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Effects of Xanthan Gum and Corn Flour on the Quality of Sponge Cake Using Response Surface Methodology

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Abstract

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Effects of partial replacement of wheat flour with corn flour (2.93–17.07%) blended with xanthan gum (0.1172–0.6828%) on physical properties, textural and sensory characteristics of sponge cakes were evaluated by response surface methodology (RSM). The significant regression models ($P \leq 0.05$) were established to explain the influence of corn flour and xanthan (Xan) on the dependent variables and optimize the formulation. Xanthan significantly increased moisture content, hardness and chewiness, but it decreased specific volume and springiness ($P \leq 0.001$). Corn flour had significant positive effects on specific volume, hardness, springiness, colour and overall acceptability ($P \leq 0.05$). Hence corn flour and xanthan significantly improved the baking quality of sponge cakes ($P \leq 0.05$) and thereby augmented the potential for using wheat-corn blend flours in cake baking. Based on RSM optimisation, a balance between amounts of corn flour (12.7%) and xanthan (0.416%) led to products with desired physical properties and acceptable sensory quality.

Keywords: cake; maizena; optimisation; RSM; wheat flour; xanthan

In the bakery industry, sponge cake is one type of widely consumed products worldwide due to its characteristic flavour, more desirable texture and colour. The quality of cake is mainly influenced by ingredients. Among kinds of ingredients, wheat flour (WF) plays an important role because gluten in WF-based dough is mainly responsible for the structure-forming capacity in cakes and characteristic viscoelasticity in batter. Nevertheless, composite flour has been applied in bakery to solve a trophic issue, improve product quality and reduce cost in recent years, such as buckwheat flour (Krupa-Kozak *et al.* 2011), cassava flour (Eduardo *et al.* 2014), rice flour (Hojjatoleslami & Azizi 2015), chickpea flour (Herranz *et al.* 2016), and corn flour (Yaseen *et al.* 2010). Corn is one of the main alimentary crops and is widely cultivated in China, and corn flour (CF) is rich in various nutrients and greatly benefits people's health (An *et al.* 2008). CF provides a natural yellow colour and characteristic flavour in processing (Preichardt *et al.* 2011). CF is commonly used in making 'Fagao', a traditional food which is a kind of steamed sponge cake in China. Furthermore, very little work has been done on the formulation of baked wheat-corn sponge cake until now. However, the wheat-corn cake has many technological problems, such as undesirable reduction of water absorption and viscosity in batter with higher CF content (Xue & Ngadi 2006; Yaseen *et al.* 2010). To tackle the above issue, hydrocolloids are applied to modify the batter properties and Xanthan (Xan) is one typical hydrocolloid widely used in bakery (Hu 2004), especially in bread and cake (Arozarena *et al.* 2001; Poonnakasem *et al.* 2015). It exhibits a highly pseudoplastic flow, and forms a weakly bound complex network due to the intermolecular bonds (Hager & Arendt 2013). In bakery products, Xan provides weak gel behaviour to improve the cohesion of starch granules, control gas entrainment, and modify the batter rheology (Katzbauer 1998; Herranz *et al.* 2016). And it also has a high capacity of retaining moisture (Ronda *et al.* 2009).

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Response surface methodology (RSM) effectively minimizes trials and provides multiple regression models to perform optimisation in an experiment design (Yang *et al.* 2013). In food research, RSM has been widely applied in optimizing ingredient levels (Akesowan 2016), processing conditions (Feng & Sun 2014), and product formulations (Jang *et al.* 2011). In this study, RSM was used to examine the functional role of Xan and CF in sponge cakes from wheat-corn flour. And model verification of the optimized sponge cake was performed.

