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Received 5 July 2019
Revised 16 August 2019
Accepted 24 August 2019

Extending the shelf-life of sponge cake by an optimized level of jujube fruit flour determined using custom mixture design

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Abstract

Purpose – Jujube fruit (JF) (*Ziziphus jujuba Mill.*) is used as pharmaceuticals food, flavors and food additives. The purpose of this paper is to study the suitability of JF incorporation into a commercial sponge cake formulation, and to produce a nutritious bakery product with appropriate organoleptic and technological characteristics.
Design/methodology/approach – The optimal level of JF was incorporated into sponge cake using a custom mixture design with three independent variables, namely, refined wheat flour (RWF, 15–28 percent), sugar (7–22 percent) and JF (0–28 percent), as well as several responses, including physical properties, texture profile analysis (TPA), sensorial evaluation and color features. Moreover, physicochemical properties (TPA and oxidative indices) of optimal cake (two of the best JF levels) were compared with control sample (without JF) during 51 days storage period, while two baking temperatures (180°C and 170°C) were used.
Findings – The optimal amounts of RWF (21.19 percent), sugar (21.20 percent) and JF (7.61 percent) required for making the sample with maximum springiness, cohesiveness, specific volume, sensorial scores and yellowness, as well as the lowest firmness, baking loss and browning were determined. Desirable effects of JF on the cake quality well maintained throughout the storage period, as TPA attributes, peroxide value, ultraviolet absorbance and acid value showed less changes in JF-incorporated cake than the control sample.
Originality/value – Incorporating JF (~7 percent) into the batter was successful to improve the physicochemical properties in both fresh and stored cake with chocolate-like color.

Keywords Physical properties, Storage quality, Colour attributes, Organoleptic assessment, Oxidative indices, Texture profile analysis

Paper type Research paper

Introduction

For decades, contributing the new sources of minerals, vitamins, dietary fibers and functional ingredients, as partial substitution of cake components, had been taken into consideration (Gómez *et al.*, 2012; Kaur *et al.*, 2017; Dankwa *et al.*, 2017). Cake formulas commonly included soft/refined wheat flour (RWF), fat, sugar and egg as main ingredients which may be considered in substitution studies. During making this, RWF plays a key role in cake making as its starch undergoes gelatinization, contributes to structure establishment and development of volume of the cake that is well-known as an important technological factor (Palav, 2016).

Many workers suggested incorporating the flours obtained from other materials into the cake batter along with/or in place of RWF (Gómez *et al.*, 2012; Kaur *et al.*, 2017; Dankwa *et al.*, 2017; Oliveira de Souza *et al.*, 2018). In the other side, sugar affects important properties in

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The authors gratefully thank Dr Ir. Peter Weegels (Director, European Bakery Innovation Centre; and Externe medewerker, Wageningen University & Research, the Netherlands) for the great comments on the manuscript scientific content and English language.

British Food Journal
Vol. 121 No. 12, 2019
pp. 3208-3232

0007-070X
DOI 10.1108/BFJ-07-2019-0489

cakes, such as sweetness, texture (as a tenderizer), color and starch gelatinization in many starch-based foods, and, hence, is considered as a key ingredient in formulation (Palav, 2016).

Some plants are considered as medicinal herbs mainly due to their secondary metabolites (flavonoids, carotenoids or polyphenols), and hence, they have long been used in the human diet (Farzaneh and Carvalho, 2015; Farzaneh *et al.*, 2018; Hosseini, Tajiani and Jafari, 2019). Jujube fruit (*Ziziphusjujuba Mill.*)belongs to the Rhamnaceae family that is used as pharmaceutical food (Liao *et al.*, 2012), flavor and food additive either in fresh or dry forms (San and Yildirim, 2010). Jujube fruit is cultivated in sub-tropical parts of Asian, Europe, Australia, Africa and America. Health-promoting characteristics of jujube have well been known (Liao *et al.*, 2012) and thus, its application in many formulations of food products, such as pastes, purees, syrups, confections, teas, breads, cakes, jellies and candy (San and Yildirim, 2010) is recommended by food scientists (Food and Agriculture Organization, 2019). Moreover, the Jujube-based products provided by Haoxiangni Jujube Co., Ltd (002582) have been approved by US Food and Drug Administration, listed as significantly regulated organizations (US Food and Drug Administration, 2019). Recently, Sharafi *et al.* (2017) studied the effect of incorporating the yoghurt powder (2.96–10.03 percent) and jujube polysaccharide (2.08–4.91 percent) on various parameters in semi-volume breads by response surface methodology. They proposed to incorporate the yoghurt powder 5.16 percent and jujube polysaccharides 3.62 percent into the bread formulation for achieving the best responses. To the best of our knowledge, the addition of jujube flour (JF) to cake formulation has not been evaluated. Therefore, considering the chemical composition of JF, functional ingredient in jujube, and increasing demands of consumers for healthy food (Kaur *et al.*, 2017; Seaman *et al.*, 1996; Brady, 1996) prompted us to undertake a study to explore the suitability of JF incorporation into a commercial sponge cake formulation and, to produce a nutritious bakery product with appropriate organoleptic and technological characteristics.

Materials and methods

Jujube flour preparation

Jujube fruits were manually harvested in September from ACECR (South Khorasan branch, Iran). At first, the fruits were washed and dried at ambient temperature to moisture content of 3.52 ± 0.20 percent. The dried fruits were partially crushed by an industrial hammer mill (Best Engineering Technologies, India) and were sieved (30 mesh). The JF was stored within two layers of polyethylene bags at 4°C until further use. Chemical composition of JF, including moisture (934.06), protein (920.152, using an automatic Kjeldahl, Gerhardt, Germany), ash (940.26), total carbohydrate (925.35B), and reducing sugar (925.36) was determined based on (AOAC, 2005) recommended for high-carbohydrate dried fruits. Bioactive compounds were extracted with hydroethanolic solvent (60 percent ethanol) at 67°C for 30 min as selected by pre-experiments. Total phenol content (TPC) in mg gallic acid equivalent (GAE)/g of JF), total flavonoid content (TFC, mg quercetin equivalent/g of JF) and IC_{50} (as hydroethanolic extract concentration required to 50 percent inhibition of $DPPH^{\bullet}$, μg/mL) for JF were determined based on methods described by Singleton *et al.* (1999), Zhishen *et al.* (1999) and Brand-Williams *et al.* (1995), respectively.

Cake preparation

The batter (900 g)composition of the control sample included sunflower oil (15 percent), sugar (22 percent), whole egg (20 percent), water (12 percent), confectionary/RWF (28 percent), salt (0.4 percent), skimmed milk (SM, 1.60 percent) and baking powder (BP, 1 percent) as a mixture of edible acids, sodium bicarbonate ($NaHCO_3$) and starch (Mahsa CO., Iran). JF (0 to 28 percent) was incorporated into the formulation as partial substitution to the RWF and sugar, which were accounted to 50 percent of the batter formulation while the proportion of the other ingredients remained the same. Sugar and eggs were mixed and whipped until semi-firm foam was achieved, followed by gradually adding the vegetable oil in a higher whipping rate. The blend of egg, sugar and oil was mixed with the sieved powders (RWF, BP and SM), and then, salt and water were added to the mixture. The mild whipping was constantly continued until uniform batter was obtained (overall time, 10 min and 30 s). The portions of the prepared batter (40 g) were poured into molds. The baking step was accomplished at 180°C for 24 min based on pre-experiments. Finally, the samples were cooled to room temperature and placed within poly ethylene bags.

Physical properties of cake

The height of the sample was recorded 50 min after baking by a caliper (M/s Rostfrei Gehartet, Germany). The collapse was calculated based on differences between two heights of the sample at withdrawal time and after cooling at room temperature by 50 min. The height measurements were performed in six replications. The water content (percent), volume index (mL), baking loss (g), and specific volume (mL/g) of the samples were measured as recommended in the literature (Gómez *et al.*, 2012; Seaman *et al.*, 1996; Marti *et al.*, 2018).

Texture evaluation

A Texture Profile Analysis (TPA) was carried out using TA Plus (M/s Lloyd, England), equipped with a 50 N load cell. The sample's crumb with dimensions of 2.5 × 2.5 cm was subjected to a double cycle of compression. The probe was programmed to compact the sample by depth of 50 percent at a crosshead speed of 0.50 mm/s. The texture data were analyzed by a NexygenPlus materials testing software (ver. 4.5.1) to calculate the hardness (N),cohesiveness, adhesiveness (Nm), springiness (percent), and chewiness (Nm) of the samples. The TPA test was carried out after 24 h of baking using six replicates in each run defined by the mixture design (Table I).

Color assessment

The color changes in both crust and crumb of the samples ($n = 6$), including color coordinates of L* (lightness) and b* (yellowness) after 24 h of baking was carried by Hunter Lab colorimeter (ColorFlex EZ Spectrophotometer, USA). Browning index (BI) was considered as a result of 100 – L*, representing the development of Maillard reactions in the crumb and crust of the samples (Marti *et al.*, 2018).

