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Research Article

Development of Gluten-Free Cake for Improving Textural and Sensory Characteristics with Chia Flour

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Lack of gluten affects the quality of gluten-free (GF) cake. Mainly due to the ingredients used and their characteristics, GF cake has numerous drawbacks such as unsatisfactory texture. The present study determines the influence of different percentages of chia seed flour and xanthan gum on the consumer aspects and also the physical quality of rice/sweet potato flour-based gluten-free (GF) cakes by adding xanthan gum. A composite central design (CCD) was applied to optimize the levels of effects of ratio of rice/sweet potato flours, chia seed flour concentration, and xanthan gum concentration on the textural and sensory properties. The results of optimization analysis observed that the best formulation was prepared from ratio of rice to sweet potato flours of 60 to 40% w/w, chia seed flour of 2.5% w/w, and xanthan gum of 0.03% w/w as optimum point. Also, one sample t–test results indicated that the experimental values of responses were close to predicted ones and confirmed them. The textural, physical, and also sensory properties showed that adding whole chia seed flour led to increase the hardness and a reduction in the specific volume of the cakes. The presence of xanthan gum was essential to soften the texture of the cake. In final, it can be stated that whole chia seed flour with suitable quality and healthy characteristics can be utilized as a good alternative ingredient to prepare various gluten-free products.

1. Introduction

Celiac disease, as intolerance to undigested peptides derived from gluten proteins, presented in some kinds of cereals like wheat, barley, and rye is an inflammatory disease that affects the small intestine leading to the malabsorption of particularly vitamins and minerals from foods, and therefore, its removal is essential for the production of products for patients with gluten intolerance [1]. Gluten, as the main structural protein, is responsible for the viscoelasticity of the dough and also sensory characteristics of many baked goods [2], and therefore, the replacement of it by other ingredients usually leads to reduce technological and sensory properties (low volume, poor texture, color, not satisfying taste, crumb structure, etc.). From a nutrition point of view, producing gluten-free bakery goods is challenging owing to the low quality especially for baking GF flour and a lack of fibres, nutrients, and vitamins [3], and therefore, it is necessary to use varied type of additives and also alternative flours in their recipes (alternative protein sources, hydrocolloids, and so on) to create a network similar to gluten [4]. These added ingredients give gluten-like properties to the dough, so the nutritional and sensorial properties can be improved. In addition, the high cost and limited availability and also, little variety of these gluten-free (GF) products are another problematic issues for food science and nutrition. For this reason, a comprehensive study has been done to replace gluten with other widely available and inexpensive compounds such as rice and maize flours mixed with maize, potato, or cassava starches [5]. However, due to the high demand for this type of products, it seems that more research is still needed to produce these products in the same quality as the original ones that can be done by combining raw natural substances, which are rich in the source of nutrients and bioactive ingredients, like whole chia seed, into the gluten-free products formulations [6]. According to the mentioned problems, over the last decade, there has been a great deal of interest in optimizing cake-making technology to increase the value of the final goods especially in the taste and quality.

One of the most suitable and also crucial cereal among food crops in human nutrition is rice (*Oryza sativa*), which is widely used as a substitute for wheat flour (WF) in the preparation of GF bakery products as it is the most abundant component of fast digestible carbohydrates, high nutritional value, and also hypoallergenic properties [7]. The ingredients like fat, dietary fiber, protein, B vitamins, minerals, and available starch may be present in different levels in varying rice cultivars [8]. Rice protein isolate which is obtained from rice flour is utilized in GF bread making as the origin of protein [9]. From the other point of view, the concentration of a rice bran protein which is derived from rice bran is considered a nonallergenic protein is a byproduct of rice production. It is used for rising the amount of protein in GF bread [10].

Sweet potato (*Ipomoea batatas* Lam) is the seventh most essential food crops in the world and fourth in tropical and subtropical countries. It is a wide ecological flexibility by adapting to extreme weather; it is a low-input agricultural system, a short and extremely flexible vegetative production cycle. Moreover, it is a good source of carbohydrates, nutrients, antioxidants, minerals and resistant starch and also, sensory versatility in terms of flesh colors. Besides, the protein of sweet potato contains essential amino acid combination that is greater to those of cereal proteins. Sweet potato flour can be replaced by brown flour, which has been shown to benefit celiac disease patients [11]. Although, sweet potato has many impressive benefits and it is cheaper than other crops, a short attention is still paid to it for production of this type of products [12]. Recently, it has become a research focus due to its unique physiological and nutritional values.

Chia (*Salvia hispanica*) is reported as an annual herbaceous plant belonging to the *Lamiaceae* family [13] and native from northern Guatemala and southern Mexico. Over the past few years, they are becoming increasingly popular and are now consumed by health conscious people all over the world [14]. They have been revalued due to their potential health properties and also less water requirements than other cereals and oil seeds to grow [15]. This seed is composed a high amount of protein (19–25%) and a high amount of dietary fibers (20–37%) with an oil content of (about 21–33%) including mainly of α-linolenic acid (approximately 60-65%) [16]. Moreover, various crucial phenolic compounds and fatty acids with high in vitro antioxidant activity have been identified in chia seed [17]. Another critical feature of chia seeds is that they could be used by people with celiac disease because they are gluten-free [18]. Additionally, chia seeds and their byproducts are especially interested due to the great oil- and water-holding capacities, characteristics that make them potential natural additives for baked products [14].

