Optimisation of gluten-free tulumba dessert with buckwheat flour and potato starch

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RESEARCH ARTICLE

Abstract

Tulumba dessert is widely preferred in Turkey; however, it cannot be consumed by celiac patients as it includes gluten. It is vital for the diet of these patients to produce different gluten-free products. In this study, buckwheat flour (BWF) and potato starch (PS) concentration, to be used in the gluten free tulumba dessert formulation, was optimised using the response surface methodology. Increasing the ratio of PS in the BWF-PS mixture caused a decrease in the hardness of the dessert samples and an increase in expansion, viscosity, adhesiveness, and yield of both the syrup including and not including samples. When considering the parameters used in the optimisation process, the optimum gluten free dessert formulation was found to be 175.87 g water, 0.13 g carboxy methyl cellulose, 2.20 g soy protein, 68.24 g BWF and 31.76 g PS. Some properties such as crispness and aftertaste of the samples prepared by this formulation were found to be very close to the control sample. However, tulumba desserts that include BWF had higher sensory scores than the control sample in terms of overall quality, flavour, symmetry, pore structure and appearance.

Keywords: buckwheat, gluten-free tulumba dessert, potato starch, RSM

1. Introduction

Popularly consumed and preferred by our society, tulumba dessert is one of the donuts that is native to Turkey. This dessert is also consumed in the Middle East and some parts of Europe (Özer *et al.*, 2012). In the process of preparing Tulumba dessert, the determined amount of flour is added to the boiled water in the first 90 seconds while constantly being mixed at low heat. When sticking to the pan is observed, oil is added to prevent sticking. It is cooked with constant mixing at medium heat. It is crucial that the starch be gelatinised while cooking so that the dessert can reach the desired degree of crispiness, otherwise the dessert will have a very soft texture in the end. When the dough temperature drops to 45-50 °C, eggs are added. After adding the eggs, when the dough temperature drops to 30 °C, the dough needs to be put into a container. Then, the dough, which is about at 25 °C, is divided into pieces that are 3.0 to 3.5 cm long and 1.60 cm in diameter and the pieces are put into oil which is at about 25 °C. It is necessary that while frying, the fullness rate of the deep fryer should remain the same so that the temperature control can be maintained (Dogan and Yurt, 2002). This dessert is ready to be served after the fried pieces of this prepared dough are kept in syrup for a certain period of time. Cereal products can be added to the initial recipe that is used in the production of the dessert to increase its hardness and crispiness, emulsifiers to regulate its texture and internal structure, sugar to have a better colour and taste,and dairy products to enhance its nutritional value.

Traditional tulumba dessert, produced with wheat flour (WF), as expected contains gluten. The compounds of gluten are gliadin and glutenin fractions. Gliadin, which is an alcohol-soluble fraction of gluten protein, cannot be digested by celiac patients. Therefore, people with celiac disease are not able to eat common bread, pasta, cake, pie, patty, biscuit, cake, tulumba dessert and many similar foods throughout their entire lives.

In gluten-free products, as an alternative to WF, different cereal flours such as rice, buckwheat, chestnut, corn and different starches are used (Arendt and Bello, 2008; Gularte *et al.*, 2012; Lazaridou *et al.*, 2007; Levent and Bilgiçli, 2011; Lopez *et al.*, 2004; Ronda *et al.*, 2009; Sanchez *et al.*, 2002; Shih *et al.*, 2006; Witczak *et al.*, 2012; Yildiz and Dogan, 2014). However, as a starch source, anything except for wheat is widely used since some celiac patients cannot even tolerate wheat starch. This is because there is a possibility that a trace of gliadin may mix with wheat starch which is a serious problem for celiac patients. Even that little amount is taken in for a long time; it may disturb celiac patients (Chartrand *et al.*, 1997; Horvath and Mehta, 2000; Lohiniemi *et al.*, 2000).

Due to its rich functional compounds and gluten-free property, buckwheat is used for the production of functional, dietetic-oriented products and diets of celiac patients (Yildiz, 2009). As buckwheat is gluten-free, it has become the major element of gluten-free diets (Wijngaard and Arendt, 2006). It has been maintained that the seeds of buckwheat are the promising material for the production of gluten-free cereal products and that has been proved with immunologic analyses; it contains no harmful protein for celiac patients (Aubrecht and Biacs, 2001).

In recent years, some gluten-free products (like bread, macaroni, noodle, biscuit and flour) are produced on a limited scale. The patients have trouble getting hold of these products, as there is no broad distribution network for them. Yet, there are many imported gluten-free products available in the market, especially on e-selling sites.

The variety of gluten-free products should be expanded so that celiac patients can meet their daily needs regularly. No attempt has still appeared to be done for gluten-free tulumba dessert. That most of the studies carried out so far have focused on cake and mainly bread, indicates the importance of a gluten-free tulumba dessert study since well qualified gluten-free tulumba desserts can be an option for celiac patients. Besides, it can be introduced into the market as an alternative food for all people.

In this study, a gluten-free tulumba dessert recipe has been developed by using a blend of buckwheat flour (BWF) and potato starch (PS) as the source of gluten-free flour with response surface method (RSM) and the effects of these compounds on some tulumba dessert's quality properties have been studied.

2. Materials and methods

Materials

In this study, special purpose WF that is a fine-textured, almost silky flour milled from soft wheat and with a low protein content (Söke flour; Söke Milling Industry and Trade Inc., Aydın, Turkey) was used for the production of control tulumba dessert; instead of WF, BWF (Fitmek; Hedef Gluten-free Industry and Trade Inc., Izmir, Turkey) and PS (Soyyiğit Food Industry and Trade Inc., Istanbul, Turkey) were used for the production gluten-free tulumba dessert. Carboxy methyl cellulose (CMC) and isolated soybean protein (SP) (Adler; KMK Laboratories Food Additives Industry and Trade Co. Ltd., Istanbul, Turkey), sunflower seed oil (Komili, Staple Food, Istanbul, Turkey), mineral water (Palandöken Desni, Erzurum, Turkey), fresh eggs and crystal sugar were also used in the study.