Therefore, the objectives of this study were to evaluate the effects of xanthan on the wheat-corn flour sponge cake physical parameters, texture and sensory attributes, optimize the basic formulation of wheat-corn flour sponge cake by RSM, and acquire the sponge cake with high acceptability. The applied xanthan in the study was a type of transparent xanthan, which was produced from *Xanthomonas campestris* XC-XH 99 pathovar. Its molecular characteristics include the typical basic molecule backbone, and different contents of acetylated mannose and pyruvic acid. The backbone of the applied xanthan has cellobiose as repeating unit and side-chains consisting of a trisaccharide composed of D-mannose (β-1,4), D-glucuronic acid (β-1,2) and D-mannose, which are attached to glucose residues in the backbone by α-1,3 linkages. Approximately 3.69% of pyruvic acid residues are linked to one-half of the terminal D-mannose at the 4 and 6 positions. Besides 5.6% of acetyl groups are linked to the D-mannose unit at *O*-6 position *O*-6. The applied xanthan has an excellent physicalo-chemical parameters and properties.

Table 1. The central composite experimental design

Treatment	Xan coded	Xan uncoded* (%)	CF coded	CF uncoded* (%)
1	0	0.4	0	10
2	1	0.6	–1	5
3	–1	0.2	–1	5
4	–1.41	0.1172	0	10
5	–1	0.2	1	15
6	0	0.4	0	10
7	0	0.4	0	10
8	1	0.6	1	15
9	1.41	0.6828	0	10
10	0	0.4	0	10
11	0	0.4	1.41	17.07
12	0	0.4	–1.41	2.93
13	0	0.4	0	10

*based on the 100 g mixture of cake formulation

MATERIAL AND METHODS

Materials. Wheat flour (WF) and corn flour (CF) were purchased from Great Value Co., Ltd. (China). WF contained 12.63% moisture, 8% protein and 0.37% ash; % wet basis, determined by the methods of AOAC (2000): 925.1, 960.52 and 923.03, respectively). CF had 13.74% moisture, 7.6% protein and 0.49% ash contents; % wet basis, determined by the methods of AOAC (2000). Xanthan (Xan) (Fufeng Biotechnology Co., Ltd., China) is a transparent standard, which contained moisture 14.58%, acetylated mannose 5.6%, pyruvic acid 4.3%, Ca^{2+} 3%, Mg^{2+} 0.11%, K^+ 0.09%, Na^+ 0.47% (AOAC 2000). The particle size of xanthan is about 63 μm. This kind of xanthan has fast hydration and transparent aqueous solution. Besides, it has tolerance to Ca and Mg. Sucrose, fresh whole eggs and double-action baking powder were purchased from the local market.

Experimental design. In this study, RSM was used to determine the optimal ingredient levels of Xan (X_1) and CF (X_2) in producing sponge cakes. Based on the preliminary baking trials, the coded levels, and the upper and lower limits for experimental variables were selected as shown in Table 1. There were in total thirteen treatments in the design (Table 1) and a two-factor central composite design (CCD) was constructed. The central point of the design was repeated five times to calculate the repeatability of the method. The effects of two independent variables on the responses were evaluated using the second-order polynomial model.

The equation derived using RSM for the prediction of the response variables is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{12} X_1 X_2 \quad (1)$$

where: β_0 – constant value of the fixed response at the central point of the experiment (the point [0, 0]); β_1 and β_2 – linear terms, β_{11} and β_{22} – quadratic terms; β_{12} – interaction regression terms; X_1 and X_2 – levels of the independent variables, Xan and CF

Sponge cake preparation. The experimental sponge cake formulations were as follows (based on the total weight of the cake formulation): liquid whole

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eggs (45%), sugar (19.5%), baking powder (0.5%) and water (5%) were fixed ingredients in the formulation. CF (5–15%) and WF (15–25%) were mixed at three ratios (CF/WF = 5/25, 15/15 and 10/20) to obtain 30% flour blend including Xan (0.1172–0.6828%). Besides, two control treatments for the experiment were designed as follows: Control 1 (C1): Xan 0, CF 0, WF 30%; Control 2 (C2): Xan 0, CF 30%, WF 0.

Cake butter (200 g) was prepared by blending the liquid whole eggs, water and sugar in a kitchen mixer with eggbeater (HM-980, Xinbao, Guangdong Xinbao Electrical Appliance Holdings Co., Ltd., China). The eggbeater made the mixture liquids foamy and creamy at speed two (machine speeds from 1 to 6) for 4 min and further mixed at speed three for 5 minutes. Then all dry ingredients (flour blends of WF and CF, Xan and baking powder) which were sieved through an 80-mesh screen were added to the mixture and mixed at speed one for 2 minutes. The mixture was further mixed at speed two for 2 min to obtain a smooth and uniform batter containing large numbers of gas cells.