Several types of hydrocolloid polysaccharides were used extensively to improve the inferior structure and also texture of GF cakes which xanthan gum (XG) is one of the most important of them. XG has high water solubility, unique rheological and physical properties, pH stability, and excellent heat resistance [19]. For example, the influence of XG and guar gums in GF pasta was investigated by [20]. These researchers found that unlike guar, the XG retains moisture during the storage and thereby inhibits creation of crack fraction on the dough structure. According to Ahlborn et al. [21], the rice flour bread containing hydroxypropylmethylcellulose and xanthan produced a bicontinuous system with some starch granules equal to what was observed by gluten. Hager [22] also reported that the adding XG to GF bread formula significantly decreased the crust thickness of bread and air cells resulting in a reduction in loaf volume.

According to the above and also due to the growing demand for high quality of GF goods and also finding new ingredients that could help to improve the structure and the final quality properties of gluten-free cake formulation, thus, the purpose of this research was to optimize the ratio of constituent compounds including rice flour, sweet potato flour, whole chia flour (WCF), and xanthan gum to produce a GF cake with quality acceptance at sensory characteristics for celiac disease patients by response surface methodology (RSM). RSM, as a collection of methods, mathematical and statistical designs, is widely utilized in food industries, and also it is the best model for optimization and development of processes. It is usually applied to evaluate the interactions between independent variables and one or more responses [23].

2. Materials and Methods

2.1. Materials. Commercial rice flour (local market of Ardabil, Iran), whole chia seeds (Kian food, Tehran, Iran), sweet potato flour (under the brand Golha Co., Tehran, Iran), xanthan gum (under the brand Barsam Co., Yazd, Iran), low-fat yoghurt (under the brand Damdaran Co., Tehran, Iran), eggs (purchased from the supermarket in Karaj, Iran), baking powder, vanilla, sugar (under the brand Golha Co., Tehran, Iran), and sunflower oil (under the brand Bahar Co., Tehran, Iran) were used as raw materials for GF cake production in this study. All other compositions were of analytical grade.

To achieve the CSF, chia seeds were grounded in a circular stainless steel grinder bowl (DPA144, Moulinex, France) and then sieved across a 40-mesh screen and stored packed in plastic containers at 4°C for 24 hours.

2.2. Chemical Composition Analysis of Whole Chia Flour (WCF). The moisture (44-15A), ash (08-01), protein content ($N \times 6.25$) (46-30), and lipids (30-25) of WCF were analyzed according to the standard AACC method [24].

2.3. Preparation of the GF Cakes. For the preparation of cake batter, whole eggs (60% *w*/*w*) were whipped to a foam and mixed with vanilla (0.6% *w*/*w*) and sugar (50% *w*/*w*) using a blender (HM330, Kenwood, Japan) for 4 min at medium speed. Then, half of the yoghurt (30% w/w) were added [25] and blended for 120 rpm for 3 min. After, all dry ingredients containing different levels of rice and sweet potato flours (0, 50, and 100%), whole chia flour (0, 2.5, and 5% w/w), xanthan gum (0, 0.15, and 0.3% w/w), and baking powder (1% w/w) were added three times and blended at 120 rpm for 3 min. The other remaining yoghurt (30% w/w) was mixed with oil (60% w/w) and then mixed for 120 rpm for 3 min. Finally, the dough samples of 40 g were poured into a cup and baked in an oven for 20 min at 180°C (under the brand Akhavan, Tehran, Iran). After cooling at room temperature for 30 min, the samples were packed for further analysis. The formulation without any sweet potato and whole chia flours was named control (only rice flour).

2.4. Analysis of Cakes. The cake analysis was performed one hour after leaving the refrigerator. The volume of the cakes was recognized through the rape seed displacement methodology, and also the specific volume (SV) of cakes was obtained by dividing the apparent volume of cake by the weight of cake [24].

The microstructure of each cake was determined by scanning electron microscopy (SEM). Prior to the evaluation, the cake samples including control and optimized formulation were sliced into thin 1×1 cm square slices and dried in a forced convection oven (at 70°C for 12 h). A NOVA 200 (FEI, Czech Republic) SEM at an accelerating voltage of 20 kV was used. Images were captured at a magnification level of 500x. Before the test, samples were sputter coated with gold-palladium to render them electrically conductive [26].

The moisture content of samples was evaluated based on the AACC 44-15A method as described by [24].

Water activity (a_w) of the samples was evaluated by a water activity meter (Novasina, TH-500, Switzerland) at 25 ± 0.02°C. Nearly 5 g of cake sample was placed into a sealed cup and placed into the device. After waiting for the water activity to come to equilibrium, measurements were recorded.

The texture profile analysis (TPA) of cakes was determined with a texture analyzer (Testometric, M350-10CT, UK), utilizing 25 mm cylindrical probe. The cake sample was cut in cubes ($20 \times 20 \times 20$ mm) and a double compression test (texture profile analysis mode) was done. The test speed was 60 mm/s, and after the first compression was carried out, right after 10 s, the second compression which was 50% of cake samples primary height was applied. The springiness, hardness, chewiness, and gumminess were measured from the force-time curves of the texture profile.