Quantitative descriptive evaluation by panelists

One day after baking, sensory evaluation of the samples was performed accordance to Gan *et al.* (2007) by40-trained panelists of age ranging from 24 to 55 years old who were familiar with both the control sample and jujube fruit since childhood. A written informed consent was received from the participants for performing this evaluation, and the procedure was approved by School of Pharmacy (Mashhad University of Medical Sciences, Iran). The samples were scored based on the following criteria ranging from 0 to 9 points of scale: surface/appearance (smooth to coarse), color (dull to desirable), firmness (soft to hard), adhesiveness (nonsticky to very sticky), sweetness, flavor and overall acceptability (weak to strong). At first, whole cakes were presented for appearance evaluations and were subsequently sliced into 2-cm-wide portions with the purpose of scoring the other organoleptic parameters.

Evaluation of storage stability

The optimum cakes determined by mixture design along with control cake were placed in poly ethylene bags, and then, they were stored within a cabinet at room condition for 51 days. A similar protocol was used for the samples (optimum and control cakes) baked at 170°C for 32 min to determine the effect of baking procedure on the results. The changes in several physicochemical parameters, including moisture content, water activity (a_w), TPA

Table I. Custom mixture design (CMD) experimental design with natural independent variables and experimental data for the observed responses

	Independent variables[a] (%)			Responses									
				Textural properties					Physical properties				
Run	RWF (A)	Sugar (B)	JF (C)	Hardness (N)	Cohesiveness	Springiness (%)	Chewiness (Nm)	Adhesiveness (Nm)	BL[b] (%)	SV[c] (mL/g)	Moisture[d] (%)	Height (cm)	Collapse (cm)
1	15	7	28	6.12	0.34	65.07	0.02	1.35×10^{-5}	12.60	0.60	22.83	3.49	0.05
2	15	22	13	1.94	0.47	71.81	0.01	-2.67×10^{-5}	14	1.55	20.21	4.21	0.03
3	20.39	15.26	14.35	3.77	0.40	78.21	0.01	-1.01×10^{-5}	13.83	1.30	21.96	4.18	0.05
4	20.39	15.26	14.35	3.75	0.41	79.04	0.02	-1.46×10^{-5}	13.72	1.24	21.92	4.20	0.05
5	20.39	22	7.61	1.33	0.45	78.07	0.01	-3.40×10^{-5}	14.74	1.76	20.59	4.39	0.04
6	20.39	15.26	14.35	3.71	0.40	78.52	0.02	-1.14×10^{-5}	13.79	1.21	21.89	4.17	0.05
7	28	11.20	10.80	8.88	0.34	80.72	0.03	-8.29×10^{-6}	13.30	1.20	23.53	4.14	0.06
8	18.23	12.08	19.69	4.71	0.38	75.69	0.02	-7.39×10^{-6}	13.45	1.09	22.25	3.78	0.06
9	28	22	0	3.07	0.44	81.79	0.01	-1.05×10^{-5}	14.25	1.78	21.74	4.75	0.05
10	23.56	7	19.44	9.25	0.33	76.74	0.03	-8.53×10^{-6}	13.32	0.81	23.93	3.79	0.08
11	26.60	17.19	6.21	4.31	0.40	82.41	0.02	-1.47×10^{-5}	13.78	1.46	22.35	4.48	0.05
12	15	7	28	6.69	0.35	66.07	0.02	1.59×10^{-5}	12.63	0.69	22.68	3.35	0.04
13	19.31	7	23.69	8.11	0.34	73.47	0.03	-2.80×10^{-8}	13.21	0.67	23.28	3.40	0.07
14	28	11.20	10.80	9.15	0.35	81.86	0.03	-8.20×10^{-6}	13.44	1.25	23.26	4.11	0.06
15	15	17.37	17.63	2.60	0.44	72.46	0.01	-1.71×10^{-5}	13.54	1.33	20.78	4.08	0.04
16	28	22	0	2.78	0.44	81.79	0.01	-1.60×10^{-5}	13.87	1.79	21.98	4.71	0.05

(*continued*)

Table I.

	Independent variables (%)			Responses										
				Sensorial evaluation^{e}							Color features			
Run	RWF (A)	Sugar (B)	JF (C)	Color	Firm-ness	Adhesiveness	Chewiness	Sweet-ness	Flavor	Overall	Crumb BI ^{f}	Crust BI	Crumb b*	Crust b*
1	15	7	28	5.50	5.33	6.80	6.20	6	3.80	5	56.89	69.23	28.40	19.35
2	15	22	13	3.33	4	4.67	5	6	5.33	5.67	47.90	69.23	32.41	17.38
3	20.39	15.26	14.35	6	3.80	3.80	4.33	6.33	5.67	5.87	49.18	67.92	32.11	22.97
4	20.39	15.26	14.35	5.67	4	4.25	4.40	6	6	6	49.45	66.33	31.53	23.32
5	20.39	22	7.61	6	3.67	2.67	3	5.75	5.50	7.67	41.51	65.29	32.59	24.38
6	20.39	15.26	14.35	6.33	3.90	4	4.37	5.92	5.83	6.33	49.63	67.34	31.51	22.43
7	28	11.20	10.80	2.50	6.33	5	5.50	4.30	5.33	5	44.83	64.03	30.66	23.35
8	18.23	12.08	19.69	3	4.75	5.25	4.67	6.25	5.67	4.67	52.54	66.91	30.19	20.96
9	28	22	0	5	5.20	4.50	4.67	4	6	6	21.59	52.11	34.95	39
10	23.56	7	19.44	2.67	5.67	4.33	4.50	6	6.33	4	53.04	66.70	29.26	20.84
11	26.60	17.19	6.21	7.25	5.50	4.33	4.60	4.60	6	6.60	39.91	60.22	32.85	28.89
12	15	7	28	5.21	5.50	6.50	6	6.25	4	4.67	57.02	69.48	28.17	19.12
13	19.31	7	23.69	5.75	5.25	4.33	5.25	6.50	5.50	4.70	54.06	68.54	29.72	21.28
14	28	11.20	10.80	2	6.50	5.25	6	4	5.67	5.25	46.62	65.57	30.66	22.06
15	15	17.37	17.63	5	4.33	5.67	5.25	6	5.25	4.67	50.8	69.49	31.4	19.92
16	28	22	0	5.33	5.75	4.4	4.60	4.33	6.33	6.33	22.65	50.76	34.31	38.31

Notes: [a]RWF, refined wheat flour; JF, Jujube flour; [b]baking loss; [c]specific volume; [d]crumb moisture; [e]Color (dull to desirable), firmness (soft to hard), adhesiveness (nonsticky to very sticky), sweetness, flavor and overall acceptability (weak to strong); [f]Browning index attributes and oxidative indices such as peroxide value (PV, mEq O_2/kg of oil), conjugated diene value (CDV, $E_{1cm}^{1\%}$), conjugated triene value (CTV, $E_{1cm}^{1\%}$) and acid value (mg KOH/g of oil) were measured for the samples during 51 days storage period. PV, CDV and CTV were determined as a measure of oxidation products formation, and acid value was measured to monitor the progress of hydrolytic oxidation in the samples. The changes in oxidation indices were evaluated to determine the effect of JF on progress of oxidation reactions during storage. Therefore, at given intervals (1, 17, 31, 51th of the storage period), the oil of the samples was extracted by hexane solvent (Scharlau, Spain, chromatography grade) in a manner similar to the previous study (Ghorbani and Hosseini, 2017). Water activity was determined by a_w meter instrument (Novasina AG, CH-8853, Switzerland). The PV and ultraviolet absorbance (CDV and CTV) of the extracted oil were measured spectrophotometrically according to the procedures described by Shantha and Decker (1994) and International Union of Pure and Applied Chemistry (IUPAC, Method 2.505) (IUPAC, 1987), respectively. Determining the acid value was based on AOAC official method (Ca 5a-40) (AOAC, 2005).

Statistical analysis and mathematical models

The product was formulated using a mixture design (Granato *et al.*, 2014). The details of the experimental design are available in the literature (Cornell, 2002). Since the intervals of each independent variable in the current study were different from the others, a custom/optimal mixture design with upper and lower limits (defined based on pre-experiments) was used (Table I) as recommended by Design Expert software (ver. 10.0.6.0, M/s Stat-Ease, USA). Variation in the physicochemical and organoleptic properties of the cake (Table I) was studied based on the modeling coefficients, considering the impact of the single components, namely, RWF (A), sugar (B) and JF (C) and their interactions (AB, AC, BC and ABC) as the ANOVA results of each response under different ratios of the main components (RWF, sugar and JF) are presented in Table AI. Regression or determination coefficient (R^2) is defined as the proportion of the variation in the response to the total variation that is a measure for good fit model which is considered satisfactory when the R^2 values are greater than 0.80 (Granato *et al.*, 2014). Considering evaluation of linear effect in mixture design, the regular *t*-test is not applicable for evaluating the significance of each component because of the relation between all the components. In this regard, Response Trace Plot (Piepel or Cox) can be applied to determine the linear effect of each component on the response variables, as the response is considered high or independent of each single component when its Piepel or Cox directions are vertical or horizontal, respectively, compared with X-axis. The direction is named Piepel when mixture design is defined in terms of pseudo component value (Cornell, 2002), as it was established in the present study.

For analyzing the data from storage stage, full factorial design in JMP10 software (SAS Institute Inc., USA) was selected using duplicate experiments. Comparison of the least square means was carried out in a significant level of 0.05.