Flour analyses: ash and total protein content

The determination of nitrogen and ash content (AACC 08-03) was performed for the flour used in the trial. Protein content (%) was calculated as a result of the multiplication of total free nitrogen by 6.25 factor (AACC, 1995).

The production of tulumba dessert

The stable and optimised ingredients with their amounts that were included in the formulation of tulumba desserts prepared with gluten-free mixture and with WF (control) are shown in Table 1. Control tulumba dessert produced with WF was produced according to the formulation reported by Dogan and Yurt (2002).

In an attempt to optimise gluten-free tulumba dessert with a blend of PS and BWF as a source of gluten-free flour, RSM was used. In the preliminary experiments that were carried out, the desired properties of tulumba dessert were not obtained when only BWF was used in the formulation as a source of gluten-free flour. After having used it along with the corn flour in order to enhance the properties of tulumba dessert made of BWF and having obtained very good results (Bulut, 2013), the usage opportunities of PS were searched. Seeing that the usage of BWF and PS gave better results according to the preliminary tests, they were included in the experimental design. The BWF ratio out of the total flour source that was used based on the preliminary experiments was determined to be 60-80%, while the ratio

Table 1. The stable and optimised formulation of control (wheat flour) and gluten-free tulumba desserts.

Ingredients	WFD (g)[1]	GFTD (g)[1]
Wheat flour	100	–
Buckwheat flour	–	60-80
Potato starch	–	20-40
Water	150	170-190
Vegetable oil	10	10
Carboxy methyl cellulose	–	0.3-0.7
Soy protein	–	1.5-4.5
Egg white powder	40	28
Egg yellow powder	17	23

[1] WFD = tulumba dessert with wheat flour (control); GFTD = gluten free tulumba dessert.

of PS was determined to be 20-40%. In order to be able to obtain BWF-based gluten-free tulumba dessert that possesses the desired properties, the RSM design presented in Table 2 was used.

Determined as a result of the preliminary tests for each formula, dough baking time, kneading time to rub the eggs into the dough (Kitchen Aid Mixer, model KSM45; St Joseph, MI, USA), initial temperature of frying oil, frying temperature and time are all shown in Table 3. Expansion value, yield values, colour change and desired crispy texture formation of the dessert were all taken into consideration during determining preparation parameters included in Table 3.

The determination of expansion (cm) and yield (%) values

The expansion values of tulumba dessert were measured with a manual micrometre and the yield values were calculated by means of the formulas in Box 1.

The determination of the textural properties of the desserts

Textural parameters of tulumba desserts that ranged from 3.0 to 3.5 cm in length and 1.87 to 2.74 cm in diameter (hardness, chewiness, cohesiveness, adhesiveness and springiness) were measured by dividing the samples into two parts using a texture analyser (TA-XTplus; Stable Micro

Table 2. Response surface method experimental design for buckwheat flour formula tulumba dessert.[1]

Run	Coded values			Real values (ingredient proportions, g /100 g BWF + PS blend)		
	X_1	X_2	X_3	PS	SP (g) + CMC (g)	Water
1	-1.00	-1.00	-1.00	20.00	1.00 + 0.70	170.00
2	0.00	0.00	0.00	30.00	3.00 + 0.50	180.00
3	-1.00	1.00	1.00	20.00	5.00 + 0.30	190.00
4	1.00	-1.00	1.00	40.00	1.00 + 0.70	190.00
5	1.00	1.00	-1.00	40.00	5.00 + 0.30	170.00
6	0.00	0.00	0.00	30.00	3.00 + 0.50	180.00
7	1.00	1.00	1.00	40.00	5.00 + 0.30	190.00
8	0.00	0.00	0.00	30.00	3.00 + 0.50	180.00
9	1.00	-1.00	-1.00	40.00	1.00 + 0.70	170.00
10	-1.00	-1.00	1.00	20.00	1.00 + 0.70	190.00
11	0.00	0.00	0.00	30.00	3.00 + 0.50	180.00
12	-1.00	1.00	-1.00	20.00	5.00 + 0.30	170.00
13	0.00	0.00	0.00	30.00	3.00 + 0.50	180.00
14	0.00	-1.63	0.00	30.00	1.63 + 1.14	180.00
15	0.00	0.00	0.00	30.00	3.00 + 0.50	180.00
16	0.00	0.00	-1.63	30.00	3.00 + 0.50	163.67
17	0.00	1.63	0.00	30.00	8.15 + 0.49	180.00
18	1.63	0.00	0.00	46.33	3.00 + 0.50	180.00
19	-1.63	0.00	0.00	13.67	3.00 + 0.50	180.00
20	0.00	0.00	1.63	30.00	3.00 + 0.50	196.33

[1] BWF = buckwheat flour; PS = potato starch; SP = soy protein; CMC = carboxy methyl cellulose.

Table 3. Pastry baking, kneading time, frying oil initial temperature, frying time and frying temperatures of tulumba desserts.

