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*Research Article*

# Physicochemical, Antioxidant, and Sensory Characteristics of Sponge Cake Fortified with Quinoa Flour, Oolong, and White Tea Powder

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Nowadays, there is a growing demand for healthy foods enriched with various functional bioactive ingredients. Cakes are ready-to-eat baked products consumed worldwide and are suitable for the development of functional food products. In this study, a Box–Behnken design was used to investigate the effect of three independent variables, including oolong tea powder (OT, 0–20%), white tea powder (WT, 0–15%), and quinoa flour (QF, 0–40%), on the quality characteristics of sponge cake during 21 days of storage. Following the evaluation of the model, the optimum levels of ingredients for the preparation of sponge cake were 15% WT, 17.17% OT, and 24.97% QF. Total phenolic content of 52.09 mg gallic acid/100 g, antioxidant activity of 0.068 mg/mL, overall acceptability of 4.89, lightness of 47.94, and peroxide value of 0.68 mEq/kg were obtained under optimized conditions. The growth of molds and yeasts was prevented during storage time. The hardness, gumminess, and chewiness of the optimized sponge cake improved with increasing WT, OT, and QF levels in comparison to the control. Scanning electron micrographs showed a more porous structure in optimized cake samples. In conclusion, the utilization of OT, WT, and QF as phenolic compounds in sponge cake led to an increase in its nutritional value and improved shelf life.

## 1. Introduction

Bakery products especially cakes are the most popular and widely consumed snacks in many parts of the world due to their ease of use, nutritional value, suitable organoleptic properties, and shelf life of about four weeks [1, 2]. The global cake market was valued at 46.06 USD billion in 2022 and is expected to expand to 58.76 USD billion in 2030, growing at an annual rate of 3.09% (Research and Markets. Global Cake Market-Growth, Trends, and Forecast, 2023–2030).

Sponge cake is a type of air-leavened cake made from flour, sugar, eggs, fat, and other ingredients.

Using fats in the formulation create a softer texture in the final product, but they are susceptible to lipid oxidation resulting in rancid odors, unpleasant flavors, and discoloration of products which consequently decrease safety and nutritional quality [3]. Furthermore, sponge cakes are intermediate moisture foods (with $a_w$ of 0.75–0.90) prone to microbial spoilage caused by molds that reduces their shelf-life [4]. In this regard, using antimicrobial and antioxidant compounds for maintaining the product quality are inevitable. However, consumers' willingness for healthy foods has directed the researchers and the food industry to seek for natural additives such as plant-based substances [5]. The researchers concluded that some herbal ingredients, such as oolong tea powder (OT) and white tea powder (WT) could be considered good alternatives to synthetic antioxidants [6].

Unfermented tea, made from young tea leaves or unopened buds, is called white tea [7]. White tea contains several polyphenolic compounds belonging to the catechin family. These compounds are known for their wide range of biological activities as antioxidants, antivirals, anticancer, antibacterial, and antifungal [8]. Oolong tea is a traditional type of tea obtained by the incomplete fermentation of fresh tea leaves. The main constituents of oolong tea are glutamic acid, epicatechin, alkaloids, polyphenols, flavonoids, tannins, vitamins, amino acids, minerals, proteins, polysaccharides, and organic acids with desirable antioxidant properties [9]. Due to the lack of fermentation processes in the production of white tea, the extract of this plant has more polyphenolic compounds than black tea and oolong tea and also has stronger antimicrobial properties compared to other types of tea [10]. It has been highlighted that chiffon cake containing 20% tea powders (green tea, oolong tea, and black tea powders) showed good antioxidant activity and acceptable sensory characteristics [11]. In another study, it has been shown that the addition of 10% green tea powder to sponge cake formulation improved antioxidant properties, sensory attributes, and glycemic potential [12].

Cakes have high energy and calorie with high levels of fat and sugar that can lead to health problems, but this can be tackled through fortification of cake formulation with health-promoting compounds and creating functional cake. One of the approaches used for improving nutritional profile of cake is partial replacement of wheat flour with other flour sources such as nonwheat grains, legumes, tubers, and pseudo-cereals [13]. In this context, adding quinoa flour (QF) can increase the nutritional value of wheat flour. Quinoa is a highly digestible and rich source of bioactive compounds. It contains proteins, phytosterols, omega 3, and 6 fatty acids, as well as carbohydrates with a low glycemic index, which have high benefits in reducing cardiovascular risks in humans [14]. QF contains 70% unsaturated fatty acids, including linoleic acid (38.9%) and oleic acid (27.7%). Also, quinoa proteins contain high amounts of essential amino acids, including methionine, lysine, and cystine [15]. It has been stated that due to high content of dietary fibers of quinoa, its inclusion in bread formulations improved gastrointestinal transit and decreased the level of cholesterol [16]. Quinoa flour has been used for production of gluten-free breads, biscuits, muffins, and cookies. Gluten-free cake formulated with 20 and 30% quinoa flour showed improved nutritional profile, high specific volume, low hardness, good color, and acceptable sensory properties [17]. In another study, the addition of 50% quinoa flour to cake formulation resulted in an improved rheological of cake batters and consequently the physical, chemical, nutritional, and sensory properties of cupcakes [18]. In this study, the effect of QF, OT, and WT on the physicochemical, textural, and overall acceptability of sponge cake samples was investigated, and an optimized formulation with desirable quality characteristics is presented.

## 2. Materials and Methods

*2.1. Materials.* OT and WT were purchased from local market (Refah Company, Lahijan, Iran). Dried OT and WT dried leaves were ground to a fine powder with a grinder (Moulinex-Grinder; MC300, France). QF was obtained by grinding quinoa seeds and then screening them to a particle size in the range of 300–500 $\mu$m. Other materials, including flour (Golha factory, Iran), sunflower oil (Bahar Company, Iran), baking powder (Cisaron Shimi Company, Iran), granulated sugar (Varamin sugar factory, Iran), vanilla powder (Jivadan company, Switzerland), and milk powder (Sigma, USA), were used for sponge cake preparation.

*2.2. Chemical Composition of Quinoa Flour, White, and Oolong Tea Powder.* Proximate composition of quinoa flour, white, and oolong tea powder was determined according to the methods of the Association of Official Analytical Chemists (AOAC) [19] for moisture (934.01), protein (984.13), fat (920.39), and ash (923.03). The carbohydrate content was determined by difference.

*2.3. Preparation of Sponge Cake.* The sponge cake was prepared according to Mau et al. [11] method with some modifications (Table 1). Wheat flour was replaced with different levels of OT, WT, and QF. For cake preparation, all the powdered ingredients, including wheat flour, emulsifier, sugar, salt, milk powder, baking powder, OT, WT, and QF, were poured into a container. Then, sunflower oil was added and mixed at medium speed for 5 min with a KitchenAid Professional mixer (Model 5KSM7990, Whirlpool, MI, USA). Eggs were added and mixed at high speed for 3 min. The sponge cake batter was poured into cake pans and baked at 180°C for 40 min in an electric oven (Europa, Malo, VI, Italy). The sponge cakes were allowed to cool for 1 h at room temperature (25°C) and then removed from the pans and packed in polypropylene bags. Sponge cake samples were stored in a dry, cool place away from sunlight until further evaluation.

*2.4. Formulation Optimization of Sponge Cake.* To optimize the factors affecting sponge cake quality, Design-Expert software (v.7.0.0, State-Ease, Inc., Minneapolis, USA) with Box–Behnken design (BBD) and response surface methodology (RSM) were used. The BBD/RSM is a technique applicable for optimizing the responses which are influenced by a range of process factors. In this method, the interactions of factors with the responses are evaluated and the optimal conditions for the process with the least number of experiments are determined. In BBD, three levels for each factor are considered, and the required experiments are set based on the combination of the factors [20].

Three independent variables were chosen as the WT level ($X_1$), OT level ($X_2$), and QF level ($X_3$). The coded levels, actual values of the independent variables, and a set of 17 experiments was employed with five replicates (used to estimate experimental error) of the center point are presented in Table 2.

*2.5. Determination of Viscosity and Specific Volume of Cake Batter.* The viscosity of the sponge cake batter was determined using a rotational viscometer (Brookfield, DV2T,

Table 1: Formulation of sponge cake.

| Ingredients | Amount (g) |
|---|---|
| Flour | 100 |
| Baking powder | 3.75 |
| Sucrose | 72 |
| Sodium chloride | 1.25 |
| Sunflower oil | 50 |
| Egg | 72 |
| Distilled water | 50 |
| Milk powder | 10 |

Table 2: Independent variables and their levels used in Box–Behnken design for the formulation of sponge cake samples containing different levels of OT, WT, and QF.

| Independent variables | Symbol | Coded levels −1 | Coded levels −1 | Coded levels −1 |
|---|---|---|---|---|
| WT level | $X_1$ | 0 | 7.5 | 15 |
| OT level | $X_2$ | 0 | 10 | 20 |
| QF level | $X_3$ | 0 | 20 | 40 |
| **Samples** | **Wheat flour (%)** | **OT[A] (%)** | **WT[B] (%)** | **QF[C] (%)** |
| 1 | 62.5 | 10 | 7.5 | 20 |
| 2 | 45 | 20 | 15 | 20 |
| 3 | 62.5 | 10 | 7.5 | 20 |
| 4 | 92.5 | 0 | 7.5 | 0 |
| 5 | 80 | 0 | 0 | 20 |
| 6 | 62.5 | 10 | 7.5 | 20 |
| 7 | 62.5 | 10 | 7.5 | 20 |
| 8 | 65 | 0 | 15 | 20 |
| 9 | 72.5 | 20 | 7.5 | 0 |
| 10 | 65 | 10 | 15 | 0 |
| 11 | 90 | 10 | 0 | 0 |
| 12 | 50 | 10 | 0 | 40 |
| 13 | 32.5 | 20 | 7.5 | 40 |
| 14 | 35 | 10 | 15 | 40 |
| 15 | 60 | 20 | 0 | 20 |
| 16 | 62.5 | 10 | 7.5 | 20 |
| 17 | 72.5 | 0 | 7.5 | 20 |

[A]OT: oolong tea powder; [B]WT: white tea powder; [C]QF: quinoa flour.

