condensed milk at constant 6 g WPC.

They observed that increase the level of condensed milk, results in an increase cake's volume and specific volume [2, 11].

RSM plot (Fig. 1), showed the effect of WPC and carrot pulp on specific volume at constant condensed milk (150 g). It was observed that as the level of carrot pulp increased, the specific volume also increased, whereas increase in WPC level results in decreased specific volume. With condensed milk held constant at 150 g, the highest specific volume, 2.48 cm^3/g, was observed in two experiments run number 12 with 50 g carrot pulp and 2 g WPC, and in run number 15 with 100 g carrot pulp and 6 g WPC. The minimum specific volume of 1.8 cm^3/g was obtained in experiment run number 6, with a constant condensed milk level of 150 g, using 0 g carrot pulp and 6 g WPC.

They observed that the increase the level of WPC, results in decrease cake's volume and specific volume [2].

The effect of WPC and condensed milk on specific volume at constant carrot pulp (50 g) is depicted in Fig. 1. It was observed that as the level of condensed milk increased, the specific volume also increased, whereas increase in WPC level results in decreased specific volume. With carrot pulp held constant at 50 g, the highest specific volume, 2.58 cm^3/g, was observed in experiment run number 11 with 250 g condensed milk and 6 g WPC. The minimum specific volume of 1.55 cm^3/g was obtained in experiment run number 9, with a constant carrot pulp level of 50 g, using 50 g condensed milk, and 6 g WPC.

Table 5: ANOVA table for effect of process variables on specific volume of carrot pulp cake

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	1.77	9	0.1966	80.14	< 0.0001	significant
A-Carrot pulp	0.4456	1	0.4456	181.58	< 0.0001*	
B-Condensed milk	0.8883	1	0.8883	362.01	< 0.0001*	
C-WPC	0.0077	1	0.0077	3.12	0.1078	
AB	0.1378	1	0.1378	56.16	< 0.0001*	
AC	0.0006	1	0.0006	0.2496	0.6282	
BC	0.0006	1	0.0006	0.2496	0.6282	
A^2	0.1228	1	0.1228	50.04	< 0.0001*	
B^2	0.1975	1	0.1975	80.50	< 0.0001*	
C^2	0.0000	1	0.0000	0.0191	0.8930	
Residual	0.0245	10	0.0025			
Lack of Fit	0.0190	5	0.0038	3.43	0.1009	not significant

*Significant at 1.0 percent level (P<0.01), **significant at 5.0 percent level (P<0.05)*

Table 6: Fit statistics data of specific volume

Std. Dev.	0.05	**R^2**	0.98
Mean	2.32	**Adjusted R^2**	0.97
C.V. %	2.14	**Predicted R^2**	0.91
		APV	26.96

Effect of process variables on springiness of carrot pulp cake

The springiness of carrot pulp cake varied within the range of 0.603 to 1.055 mm as shown in Table 4. The springiness was observed maximum of 1.055 mm for the run 11 executed using 50 g carrot pulp, 250 g condensed milk, and 6 g WPC while the minimum of 0.603 mm for the run 9, with 50 g carrot pulp, 50 g condensed milk, and 6 g WPC in Table 4. As shown in Table 7, the quadratic model for springiness achieved an F-value of 37.34 and a *P*-value of < 0.0001 indicating that the model was highly significant. The lack of Fit was not significant compared to the pure error, suggesting that the model was well fitted to the experiment. The multiple regression equation developed to predict the springiness under the influence of various factors is presented below:

$$\text{Springiness (mm)} = 0.998 - 0.0111^{*}A + 0.097^{*}B - 0.011^{*}C + 0.0104^{*}AB + 0.0043^{*}AC + 0.0103^{*}BC - 0.001^{*}A^2 - 0.0414^{*}B^2 - 0.0005^{*}C^2$$

The values shown in Table 7 and above equation reveals that the linear parameters (B) shown a highly significant effect ($P<0.01$) on the springiness while, the effects of parameters (A), and (C) were not-significant ($P>0.05$). The quadratic term of the factor represents the impact of the ingredient at its highest level used during product standardization. The effect of the factor (B^2) was highly significant ($P<0.01$) while the (AB), (AC), (BC), (A^2) and (C^2) parameters shown not-significant ($P>0.05$) effects at quadratic levels.

