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OPTIMIZATION OF QUINOA AND SOY MILK FOR STEAMED PUMPKIN CAKE USING RESPONSE SURFACE METHODOLOGY

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***Abstract*— This present study aimed to enhance nutrients and reduce fat content in steamed pumpkin cakes. Two independent variables, including quinoa (30−80% w/w by pumpkin weight) and soymilk (15−60% w/w by coconut milk weight), were studied using response surface methodology. The statistical results showed that the quinoa inclusion had significant linear and quadratic effects ($p<0.05$). The soymilk showed a negligible effect, and there was no interaction effect between the two variables. Increasing quinoa has decreased all sensory scores of the samples, mainly when replacing pumpkin flesh with more than 50% quinoa inclusion. The pumpkin cake with 30% quinoa and 46% soymilk was the optimal formulation with a 0.936 desirability value. The optimal sample lowered all sensory attributes than the regular sample, particularly the appropriate qualities, such as unpleasant flavor and softer texture. About 54 percent of the consumers were willing to buy the product. The product is healthy with a 14.6% protein increment and 27% fat reduction.**

***Keywords*— Dessert, pumpkin cake, quinoa, soymilk, response surface methodology**

I. INTRODUCTION

The increase in the global snack market size, with a CAGR of 3.34% during the forecast period (2019-2026), has fuelled the development of nutritious, lower calories, and better gut health food products consumed between meals [1]. It aims to reduce the risk of chronic diseases, such as obesity, heart disease, type 2 diabetes, high blood pressure, and colon cancer [2]. A Thai steamed pumpkin cake (Khanom Fak Thong) is a popular dessert with a sweet and rich taste and easily chewing and swallowing texture. It is made from pumpkin, coconut milk, and sugar and is usually topped with shredded coconut. With containing the main pumpkin, the steamed pumpkin cake is considered a healthy dessert. Pumpkin is a highly nutritious ingredient, particularly rich in beta carotene, vitamin A, C, and E, promoting eye health (good vision) and preventing degenerative eye disease [3]. The flesh is low in calories, fat, protein, and cholesterol and contains high dietary fiber, riboflavin, potassium, copper, and manganese [4]. However, in the composition, the dessert still includes a large amount of coconut milk and sugar, which are harmful and linked to chronic diseases.

Plant-based ingredients fortification is considered a viable strategy to improve nutrients and simultaneously create diversified dessert products. Although the steamed pumpkin cake is beneficial for health, it is not a good protein and amino acids source. Quinoa (*Chenopodium quinoa)* contains approximately 12-16% dietary fiber and 12-18% protein, with a higher lysine (5.1-6.4%) and methionine (0.4-1.0%) content than common cereals and legumes [5]. It is rich in vitamins and minerals, particularly manganese and iron, antioxidants, and a good source of 50-54% linoleic and 22-25% oleic acids [6]. Due to the high quantity of protein and fiber, quinoa is a good alternative to supplement the nutrients in food products.

Traditionally, coconut milk is commonly used in Thai desserts. It is a fat-rich ingredient that contains 40% fat (35% saturated fat) and 12% carbohydrate contents but low protein (0.2%) [7]. Overconsumption of high-calorie desserts causes the incidence of chronic human diseases. It has been responded to by developing reduced-calorie products. Soymilk, a low-fat product made from soybeans, contains 2% fat, no saturated fat, 3% protein, and 5% carbohydrate [8]. It is rich in soy protein, which effectively reduces bad cholesterol. Also, it contains high phytochemicals like isoflavones, exhibiting antioxidant, anticancer, antimicrobial, and anti-inflammatory properties [9]. However, most reduced-fat products show different product characteristics and sensory attributes from their full-fat counterparts. Creating reduced-fat foods that consumers desire is challenging; the optimal ingredients that match consumer preference are critical for good products. Response surface methodology (RSM) is a tool that effectively explains the effect of independent variables and their interactions on responses and optimizes a process condition [10]. Therefore, using RSM, this study aimed to

develop a healthy steamed pumpkin cake enriched with quinoa and soymilk. The appropriateness of sensory attributes and consumer acceptability was also investigated in an optimal formulation.

