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# Effect of dragon fruit oligosaccharide, stabilizer and sucrose on physical and sensory quality of ice cream

[1*]Wichamanee, Y., [1]Acharaphan, M. and [2]Santad, W.

[1]*Department of Food Science, Faculty of Science, Burapha University, Bangsaen, Chonburi 20131 Thailand*

[2]*Nutraceutical and Functional Food Research and Development Center, Faculty of Agro-Industry, Prince of Songkla University, Hat Yai, Songkhla, 90112 Thailand*

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**Abstract**

This research was study the relation between quantities of dragon fruit oligosaccharide ($X_1$) (2.0 -6.0 g/100g), stabilizer ($X_2$) (0.2-0.8 g/100g) and sucrose ($X_3$) (8.0-12.0 g/100g) with quality of ice cream using regressions analysis. For this purpose, experiments were carried out using a three-factor central composite design (CCD). Regression model expressing viscosity of ice cream mixed, $L^*$ color, overrun value, texture liking and overall liking acceptability as a function of ingredient variables were significantly ($p<0.05$) fitted, with high coefficient of determination value ($R^2 \geq 0.75$). Response surface methodology (RSM) was used to develop predictive models for simulation and optimization of the ice cream formulation. The obtained overall liking equation was used to select the optimal values of independent variables. The acceptable greatest overall liking score was reached under the optimal conditions at dragon fruit oligosaccharide 4.00 g/100g combined with stabilizer 0.20-0.46 g/100g and sucrose 8.00-9.27 g/100g or stabilizer 0.54-0.80 g/100g and sucrose 10.28-12.00 g/100g. Moreover, validation tests were performed and the results were very close to the predicted values.



## Introduction

Prebiotics are normally non-digestible dietary carbohydrates which are selectively fermented resulting in benefits upon host health (Roberfroid *et al*., 2010). There are certain carbohydrates with well-known as prebiotic particular some non-digestible oligosaccharides (Di Bartolomeo *et al*., 2013). Dragon fruit or pitaya (*Hylocereusundatus* (Haw) is native plant from Mexico, Central and South America and has been grown in Viet Nam. Flesh dragon fruit has been reported as a source of oligosaccharide which can be extracted by water and heat then dried by freeze dryer. It was found that the dragon fruit oligosaccharides resistance to human salivary α-amylase hydrolysis and human stomach acid hydrolysis and stimulated the growth of Lactobacillus delbrueckii and growth stimulation higher than inulin (Wichienchot *et al*., 2009). Nowadays, the development of products as functional food enriched with prebiotic substance could be satisfying the high demands of the market. It is important to evaluate the physicochemical and sensorial properties of these functional foods before to study their functional and therapeutic properties. There was no research reported the adoption of dragon fruit oligosaccharides in ice cream product. Actually, ice cream was a dairy product with high nutritional value suitable for consumption and it could supplement with prebiotic efficiently (Cruz *et al*., 2009). It is interesting to add the dragon fruit oligosaccharide in ice cream to enhance functional properties as a source of prebiotic for stimulation on growth of probiotic.

Response surface methodology (RSM) was a statistic technique to describe the relation of product properties referred to regression equations which explain inter-relations between input parameters and product properties (Colona *et al*., 1984). The use of RSM in prediction and explanation of product ingredients or process variables has also been reported by many other researchers (Sushma and Saxena, 2000; Rathi *et al*., 2002; Gill *et al*. 2004). Although ice cream formulations depending on the manufacturing process, generally they are composed of cream, sugar, milk, stabilizer, colors and flavor. Each ingredient has a purpose in the product (Clarke, 2004). Therefore the objective of this work was to study the effects of product ingredients on quality of ice cream supplemented with dragon fruit oligosaccharides. Investigations have been undertaken to elucidate the effects of three ingredients

*Corresponding author.
Email: *wich@buu.ac.th*

at difference levels: dragon fruit oligosaccharides, stabilizer and sucrose on physical quality and sensory acceptability of ice cream. The optimal ice cream formulation was validated using RSM.

## Materials and Methods

*Dragon fruit oligosaccharide preparation*

White fresh dragon fruit were obtained from local market in Chonburi, Thailand. Dragon fruit oligosaccharide was extracted according to Wichienchot *et al.* (2009). Skin of dragon fruit was manually peeled and their flesh was extracted at ambient temperature (27±1°C) by distillated water. Mixing the flesh and distillated water in the ratio of 1:1 (w/w), stirring continuously then filtered through a cheesecloth bag to remove the seeds. The extraction was added by 95% ethanol in the ratio of 1:1 (v/v), sample was mixed and kept at -20°C and left for 24 hr. Sample was filtered through a cheesecloth bag again to obtain precipitant. Precipitant was dried by freeze dryer.