Dessert	Pastry baking (min)	Kneading with mixer (min)	Oil initial temperature (°C)	Frying temperature (°C)	Frying time (min)
Wheat flour (control)	7.5	3.0	25	150	20
Buckwheat flour	10.5	5.0	80	120	18

Box 1. Fomulas

$$\text{Yield of dessert without syrup (\%)} = 100 - \frac{\text{unfried dough weight} - \text{weight of dessert without syrup}}{\text{weight of dessert without syrup}} \times 100 \quad (1)$$

$$\text{Yield of dessert with syrup (\%)} = 100 - \frac{\text{unfried dough weight} - \text{weight of dessert with syrup}}{\text{weight of dessert with syrup}} \times 100 \quad (2)$$

Systems, Godalming, Surrey, UK) equipped with a load cell of 5 kg and a P/5 cylindrical probe according to texture profile analysis (TPA) method. The test conditions were a pre-test speed of 1 mm/s, test speed of 1 mm/s, post-test speed of 10 mm/s, distance of 30 mm and trigger force of 5 g. The measurements were performed in triplicate with at least three replications. The following parameters were quantified: hardness (g), defined as a maximum force required to compress the sample in TPA; adhesiveness (g×s), under the baseline after the first compression in TPA; and springiness (mm), the ability of the sample to recover its original form after a deforming force is removed in texture compression; cohesiveness, the extent to which the sample could be deformed prior to rupture in TPA (Area 2/Area 1; Area 1 was the total energy required for the first compression, and Area 2 was the total energy required for the second compression); and chewiness (g×mm), work required to masticate the sample before swallowing (it was a calculated parameter equal to hardness × cohesiveness × springiness).

Sensory analysis

Sensory analysis is highly important as it reflects the consumers' preference and expectations in relation to the quality of the product. The sensory analysis of the gluten-free tulumba desserts produced after the optimisation closest to the control was carried out by the staff (16 people; 9 males and 7 females) of Iğdır University. The panellists were informed about the evaluation criteria before the panel. Control and gluten-free tulumba dessert was offered to the members of the panel within the numbered sample pots along with water and sensory assessment form. The appreciation levels of the panellists were determined using a 10 cm long divided scale (1 = extremely disliked, 10 = extremely liked). Every dessert was assessed in terms of seven parameters stated in the form (appearance, pore structure, symmetry, crispness, flavour, aftertaste, and overall quality). Each test was applied twice. Then, the average and standard error values of every parameter were calculated.

Statistical analysis

The optimum level of the components that are unstable in the formulation (Table 1) for gluten-free tulumba dessert was determined with RSM. The desserts that were prepared in accordance with the experimental design (Table 2) in order to develop a formula of gluten-free tulumba dessert closest to control tulumba dessert were compared in terms of parameter and the variance analyses of the obtained values were carried out in 'factorial experimental designs' by using the statistical programs StatGraphics Centurion 15.1 (StatGraphics, 2006) and CoStat (CoHort, 2004). Whether the difference between the factor averages was important or not was determined by means of LSD test at a level of $P<0.05$. Besides, the results of the sensory analysis in which 16 panellists participated were also subjected to statistical analysis.

The results of the variance analyses that were carried out for formula optimisations were also shown with standardised Pareto charts. On these charts, the linear and quadratic effects of each component and the significance levels of the effects of interactions that belong to these are shown as horizontal bar chart. The line that is drawn in parallel with the y-axis shows the importance level according to $P<0.05$. The longer the bar that falls on the right side of this line is, the more effect it makes. While the fact that the effect level is (+) representing that the effect increases in direct proportion with the corresponding component concentration, the fact that it is (-) representing that its effect decreases.

3. Results and discussion

Flour properties

The protein content of WF and BWF used in the study was found as 9.0 and 10.32%, respectively. As for their ash contents, they were respectively 0.48 and 1.93%.

Production of control tulumba dessert

The results with regard to the evaluated properties of control tulumba dessert produced with WF according to the formulation given in Table 1 are shown in Table 4.

The production of gluten-free tulumba dessert

The effect of the components that were included in the model in view of the various properties of gluten-free tulumba desserts produced according to the experimental

Table 4. Some quality properties of control tulumba dessert produced with wheat flour

Tulumba dessert properties	Measured value
Expansion (cm)	2.77±0.05
Yield of dessert with syrup (%)	86.52±1.45
Yield of dessert without syrup (%)	73.86±1.44
Hardness (g)	110.75±5.53
Chewiness (g×mm)	133.78±7.59
Adhesiveness (g×s)	-16.97±4.63
Cohesiveness	0.457±0.047
Springiness (mm)	2.273±0.167

design is evaluated below. Predicted model equations indicating the effect of each mixture component and their interactions on properties of gluten-free tulumba desserts are given in Table 5.

Expansion

The expansion values of gluten-free tulumba desserts that are produced from BWF and PS as the source of flour ranged between 1.87 (16.8%) and 2.74 (71.2%) cm. 78.84% of this difference in the expansion values can be explained by the linear and quadratic effects of the components in the model (water, SP-CMC blend and BWF-PS blend) and the interactions between components. The most effective factor to have an effect on expansion value is the linear effect of the blend of BWF-PS ($P<0.001$), which is statistically important, as well. Besides, the interaction between the blend of BWF-PS and SP-CMC affected the expansion value of tulumba desserts in a statically important way ($P<0.05$). As the ratio of PS in the blend increased, the expansion value of tulumba dessert also increased (Figure 1A). The similar case was observed in tulumba desserts that were prepared by using the blend of corn flour-potato starch (CF-PS) (Bulut, 2013). The addition of pregelatinised rice flour generally reduced the change of volume of gluten free donut prepared with blend of commercial gluten free flour and rice flour, which could be resulted from certain physical properties of pregelatinised rice flour reducing the expansion amount during proofing and frying (Melito and Farkas, 2013).

In spite of this, the quadratic effects of the different water levels used in the formula, the alterations in the blend of SP-CMC and the component included in the model on the expansion value of tulumba desserts were found to be statistically insignificant ($P>0.05$) (Figure 1A). While the expansion value of the control tulumba desserts produced with WF was 2.77±0.047 cm, this value was determined as 2.49±0.42 cm in a study that was carried out by Özen (2006). On the other hand, the expansion values of tulumba desserts produced with gluten-free CF-PS varied between 1.83 and 2.44 cm (Bulut, 2013).