The crust color of the cake samples was determined using the CIE-$L^*a^*b^*$ uniform color space by the means of a Minolta colorimeter (Chromameter CR-400, Konica Minolta, Tokyo, Japan). Color parameters indicate L^* the lightness, a^* the hue on a green (-) to red (+) axis, and b^* the hue on a blue (-) to yellow (+) axis. Measurements were done on three slices from each run [27]. Triplicate readings were carried out from different part of cake crust, and the mean value was recorded.

Browning index (BI) represents the purity of brown color and is assumed as an important parameter associated with browning. BI was calculated as the following [28]:

$$\mathrm{BI} = \frac{[100((a*+1.75L*)/(5.645L*+a*-3.012b*)-0.31)]}{0.17}, \quad (1)$$

where BI is the browning index and L, a, and b are the CIE Lab parameters.

The sensory characteristics of cake samples (24 h after baking) were assessed by 30 untrained panelists (aged 30-55 years) from the Department of Food Science and Engineering at University of Tehran. They were all familiar with the products being tested. They were made informed about the taste of GF cakes, and additionally, they had no disease which was related to gluten. The acceptance test of the formulations was determined applying a 7-point hedonic scale, ranging from 1 to 9 (1 = dislike extremely, 9 = like extremely) to taste, aroma, texture, and overall quality as described by [29].

2.5. Experimental Design and Statistical Analysis. In this study, a central composite design with three variables in three levels and six center points was applied to evaluate the effect of independent variables on the responses (Table 1). Independent variables were including the ratio of rice to sweet potato flours, chia flour, and XG. For expressing the crucial factors for GF cake quality, five dependent variables were chosen as responses: sensory properties (taste, texture, aroma, and overall acceptability) and textural property (hardness), as shown in Table S1 (Supplementary material). After preliminary trials, the maximal and minimal rates of the independent variables were chosen. The ratio of rice to sweet potato flour levels were 100% w/w rice flour, 50/50% w/w rice and sweet potato flours, and 100% w/w sweet potato flour; chia flour levels were 0-5% w/w; and xanthan gum levels were 0-0.3% w/w. For analysis of the optimized formulation, three ratios of every variable were selected, and 20 baking trials were performed (Table 1). Six replicates (trials 2, 7, 10, 14, 15, and 16) at the center of the design were utilized to allow for estimation of the pure error at sum of the square.

It should also be noted that the Minitab software (Version 18, Minitab, PA, USA) was employed for the evaluation of the data. Sufficiency of the data was assessed, utilizing coefficient of determination (R^2), F value, and also a lack of fit. The effect of variables at linear, quadratic, and interactive levels on the response was described using various levels of significance (Table S2). For comparing the predict samples and the experimental values, the one sample t-test ($p \leq 0.05$) was applied. Differences in treatment means were identified by Tukey's test and one-way analysis of variance (ANOVA). Finally, a student's t-test ($p \leq 0.05$) was also applied to evidence differences for GF cake and the control (only rice flour).

3. Results and Discussion

3.1. Chemical Composition. The obtained results from WCF analysis observed that the protein, moisture, ash, and lipid

Table 1: Run order of the central composite design, with the corresponding factor levels.

Run	Formulation	Rice flour	Sweet potato flour	Whole chia flour	Xanthan gum
1	R100CSF5	100	0	5	0
2	R50P50CSF2/5XG0/15	50	50	2.5	0.15
3	R100	100	0	0	0
4	R50P50XG0/15	50	50	0	0.15
5	P100CSF2/5XG0/15	0	100	2.5	0.15
6	P100CSF5XG0/3	0	100	5	0.3
7	R50P50CSF2/5XG0/15	50	50	2.5	0.15
8	P100	0	100	0	0
9	R50P50CSF5XG0/15	50	50	5	0.15
10	R50P50CSF2/5XG0/15	50	50	2.5	0.15
11	R100CSF5XG0/3	100	0	5	0.3
12	P100XG0/3	0	100	0	0.3
13	P100CSF5	0	100	5	0
14	R50P50CSF2/5XG0/15	50	50	2.5	0.15
15	R50P50CSF2/5XG0/15	50	50	2.5	0.15
16	R50P50CSF2/5XG0/15	50	50	2.5	0.15
17	R100CSF2/5XG0/15	100	0	2.5	0.15
18	R100XG0/3	100	0	0	0.3
19	R50P50CSF2/5XG0/3	50	50	2.5	0.3
20	R50P50CSF2/5	50	50	2.5	0

R: rice flour; P: potato flour; CSF: chia seed flour; XG: xanthan gum.

content were 18.98, 8.1, 5.7, and 31%, respectively. A high amount of lipids and proteins were observed in chia seeds which was similar to that reported by [30]. However, the moisture content of this chia is higher than that stated by [31], who found 5.74 ± 0.17 g/100 g. These significant difference in combination of chia seeds could be assigned to the chia planting season, growing locations, and environmental effects such as temperature, soil, and light [32].

3.2. Diagnostic Checking of the Models. The obtained results of the RSM are observed in Table S2 (contained in the supplementary data). By evaluating the multiple regression responses, estimated regression coefficients for dependent variable were gained (Table S2), and the obtained results of mathematics models are displayed below.