Results and discussion

In the present study, chemical composition of JF, including moisture (3.93 ± 0.04 percent), protein (5.38 percent), ash (2.19 ± 0.03 percent), total carbohydrate (70 ± 1.12 percent) and reducing sugar (24.70 ± 0.90 percent) indicated that JF could be considered as a useful resource supplying a part of the energy required by human body. Moreover, the main bioactive compounds of JF (dry basis) and antioxidative capacity of hydroethanolic extract of JF measured as TPC, TFC and IC_{50} were 15.56 mg GAE/g of JF (~3.98 wet basis), 12.07 mg quercetin equivalent/g of JF (~3.09 wet basis) and 14,831.33 μg/mL, respectively, suggesting that flour or extracts from jujube fruit could be used as functional additive in food products in agreement with the literature (San and Yildirim, 2010; Food and Agriculture Organization, 2019). These values are comparable with the other fruits in wet basis, such as peeled apples, peaches and pears (2.2–6.8 mg GAE/g) (Leontowicz *et al.*, 2002), while fresh rosemary leaves, as one of the most commercially-used plants, significantly showed a higher TPC (28.66 mg GAE/g) (Hosseini *et al.*, 2018). Generally, 2–3 mg of phenolic compounds are found per one gram of more fruits (wet basis), such as cherry, apple, pear, grape and berries, while the total dietary intake of these compounds is almost 1 g/day. In general, a classification has been recommended for the level of phenolic compounds, including low (< 1 mg GAE/g), moderate (1–5 mg GAE/g) and high (> 5 mg GAE/g) (Yalcin and Çapar, 2017). Therefore, Jujube fruit could be graded as medium, and is suitable to be used as a resource supplying the phenolic compounds in dietary.

Model fitting from mixture design

The mixture design is recommended to use when a new food formulation is proposed as it allows us to provide a blend comprising the ideal amount of each component, generating the product with the best properties (texture, odor, taste, etc.). So far, several fruit-based and functional products, such as pulp concentrate, desserts, juices and smoothies have properly been formulated using mixture design (Granato *et al.*, 2014).

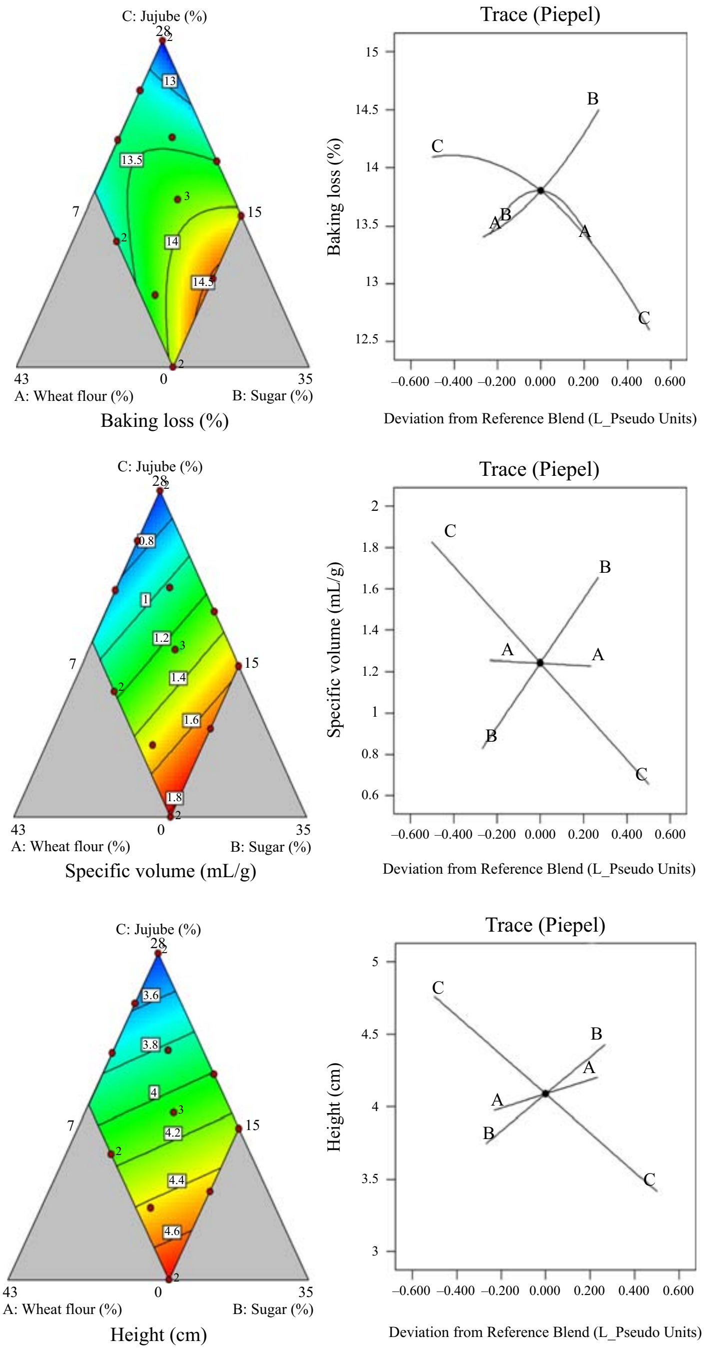
Based on the results (Table AI), linear, quadratic and special cubic models were used with predictive purposes, because they provided the best fits of the experimental data as all R^2 values, even for sensory data excluding surface and chewiness, were higher than 0.94. Moreover, the ANOVA was performed to detect the significance of the lack-of-fit. The lack-of-fittest helps to reveal that the experimental data fitted to a predictive model are included in the regression (Varnalis *et al.*, 2004). The results of this study confirmed that the models suggested for all the responses were highly appropriate and adequate due to satisfactory values of R^2, as well as insignificant lack-of-fits for all the response variables (Table AI).

Physical properties of cake

Depending on ratios of RWF, sugar and JF in the cake formulation; baking loss, specific volume, height, collapse and moisture content were ranged from 12.60 to 14.74 percent, 0.60 to 1.79 mL/g, 3.35 to 4.75 cm, and 20.21 to 23.93 percent, respectively (Table I).

Based on Piepel directions (Figure 1), it was found that the sugar content and partial replacement of JF to RWF had the most effect on the baking loss either directly or inversely proportional, respectively. Therefore, constant increasing in JF content or incorporating the average level of RWF into the cake formulation had positive impact on reduction in baking loss in the samples. The water holding capacity was positively influenced by the replacement of RWF and sugar with JF which may be due to greater capacity of binding water by JF. This is possible because of high number of hydroxyl groups present in JF polysaccharides and monosaccharides (fructose, glucose, arabinose, galactose and rhamnose) than RWF or sugar (Sharafi *et al.*, 2017; de Wit, 1998). Earlier studies also reported reducing the baking loss in sponge and pound cakes when egg was substituted with whey protein isolates (WPI) that has high water-binding capacity (Diaz-Ramirez *et al.*, 2016; Paraskevopoulou *et al.*, 2015). Further, consistency in these results was evident from the moisture data, where the moisture content of the cakes was inversely related to sugar content, but, directly related to RWF and JF. The percent of RWF, sugar and JF required for minimum baking loss of 12.60 percent was 15, 7 and 28 percent, respectively, as postulated in contour plot (Figure 1).

According to Piepel direction for specific volume, the most important factor that directly affected specific volume was sugar followed by inverse effect of JF. However, RWF coefficient showed a little influence on the specific volume. Specific volume was diminished constantly with substitutions of RWF and sugar by JF up to 28 percent. This phenomenon can be explained by a lower volume and a higher weight of the jujube-incorporated cake compared to the control because of reduced aeration while mixing and simultaneously increased water content. Therefore, the strong capacity of the JF in water absorption led to



(continued)

Figure 1.
Contour and Piepel Response Trace Plots from custom mixture design illustrating the effect of RWF, sugar and JF levels on physical properties and textural characteristics of sponge cake