Table 5. Predicted model equations indicating effect of each component[1] and their interactions on some properties of tulumba dessert samples.

Parameters (Y)	Predicted model equations	$(R^2)^2$
Expansion (cm)	$Y = -7.76244 + 1.87072X_2 + 0.11362X_1 + 0.08908X_3 + 0.00363X_2^2 - 0.014X_2X_1 - 0.00825X_2X_3 - 0.00013X_1^2 - 0.00047X_1X_3 - 0.00021X_3^2$	78.84
Yield of dessert with syrup (%)	$Y = -370.717 + 14.95800X_2 + 3.64846X_1 + 4.28804X_3 + 0.47066X_2^2 + 0.04862X_2X_3 - 0.09412X_2X_3 + 0.00617X_2^2 - 0.02031X_1X_3 - 0.00991X_3^2$	82.46
Yield of dessert without syrup (%)	$Y = -976.994 + 27.1297X_2 + 4.59057X_1 + 10.753X_3 + 0.91806X_2^2 + 0.16162X_2X_1 - 0.18337X_2X_3 + 0.00673X_1^2 - 0.02424X_1X_2 - 0.02766X_2^2$	71.44
Hardness (g)	$Y = 2.856.65 + 14.4286X_2 - 18.7469X_1 - 26.2721X_3 + 0.81032X_2^2 + 0.88604X_2X_1 - 0.23566X_2X_3 + 0.11170X_1^2 + 0.05900X_2X_3 + 0.06553X_3^2$	79.43
Adhesiveness (g×s)	$Y = -116.451 + 76.0787X_2 + 32.6257X_1 - 4.7846X_3 - 6.5229X_2^2 - 1.73343X_2X_1 - 0.17647X_2X_3 - 0.08424X_1^2 - 0.14568X_1X_3 + 0.02590X_3^2$	76.74
Chewiness (g×mm)	$Y = 77.3396 - 383.592X_2 + 6.27621X_1 + 2.45449X_3 + 2.21078X_2^2 - 0.224163X_2X_1 + 2.22606X_2X_3 - 0.02790X_1^2 + 0.02191X_1X_3 + 0.01165X_3^2$	40.82
Cohesiveness	$Y = 3.17594 - 1.22713X_2 - 0.03371X_1 - 0.03259X_3 + 0.02437X_2^2 + 0.00062X_2X_1 + 0.00685X_2X_3 - 8.344E\text{-}7X_1^2 + 0.00021 X_1X_3 + 0.00009X_3^2$	65.08
Springiness (mm)	$Y = -31.5232 - 3.71123X_2 + 0.36731X_1 + 0.29488X_3 - 0.13415X_2^2 - 0.02432X_2X_1 + 0.02495X_2X_3 - 0.00160X_1^2 - 0.00143X_1X_3 - 0.00067X_3^2$	30.18

[1] X_1 = g potato starch/100 g; X_2 = carboxy methyl cellulose-soy protein blend; X_3 = water.
[2] R^2 = coefficient of determination.

