

## Optimization of Strawberry-Longan Bar Formulation Using Response Surface Methodology

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### ABSTRACT

*Optimization of a strawberry-longan bar was done using response surface methodology (RSM). Ten strawberry-longan bar formulations were formulated by mixing three basic ingredients: dried strawberry (25-35%), dried longan (25-35%) and mixed crisp; mixture of dried almond, dried cashew nut and dried banana (10-25%). All formulations contained 10% glucose syrup, 13% strawberry syrup and 2% sunflower oil. The sensory qualities (overall liking, appearance, flavor and texture), texture measurements (hardness and stickiness), moisture content, water activity and color parameters were evaluated. Parameter estimates were determined by performing regression analysis with no intercept option. Area within the response surface plots having predicted acceptability scores of at least 5.6 (on a 9-point hedonic scale) for appearance and texture were selected to derive a predicted optimum formulation range. The prediction models generated in this study were verified as adequate to predict the sensory and physical qualities of strawberry-longan bar. The selected optimal formulation of strawberry-longan bar consisted of 28% dried strawberry, 27% dried longan, 20% mixed crisp, 10% glucose syrup, 13% strawberry syrup and 2% sunflower oil.*

**Key words:** Optimization, Strawberry, Longan, Response surface methodology (RSM), Mixture design

### INTRODUCTION

Busy lifestyles and the increasing demand from consumers for meals and snacks that are quick sources of good nutrition have driven manufacturers to produce a variety of snack-type foods (Choi et al., 2007; Rigik, 2011). Snack bar is a kind of healthy snack. It can be a good source of nutrition. The product is conformed to busy life styles of consumers. The basic method of making snack bar is prepared by mixing dried fruit, nut and fruit juice together prior to heating with the binder, glucose syrup or corn syrup. Then, the mixtures were pressed into a bar size and cooled or baked before cut into a piece (Dutcosky et al., 2006; Yang and Garfield, 2006). Rigik (2011) reported that, according to SymphonyIRI, total snack bar sales jumped 11.26% to \$534.9 million for the 52 weeks ended Dec. 26, 2010.

Strawberry (*Fragaria ananassa*) fruits are the popular fruit and widely consumed. These fruits are cultivated in many countries and also in the northern part of Thailand. They contain phenolic compounds that provide an antioxidant, anticancer and anti-neurodegenerative properties (Seeram et al., 2006). They are seasonal fruits and rapidly perishable. Several methods had been processed for extending shelf-life of strawberry fruits. Drying is the most important process to preserve crops and foods of all varieties, including strawberry fruits (Doymaz, 2008).

Longan (*Dimocarpus longan* Lour.) fruits are an important subtropical fruit in Thailand. There are widely grown in Chiang Mai and Lamphun provinces. Longan fruits are mainly consumed fresh. The export value of longan fruits was almost \$ 480 million in 2011 (Office of Agricultural

Economics, 2012). Longan fruits contain several vitamins especially large amounts of vitamins A and C and minerals. They also contain phenolic compounds such as gallic acid, which indicate that this fruits has antioxidant properties (Jiang, 1999; Rangkadilok et al., 2007; Sahelian, 2005). Several methods have been implemented to add value to longan fruits since the increase of longan fruit production caused depreciation in market price (Varith et al., 2007) and the profit share was not contributed to the farmers (Office of Agricultural Economics, 2008). Drying method is the prior process to preserve longan as dried longan.

Response surface methodology (RSM) is a useful tool for agro-industrial product development such as the optimization of ingredient levels, formulations and processing conditions (Mendes et al., 2001; Vatsala et al., 2001; Sin et al., 2006; Gan et al., 2007; Kahyaoglu, 2008). Optimization of formulations, processing conditions and sensory qualities of various snack products has been performed (Prinyawiwatkul, et al., 1993, 1997; Dutcosky et al., 2006; Charunuch et al., 2008; Sriwattana et al., 2008).