After that, the batter (43 ± 2 g) was placed into a paper baking cup (6.0 cm diameter and 5.5 cm height) and baked at 200°C for 30 minutes. The cakes were then left for 20 min at room temperature to cool, removed from the cup and packed hermetically in a plastic polyvinylidene chloride bag. The specific volume, moisture content, texture and sensory evaluation of the fresh cakes were measured immediately.

Physical measurements

Specific volume. The cake volume was measured using the rapeseed displacement according to the method of Poonnakasem *et al.* (2015) with minor modifications. The cake sample was cut into 30 × 30 × 25 mm^3 cubes, and weight, volume and specific volume were measured and calculated.

Moisture content. The moisture of the crumb was determined according to the method used by Maleki and Milani (2013). Samples (3 ± 0.01 g) were collected from the middle section of each cake. The moisture content was determined as the ratio of the moisture weight to the cake weight before being placed in the oven.

Texture measurement. Texture profile analysis (TPA) was carried out using an LFRA Texture Analyser (Brookfield Engineering Laboratories, Inc., USA). A P50 aluminium cylinder probe was used for the crumb texture profile analysis. The test speed was set at 1 mm/s, trigger force at 5 g, and target value at 10 millimetres. The recovery time was 10 s between the double cycles. The TPA curves were analysed for hardness, springiness and chewiness. They were selected as response variables. Five samples of each cake formulation were measured to obtain an average value.

Sensory evaluation. Sensory analysis included two sections: one was quantitative descriptive analysis (QDA) for cake sensory characteristics such as cake surface, colour and flavour (Herranz *et al.* 2016). The other was evaluation of the overall acceptability (9-point hedonic scale). Samples were cut into 2 cm-cubes and coded with three-digit codes randomly in plastic containers. Each sample was evaluated three times by each panellist and consumer.

QDA was conducted by a panel of 13 trained panellists in the Laboratory of Food Science and Technology, ECUST. Before sensory evaluations, the panellists were instructed to apply the standards of descriptive sensory evaluation and recognize cake quality characteristics: cake appearance, crumb colour and flavour (Table 2). The intensity of specified attribute was described by a 10-cm line scale with descriptors anchored at both ends. All the samples were marked across the scale for intensity of each of the attributes by the trained panellists. The marks were transformed to the corresponding value. Colour was selected as the response variable.

Evaluation of the overall acceptability was carried out by a panel of 26 consumers recruited from ECUST using a 9-point hedonic scale (1 – dislike extremely, 5 – neither dislike nor like and 9 – like extremely). Each consumer assessed the basis of acceptability of each sample colour, odour, air cell, taste, texture and overall liking using a 9-point hedonic scale (Maj-

Table 2. Scale and standardized sensory language with reference materials for the description of sponge cake

Attribute	References	Intensity	
		0	10
Appearance	conformation and sizes of the spongy pore on the surface	puffed	spongy
Colour	intensity of yellowness reflected from samples	faint yellow	bright yellow
Flavour	intensity of flavour in the samples	week	strong

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zoobi *et al.* 2016). Consumers were asked to assess and record their liking of each attribute and overall acceptability. And overall acceptability was selected as the response variable.

Optimisation and model verification. Optimum ingredient levels of Xan and CF were obtained by predictive models and superimposing plots. Meanwhile, the optimum formulation was selected to calculate the predicted values of response variables with the prediction equations derived by RSM. The optimum formulation was applied to perform another experiment for model verification under the same experimental conditions. And the results were compared with the predicted values of the mathematical model.

Statistical analysis. Design-Expert software (Version 8.0.5.0; Stat-Ease Inc., USA) was used to design the experiment and generate surface response plots. Data for instrumental parameters and sensory attributes were subjected to one-way analysis of variance, and means with a significant difference ($P \leq 0.05$) were calculated by Duncan's multiple range test with SPSS Statistics 16.0 (SPSS Inc., USA).