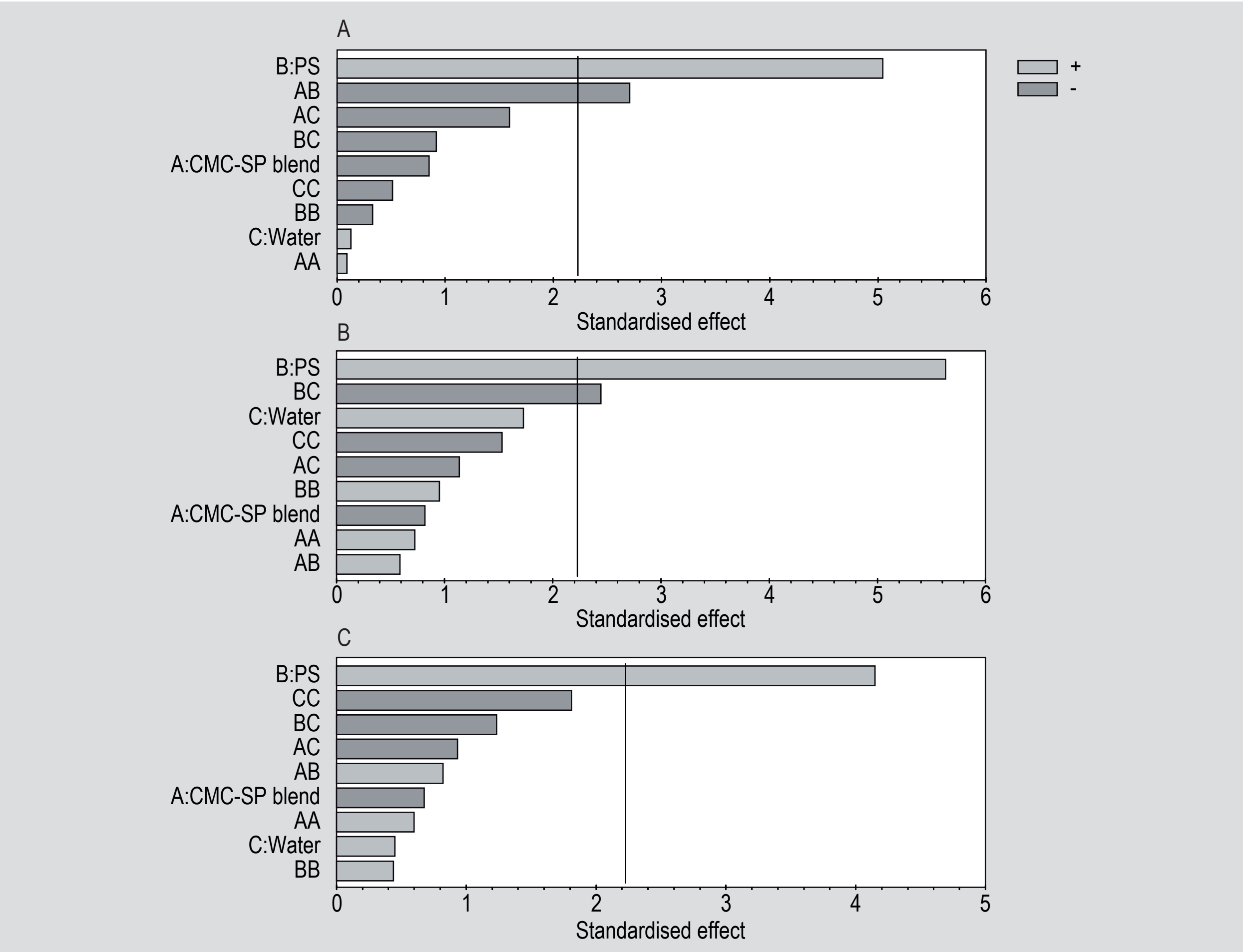

Figure 1. Effect of component levels on (A) expansion, (B) yield of dessert with syrup and (C) yield of dessert without syrup samples of buckwheat tulumba dessert (PS = potato starch (ratio (%) in the blend of buckwheat flour and potato starch); CMC = carboxy methyl cellulose; SP = soy protein; AA, BB, CC = quadratic effect of components; AB, AC, BC = interactions between components).

In another study, the percentage of the change of the volume of donut due to the frying process at the three oil temperatures showed an augment with particular behaviours at each oil temperature. It can be observed that a maximum donut expansion was found as 77.9, 71.4 and 37.3% in the samples processed at 180 °C for 120 s, at 190 °C for 105 s and at 200 °C for 75 s, respectively (Vélez-Ruiz and Sosa-Morales, 2003).

Yield of dessert with syrup

Yield values of tulumba desserts with syrup that were produced using BWF and PS varied between 78.3-92.40%. The linear and quadratic effects of components and interactions between components included in the model can account for these alterations having the rate of 82.467% (R^2=82.467). The linear effect of the blend of BWF-PS that was used in the formula had an effect on the yield of tulumba dessert with syrup at a level of P<0.001. As the PS ratio of the blend of BWF-PS increased, the yield also increased. The interaction of water with the blend of BWF-PS had a statistically important effect on the yield with syrup at a level of P<0.05. Linear and quadratic effect of the water also had an effect on yield with syrup. However, this effect was determined as statistically insignificant (P>0.05). Besides, the linear and quadratic effect of CMC-SP blend used in the formula and its interaction with the other components were found to be statistically insignificant (P>0.05) (Figure 1B).

Yield of dessert without syrup

Syrup-free yield values of tulumba desserts that were produced with BWF and PS varied between 59.84-85.71%. 71.44% of this difference that took place in syrup-free yield value can be explained by our model consisting of the linear and quadratic effects and interactions of components. The alteration that took place in this range might be a result of the massive alterations that happened in the blend of BWF-PS, as was the case with syrup yield (P<0.01). Used within the formula, PS in the blend of BWF-PS had a quite important effect. As the PS content of the flour blend increased, the syrup-free yield increased. Neither the linear effects of water and CMC-SP blend, nor the quadratic effects and interactions included in the model had a statistical importance on the syrup-free yield ($P>0.05$) (Figure 1C).

Yildiz and Dogan (2014) reported that once the PS ratio in the formula raises in a gluten-free cake experiment in which the blend of PS and BWF were used as a source of flour, the specific volume of the obtained cake increases. The most functional feature of starch is how it reacts in accordance with heat in the existence of water. When a blend of PS and water is heated over the critical control point, which is 60 °C for PS, hydrogen bonds that hold the granule, becoming weaker, inflate and get several times bigger than the initial size (Bemiller and Whistler, 2009). This increase depending on the rising starch ratio in expansion and yield value of tulumba desserts along with the volume of the cake can be associated with the previously mentioned features of starch.

Hardness

The hardness value of tulumba desserts that were prepared with BWF and PS as the source of flour varied between 89.34-161.25 g. Our model consisting of linear and quadratic values and interactions of the components can successfully explain 79.43% of the total difference. While the effect of BWF-PS blend on hardness value of tulumba desserts was $P<0.01$, the effect of different water levels and the quadratic effect of BWF-PS was found to be important at a level of $P<0.05$. The increase of the water level in the formula and the increase of PS ratio of BWF-PS blend in the formula decreased the hardness value. The quadratic effect of the blend of BWF-PS increased the hardness value. Yet, the interaction of SP-CMC blend with BWF-PS blend and the interaction of water with BWF-PS blend was found to be statistically an insignificant effect on the hardness ($P>0.05$) (Figure 2A). In a study of gluten-free cake in which the blend of chestnut flour and PS blend as the source of flour, it was stated that the hardness ratio of the cakes that were obtained with the increase of the PS ratio in the formula decreased (Yildiz and Dogan, 2014). In another study, much softer tulumba dessert was obtained with wheat starch in tulumba samples that were produced by adding other cereal products (semolina, flour under the semolina, vital gluten, corn flour, wheat starch and rice flour) instead of 20% of the current WF (Özen, 2006).

