

Playing with the senses: application of box-behnken design to optimize the *bukayo* formulation

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Abstract

A three-level Box-Behnken design of response surface methodology was employed to optimize the formulation of *bukayo* or coconut toffee based on overall acceptability sensory attribute. The independent variables were different levels of young coconut meat (250 – 500 g), *sinakob* (250 – 500 g), and coconut juice (250 – 500 g) with fifteen different runs of three similar center points. The analysis of variance showed that quadratically, coconut juice and *sinakob* showed significantly higher effect ($p < 0.05$) on the overall acceptability of *bukayo* whereas the “Lack of Fit” was non-significant relative to the pure error. For optimization, the goal was to maximize the overall acceptability response. The optimum formulation conditions of 430 g young coconut meat, 400 g *sinakob*, and 340 g coconut juice yielded an experimental overall acceptability score of 8.04 which is close to the predicted score of 7.11 with composite desirability of 0.87 on a nine-point hedonic scale. The regression model equation for overall acceptability could predict response yield until at least 84.65% of accuracy. Box-Behnken design of RSM performed well in the optimization of the *bukayo* formulation with a very high degree of overall acceptability. The strong and positive correlations enable the application of colorimetry as an indication of the overall acceptability and sensory color of the *bukayo* product.

1. Introduction

Coconut is one of the most important crops in tropical areas. Indonesia dominates the world as one of the biggest coconuts producing country with a production of 18 million tons of coconuts followed by the Philippines with an annual production of 15 million tons of coconuts (Burton, 2018). The various edible products from coconut include coconut milk, dried coconut or copra, desiccated coconut, coconut oil, coconut water, nata-de-coco, coconut flour, vinegar, and coconut jam (Sangamithra *et al.*, 2013; Prades *et al.*, 2016). *Bukayo* or coconut toffee is an after-meal sugar fix and one of the widely processed desserts in Pangasinan, Philippines. It is made by simmering coconut meat strips in a mixture of coconut juice and brown or white sugar until liquid is heavily reduced, the mixture is then formed into balls and left to harden to a chewy consistency (Pascual, 2017).

Experimental designs capable of predicting the optimum conditions of the combined factors are important to save time and resources. The most common approach is the classical one-variable-at-time technique. This method involves changing one variable at a time

while keeping the others at constant levels (Keshani *et al.*, 2010). While such experiments are simple to plan and execute, they are inefficient and failed to detect any interaction amongst the independent variables. Furthermore, it will require more experimentation and there is no assurance that it will produce reliable results (Montgomery, Runger and Hubbele, 2001). A Box-Behnken design was employed among other response surface methodologies because it provides the minimum number of experiments, a shorter time of operation, and feasibility of providing valuable information on the interactions among experimental parameters (Tan *et al.*, 2012). Several researchers employed a Box-Behnken approach for optimization studies across the fields such as to optimize the drying process of persimmon leather production (Dursun and Dalgiç, 2018); to establish the optimum experimental condition of cake batter mixing (Tan *et al.*, 2012); to optimize the foaming conditions for tomato juice as a function of egg albumin concentration, carboxymethyl cellulose, and whipping time (Balasubramanian *et al.*, 2012), and to optimize spent hen meat level, oil level, and cooking time for development of ready-to-eat chicken meat caruncles on the basis of sensory attributes - color/appearance, flavor,

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crispiness, after-taste, meat flavor intensity, and overall acceptability (Singh *et al.*, 2015).

In the realm of new product development, response surface methodologies hold the key position so that commercial production can be realized for a new product. With these response surface methodologies, the product developer can accomplish many different objectives ranging from understanding how ingredients and their interactions drive ratings, to optimizing a product subject to nonlinear constraints, and even reverse-engineering a formulation so that knowing the sensory or image profile can help determine what combination of formulation/process variables reproduce that subjective attribute profile (Moskowitz and Maier, 2007).

Effects of potassium sorbate on the shelf-life and sensory qualities of *bukayo* have been studied previously by Pascual (2017). *Bukayo* has not been studied before in terms of optimized production techniques. Hence, the objective of this study is to establish an optimal *bukayo* formulation by varying the amount of young coconut meat, *sinakob*, and coconut juice using a Box-Behnken design.