The objective of this study was to optimize the strawberry-longan bar formulations to obtain a product that meet the target of using the mixture of dried strawberry and dried longan at least 50% of the total formulation and acceptable to consumer.

## MATERIALS AND METHODS

### Preparation of ingredients

Fresh strawberries (cultivar 329), obtained from Samoeng district, Chiang Mai province were cleaned and trimmed. They were mixed with sugar (2:1) and kept at 4°C for 24 h of osmotic dehydration. Strawberry fruits were separated from the osmotic solution and dried at 70°C for 6 h using hot air oven (Memmert model 600, Germany). Dried strawberries were cut into small pieces (0.3×0.3×0.3 cm) and kept in a foil pouch at 4°C until used. Strawberry syrup was prepared by filter the osmotic solution with muslin cloth, slightly heated and stirred until it reached 50 °Brix

Dried longans (cultivar Edor) were supplied by Thongpoon Food Limited Partnership, Lamphun, Thailand. They were cut into small pieces (0.3×0.3×0.3 cm) and kept in a foil pouch at 4°C until used.

Mixed crisps were prepared by mixing dried bananas, dried cashew nuts and dried almond slices (ratio 4:2:1). Dried bananas were prepared from ripe bananas (*Musa sapientum* Linn.), with total soluble solid 20–25 °Brix. They were cleaned and boiled in boiling water for 1 min before sliced into strips (0.1–0.2 cm in thickness). The banana slices were soaked in 1% of CaCl<sub>2</sub> solution for 30 min and drained for 15 min before drying. Drying process was performed using convection drying oven (Otto, Thailand) at 150°C for 15 min. Dried bananas were ground and sifted using sieve No. 4 (4.75 mm, Endecotts Ltd., London, UK) before mixed with dried cashew nut and dried almond. Cashew nuts and dried almond slices were prepared using convection drying oven (Otto, Thailand) at 125°C for 10 min. Then, they were ground into small pieces and sifted using sieve No.4 (4.75 mm, Endecotts Ltd., London, UK). Glucose syrup (Capital Glucose Co., Ltd., Thailand) and sunflower oil (Thanakorn Vegetable Oil Products Co., Ltd., Thailand) were used.

### Strawberry-longan bars production

Strawberry-longan bar production was modified from Yang and Garfield (2006). Bars were prepared in batches of 1.0 kg of each formulation as shown in Table 1. Glucose syrup and strawberry syrups were mixed together and heated at 70°C for 3 min. Dried strawberries and dried longan fruits were added into the mixtures. The mixtures were slightly stirred and maintained at the temperature of 70°C for 3 min. After that sunflower oil and mixed crisp were added into the mixtures. Nine hundred grams of the mixtures was poured and pressed into 28×38×2.5 cm aluminum tray and cooled at 4°C for 1 h prior to cut into 2.5×2.5 cm bars (Yang and Garfield, 2006). All bars were kept in a foil pouch at 4°C until used.

### Experimental design

Extreme vertices mixture design was used to formulate the strawberry-longan bar over a range of 3 components. The mixture components consisted of dried strawberry (25-35%), dried longan (25-35%) and mixed crisp (10-25%). The experimental ranges of these 3 components were established to meet target of using the mixture of dried strawberry and dried longan at least 50% of each total formulation. All formulations contained 10% glucose syrup, 13% strawberry syrup and 2% sunflower oil. The experimental design and statistical analysis were performed using Design-Expert, a statistical package (Statease Inc., Minneapolis, Minn., U.S.A.). The complete design consisted of 10 formulations including 2 replicates of the center point (Table 1). The responses measured were sensory qualities (overall liking, appearance, flavor and texture), texture measurements (hardness and stickiness), moisture content, water activity and color parameters ( $L$ ,  $a$  and  $b$ ).