Adhesiveness

Adhesiveness values of tulumba desserts that were produced using BWF and PS varied between -72.65 and -7.08 g.s. 76.74% of the total difference that belongs to the adhesiveness value of tulumba dessert can be explained by the linear and quadratic effects of the components that were taken into the model (water, SP-CMC blend and BWF-PS blend) and the interactions between the components. The increase of the PS ratio in the blend of BWF-PS increased

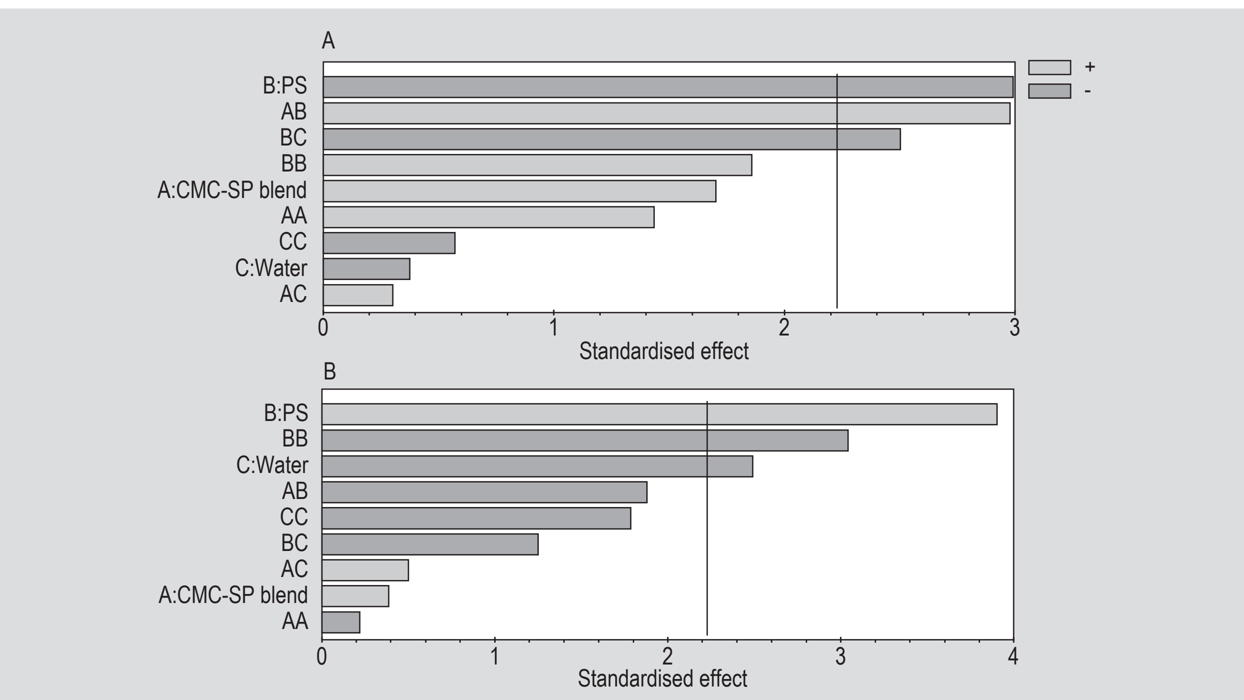

Figure 2. The effect of component levels on (A) adhesiveness and (B) hardness of buckwheat tulumba dessert (PS = potato starch (ratio (%) in the blend of buckwheat flour and potato starch); CMC = carboxy methyl cellulose; SP = soy protein; AA, BB, CC = quadratic effect of components; AB, AC, BC = interactions between components).

the adhesiveness value. In the study that was carried out by Bulut (2013), it was stated that the adhesiveness value of tulumba desserts that were prepared using CF-PS blend increased as a result of the increase in the PS ratio in the blend. The linear effect of the blend of BWF-PS that was used in the formula, the interaction of BWF-PS blend with SP-CMC blend and the interaction of BWF-PS blend with water had an effect on the adhesiveness of tulumba dessert at a level of $P<0.05$. In addition to this, the linear effect of water and SP-CMC blend on the adhesiveness was found to be statistically insignificant ($P>0.05$) (Figure 2B).

Chewiness

The chewiness values of tulumba desserts prepared using the blend of BWF-PS ranged between 15.75 and 125.487 g×mm. The increase of PS in the blend of BWF-PS and likewise the increase of SP in the blend of SP-CMC increased the chewiness value. Yet, the linear (water, SP-CMC blend and BWF-PS blend) and quadratic effects of the components taken into model about the chewiness values of tulumba dessert along with the interaction effects between the components were found as statistically insignificant ($P>0.05$) (Figure 3A). Our model consisting of linear and quadratic values and interactions of the components can only explain 40.82% of the total difference in the chewiness values of tulumba dessert.

Cohesiveness

The cohesiveness values of tulumba desserts produced by using BWF and PS as the source of flour varied between 0.22 and 0.65. 65.08% of the total difference that belongs to cohesiveness property can be explained by the linear and quadratic effects of water, the blend of SP-CMC and the blend of BWF-PS components and by the interactions of