II. Material and Methods

A. Materials

Ripe pumpkin (*Cucurbita moschata* Decne) was used. Coconut milk (Aroidee®, Thai Agri Foods, Thailand), soymilk (So good "lite", Earth's Own Food Company Inc., Australia), rice flour (Erawan®, Cho Heng Rice Vermicelli Factory Co., Ltd., Nakhon Prathom, Thailand), tapioca starch (Five Stars Fish brand®, ETC International Tradings Co., Ltd., Nonthaburi, Thailand), tapioca flake (Five Stars Fish brand®, ETC International Tradings Co., Ltd., Nonthaburi, Thailand), and quinoa seed (Arrowhead Mills, The Hain Celestial Group, Inc., USA). Other ingredients included refined sugar, palm sugar, salt, and shredded coconut were used.

B. Methods

Experimental design

The effect of independent variables, including quinoa and soymilk on sensory properties of pumpkin cakes was studied using a central composite rotatable design (CCRD). The experimental design combined with five coded levels, −1.41, −1, 0, 1, 1.41, and coded (actual) values, generating thirteen treatments (Table 1). The mathematical model used for predicting of the responses is in the equation below:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_{11} X_1^2 + b_{22} X_2^2 + b_{12} X_1X_2 \qquad (1)$$

Where Y is the observed response; X_1 and X_2 represent the quinoa and soymilk, respectively; b_0 is the intercept, b_1 and b_2 are linear, b_{11} and b_{22} are quadratic, and b_{12} is the interaction coefficients, respectively.

Preparation of steamed pumpkin

Ripe pumpkin was cut into small chunks and washed with tap water. The chunk was steamed for 20 min, and then mashed with a fork until fine.

Preparation of cooked quinoa

Cleaned quinoa seed was added into a saucepan, poured over with water (1 part quinoa in 2 parts water), and heated until boiling. Simmered the quinoa for about 15-20 min or until the grain became translucent.

Preparation of pumpkin cake

The regular steamed pumpkin cake recipe included 60 g rice flour, 20 g tapioca flour, 20 g tapioca flake, 150 g coconut milk, 200 g steamed pumpkin flesh, 50 g sugar, 30 g palm sugar, and 2 g salt. Added rice flour, tapioca flour, and tapioca flake to a bowl, and then thoroughly mixed for 1 min. Coconut milk (1/3 in total) was added gradually and whisked until well combined (5 min). Poured the mixture into a mashed pumpkin bowl, as previously prepared by blending steamed pumpkin, quinoa, coconut milk (2/3 in total), sugar, palm sugar, and salt using a food processor (Model MK-F300, Panasonic, Malaysia), and mixed until homogeneous. The mixture was filled into the molds in the steamer and topped with shredded coconut. After 15-20 min steam, removed and let cool before removing the cake from the molds. In the RSM study, pumpkin cake was prepared by replacing the pumpkin flesh with quinoa (30-80% by weight) and coconut milk with soymilk (15-60% by weight).

Sensory evaluation

Twenty-four people, who occasionally consumed pumpkin cake, were recruited from the Department of Food Science and Technology in the University of the Thai Chamber of Commerce in Thailand. The RSM evaluated the preference test to color, taste, texture and overall acceptability using a 9-point hedonic scale (1 = extremely dislike, 9 = extremely like). A total of 80 consumers (age 18-50 years) was used for evaluating the purchasing decision by a 5-point scale test (1 = certainly would not buy, 5 = certainly would buy). The just-about-right scale (JAR) (−2 = much too little, +2 = much too much) was used to test the appropriateness of sensory attributes. The sensory test was performed in individual booths with three-digit numbers coded samples. Panelists were instructed to rinse their palates before testing each sample.

Proximate analysis

Chemical compositions (moisture, protein, fat, ash, and total carbohydrate) of regular and optimal pumpkin cakes were determined according to AOAC methods [11].