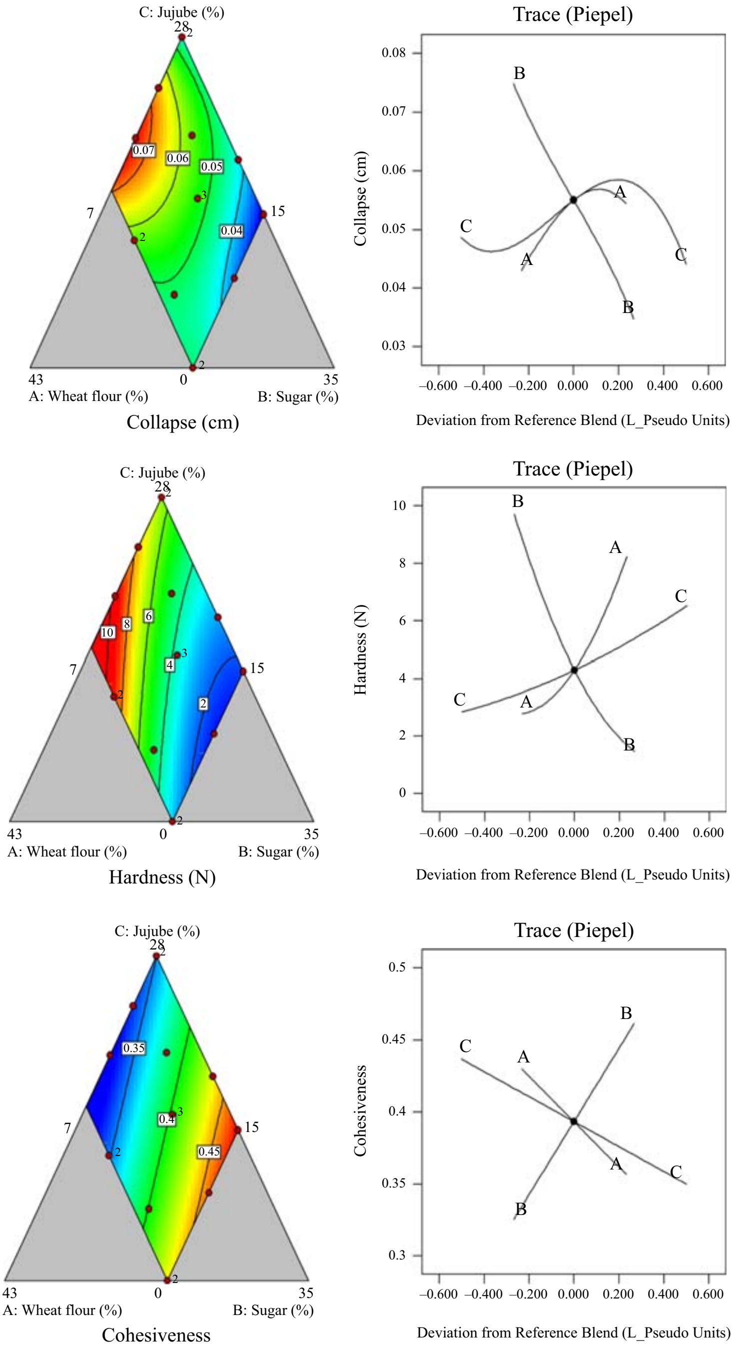


Figure 1.

(continued)

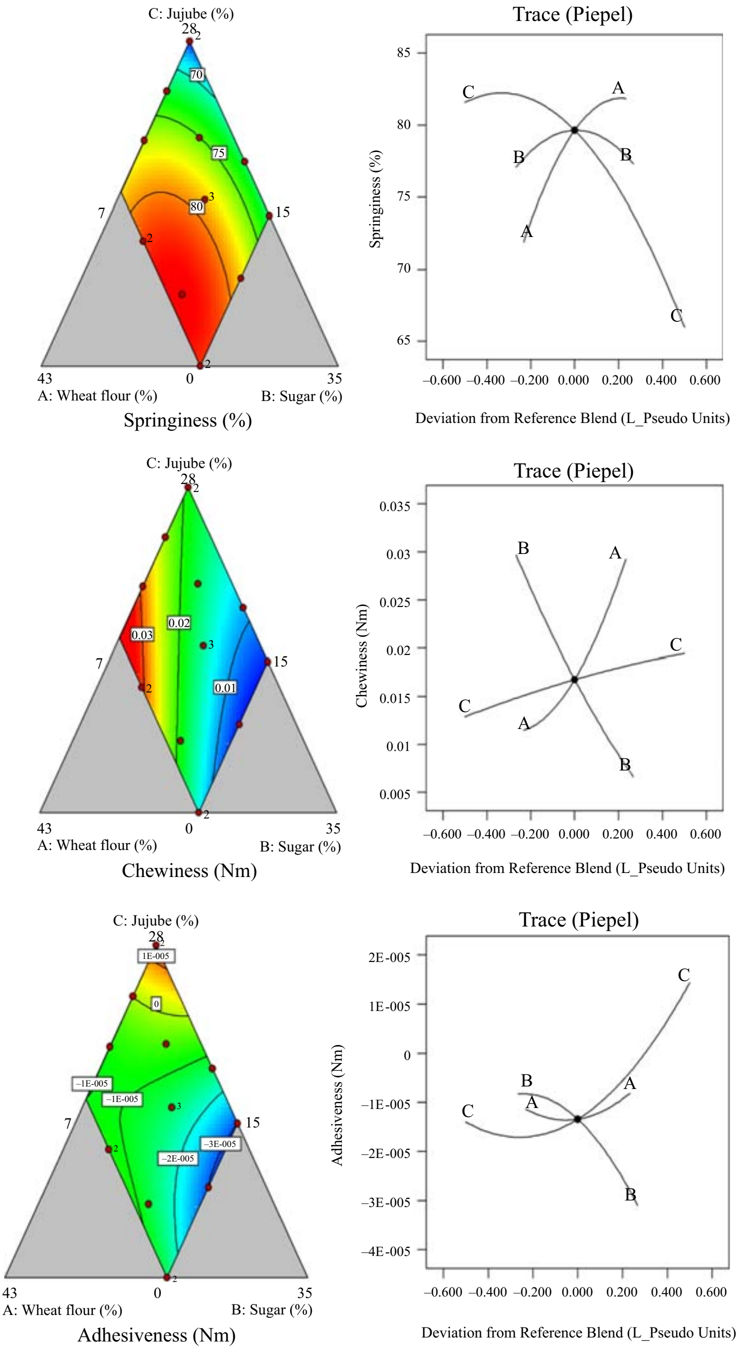

C: Jujube (%)
28
70
75
80
7
15
43
0
35
A: Wheat flour (%)
B: Sugar (%)
Springiness (%)
Trace (Piepel)
Springiness (%)
85
80
75
70
65
A
B
C
–0.600 –0.400 –0.200 0.000 0.200 0.400 0.600
Deviation from Reference Blend (L_Pseudo Units)
C: Jujube (%)
28
0.03
0.02
0.01
7
15
43
0
35
A: Wheat flour (%)
B: Sugar (%)
Chewiness (Nm)
Trace (Piepel)
Chewiness (Nm)
0.035
0.03
0.025
0.02
0.015
0.01
0.005
A
B
C
–0.600 –0.400 –0.200 0.000 0.200 0.400 0.600
Deviation from Reference Blend (L_Pseudo Units)
C: Jujube (%)
28
1E-005
0
–1E-005
–1E-005
–2E-005
–3E-005
7
15
43
0
35
A: Wheat flour (%)
B: Sugar (%)
Adhesiveness (Nm)
Trace (Piepel)
Adhesiveness (Nm)
2E-005
1E-005
0
–1E-005
–2E-005
–3E-005
–4E-005
A
B
C
–0.600 –0.400 –0.200 0.000 0.200 0.400 0.600
Deviation from Reference Blend (L_Pseudo Units)

Figure 1.

an increase in batter viscosity which in turn interferes in air bubble distribution within the batter thus, resulting in a reduced specific volume and height. Similar observations were reported by other studies applying different proteins with high water-binding capacity in pound, layer, and sponge cakes (Gómez *et al.*, 2012; Paraskevopoulou *et al.*, 2015).

JF proportion negatively while sugar and RWF positively affected cake height. The height of the cake prepared without JF was 4.71 cm maximum in contrast to 3.44 cm for cake with 28 percent JF. Based on linear terms, the occurrence of collapse in the samples was inhibited as sugar content in the formulation was linearly increased. This can be due to the fact that the incorporated JF ranging between 7 and 25 percent may have negative effect on the starch gelatinization, resulted in enhanced collapse. However, collapse was prevented by high JF levels (> 25 percent) probably due to the increased viscosity of the JF-incorporated batter. Turabi *et al.* (2008) reported that the collapse of rice cake prevented in oven as the apparent viscosity of the cake batter increased using xanthan gum. According to coefficient estimates (Table AI), three component blending (ABC) was more effective factor avoiding collapse in the sample as compared with single and two component coefficients. Therefore, the minimum extent of the collapse (0.031–0.036 cm) in the sample was recorded using a mixture comprised RWF 15 to 20.39 percent, sugar 22 percent and JF 7.61–13 percent. Therefore, incorporating the low levels of JF had a positive impact on the cake structure, resulting in a significant limitation in the collapse occurrences.

The starch gelatinization has an important role in the formation and subsequent changes (during storage) of the product structure that is influenced by some parameters, namely, granule size, gelatinization temperature as well as the water requirement of the starch (Le-Bail *et al.*, 2018). According to Wilderjans *et al.* (2008), lower water availability for starch leads to a lower specific volume in the product. In the present work, JF substitutions with RWF not only reduce starch content of the cake, but also it is competed with starch for preserving the added water. In fact, the formation of protein network (thermal-induced denaturation) along with sufficiently rigid starch during baking step results in a stable structure with a reduced collapse (Hesso *et al.*, 2015). The final volume, height and structure of the cake are highly dependent on the interaction of these processes (Hesso *et al.*, 2015) hence, the optimal blend determined based on the best physical properties of the cake was a mixture of RWF, sugar and JF at 28, 19.38 and 2.62 percent, respectively. A correlation was observed between moisture content and the other physical parameters, particularly specific volume ($r^2 = 0.42$) and collapse ($r^2 = 0.67$), confirming the significant effect of water fraction on starch gelatinization. But, these correlation coefficients were moderately low indicating that protein network formation may also the other alternate significant parameter influencing these two responses.