2. Materials and methods

2.1 Materials preparation

Young coconut meat (grated), coconut juice (5.5° Brix), and *sinakob* (made from concentrated sugarcane juice) were purchased from the local market of Bayambang, Pangasinan. All materials except for *sinakob* came from the same batch. The preferred nut in processing *bukayo* is between 9 to 10 months old (PNS, 2017).

2.2 Box-Behnken design

Table 1. Variables and levels used in the Box-Behnken design.

Variable	Level		
	Low (-1)	Central (0)	High (+)
Independent variables			
Young coconut meat	250	375	500
<i>Sinakob</i> (sugar)	250	375	500
Coconut Juice	250	375	500
Dependent variable			
Overall Acceptability			

A randomized Box-Behnken experimental design to establish the optimum experimental formulation of *bukayo* was implemented using Minitab Statistical Software Release 17 (Minitab Inc, State College, PA, USA). A Box-Behnken with three factors such as young coconut meat, *sinakob*, and coconut juice were selected to observe the effects on the overall acceptability of

bukayo (Table 1). The coconut meat ranged from 250 – 500 g, *sinakob* from 250 – 500 g, and coconut juice from 250 – 500 g. A total of fifteen experimental runs with three factors and three levels were conducted. The order of the experiments was randomized to avoid any bias. A full quadratic polynomial model was chosen as the best-fitted model to demonstrate the influence of the factor and their interactions on the response variable (Tan *et al.*, 2012; Liu *et al.*, 2016).

2.3 Bukayo preparation

All the ingredients were weighed on a digital scale (NKS-6, Timbangan, Philippines). Ingredients were poured into a wok and cooked with stirring at medium fire for 30 min. After cooking, the *bukayo* formulations were allowed to cool and stored for further analysis.

2.4 Sensory analysis

A nine-point hedonic test (1-dislike extremely, 2-dislike very much, 3-dislike moderately, 4-dislike slightly, 5-neither like nor dislike, 6-like slightly, 7-like moderately, 8-like very much, and 9-like extremely) was performed to measure overall consumer acceptability, color, taste, sweetness, and texture of the fifteen (15) formulations of *bukayo*. A total of 50 untrained panelists whose ages range from 18 to 60 were randomly chosen from the University Campus. The panelists were told how to evaluate the samples using the parameters in the method explained by Everitt (2009).

2.5 Validation of the optimized formulation

The overall consumer acceptability of the optimized *bukayo* formulation was validated through a nine-point hedonic test. Experimental overall consumer acceptability was compared with the predicted overall consumer acceptability using a student t-test at $p=0.05$.

2.6 Physical and chemical analyses of the preferred formulation

Proximate analyses of the fifteen *bukayo* formulations were determined in terms of percent moisture content (925.49 B), crude fat (920.177), crude protein (925.49 H), and water activity (978.18) using the methods used by the Association of Official Analytical Chemists (AOAC, 2016). Subtracting the sum of fat content, protein content, ash content, and moisture from 100 gave the total carbohydrate content (Onyeike *et al.*, 2000). Lightness (L^*), redness ($+a^*$), yellowness ($+b^*$), hue angle (h), and chroma (C^*) were measured against a High-Quality Portable Colorimeter (NR60CP, China).

2.7 Statistical analyses

The overall consumer acceptability response for the

fifteen *bukayo* formulations was used with response surface methodology (RSM) to optimize Box-Behnken design factors. The numerical optimizations, contour plots, and the model equation were generated in Minitab Statistical Software Release 17 (Minitab Inc, State College, PA, USA) (Dursun and Dalgıç, 2018). Correlation heatmap was generated using the R (version 3.2.4, released 2016) statistical package.

3. Results and discussion

3.1 Response surface regression analysis

The analysis of variance is essential to test the significance and adequacy of the model. Fisher's *F*-test value was used to ascertain the goodness-of-fit of the regression model. As shown in Table 2, the *F*-value obtained, 3.06, is less than the *F*-value (250.84 at 95% significance) obtained from the standard distribution table, confirming the adequacy of the model. The significance of each factor was determined by *p*-value. Results revealed that the quadratic term of coconut juice and *sinakob* significantly influenced the overall acceptability of *bukayo* ($p < 0.05$). Meanwhile, the linear term of coconut juice, *sinakob*, and young coconut meat, the quadratic term of young coconut meat and the interaction effects were not significant ($p > 0.05$).