Statistical analysis

All analyses were carried out in triplicate unless otherwise indicated. In the case of formulation optimization, data were analyzed for regression and analysis of variance (ANOVA) using Design–Expert® Trial Educational version 8.0.2 software (State-Ease Inc., Minneapolis, Minnesota, USA). In other studies, data were analyzed by ANOVA at the 95% confidence level. Means with a significant difference ($p<0.05$) were compared using the t-test method [12].

III. Result and Discussion

Model evaluation

Sensory results of pumpkin cake supplemented with quinoa and soy milk are presented in Table 1. All formulations showed mean values ranging from "slightly dislike (4.8)" to "moderately like (7.7)" response. The result revealed that increasing quinoa from 30% to 80% decreased all sensory scores, including the color, flavor, texture, and overall acceptability. At the same time, the soy milk replacement from

15% to 60% showed a slight effect. Thus, the sample (no.5), which replaced pumpkin with 19.6% quinoa and coconut milk with 37.5% soy milk, received the highest sensory perception. Regression analysis and ANOVA results (Table 2) revealed ($p<0.05$) linear and quadratic effects for all sensory models described below.

TABLE I. EXPERIMENTAL CONDITIONS AND SENSORY RESULTS OF PUMPKIN CAKES WITH VARIOUS QUINOA AND SOYMILK LEVELS

Run	Coded (actual) values[1)]		Sensory scores			
	X_1: Quinoa	X_2: Soymilk	Color	flavor	Texture	Overall acceptability
1	−1 (30)	−1 (15)	7.5	6.8	7.0	7.0
2	+1 (80)	−1 (15)	4.8	5.5	5.7	5.6
3	−1 (30)	+1 (60)	7.2	6.8	6.9	7.0
4	+1 (80)	+1 (60)	5.3	5.0	5.5	5.5
5	−1.41 (19.6)	0 (37.5)	7.7	6.8	7.2	7.3
6	+1.41 (90.4)	0 (37.5)	4.9	5.1	5.9	5.3
7	0 (55)	−1.41 (5.7)	6.3	6.0	6.4	6.2
8	0 (55)	+1.41 (69.3)	7.3	6.3	6.5	6.7
9	0 (55)	0 (37.5)	7.2	6.5	6.7	6.8
10	0 (55)	0 (37.5)	7.1	6.3	6.6	6.8
11	0 (55)	0 (37.5)	6.8	6.1	6.5	6.7
12	0 (55)	0 (37.5)	6.5	6.2	6.2	6.2
13	0 (55)	0 (37.5)	6.8	6.1	6.5	6.7

[1)]Code values: X_1 = quinoa (% by pumpkin weight) and X_2 = soymilk (% by coconut milk weight).

TABLEII. REGRESSION ANALYSIS FOR SENSORY PROPERTIES OF PUMPKIN CAKES WITH VARIOUS QUINOA AND SOYMILK LEVELS

Term	Color			Flavor		
	Coef.[1)]	SS[2)]	*p*-value	Coef.	SS	*p*-value
Model		10.74	0.0006		3.76	<0.0001
Intercept	6.90			6.11		
X_1: Quinoa	-1.69	9.06	<0.0001	-0.69	3.76	<0.0001
X_2: Soymilk	0.21	0.36	0.1153	-5.73e	2.63	0.9428
X_1X_2	0.20	0.16	0.2767			
X_1^2	-0.40	1.12	0.0162			
X_2^2	-0.13	0.12	0.3420			
Lack of fit		0.06	0.3788		0.38	0.2224
R-square		0.9272			0.8857	

Term	Texture			Overall acceptability		
	Coef.	SS	*p*-value	Coef.	SS	*p*-value
Model		2.59	<0.0001		4.11	<0.0001
Intercept	6.43			6.43		
X_1: Quinoa	-0.57	2.59	<0.0001	-0.71	4.07	<0.0001
X_2: Soymilk	-9.15	6.70e	0.8964	0.07	0.04	0.4465
X_1X_2						
X_1^2						
X_2^2						
Lack of fit	0.22	0.5429		0.41	0.5220	
R-square	0.8734			0.8590		