RESULTS AND DISCUSSION

Fitting models from RSM. The effects of Xan and CF on the physical properties (moisture content and specific volume), texture parameters (hardness, chewiness and springiness) and sensory attributes (colour and overall acceptability) are presented in Table 4. Three dimensional plots as well as contour plots for the models were constructed to make trends visual and observe the location of the optimum on the curve diagram (Figure 1). Significance of the lack of fit, R^2, and model significance were determined (Table 4). The coefficient of determination R^2 represented model adequacy and measured how well the regression model fits the raw data (Hager & Arendt 2013). The regression models with high values of R^2 ($R^2 \geq 75$) indicated a reasonable fit of the model to the experimental data (Chaiya *et al.* 2015). The R^2 values of all of the responses, except for overall acceptability (74.42%), exceeded 75% indicating a high proportion of variation (Table 4). Besides, all the lack of fit terms was insignificant. Therefore, the response surface models were adequate for the independent and dependent variables.

Effects of Xan and CF on physical properties and sensory evaluation

Specific volume. Specific volume, indicating the amount of air that remains in the final products, is one of the most important visual characteristics

Table 3. The mean response values of experimental data for response surface analysis

Treatment	Specific volume (ml/g)	Moisture content	Hardness (g)	Chewiness (g mm)	Springiness (mm)	Colour (panel)	Overall acceptability (hedonic)
C1	2.84 ± 0.01^{b}	0.3695 ± 0.0060^{f}	715.5 ± 4.6^{ef}	6430.6 ± 5.8^{g}	9.75 ± 0.19^{ab}	5.7 ± 0.12^{f}	6.7 ± 0.2^{cd}
C2	3.67 ± 0.17^{a}	0.2960 ± 0.0124^{h}	976.5 ± 7.5^{d}	7958.5 ± 10.3^{f}	9.8 ± 0.13^{a}	7.9 ± 0.22^{a}	6.3 ± 0.03^{de}
1	2.1993 ± 0.0306^{de}	0.3998 ± 0.0064^{de}	970.48 ± 0.62^{d}	9512.54 ± 0.53^{d}	9.09 ± 0.02^{e}	6.1 ± 0.1^{de}	7.3 ± 0.1^{abc}
2	1.7938 ± 0.0547^{g}	0.4495 ± 0.0018^{a}	1390.20 ± 0.67^{b}	9169.10 ± 0.06^{e}	8.27 ± 0.01^{h}	5.8 ± 0.2^{ef}	6.8 ± 0.2^{cd}
3	2.1687 ± 0.0460^{e}	0.3785 ± 0.0093^{f}	650.75 ± 0.72^{f}	5012.07 ± 0.57^{h}	8.95 ± 0.05^{fg}	6.1 ± 0.2^{de}	6.1 ± 0.1^{e}
4	2.4703 ± 0.0857^{c}	0.3599 ± 0.0020^{g}	459.00 ± 1.15^{g}	5990.06 ± 0.02^{g}	9.23 ± 0.03^{cd}	6.8 ± 0.1^{bc}	6.5 ± 0.2^{de}
5	2.7943 ± 0.0677^{b}	0.3445 ± 0.0042^{h}	741.42 ± 0.86^{ef}	6706.45 ± 0.70^{f}	9.93 ± 0.03^{a}	7.2 ± 0.1^{b}	7.3 ± 0.1^{abc}
6	2.3256 ± 0.1182^{d}	0.4119 ± 0.0019^{c}	1149.63 ± 0.96^{bc}	10956.10 ± 0.92^{ab}	9.22 ± 0.04^{d}	6.2 ± 0.2^{de}	7.5 ± 0.2^{ab}
7	2.2496 ± 0.1558^{d}	0.4039 ± 0.0026^{d}	907.63 ± 0.65^{de}	9340.00 ± 1.73^{d}	9.19 ± 0.05^{d}	5.8 ± 0.1^{ef}	6.8 ± 0.4^{cd}
8	2.0023 ± 0.2386^{f}	0.3932 ± 0.0039^{e}	1689.63 ± 1.18^{a}	9910.58 ± 0.45^{c}	9.09 ± 0.02^{e}	6.9 ± 0.1^{bc}	6.4 ± 0.1^{de}
9	1.8203 ± 0.1488^{g}	0.4397 ± 0.0006^{ab}	1520.38 ± 0.70^{ab}	10228.90 ± 0.40^{c}	8.79 ± 0.03^{g}	6.6 ± 0.2^{cd}	6.3 ± 0.2^{de}
10	2.2386 ± 0.0005^{d}	0.4185 ± 0.0024^{b}	1095.52 ± 1.22^{c}	8978.45 ± 0.96^{ef}	9.25 ± 0.01^{cd}	5.9 ± 0.1^{ef}	7.7 ± 0.1^{a}
11	2.6140 ± 0.1024^{c}	0.3641 ± 0.0031^{g}	1268.75 ± 0.43^{c}	9195.51 ± 1.88^{de}	9.64 ± 0.02^{b}	7.4 ± 0.2^{b}	7.2 ± 0.2^{abc}
12	1.9528 ± 0.1091^{fg}	0.3949 ± 0.0077^{e}	692.00 ± 2.02^{f}	6385.03 ± 0.03^{g}	8.53 ± 0.02^{h}	5.5 ± 0.2^{f}	6.5 ± 0.1^{de}
13	2.4006 ± 0.0593^{cd}	0.4097 ± 0.0053^{cd}	1066.75 ± 1.25^{cd}	11106.30 ± 1.85^{a}	9.32 ± 0.03^{c}	6.1 ± 0.2^{de}	7.1 ± 0.2^{bc}