The "Lack of Fit Test" compares the residual error to the pure error from replicated design points. The lack of fit *F*-value of 0.46 is not significant as the *p*-value is > 0.05 . The non-significance lack of fit suggested that the model was valid for the present study.

The resulting regression equation for the overall acceptability of *bukayo* was fitted as follows:

$$\begin{aligned} \text{Overall Acceptability} &= -52.3 + 0.0380 \text{ Young Coconut} + 0.1370 \text{ Sinakob} \\ &+ 0.1330 \text{ Coconut Juice} - \\ &0.000016 \text{ Young Coconut} * \text{Young Coconut} - 0.000160 \\ &\text{Sinakob} * \text{Sinakob} - \\ &0.000128 \text{ Coconut Juice} * \text{Coconut Juice} - \\ &0.000016 \text{ Young Coconut} * \text{Sinakob} - \\ &0.000048 \text{ Young Coconut} * \text{Coconut Juice} - \\ &0.000032 \text{ Sinakob} * \text{Coconut Juice} \end{aligned}$$

Data from the Box-Benken was substituted into the model to evaluate the validation of the model through the coefficient of determination (R^2), which represents the proportion that the model can explain for the variation in the responses. Models with R^2 values of ≥ 0.60 can be considered as a valid model (Gong et al., 2007). The R^2 of the model was 0.85 which indicated a good fit between predicted values and the experimental data points. In addition, this implied that 84.65% of the variations for overall acceptability of *bukayo* are

explained by the independent variables and this also suggested that the model does not explain only about 15.35% of the variation.

The overall acceptability was evaluated with four checkpoint batches. The results indicate that the measured sensory attributes were as expected. When measured sensory attributes were compared with predicted sensory attributes values using a student *t*-test, the differences were found to be insignificant ($p > 0.05$) indicating that the obtained mathematical equation is valid for predicting the overall acceptability of *bukayo*.

The relationship between the dependent and independent variables was further elucidated by constructing a contour plot. Three (3) 3D contour plots were generated from each response at the hold value of 375 (Figure 1). The contour plots of the overall acceptability of *bukayo* represented a response surface with a simple maximum, which suggests that the quality score increases as the color gets darker (Minitab, 2003). The darker regions identify higher *z*-values. The contour levels revealed a peak center in the vicinity of 350 – 500 g young coconut meat (Figure 1a), 300 – 400 g *sinakob* (Figure 1b), and 350 – 450 g coconut juice (Figure 1c). Overall acceptability scores in this peak region are greater than 7.

3.2 Response optimization

After studying the effect of the independent variables on the response, the levels of these variables that give the desired response for the *bukayo* formulation was determined. The optimization and individual desirability of the response variable were obtained by specifying the goal. In this case, the goal chosen was to maximize the response. The target value for the response was set based on the definition of the best quality example, maximum overall acceptability score. In maximizing a response, the individual desirability is one for all response values greater than or equal to that target maximum and it increases for response values less than the target (Minitab, 2003). If the goal is to target response, the desirability is one at the target and decreases the more the response deviates from the target in either direction (Minitab, 2003).

The desirability approach is an established tool for the optimization of design variables including single and multiple responses (Varala et al., 2016). The response optimizer function of the Minitab software was used to find the optimum combination of *bukayo* formulation variables that maximizes the responses simultaneously using desirability function. A maximum level of overall acceptability was set for maximum desirability.