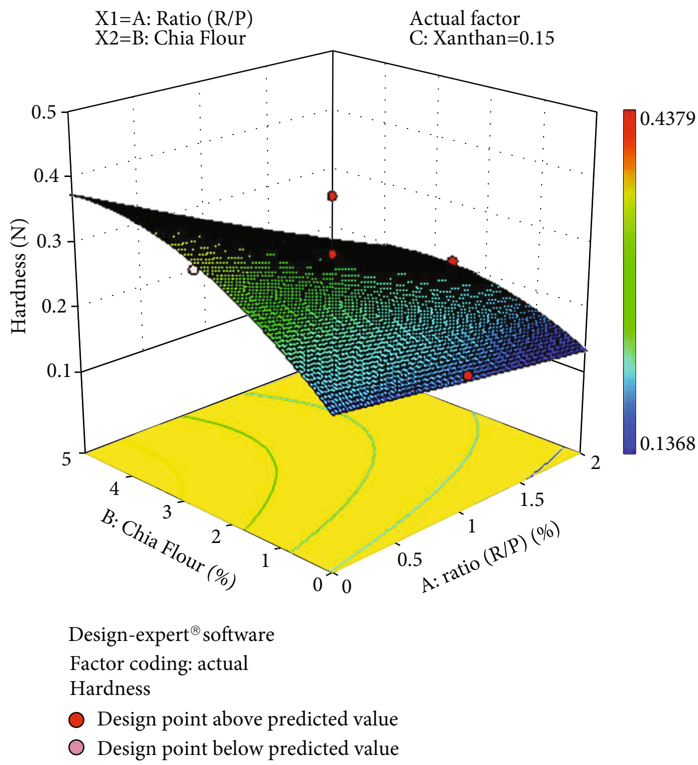
$$\begin{aligned}
\text{Taste} &= 2.778 + 1.677\,X_1 + 0.502\,X_2 - 4.493\,X_3,\\
\text{Aroma} &= 2.778 + 1.677\,X_1 + 0.502\,X_2 - 4.493\,X_3,\\
\text{Overall Acceptance} &= 2.561 + 1.163\,X_1 + 0.5779\,X_2 - 1.123\,X_3,\\
\text{Texture} &= 2.607 + 0.611\,X_1 + 0.330\,X_2 + 2.463\,X_3,\\
\text{Hardness} &= 0.1764 - 0.0304\,X_1 + 0.0873\,X_2 - 0.2393\,X_3,
\end{aligned} \tag{2}$$

where X_i is the coded independent factors (X_1 = ratio of rice to potato flours, X_2 = WCF concentration, and X_3 = XG concentration) including linear effects. After the models were achieved, ANOVA was used to confirm their potential to represent the information.

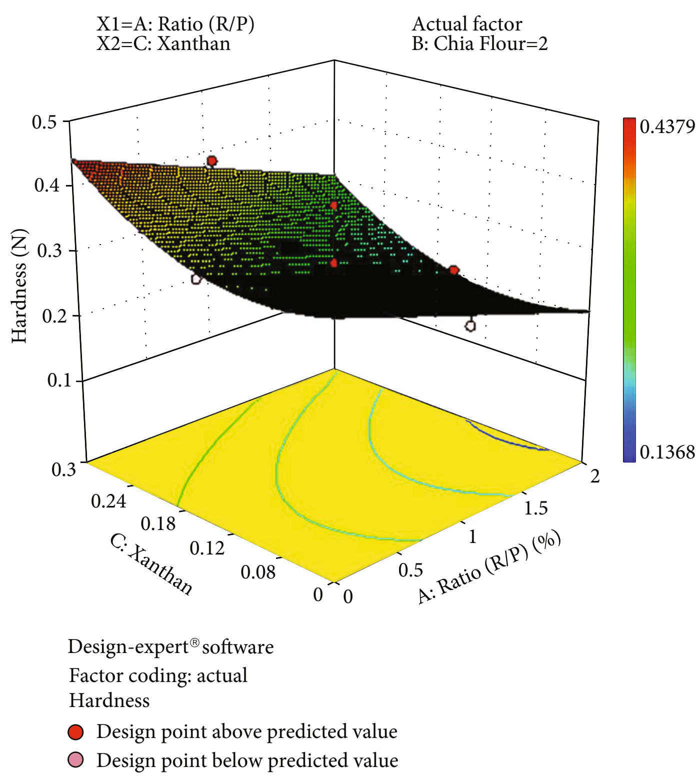
In fact, the statistical importance of the model terms was evaluated with analysis of variance (ANOVA). As can be seen in Table S2, the effect of the linear model for hardness, linear and square models for taste, square model for texture, linear and square models for aroma, and linear, square, and interaction models for overall acceptability were crucial ($p < 0.05$). The low p value ($p < 0.05$ for all responses) showed that the proposed models were widely important and more than 97.5, 98.5, 97, 98, and 96% of the responses for hardness, taste, texture, aroma, and overall acceptability could be described by them because the calculated determination coefficient for these responses was 97.57, 98.53, 97.20, 98.37, and 96.10%, respectively. Additionally, for all responses lack-of-fit was no significant (0.907, 0.088, 0.224, 0.205, and 0.426 for hardness, taste, texture, aroma, and overall acceptability, respectively), which illustrated the experimental data well fitted with the quadratic polynomial model was, and there is no require to the higher-order equations.