Different lower-case letters within the same column are different significantly ($P \leq 0.05$) by a Duncan's test; $^{*}P \leq 0.05$; $^{**}P \leq 0.01$; $^{***}P \leq 0.001$; ns – not significant. The values are mean ± standard deviation ($n = 3$)

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of sponge cakes and strongly influences consumer's choices (Chaiya *et al.* 2015). The significant linear impact ($P \leq 0.001$) and quadratic impact ($P \leq 0.05$) of Xan on the specific volume was observed (Table 4). The increasing Xan content decreased the specific volume of cakes (Figure 1A). For treatments 4, 13, and 9, the CF content (10%) and the mixing ratio of CF/WF (10/10) were fixed, and the specific volume decreased with increasing Xan from 2.4703 to 1.8203 ml/g (Table 3). A similar tendency was also observed in the recent researches (Chaiya *et al.* 2015, Poonnakasem *et al.* 2015). While CF exhibited a significantly positive effect ($P \leq 0.001$) on specific volume (Table 4). The specific volume values ranged from 1.9528 to 2.6140 ml/g with the increasing addition of CF in treatments 12, 13 and 11 (0.4% Xan). There was also a conspicuous increasing trend in specific volume with increasing CF according to Figure 1A. This could partly be attributed to the reduction in viscosity of batter caused by CF (Xue & Ngadi 2006). Moreover, the predictive model for effects of Xan and CF levels on specific volume was adequate, based on the insignificant lack of fit, satisfactory R^2 (96.59%), and model significance ($P \leq 0.001$).

Moisture content. The moisture content of crumb was significantly influenced by Xan and CF ($P \leq 0.001$) in linear terms (Table 4). The moisture content increased with Xan and was dose-increasing obviously (Figure 1B), which showed a high capacity of Xan to retain water. Xanthan revealed a highlighted ability to increase the crumb moisture retention due to its notable water-binding capacity (Poonnakasem *et al.* 2015). Xanthan reduced the mobility of the water molecules and might transform free water to bound water (Maleki & Milani 2013). Oppositely, CF exhibited negative linear impact ($P \leq 0.001$) and quadratic impact ($P \leq 0.01$) on moisture content. The result was connected with the fact that corn flour had lower contents of protein and carbohydrates than wheat flour and wheat-corn flour had lesser water absorption (Yaseen *et al.* 2010). Furthermore, the cakes with higher CF content were more cellular and puffed according to experimental observation, which resulted in moisture loss easily at a high temperature. Besides, the predictive model for effects of Xan and CF levels on moisture content was adequate based on R^2 (95.52%) and insignificant lack of fit. Therefore, the sponge cake obtained higher water content by keeping a balance of two factors.