As indicated in Table 8, the adjusted R^2 and predicted R^2 for the specific volume were 0.94 and 0.79, respectively while the coefficient of determination (R^2) was 0.97. A higher R^2 values approaching 1.00 indicated a better fit for the quadratic model. The adequate precision value (APV) for springiness was 24.17, significantly surpassing the minimum desirable APV value of 4.00. This suggests that the model is reliable for predicting the response within the design space. The three-dimensional response surfaces are plotted to illustrate the interactions among the variables on springiness are shown in Fig. 2.

Table 7: ANOVA table for effect of process variables on springiness of carrot pulp cake

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.2022	9	0.0225	37.34	< 0.0001*	significant
A-Carrot pulp	0.0020	1	0.0020	3.27	0.1007	
B-Condensed milk	0.1504	1	0.1504	250.02	< 0.0001*	
C-WPC	0.0019	1	0.0019	3.23	0.1027	
AB	0.0009	1	0.0009	1.45	0.2570	
AC	0.0001	1	0.0001	0.2487	0.6288	
BC	0.0008	1	0.0008	1.40	0.2635	
A^2	0.0000	1	0.0000	0.0422	0.8414	
B^2	0.0431	1	0.0431	71.56	< 0.0001*	
C^2	6.401E-06	1	6.401E-06	0.0106	0.9199	
Residual	0.0060	10	0.0006			
Lack of Fit	0.0050	5	0.0010	4.96	0.0517	not significant

*Significant at 1.0 percent level (P<0.01), **significant at 5.0 percent level (P<0.05)*

Table 8: Fit statistics data of springiness

Std. Dev.	0.02	**R^2**	0.97
Mean	0.96	**Adjusted R^2**	0.94
C.V. %	2.55	**Predicted R^2**	0.79
		APV	24.17

The effect of condensed milk and carrot pulp on springiness at constant WPC (6 g) is depicted in Fig. 2. The results indicates that as the levels of condensed milk increased, the springiness

also increased, whereas no significant effect of increase carrot pulp level on springiness. The springiness was observed maximum (1.055 mm) for the run 11 executed using 50 g carrot pulp, and 250 g condensed milk at constant 6 g WPC while the minimum of 0.603 mm for the run 9, with 50 g carrot pulp, 50 g condensed milk at constant 6 g WPC.
They observed that the increase the level of condensed milk, results in an increase the springiness of cake [11]. They found that a higher carrot pomace content causes the cake's springiness to decrease [12]. Both results support the results obtained in the present study.
RSM plot (Fig. 2), shows the effect of WPC and carrot pulp on springiness at constant condensed milk (150 g). It was observed that as the levels of carrot pulp and WPC increased, there was no significant effect on springiness. With condensed milk held constant at 150 g, the highest springiness of 1.023 mm was observed in experiment run number 20 with 50 g carrot pulp and 6 g WPC. The minimum springiness of 0.976 mm was obtained in experiment run number 15, with a constant condensed milk level of 150 g, using 100 g carrot pulp and 6 g WPC.
The effect of WPC and condensed milk on springiness at constant carrot pulp (50 g) is depicted in Fig. 2. It was observed that as the level of condensed milk increased, the springiness also increased, whereas no significant effect of increase WPC level on springiness. With carrot pulp held constant at 50 g, the highest springiness of 1.055 mm was observed in experiment run number 11 with 250 g condensed milk and 6 g WPC. The minimum springiness of 0.603 mm was obtained in experiment run number 9, with a constant carrot pulp level of 50 g, using 50 g condensed milk, and 6 g WPC.

