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Optimization of producing functional sponge cake using a combination extract of green tea, white tea, and ginger

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ORIGINAL ARTICLE

Abstract

Plant extracts play an important role in improving the quality properties and enhancing the shelf life of food products. In the present study, different concentrations of green tea (0–2%), white tea (0–2%), and ginger (0 to 1.5%) extracts were used to formulate a sponge cake. Response surface methodology was used to investigate cake quality attributes. For each response, a second-order polynomial model with high coefficient of determination (R^2; >0.95) was developed using multiple linear regression analysis. The overall optimum area with high stability was found at a combined level of green tea (1.44%), white tea (1.71%), and ginger (0.75%) extracts.

Keywords: ginger, response surface methodology, sponge cake, tea

Introduction

Consumers' demand for healthier food products that prevent nutrition-related diseases and improve physical and mental well-being has led to the accelerated growth of functional foods market. A large number of potentially active nutrients and their multifunctional properties make them perfect candidates for the production of health-promoting food and supplements (Pinto et al. 2014; Siro et al. 2008). Among different food systems, baked products provide an excellent opportunity to incorporate food-grade fractions. Hence, nowadays the bakery industry seeks to improve the health attributes of their products by using functional ingredients that in some way can lead to healthier food products. In the bakery industry, cakes have become popular and a type of popular snack globally. Sponge cake is a cake based on flour (usually wheat flour), sugar, and eggs, and is sometimes leavened with baking powder. The quality of cakes depends on many factors, such as the ingredients used for batter preparation, aeration of batters, and process conditions (Pinto et al. 2014).

Functional food products are novel products enriched with various ingredients, such as live microorganisms (probiotics), nutrients, dietary fiber, phytochemicals, and other substances. These ingredients show a possible health-enhancing or disease-preventing values and are utilized at a safe and sufficient concentration to achieve intended benefits (Temple 2022).

The antioxidant properties of polyphenols found in green tea are the main health-promoting factors of this plant (Sinija and Mishra 2008; Timoshenkova et al. 2020).

White tea is a nonfermented brewage made from young tea leaves or Norse tea roots and is a rich source of antioxidants, such as catechins, compared to green tea (Hajiaghaalipour et al. 2015). Owing to the lack of fermentation in white tea, compared to black and oolong tea, the polyphenolic compounds in this tea are higher in concentration (Gramza-Michałowska et al. 2016).

Ginger (*Zingiber officinale Roscoe*) has been used as a spice in various foods for thousands of years. Ginger is considered as a dietary supplement by the US Food and Drug Administration (FDA) and is a part of herbal medicines listed in the World Health Organization (WHO) monograph. The spicy flavor of ginger is due to important compounds, such as volatile essential oils and nonvolatile oleoresins (Shukla and Singh 2007). (Hollyer et al. 2002) demonstrated the effects of ginger on the stomach and intestines. The pharmacopeias of England, Thailand, Iran, and China mention ginger as an effective plant in the treatment of nausea and vomiting during pregnancy (Keating and Chez 2002; Moradi Lake, Taleb, and Saidi 2008).

Various studies have reported the influence of adding natural ingredients on the functional properties of cakes (Luo et al. 2020; Indriani et al. 2020; Lenka, Kumari, and Pradhan 2020; Taglieri et al. 2022). However, according to our knowledge, no study has been conducted about the fortification of sponge cake by green and white tea and ginger extracts. Therefore, the aim of this study was to determine the effect of green tea, white tea, and ginger extracts on the physicochemical and sensory properties of sponge cake, and to find the optimal point of different concentrations of these compounds in producing cake using response surface methodology (RSM).

Materials and methods

Materials

Ingredients used for preparing samples included wheat flour (protein content: 11.18 ± 0.68%; fiber: 2.3 ± 0.10%; fat: 0.69 ± 0.05% moisture: 12.78 ± 1.03%; and ash: 0.58 ± 0.03; Sahar company, Tehran, Iran), white sugar (Sugar Noor Company, Sepahan, Isfahan, Iran), skimmed milk powder (0/1 fat; Pegah Company, Tehran, Iran), fresh ginger rhizomes (Supermarket, Kashan, Iran), green tea and white tea (Refah Company, Lahijan, Iran), baking powder (Behfar Company, Gilan, Iran), canola oil (Ladan Company, Tehran, Iran), fresh eggs (Zardeh Talaei Company, Tehran, Iran), and tap water. All the chemicals used in this study were of analytical grade and purchased from chemical suppliers.