RV, USA). The specific volume of batter was measured by dividing the weight of 100 mL of batter by the weight of 100 mL of water [21].

### 2.6. Physicochemical Characteristics of Sponge Cake

*2.6.1. pH and Moisture Content.* The moisture of cake samples was determined by AACC method 44-15.02 (AACC, 2010), and the pH of the cake was measured using a pH meter (SP-701, Suntex, Taiwan).

*2.6.2. Color Characteristics.* The upper surface color of the cakes was measured by HunterLab (Hunter Lab, Color Flex, USA) and expressed as $L^*$ (lightness), $a^*$ (redness), and $b^*$ (yellowness). Three measurements were taken from the surface of the cakes at room temperature (25°C), and the mean value was recorded [22].

*2.6.3. Peroxide Value.* The lipid fraction was extracted from cake samples according to the method of Iranian National Standard No. 37 [23] using 200 mL n-hexane mixed with 100 g cake samples in a laboratory shaker at 25°C. After filtration and separation of the lipid fraction, the solvent was removed by a rotary evaporator at 40°C.

Peroxide value (PV) was determined by titration of lipid fractions of samples (5 g) dissolved in 30 mL of chloroform: glacial acetic acid mixture (2 : 3; v/v) in the presence of saturated potassium iodide solution and starch as an indicator with 0.02 M sodium thiosulphate solution from a purple to a slightly yellow or colorless endpoint. The results of PV were shown in milliequivalents of active oxygen per kg of fat sample (meq $O_2$/kg) and were calculated according to the following equation:

$$PV = (V - V0)9\frac{c}{m}, \tag{1}$$

where $V$ and $V0$ are the volume (mL) of sodium thiosulphate exhausted by the test sample and blank, respectively, $m$ is the mass of the lipid fraction sample (g), and $c$ is the concentration of sodium thiosulphate (mM).

*2.6.4. Total Phenolic Content and Antioxidant Activity.* The cake sample was mixed with ethanol (50% v/v) at a ratio of 1 : 10 and shaken for 24 h at room temperature (25°C). The mixture was filtered using Whatman filter paper, and then the solvent residue was removed at 40°C, and the obtained extract was kept in the refrigerator for further analysis. The method of Singleton and Rossi [24] was used for the determination of total polyphenol content in cake samples, with some modifications. 0.5 mL of extract was added to 2.5 mL of Folin–Ciocalteu reagent (10%, v/v) and 2 mL of $NaHCO_3$ solution (7.5%, w/v), vortexed for 15 seconds, kept in a dark place for 30 min at 25°C, and then the absorbance was measured at 760 nm by spectrophotometer. Total phenolic content was calculated according to the standard curve of gallic acid and expressed as mg gallic acid equivalents (GAE) per g dry weight.

The antioxidant activity of the cake extracts was measured according to the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging method described by Sangsrichan and Wanson [25]. A 0.1 mL extract sample was added to a 3.9 mL DPPH solution (0.1 g/L in ethanol) and mixed. The mixture was kept for 30 min at 25°C in a dark place until the reaction took place. Afterwards, the absorbance was measured at 517 nm by spectrophotometer, and antioxidant activity was expressed as a percentage of DPPH radical scavenging activity and calculated using the following formula:

$$\text{DPPH radical scavenging activity\%} = \left[\frac{A_{\text{DPPH}} - A_{\text{Extract}}}{A_{\text{DPPH}}}\right] \times 100, \tag{2}$$

where $A_{\text{DPPH}}$ is the absorbance value of the DPPH blank sample and $A_{\text{Ext}}$ is the absorbance value of the test solution.

*2.7. Texture Analysis.* The effect of optimum levels of OT, WT, and QF on the texture properties of sponge cake samples was evaluated using a texture analyzer (TA-XT2 Texture Analyzer, Stable Microsystems, Surrey, UK), according to Conte et al. [26]. Texture profile analysis involved compressing the sample twice and quantifying the mechanical properties, such as hardness, springiness, cohesiveness, chewiness, and resilience. Texture profile analysis was carried out under the following conditions: pretest speed = 0.8 mm/s; test speed = 1 mm/s; post-test speed = 5 mm/s; strain = 30%. 25 mm thick cake samples were cut using a cylindrical probe with a diameter of 25 mm to obtain samples with a 25 mm height and a 25 mm diameter. The mean values of ten measurements were reported. The cake crust structure was observed using a scanning electron microscope (JEOL JSM-5600LV, Tokyo, Japan). The cake samples were fixed with 3.0% glutaraldehyde in 0.1 M phosphate buffer at pH 7.2, dehydrated with ethanol, silver-coated by a sputter, and observed with a microscope.

*2.8. Molds and Yeasts Count.* Molds and yeasts count were determined according to the method of Iranian National Standard No. 10899-2 [27] using the pour plate method at 0, 7, 14, and 21 days of storage. Plates containing samples were incubated at 30°C for 72 h in an incubator, and then the number of colonies was counted.

*2.9. Sensory Evaluation.* The five-point hedonic test was used to determine the overall acceptance of sponge cakes (1 = strongly dislike, 5 = strongly like). Three-digit random codes were assigned to the samples, and 30 untrained assessors (15 male and 15 female, age between 25 and 40 years old) evaluated the overall acceptance of the samples [28].

*2.10. Statistical Analysis.* The parameter used for cake optimization was analyzed by standard response surface methodology (RSM). In this study, BBD with three variables at three levels was used to evaluate the production of sponge cake using Design-Expert software version 9.0 (Stat-Ease Inc., Minneapolis, MN, USA) [29]. All the experiments were performed in triplicate, and all data were expressed as mean ± standard deviation using one-way analysis of variance (ANOVA). Also, Duncan's multiple range test was used to identify significant differences between means at the significance level of $P < 0.05$ in the SPSS 12.0 software (SPSS Inc., Chicago, USA).

## 3. Results and Discussion

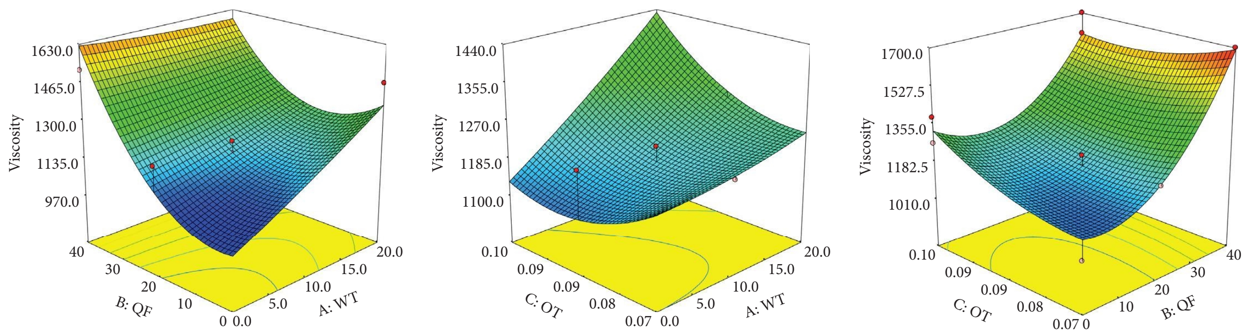
*3.1. Proximate Composition.* Table 3 demonstrates chemical composition of QF, OT, and WT. The proximate composition of quinoa flour was consistent with previous studies: moisture content of 8.9–12.41%, protein content of 13.46–18.5%, fat content of 5.01–6.60%, ash content of 2.5–2.82%, and carbohydrate content of 13.4–15.36% [17, 30, 31]. Regarding WT and OT, the results were similar to [6, 32].

*3.2. Cake Batter Viscosity and Specific Volume.* According to Figure 1, it was observed that the viscosity of the cake batter increased with increasing levels of OT, WT, and QF. Regression coefficients showed that QF had a greater effect on the viscosity and volume of cake samples compared to WT and OT.

Table 3: Proximate composition of QF, WT, and OT.

| Sample | Moisture (%) | Protein (%) | Fat (%) | Ash (%) | Carbohydrate (%) |
|---|---|---|---|---|---|
| QF | 10.38 ± 0.15 | 17.45 ± 0.24 | 5.64 ± 0.03 | 2.39 ± 0.02 | 64.13 ± 0.82 |
| WT | 7.76 ± 0.01 | 29.81 ± 0.11 | 3.82 ± 0.02 | 7.39 ± 0.03 | 50.12 ± 0.92 |
| OT | 8.11 ± 0.01 | 28.22 ± 0.09 | 4.13 ± 0.02 | 7.45 ± 0.02 | 51.67 ± 0.95 |

Values represent mean ± standard deviation for triplicate determinations. OT: oolong tea powder; WT: white tea powder; QF: quinoa flour.




(a) (b) (c)

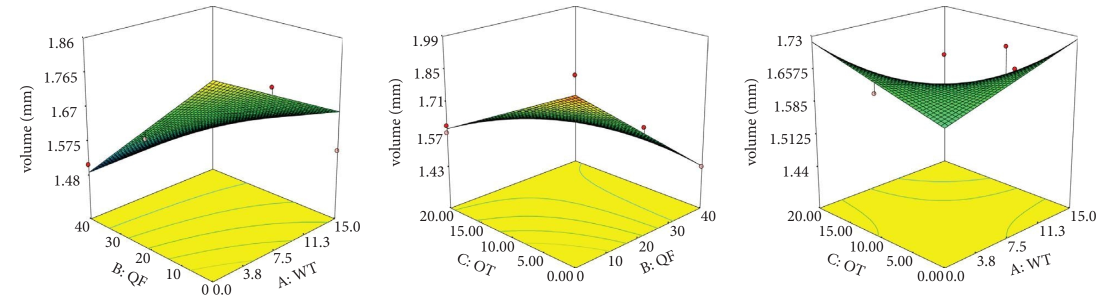
Figure 1: 3D surface plots for the effect of (a) QF and WT, (b) OT and WT, and (c) OT and QF on the viscosity of sponge cake batter. (OT: oolong tea powder; WT: white tea powder; QF: quinoa flour).