Texture characteristics

Texture parameters were significantly changed with substitution of JF to RWF and/or sugar to produce the sponge cake (Table I). ANOVA from regression models along with fitness parameters for suggested models are observed in Table AI.

The RWF and sugar components had strong influence on the hardness of the samples followed by JF content. An increase in either RWF or JF from 15 to 28 percent or 0 to 28 percent, respectively, resulted in enhancement of product hardness. Contrary, are verse effect was observed by increasing the sugar content that is in agreement with Oliveira de Souza *et al.* (2018) who reported an increase in the porosity and reduction in firmness of sponge cakes as sugar content elevated. Wilderjans *et al.* (2008) reported that soy protein isolate with high water-binding capacity reduced the free water, influenced the starch gel structure and increased the cake firmness. Sharafi *et al.* (2017) claimed that jujube polysaccharide appears to enhance crumb firmness in semi-volume breads by forming a gel-like structure with molecular interactions that associated with increased viscosity. Incorporating JF to the batter led to reduction in the air cells, hence the force needed to compress the cake (hardness) enhanced. Based on contour plot (Figure 1), the lowest hardness (1.41 N) of the sample was achieved by a formulation containing RWF, Sugar and JF at the rate of 19.50, 22.30 and 8.19 percent, respectively.

Springiness and cohesiveness are improved as the internal bonding in a three-dimensional protein network is developed and promote the consumer acceptance (Paraskevopoulou *et al.*, 2015). The contour plots and Piepel direction of the cohesiveness (Figure 1) indicated the strong positive effect of sugar as well as the mild negative effect of JF and median negative effect of RWF on the cohesiveness of the cake. As it can be seen from contour plot (Figure 1), the highest cohesiveness (0.47) was obtained with mixture of RWF, sugar and JF at 15, 22 and 13 percent, respectively. This demonstrates the positive impact of JF on the cake crumb structure.

A rapid reduction in springiness was seen where JF content was higher than 10 percent. Other work also showed that the increase in sugar reduced springiness as a result of change in the thermosetting mechanism that adversely affects the growth and retention of bubbles. In fact, high amounts of sugar lead to an increase in viscosity of the batter via holding the free water. Some workers reported elevation in the temperature of both starch gelatinization and egg white protein denaturation with decrease in the available water in the batter (Oliveira de Souza *et al.*, 2018). Blending the independent variables (AB, AC and BC; Table AI) had positive effect on the springiness of the sample. Moreover, contour plot of the springiness (Figure 1) showed that a mixture consisting RWF 26.60 percent, sugar 17.19 percent and JF 6.21 percent provided the best springiness (82.41 percent) for the cakes.

The interaction among coefficients of A, B and C showed a positive effect on chewiness of the cakes with a stronger impact on the reduction of the force required to chew the sample compared to the case when they were used separately. The lowest chewiness (0.0062 Nm) was recorded via blending the RWF, sugar and JF in the proportion of 18.19, 22.32 and 9.49 percent, respectively (Figure 1).

Adhesiveness is attributed to a combination of cohesive and adhesive forces, denoting the extent of attraction between surfaces of different materials (Adhikari *et al.*, 2001). Based on Piepel direction, the adhesiveness of the sample was highly affected by sugar and JF content, followed by partially to RWF content. Since adhesiveness depends on the combined effect of the viscoelasticity and viscosity of material (Adhikari *et al.*, 2001), the synergistic effect of JF on the response was probably due to the increase in viscosity of the cake batter through water-binding enhancement. Based on TPA characteristics, a mixture of RWF, sugar and JF in the proportion of 20.70, 22 and 7.30 percent was suitable for cake making.

Sensory evaluation

The cakes prepared with different ratios of RWF, sugar and JF were assessed by panelists using a nine-point sensorial trial.

In the case of the color attribute, the coefficient estimates for RWF (137.26) and sugar (−130.71) were greater than JF (5.35), demonstrating that the former two ingredients were the major variables influencing the color scores. Since the estimated coefficient for sugar ×JF was positive (Table AI), blending these components also had more influence on promoting the color score than using them separately. A high color score (8.34) was recorded by a blend of sugar 19 percent and JF 9.50 percent when RWF factor was 21.50 percent.

The increase in firmness score was inversely related to RWF, followed by JF or sugar. Based on negative signs for interaction coefficients (AB and AC), blending the components had a positive influence such as more reduction in the firmness scores (softer crumb) rather than using single components. The best firmness score (3.59) was recorded for the sample prepared using a mixture of RWF18.98 percent, sugar 22.27 percent and JF 8.75 percent. Interestingly, these levels were matching to those determined by instrumental texture analyzer.

According to Piepel directions, the linear terms of RWF and JF had the most influence on adhesiveness score of the samples. In spite of the instrumental evaluation, sugar content showed a little impact on organoleptic adhesiveness. Moreover, the best response score (2.72), corresponding to the least adhesion of the sample to the mouth inside, was observed for a mixture of RWF, sugar and JF consisted of 21.86, 22.30 and 5.84 percent, respectively, which was nearly in agreement with TPA data.

The main terms (A, B and C) were differently affected the sweetness as increasing the sweetness was recorded with a reduction in RWF content or with an increase in either JF or SU. Based on Figure 2, the highest score of the sweetness (6.5) was recorded for a sample containing19.31, 7 and 23.69 percent of RWF, sugar and JF, respectively.

The JF was the main factor influencing the flavor score, as the higher scores were observed when JF ranged between 0 and 19 percent which declined in further substitutions of JF. This is probably due to the unique flavor of JF and the development of aromatic compounds from Maillard and caramelization reactions when JF was less than 19 percent. This was strengthened by panelists' negative scores as JF content was beyond 19 percent. The chewiness data analysis was partially dissimilar to the one obtained from instrumental evaluation as RWF 22.06 percent, sugar 22.30 percent and JF 5.64 percent required to achieve desirable result.

The results showed that the overall acceptability of the samples was mainly affected by the positive interaction between RWF, JF and sugar. Moreover, the sugar content was predominant single factor promoting the acceptability followed by JF and RWF levels, respectively. Considering the linear terms, JF levels higher than 17 percent had negative effect on the overall acceptability. However, the ABC coefficient showed the most positive influence on the response as the highest score for overall acceptability of the samples (7.85) was obtained by a mixture of RWF 21.86 percent, sugar 22.21 percent and JF 5.93 percent (Figure 2).

Color features

The main factor developing brown color in both crumb and crust of the samples was JF, followed by RWF; while occurrence of browning in the crumb or crust of the samples was partially or not affected by sugar content, because sucrose hardly contributes in Maillard reaction (Palav, 2016). Extending the browning in baking products, such as cakes and breads is mainly attributed to Maillard and caramelization reactions (Le-Bail *et al.*, 2018). Maillard reaction is introduced as a result of interaction between reducing sugar and amino groups during heating. This can be intensified by increasing the reducing monosaccharaide content (or amino groups) in baked product (Palav, 2016) and same was observed in the present study by incorporating JF in the cake. Many other research studies also reported similar results (Sharafi *et al.*, 2017; Marti *et al.*, 2018).

Validation of experimental data

In order to validate the suggested fitted models for all responses, triplicate experiments were carried out with the best proportions of the independent variables (RWF, SU and JF) from optimization process (Jalili *et al.*, 2018) with or without crust color (Table II; analyses 1 and 2, respectively), because the crust color could be modified by adjusting the time and temperature of baking process. It can be seen that the experimental data were consistent with the model predictions, indicating that the models for all responses were able to describe the experimental space; hence they could be used to determine the relationship between independent and response values.

Changes in physicochemical properties during storage

With the development of oxidation reactions, the formation of hydroperoxides in the lipids is associated with generating the dienoic and trienoic acids. These oxidative parameters can be measured as PV (mEq O_2/kg of oil), CDV ($E^{1\%}_{1cm}$) and CTV ($E^{1\%}_{1cm}$), respectively, indicating the relative progression of oxidation reactions in lipids (Shahidi, 2005). The variations in oxidative