Extraction process

Green tea, white tea, and ginger extracts were prepared by the maceration method. The plant samples were dried and powdered using an electric grinder to increase contact surface. Powder of each plant was mixed with 70% ethanol as a solvent. For this purpose, 10 g of plant sample powder was poured into an extract container. Then, 100-mL ethanol 70% was added gradually. The obtained extract was filtered with Whatman paper No. 1, the ethanol in the extract was removed with RE300 rotary evaporator at 40°C, and the process was continued until the extract reached Brix70%. The resulting extracts were refrigerated for experiments.

Phenolic content, antioxidant activity (2,2-diphenyl-1-picryhydrazyl [DPPH] radical scavenging capacity [RDSC]), and moisture content of the white tea extract were 53.47 ± 2.41 mg gallic acid equivalent (GAE)/g dry weight of tea, 67.02 ± 3.81%, and 14.1 ± 1.03%, respectively. These values for green tea extract were 47.2 ± 2.11 mg GAE/g dry weight of tea, 58.27 ± 1.89%, and 13.6 ± 0.6%, respectively. The moisture content of ginger extract was 10.7 ± 0.81%, its total phenolic content was 24.67 ± 0.91 mg GAE/g dry weight of ginger, and its antioxidant activity was 33.4 ± 1.11%.

Preparing Sponge cake

For preparing cake batter (750 g), whole eggs and sugar were whipped in a mixer (SHMB-300, Sapaor, China) for 10 min, followed by addition of water, skimmed milk, and vanilla. Then, flour was sieved along with baking powder with or without green tea, white tea, and ginger extracts (concentrations of these extracts are given in Table 1) and added gradually to the cream and mixed slightly using a plastic spoon. Oil was added to the recipe and mixed gently to obtain cake batter. Finally, equal amount of this batter (50 g) was poured in nonstick cup muffin pans and baked for 20 min in an oven at 180–190°C (800-Memmert, Germany). Sponge cakes were allowed to cool at room temperature. These were taken out from muffin pans with care and placed in plastic zipper bags. The bags with contents were stored in a dry and cool environment prior to analyses. Pretreatment showed that adding more than 1.5% of ginger extract (i.e., 2%) caused an unpleasant spicy taste in sponge cakes. Therefore, 1.5% of ginger extract is the maximum level considered for tasty sponge cakes.

Physicochemical analyses

Sponge cakes were analyzed by pursuing the following methods described by the American Association for Clinical Chemistry (AACC, 2000): moisture

Table 1. Independent variable values of the process and their corresponding levels.

Independent variables	Symbols	–1	0	1+
Green tea extract (% w/w)	A	0	1	2
White tea extract (% w/w)	B	0	1	2
Ginger extract (% w/w)	C	0	0/75	1/5

(method 44-15A), ash (08-01), protein (method 46-13), and fat (method 30-25).

Determination of total phenolic content (TPC)

Total phenolic content of each extract was determined by the Folin–Ciocalteu micro-method. Briefly, in a 50-mL volumetric flask, 1 mL of standard solution of gallic acid, 6 mL of methanol, 2.5 mL of Folin–Ciocalteu reagent, and 5 mL of 7.5% Na_2CO_3 were added, making the final volume by adding purified water. The solutions were stored overnight and the spectrophotometric analysis was performed at λ = 765 nm (WPA S2000, UK). The total phenolic content of the samples and canola oil was expressed as GAE using the following linear equation based on the calibration curve:

$$Y = 0.008X + 0.029; R^2 = 0.094,$$

where Y is the absorbance at 760 nm and X is concentration in GAE (μg/mL) (Capannesi et al. 2000; Javanmardi et al. 2003).

Sensory evaluation

Cakes were evaluated for their sensory characteristics by 12 semi-trained panelists (six females and males each, aged 20–40 years) using a 5-point Hedonic rating test. Consumer acceptance testing was done using a successive-category scale to score the overall acceptance of the product. Samples were coded with three random digits and placed in disposable colorless plates for presenting to panelists (Stone and Sidel 2004). Panelists evaluated the sensory properties of cake samples on a 5-point scale, where 1, 2, 3, 4, and 5 represented "disliked very much," "disliked moderately," "neither liked nor disliked," "liked moderately," and "liked very much", respectively (Serin and Sayar 2016). All analyses were performed in triplicate.