Effect of process variables on overall acceptability of carrot pulp cake

The overall acceptability of carrot pulp cakes varied within the range of 5.1 to 8.3 (on 9-point hedonic scale base) as shown in Table 4. The overall acceptability was observed maximum (8.3) for the run 5 executed using 75 g carrot pulp, 200 g condensed milk, and 4 g WPC while the minimum (5.1) for the run 9, with 50 g carrot pulp, 50 g condensed milk, and 6 g WPC in Table 4.
As shown in Table 9, the quadratic model for overall acceptability achieved an F-value of 29.77 and a *P*-value of < 0.0001 indicating that the model was highly significant. The lack of Fit was not significant compared to the pure error, suggesting that the model was well fitted to the experiment. The multiple regression equation developed to predict the overall acceptability under the influence of various factors is presented below:
$$\text{Overall acceptability} = 7.61 + 0.25{*}A + 0.675{*}B - 0.2375{*}C - 0.05{*}AB + 0.025{*}AC + 0{*}BC - 0.0705{*}A^2 - 0.233{*}B^2 - 0.108{*}C^2$$
The values shown in Table 9 and above equation revealed that the linear parameters (A), (B), and (C) showed a highly significant effect ($P<0.01$) on the overall acceptability.
The quadratic term of the factor represents the impact of the ingredient at its highest level used during product standardization. The effect of the factor (B^2) was highly significant ($P<0.01$). The interaction effects of factors (C^2) was significantly ($P<0.05$) on the overall acceptability as shown in Table 9 while the (AB), (AC), (BC), and (A^2) parameters shown not-significant ($P>0.05$) effects at quadratic levels.
As indicated in Table 10, the adjusted R^2 and predicted R^2 for the overall acceptability were 0.93 and 0.76, respectively while the coefficient of determination (R^2) was 0.96. A higher R^2 values approaching 1.00 indicated a better fit for the quadratic model. The adequate precision value (APV) for overall acceptability was 20.96, significantly surpassing the minimum desirable APV value of 4.00. This suggests that the model is reliable for predicting the response within the design space.
The three-dimensional response surfaces are plotted to illustrate the interactions among the variables on overall acceptability are shown in Fig. 3.
Table 9: ANOVA table for effect of process variables on overall acceptability of carrot pulp cake

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	10.67	9	1.19	29.77	< 0.0001	significant
A-Carrot pulp	1.0000	1	1.0000	25.10	0.0005*	
B-Condensed milk	7.29	1	7.29	182.98	< 0.0001*	
C-WPC	0.9025	1	0.9025	22.65	0.0008*	
AB	0.0200	1	0.0200	0.5020	0.4948	
AC	0.0050	1	0.0050	0.1255	0.7305	
BC	0.0000	1	0.0000	0.0000	1.0000	
A^2	0.1248	1	0.1248	3.13	0.1072	
B^2	1.36	1	1.36	34.25	0.0002*	
C^2	0.2930	1	0.2930	7.35	0.0219**	
Residual	0.3984	10	0.0398			
Lack of Fit	0.3301	5	0.0660	4.83	0.0544	not significant

*Significant at 1.0 percent level (P<0.01), **significant at 5.0 percent level (P<0.05)*

Table 10: Fit statistics data of overall acceptability

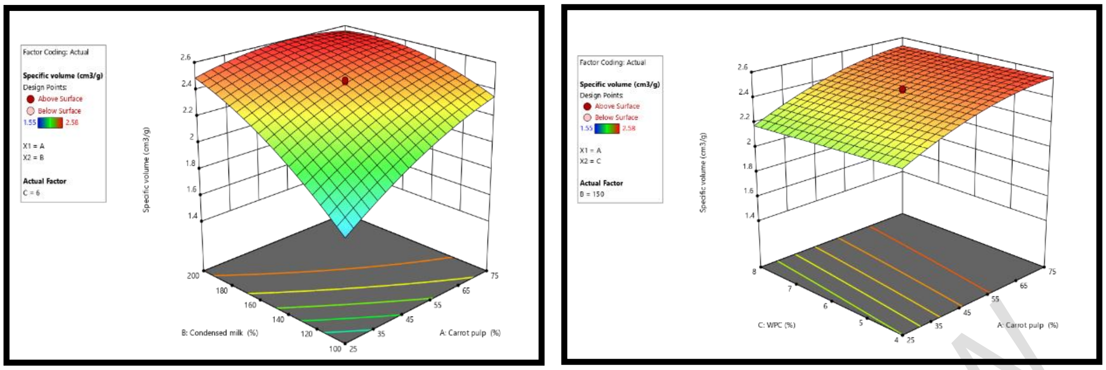
Std. Dev.	0.20	**R^2**	0.96
Mean	7.28	**Adjusted R^2**	0.93
C.V. %	2.74	**Predicted R^2**	0.76
		APV	20.96

The effect of condensed milk and carrot pulp on overall acceptability at constant WPC (6 g) is depicted in Fig. 3. The results indicated that as the levels of carrot pulp and condensed milk increased, the overall acceptability also increased. It was observed that, the impact of condensed milk was more pronounced than that of carrot pulp. The overall acceptability was observed maximum of 8.1 for the run 11 executed using 50 g carrot pulp, and 250 g condensed milk at constant 6 g WPC while the minimum (5.1) for the run 9, with 50 g carrot pulp, and 50 g condensed milk at constant 6 g WPC.