*Ice cream production*

The ingredients (skimmed milk powder, sucrose and cream with 35 g/100g fat) for ice cream production were purchased from local market. Commercial stabilizer (Fulfill I 400) was acquired from Vicchi Enterprise Company Ltd (Thailand). A second-order central composite design (CCD) with three variables was used to study the response pattern. In our preliminary studies, we have investigated the effect of ice cream ingredients such as skimmed milk, sucrose, cream, stabilizer and dragon fruit oligosaccharide on physicochemical quality and sensory acceptability of ice cream supplemented dragon fruit oligosaccharide. It was showed that dragon fruit oligosaccharide, stabilizer and sucrose had significantly affected whereas the other ingredients were negligible. The three variables were dragon fruit oligosaccharide ($X_1$:2.0 to 6.0 g/100g) stabilizer ($X_2$:0.2 to 0.8 g/100g) and sucrose ($X_3$:8.0 to 12.0 g/100g), at each five levels were studied. The critical ranges of selected parameters were determined by preliminary experiments based on the literature review. All ice cream mix formulation consisted of cream 25.60 g/100g and skimmed milk 10.20 g/100g. All dry ingredients were mixed with water which took the water content of the fluid ingredients into account. The ice cream mixed was homogenized by using Warring blender (2 min) and pasteurized (85°C, 30 s). The samples were hardened at 4°C for 24 h and then stored overnight in a freezing cabinet at −20°C.

*Physical analysis of ice cream*

The apparent viscosity of the ice cream mixed was determined using a Brookfield viscometer (Model DV-III, Brookfield, USA) at temperature 5°C ± 0.5 °C. The readings were made at 12 rpm with spindle number 3 and the results expressed in centipoises (Chang *et al*., 1995). Melting was analyzed using a wire mesh by placing 50 ± 2 g of ice cream on the wire mesh and allowing it to melt at room temperature (27°C ± 1°C) for 60 minutes. The melted ice cream volume was measured every 10 min for 60 min. The data recorded were use to determine the melting rate (mL/min). Overrun test was analyzed according to Dervisoglu and Yazici (2006). Overrun was determined by measuring the ice cream mix volume before and after cooling using a standard 100 mL cup. Comparisons of the volume of the original ice cream mixed allow calculation of the overrun.

$$\text{Overrun} = [(\text{ice cream volume} - \text{mix volume}) / \text{mix weight}] \times 100$$

Color analysis of ice cream was conducted with Hunter Lab colorimeter (Miniscan XE plus, Hunter lab, USA) equipped with illuminant D65, in reflectance mode and in the CIE $L^*$, $a^*$ and $b^*$ color scale.

*Sensory analysis of ice cream*

The sensory evaluation of the ice cream samples was conducted using acceptance test. A panelist group of 30 assessors (age between 18-45 years old) were students and faculty members of Food Science Department, Burapha University, Chonburi, Thailand. Panelists were selected according to their interests in ice cream consumption and willingness to participate. They were given information about basic sensory attributes of ice cream (color, odor, taste and mouthfeel texture). The samples were served approximately 25 g of each sample coded with a three-digit randomized number. Color, odor, sweetness, texture and overall liking acceptability of each samples were evaluated using 9-point hedonic scale (1= extremely dislike and 9= extremely like).

*Statistical analysis*

The response variables obtained from the experiments were analyzed using the SPSS software version 13. The regression procedures were used for testing significance and developing appropriate models for predicting each response. A quadratic model was chosen for the description of the response variables ($Y_{1-11}$) to the factor variables: dragon fruit oligosaccharide ($X_1$) stabilizer ($X_2$) and sucrose ($X_3$)

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_{11}X_1^2+\beta_{22}X_2^2++\beta_{33}X_3^2+\beta_{12}X_1X_2+\beta_{13}X_1X_3+\beta_{23}X_2X_3+\beta_{123}X_1X_2X_3$$

Fischer's test was used for determination of the relation of the model equation, while Student's t-test was performed for the determination of statistical significance of regression coefficients. The regression validity was checked by estimating the determination coefficient ($R^2$) and the associated p-value. The experimental and predicted values were compared in order to determine the validity of the model. The adequacy of the model was also checked by estimating the root-mean-squares error (RMSE) which was shown as follows:

$$\text{RMSE}(\%)=100\sqrt{\sum\frac{\left[(Y_{ex}-Y_{pred})/Y_{pred}\right]^2}{N}}$$

where $N$ is the number of points, $Y_{pred}$ is the predicted value, $Y_{ex}$ is the experiment value.

The equation was expressed as surface plot in order to visualize the relationship between the response and factor levels. Optimal conditions for the ice cream formulation were obtained using the predictive equations. Graphical optimization procedures were carried out for predicting the optimum level of independent variables leading to the desirable response goals. Experimental data was compared with the fitted values predicted by the model in order to verify the adequacy of the regression model.