Texture. Cake crumb with low hardness, moderate chewiness and springiness was more desired and acceptable by consumers. The TPA parameters and response surfaces for hardness, chewiness, springiness are shown in Table 3 and Figure 1C, D and E. The predictive models for effects of Xan and CF levels on texture parameters were adequate ($P \leq 0.001$) and lack of fits was insignificant ($P \geq 0.05$, Table 4).

In the present study, the crumb hardness significantly increased as Xan levels increased ($P \leq 0.05$). For treatments 4, 6, and 9, the hardness values increased significantly (from 459 g to 1520.38 g) at the mixing ratio of WF/CF = 10/10 containing 0.1172%,

Table 4. Coefficients estimated of the predictive regression model and ANOVA for each response variable

Terms	Coefficients estimate						
	specific volume	moisture content	hardness	chewiness	springiness	colour	overall acceptability
β_0	2.28	0.41	1038	6528.47	9.21	6.02	7.28
β_1	-0.26^{***}	0.029^{***}	398.58^{***}	2064.44^{***}	-0.27^{***}	-0.11^{ns}	-0.06^{ns}
β_2	0.22^{***}	-0.017^{***}	150.72^{**}	-225.47^{*}	0.42^{***}	0.61^{***}	0.22^{*}
β_{12}	-0.1^{*}	-0.00558^{ns}	52.19^{ns}	-438.23^{ns}	-0.04^{ns}	0	-0.4^{*}
β_{11}	-0.075^{*}	-0.00404^{ns}	9.09^{ns}	90.42^{*}	-0.099^{ns}	0.32^{***}	-0.43^{*}
β_{22}	-0.00581^{ns}	-0.014^{**}	4.43^{ns}	-619.18^{**}	-0.061^{ns}	0.20^{**}	-0.21^{ns}
Model (P)	$< 0.0001^{***}$	0.0001^{***}	0.0005^{***}	0.0019^{**}	0.0004^{***}	$< 0.0001^{***}$	0.011^{*}
Lack of fit(F)	0.53^{ns}	1.82^{ns}	2.18^{ns}	0.23^{ns}	5.03^{ns}	0.66^{ns}	0.59^{ns}
R^2	0.9659	0.9552	0.9358	0.9032	0.9387	0.9609	0.7424

$^*P \leq 0.05$; $^{**}P \leq 0.01$; $^{***}P \leq 0.001$; ns – not significant

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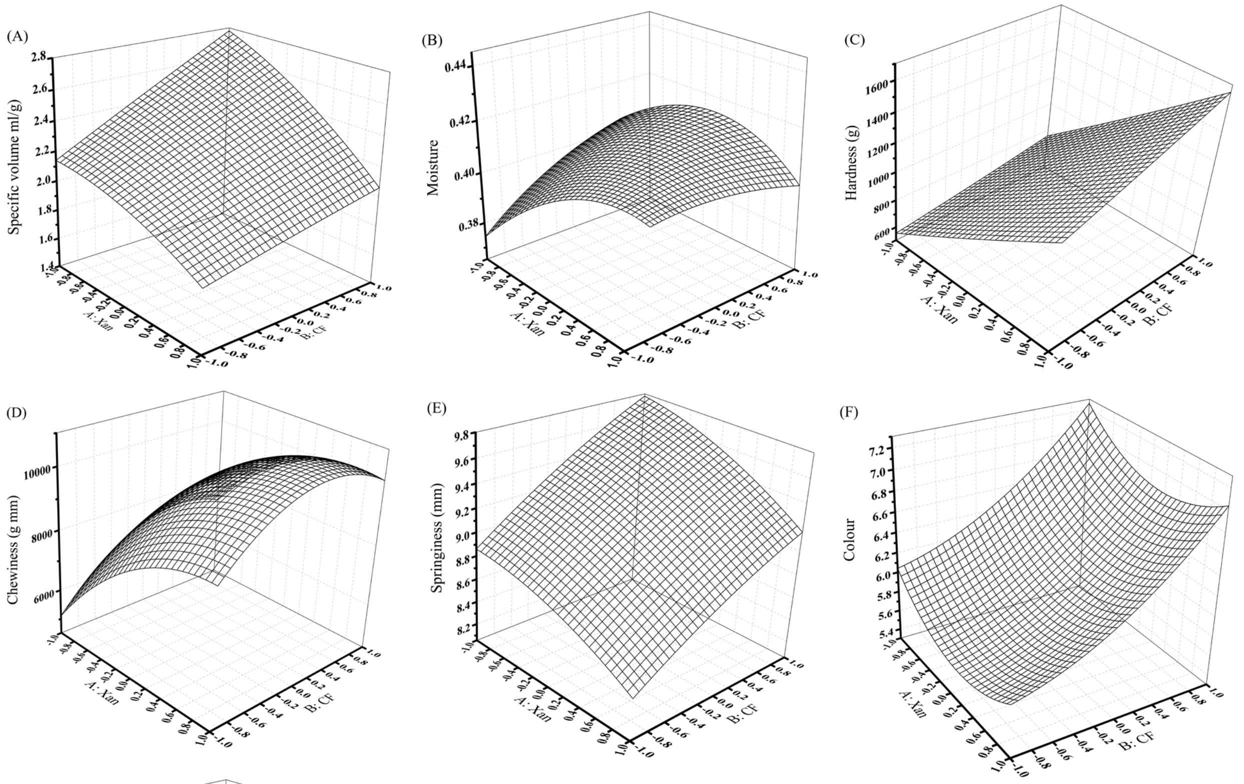