Statistical analysis

In this study, the Microsoft Office 2021 software was used to draw tables and charts and Minitab Version 16 was used to analyze data and draw optimization charts. The data were presented in the form of mean ± standard deviation of three replications. Independent variables in actual and coded forms are presented in Table 1. Deviation from mean at 95% interval was applied to determine differences in results. The response surface methodology with Central Composite Design (CCD) was used to design experiments to investigate the effects of independent parameters (variables), including levels of green tea, white tea and ginger extracts. A central composite design was chosen to optimize process variables at two levels with nine components, including six replications at the central point to estimate experimental error (Table 2).

Table 2. Statistical design of central composite design.

Run	Green tea extract (w/w%)	White tea extract (w/w%)	Ginger extract (w/w%)
1	1	2	1.5
2	2	1	1.5
3	1	1	0.75
4	0	1	1.5
5	1	0	0
6	1	0	1.5
7	0	2	0.75
8	1	1	0.75
9	1	2	0
10	1	1	0.75
11	0	1	0
12	2	1	0
13	2	2	0.75
14	1	1	0.75
15	0	0	0.75
16	1	1	0.75
17	2	0	0.75

Results and discussion

Fat content

Statistical models presenting fat, moisture, protein content, total phenolic content, acidity, peroxide value, and sensory properties as a function of dependent variables are shown in Table 3, where A, B, and C are

Table 3. Variance analysis (ANOVA) of response surface model for fat content.

Source	DF	F value	*p* value (Prob > F)	Significant
Model	9	6.99	0.0058	($p < 0.05$)
Green tea extract (w/w%) (A)	1	28.26	0.0007	
White tea extract (w/w%) (B)	1	10.64	0.0115	
Ginger extract (w/w%)(C)	1	0.0679	0.8010	
AB	1	0.0925	0.7687	
AC	1	1.97	0.1978	
BC	1	2.22	0.1746	
A2	1	7.22	0.0276	
B2	1	11.84	0.0088	
C2	1	1.59	0.2427	

Table 4. Variance analysis (ANOVA) of response surface models for various parameters.

Parameters	Model	R^2	R^2-adj	R^2 pred
Fat (%)	$Y = 10.6 + 0.056A + 0.034B + 0.04A^2 + 0.051B^2$	73.17	61.74	62.0
Moisture (%)	Y = 9.00+ 0.036A + 0.012B + 0.02A2 + 0.032B2	73.17	61.74	70.12
Acidity (%)	$Y= 0.203 – 0.020 A – 0.194B$	88.67	75.93	68.32
Peroxide value (meq O_2/kg)	$Y = 0.89 – 0.11A – 0.09B + 0.08 AB + 0.03 A^2$	97.88	95.48	21.30
Total phenol (mg/g)	$Y=153.18 + 22.77 A + 25.01B + 10.65 C –3.28 AB – 3.62 AC – 4.34BC + 3.38 A^2$	99.66	99.28	59.44
Color score	$Y= 40.78 – 0.13 A – 0.13 B – 0.1C^2$	91.21	81.32	60.22
Appearance score	$Y=4.81 – 0.11A – 0.109B – 0.09 C^2$	90.82	80.50	72.00
Flavor score	$Y = 4.75 – 0.1 A – 0.08 B$	68.39	61.61	10.72
Overall acceptance score	$Y = 4.75 – 0.092 A – 0.07B$	85.22	82.05	17.11

A, B, and C are respective concentrations of green tea, white tea, and ginger extract.

respective concentrations of green tea, white tea, and ginger extracts.

Table 3 shows that the effects of green tea extract (A and A^2) and white tea extract (B and B^2) on fat content were significant ($p < 0.05$); however, the effect of other parameters on fat content was not significant ($p > 0.05$). The maximum significance was observed with green tea extract.