**Table 1.** Compositions (%) of strawberry-longan bar formulations in a 3-component\* mixture design.

Formulation number	Strawberry	Longan	Mixed crisp
1	30	25	20
2	35	27.5	12.5
3	35	25	15
4	30	35	10
5	35	30	10
6	25	25	25
7	25	25	25
8	25	35	15
9	30	30	15
10	25	30	20

\*The 3-component mixture was 75% of the actual formulation. All formulations contained 10% glucose syrup, 13% strawberry syrup and 2% sunflower oil.

### Physicochemical measurements

Texture characteristics (hardness and stickiness) of strawberry-longan bar were evaluated using the TA.XT2 Texture Analyzer (Stable Microsystems, U.K.). A 6.0-mm cylinder probe was attached to the load cell. The set mode was set to measure compression force. Pretest, test and post test speeds were set to 1, 2, 10 mm/s, respectively, and the trigger force was 20 g (Stable Micro Systems Ltd., 2005). The probe was adjusted to compress 6 mm depth into a sample (size 4×3×2 cm). The hardness values were analyzed from maximum force value and stickiness values were analyzed from maximum negative force value. Moisture content was determined according to a slightly modified method of Vijayanand et al. (2000). Water activity ( $a_w$ ) was measured using a water activity meter (AquaLab LITE, DECAGON, U.S.A.). Color measurements (lightness,  $L$ ; redness,  $a$ ; and yellowness,  $b$ ) were performed with a colorimeter (Chroma meter CR-400, KONICA MINOLTA, Japan). The illuminant D65 and an angle of 10 were used.

### Consumer acceptance test

Sensory laboratory test was conducted at the sensory laboratory of Division of Product Development Technology, Chiang Mai University, Chiang Mai, Thailand. A hundred consumers were recruited from the students of Chiang Mai University. They were prescreened using two questions: (1) Do you like to have dried strawberry and dried longan? and (2) Have you ever heard about snack bar or even try it once? Ten formulations, each coded with a 3-digit random number, were monadically served at ambient temperature. Each formulation was served in a 7×12 cm<sup>2</sup> foil

pouch. The order of serving to each panelist was randomized to minimize bias. Panelists were compulsory break for 10 min after completed 4 samples. Then, they were rated the next 3 samples and compulsory break again for 10 min. After that, they were rated the last 3 samples. Panelists rated each sample using a 9-point hedonic scale (Peryam and Pilgrim, 1957), wherein 1 = dislike extremely, 5 = neither dislike nor like, and 9 = like extremely, for the overall liking, appearance, flavor and texture using a paper ballot. Distilled water was supplied to panelists to cleanse their palate and minimize any residual effect between samples. A small gift was provided to panelists.