3.3. Hardness. From the perspective of the consumer, textural characteristics of cake is another critical features, which have significantly influence on the consumer perception for appearance and overall acceptability of the food products. It has been reported that this feature is determined by the levels of the composition of the main component (butter, sugar, eggs, and margarine) [33].

Hardness defined as the force required to compress a food by a specific length at a specific rate. According to Table S2, in our work, the analysis of variance (ANOVA) results revealed that the most important effects ($p \leq 0.05$)

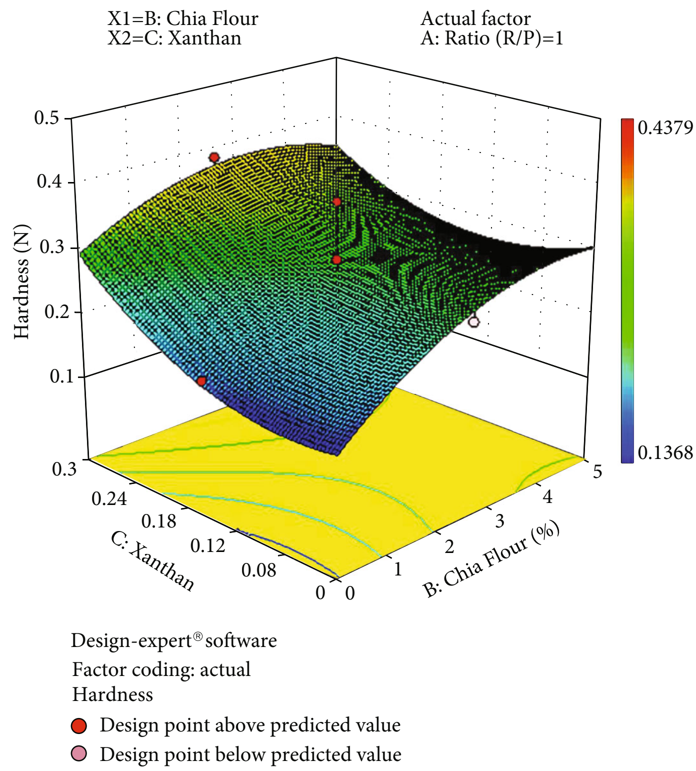


(a)



(b)

Figure 1: Continued.



(c)

Figure 1: The effect of chia seed flour, ratio of rice and sweet potato flours, and xanthan on the hardness of cakes.

of ratio of rice/sweet potato (R/P), WCF, and XG and the interaction of the variables on the firmness. The variation of the components of GF cakes, as a function of different flours concentrations used, is shown in Figures 1(a)–1(c).

As can be seen from Figure 1(a), with an increase in WCF up to 2.5%, the hardness was significantly increased which could be due to the great capacity of chia seed mucilage water retention, a high amount of protein and also fiber content and the effect of starch dilution. In addition, the rough WCF with bran particles maybe interrupted the starch gel uniformity and gas cells in the dough, ending in a higher hardness and a lower specific volume in cakes samples. It is important to note that hardness was reduced by increasing the level of XG (Figures. 1(b) and 1(c)) since XG was found to be more water absorbing due to the presence of hydroxyl group and as a result retain the content of water and thereby decrease the hardness [34].

In similar study, Coelho and Salas-Mellado [35] found that the quality of the wheat breads were influenced by adding 2-20% of WCF in their formulations. These researchers reported that adding chia flour leads to increase the firmness and also reduces the volume of final product. Consequently, the porosity, the specific volume, and crumb texture of final product could be modified by utilizing whole chia flour. In another study, the chewiness and hardness of the GF products were rose by the addition of chia seed flour [36]. Sung et al. [37] prepared a gluten-free rice layer cake by using chia seed flour (0-30%). They found that firmness rose from 8.02 N to 16.56 N.

3.4. Sensory Acceptability. Sensory evaluation of gluten-free cakes is displayed in Table S1. A great of the sensorial scores were from 4 to 6 (scores categorized as "indifferent" and "like a lot") except for the samples of cakes with 5% WCF which obtained average scores of between 3 and 4 (scores as classified as "dislike" and "indifferent") on the 7-point hedonic scale was provided by the assessors. No significant difference was obtained between the features of overall acceptability, texture, and taste scores of the mixture of rice and potato flours with 2.5% WCF cakes with the standard rice cake counterpart. From the observation information in Table S1, it can be derived that the best addition ratio of WCF to obtain a high-overall acceptability score was 2.5%. Some of the panelist remarked that they had felt a bitter aftertaste after eating cakes with high levels of WCF and also firmer at the ends, which adversely affected the realization of the assessors as regards this feature. The GF cakes made from potato flours with 5% WCF presented darker crust color, which reduced the color acceptability compared with rice flour cake. It is important to note that these significant negative effects of chia flour on the gluten-free cakes' physical and nutritional parameters can be a result of the particle size distribution (PSD) and chemical compounds and also the ratio of hydration influence on the dough rheological features. In addition, using the coarse form of whole chia flour with potato flours maybe led to disruption of gas cell capacity and also, shape stabilization of starch gel in dough, which could result in increase in crumb firmness in cake formulation. Evidently, darker crust color and reduce in the softness of cakes were an important reason for the lower grades given to the samples with high percentage of WCF. In another study [35], assessed the overall quality acceptance of bread making containing with wheat flour and chia seed flour acceptability for bread making with wheat and chia flours and reported the overall acceptability of grades ranging from "liked moderately" to "liked."