## Results and Discussion

Physicochemical characterization of the dragon fruit oligosaccharide has been reported according to previous work carried out (Mahabandha *et al*., 2012). The moisture content of dragon fruit oligosaccharide powder was low (4.21%). It was light brown in color which the CIE $L^*$, $a^*$ and $b^*$ color scale were 81.01, 0.93 and 12.76, respectively. Dragon fruit oligosaccharide powder was particularly solubilized in water (soluble index was 46.40%) and performed the slightly ability to absorbed water (absorption index was 3.39%). The solution of 30% dragon fruit oligosaccharide exhibited stickiness solution with apparent viscosity as 142.67 cP.

*Analysis of the equation*

Table 1 presents the results of fitting model of data. The ANOVA analysis indicates a good model performance with the determination coefficient ($R^2$) values of 0.75, 0.80, 0.79, 0.98 and 0.96 for viscosity of ice cream mixed ($Y_1$), $L^*$ color ($Y_2$), overrun value ($Y_5$), texture liking ($Y_{10}$) and overall liking acceptability ($Y_{11}$), respectively. $R^2$ is defined as the ratio of the explained variation to the total variation and it is a measurement of the degree of fitness (Nath&Chattopadhyay, 2007). These can explain about 75-98% of calculated model. The statistical significance of the terms in the regression equations was examined by ANOVA for each response and the significance test level was set at 5% ($p<0.05$). The p-value was used as a tool to check the significance of each equation. The smaller value of p, the more significant of the corresponding equation. It can be seen from the Table 1 that equation of $Y_1$, $Y_2$, $Y_5$, $Y_{10}$ and $Y_{11}$ were significant, with small p-value ($p< 0.05$).

The results indicated that all five models of viscosity of ice cream mixed, lightness and overrun of ice cream, as well as sensory acceptability in terms of texture and overall liking could fit well for the prediction. The regression coefficients of the intercept, linear, quadratic and interaction terms of the model were calculated using the least square technique and the significant terms were displayed in the equations.

Data results in terms of $a^*$ ($Y_3$) and $b^*$ ($Y_4$) color values, melting rate ($Y_6$) sensorial acceptability in terms of color ($Y_7$), odor ($Y_8$) and sweetness ($Y_9$) were showed that the regression modes was not adequate (p-value > 0.05). So in this case, indicating that the used range treatment effects was minor for these response properties of ice cream.

The fitted linear model for ice cream mixed viscosity ($Y_1$) was given in the equation. Ice cream mixed viscosity had directly positive effect from the content of dragon fruit oligosaccharide ($X_1$) and stabilizer ($X_2$). The linear terms of dragon fruit oligosaccharide ($X_1$) and stabilizer ($X_2$), as well as the interaction term between oligosaccharide and stabilizer ($X_1X_2$) had the significantly effects on lightness of ice cream ($Y_2$). In terms of overrun ($Y_5$) and texture liking ($Y_{10}$), only the linear and quadratic terms of dragon fruit oligosaccharide ($X_1$) had significant effects on volume and textural properties of ice cream. The predicted polynomial regression equation for overall liking acceptability ($Y_{11}$) seems to be the most interesting model. This is because the equation can illustrate the relation of all three factors ($X_1$, $X_2$, $X_3$) and the overall liking where reflecting acceptable quality of the ice cream.

Obviously, dragon fruit oligosaccharide played an important role on both physical (viscosity of ice cream mixed, $L^*$ color and overrun value) and sensory (texture and overall liking) properties of ice cream. The increase of dragon fruit oligosaccharide in the ice cream formulation caused an increase in

Table 1. Coded equations for quality parameters of ice cream as a function of the quantities of dragon fruit oligosaccharide ($X_1$), stabilizer ($X_2$) and sucrose ($X_3$)