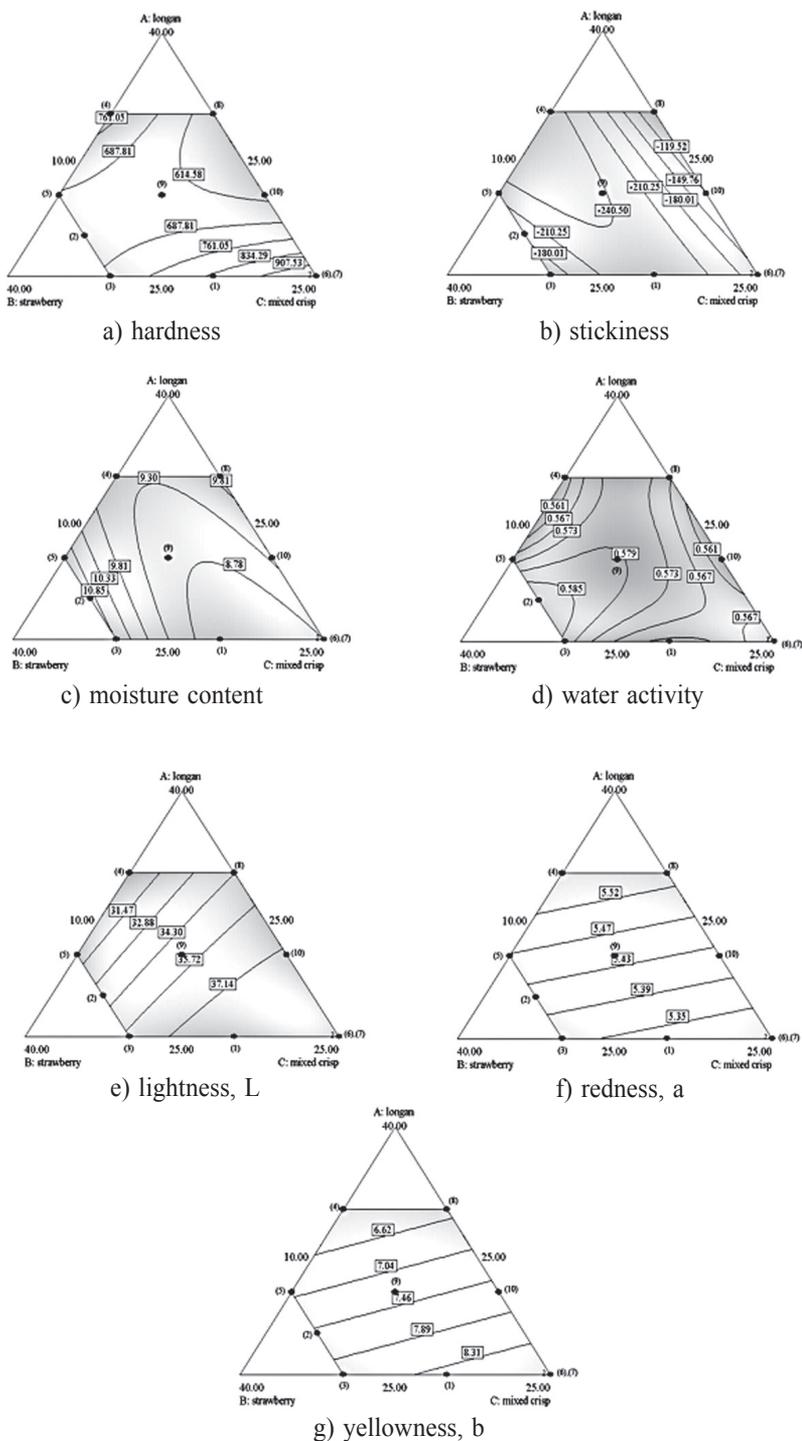
### Statistical Analysis

The response data obtained from the instrumental measurements and consumer acceptance test were analyzed. RSM was applied to experimental data using the Design-expert statistical package version 6.0.10 (Statease Inc.). Areas within the contour plots having predicted acceptability scores of at least 5.6 (on a 9-point hedonic scale) for appearance, flavor and texture were selected to derive a predicted optimum formulation range. The mean and standard deviation values of consumer acceptance data and physicochemical measurements were calculated.