Sandri et al. [38] used various amount of WCF (5, 10, and 14%) with rice flour for gluten-free bread preparation. The total scores of acceptability were 8.7, 8.1, and 7.9 out of the 10-point scale, and also they were almost the same to their white GF bread. The addition of 5–14% WCF rose the amount of proteins, lipids, and dietary fiber compared with the white GF breads.

3.5. Optimization of Cake Formulation. One of the most important aims of response surface methodology is to find the optimum point of multiple factors. Based on the above-described outcomes, it could be claimed that whole of the independent variables were crucial for explaining the features of the cake, and the quality of GF cake was not dependent on a one principal factor. Therefore, the next phase included the detection of the best composition of components that are capable to manufacture the expected features of the final good. In determination of these optimum points, maximum values of taste, maximum texture, maximum aroma, and minimum firmness were considered, and the obtained results were carried out through the Minitab software as shown in Table 2. By observing the results of optimization analysis we can find that the interaction and also individual impact of variables on final responses are crucial. Furthermore, desirability analysis (0.8960) revealed that the formulation containing 60/40 kg/100 kg of ratio of rice to sweet potato flours, 2.5 kg/100 kg whole chia seed flour, and 0.03 kg/100 kg xanthan gum. The GF cake was produced three times, and the obtained results showed that the experimental values were close to predicted ones and confirmed them ($p > 0.05$ based on one sample t–test outcomes). There was no statistically significant difference ($p > 0.05$) was discovered between the outcomes gained from validation test, demonstrating that the model obtained with the optimization was experimentally successful.

3.6. Comparison of the Quality Properties of Gluten-Free Cake and Control Cake. The optimized cake was compared with the control cake prepared with rice (control). The specific volume of optimized and control cakes was 1.53 ± 0.16 ml/g and 1.82 ± 0.26 ml/g, respectively, with no significant difference between cakes. However, the specific volume of control sample decreased slightly when the potato and chia flours were added which may be connected to the lack of the wheat gluten network, and it was more evident to the chia and potato flours because of less expansion and starch gelatinization during the baking. In a study by [39], the use of fiber in baked products is examined a positive effect on final product. However, these researchers showed that the fibers can lead to problems in the technological quality because of a decrease in the volume and elasticity of the crumbs. Likewise, Huerta et al. [40] investigated that the free gluten bread had a lower volume than traditional one. These authors mentioned that the specific volume was significantly reduced when fiber ingredient was added to the bread due to the reduction of gas cells caused by structure deformation of the bread dough. Moreover, these dietary fibers content strongly influence by water absorption and also decrease the availability of ingredients for the growth and formation of the bread [35].

Table 2: Predicted and measured values for the responses at optimum conditions.

Independent variables (responses)	Optimum conditions Measured value	Predicted value
Hardness (N)	0.2516 ± 0.04	0.2233
Taste	4.79 ± 0.25	4.488
Texture	4.506 ± 0.16	4.776
Aroma	4.758 ± 0.32	4.558
Acceptability	4.97 ± 0.22	4.76

Conversely, Bozdogan et al. [41] studied the enrichment of quinoa-based GF cupcakes with pear pomace powder (PPP) and xanthan gum (XG). The addition of PPP affected the crumb hardness and the cake volumes by increasing and decreasing, respectively, although adding XG to the mixture caused to the high volume in the samples and the reduction in the hardness of them. Physical properties, desirability analysis, and physicochemical parameters evaluated that the addition of until 8% of PPP and 0/5% XG for enriching the GF cupcakes were suitable.

SEM images of the cupcakes are presented in Figure 2(a). As can be seen, the gas cells (black section) were visible mostly in control, and although, this sample showed a lack of gluten network forming with a uniform gas cells, the optimized cake had tunnel formation with irregular form of air bubbles distribution. According to the SEM images of the cakes, coalescence of pore sizes and formation of channel-like structure was not demonstrated in the optimized cake, and this was while the extremely high denser matrix was sometimes observed in some parts of it probably owing to the operation of the mucilage from the chia seeds in the dough. In general, a negative correlation was shown between potato and chia flours in the optimized cake.