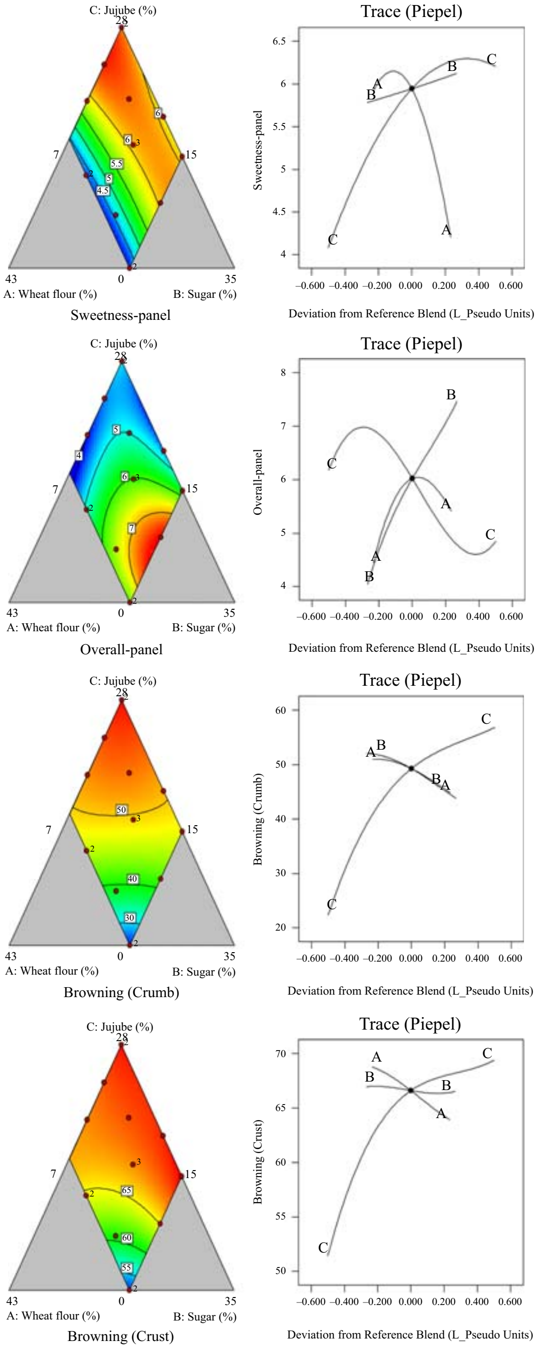


Figure 2.
Contour and Piepel Response Trace Plots from custom mixture design illustrating the effect of RWF, sugar and JF levels on sensorial and color characteristics of sponge cake

Table II.
Validation results for models obtained from custom mixture design in optimization experiments

Considering crust color data			Optimum blends (%)		
		RWF[a]	Sugar		Jujube flour
Positive (analysis 1)		24.19	21.46		4.36
Negative (analysis 2)		21.20	21.20		7.60
			Response values		
Response variables	Target	Observed	Estimated (analysis 1)	Observed	Estimated (analysis 2)
Textural properties					
Hardness (N)	Minimize	2.19	2.07	1.73	1.74
Cohesiveness	Maximize	0.48	0.443	0.49	0.45
Springiness (%)	Maximize	81.67	81.19	78.28	79.45
Chewiness (Nm)	Minimize	1.07×10^{-2}	1×10^{-2}	8.29×10^{-3}	8.00×10^{-3}
Adhesiveness (Nm)	Minimize	-2.39×10^{-5}	-2.34×10^{-5}	-2.23×10^{-5}	-2.73×10^{-5}
Physical properties					
Baking loss (%)	Minimize	14.23	14.42	14.56	14.46
Specific volume (mL/g)	Maximize	1.71	1.72	2.06	1.65
Crumb moisture (%)	Non	21.96	21.33	20.25	21.01
Height (cm)	Maximize	4.77	4.59	4.77	4.46
Collapse (cm)	Minimize	4.30×10^{-2}	4.30×10^{-2}	3.30×10^{-2}	3.90×10^{-2}
Sensorial evaluation					
Color	Maximize	6.00	5.36	7.17	7.04
Firmness	Minimize	4.80	4.24	4.40	3.73
Adhesiveness	Minimize	4.75	3.14	4.50	2.98
Chewiness	Minimize	4.75	3.57	4.75	3.42
Sweetness	Maximize	5.33	5.37	5.60	5.94
Flavor	Maximize	6.40	5.90	6.25	5.72
Overall acceptability	Maximize	6.40	7.506	7.25	7.584
Color features					
Crumb browning index	Minimize	36.97	34.88	41.37	41.57
Crust browning index	Minimize	62.75	59.83	66.55	64.40
Crumb b^* (yellowness)	Maximize	31.26	33.64	31.16	33.21
Crust b^* (yellowness)	Maximize	26.70	30.27	23.71	25.31
Desirability			0.71		0.75

Note: [a]Refined wheat flour

indices and textural attributes of the samples during 51 days storage period were illustrated in Figure A1. For ease of analysis, the percentage of changes in the parameters was calculated as presented in Table III. Formation of conjugated trienoic acids was not affected ($p > 0.05$) by baking procedure, JF level and their interactions, while the rest of the parameters were significantly ($p < 0.05$) influenced by at least two terms, confirming the important effect of added JF and baking temperature on both oxidative indices and textural properties of stored cake (Table III). In line with the literature (Pegg, 2005; Ghorbani and Hosseini, 2017; Hosseini, Ghorbani, Jafari and Sadeghi Mahoonak, 2019), the trend of changes in CTV was different from the other oxidative parameters. In fact, in fatty acids with three or more double bonds, CD moieties are formed at the earlier steps of the oxidation reaction, followed by the CT moiety (Pegg, 2005). Therefore, the changes in CTV of the samples required a longer time to become significant as compared with the other oxidative indices.

Based on Table III, the results showed that JF, especially at a level of about 7 percent, highly protected the samples against oxidation, probably due to present of a considerable amount of antioxidant compounds in JF as above mentioned. Based on physical parameters presented in Table III, the afore-mentioned improving effects of JF on textural properties and water content of cake well maintained throughout the storage period. Finally, a prediction

Table III. Percentage of variations in the physicochemical indices of the samples during storage at room temperature for 51 days

Treatment[a]	Percentage of variations (%)[b]					
	CDV	CTV	PV	Acid value	Moisture	A_w
J5T1	32.32±1.12^{c}	95.22±0.63^{a}	12.08±11.20^{c}	58.56±1.71^{ab}	−32.35±0.01^{b}	−13.75±0.26^{c}
J7T1	23.17±0.05^{b}	79.82±10.68^{a}	−6.32±0.59^{c}	28.58±0.89^{c}	−32.35±0.39^{b}	−13.71±0.05^{c}
CT1	40.34±0.61^{a}	60.71±4.43^{a}	302.83±3.58^{a}	63.18±4.01^{a}	−32.76±0.08^{b}	−12.12±0.05^{a}
J5T2	31.19±3.59^{b}	79.60±21.69^{a}	20.88±8.57^{c}	38.66±1.85^{c}	−28.50±0.14^{a}	−14.72±0.21^{d}
J7T2	28.42±1.07^{bc}	68.41±9.71^{a}	−4.27±4.71^{c}	29.94±1.07^{c}	−28.81±0.03^{a}	−12.94±0.02^{b}
CT2	32.50±0.78^{b}	64.61±6.79^{a}	226.07±18.82^{b}	44.52±8.70^{bc}	−35.72±0.72^{c}	−14.13±0.22^{cd}
BP effect	0.2398	0.2761	0.0085*	0.0019*	0.0003*	0.0003*
JFC effect	0.0003*	0.0539	< 0.0001*	0.0003*	< 0.0001*	0.0002*
Interactions	0.0041*	0.4732	0.0015*	0.0176*	< 0.0001*	< 0.0001*
	Hardness	Cohesiveness	Springiness	Chewiness	Adhesiveness	Stiffness
J5T1	94.52±0.15^{d}	−27.20±0.74^{a}	−4.40±0.46^{c}	30.59±1.12^{c}	−13.99±1.50^{a}	102.43±9.08^{d}
J7T1	212.30±4.80^{c}	−28.18±1.23^{a}	−4.17±0.59^{bc}	107.54±6.63^{b}	−37.36±13.08^{ab}	145.57±10.78^{cd}
CT1	300.31±0.88^{b}	−51.91±1.22^{c}	−11.32±0.35^{d}	83.81±8.26^{b}	−61.74±2.53^{b}	689.18±26.12^{b}
J5T2	180.20±2.49^{c}	−28.41±1.40^{a}	−2.18±1.05^{ab}	89.80±4.91^{b}	−52.43±19.04^{ab}	190.41±49.92^{cd}
J7T2	290.02±27.86^{b}	−26.51±0.41^{a}	−0.08±0.02^{a}	185.69±22.80^{a}	−57.12±4.14^{b}	215.15±15.37^{c}
CT2	367.03±1.23^{a}	−39.98±1.41^{b}	−9.26±0.23^{d}	161.19±5.44^{a}	−51.28±9.43^{ab}	858.31±2.69^{a}
BP effect	< 0.0001*	0.0007*	0.0001*	< 0.0001*	0.0379*	0.0003*
JFC effect	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*	0.0510	< 0.0001*
Interactions	0.5451	0.0004*	0.0746	0.4207	0.0419*	0.0602

Notes: [a]J5: Jujube 5 percent, J7: Jujube 7 percent, T1: 180°C for 24 min, T2: 170°C for 32 min; C, control cake, BP, baking procedure, JFC, jujube flour concentration; [b]Values are duplicate mean ± standard deviation; [c,d]Means with the same letters within the same columns are not significantly different ($p < 0.05$). CDV, conjugated diene value; CTV, conjugated triene value; PV, peroxide value; A_w: water activity. *$p < 0.05$

profiler as provided by statistical software, demonstrating the best levels of the independent variables required for preparing a cake with the best physicochemical features as shown in Figure 3. Take this optimization into account, the lower increase in oxidative indices and firmness, the higher water holding capacity, and the lower decline in cohesiveness and springiness of texture during 51 days storage period was obtained by a cake formulation containing ~7 percent JF and by a baking temperature of 180°C for 24 min (Figure 3).