[1)]Coef., correlation regression
[2)]SS, sum of squares

$$\text{Color} = 6.90 - 1.06X_1 - 0.41X_1^2 \quad (2)$$
$$\text{Flavor} = 6.11 - 0.69X_1 \quad (3)$$
$$\text{Texture} = 6.43 - 0.57X_1 \quad (4)$$
$$\text{Overall acceptability} = 6.43 - 0.71X_1 \quad (5)$$

The models had coefficients of determination (R^2) ranged between 0.8590 and 0.9272, following a non-significant lack of fit value ($p>0.05$) (Table 2). The high R^2 value close to 1.0 indicates the reliability of the equations for changes of responses, and the model fits well with the actual data. Among all responses, the color model showed the highest R^2 (0.9272), suggesting that it can explain 92% of the total sum of color changes. This model cannot define only 8% of the total variability. To understand easily, the results of sensory responses were illustrating in three dimensional graphs (Fig. 1).

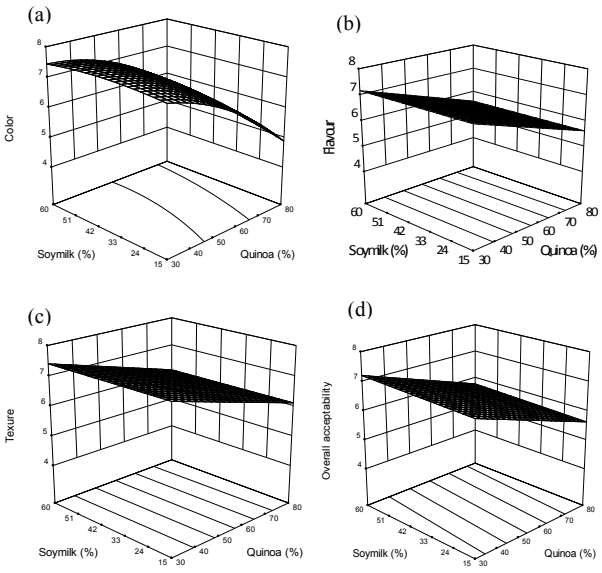

Fig. 1 RSM Graphs Of Pumpkin Cakes With Various Quinoa And Soymilk Levels: (A) Color, (B) Flavor, (C) Texture, And (D) Overall Acceptability

Sensory quality of pumpkin cakes with quinoa and soymilk

As shown in Table 2, the addition of quinoa showed negative linear effects on color, flavor, texture, and overall acceptability and a quadratic effect on color ($p<0.05$). Still, the soymilk inclusion was negligible ($p>0.05$). There was no interaction effect between the two variables. Among all attributes, the pumpkin replacement with quinoa mainly

affected the color scores than other attributes. There was a parabolic decrease in the color of samples with increasing quinoa levels from 30% to 80% (Figure 1a). The color slightly decreased at 30% to 50% quinoa inclusion level; the change is insignificant because the cakes were still acceptable in the "moderately like" level. Afterward, the cake showed a substantial color change, particularly receiving the lowest color score (~4.8) at the 80% quinoa, corresponding with the "slightly dislike" response. The finding indicates that the pumpkin cake would be preferred for the color if limiting the quinoa replacement to no more than 50%. The result highlights the role of recipe constituents, changing the color from intensely yellow (pumpkin flesh) to pale yellow due to the slightly brown color of the cooked quinoa. Reducing the pumpkin portion also decreases glucose and fructose, leading to the brighter or less dark color formation through the Maillard browning reaction [13].

The rising of quinoa was found to drop the flavor perception of the pumpkin cakes (Figure 1b). The high quinoa proportion, from around 60% to 80% pumpkin replacement, has caused the excessive quinoa's nutty taste and flavor to mask the original flavor of the product. This is why lower flavor score was found at high quinoa addition.