The moisture of the optimized and control cakes was 27.57 ± 0.28% and 24.260 ± 0.37%, respectively. In addition, water activity of the optimized cake (0.9885 ± 0.0148) was more than the control sample (0.6350 ± 0.0354). It is extremely crucial to determine the water content in cakes because it has potential impact on the sensory, physical, and other features of the cake. Generally, the gluten-free cakes have low ability to maintain water content among the storage [34]. However, the higher moisture contents observed in the present study can be due to the presence of the chia seeds with high water holding capacity [42]. In similar study, Muñoz et al. [42] reported high chia seed mucilage was responsible for water retention and led to an increase in volume when placed in water. A similar tendency

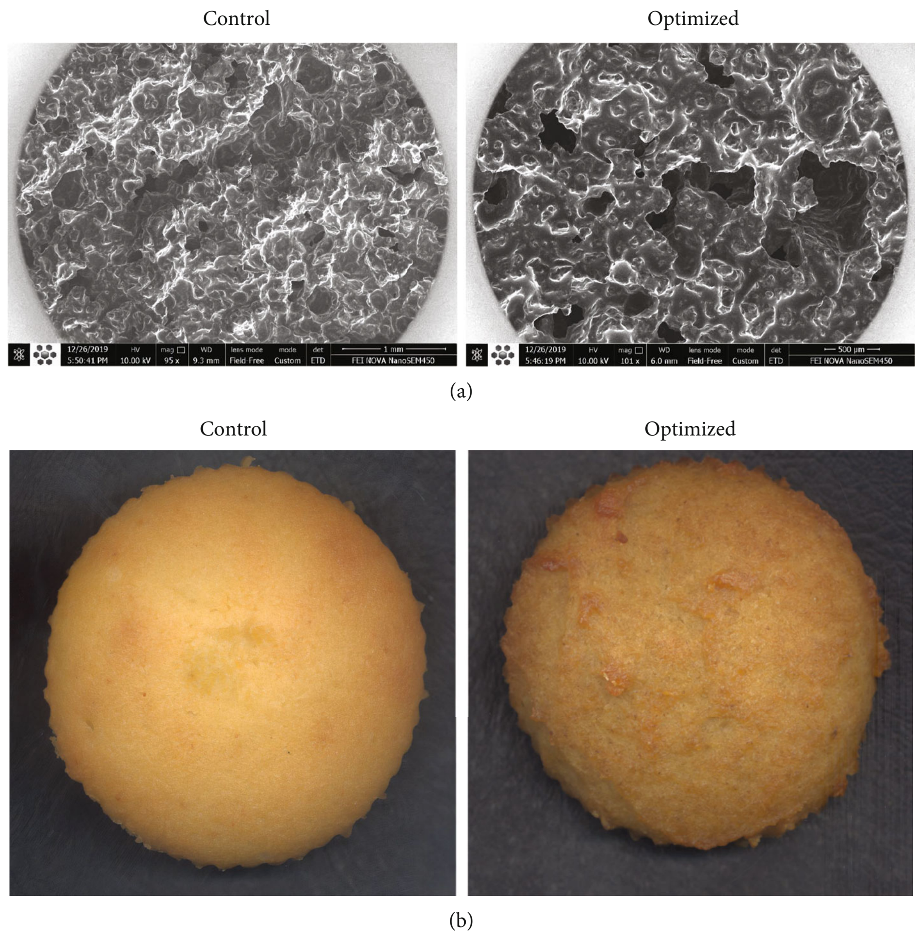


Figure 2: Scanning electron micrographs and crust images of the gluten-free cake formulations ((a) scanning electron micrographs, (b) crust image).

in the high-water retention capacity of cake samples during storage period was observed by [43]. These authors found that combination of hydrocolloids such as XG influence the staling rate and is also beneficial to increase texture properties. It is proven that xanthan gum increases the moisture content; consequently, it delays retrogradation of amylopectin in bread.

Hardness and chewiness are important indices to analyze the quality of cakes and have a direct relationship with the softness of the cake. Based on the results of textural properties (Table 3), both the hardness and chewiness of optimized cake were higher than that of control cake ($p \leq 0.05$). It should also be noted that hardness showed a negative correlation with specific volume. In fact, a lower specific volume of cakes resulting in higher hardness due to the crumb structure was denser, and thicker cells were formed. Moreover, without gluten which is definitely responsible for giving batter a texture that is more resistance against from stretching, cake batters and the cakes prepared from that batter will not be strong enough to hold its own and will crumble with mild perturbation.

So, addition of sweet potato flour and WCF were successful in giving a tougher texture to the batter network and also helping in formation of a more extensively bonded network.

Table 3 shows that the use of WCF led to an increase in the gumminess of the samples, while no significant differences were observed for springiness. Singh et al. [44] also determined the effect of combination of corn and potato starch on millet-based breads. These authors found that corn starch rose bread volume and led to a decrease in bread firmness. In addition, potato starch had a reducing influence in bread volume and caused in a higher firmness. In another study, Mohammed et al. [45] observed that incorporation of chickpea flour into wheat bread led to a decrease in baking loss probably related to the high water retention capacity of chickpea protein than wheat gluten network. Similarly, Gularte et al. [46] observed a major boost in the firmness and chewiness of the GF cake mix with legume flour than wheat cake as a control.

The results obtained from the present study were similar with the studies regarding the cakes made by chia seed flour to rice flour reported by [37]. They showed that springiness did not change, while resilience and cohesiveness decreased gradually in samples.

The color of the bakery product is a significant sensory attribute for consumers. The obtained results observed that the color of samples were considerably impressed by the use of chia flour and the L^* and b^* values of crust color displayed a great differences compared with the control cake

Table 3: Textural parameters and color values of the gluten-free cake.