Mau et al. [11] reported that by replacing green tea, oolong, and black tea powder in the chiffon cake formulation, the viscosity of the batter increased. This could be attributed to the high water binding capacity of the fibers in OT, WT, and QF. The low lignin content and high content of cellulose and hemicellulose results in higher water binding capacity [33]. Similar results have been observed by incorporation of date powder [34], mushroom powder [35], and drumstick leaves powder [36].

With increasing the level of each of the variables, the specific volume of cake decreased (Figure 2). A suitable batter for the cake should have the ability to create an appropriate viscosity to prevent joining bubbles and leaving the surface in the initial stage of heating [33]. The reduction of specific volume can be attributed to the replacement of wheat flour with flours containing high fiber content, as these compounds weaken the three-dimensional network of gluten (gluten network structure consisting gliadins and glutenins which are connected through covalent and noncovalent bonds), which is responsible for storing carbon dioxide and water vapor during the baking process [37]. Similarly, Aydogdu et al. [38] reported a decrease in the specific volume of cake batter by increasing the level of pea, oat, apple, and lemon fibers. It was highlighted that fibers disturbed the starch-gluten matrix and caused a decrease in the gas retention capacity and a low specific volume. However, the obtained results are in contradiction with some studies reporting an increase in specific volume by an increment of fiber level, which can be attributed to the nature and level of dietary fiber used in the formulation [33].

*3.3. Physicochemical Characteristics.* The results revealed that adding QF, OT, and WT had a significant effect on the moisture content of cake samples. It was found that increasing the amount of QF led to an increase in the moisture content in different samples, which is consistent with the results of Levent [39]. QF absorbed moisture due to the presence of carbohydrates, starch, and protein in its structure [40]. Starch increased the water absorption capacity and moisture in cake samples by absorbing water in the batter formation stage. Also, the presence of protein in QF assisted to the absorption of water and increased the moisture level in cake samples [41]. As the levels of OT and WT increased, the moisture content decreased. Also, Lu et al. [42] and Mashkour et al. [12] reported a decrease in moisture content from 36 to 35% and 25 to 22% by supplementation of green tea powder in cake formulation. Furthermore, with increasing storage time, the amount of moisture showed an increasing trend (Figure 3), which could be due to the absorption of moisture from the surface of the cake samples during storage.

With increasing OT, WT, and QF in the formulation, pH showed a decreasing trend (Figure S1). This is due to the presence of high amounts of polyphenols and organic acids, such as ascorbic acid, that decrease pH due to their acidic nature [41]. pH decreased in all sponge cake samples during the storage period. This can be due to the destructive reactions of ascorbic acid in cake samples, the formation of melanoidin, furfural, and aldehyde compounds such as malondialdehyde and ketones, the oxidation of reducing sugars and triglycerides, and the degradation of amino acids. Also, the baking process at high temperatures, which was accompanied by the Maillard reaction and the presence of amino compounds and reducing sugars, resulted in a reduction of pH in cake samples [43]. It was found that QF level had the least effect on pH, while WT showed the greatest effect. The active ingredients in tea, phenolic acids, gallic acid and its derivatives, and catechins caused an acidic




(a) (b) (c)

Figure 2: 3D surface plots for the effect of (a) QF and WT, (b) OT and QF, and (c) OT and WT on the specific volume of sponge cake. (OT: oolong tea powder; WT: white tea powder; QF: quinoa flour).

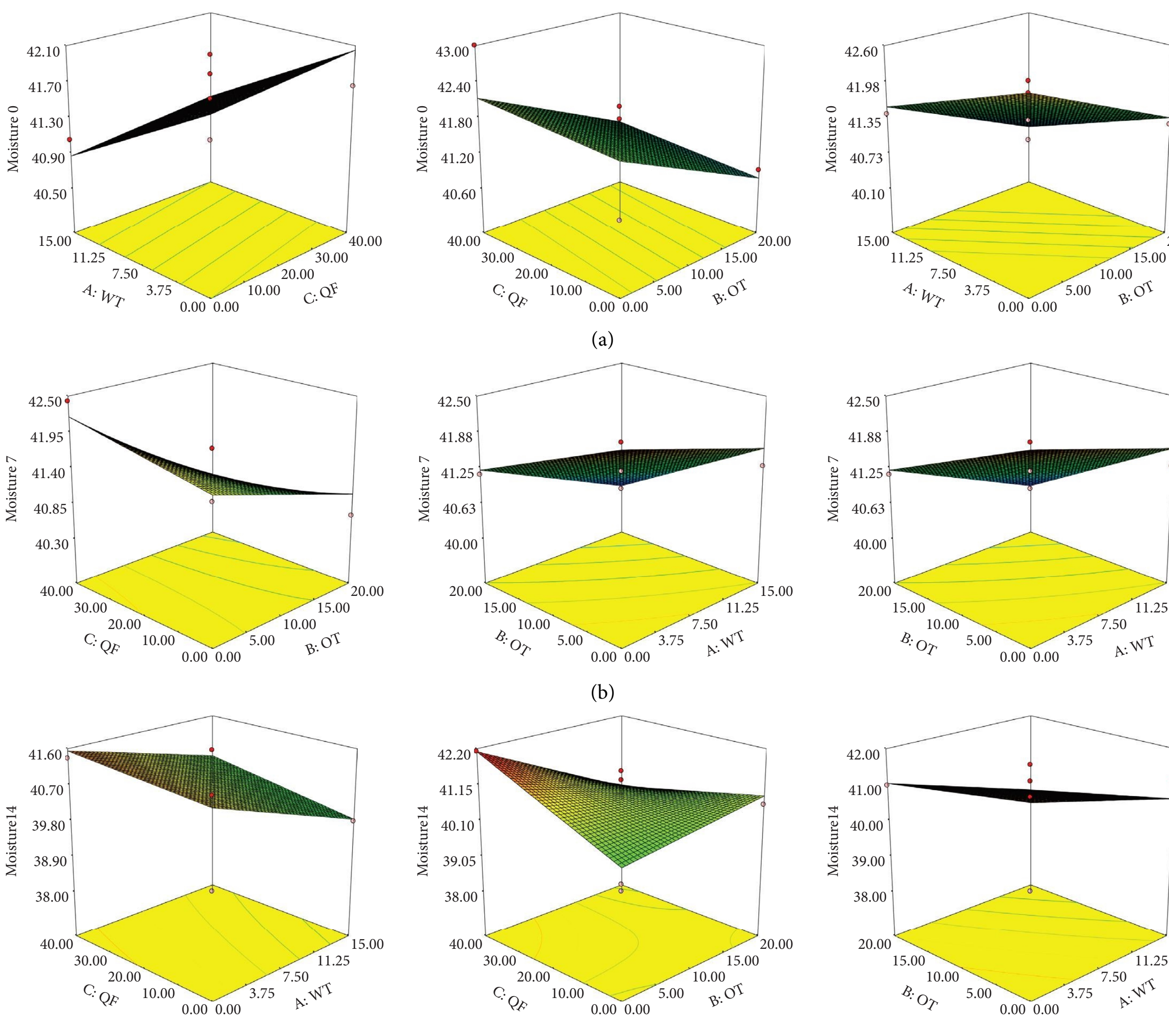
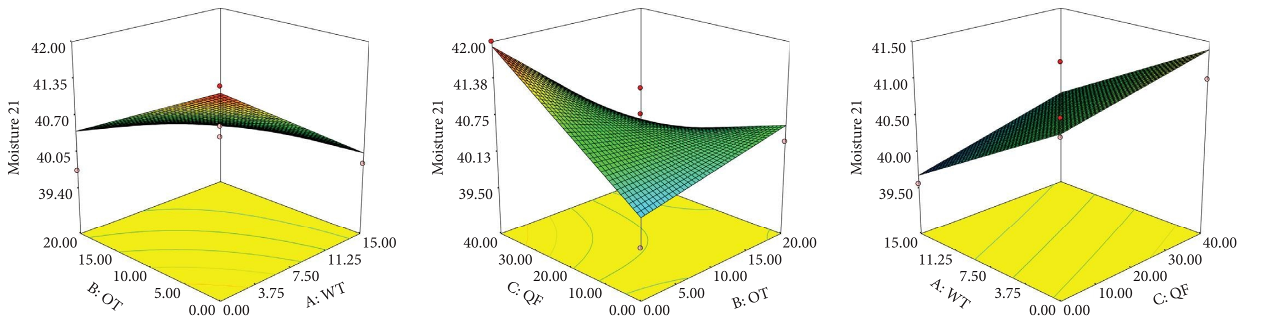



Figure 3: Continued.




(d)

Figure 3: 3D surface plots for the effect of variables on the moisture of sponge cake samples on (a) day 0, (b) day 7, (c) day 14, and (d) day 21 of storage. (OT: oolong tea powder; WT: white tea powder; QF: quinoa flour).

and antioxidant nature in sponge cake samples fortified with white and oolong tea powders. In QF-supplemented samples, phenolic compounds such as polyphenols with a hydroxyl structure reduced the pH of cake samples.

All three variables had a significant effect ($P < 0.05$) on acidity. WT and OT increased the acidity of samples (Figure 4) due to their high antioxidant compounds and various organic acids [7]. The effect of WT on acidity was greater than that of other variables. This can be attributed to the presence of high amounts of polyphenols and organic acids, such as ascorbic acid. During the storage period, acidity increased in the sponge cake samples, which can be attributed to the breakdown of simple sugars into lactic acid, lowering the pH, denaturation of simple and complex proteins, breakdown of triglycerides, and production of hydroperoxides [44].