The correlation between the predicted values and the actual data can be used to evaluate the fitness of the response surface model (Table 4). Therefore, the model can be used to predict the fat content. According to the coefficient of determination (R^2), the proposed model showed a good fit for the obtained results. The model accuracy with R^2 and R^2-adjusted parameters is also reported in ANOVA tables. The models were checked using a numerical method, including R^2, which provided a measure of how well future outcomes are likely to be predicted by the model. In general, a lack of fit test for the model describes variation in the data around the fitted model (Trinh and Kang 2010).

According to Figure 1, the optimal concentrations of green tea (1%), white tea (1%), and ginger extracts (0.8%) were determined as significant levels of fat content in the treatments. As the levels of extracts increased, the fat content also increased, and the green tea extract had the maximum effect. Figure 1 shows good fit of the experimental data with the predicted data. Green and white tea extracts might contain carotenoids and other fat-soluble compounds that significantly affected the fat content of the product (Yuanita et al. 2022).

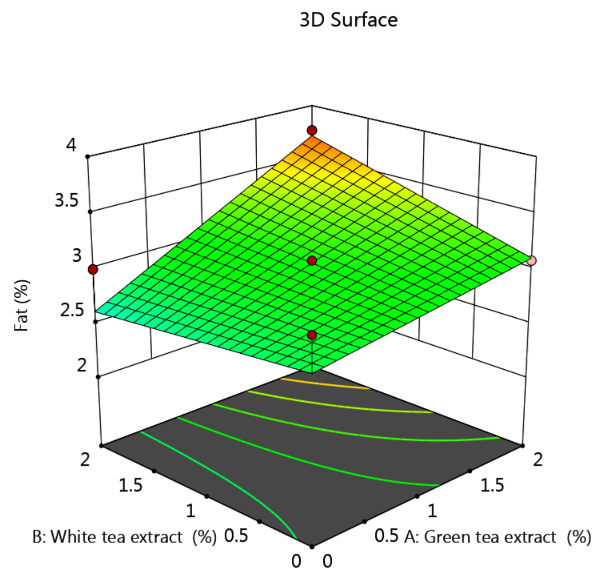

Figure 1. Effect of green tea and white tea extracts on the fat content of cake (the concentration of ginger extract was considered constant: 0.75%).

Moisture content

Table 5 shows the results of the ANOVA quadratic model using the RSM for the moisture content. The results revealed that the source of changes had no significant effect on the moisture content ($p > 0.05$).These results were in agreement with Senanayake *et al.* (2019), who reported that the addition of coconut oil meal and sesame oil meal phenolic extracts had a insignificant effect on the moisture content of cake samples (Senanayake et al. 2019). Moreover, Ma *et al.* (2020) found that the addition of vine extract did not affect the moisture content of bread crumb.

The values of R^2 and R^2-adjusted were 73.17% and 61.74%, respectively, which indicated moderate fit of the model to the experimental data (Table 4).

Table 5. Variance analysis (ANOVA) of response surface model for moisture content.

Source	DF	F value	*p* value (Prob > F)	Significant
Model	9	0.1943	0.9878	$p > 0.05$
Green tea extract (w/w%) (A)	1	0.0571	0.8172	
White tea extract (w/w%) (B)	1	0.2017	0.6653	
Ginger extract (w/w%) (C)	1	0.0034	0.9553	
AB	1	1.24	0.2979	
AC	1	0.0229	0.8835	
BC	1	0.0333	0.8598	
A^2	1	0.0117	0.9165	
B^2	1	0.0202	0.8904	
C^2	1	0.0905	0.7712	

Table 6. Variance analysis (ANOVA) of response surface model for acidity.

Source	DF	F value	*p* value (Prob > F)	Significant
Model	9	6.96	0.0059	$p < 0.05$
Green tea extract (w/w%) (A)	1	29.16	0.0006	
White tea extract (w/w%) (B)	1	25.78	0.0010	
Ginger extract (w/w%) (C)	1	0.0595	0.8134	
AB	1	0.0131	0.9119	
AC	1	0.3479	0.5716	
BC	1	1.12	0.3204	
A^2	1	2.16	0.1799	
B^2	1	2.16	0.1799	
C^2	1	1.54	0.2504	

Acidity

According to Table 6, green tea and white tea extracts had a more significant effect on acidity changes with respect to F- and *p*-values. Non-fit was also considered insignificant. According to Figure 2, with increasing concentrations of green tea and white tea extracts, the acidity of the product decreased significantly, while the ginger extract had no significant effect on acidity. Of all the extracts, green tea extract had a more significant effect on acidity, but Figure 2 shows a poor fit of the predicted experimental data. Increase in acidity with increasing concentration of extracts could be due to the acidic nature of these compounds (Kailasapathy 2006).