RSM plot (Fig. 3), showed the effect of WPC and carrot pulp on overall acceptability at constant condensed milk (150 g). It was observed that as the level of carrot pulp increased, the overall acceptability also increased, whereas increase in WPC level results in decreased overall acceptability. With condensed milk held constant at 150 g, the highest overall acceptability of 7.8 was observed in experiment run number 15 with 100 g carrot pulp and 6 g WPC. The minimum overall acceptability of 6.5 was obtained in experiment run number 14, with a constant condensed milk level of 150 g, using 50 g carrot pulp and 10 g WPC.

The effect of WPC and condensed milk on overall acceptability at constant carrot pulp (50 g) is depicted in Fig. 3. It was observed that as the level of condensed milk increased, the overall acceptability also increased, whereas increase in WPC level results in decreased overall acceptability. In experiment run number 11 where in 250 g condensed milk and 6 g WPC were added with carrot pulp held constant at 50 g, the highest overall acceptability of 8.1 was observed. The minimum overall acceptability of 5.1 was obtained in experiment run number 9, with a constant carrot pulp level of 50 g, using 50 g condensed milk, and 6 g WPC.

They observed that incorporating yellow carrot pomace up to 20% increased the overall acceptability of the cakes [13]. They found that the addition of 10% carrot pomace powder and 10% orange peel improves the product's overall acceptability, texture, appearance, and flavor [14]. They observed that the cake contained 5% fruit pulp waste powder (pineapple) was thought to be the most palatable option [15]. They noted that the absence of grease and



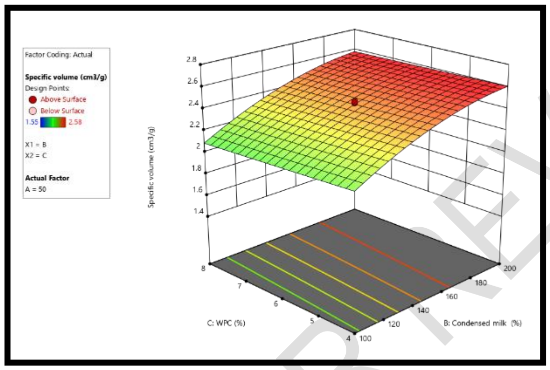
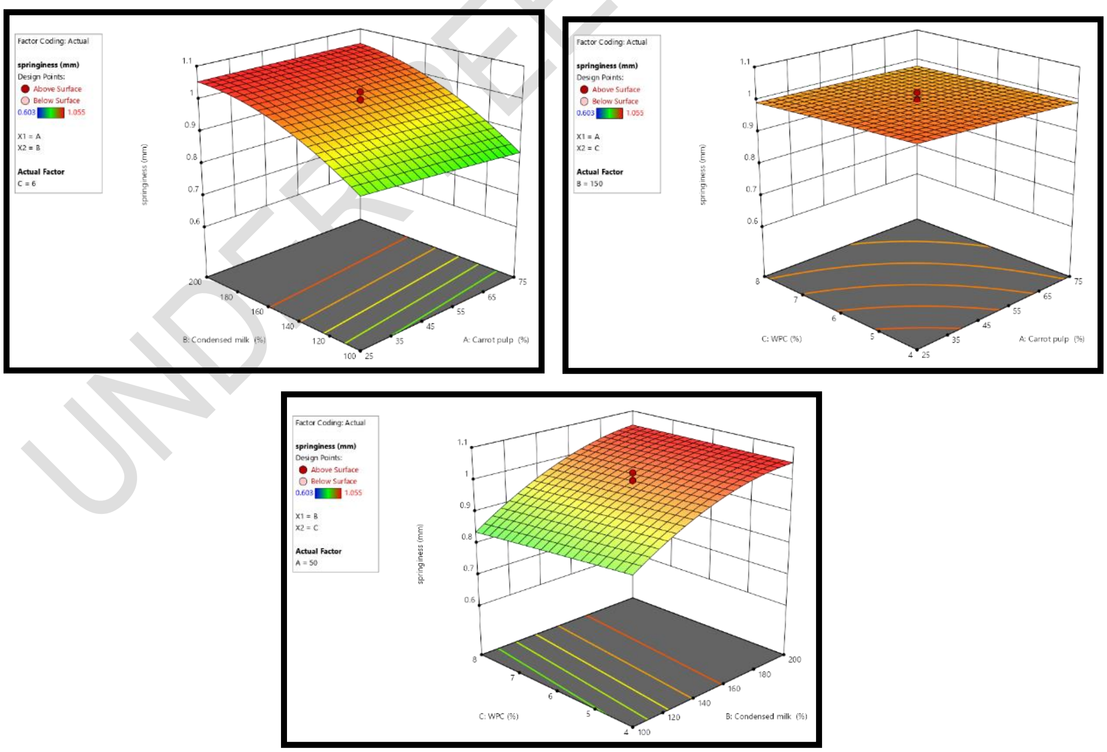
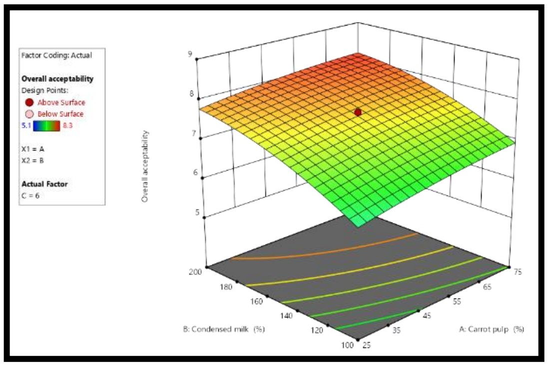
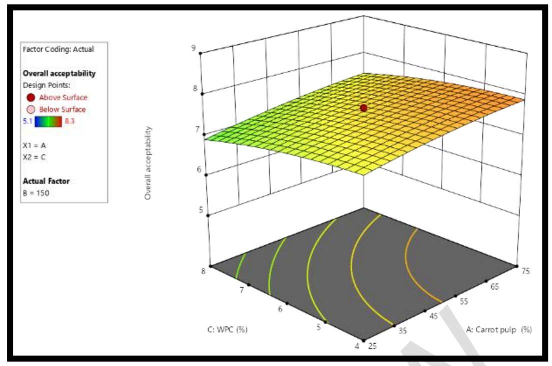