It was observed that with increasing the level of variables, the amount of total phenolic content increased in cake samples (Figure 5). White tea contains much higher levels of phenolic compounds than oolong tea and QF due to the lack of fermentation. The phenolic compounds in cake samples decreased during shelf life. Mau et al. [11] replaced green tea, oolong, and black tea powder as a part of flour in chiffon cake and reported that with the increase in powder levels, the total phenolic content and antioxidant activity increased. In another study by Pourzafar et al. [45], increasing the level of green tea, white tea, and ginger extract increased total phenolic content of sponge cake.

According to Figure 6, it was shown that the inhibition of DPPH increased with the increase of WT, OT, and QF levels, which could be explained by the presence of high levels of phenolic compounds and the probability of hydrogen donation to free radicals [40]. Also, regression coefficients showed that WT had the greatest free radical scavenging activity, followed by OT and QF. The antioxidant properties of cake samples decreased during their shelf life. Similarly, Ahmad et al. [46] reported an increase in the inhibition of DPPH in cookies with an increase in the amount of green tea powder that was attributed to the polyphenols and natural antioxidant compounds like myristic acid and palmitic acid. Also, the incorporation of 1 g green tea powder into 100 g whole-wheat flour enhanced the antioxidant activity by 18.5%. It was stated that catechins, vitamin C, carotenoids, and selenium in green tea exhibited antioxidant activity [47]. In a study by Xu et al. [48], the addition of quinoa flour (5–15%) to wheat bread increased total phenolic content and DPPH radical scavenging activity. According to Gil et al. [49], the predominant compounds in the extractable fraction of quinoa bread were p-hydroxybenzoic acid, quercetin, and rutin, while ferulic and sinapic acids were the most abundant compounds in the hydrolyzable fraction.

With increasing the concentrations of WT, OT, and QF, the peroxide value decreased in cake samples (Figure S2). WT had a greater effect on peroxide value than OT and QF due to the presence of antioxidant compounds. As white tea has the highest amount of catechins compared to OT and QF, the samples containing the highest concentration of WT had the lowest peroxide value after 21 days of storage. With increasing storage time, the peroxide value increased, which can be attributed to the breakdown of triglycerides and the production of free fatty acids, aldehydes, and ketones during storage [50].

According to Iranian National Standard No. 2553 [51], the peroxide value for cake should not exceed 2 meq $O_2$/kg. The results indicated that the peroxide value of lipid fractions extracted from sponge cake samples was lower than this limit during 21 days, except in three samples containing the lowest levels of OT, WT, and QF. According to Taghvaei and Jafari [52], tea polyphenols are a suitable mixture of antioxidants with the capability of scavenging oxygen radicals and chelation of metal ions. Similarly, in a study by Kozlowska et al. [53], the addition of green tea extract to sponge cake resulted in a lower peroxide value in the lipid fraction after baking compared to the control samples. Addition of grapefruit peel powder to cake decreased peroxide value during 14 days of storage due to the high amounts of phenolic compounds in the powder [54].

Color is one of the most essential characteristics of foods, being supposed as a quality key that determine their acceptance. By increasing OT, WT, and QF levels, the $L^*$ value of cake samples decreased (Figure S3) and QF addition showed less impact on $L^*$ compared to the other two variables. The presence of pigments such as chlorophyll, carotenoids, and polyphenols, as well as fiber compounds with moisture retention ability caused a darker color in cake samples [9]. The samples with the highest concentration of

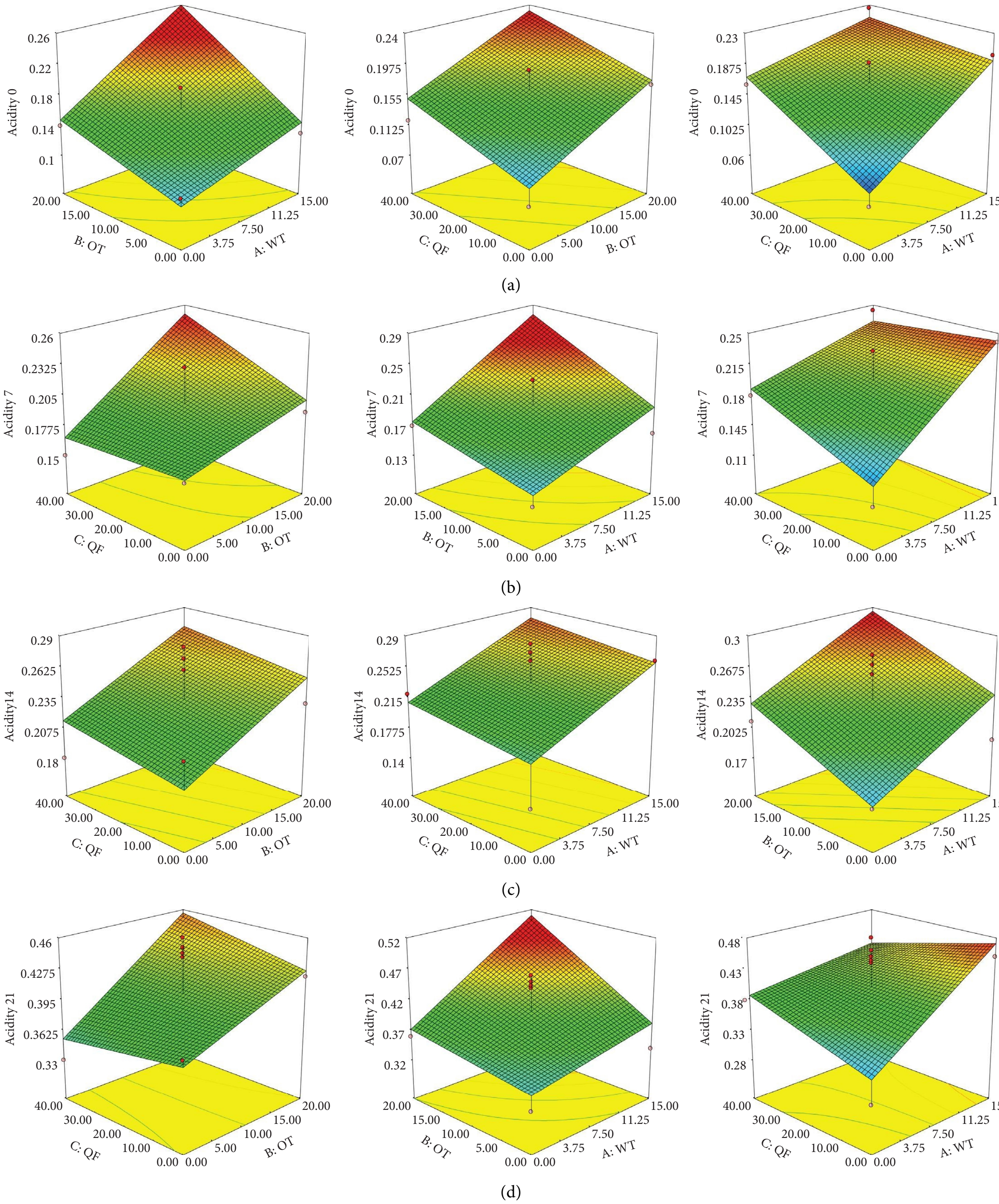



Figure 4: 3D surface plots for the effect of variables on sponge cake samples acidity on (a) day 0, (b) day 7, (c) day 14, and (d) day 21 of storage. (OT: oolong tea powder; WT: white tea powder; QF: quinoa flour).

WT showed the highest decrease in $L^*$. Also, during the shelf life, the $L^*$ of all samples decreased, which could be attributed to the oxidation of fats and ascorbic acid and the decomposition reactions of amino and organic acids [55]. Singh et al. [56] reported a decrease in the $L^*$ value in the crust of gluten-free and egg-free muffins using modified rice flour and jambolan fruit pulp in the presence or absence of xanthan gum. Similar results have been obtained by incorporation of *Clitoria ternatea* extract [3], olive stone powder [33], dried button mushroom powder [35], drumstick leaves powder [36], *Rubus coreanus* powder [57], and jujube powder [58] to sponge cake formulation.