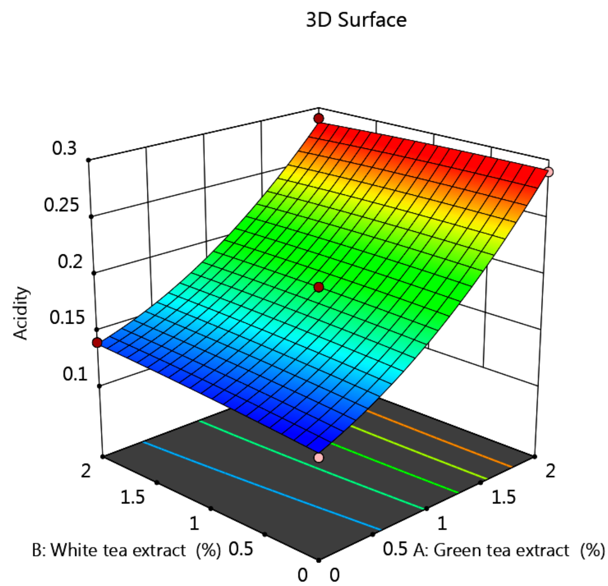

Figure 2. Effect of green tea and white tea extracts and ginger concentration on the acidity content of cake (the concentration of ginger extract was considered constant: 0.75%).

According to Table 4, R^2 and R^2_{-} adjusted were appropriate, but the model was not fully capable of predicting the data with the test results of the acidity (Table 4).

Peroxide value

According to Table 7, green (A) and white tea extracts (B), the interactions of these extracts (AB) and the square of green tea extract (A^2) had a significant effect on peroxide value changes ($p < 0.05$), among which, the effect of the green tea extract was more significant than other

Table 7. Variance analysis (ANOVA) of response surface model for peroxide value.

Source	DF	F value	*p* value (Prob > F)	Significant
Model	9	40.88	<0.0001	$p < 0.05$
Green tea extract (w/w%) (A)	1	116.30	<0.0001	
White tea extract (w/w%) (B)	1	77.47	<0.0001	
Ginger extract (w/w%) (C)	1	4.15	0.0760	
AB	1	31.31	0.0005	
AC	1	0.0000	0.9955	
BC	1	1.03	0.3409	
A^2	1	6.50	0.0342	
B^2	1	3.55	0.0963	
C^2	1	2.40	0.1596	

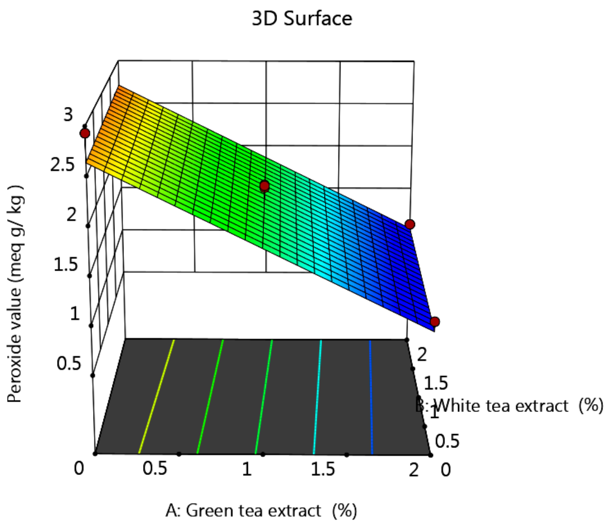

Figure 3. Effect of green tea, white tea, and ginger extracts on the peroxide value of cake (the concentration of ginger extract was considered constant: 0.75%).