## RESULTS AND DISCUSSION

### Physicochemical measurements

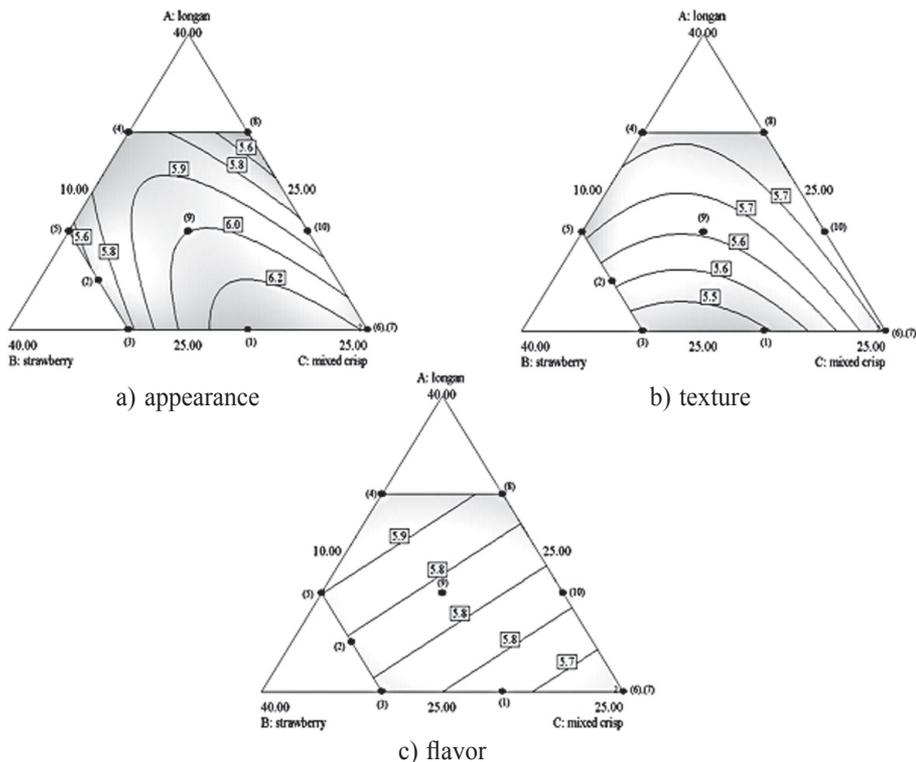
Physicochemical measurements of the strawberry-longan bar are shown in Figure 1. The ranges of hardness and stickiness were 425.65 to 1007.28 g force and -81.63 to -250.81 g force, respectively. As contour plot of hardness (Figure 1 a), increasing levels of mixed crisp in the formulation generally resulted in increasing hardness value. As the stickiness range of two commercial snack bar; mixed cereal bar with fruit and nut (Alpen™ Fruit and Nut Bar, Weetabix Ltd., England) and mixed berry bar (Nature Valley™ Chewy Trail Mix Bars, General Mills Sales, Inc., USA) were -83.58 to -137.99 g force and -75.75 to -334.64 g force, respectively. The stickiness values of strawberry-longan bar in this study were conformed to the commercial snack bars. Moisture contents of all formulations ranged from 7.56 to 10.69%. The results were conformed to Thai Industrial Standard number 919-2532 (Thai Industrial Standards Institute, 1989) which stated that, the moisture content of dehydrated fruit should be less than 18%. The  $a_w$  of all formulations were ranged 0.552 to 0.593 and no significant differences among the 10 formulations (data not shown). All formulations had the  $a_w$  values less than 0.60 that could be inhibited the microbial proliferation (Rahman and Labuza, 2007). Color lightness ( $L$ ), redness ( $a$ ) and yellowness ( $b$ ) values ranged from 29.76 to 40.82, 4.67 to 6.00 and 6.26 to 9.17, respectively.



**Figure 1.** Mixture response surface contour plots displaying combined effects of dried strawberry, dried longan and mixed crisp on physicochemical measurements of strawberry-longan bar. Numbers in parentheses correspond to 10 formulations shown in Table 1.

### Consumer acceptance test

Consumer acceptability ratings of the strawberry-longan bar formulations are shown in Figure 2. The results showed that, mean values of overall liking, appearance, flavor and texture of 10 formulations ranged from 5.6 to 6.0, 5.6 to 6.4, 5.6 to 6.2 and 5.5 to 5.8, respectively. The strawberry-longan bar formulations were acceptable to consumers who participated in this study. There were no difference ( $P<0.05$ ) in the overall liking, flavor and texture scores between the all formulations, except appearance acceptability.



**Figure 2.** Mixture response surface contour plots displaying combined effects of dried strawberry, dried longan and mixed crisp on sensory acceptability of strawberry-longan bar. Numbers in parentheses correspond to 10 formulations shown in Table 1.