| Parameter | Coded equation | $R^2$ | p-value |
|---|---|---|---|
| 1. Viscosity | $Y_1 = 139.795 + 51.752X_1 + 53.119X_2$ | 0.75 | 0.04* |
| 2. L* color | $Y_2 = 82.686 - 2.302X_1 + 2.348X_2 + 2.809X_1X_2$ | 0.80 | 0.04* |
| 3. a* color | $Y_3 = -0.347 - 0.572X_1X_2$ | 0.58 | 0.52$^{ns}$ |
| 4. b* color | $Y_4 = 13.016 + 5.77X_1$ | 0.48 | 0.75$^{ns}$ |
| 5. Over run value | $Y_5 = 11.273 - 4.685X_1 + 3.327X_1^2$ | 0.79 | 0.04* |
| 6. Melting rate | $Y_6 = 13.881 - 3.26X_1 + 2.24X_2^2$ | 0.56 | 0.58$^{sn}$ |
| 7. Color liking | $Y_7 = 6.922 - 0.237X_1 - 0.657X_1^2$ | 0.83 | 0.06$^{ns}$ |
| 8. Odor liking | $Y_8 = 5.659 + 0.179X_2X_3$ | 0.71 | 0.25$^{ns}$ |
| 9. Sweetness liking | $Y_9 = 6.08 + 0.87X_2X_3 - 1.081X_1^2$ | 0.70 | 0.08$^{ns}$ |
| 10. Texture liking | $Y_{10} = 6.606 - 0.608X_1 - 0.286X_1^2$ | 0.98 | 0.01* |
| 11. Overall liking | $Y_{11} = 7.268 + 0.591X_2X_3 - 1.13X_1^2$ | 0.96 | 0.03* |

$X_1$ = dragon fruit oligosaccharide, $X_2$ = stabilizer and $X_3$ = sucrose
* Significant for $p \leq 0.05$, $^{ns}$ Not significant for $p > 0.05$

Table 2. The experimental and predicted results of ice cream mixed viscosity ($Y_1$), L* color ($Y_2$), over run ($Y_5$), texture liking ($Y_{10}$) and overall liking acceptability ($Y_{11}$), for validation the equation

| No. | Viscosity (cP) | | L* color | | Over run | | Texture liking | | Overall liking | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $Y_{ex}$ | $Y_{pred}$ | $Y_{ex}$ | $Y_{pred}$ | $Y_{ex}$ | $Y_{pred}$ | $Y_{ex}$ | $Y_{pred}$ | $Y_{ex}$ | $Y_{pred}$ |
| 1 | 38.67 | 34.92 | 84.33 | 85.45 | 18.66 | 19.29 | 6.80 | 6.93 | 7.17 | 6.75 |
| 2 | 32.12 | 34.92 | 79.23 | 85.45 | 16.30 | 19.29 | 5.93 | 6.93 | 5.30 | 5.57 |
| 3 | 127.05 | 141.16 | 83.04 | 84.53 | 21.85 | 19.29 | 6.10 | 6.93 | 5.07 | 5.57 |
| 4 | 166.79 | 141.16 | 80.16 | 84.53 | 20.00 | 19.29 | 5.10 | 6.93 | 4.37 | 6.75 |
| 5 | 122.07 | 138.43 | 85.63 | 75.23 | 9.98 | 9.92 | 5.93 | 5.71 | 4.97 | 6.75 |
| 6 | 119.07 | 138.43 | 76.67 | 75.23 | 9.83 | 9.92 | 5.63 | 5.71 | 5.70 | 5.57 |
| 7 | 285.6 | 244.67 | 85.85 | 85.54 | 9.01 | 9.92 | 6.13 | 5.71 | 6.73 | 5.57 |
| 8 | 204.52 | 244.67 | 76.14 | 85.54 | 9.75 | 9.92 | 5.90 | 5.71 | 5.80 | 6.75 |
| 9 | 57.38 | 52.75 | 84.42 | 86.56 | 28.07 | 28.57 | 5.43 | 6.82 | 4.53 | 4.09 |
| 10 | 281.06 | 226.84 | 78.79 | 78.81 | 11.33 | 12.81 | 4.83 | 4.77 | 3.60 | 4.09 |
| 11 | 66.17 | 50.45 | 78.79 | 78.74 | 16.73 | 11.27 | 6.63 | 6.61 | 6.70 | 7.29 |
| 12 | 229.93 | 229.14 | 82.59 | 86.64 | 11.84 | 11.27 | 6.70 | 6.61 | 6.63 | 7.29 |
| 13 | 130.07 | 139.80 | 82.16 | 82.69 | 11.77 | 11.27 | 6.47 | 6.61 | 6.50 | 7.29 |
| 14 | 130.67 | 139.80 | 82.24 | 82.69 | 14.32 | 11.27 | 6.57 | 6.61 | 6.37 | 7.29 |
| 15 | 103.78 | 139.80 | 83.13 | 82.69 | 11.73 | 11.27 | 6.90 | 6.61 | 7.27 | 7.29 |
| 16 | 106.42 | 139.80 | 83.14 | 82.69 | 11.41 | 11.27 | 6.92 | 6.61 | 7.24 | 7.29 |
| 17 | 105.43 | 139.80 | 82.98 | 82.69 | 11.33 | 11.27 | 6.89 | 6.61 | 7.20 | 7.29 |
| 18 | 109.51 | 139.80 | 81.34 | 82.69 | 10.96 | 11.27 | 6.79 | 6.61 | 7.37 | 7.29 |
| RMSE (%) | 17.50 | | 4.90 | | 14.55 | | 9.53 | | 13.74 | |

viscosity, which favored the texture liking and overall liking of more viscous ice cream texture. However increasing of dragon fruit oligosaccharide made the ice cream trend to darken.