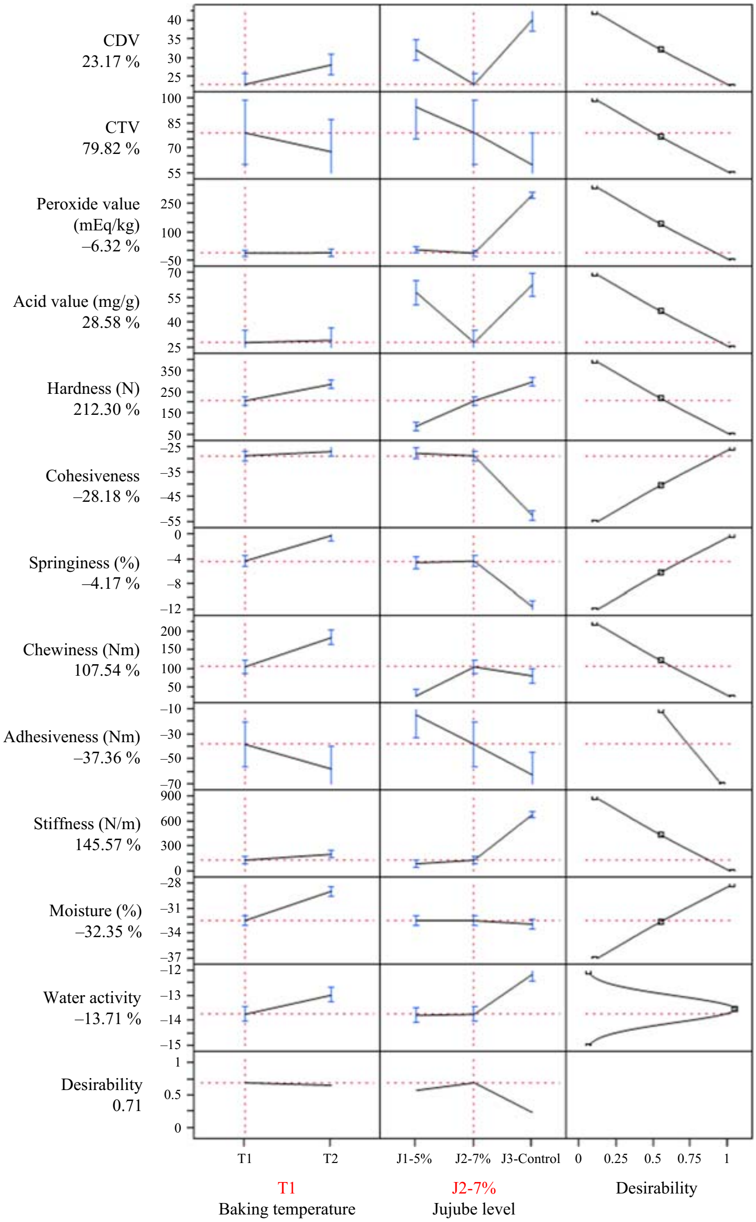


Figure 3.
Prediction profiler illustrating the optimum level of baking temperature and JF needed to achieve the best physicochemical characteristics for cake stored within polyethylene pouches for 51 days

Conclusions

A custom mixture design was successfully used to explain the relationship between independent and response variables and to estimate the optimum levels of RWF (21.19 percent), sugar (21.20 percent) and JF (7.61 percent) for making the cake with promoted physical, textural and organoleptic properties as well as minimum browning from Maillard reaction. The low levels of JF such as ~7 percent are suggested to use in making cake for improving the physicochemical features in both fresh and stored cake. This can be done without applying the extra cost in the product since the incorporated JF is not only a functional additive, but also is a partial substitution for RWF and sugar in the cake batter.

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(The Appendix follows overleaf.)

Appendix 1

Table AI. ANOVA results of regression models estimated from custom mixture design for textural, physical, sensorial and color characteristics of sponge cake

ANOVA source	Cohesiveness			Specific volume (mL/g)			Height (cm)		
	F-value	p-value	Coefficient	F-value	p-value	Coefficient	F-value	p-value	Coefficient
Linear model	629.38	$<$ 0.0001	–	351.28	$<$ 0.0001	–	174.37	$<$ 0.0001	–
Linear mixture	629.38	$<$ 0.0001	–	351.28	$<$ 0.0001	–	174.37	$<$ 0.0001	–
A-RWF [d]	–	–	0.27	–	–	1.20	–	–	4.46
B-Sugar	–	–	0.58	–	–	2.37	–	–	5.02
C-Jujube flour	–	–	0.35	–	–	0.66	–	–	3.41
Lack of fit	0.54	0.7881	–	2.15	0.2080	–	4.64	0.0538	–
CV%[a]–R^2/R^2_{Adj}[b]$/R^2_{\text{Pred}}$[c]		1.28–0.9898/0.9882/0.9843			4.56–0.9818/0.9790/0.9722			2.11–0.9641/0.9585/0.9475	
	Moisture content (%)						Color-panel		
Linear model	369.76	$<$ 0.0001	–		Cubic model		54.66	$<$ 0.0001	–
Linear Mixture	369.76	$<$ 0.0001	–		Linear mixture		30.76	0.0007	–
A-RWF	–	–	26.11		A-RWF		–	–	137.26
B-Sugar	–	–	17.88		B-Sugar		–	–	–130.71
C-Jujube flour	–	–	22.71		C-Jujube flour				5.35
Lack of fit	1.58	0.3182	–		AB		0.26	0.6286	21.28
CV%–$R^2/R^2_{\text{Adj.}}/R^2_{\text{Pred}}$		0.67–0.9827/0.9801/0.9708			AC		19.88	0.0043	–266.47
	b* (Crumb yellowness)				BC		89.34	$<$ 0.0001	269.74
Linear model	117.13	$<$ 0.0001	–		ABC		0.18	0.6866	–18.32
Linear Mixture	117.13	$<$ 0.0001	–		AB(A-B)		34.09	0.0011	–347.25
A-RWF	–	–	31.79		AC(A-C)		23.30	0.0029	–164.25
B-Sugar	–	–	36.40		BC(B-C)		98.66	$<$ 0.0001	212.59
C-Jujube flour	–	–	28.41		Lack of fit		0.010	0.9224	–
Lack of fit	3.28	0.1035	–		CV%– $R^2/R^2_{\text{Adj}}/R^2_{\text{Pred}}$			5.70–0.9879/0.9699/0.9487	
CV%–$R^2/R^2_{\text{Adj.}}/R^2_{\text{Pred}}$		1.51–0.9474/0.9393/0.9185							

(*continued*)

Table AI.

ANOVA source	Springiness (%)			Baking loss (%)			Hardness (N)		
	F-value	p-value	Coefficient	F-value	p-value	Coefficient	F-value	p-value	Coefficient
Quadratic model	240.63	< 0.0001	–	52.06	< 0.0001	–	315.28	< 0.0001	–
Linear Mixture	511.72	< 0.0001	–	105.90	< 0.0001	–	729.23	< 0.0001	–
A-RWF	–	–	65.80	–	–	9.25	–	–	26.59
B-Sugar	–	–	61.54	–	–	16.45	–	–	2.78
C-Jujube flour	–	–	65.97	–	–	12.60	–	–	6.51
AB	52.81	< 0.0001	72.55	3.48	0.0918	3.94	105.92	< 0.0001	−44.22
AC	60.32	< 0.0001	51.38	37.89	0.0001	8.62	26.54	0.0004	−14.67
BC	40.31	< 0.0001	32.96	4.22	0.0669	−2.26	22.99	0.0007	−10.71
Lack of fit	1.43	0.3521	–	0.85	0.5687	–	1.77	0.2731	–
CV%–$R^2/R^2_{\text{Adj.}}/R^2_{\text{Pred}}$	0.79–0.9918/0.9876/0.9796			0.94–0.9630/0.9445/0.8684			5.18–0.9937/0.9905/0.9819		
	Chewiness (Nm)			Adhesiveness (Nm)			Firmness-panel		
Quadratic model	110.72	< 0.0001	–	47.97	< 0.0001	–	46.06	< 0.0001	–
Linear Mixture	256.55	< 0.0001	–	81.63	< 0.0001	–	78.65	< 0.0001	–
A-RWF	–	–	0.086	–	–	3.163×10^{-5}	–	–	19.22
B-Sugar	–	–	-4.213×10^{-3}	–	–	-9.108×10^{-5}	–	–	4.39
C-Jujube flour	–	–	0.019	–	–	1.435×10^{-5}	–	–	5.49
AB	22.86	0.0007	−0.099	2.57	0.1400	8.096×10^{-5}	37.33	0.0001	−23.23
AC	13.02	0.0048	−0.049	15.10	0.0030	-1.300×10^{-4}	56.95	< 0.0001	−19.01
BC	0.013	0.9115	1.226×10^{-3}	3.44	0.0934	4.869×10^{-5}	3.26	0.1010	−3.57
Lack of fit	2.16	0.2093	–	2.31	0.1903	–	1.65	0.2984	–
CV%–$R^2/R^2_{\text{Adj.}}/R^2_{\text{Pred}}$	7.04–0.9823/0.9734/0.9442			30.83–0.9600/0.9400/0.8577			4.62–0.9584/0.9376/0.9093		
	Adhesiveness-panel			Chewiness-panel			Sweetness-panel		
Quadratic model	51.27	< 0.0001	–	25.77	< 0.0001	–	59.95	< 0.0001	–
Linear Mixture	46.75	< 0.0001	–	24.74	0.0001	–	119.57	< 0.0001	–
A-RWF	–	–	19.73	–	–	19.19	–	–	−6.58
B-Sugar	–	–	−0.62	–	–	1.74	–	–	6.47
C-Jujube flour	–	–	6.68	–	–	6.17	–	–	6.21
AB	20.31	0.0011	−17.96	23.62	0.0007	−21.20	19.82	0.0012	14.76
AC	140.58	< 0.0001	−31.32	77.51	< 0.0001	−25.46	58.22	< 0.0001	16.76
BC	12.56	0.0053	7.35	2.87	0.1213	3.84	0.97	0.3475	−1.70
Lack of fit	2.17	0.2079	–	3.65	0.0910	–	0.75	0.6202	–
CV%–$R^2/R^2_{\text{Adj.}}/R^2_{\text{Pred}}$	5.08–0.9625/0.9437/0.9028			5.38–0.9280/0.8920/0.7474			3.63–0.9677/0.9516/0.9072		