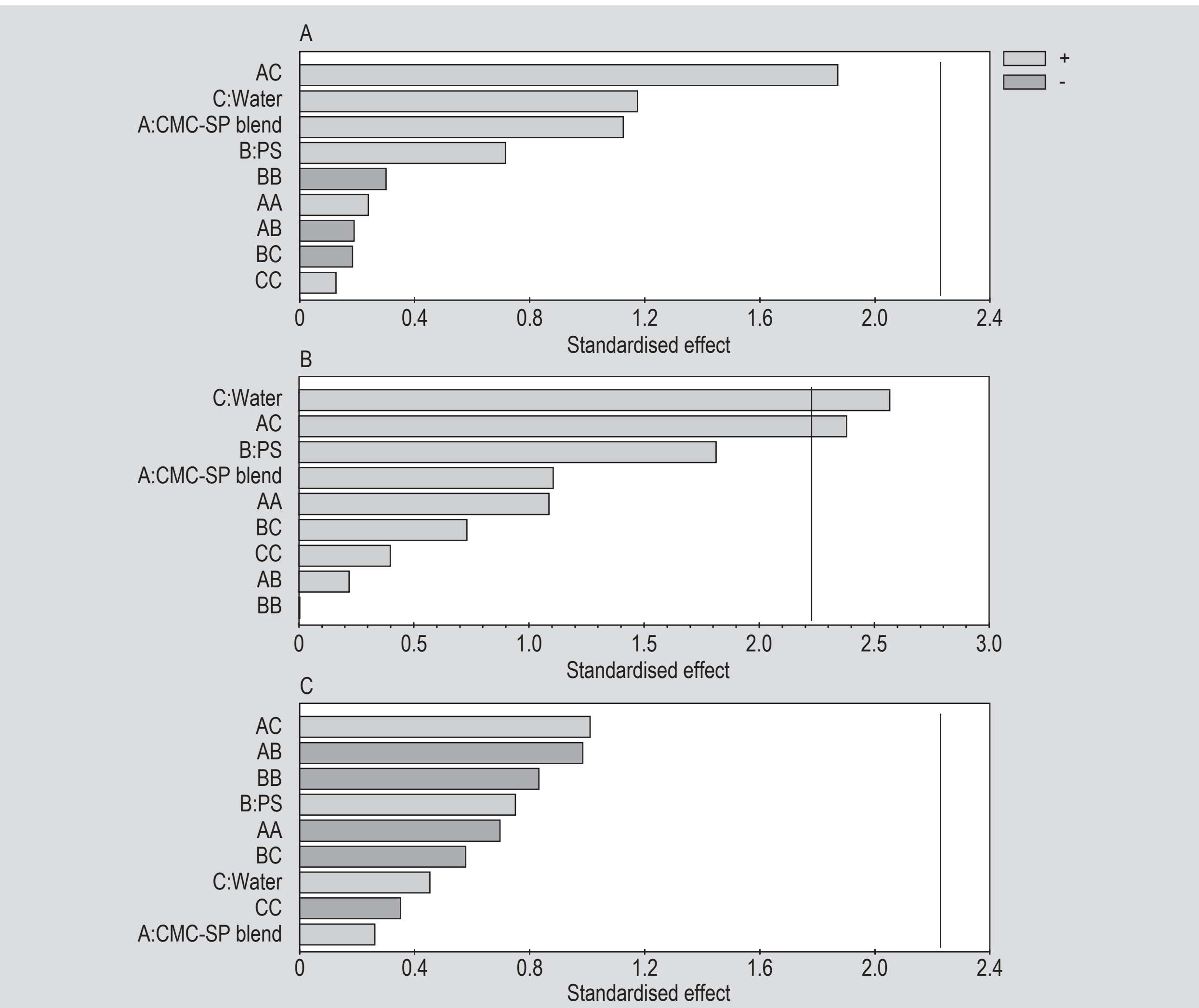

Figure 3. Effect of component levels on (A) chewiness, (B) cohesiveness and (C) springiness of buckwheat tulumba dessert (PS = potato starch (ratio (%) in the blend of buckwheat flour and potato starch); CMC = carboxy methyl cellulose; SP = soy protein; AA, BB, CC = quadratic effect of components; AB, AC, BC = interactions between components).

these components. The linear effects of the water used in the formula and the interaction of the blend of SP-CMC on the value of cohesiveness were found as statistically significant ($P<0.05$) (Figure 3B). The effect of the blend of SP-CMC that was used in the formula on the cohesiveness value of tulumba dessert formed the parabola chart. The least cohesiveness value was observed in the sample including 0.43 g CMC and 3.7 g SP with 100 g blend of BWF and PS and the increasing-decreasing SP-CMC values increase the cohesiveness.

Springiness

The springiness value of the gluten-free tulumba desserts produced using BWF and PS as the source of flour ranged between 0.053 and 0.095 mm. Onto the springiness values of tulumba dessert, linear effect of the components taken into the model (water, the blend of SP-CMC and the blend BWF-PS), quadratic effects of these components and the effects of interactions between the components were found as statistically insignificant ($P>0.05$) (Figure 3C). Consisting of the interactions and linear and quadratic effects of the components, our model explained very little (30.18%) of the total differences that happened in the springiness value of tulumba dessert.

Formula optimisation

One of the most significant methods preferred in product development studies is the optimisation of multiple factors and the usage of appreciation values. This is the reason why RSM is commonly used (Dogan and Yildiz, 2010). Having been used for the first time by Harrington (1965), the appreciation value is obtained as a result of the transformation of the analysed quality properties into the scale ranging between 0 and 1. When the factors are evaluated all together, the average total appreciation value is obtained. And this is the geometric average of the appreciation values that belong to every factor (Akbas *et al.*, 2012).

The source of flour along with the different water levels used for the formula of the gluten-free tulumba desserts prepared with the blend of BWF-PS and the effects of the alterations in the blend of CMC-SP on the general appreciation level are shown in Figure 4. Taking into account of the properties of all tulumba desserts evaluated within the scope of the study, along with the stable ingredients when 100 g blend of BWF and PS at the rates of 68.24:31.76 was used with 175.87 g water, 0.13 g CMC and 2.20 g SP blend, it became possible to produce gluten-free tulumba dessert with BWF closest to control tulumba desserts (Figure 5). The optimum points were determined with respect to physical properties of the control wheat tulumba dessert (Table 4). It was reported that RSM optimisation methodology can be used to develop an optimum gluten-free rice bread formulation to obtain rice bread quality parameters of which were found to be very similar to control wheat bread (Kittisuban *et al.*, 2014). In the evaluation of these gluten-free desserts, in the view of the adhesiveness, hardness, cohesiveness, expansion and yield values of tulumba dessert, total desirability value was found to be 0.963 (Table 6).