The behavior of the predicted responses was

Table 2. Analysis of variance (ANOVA) for response surface quadratic model.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	45.48	5.05	3.06	0.16
Linear	3	6.75	2.25	1.36	0.36
Young Coconut	1	0.5	0.5	0.3	0.61
<i>Sinakob</i>	1	0.13	0.13	0.08	0.79
Coconut Juice	1	6.13	6.13	3.71	0.11
Square	3	35.23	11.74	7.12	0.03
Young Coconut*Young Coconut	1	0.23	0.23	0.14	0.72
<i>Sinakob</i> * <i>Sinakob</i>	1	23.08	23.08	13.99	0.01
Coconut Juice*Coconut Juice	1	14.77	14.77	8.95	0.03
2-Way Interaction	3	3.5	1.17	0.71	0.59
Young Coconut* <i>Sinakob</i>	1	0.25	0.25	0.15	0.71
Young Coconut*Coconut Juice	1	2.25	2.25	1.36	0.3
<i>Sinakob</i> *Coconut Juice	1	1	1	0.61	0.47
Error	5	8.25	1.65		
Lack-of-Fit	3	6.25	2.08	2.08	0.34
Pure Error	2	2	1		
Total	14	53.73			

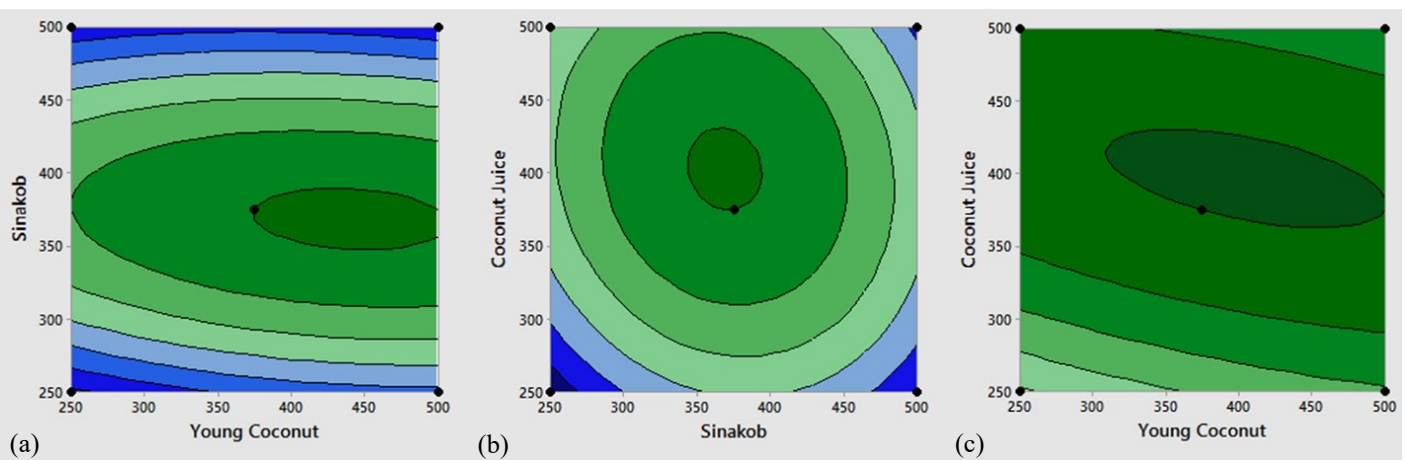


Figure 1. Effect of (a) young coconut meat and sinakob, (b) coconut juice and sinakob, (c) young coconut meat and coconut juice on the overall acceptability of *bukayo*.

generated from the optimized factors of 404.04 g young coconut meat, 368.69 g *sinakob*, and 398.81 g coconut juice, while the behavior of the actual responses which is predicted from a feasible experimental run at round figures of factor levels was also generated and compared. The goal for the response, the predicted response at current factor settings, y and the individual desirability, d , are given in the left column. The vertical and horizontal lines on the graph represent the current factor settings and response values. The composite desirability of these observed optimum factors was 0.87 (Figure 2a).

In order to make these factors feasible in experimental runs, these observed optimum parameters were drawn to the nearest round figures of 400 g young coconut meat, 370 g *sinakob*, and 400 g coconut juice. From these rounded figures of factors, the individual desirability obtained for overall acceptability was retained at 0.87 (Figure 2b).