*Validation of the equation*

In order to verify the predictive capacity of the model, results of all experiment conditions were used for viscosity of ice cream mixed ($Y_1$), L* color ($Y_2$), overrun value ($Y_5$), texture liking ($Y_{10}$) and overall liking acceptability ($Y_{11}$). RMSE reported in the Table 2 indicate the adequacy of the equation for describing the quality parameters of ice cream under the given experimental conditions. Table 2 also compares the experimental data with the predicted data which show RMSE value between 4.90 and 17.50%. RMSE provides a measure of the goodness-of-fit of a model to the data used to produce it (Box and Draper, 1987). Table 2 showed the low values for RMSE, which indicated a good fit of the experimental data. So that the experimental results of viscosity of ice cream mixed ($Y_1$), L* color ($Y_2$), overrun value ($Y_5$), texture liking ($Y_{10}$) and overall liking acceptability ($Y_{11}$) were in agreement with the predicted values.

*Analysis of contour plots*

Response surface methodology in form of contour plots were used to visualize the relationship between experimental and response levels in this research. The best way of expressing the effect of any independent variable on dependent variable was to generate response plots of models, which were done by varying two variables within the experimental range under investigation (Bachirbey *et al.*, 2014). The equations of overrun value and texture liking significantly depend on the single

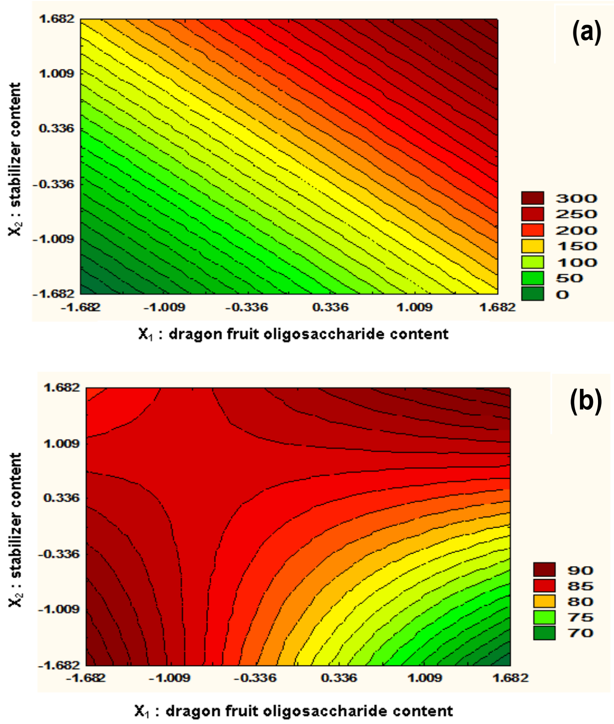


Figure 1. Contour plot for the effects of dragon fruit oligosaccharide ($X_1$) and stabilizer ($X_2$) on ice cream mixed viscosity (cP) (a) and ice cream $L^*$ color (b)

factor of dragon fruit oligosaccharide which cannot plot the contour response. It can be seen from both equations that the higher content of dragon fruit oligosaccharide enrichment of ice cream trended to decrease the overrun volume and affected lower texture perception. According to Varela *et al.* (2014) in-mouth texture largely determines the acceptability of ice cream, making it is a key quality factor. Its perception involves movements of the tongue and other oral structures while the product melts and becomes a smooth, creamy viscous liquid as its temperature increases. Actually, texture properties in terms of iciness, coldness, creaminess, roughness, gumminess, and mouth coating were assessed by consumer. Whereas, the equation of overall liking score related with all three independent variables so the contour must plot by varying two variables and holding the other variable constant.

The impact of dragon fruit oligosaccharide and stabilizer levels on ice cream mixed viscosity can be seen in Figure1 (a). The increase in dragon fruit oligosaccharide and stabilizer content resulted in the increase of viscosity of ice cream mixed. Due to ice cream mixed rheology was affected by many factors including the presence of components and their concentration such as fat, polysaccharides, proteins and stabilizer (McClements, 1999). The increased viscosity of the dragon fruit oligosaccharide enriched ice cream mixes seems to be caused by water retention from the soluble fibres part. The contribution of the soluble matter to the aqueous phase affecting the hydrated biopolymers formation (Soukoulis *et al.*, 2009). So that the contribution of the soluble fibers in the viscosity reinforcement of samples enriched with dragon fruit oligosaccharide content. According to Pszczola (1999), oligosaccharide composed with soluble fibres which can offer a variety of technological functional properties such as water retention, enhanced viscosity for improving binding and texture. Oligosaccharide can be used as food ingredient acts as a texture modifier by holding in moisture, which helps keep the product more soft and elastic. This finding was consistent with the study of Sun-Waterhouse *et al.* (2013), stating that the addition of aqueous fractions from purees of kiwifruit which contained a significant amount of water soluble polysaccharides could cause a change in viscosity imparting properties of ice cream mixed. The soluble fiber polysaccharide such as inulin altered the viscosity of ice cream mixes and the texture of the resultant ice cream product. Soluble fiber polysaccharides also played an important role in milk coagulation kinetics such as the gel time and coagulum firming rates.