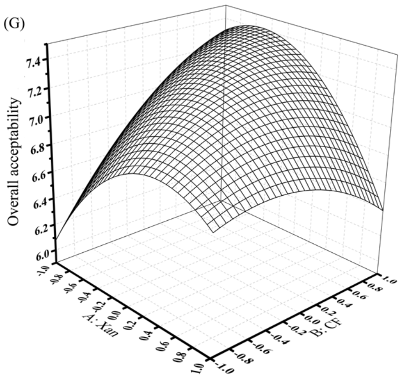

Figure 1. Response surface and contour plots showing the effects of Xan and CF on specific volume (**A**), moisture content (**B**), hardness (**C**), chewiness (**D**), springiness (**E**), colour (**F**) and overall acceptability (**G**) of cake

0.4% and 0.6828% Xan ($P \leq 0.05$). Moreover, the cake with lower specific volume had higher hardness. Both in cake and bread, addition of xanthan resulted in much firmer crumb and hardening (Lazaridou *et al.* 2007; Chaiya *et al.* 2015). Meanwhile, CF also had significantly positive effects on the hardness ($P \leq 0.01$). The hardness ranged from 650.75 g to 741.42 g, with increasing CF containing 0.2% Xan (treatments 3 and 5).

The response surface plots for chewiness indicated that Xan increased chewiness and conversely CF decreased this attribute (Figure 1D). This trend was evident in the polynomial equation from the positive linear term for Xan ($P \leq 0.001$) and negative linear term for CF ($P \leq 0.05$, Table 4). Besides, the predictive models for two factors on chewiness were adequate. Thus optimisation for two factors was feasible to obtain acceptable chewiness.

As for the sponge cake springiness, Xan exhibited a negative impact on it ($P \leq 0.001$). On the contrary, CF had significantly positive effects and increased the cake springiness with increasing doses ($P \leq 0.001$). This could partly be attributed to the replacement of CF that greatly altered the viscosity and viscoelastic properties of batter. Corn flour had lower protein content than wheat flour (Yaseen *et al.* 2010), and increased storage modulus (G'_{max}) and loss modulus (G''_{max}) of wheat corn-based batter systems at different combination ratios (Xue & Ngadi 2006).