### Optimization of strawberry-longan bar

The optimization technique provided product formulations and processing conditions in food product development (Dutcosky et al., 2006; Sin et al., 2006; Gan et al., 2007; Sriwattana et al., 2008). The predicted regression model was used to generate contour plot for each attribute of strawberry-longan bar to display combined effect of dried strawberry, dried longan and mixed crisp on sensory acceptability and instrumental measurements. The ranges of dried strawberry, dried longan and mixed crisp had significant effect on consumer acceptability (appearance and texture) and physicochemical properties (stickiness,  $L$  and  $b$ ) as contour plots shown in Figure 1, 2 and the regression models shown in Table 2. All the models were significant ( $P<0.05$ ) and did not present lack of fit. The adjusted coefficients of determination ( $R^2_{adj}$ ) varied between 55.71 and 72.47%. According to Prinyawiwatkul et al. (1997), the regression models for obtaining the optimum formulation of chicken nuggets were explained using  $R^2_{adj}$  values varied from 68 to 92%. Thus, the regression models developed in this study for predicting appearance and texture acceptability, sticki-

ness, *L* and *a* values were adequate. The majority of models were quadratic equations. Therefore, the binary combinations were significant, except for *b* model.

The appearance and color are the most important attributes that influence the consumers to buy a food product (MacDougall, 1983). For appearance acceptability, increasing levels of mixed crisp in the formulation generally resulted in increasing acceptability (Figure 2a and Table 2). Similarly, the *L* and *b* values of the bars tended to increase with increasing levels of mixed crisp (Figure 1 and Table 2). It was indicated that, mixed crisp had more effected on appearance of strawberry-longan bar while strawberry and longan had slightly effected. For texture acceptability and texture measurement as stickiness, the increasing levels of dried longan tended to increase the texture acceptability scores (Figure 2b and Table 2). Therefore, appearance and texture acceptability were considered as a limiting factor for attaining the optimum formulation (a cut-off point of 5.6).

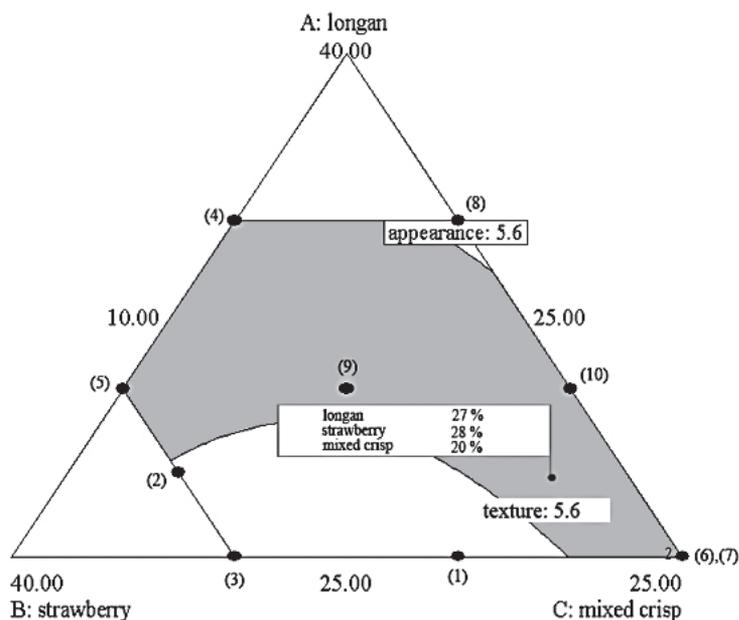
**Table 2.** Model and goodness-of-fit obtained from sensory and physicochemical measurements of the strawberry-longan bar formulations.