The same effect was also observed when increase stabilizer content. The stabilizer used in this study was a mixture of commercial hydrocolloids. Hydrocolloids affect ice cream texture through different mechanisms, which include increasing viscosity and water retention, preventing separation of the ice cream mix (an oil in water emulsion) and producing charged films at the interfaces so the individual droplets tend to resist each other and avoiding agglomeration (Helgerud *et al.*, 2010). Muse and Hartel (2004) also mentioned that generally the existence of stabilizer induces apparent viscosity of liquid phase and thus, the thick of the ice cream mixed with high content of stabilizer could be observed. Stabilizer increase the viscosity of the ice cream mixed, due to their water holding and micro-viscosity enhancement ability. This finding is consistent with the study of Bolliger *et al.* (2000) reported that stabilizer, guar gum concentrations ranging from 0 to 0.25%, played an important role in increasing viscosity of ice cream mixed and hence successively decreasing the water content which help recrystallization protection in ice.

Color is the first criterion that is used in the acceptance or rejection of a product. Thus, if the developed ice cream gave the irregular color, the product probably was rejected. However changing all three ingredients of dragon fruit oligosaccharide, stabilizer and sucrose in studied range had no significant influence ($p>0.05$) on both $a^*$ (greenness)

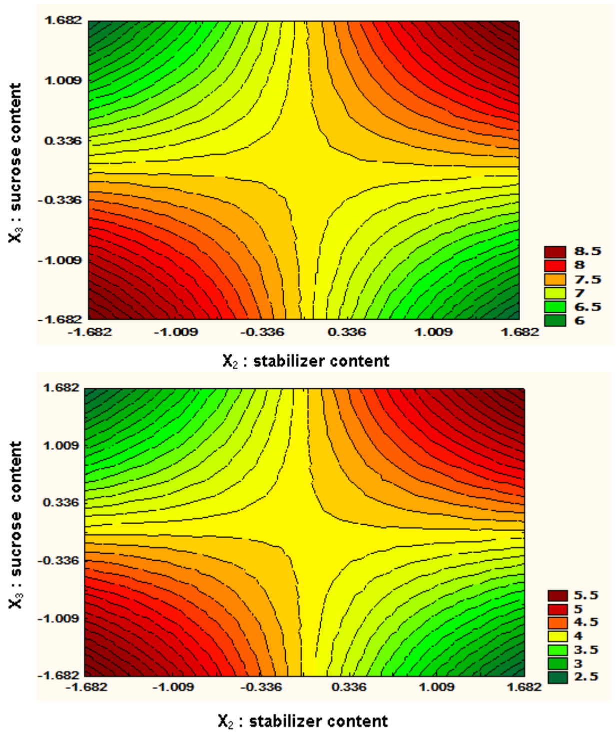


Figure 2. Contour plot for the effects of stabilizer ($X_2$) and sucrose ($X_3$) on ice cream overall liking acceptability, when dragon fruit oligosaccharide was fixed at 0 (center point code level) (a), and when dragon fruit oligosaccharide was fixed at +1.682 (maximum point code level) (b)

and b* (yellowness) of ice cream. Figure1 (b) illustrates the effect of these independent variables on L* color value or lightness of ice cream. Considering L* color value at the maximum level of dragon fruit oligosaccharide combined with minimum level of stabilizer, it was found that the L* color value decreased with increasing dragon fruit oligosaccharide content. A reduction of the lightness at high dragon fruit oligosaccharide levels could be due to the light brown in color of dragon fruit oligosaccharide powder itself. Therefore, the color of ice cream is usually similar to the color of the ingredients added.

However, at the high content of stabilizer, even though the high content of dragon fruit oligosaccharide powder was added the ice cream showed high value of L*. It seem to be the synergic effect between viscosity and L* color of ice cream. Since the higher viscosity of solutions and emulsions can decrease the particle movement (Dickinson, 2009). Therefore, it can effectively decrease the darkening from dragon fruit oligosaccharide particles movement.