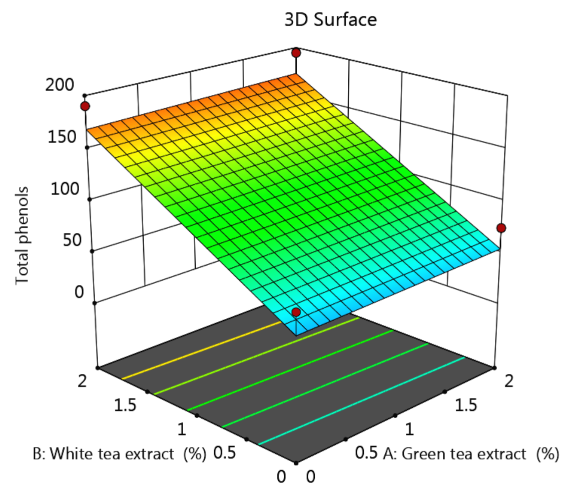

Figure 4. Effect of green tea, white tea, and ginger extracts on the total phenol content of cake (the concentration of ginger extract was considered constant: 0.75%).

extracts on the peroxide value. The F- and *p*-values represent this result well (Table 7).

R^2 and R^2-adjusted for the peroxide value were significant, which indicated optimal fit of the model to the experimental data (Table 4). Therefore, the model can be used to predict peroxide value changes. According to R^2 and R^2-adjusted, the proposed model corresponds to the obtained results. According to Figure 4, the correlation between predicted and actual data on green tea extract was higher than white tea and ginger extract. With increasing the concentration of all three extracts, the peroxide value decreased(Figure 3). This result was consistent with the findings of Khaki *et al.* (2009), who investigated the effect of chamomile extract on the quality properties of the cake. However, it was not consistent with the results of (Izzreen and Noriham 2011). The antioxidant effect of the extracts could be related to their phenolic compounds (Khoshnoudi-Nia, Sharif, and Jafari 2020). In some studies, a good linear relationship was reported between antioxidant activity and total phenols present in many plants (Sharifi and Khoshnoudi-Nia 2022; Pourshoaib, Ghatrami, and Shamekhi 2022; Timoshenkova et al. 2020).

Total Phenolic Content

Most of the changes, including concentrations of all extracts and their interactions, indicated a good fit for data in a quadratic model ($p < 0.05$). The most significant effect was observed for green tea extract (Table 8). As shown in Table 4, R^2 and R^2-adjusted demonstrated good fit of both predicted and experimental data.

Table 8. Variance analysis (ANOVA) of response surface model or total phenols.

Source	DF	F value	*p* value (Prob > F)	Significant
Model	9	261.27	<0.0001	$p < 0.05$
Green tea extract (w/w%) (A)	1	700.06	<0.0001	
White tea extract (w/w%) (B)	1	845.03	<0.0001	
Ginger extract (w/w%) (C)	1	153.37	<0.0001	
AB	1	7.72	0.0240	
AC	1	9.38	0.0155	
BC	1	13.49	0.0063	
A^2	1	0.0000	0.9968	
B^2	1	0.7145	0.4225	
C^2	1	7.88	0.0230	

As expected, the total phenolic content increased with increase in the concentration of extracts. As mentioned in the “Extraction process” of the “Materials and Methods” section, the total phenolic content of white tea and green tea extracts was higher than that of ginger extract. Hence, the highest R^2 was associated with green tea and white tea extracts. As shown in Figure 4, the model had a high fit for experimental data. The results were in agreement with the studies conducted on the effect of various extracts on the phenolic compounds of bakery products (Timoshenkova et al. 2020; Horanni and Engelhardt 2013; Izzreen and Noriham 2011).

The phenolic content and the antioxidant activity of plant extracts could be influenced by plant growth conditions, climatic conditions, and extraction methods (Onacik-Gür and Zbikowska 2022; Khoshnoudi-Nia, Sharif, and Jafari 2020). Phenolic compounds are volatile and semi-volatile polymers that are sensitive to environmental conditions, and deprivations during preparation and storage are almost unavoidable (Khoshnoudi-Nia, Sharif, and Jafari 2020). Therefore, encapsulation of plant extracts can increase and prolong their effectiveness by protecting bioactive compounds (Mahmoudi et al. 2020).