Sample	Hardness	Springiness	Gumminess	Chewiness	L^*	a^*	b^*	BI
Control (rice)	$0.1183^{b} \pm 0.00879$	$0.9237^{a} \pm 0.1321$	$0.14743^{b} \pm 0.0109$	$0.1367^{b} \pm 0.0263$	$64.287^{b} \pm 1.312$	$5.543^{a} \pm 1.013$	$45.023^{a} \pm 1.448$	$296.73^{a} \pm 10.68$
Optimized	$0.2516^{a} \pm 0.0411$	$0.99043^{a} \pm 0.01257$	$0.3359^{a} \pm 0.0385$	$0.03326^{a} \pm 0.037$	$54.26^{a} \pm 1.74$	$8.223^{a} \pm 1.682$	$40.05^{b} \pm 0.962$	$311.7^{a} \pm 13.41$

Mean values ± standard deviation of 3 replicates. Values followed by different letters in the same column are significantly different ($p < 0.05$).

Table 4: Sensory evaluation values of the gluten-free cakes.

Sample	Taste	Texture	Aroma	Color	Overall acceptability
Control (rice)	$4.57^{a} \pm 0.12$	$4.08^{a} \pm 1.013$	$4.52^{b} \pm 0.64$	$5.34^{a} \pm 0.91$	$4.71^{a} \pm 0.8$
Optimized	$4.79^{a} \pm 0.10$	$4.506^{a} \pm 0.115$	$4.75^{a} \pm 0.057$	$4.4^{b} \pm 0.17$	$4.97^{a} \pm 0.11$

Different letters in columns differ statistically at a level of 5% probability by Tukey's test ($p \le 0.05$). Score: 1 = very much disliked; 2 = disliked a lot; 3 = disliked; 4 = indifferent; 5 = liked; 6 = liked a lot; 7 = liked very much.

(Table 3). Also, the optimized cake made with chia flour had significantly lower lightness (L^*) than the control cake possibly owing to the presence of dark pigment in chia seeds and also with adding potato and chia seed flours, the crust became more yellowish (b^*). Chia seeds contain a large number of color ranges from black-spotted to white [16], and thus adding it to the product creates a darker color in it, as seen in Figure 2(b). In addition, in confectionery and bakery products, the color parameter could be relying on many factors such as cooking conditions (time and temperature), ingredients used (such as sugar), and chemical reactions (like Maillard and caramelization) that are occurred during baking [47] and therefore, depending on the amino acids and reducing sugar content of ingredients, the product may be produced in different colors [48]. Chia flour has a higher amount of protein compare to the rice flour and also a different amino acid combination. When chia seed is added, those ingredients are protected and do not interface with the components of the rice flour and consequently do not involve in the coloration of the crust. In a similar study, Steffolani et al. [49] reported that the effect of replacing rice flour with 15% chia flour on crumb color of final GF bread, increased the hardness as a result decreased specific volume, but it did not decrease the overall quality of acceptability.

The sensory characteristics of samples are shown in Table 4. This table presented that though major differences were discovered in the samples' color, there was no difference between the cakes in regarding the taste, overall acceptability, and texture. It must be noticed that the panelists were not celiac and were accustomed to eating cake made with wheat flour. In addition, changes in color and aroma of the optimized cake were not negatively affected overall acceptance, and also the addition of a chia (2.5%) did not effect on the evaluation of overall sensory. Similarly, in the work of Huerta et al. [50] was reported when preparing gluten-free breads. They used chia flour (2.5%, 5.0%, and 7.5%) to substitute soy flour and rice flour in order to replace the gum needed in this type of bread. The replacement of soy and rice flour with 2.5% of chia flour produced bread with sensory characteristics similar to the standard (without chia flour) in whole of the analyzed attributes. Consequently, it could be inferred that the use of chia flour represents a promising alternative in order to boost the sensory and physical properties of GF breads.

In contrast, chia seed flour-based cookies did not differ considerably visually and sensorially (texture, appearance, aroma, color and taste) compared to wheat flour-based cookies reported by [51].

4. Conclusion

Response surface methodology was utilized to optimize the incorporation amounts of whole chia flour (WCF) and xanthan gum (XG) for making gluten-free cakes based on rice–potato flour. The optimization process showed that optimized textural and sensory properties were obtained in ratio of rice to potato flour of 60 to 40% *w*/*w*, WCF of 2.5% *w*/*w*, and xanthan gum of 0.03% *w*/*w*. The obtained results observed that it is possible to expand gluten-free cake with good quality properties similar to commercial cakes using alternative ingredients such as chia seed flour. Also, all statistical terms (p value, lack-of-fit test, and coefficient of determination) exhibited the statistical sufficiency of the predicted model. Both chia and potato flours had a positive effect on the sensory attributes cakes. XG demonstrated a positive effect on the moisture of cakes and created a softer texture. The result indicated that the nutritional, textural, sensory properties, and also physical, it seems that chia seed flour has a high potential for application in gluten-free bakery goods.

Data Availability

Data will be made available on request.

Conflicts of Interest

The authors have declared no conflicts of interest for this article.

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Supplementary Materials

Table S1: sensory evaluation and textural property of gluten-free cakes. Table S2: analysis of variance (ANOVA) of the gluten-free cake. *(Supplementary Materials)*

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