Sensory evaluation

Control tulumba dessert and gluten-free tulumba dessert were put through sensory evaluation. The members of the panel evaluated each tulumba dessert in terms of their appearance, pore structure, symmetry, crispness, taste and aroma, the mouth feel and overall quality. Crispness and aftertaste values of gluten free tulumba dessert were very close to the control sample. However, the desserts including

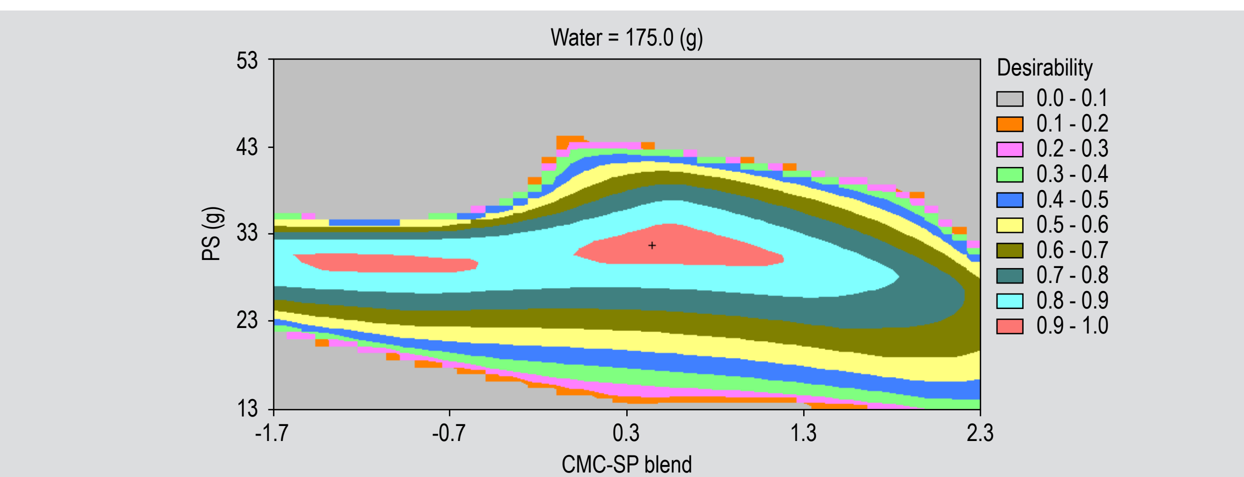

Figure 4. Total desirability values of buckwheat flour-potato starch blends, carboxy methyl cellulose-soy protein blends and water levels (CMC-SP blend = carboxy methyl cellulose-soy protein blends, g/100 g flour blend; PS = potato starch, g/100 g buckwheat flour-potato starch blend; water, g/100 g flour blend).

Figure 5. (A) Control tulumba dessert and (B) buckwheat tulumba dessert.

Table 6. Predicted and measured values for the responses (independent variables) at optimum buckwheat flour-potato starch blend, carboxy methyl cellulose-soy protein blend and water levels for tulumba dessert.

Tulumba dessert properties	Predicted value	Measured value
Adhesiveness (g×s)	-25.00	-25.41
Cohesiveness	0.30	0.34
Hardness (g)	110.69	112.31
Expansion (cm)	2.33	2.39
Yield of dessert without syrup (%)	76.00	75.34
Yield of dessert with syrup (%)	85.62	84.95
Desirability	0.963	

BWF had higher sensory scores than the control sample in terms of overall quality, flavour, symmetry, pore structure and appearance. The points that were given by the panellists and their statistical comparisons are shown in Table 7. In many studies, the optimised gluten free products received lower scores than the reference WF products (Arendt and Bello, 2008; Kittisuban *et al.*, 2014; Melito and Farkas, 2013; Lazaridou *et al.*, 2007; Yildiz and Dogan, 2014). We are of the opinion that gluten-free tulumba desserts are considered as an alternative product by the panellists due to their colour that was similar to that of chocolate and that's why they received high-scores.

4. Conclusions

In this study, a successful application of RSM was carried out to optimise the formulation of gluten-free tulumba dessert using the blend of BWF-PS as a source of flour. It has become possible to produce the gluten-free tulumba dessert quality that is very similar to control tulumba desserts. The formula that was determined by the optimisation programme, the properties of tulumba dessert estimated and determined are practically so close to one another. PS had a significant effect on enhancing the quality properties of tulumba dessert. While the increase in the proportion of PS in the blends of BWF and PS decreased the hardness of the dessert, the expansion, adhesiveness and yield values of dessert increased. According to the results of the present study, it should be possible to optimise gluten free product formulation using RSM. By this way, alternative gluten free products with desired quality can be produced.

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Table 7. Sensory evaluation scores for control tulumba dessert (WFD) and buckwheat flour formula tulumba dessert (BWFD).[1]

Parameters	BWFD±SE	WFD±SE	LSD
Appearance	8.442±0.49^a	6.042±0.49^b	1.363
Pore structure	7.171±0.61^a	4.928±0.61^b	1.753
Symmetry	8.664±0.44^a	7.092±0.44^b	1.248
Crispness	7.650±0.49^a	7.100±0.49^a	1.404
Flavour	7.714±0.49^a	6.221±0.49^b	1.396
Aftertaste	8.278±0.46^a	7.057±0.46^a	1.327
Overall quality	8.492±0.35^a	6.778±0.35^b	0.994

[1] Parameters were compared separately. Different small letters indicate that they are significantly different from each other when compared within each parameter (by LSD test, $P<0.05$); SE = standard error.

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