Sensory Evaluation

Color Score

Change in color indicates chemical changes in the food during thermal processes, such as Maillard reaction or non-enzymatic browning, browning, caramelization or browning of sugar, frying, and drying (Edwards 2007). Interaction between extract compounds and other cake ingredients during the preparation and storage periods affect Maillard or caramelization reactions (Gularte et al. 2012; Kırbaş, Kumcuoglu, and Tavman 2019). The color of extracts can also influence the color of bakery products (Timoshenkova et al. 2020).

As shown in Table 9, the linear effects of green tea and white tea extracts, besides the square of ginger extract, on color scores were significant ($p < 0.05$). As observed in Table 4, R^2 and R^2-adjusted were high and the model had a good fit for the experimental data.

The results showed decrease in color scores by increasing the concentration of extracts. The lightness of the cake crumb decreased with addition of extracts because of the darker color of extracts, compared to wheat flour. The results were in agreement with those described by previous studies (Senanayake et al. 2018; Timoshenkova et al. 2020). Various factors affected the crust color of cakes, such as moisture of the cake crust, intensity of Millard reactions, and presence of color compounds in cake formulation. However, the ingredients used in cake formulation mainly affected color of the cake crumb (Ajila, Leelavathi, and Rao 2008).

Appearance score

The linear effect of three extracts and the square of ginger extract significantly affected appearance scores of the product ($p < 0.05$; Table 10). As observed in Table 4, R^2 and R^2-adjusted values for the appearance were high, which indicated a significant fit for the experimental data ($p < 0.05$). This indicated that the model had a good fit for the experimental data.

Appearance scores decreased with the increasing concentrations of three extracts. The panelists reported that the size of the crumb porous was smaller in fortified samples with extracts, compared to the control sample. Studies reported a reduction trend in specific volume after addition of phenolic compounds during cake formulation because of disruption in gluten network and reduced gas-retention capacity (Mahmoudi et al. 2020; Taglieri et al. 2022; Usman et al. 2020; Kırbaş, Kumcuoglu, and Tavman 2019; Lavelli and Corti 2011).

This could be related to the presence of hydroxyl groups in phenolic compounds that may directly bond with proteins and other compositions of wheat flour and affect the texture properties of bakery products (Arı Akın et al. 2021; Elkatry et al. 2022; Sabet Ghadam et al. 2022;

Table 9. Variance analysis (ANOVA) of response surface model for color score.

Source	DF	F value	*p* value (Prob > F)	Significant
Model	9	9.22	0.0023	$p < 0.05$
Green tea extract (w/w%) (A)	1	32.37	0.0005	
White tea extract (w/w%) (B)	1	32.37	0.0005	
Ginger extract (w/w%) (C)	1	1.26	0.2950	
AB	1	0.7201	0.4208	
AC	1	1.23	0.3004	
BC	1	1.23	0.3004	
A^2	1	0.3421	0.5747	
B^2	1	0.3421	0.5747	
C^2	1	10.71	0.0113	

Table 10. Variance analysis (ANOVA) of response surface model for appearance score.

Source	DF	F value	*p* value (Prob > F)	Significant
Model	9	8.80	0.0027	$p < 0.05$
Green tea extract (w/w%) (A)	1	30.12	0.0006	
White tea extract (w/w%) (B)	1	28.16	0.0007	
Ginger extract (w/w%) (C)	1	3.00	0.1214	
AB	1	1.61	0.2402	
AC	1	0.6854	0.4317	
BC	1	0.0444	0.8383	
A^2	1	0.2244	0.6484	
B^2	1	2.30	0.1680	
C^2	1	10.51	0.0118	

Shahidi et al. 2020). Probably, for this interaction, the firmness of samples containing a higher concentration of extract was more than other samples. As observed in Table 4, the model presented based on the concentration of green tea, white tea, and the ginger square extracts revealed good appearance score of the cake sample (R^2_{adj} = 80.5, and R_{pred} = 72.00).

Flavor score

The green tea and white tea extracts significantly affects the flavor scores (p < 0.05; Table 11). The flavor scores decreased with the increasing concentration of extracts. However, ginger extract did not have a significant effect on flavor scores of cake because of its lower concentration and compatibility of its taste with cake's flavor (bakery consumers are familiar with ginger taste).