As occurred from the equation for overall liking acceptability, it's depended also on the sucrose, stabilizer and dragon fruit oligosaccharide content. The contour plots for the overall liking acceptability as a function of all variables were shown in Figure 2(a) and Figure 2(b) when fixed

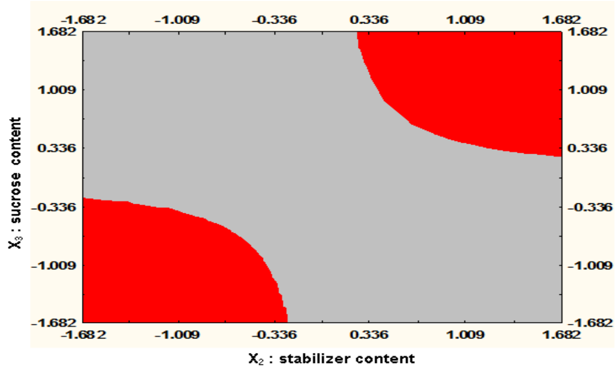


Figure 3. Contour plot of overall liking score more than 8 point (at least like extremely level) for the effects of stabilizer ($X_2$) and sucrose ($X_3$) on ice cream overall liking acceptability, when dragon fruit oligosaccharide was fixed at 0 (center point code level)

dragon fruit oligosaccharide at 0 (center point) and +1.682 (maximum point), respectively. The response contours of Figure 2(a) and Figure 2(b) were shown the same trend. As can be seen in both contour plots, the maximum values of overall liking score were obtained at the minimum level of sucrose and stabilizer. Nevertheless, these were obtained at the maximum level of sucrose and stabilizer. However the higher overall liking score (6.0-8.5) of ice cream was responsible for the dragon fruit oligosaccharide at center point level (Figure 2(b)). The higher sensory acceptability score indicate the contribution of dragon fruit oligosaccharide must selected at only moderately level. Since the range of overall sensory score of ice cream was higher than 5, its sensory properties were considered to be acceptable (Lazaridou *et al.*, 2007).

*Optimization and verification of the model*

Graphical optimization was adopted to determine the optimum combination of dragon fruit oligosaccharide, stabilizer and sucrose. The corresponding sensory property was determined as a constraint in the optimization. Response contour plots obtained for overall liking acceptability combination of the two variables of stabilizer and sucrose, at the medium level of dragon fruit oligosaccharide, was used as following:

$$\text{Overall liking} = 7.268 + 0.591X_2X_3;\ X_1 = 0$$

The regions meeting the overall sensory liking since 8 (extremely like level) were identified. As depicted in Figure 3, the result illustrated the two possible area conditions of ingredient quantity which achieved the constraint. There were two regions of minimum level of sucrose and stabilizer as well as maximum level of sucrose and stabilizer, at the medium level of dragon fruit oligosaccharide. It was suggested that at the medium level of dragon fruit oligosaccharide (coded value = 0, actual value = 4 g/100g), the optimum content of stabilizer and sucrose ranged from 0.20 g/100g to 0.80 g/100g and from 8.00 g/100g to 12.00 g/100g, respectively. In this study, the six optimum contents of stabilizer and sucrose were chosen at the edge and centroid of the optimum region (Figure 3). Using all optimized formulations which were estimated their sensory overall liking score between 7.65 to 7.95 which means very like to extremely like level. A verification experiment using the optimized ice cream formulations were evaluated. The result was compared with the predicted responses from the model equations. The experimental and predicted values of the developed ice cream were found to be similar which RMSE as 1.66% indicating the suitability of the model equation for predicting optimum conditions. Julian (2004) stated that RMSE should less than 20% to demonstrate that the equation had low tolerances and reliable to used.

## Conclusions

The relation equation between quantity of the developed ice cream ingredient which were dragon fruit oligosaccharide and stabilizer and sucrose with the quality of ice cream as following: viscosity of ice cream mixed, $L^*$ color, overrun value, texture liking and overall liking gave satisfactory values of $R^2$, and model significant. Response surface methodology illustrated the two possible area of ingredient quantity to get the sensory acceptable ice cream. There were 1) using stabilizer range between 0.20 g/100g and 0.46 g/100g combined with sucrose rage between 8.00 g/100g and 9.27 g/100g and 2) using stabilizer range between 0.54 g/100g and 0.80 g/100g combined with sucrose rage between 10.28 g/100g and 12.00 g/100g both conditions with a constant of dragon fruit oligosaccharide powder at 4.00 g/100g.

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## References

Bachirbey, M., Meziant, L., Benchikh, Y. and Louaileche, H. 2014. Deployment of response surface methodology to optimize recovery of dark fresh fig (*Ficus carica* L.var. Azenjar) total phenolic compounds and antioxidant activity. Food Chemistry 162(1): 277–282.

Bolliger, S., Goff, H. D., and Tharp, B. W. 2000. Correlation between colloidal properties of ice cream mix and ice cream. International Dairy Journal 10: 303-309.