The optimized formulation was reproduced to validate the results and found out that the predicted overall acceptability (7.11) (Figure 2b) was found to be very close to the experimental overall acceptability

(8.04) on a nine-point hedonic scale. A mean liking score of 7.00 or higher on a nine-point scale is usually indicative of highly acceptable sensory quality (Everitt, 2009); hence, the optimized *bukayo* in this study could be used confidently as a good illustration of target quality.

3.3 Comparison of the sensory and physicochemical characteristics of the *bukayo* formulation

Listening to the voice of the consumers is important to realize the commercial production of a food product. In addition, this voice should be supported by instrumental analysis parameters. Correlations among physicochemical and sensory traits of *bukayo* were visualized through a heat map (Figure 3). Correlation coefficients were classified as weak ($r \leq 0.35$), moderate ($r = 0.36-0.67$), and strong ($r = 0.68-1.00$) (Taylor, 1990). All the sensory parameters were positive and strongly correlated. Water activity and crude protein were positive and moderately correlated with the overall acceptability; i.e. overall acceptability increased as water activity and crude protein increased. Interestingly, all the colorimeter values (L^* , $+a^*$, $+b^*$, C , h) were positive

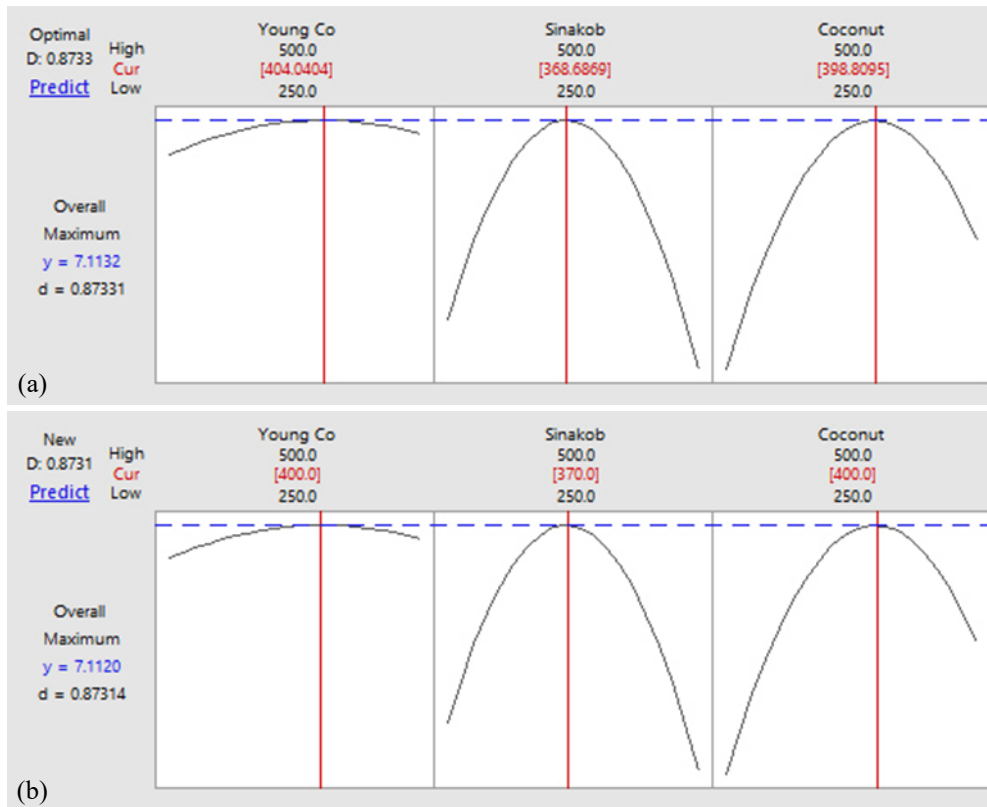


Figure 2. Response behavior of overall acceptability from (a) the observed optimum condition and (b) feasible experimental condition.