Fig. 1 Interaction of process variables on specific volume of carrot pulp cake







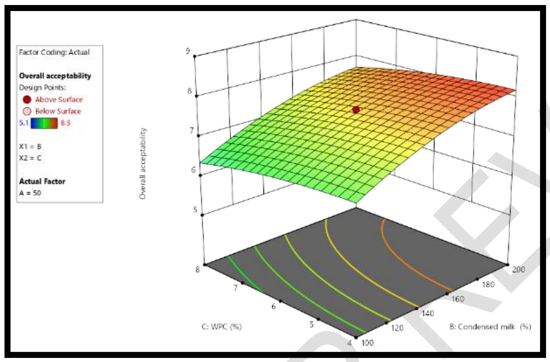


Fig. 2 Interaction of process variables on springiness of carrot pulp cake

enhanced crust colour, flavour, richness, and appearance of cake are all attributed by the condensed milk [11].

3.1.2 Optimization of process parameters for carrot pulp cake using quadratic regression model of response surface methodology

The optimization of process parameters was done to find the optimal combinations of variables for making carrot pulp cake *viz*. carrot pulp, condensed milk, and WPC that would result in the product having the most acceptable specific volume, springiness, and overall acceptability. The data received for the responses were examined in Design-Expert Software. The optimization criteria/targets were as follows, as shown in Table 11.