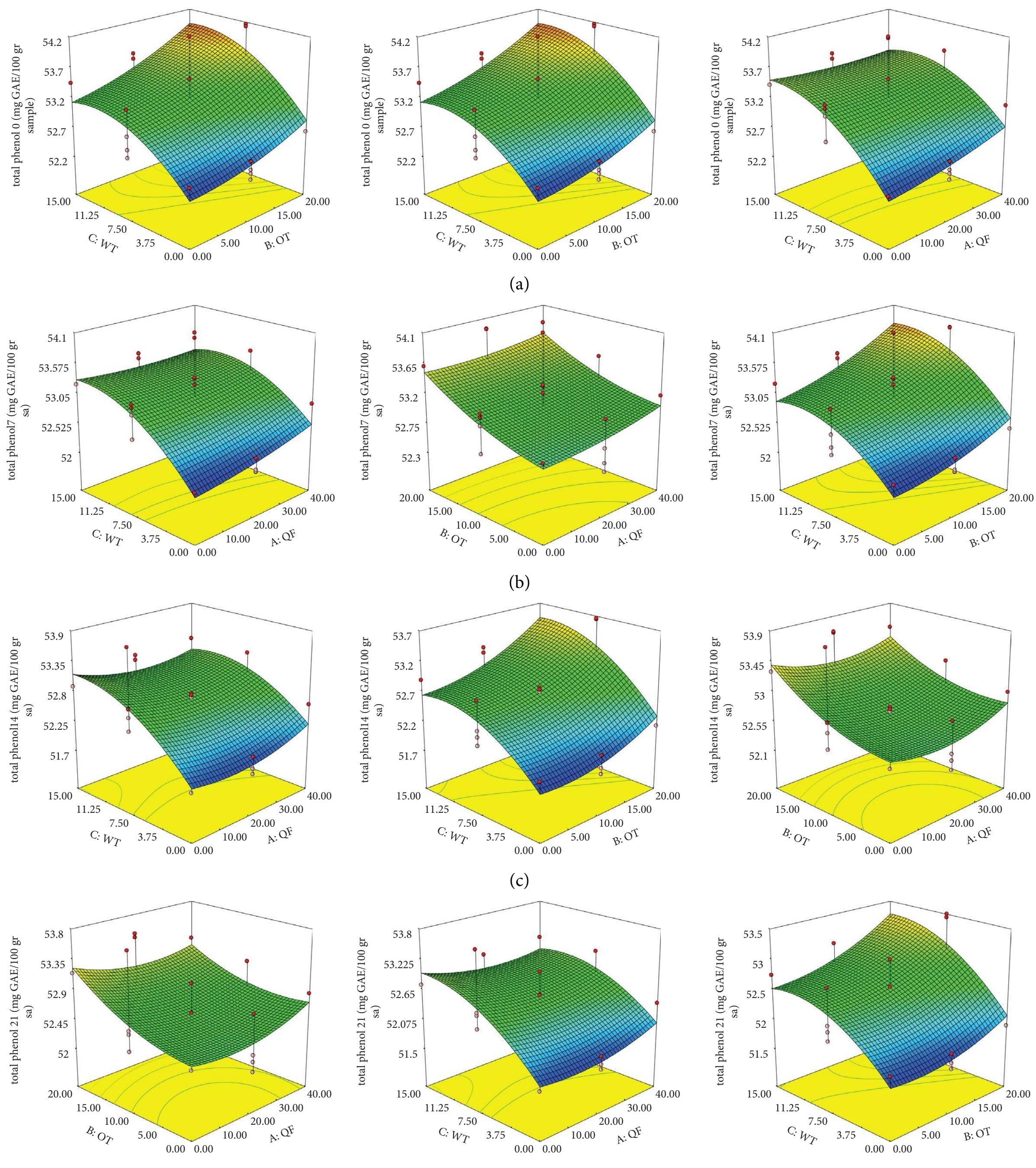



Figure 5: 3D surface plots for the effect of variables on total phenolic content of sponge cake samples (a) day 0, (b) day 7, (c) day 14, and (d) day 21 of storage. (OT: oolong tea powder; WT: white tea powder; QF: quinoa flour).

The results showed that $a^*$ value increased in different cake samples over time (Figure S4). This can be explained by the production of by-products from browning reactions, such as melanoidin and furfural, which increased $a^*$ in sponge cake samples [11]. Increasing WT and OT level led to a decrease of $a^*$ value and a greener cake, while increasing QF level resulted in an increase of $a^*$ value and redness in the sample. According to Bozdogan et al. [18], the increasing redness of cake crumb fortified with quinoa flour could be associated with its natural color. Moreover, redness in the crust of cakes can be ascribed to the caramelization and Maillard reactions. An increased protein content of cake as a result of adding quinoa flour reacting with reducing sugars during baking increased the speed and intensity of browning reactions and formation of dark-brown compounds [56].

Stikic et al. [59] added 20% QF to the bread formulation and obtained a product with a reddish-yellow color and a crispy texture. This is in agreement with previous work of El-Sohaimy et al. [15] and El-Sohaimy et al. [60], who reported that increasing the level of quinoa flour in bread

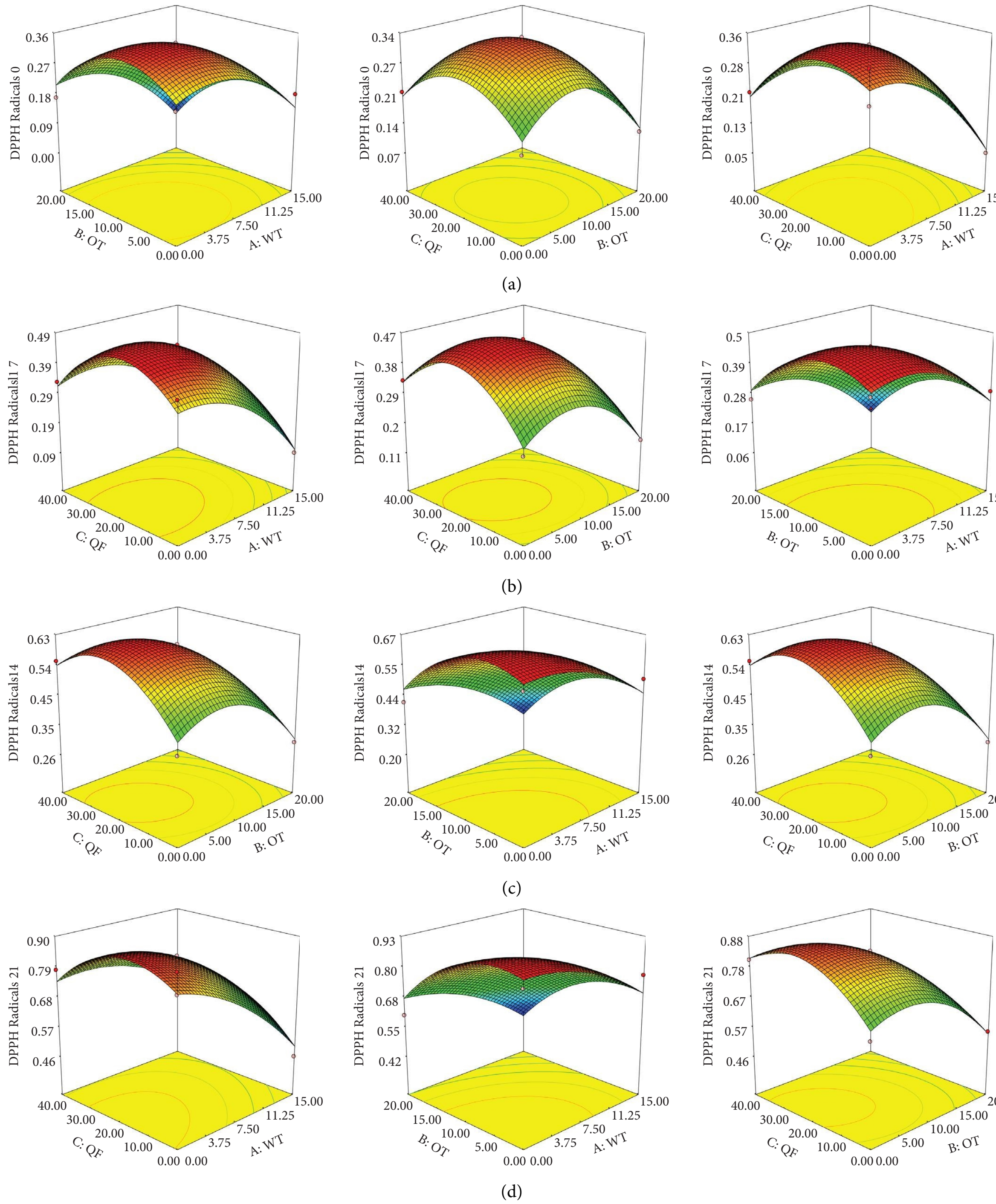



Figure 6: 3D surface plots for the effect of variables on antioxidant activity of sponge cake samples (a) day 0, (b) day 7, (c) day 14, and (d) day 21 of storage. (OT: oolong tea powder; WT: white tea powder; QF: quinoa flour).

formulation increased redness of bread due to high content of protein. $a^*$ value increased during the shelf life as a consequence of a decrease in humidity and increase in the levels of pigments, such as furfural and methyl furfural.

The trend of changes in $b^*$ value was similar to that of $a^*$ value, and the variables (QF, WT, and OT) reduced the $b^*$ value of cake samples. Tea powders decreased the $L^*$, $a^*$, and $b^*$ values, while QF reduced the $L^*$, but caused the cake samples to turn yellow and red. In accordance with this result, addition of green tea powder to whole-wheat flour pan bread decreased $b^*$ value. It was stated that green tea powder influenced bread crumb as a result of oxidation of catechins and formation of compounds with deep color such as theaflavins, thearubigins, and theabrownines, during high temperatures in the baking process. Also, break-down of chlorophyll and generation of magnesium chlorophyll with brown color affected the color of bread [47].

*3.4. Molds and Yeasts Counts.* Molds and yeast growth were not detected in most of the sponge cake samples during the storage period, which can be due to the presence of antimicrobial compounds in the samples, packaging in impermeable plastics to oxygen and moisture, as well as storage temperature. According to Iranian National Standard No. 10889-2 [27], the number of mold and yeast in cake samples should be below 100, and the amount of mold and yeast in the samples was within the allowable range after 21 days of storage. Polyphenols in oolong tea and white tea produce hydrogen peroxide under certain conditions and have an inhibitory effect on microorganisms [44]. It should be noted that the synergistic effect of the phenolic compounds plays an important role in reducing the microbial load. In a study by Wu et al. [55], adding instant green tea powder to the sponge cake resulted in a decrease in mold and yeast counts compared to the control sample.

*3.5. Sensory Evaluation.* The results showed that with increasing OT, WT, and QF, the overall acceptability of cake samples decreased (Figure S5). Low levels of OT, WT, and QF increased overall acceptability, while at higher levels, a decreasing trend was detected. It was also found that samples containing low levels of QF received higher scores, and samples with high levels of WT received lower scores. Similarly, Wu et al. [55] reported that adding 12.5% instant tea powder to cake formulation resulted in the highest overall acceptability and an excessive amount of tea powder lowered the acceptability score of the product. Mashkour et al. [12] reported that cake samples with 10% green tea powder received the highest score in overall acceptability. Rothschild et al. [61] studied the effect of QF on the consumers' overall acceptability of a gluten-free cake formulation. They reported that no significant differences were observed between commercial chocolate cake, and cakes containing QF, which had the highest sensory scores. Also, Demir and Kilinç [14] stated that the addition of QF improved all sensory properties of cookie samples. In a study by Mohammad et al. [41], substitution of wheat flour with 25% quinoa flour increased the sensory acceptability of sponge cake.