Box, G. E. P. and Draper, N.R. 1987. Empirical Model-Building and Response Surfaces. New York: Wiley.

Chang, J.L., Marshall, R.T. and Heymann, H. 1995. Casein micelles partially hydrolyzed by chymosin to modified the texture of low fat ice cream. Journal of Dairy Science 78(4): 2617-2623.

Clark, C. 2004. The Science of Ice Cream, Cornwall: TJ International Ltd.

Colona, P., Doublier, J.L., Melcion, J.P., Monfredon, F.D. and Mercier, C. 1984. Extrusion cooking and drum drying of wheat starch. I. Physical and macromolecular modifications. Cereal Chemistry 61(6): 538–543.

Cruz, A.G., Antunes, A.E.C., Sousa, A.O.P., Faria J.A.F., and Saad, S.M.I. 2009. Ice-cream as a probiotic food carrier. Food Research International 42(9): 1233–1239.

Dervisoglu, M. and Yazici, F. 2006. The effect of citrus fibre on the physical, chemical and sensory properties of ice cream. Food Science Technology International 12(2): 159-164.

Di Bartolomeo, F., Startek, J.B. and Van den Ende, W. 2013. Prebiotics to fight diseases: Reality or Fiction. Phytotherapy Research 27(10): 1457–1473.

Dickinson, E. 2009. Hydrocolloids as emulsifiers and emulsion stabilizers. Food Hydrocolloids 23(6): 1473-1482.

Gill, B.S., Sodhi, N.S., Singh, N., Singh, M., and Singh, D. 2004. Effects of obrix, sodium alginate and drying temperature on color, texture and sensory properties of Dushehari mango leather. Journal of Food Science and Technology 41(4): 278–373.

Helgerud, T., Gaserod, O., Fjaereide, T., Andersen, P. O., and Larsen, C. K. 2010. Alginates. In A. Imeson (Ed.), Food Stabilisers, Thickeners and Gelling Agents. Oxford: John Wiley & Sons, Ltd.

Julian, J.F. 2004. Linear Model with R. London: Chapman and Hall.

Lazaridou, A., Duta, D., Papageorgiou, M., Belc, N., and Biliaderis, C.G. 2007. Effects of hydrocolloids on dough rheology and bread quality parameters in gluten-free formulations. Journal of Food Engineering 79(3): 1033-1047.

Mahabandha, A., Yuenyongputtakal, W. and Wichienchot, S. 2012. Quality of white flesh dragon fruit oligosaccharide powder and application in milk ice cream. Proceedings of the 1st KMITL-Agro Industrial Conference, p. 221-227. Thailand: The Emerald Hotel.

McClements, D.J. 1999. Food Emulsions: Principles, Practice and Techniques. Florida: CRC Press.

Muse, R., and Hartel, W. 2004. Ice cream structural elements that affect melting rate and hardness. Journal Dairy Science 87: 1-10.

Nath, A. and Chattopadhyay, P.K. 2007. Optimization of oven toasting for improving crispness and other quality attributes of ready to eat potato-soy snack using response surface methodology. Journal of Food Engineering 80(4): 1282-1292.

Pszczola D. E. 1999. Emerging ingredients: believe it or

not. Food Technology 53: 98-104.
Rathi, P., Goswami, V.K., Sahai, V. and Gupta, R. 2002. Statistical medium optimization and production of a hyperthermostable lipase from *Burkholderia cepacia* in a bioreactor. Journal of Applied Microbiology 93(6): 930–936.
Roberfroid, M., Gibson, G.R., Hoyles, L., McCartney, A.L., Rastall, R. and Rowland, I. 2010. Prebiotic effects: metabolic and health benefits. British Journal of Nutrition 104: S1–S63.
Soukoulis, C., Lebesi, D. and Tzia, C. 2009 Enrichment of ice cream with dietary fiber: Effects on rheological properties, ice crystallization and glass transition phenomena. Food Chemistry 115: 665-671.
Sun-Waterhouse, D. 2013. Advances in Food Science and Nutrition. New York: Wiley.
Sushma T. and Saxena, D.C. 2000. Formulation of Extruded Snack Food (Gum Based Cereal–Pulse Blend): Optimization of Ingredients Levels Using Response Surface Methodology. LWT - Food Science and Technology 33(5): 354-361.
Varela, P., Pintor, A. and Fiszman, S. 2014. How hydrocolloids affect the temporal oral perception of ice cream. Food Hydrocolloids 36: 220-228.
Wichienchot, S., Jatupornpipat, M. and Rastall, R.A. 2009. Oligosaccharides of pitaya (Dargon fruit) flesh and prebiotic properties. Food chemistry 120(3): 850-857.