Sensory evaluation. The average scores of sensory evaluation of sponge cakes are shown in Table 3. The colour of cakes was significantly influ-

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Table 5. Physical and sensory acceptability of sponge cake prepared from the optimal concentration (0.416% Xan and 12.7% CF)

Treatment	Optimal product		C1	C2
	predicted values	experimental values		
Specific volume (ml/g)	2.3749	2.3697 ± 0.0023^{c}	2.84 ± 0.01^{b}	3.67 ± 0.17^{a}
Moisture content	0.3976	0.3989 ± 0.0013^{a}	0.3695 ± 0.0060^{b}	0.2960 ± 0.0124^{c}
Hardness (g)	1 154.25	1 198.5 ± 2.78^{a}	715.5 ± 4.6^{c}	976.5 ± 7.5^{b}
Chewiness (g mm)	10 189.4	10 112.4 ± 2.62^{a}	6430.6 ± 5.8^{c}	7958.5 ± 10.3^{b}
Springiness (mm)	9.4	9.4 ± 0.2^{b}	9.75 ± 0.19^{a}	9.8 ± 0.13^{a}
Colour (panel)	6.4	6.5 ± 0.2^{b}	5.7 ± 0.12^{c}	7.9 ± 0.22^{a}
Overall acceptability	7.32	7.4 ± 0.17^{a}	6.7 ± 0.2^{b}	6.3 ± 0.03^{b}

Mean ± standard deviation (n = 3) followed by different lower-case letters within the same column are significantly different ($P \leq 0.05$) by a Duncan's test

enced by CF content in linear effect ($P \leq 0.001$) but it was not influenced by Xan (Table 4). The increasing CF content was responsible for increasing the yellowness of sponge cakes (Figure 1F). Yellowness of bakery products is formed by caramel and Maillard reaction during baking. Moreover, the addition of corn flour contributed to augmentation of the colour intensity and uniformity, when not only the cake crust but also the crumb had fine and uniform colour.

The overall acceptability scores of thirteen formulations ranged from 6.1 to 7.7. Based on Table 4 and Figure 1G, the overall acceptability was linearly influenced by CF ($P \leq 0.05$) and not considered significantly relevant to Xan ($P > 0.05$). Though research reported that cakes with xanthan were considered better in overall appreciation and texture (Preichardt *et al.* 2011), in the present study, Xan did not improve the cake acceptability due to its undesired influence on specific volume and hardness. Conversely, CF showed a prominent improvement in the overall appreciation, especially in colour and flavour. Thus, it is necessary to control the Xan and CF content to obtain cakes with soft, smooth and fine texture.

Optimisation of basic formulation and model verification. Optimal concentration of Xan and CF in the sponge cake formulation was obtained with the following criteria: maximum moisture content, higher specific volume, low hardness, moderate chewiness and springiness, proper sensory scores on yellowness and high values of overall acceptability (Gan *et al.* 2007). Therefore the optimal Xan and CF contents corresponding to the optimisation criteria were determined at 0.416% and 12.7%, respectively.

In the subsequent study, the optimal formulation point was selected for model verification. The experimental and predicted values indicated that the models were valid (Table 5). Thus, the model can be used to optimize the basic formulation of baked wheat-corn sponge cake. Furthermore, the results for the C1 and C2 were also outlined in Table 5 and were compared with the optimal formulation results. There were significant differences forin the parameters of specific volume, moisture content, chewiness, and colour between three treatments (optimal product, C1 and C2) ($P \leq 0.5$). Obviously, the optimal product had significantly higher overall acceptability than the products of C1 and C2 ($P \leq 0.5$).

CONCLUSIONS

RSM successfully investigated the effects of xanthan and corn flour on sponge cakes and optimized levels of two variables in the formulation. Xanthan exhibited high ability of moisture retention in cakes and made the crumb humid. Apparently, the sponge cake with high xanthan content (0.6%) and lower corn flour (5%) content had higher moisture content than the other treatments, though xanthan resulted in a decrease of springiness and an increase of hardness and chewiness to a different extent. Corn flour enhanced the specific volume, springiness and colour of sponge cake significantly. By the RSM overlay plot, the optimal levels were 0.416% xanthan and 12.7% corn flour. Based on the optimal formulation, wheat-corn flour based sponge cakes with high quality were yielded (7.4 on a 9-point hedonic scale). Overall, results of this study suggested that the quality of sponge cakes could be significantly improved by a combination of xanthan and corn flour. Meanwhile the study enhanced the potential of using

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nutritious and low cost corn flour in baking sponge cake. Moreover, effects of xanthan and corn flour on the quality of wheat flour-based sponge cakes during storage in different conditions should be further studied.

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