According to the regression coefficient in equation 2-4, the texture model was less affected by the quinoa level, showing the lowest X_1 coefficient at 0.57 (equation 4). Figure 1c reflected a slight change in texture scores in the range of 7.2 to 6.1 relative to the 30% to 80% quinoa addition. The pumpkin cake was softer when increasing the quinoa levels. Nevertheless, most panelists felt the obtained texture with less creamy was too weak, and they did not admire the way the pumpkin cake breaking down during oral mastication. This may dissatisfy the panelists' preference, lowering texture scores.

The overall acceptability in Figure 1d presented a similar RSM graph as received by flavor and texture. The recommended overall acceptability, at a quinoa inclusion (<60%) and soymilk (15-60%), will provide a pumpkin cake with a "like moderately" level. The impact of individual consumer reaction, texture pleasantness, and taste-flavor interactions might be noted for the sensory perception.

Formulation optimization and validation

By the Design-Expert® software, the pumpkin cake achieved by replacing the pumpkin with 30% quinoa and coconut milk with 46% soymilk was the optimal sample with a 0.936 desirability value. The product had predicted scores of color, taste, texture, and overall acceptability at 7.6, 7.0, 7.0, and 7.2, respectively. While the experimental values (n = 3) were 7.4, 7.4, 7.3 and 7.4, respectively, which revealed a percentage of relative error of 2.6%, 5.7%, 4.3% and 2.8%, respectively. The result ensures that the predicted model of the pumpkin cake is reliable.

Comparative sensory evaluation of regular and optimal pumpkin cakes

Sensory results of the optimal pumpkin cake incorporated with 30% quinoa and 46% soymilk against the regular sample are demonstrated in Figure 2. The hedonic scale test relatively denoted lowered all attributes scores in the optimal sample, though it received the overall acceptability at the "like moderately" level as did the regular (Figure 2a). Most consumers are willing to buy the optimal sample, as noticed by 54% of consumers rated in scores of 5 and 4 (would certainly or possibly buy the product) relative to 56% for the regular (Figure 2b). The observation would be motivated by the importance of health and wellness.

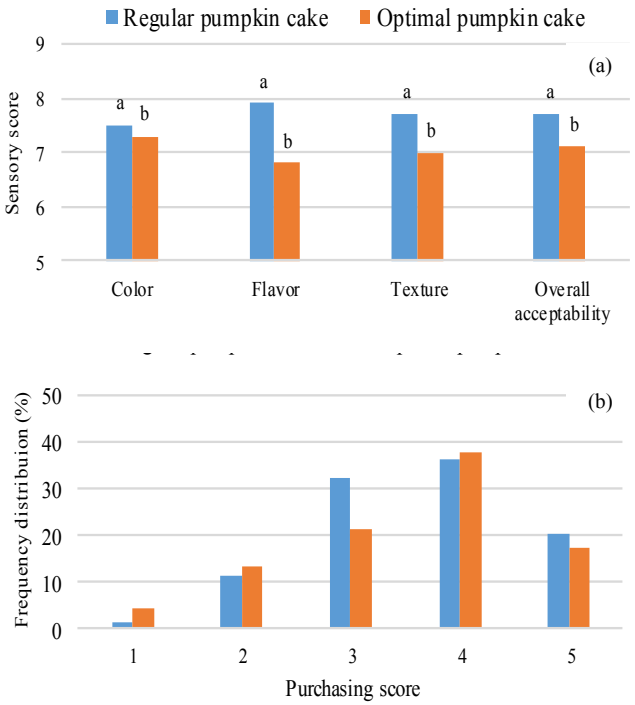

Fig. 2 Sensory Evaluation Of The Regular And Optimal Pumpkin Cakes: (A) 9-Point Hedonic Scale And (B) Purchasing Intention

According to the JAR results of the optimal sample, consumers who selected the flavor scales of -1 and -2 (too low), 3 (just about right), and 1 and 2 (too high) were 43%, 37%, and 20%, respectively. While, those for texture were 23%, 25%, and 52%, respectively (Figure 3a-b). The result suggests that the sample is not flavor enough and the texture is too weak. The modifications required are the reduction of unpleasant flavor intensity and adjustment of appropriate texture. Replacing coconut milk (10-15% fat) with soymilk (2-3% fat) has caused the lowered lubricated oil, a great flavor carrier for spices and other fat-soluble ingredients in the sample to our mouths [9]. It may support why the optimal product has a reduced flavor.