*3.6. Optimization of Sponge Cake Preparation.* Optimum operating conditions were performed to determine the optimized sponge cake sample using the numerical optimization technique with Design-Expert software (Figure 7). For this purpose, the optimum conditions were first selected by the software. The response surface method was able to estimate the optimized formulation of sponge cake samples with high desirability (0.95). Optimum conditions for sponge cake were determined as 15% WT, 17.17% OT, and 24.97% QF which was equivalent to the desirability of 0.95, and total phenolic content of 52.09 mg gallic acid/100 g sample, antioxidant activity of 0.068 mg/mL, overall acceptability of 4.89, lightness of 47.94, and peroxide value of 0.68 mEq/kg. Therefore, using this optimized formulation, the optimum sponge cake was produced, and its texture properties were compared with the control sample.

*3.7. Microstructure and Texture Analysis.* According to the scanning electron microscopy (SEM) graphs for control and optimized samples (Figure 8), there was a low number of pores in the microstructure of the control sample, but enriched cake samples had a more porous structure. In control samples, a lump was observed on the crust, which could be due to the presence of sodium bicarbonate and the baking process at a temperature above 180°C, which was accompanied by moisture loss. In the optimized samples, in addition to this lump, pores were observed in all areas of the product, which was due to the effect of WT, OT, and QF on the crust and texture of the cake sample.

Texture analysis of control and optimized cake samples (Table 4) showed that the hardness of optimized cake samples increased and the texture strength improved, which can be related to the reduction of moisture in the samples. According to Premi and Sharma [36], the interactions between fibers and other components such as gluten, starch, and fat in batter affected the hardness of sponge cake. The fibers decreased air entrapment and prevented sponge cake expansion during baking. According to Mashkour et al. [12], increasing the green tea powder replacement increases the phenolic compounds, which leads to more hydrogen bond formation between protein molecules and phenolic groups and consequently a harder texture. The hardness of cake is directly related to its density and inversely correlated with specific volume [33]. The results showed that by increasing QF, the texture hardness increased, which could be explained by the weakening of the gluten network [62]. Increased hardness of the cake texture due to the increase in the level of QF is directly related to the high viscosity of the batter [56]. Cohesiveness indicates the degree of internal resistance of food tissue. The results showed that cohesiveness was lower in optimized cake samples compared to the control. Similarly, Pasukamonset et al. [3] reported a significant decrease in the cohesiveness of sponge cake fortified with *Clitoria ternatea* compared to control sample.

Gumminess is calculated by multiplying hardness and cohesiveness. The results showed that gumminess increased in optimized cake sample compared to control. This result is in agreement with previous studies illustrating that sponge cake containing tea powder and chickpea flour caused an increase in gumminess [11, 63]. The extent of recovery between the first and second compression represents the elasticity of sample cakes and is described as the springiness value. Springiness was higher in optimized cake sample compared to control. On the contrary, adding *Clitoria ternatea* powder and green tea powder to sponge cake decreased springiness that was attributed to the weaker and less elastic gluten structure of the cakes caused by the polyphenols [3]. Chewiness demonstrates the amount of energy required to disintegrate a food for swallowing, indicating the

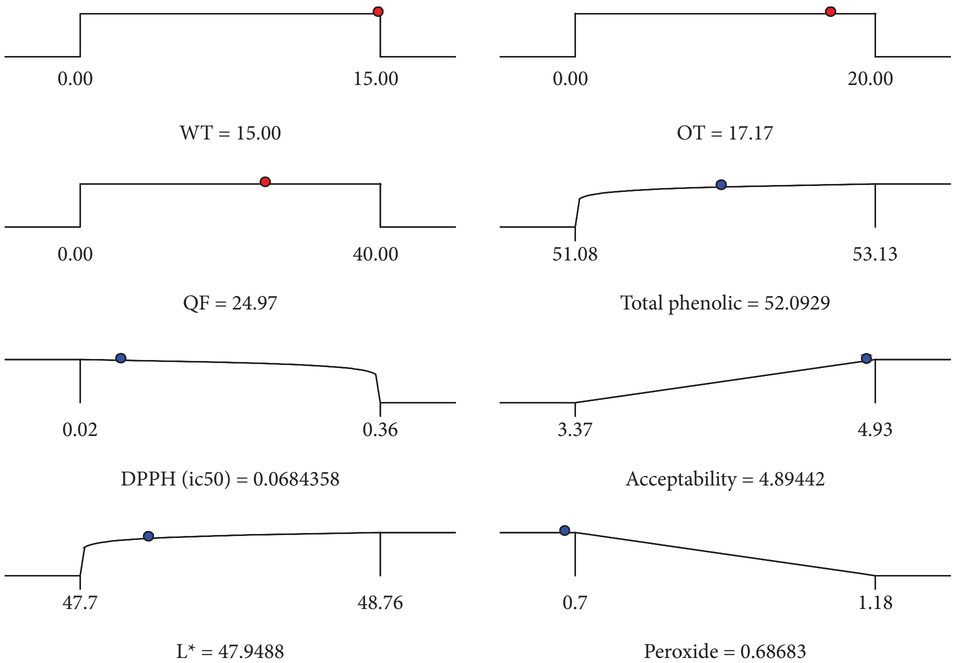
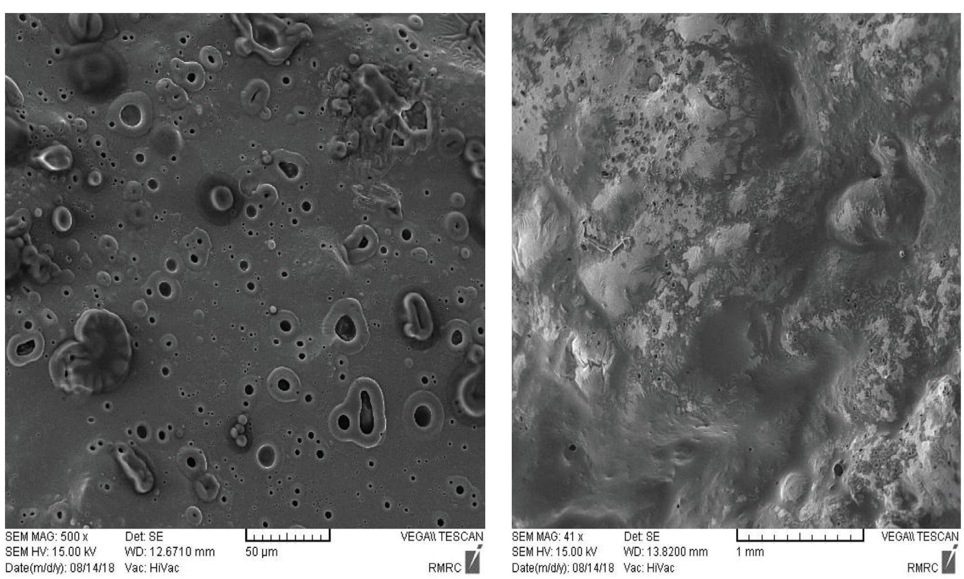
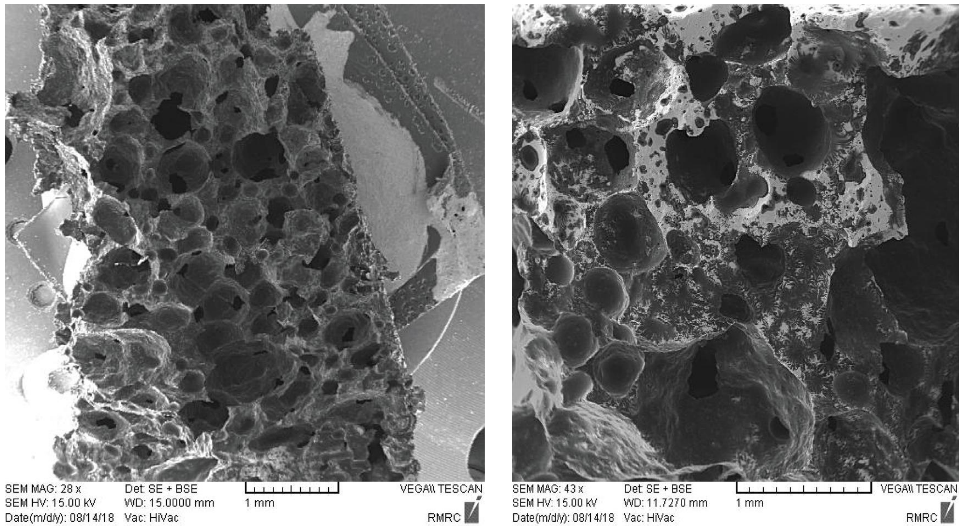



Figure 7: Two-dimensional results obtained from the process of optimizing sponge cake samples containing OT, WT, and QF. (OT: oolong tea powder; WT: white tea powder; QF: quinoa flour).




(a) (b)

Figure 8: Continued.




(c) (d)

Figure 8: Scanning electron microscope images of: (a) the crust of optimum samples fortified with oolong and white tea powder and quinoa flour; (b) crust of control sample; (c) cross-section of optimum sample enriched with oolong and white tea powder and quinoa flour; and (d) cross-section of control sample.