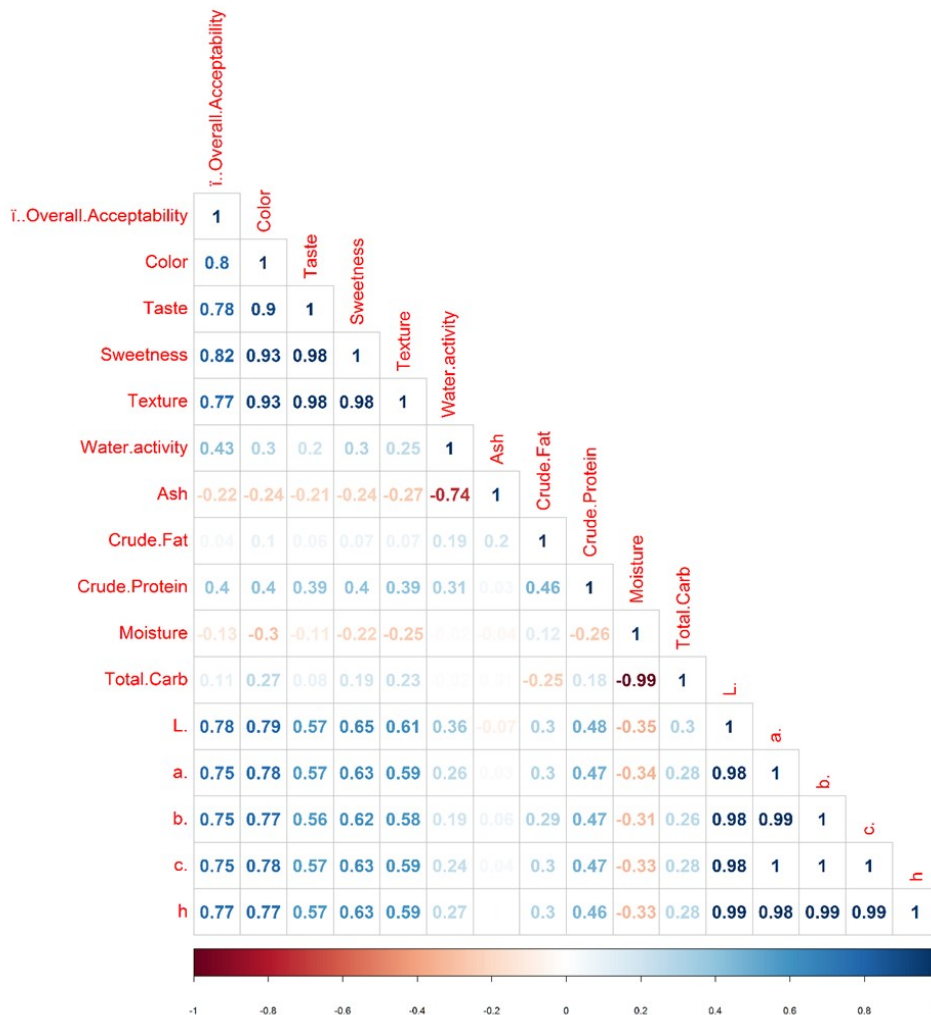


Figure 3. Heat map showing Pearson's correlation coefficients among the physicochemical and sensory characteristics of bukayo.

and strongly correlated with overall acceptability. This indicates that colorimeter values have direct impacts on the quality of the final product and therefore, the quality of the *bukayo* could be regulated by controlling these properties.

4. Conclusion

A three-level Box-Behnken design was applied for modeling and optimizing of *bukayo* and three factors were defined as the variables: young coconut meat, *sinakob*, and coconut juice. Overall acceptability was defined as the response. Some conclusions have been drawn as follows: The *F*-values for the overall acceptability model was significant and that for “lack-of-fit” was non-significant ($p < 0.05$), thereby confirming the validity of the model. Also, this model adequately explained the variation of the response with satisfactory R^2 value, which indicated that 84.65% of the variations could be well explained by the model. By using the Box-Behnken design of the experiment, the optimal process formulations of *bukayo* were 400 g young coconut meat, 370 g *sinakob*, and 400 g coconut juice. This was selected to give a maximum overall acceptability score. Colorimeter values were positive and moderate to strongly correlated with the sensory parameters, hence, colorimetry can be used in the production of highly acceptable *bukayo*. This research can serve as a reference in terms of the optimization of native delicacies, investigating the effects of each process factor.

Conflict of Interest

All authors declare that there is no conflict of interest regarding the publication of this paper.

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