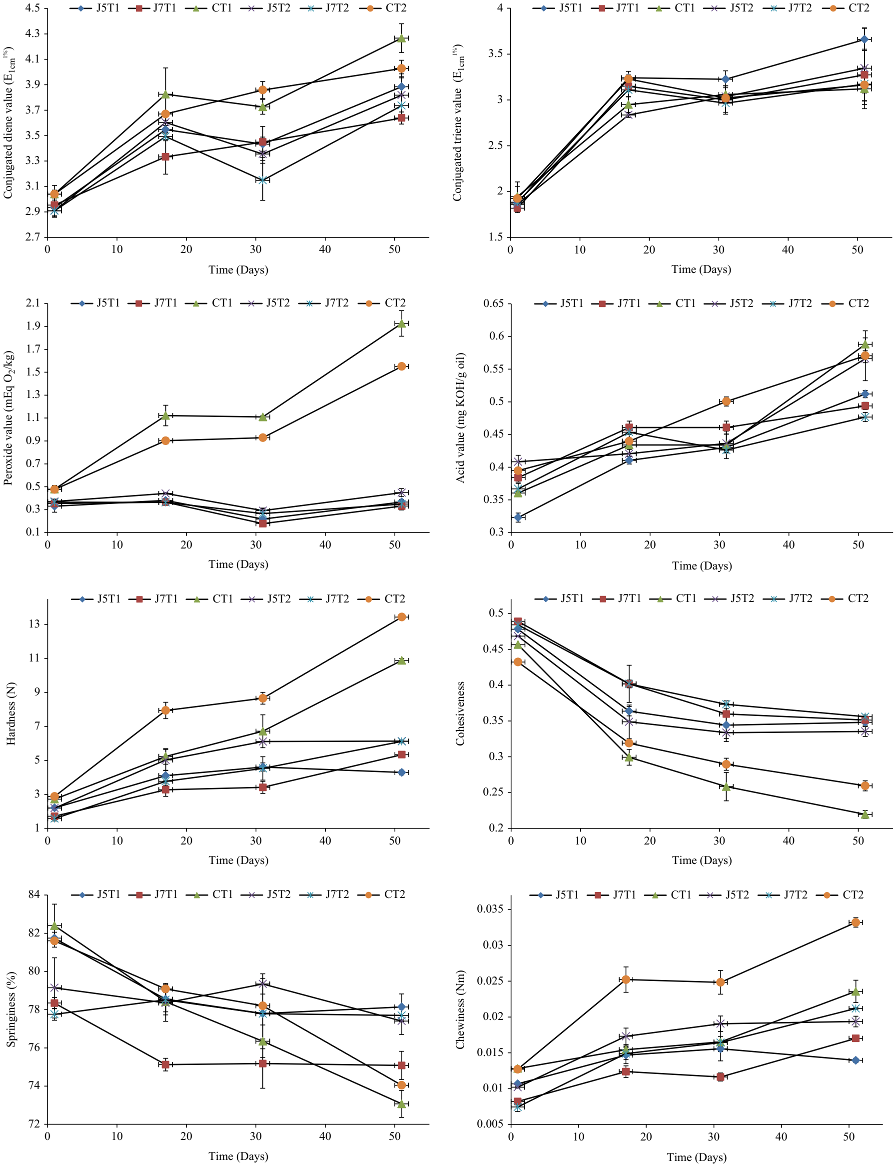
(*continued*)

Table AI.

ANOVA source	Collapse (cm)			Flavor-panel			Overall acceptability-panel		
	F-value	*p*-value	Coefficient	*F*-value	*p*-value	Coefficient	*F*-value	*P*-value	Coefficient
Special cubic model	54.05	$<$ 0.0001	–	32.89	$<$ 0.0001	–	44.11	$<$ 0.0001	–
Linear Mixture	109.66	$<$ 0.0001	–	52.75	$<$ 0.0001	–	78.30	$<$ 0.0001	–
A-RWF	–	–	−0.046	–	–	−2.34	–	–	1.48
B-Sugar	–	–	−0.042	–	–	2.10	–	–	13.25
C-Jujube flour	–	–	0.044	–	–	3.89	–	–	4.85
AB	56.84	$<$ 0.0001	0.37	36.87	0.0002	24.74	1.88	0.2036	−6.46
AC	89.82	$<$ 0.0001	0.27	70.40	$<$ 0.0001	20.05	0.20	0.6691	1.22
BC	21.00	0.0013	0.13	15.84	0.0032	9.11	30.71	0.0004	−14.68
ABC	53.01	$<$ 0.0001	−0.55	34.97	0.0002	−36.86	74.03	$<$ 0.0001	62.07
Lack of fit	1.35	0.3670	–	0.97	0.4993	–	0.90	0.5290	–
CV%–R^2/R^2_{Adj}/R^2_{Pred}	4.58 – 0.9730/0.9550/0.9268			3.48 – 0.9564/0.9273/0.8337			4.02 – 0.9671/0.9452/0.9116		
	Browning index (Crumb)			Browning index (Crust)			b* (Crust yellowness)		
Special cubic model	414.50	$<$ 0.0001	–	119.24	$<$ 0.0001	–	423.74	$<$ 0.0001	–
Linear Mixture	1,051.03	$<$ 0.0001	–	262.52	$<$ 0.0001	–	866.88	$<$ 0.0001	–
A-RWF	–	–	39.20	–	–	67.13	–	–	1.60
B-Sugar	–	–	39.39	–	–	75.91	–	–	4.37
C-Jujube flour	–	–	56.84	–	–	69.38	–	–	19.26
AB	15.57	0.0034	−68.35	21.49	0.0012	−82.15	194.81	$<$ 0.0001	143.13
AC	0.12	0.7364	3.53	0.59	0.4625	−7.98	31.03	0.0003	33.51
BC	0.012	0.9137	1.08	1.65	0.2314	−12.78	19.02	0.0018	25.12
ABC	35.17	0.0002	157.14	19.60	0.0017	120.02	70.72	$<$ 0.0001	−131.93
Lack of fit	2.04	0.2269	–	1.04	0.4688	–	0.49	0.7430	–
CV%–R^2/$R^2_{\text{Adj.}}$/R^2_{Pred}	1.77–0.9964/0.9940/0.9875			1.28–0.9876/0.9793/0.9607			2.01–0.9965/0.9941/0.9895		

Notes: [a]Coefficient of variations (%); [b]Adjusted determination coefficient; [c]Predicted determination coefficient; [d]Refined wheat flour

Appendix 2



(continued)

Figure A1.
The variations in physicochemical parameter of samples during storage at room temperature for 51 days

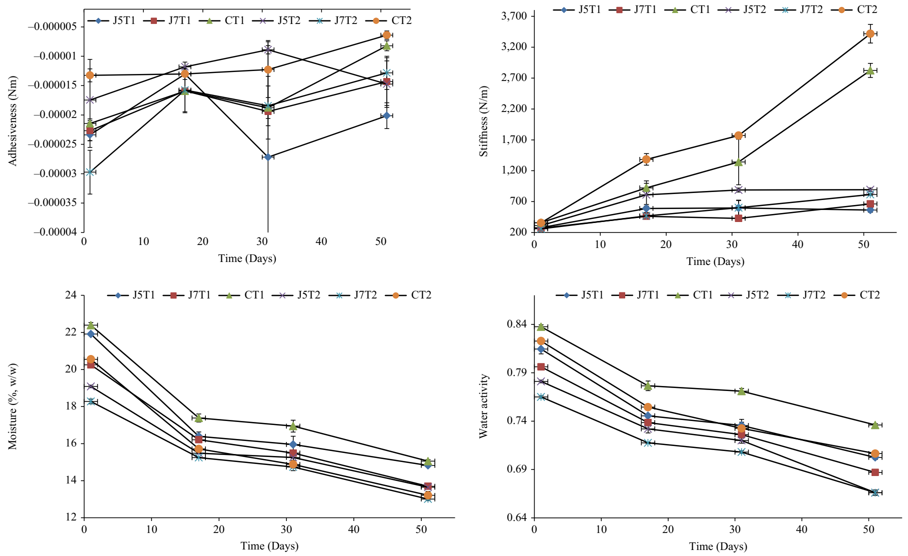


Figure A1.

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