Table 4: Texture analysis of control and optimized sponge cake samples.

| Samples | Hardness (g) | Cohesiveness | Gumminess (g) | Springiness | Chewiness (mJ) |
|---|---|---|---|---|---|
| Control[A] | 215 | 0.67 | 144 | 12.69 | 17.91 |
| Optimum[B] | 317 | 0.61 | 233 | 12.97 | 29.70 |

[A]Control: sponge cake sample contains 100% wheat flour. [B]Optimum: sponge cake sample contains 42.86% wheat flour, 17.17% OT (oolong tea powder), 15% WT (white tea powder) and 24.97% QF (quinoa flour).

rate of cake breakdown. The chewiness improved in the optimized sample compared to the control sample. According to Qasem et al. [64], the chewiness and hardness of samples are strongly interrelated and they follow similar trend.

## 4. Conclusions

A novel formulation of sponge cake with quinoa flour, white and oolong tea powders was developed. Incorporation of these ingredients improved quality characteristics of sponge cake. The presence of phenolic compounds in the powders contributed to the reduction of peroxide value and microbial growth during storage. Also, the cake samples produced by the optimized formulation (15% WT, 17.17% OT, and 24.97% QF) showed improved hardness, gumminess, and chewiness compared to control samples. Therefore, the use of quinoa flour, white, and oolong tea powders represents a new direction for the development of functional sponge cake with improved nutritional profile, antioxidant activity, and potential health benefits. Further research could investigate in vitro digestibility and potential health effects of fortified sponge cake and the feasibility for commercial production. In addition, quinoa flour, white, and oolong tea powders can be used in other bakery products such as bread, cookie, and biscuit.

## Abbreviations

BBD: Box–Behnken design
RSM: Response surface methodology
PV: Peroxide value
OT: Oolong tea powder
WT: White tea powder
QF: Quinoa flour
GAE: Gallic acid equivalents
DPPH: 2,2-Diphenyl-1-picrylhydrazyl
SEM: Scanning electron microscopy.

## Data Availability

The data collected to support this study are included within the article.

## Additional Points

*Highlights*. (i) A novel functional sponge cake using oolong tea powder, white tea powder, and quinoa flour was developed. (ii) Increasing the levels of WT, OT, and QF improved texture properties of the optimized sponge cake compared to control. (iii). Incorporation of OT, WT, and QF in combination could improve the quality, safety, and sensory characteristics of sponge cake.

## Ethical Approval

This research has received ethical approval from Shahid Beheshti University of Medical Sciences.

## Conflicts of Interest

The authors declare that they no conflicts of interest.

## Authors' Contributions

F.F. and M.M. conceptualized the study. A.A. performed investigation. M.M. and N.K. contributed to formal analysis. F.F. performed data curation. A.A. wrote the original draft. F.F. and M.M. reviewed and edited the manuscript. All authors have read and agreed to the finalized version of the manuscript.

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## Supplementary Materials

The supplementary material file included five figures presenting 3D surface plots for the effects of different variables on pH, peroxide value, $L^*$, $a^*$, and overall acceptability of sponge cake samples during 21 days of storage. (*Supplementary Materials*)

## References

[1] M. Mohammadi, N. Khorshidian, M. Yousefi, and A. M. Khaneghah, "Physicochemical, rheological, and sensory properties of gluten-free cookie produced by flour of chestnut, date seed, and modified starch," *Journal of Food Quality*, vol. 2022, Article ID 5159084, 10 pages, 2022.

[2] M. O. Aljobair, "Effect of chia seed as egg replacer on quality, nutritional value, and sensory acceptability of sponge cake," *Journal of Food Quality*, vol. 2022, Article ID 9673074, 11 pages, 2022.

[3] P. Pasukamonset, T. Pumalee, N. Sanguansuk et al., "Physicochemical, antioxidant and sensory characteristics of sponge cakes fortified with Clitoria ternatea extract," *Journal of Food Science and Technology*, vol. 55, no. 8, pp. 2881–2889, 2018.

[4] M. Gonda, C. Rufo, G. Cecchetto, and S. Vero, "Evaluation of different hurdles on *Penicillium crustosum* growth in sponge cakes by means of a specific real time PCR," *Journal of Food Science and Technology*, vol. 56, no. 4, pp. 2195–2204, 2019.

[5] E. Zang, L. Jiang, H. Cui et al., "Only plant-based food additives: an overview on application, safety, and key challenges in the food industry," *Food Reviews International*, vol. 39, no. 8, pp. 5132–5163, 2023.

[6] D. Lelita and A. Putri, "Antioxidant capacity of white tea (*Camelia sinensis*) extract: compared to green, oolong and black tea," in *IOP Conference Series: Earth and Environmental Science*, Semarang, Indonesia, November 2019.

[7] M. Wong, S. Sirisena, and K. Ng, "Phytochemical profile of differently processed tea: a review," *Journal of Food Science*, vol. 87, no. 5, pp. 1925–1942, 2022.

[8] S. Bag, A. Mondal, A. Majumder, and A. Banik, "Tea and its phytochemicals: hidden health benefits and modulation of signaling cascade by phytochemicals," *Food Chemistry*, vol. 371, Article ID 131098, 2022.

[9] K. W. Ng, Z. J. Cao, H. B. Chen, Z. Z. Zhao, L. Zhu, and T. Yi, "Oolong tea: a critical review of processing methods, chemical composition, health effects, and risk," *Critical Reviews in Food Science and Nutrition*, vol. 58, no. 17, pp. 2957–2980, 2018.

[10] P. Muniandy, A. B. Shori, and A. S. Baba, "Influence of green, white and black tea addition on the antioxidant activity of probiotic yogurt during refrigerated storage," *Food Packaging and Shelf Life*, vol. 8, pp. 1–8, 2016.

[11] J. L. Mau, T. M. Lu, C. C. Lee, L. Y. Lin, C. H. Cheng, and S. D. Lin, "Physicochemical, antioxidant and sensory characteristics of chiffon cakes fortified with various tea powders," *Journal of Food Processing and Preservation*, vol. 39, no. 5, pp. 443–450, 2015.

[12] M. Mashkour, A. Azari, M. Hashemi Shahraki, M. Raeisi, and M. Ebrahimi, "Effect of green tea powder on physicochemical properties and glycemic potential of sponge cake," *Journal of Food Quality*, vol. 2022, Article ID 1065710, 7 pages, 2022.

[13] M. Shobeiri, A. H. Elhami Rad, Z. Sheikholeslami, M. S. Zenozian, and M. R. Saeedi Asl, "The effects of quinoa and okra incorporation on the quality of diet cake," *Food Science and Technology International*, vol. 29, no. 4, pp. 417–427, 2023.

[14] M. K. Demir and M. Kilinç, "Utilization of quinoa flour in cookie production," *International Food Research Journal*, vol. 24, no. 6, pp. 2394–2401, 2017.

[15] S. El-Sohaimy, M. Shehata, T. Mehany, and M. Zeitoun, "Nutritional, physicochemical, and sensorial evaluation of flat bread supplemented with quinoa flour," *International Journal of Food Science*, vol. 2019, Article ID 4686727, 15 pages, 2019.

[16] J. Ballester-Sánchez, M. C. Millán-Linares, M. T. Fernández-Espinar, and C. M. Haros, "Development of healthy, nutritious bakery products by incorporation of quinoa," *Foods*, vol. 8, no. 9, p. 379, 2019.

[17] R. Hamzehpour and A. A. Dastgerdi, "The Effects of quinoa and amaranth flour on the qualitative characteristics of gluten-free cakes," *International Journal of Food Science*, vol. 2023, Article ID 6042636, 6 pages, 2023.

[18] N. Bozdogan, S. Kumcuoglu, and S. Tavman, "Investigation of the effects of using quinoa flour on gluten-free cake batters and cake properties," *Journal of Food Science and Technology*, vol. 56, no. 2, pp. 683–694, 2019.

[19] AOAC, *Official Methods of Analysis. Association of Official Analytical Chemists*, AOAC, Washington, DC, USA, 2002.

[20] C. Demirel, A. Kabutey, D. Herák, A. Sedlaček, Č. Mizera, and O. Dajbych, "Using Box–Behnken design coupled with response surface methodology for optimizing rapeseed oil expression parameters under heating and freezing conditions," *Processes*, vol. 10, no. 3, p. 490, 2022.

[21] K. Y. Song, O. Hyeonbin, Y. Zhang, and Y. S. Kim, "Quality characteristics and antioxidant properties of sponge cakes containing black carrot (Daucus carota ssp. sativus var. atrorubens Alef) flour," *Progress in Nutrition*, vol. 18, no. 2, pp. 176–183, 2016.

[22] M. Azizi, F. Fazeli, M. Mohammadi, and A. Mousavi Khaneghah, "Incorporation of essential oils in Iranian traditional animal oil: an assessment of physicochemical and sensory assessment," *Italian Journal of Food Science*, vol. 33, no. SP1, pp. 69–77, 2021.

[23] Iranian National Standardizatio Organization, *Biscuit- Specifications and Test Methods*, INSO, Industrial City, Iran, 8th edition, 2019.

[24] V. L. Singleton and J. A. Rossi, "Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents," *American Journal of Enology and Viticulture*, vol. 16, no. 3, pp. 144–158, 1965.

[25] S. Sangsrichan and W. Wanson, "The antioxidant capacity of honey samples collected in the north part of Thailand in relationship with its total polyphenol," *KMITL Science and Technology Journal*, vol. 8, no. 2, pp. 68–73, 2008.

[26] P. Conte, A. Del Caro, P. P. Urgeghe et al., "Nutritional and aroma improvement of gluten-free bread: is bee pollen effective?" *Lebensmittel-Wissenschaft and Technologie*, vol. 118, Article ID 108711, 2020.

[27] Iranian National Standardizatio Organization, "Microbiology of food and animal feeding stuffs-Horizontal method for the enumeration of yeasts and moulds," *Part 2: colony count technique in products with water activity less than or equal to 0.95*, pp. 10899–10901, INSO, Industrial City, Iran, 1st edition, 2008.