Parameter	Equation	$R^2_{adj}$ (%)	<i>P</i> *
Appearance	$Y_A = -0.16L - 0.33S - 0.006M + (0.02LS) + (0.01S \times M)$	65.38	0.0490
Texture	$Y_T = 0.07L + 0.09S + 0.14M - (0.003S \times M)$	55.71	0.0496
Stickiness	$Y_S = 69.43L + 105.42S + 12.74M - (4.87L \times S) - (2.89S \times M)$	69.44	0.0365
<i>L</i>	$Y_L = 0.14L + 0.25S - 0.99M + (0.04L \times M) + (0.04S \times M)$	69.65	0.0359
<i>b</i>	$Y_B = -0.01L + 0.15S + 0.21M$	72.47	0.0045

*L* = dried longan, *S* = dried strawberry, *M* = mixed crisp (actual components)

\**P* = Probability level (*P*<0.05)

The optimum formulation was determined by superimposing the contour plots of appearance and texture acceptability, *L*, *b* and stickiness values (Figure 3). For appearance and texture acceptability, scores of at least 5.6 (on a 9-point hedonic scale) were selected to derive a predicted optimum formulation of strawberry-longan bar. The optimum formulation of strawberry-longan bar had been analyzed by the Design-expert statistical package version 6.0.10 (Statease Inc.). The selected optimal formulation consisted of 28% dried strawberry, 27% dried longan and 20% mixed crisp (Figure 3) that would meet the acceptability scores of at least 5.6 on a 9-point hedonic scale for appearance and texture. The cut-off point of 5.6 was arbitrarily chosen. Prinyawiwatkul et al. (1993, 1997) used a cut-off point of 5.5 and 5.4 to obtain the optimum of extruded snacks and chicken nugget formulations, respectively. Deshpande et al. (2008) also used a cut-off point of 5.0 to obtain the optimum peanut-soy beverage formulations. Meanwhile, Sriwattana et al. (2008) used a cut-off point of 6.5 to obtain the optimum rice snack formulations.



**Figure 3.** The optimum range (shaded area) of strawberry-longan bar formulations that has the acceptability ratings of appearance and texture of greater than 5.6 on a 9-point hedonic scale. Numbers in parentheses correspond to 10 formulations shown in Table 1.

#### Verification of the optimum formulation range

The adequacy of the model equations for predicting optimum response values was tested using 28% dried strawberry, 27% dried longan and 20% mixed crisp (Table 3). The results showed that the percentage of difference of appearance, texture stickiness,  $L$  and  $b$  values were relatively small with 1.60, 2.52, 3.28, 7.78 and 5.29, respectively. Hu (1999) was suggested that, the percentage difference between predict and experimental values less than 10% were suitable for predicting model and Gan et al. (2007) was used 5% of difference to verified model for the optimum formulation of cassava cake. In this study, all of the responses had % of difference less than 10%. Thus, the model can be used to optimize the formulation of strawberry-longan bar.

**Table 3.** Predicted and experimental values for strawberry-longan bar formulations.

Response variables	Predicted values	Experimental values*	% of difference
Appearance**	6.2	6.1±0.2	1.60
Texture**	5.6	5.8±0.2	2.52
Stickiness***	-215.60	-208.75±13.3	3.28
$L$ ***	37.88	35.15±0.5	7.78
$b$ ***	8.34	5.89±0.2	5.59

\*Formulation containing 27% longan, 28% strawberry and 20% mixed crisp

\*\*Experimental values of appearance and texture were evaluated acceptability ratings of the optimized formulation using a 9-point hedonic scale and based on 100 consumer responses.

\*\*\* Mean±standard deviation (n = 4).

## CONCLUSION

Response surface methodology is a useful tool in optimization of the formulation of strawberry-longan bar. The levels of dried strawberry, dried longan and mixed crisp affected consumer acceptability (appearance and texture), stickiness and color parameters (*L* and *b*) of strawberry-longan bar. The model equation developed can be used for predicting the quality of strawberry-longan bar. Appearance and texture acceptability were a limiting factor in obtaining the optimum formulation range, which consisted of 25% to 35%, dried strawberry, 25% to 35% dried longan and 10% to 25% mixed crisp. This optimum formulation range was presented the appearance acceptability and texture acceptability scores of at least 5.6 on a 9-point hedonic scale.

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