White and green tea extracts significantly affected the cake flavor. The panelists felt a slightly bitter and grassy taste in the samples containing a higher concentration of green tea and white tea extracts. These tastes could be related to the phenolic compounds of the extracts (Elkatry et al. 2022). According to Table 4, R^2 and the R^2-adjusted were very low, indicating that the model did not fit well with the experimental data. Scores given to the flavor depends on personal taste and eating habits (O'Neill, Rebane, and Lester 2004). Therefore, its prediction is less accurate than other parameters.

Table 11. Variance analysis (ANOVA) of response surface model for flavor score.

Source	DF	F value	*p* value (Prob >F)	Significant
Model	3	10.09	0.0008	p < 0.05
Green tea extract (w/w%) (A)	1	14.93	0.0017	
White tea extract (w/w%) (B)	1	9.11	0.0092	
Ginger extract (w/w%) (C)	1	1.43	0.2513	

Table 12. Variance analysis (ANOVA) of response surface model for overall acceptance score.

Source	DF	F value	*p* value (Prob > F)	Significant
Model	3	26.90	<0.0001	p < 0.05
Green tea extract (w/w%) (A)	1	43.51	<0.0001	
White tea extract (w/w%) (B)	1	28.57	0.0001	
Ginger extract (w/w%) (C)	1	0.0381	0.8480	

Overall acceptance score

Green tea and white tea extracts had significant effects on overall acceptance scores (p < 0.05; Table 12), while ginger extract had no significant effect on overall acceptance scores (p > 0.05). As observed in Table 4, R^2 and the R^2-adjusted for overall acceptance scores were high and indicated optimal fit of the model with the experimental data.

Optimization

The RSM evaluated the effects of green tea, white tea, and ginger extracts' concentrations, and interactions between the extracts, to optimize the formulation of provided functional sponge cake. The optimal values of variables were obtained by the direct search method and numerical analyses based on the criterion of desirability functions (Table 13). Optimized treatments were 1.44% for green tea extract, 1.71% for white tea extract, and 0.75% for ginger extract. Validation of statistical model was determined by performing the confirmation run. To confirm the reliability of the response surface

Table 13. Optimization criteria used in this study.

Name	Goal	Lower limit	Upper limit	Lower weight	Upper weight	Importance
A: Green tea extract	Within range	0	2	1	1	3
B: White tea extract	Within range	0	2	1	1	3
C: Ginger extract	Within range	0	1.5	1	1	3
Moisture	Within range	9.83	12.09	1	1	3
Acidity	Within range	0.12	0.29	1	1	3
Peroxide value	Minimize	1.039	2.998	1	1	5
Fat	Minimize	2.04	3.95	1	1	3
Total phenols	Maximize	14.408	194.638	1	1	5
Overall acceptance	Maximize	3	4.9	1	1	5

model, a cake with optimized factor levels was prepared and evaluated, and compared with that predicted by the regression equation. The experimental results were in good agreement with the predicted values, which confirmed the predictability and validity of the model. Therefore, the values for stability tests were very close to the experimental values demonstrating that the model is applicable, which showed that determination coefficient (R^2) = 0.99.

Conclusion

With increase in extract concentrations, the fat and moisture content increased and decreased, respectively. Green tea and white tea extracts had a more significant effect on changes in the acidity of the cakes. The acidity decreased significantly with increase in the concentration of tea extracts. Green tea extract had a more significant effect on peroxide value, and the model used for these parameters was significant. The peroxide value decreased and the total phenolic content increased with increase in the concentration of all three extracts. The linear effects of these extracts on the appearance scores were significant. R^2 and the R^2-adjusted values for the appearance were high, indicating a significant fit of the model to the experimental data. Color scores decreased with increase in the concentration of each of the three extracts. The effects of green tea and white tea extract on flavor scores were also significant. The flavor scores decreased with increase in the concentration of three extracts. R^2 and the R^2-adjusted values for the overall acceptance scores were high and indicated good fit of the model to the experimental data. Finally, it was observed that RSM was one of the techniques effective for optimizing experimental results, and significantly helping food producers, especially research and development scientists, to produce food formulations with desirable quality properties.

Author Contributions

Zohreh Pourzafar and Amir Hossein Elhamirad developed oil cakes and provided research design. Mohammad Armin exercised research analysis. Masoud Shafafi Zenozian analyzed the data statistically and reviewed the manuscript.

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Conflict of Interest

The authors declared that they had no conflict of interest.

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