[28] M. Puchol-Miquel, C. Palomares, I. Fernández-Segovia, J. M. Barat, and É. Perez-Esteve, "Effect of the type and degree of alkalization of cocoa powder on the physico-chemical and sensory properties of sponge cakes," *LWT-Food Science and Technology*, vol. 152, Article ID 112241, 2021.

[29] M. Yolmeh and S. M. Jafari, "Applications of response surface methodology in the food industry processes," *Food and Bioprocess Technology*, vol. 10, no. 3, pp. 413–433, 2017.

[30] B. Contreras-Jiménez, O. L. Torres-Vargas, and M. E. Rodríguez-García, "Physicochemical characterization of quinoa (Chenopodium quinoa) flour and isolated starch," *Food Chemistry*, vol. 298, Article ID 124982, 2019.

[31] C. A. Curti, P. M. Vidal, R. N. Curti, and A. N. Ramón, "Chemical characterization, texture and consumer acceptability of yogurts supplemented with quinoa flour," *Food Science and Technology*, vol. 37, no. 4, pp. 627–631, 2017.

[32] E. Uzodinma, E. Onwurafor, and L. Amie, "Effect of processing methods on nutritional, phytochemical and sensory properties of powdered herbal tea from bushbuck leaf (*Gongronema latifolium*)," *Nigerian Food Journal*, vol. 36, no. 2, pp. 73–82, 2019.

[33] R. Jahanbakhshi and S. Ansari, "Physicochemical properties of sponge cake fortified by olive stone powder," *Journal of Food Quality*, vol. 2020, pp. 1–11, 2020.

[34] N. M. Alkehayez, A. H. Alshawi, and M. O. Aljobair, "The physicochemical composition and sensory attributes of sponge cake fortification with date powder," *Food Science and Technology*, vol. 42, Article ID 92522, p. 6, 2022.

[35] B. Arora, S. Kamal, and V. P. Sharma, "Sensory, nutritional and quality attributes of sponge cake supplemented with mushroom (Agaricus bisporus) powder," *Nutrition and Food Science*, vol. 47, no. 4, pp. 578–590, 2017.

[36] M. Premi and H. Sharma, "Effect of drumstick leaves powder on the rheological, micro-structural and physico-functional properties of sponge cake and batter," *Journal of Food Measurement and Characterization*, vol. 12, no. 1, pp. 11–21, 2018.

[37] M. Majzoobi, Z. V. Poor, J. Jamalian, and A. Farahnaky, "Improvement of the quality of gluten-free sponge cake using different levels and particle sizes of carrot pomace powder," *International Journal of Food Science and Technology*, vol. 51, no. 6, pp. 1369–1377, 2016.

[38] A. Aydogdu, G. Sumnu, and S. Sahin, "Effects of addition of different fibers on rheological characteristics of cake batter and quality of cakes," *Journal of Food Science and Technology*, vol. 55, no. 2, pp. 667–677, 2018.

[39] H. Levent, "The effects of chia (Salvia hispanica L.) and quinoa flours on the quality of rice flour and starch based-cakes," *Gıda*, vol. 43, no. 4, pp. 644–654, 2018.

[40] K. C. Miranda-Ramos and C. M. Haros, "Combined effect of chia, quinoa and amaranth incorporation on the physico-chemical, nutritional and functional quality of fresh bread," *Foods*, vol. 9, no. 12, p. 22, 2020.

[41] A. A. Mohammad, H. M. Amer, F. M. Mehaya, and M. S. Hussein, "Quinoa as non–wheat flour source and its utilization in sponge cake production: cultivation, nutritional and technological assessment," *Sciences*, vol. 9, no. 2, pp. 332–340, 2019.

[42] T. M. Lu, C. C. Lee, J. L. Mau, and S. D. Lin, "Quality and antioxidant property of green tea sponge cake," *Food Chemistry*, vol. 119, no. 3, pp. 1090–1095, 2010.

[43] M. Vatankhah, F. Garavand, B. Mohammadi, and A. Elhamirad, "Quality attributes of reduced-sugar Iranian traditional sweet bread containing stevioside," *Journal of Food Measurement and Characterization*, vol. 11, no. 3, pp. 1233–1239, 2017.

[44] D. Atalay and H. S. Erge, "Determination of some physical and chemical properties of white, green and black teas (Camellia sinensis)," *Gida*, vol. 42, no. 5, pp. 494–504, 2017.

[45] Z. Pourzafar, A. H. Elhamirad, M. S. Zenoozian, and M. Armin, "Optimization of producing functional sponge cake using a combination extract of green tea, white tea, and ginger," *Italian Journal of Food Science*, vol. 35, no. 2, pp. 33–43, 2023.

[46] M. Ahmad, W. N. Baba, T. Awani et al., "Effect of green tea powder on thermal, rheological and functional properties of wheat flour and physical, nutraceutical and sensory analysis of cookies," *Journal of Food Science and Technology*, vol. 52, no. 9, pp. 5799–5807, 2015.

[47] J. Ning, G. G. Hou, J. Sun, X. Wan, and A. Dubat, "Effect of green tea powder on the quality attributes and antioxidant activity of whole-wheat flour pan bread," *LWT-Food Science and Technology*, vol. 79, pp. 342–348, 2017.

[48] X. Xu, Z. Luo, Q. Yang, Z. Xiao, and X. Lu, "Effect of quinoa flour on baking performance, antioxidant properties and digestibility of wheat bread," *Food Chemistry*, vol. 294, pp. 87–95, 2019.

[49] J. V. Gil, A. Esteban-Muñoz, and M. T. Fernández-Espinar, "Changes in the polyphenolic profile and antioxidant activity of wheat bread after incorporating quinoa flour," *Antioxidants*, vol. 11, no. 1, p. 15, 2021.

[50] J. Sriti, I. Bettaieb, O. Bachrouch, T. Talou, and B. Marzouk, "Chemical composition and antioxidant activity of the coriander cake obtained by extrusion," *Arabian Journal of Chemistry*, vol. 12, no. 7, pp. 1765–1773, 2019.

[51] Iranian National Standardizatio Organization, *Cake – Specifications and Test Methods*, INSO, Industrial City, Iran, 4th edition, 2021.

[52] M. Taghvaei and S. M. Jafari, "Application and stability of natural antioxidants in edible oils in order to substitute synthetic additives," *Journal of Food Science and Technology*, vol. 52, no. 3, pp. 1272–1282, 2015.

[53] M. Kozłowska, A. Żbikowska, A. Szpicer, and A. Półtorak, "Oxidative stability of lipid fractions of sponge-fat cakes after green tea extracts application," *Journal of Food Science and Technology*, vol. 56, no. 5, pp. 2628–2638, 2019.

[54] A. N. Ukom, M. C. Ezenwigbo, and F. U. Ugwuona, "Grapefruit peel powder as a functional ingredient in cake production: effect on the physicochemical properties, antioxidant activity and sensory acceptability of cakes during storage," *International Journal of Gastronomy and Food Science*, vol. 28, Article ID 100517, 2022.

[55] L. Y. Wu, H. Xiao, W. J. Zhao et al., "Effect of instant tea powder with high ester-catechins content on shelf life extension of sponge cake," *Journal of Agricultural Science and Technology A*, vol. 15, no. 3, pp. 537–544, 2013.

[56] J. P. Singh, A. Kaur, K. Shevkani, and N. Singh, "Influence of jambolan (*Syzygium cumini*) and xanthan gum incorporation on the physicochemical, antioxidant and sensory properties of gluten-free eggless rice muffins," *International Journal of Food Science and Technology*, vol. 50, no. 5, pp. 1190–1197, 2015.

[57] J. H. Lee, "Physicochemical and sensory characteristics of sponge cakes with *Rubus coreanus* powder," *Preventive Nutrition and Food Science*, vol. 20, no. 3, pp. 204–209, 2015.

[58] H. Najjaa, A. Ben Arfa, W. Elfalleh, N. Zouari, and M. Neffati, "Jujube (Zizyphus lotus L.): benefits and its effects on functional and sensory properties of sponge cake," *PLoS One*, vol. 15, no. 2, Article ID e0227996, 2020.

[59] R. Stikic, D. Glamoclija, M. Demin et al., "Agronomical and nutritional evaluation of quinoa seeds (Chenopodium quinoa Willd.) as an ingredient in bread formulations," *Journal of Cereal Science*, vol. 55, no. 2, pp. 132–138, 2012.

[60] S. El-Sohaimy A, M. Shehata G, T. A. Djapparovec, T. Mehany, M. Zeitoun A, and A. Zeitoun M, "Development and characterization of functional pan bread supplemented with quinoa flour," *Journal of Food Processing and Preservation*, vol. 45, no. 2, Article ID e15180, 2021.

[61] J. Rothschild, K. A. Rosentrater, C. Onwulata et al., "Influence of quinoa roasting on sensory and physicochemical properties of allergen-free, gluten-free cakes," *International Journal of Food Science and Technology*, vol. 50, no. 8, pp. 1873–1881, 2015.

[62] G. M. Turkut, H. Cakmak, S. Kumcuoglu, and S. Tavman, "Effect of quinoa flour on gluten-free bread batter rheology and bread quality," *Journal of Cereal Science*, vol. 69, pp. 174–181, 2016.

[63] M. Gómez, B. Oliete, C. M. Rosell, V. Pando, and E. Fernández, "Studies on cake quality made of wheat–chickpea flour blends," *LWT-Food Science and Technology*, vol. 41, no. 9, pp. 1701–1709, 2008.

[64] A. A. A. Qasem, M. S. Alamri, A. A. Mohamed, S. Hussain, K. Mahmood, and M. A. Ibraheem, "Soluble fiber-fortified sponge cakes: formulation, quality and sensory evaluation," *Journal of Food Measurement and Characterization*, vol. 11, no. 3, pp. 1516–1522, 2017.