Proximate composition

Chemical compositions of regular and optimal pumpkin cakes are presented in Figure 4. There were no significant differences in moisture, ash, and carbohydrate contents between the regular and optimal samples. Lower fat and higher protein were found in the optimal sample, with a 14.6% protein increment and a 27% fat reduction. Increasing protein in the optimal sample referred to the high protein content of quinoa (~16%) [14] against pumpkin flesh (<1%) [15]. In comparison, soy milk has 10 times more protein than coconut milk. It was in agreement with El-Sohaimy *et al*. [16], who indicated a higher protein in flatbread supplemented with quinoa flour. Thus, incorporating quinoa can make a reduced-fat pumpkin cake based on the FDA label with more protein.

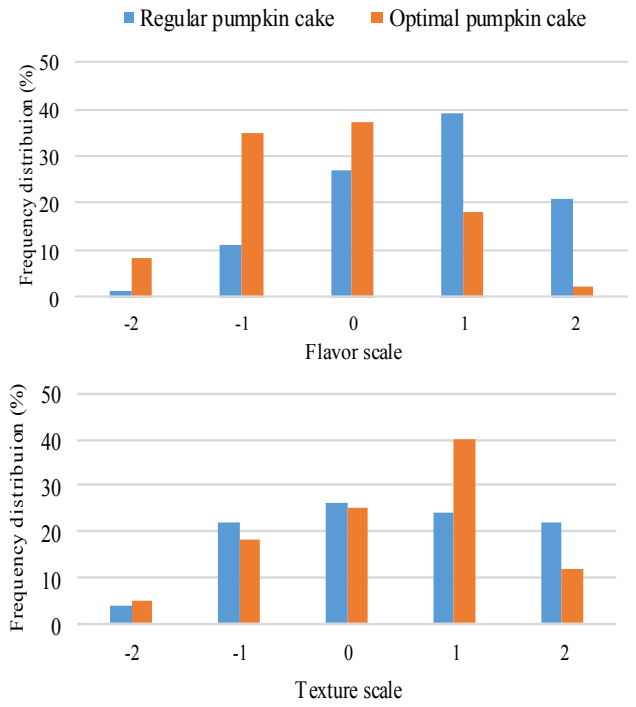

Fig. 3 Just-About Right Scale Results of Optimal Pumpkin Cakes: (A) Flavor And (B) Texture

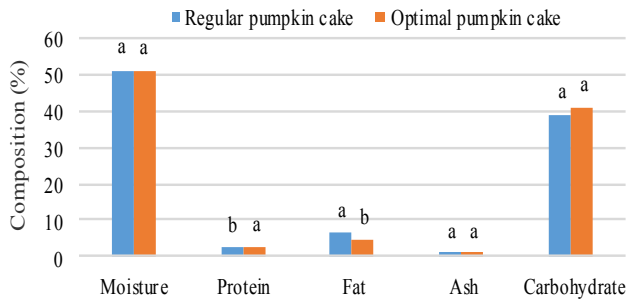

Fig. 4 Chemical Composition of the Regular and Optimal Pumpkin Cakes

IV. Conclusion

RSM is an effective tool that can explain the role of quinoa and coconut milk on the quality changes of steamed pumpkin cakes. The pumpkin replacement with quinoa showed a greater effect on sensory perception of the samples, while the coconut milk replacement with soymilk was negligible. The more the quinoa inclusion, the less the sensory attributes were obtained for the cakes. All of these, the color was the most affecting attribute. The pumpkin cake incorporated with 30% quinoa and 46% soymilk is the optimal formulation; however, they are needed for flavor and texture development. The product has a 27% fat reduction and 14.6% protein increment.

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