Table 11: Selected criteria/ targets for optimization of process parameters for carrot pulp cake

Name	Criteria/ targets	Lower Limit	Upper Limit
Independent Variables			
Carrot pulp (g)	is in range	25	75
Condensed milk (g)	is in range	100	200
WPC (g)	is in range	4	8
Dependent Variables			
Specific volume (cm^3/g)	maximize	1.55	2.58
Springiness (mm)	maximize	0.603	1.055
Overall Acceptability (out of 9)	maximize	5.1	8.3

Table 12: Optimized solution for carrot pulp cake as suggested by quadratic regression model of RSM

Optimized Factors			Optimized Responses			Desirability of the model
Carrot pulp (g)	Condensed milk (g)	WPC (g)	Specific volume (cm^3/g)	Springiness (mm)	Overall acceptability (out of 9)	0.99
70.8	200	4.2	2.58	1.049	8.3	

Table 13: Validation of the optimized RSM model for carrot pulp cake

Analysis	Predicted value	95% PI low	Actual value	95% PI high
Specific volume (cm^3/g)	2.58	2.48	2.59 ± 0.01	2.68
Springiness (mm)	1.049	1.00	1.046 ± 0.01	1.10
Overall acceptability (out of 9)	8.28	7.90	8.10 ± 0.1	8.60

Values expressed as mean ± sd (n=3)

Using the parameters and their limits, the RSM recommended an optimized solution, which is shown in Table 12. That includes 70.8 g carrot pulp, 200 g condensed milk, and 4.2 g WPC and responses were 2.58 cm^3/g specific volume, 1.049 mm springiness, and 8.3 overall acceptability as the model was 99% desirable.
Table 13 shows the validation of the carrot pulp cake of the actual values for specific volume (2.59 ± 0.01 cm^3/g), springiness (1.046 ± 0.01 mm), and overall acceptability (8.10 ± 0.1) closely align with the predicted values, remaining well within their respective 95% prediction intervals.

3.2 Proximate Composition of Optimized Carrot Pulp Cake

The carrot pulp cake has 27.49, 7.01, 15.6, 0.01, 1.57 and 49.89% moisture, protein, fat, ash, crude fiber, and carbohydrates (by difference), respectively.

4. CONCLUSION

The present research has highlighted the significant benefits of carrot pulp, into bakery products. The effects of process parameters such as carrot pulp, condensed milk, and whey protein concentrate (WPC) on the cake's quality attributes, including specific volume, springiness, and overall acceptability was systematically assessed using CCD or RSM. Interaction effect of process variables was evaluated at five levels with 20 run experimental design. The quadratic model was suggested by software and showed a well fit for the specific volume, springiness, and overall acceptability of carrot pulp cake, with R^2 values of 0.98, 0.97, and 0.96, respectively. The quadratic model for specific volume had an F-value of 80.14 and a P-value of < 0.0001, indicating highly significance. The lack of fit was not significant, confirming the model fitted well. Linear parameters (A) and (B) had a significant impact (P<0.01) on specific volume, while parameter (C) was not significant (P>0.05). Furthermore, the interaction of factors (AB) was highly significant (P<0.01) and quadratic effects (A^2) and (B^2) were significant (P<0.01), however, (AC), (BC), and (C^2) were not significant (P>0.05). The quadratic model for springiness had an F-value of 37.34 and P-value of < 0.0001, indicating higher significance level. The lack of fit was not significant, confirming a good model fit. Linear parameter (B) had a significant effect (P<0.01) on springiness, while parameters (A) and (C) were not significant (P>0.05). The quadratic effect of (B^2) was highly significant (P<0.01), whereas interactions (AB), (AC), (BC), and quadratic terms (A^2) and (C^2) were not significant (P>0.05). A quadratic model showed higher significance level for overall acceptability. The F-value of 29.77 and a P-value of < 0.0001 indicating a well-fitted model without significant lack of fit. Linear parameters (A, B, and C) significantly affected the acceptability ($P < 0.01$), with the quadratic term (B^2) showing highly significant effect ($P < 0.01$). Interaction effects (C^2) were significant ($P < 0.05$), while (AB), (AC), (BC), and (A^2) were not significant ($P > 0.05$) at quadratic levels. Based on response surface methodology (RSM), an optimized solution for carrot pulp cakes was recommended in a blend of 70.8 g carrot pulp, 200 g condensed milk, and 4.2 g WPC. The corresponding responses were 2.58 cm^3/g specific volume, 1.049 mm springiness, and 8.3 (out of 9) overall acceptability. The model achieved 99% desirability, indicating a highly favorable results within the predefined parameter limits. The carrot pulp added significant nutritional benefits, including additional vitamins and dietary fiber, thereby enhancing the health profile of the final product. This approach supports the development of healthier bakery options while contributing to more environmentally friendly food processing practices. Future research could explore additional variables and scaling-up processes to further refine the formulation and expand its commercial application.

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