

Optimization of banana bar formulation to provide a nourishing snack for toddlers using response surface methodology

Achmat SARIFUDIN¹ , Nok AFIFAH¹ , Novita INDRIANTI¹ , Dewi DESNILASARI¹ ,
Dita KRISTANTI¹, Lia RATNAWATI¹, Riyanti EKAFITRI¹ 

Abstract

The development of banana-based snack bars that fulfill the nutritional requirement for toddlers is required. In this study, we analyzed the effects of different concentrations of banana puree, banana flour and potato starch on the characteristics of inulin, dietary fiber, protein, and potassium as well as the hardness of banana bars using response surface methodology. In total, 14 experimental models were generated using a simplex lattice design. Results demonstrated that the quadratic model appeared to be the best fitting model for assessing dietary fiber and hardness response of banana bars; meanwhile, the linear model was found to be the best fitting model for assessing protein and potassium response, and the special cubic model was best fitted for assessing inulin response. Results of the optimization process suggested that banana bars prepared using 20% banana puree, 20.50% banana flour and 9.50% potato starch was the best solution for this combination of variables, with a desirability value of 0.923.

Keywords: banana; dietary fiber; inulin; nourishing snack; potassium; toddler.

Practical Application: The optimization nourishing banana bar formula in snack production.

1 Introduction

Toddlers include children aged 1–5 years. Within these ages, complete nutrition fulfillment is critical to assure the optimal growth in their next life phase. The important nutrition for toddler development is a protein. During this period, toddler also needs micronutrients such as oligosaccharides, fiber, and minerals particularly calcium and potassium. This nutrition can be fulfilled by the consumption of nourish foods. The lack of nutrition could be owing to the intake of nutrients that cannot be digested properly in the gut. The absorption of nutrients in the gut is closely associated with the balance of intestinal microflora (Roberfroid et al., 2010; Scheid et al., 2013). Prebiotics are nondigestible food ingredients that have beneficial effects on the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon, thereby improving the health of the host (Abed et al., 2016).

Banana (*Musa spp.*) is one of the world's most important crops. About 15 million tons are exported every year, thereby making bananas the fifth most important agricultural product for in global trade after cereals, sugar, coffee and cocoa. Around 80% of these exports are from the Latin Americas (Maselkowski & Olenius, 2014). In 2019, global banana exports reached a record high of 10.2 million tons, increases of 5% compared to 2018 (Food and Agriculture Organization, 2020). Banana (*Musa spp.*) cultivated in Indonesia; it is easily available and has high economic, cultural and nutritional values. Banana production in Indonesia reached around 7.3 million tons (Badan Pusat Statistik, 2019).

Bananas contain inulin compounds that act as natural prebiotics. Megala & Hymavathi (2018), state the uses of inulin

and FOS such as acting as bifidogenic agents, stimulating the immune system, decreasing the levels of pathogenic bacteria's in the intestine, relieving constipation, decreasing the risk of osteoporosis, reducing the risk of atherosclerosis etc. Bananas also present high content of dietary fiber (DF), resistant starch, phenolic compounds, minerals, carotenoids, flavonoids, and amine compounds (Borges et al., 2020; Khoozani et al., 2019). According Müller et al. (2018) fiber is considered in the formulation of the functional food, due to its beneficial health effects in gut regulation, satiety, appetite control, glycemic regulation, and cancer prevention. Dietary fiber, maintains a healthy intestine and decreases the time spent by waste material in the gastrointestinal tract (Adeola & Ohizua, 2018). The inulin content of bananas is 0.3-0.7 g/100 g and that of banana flour is 0.9-2.0 g/100 g (Desnilasari & Lestari, 2014). Flour prepared from unripe bananas contains approximately 73.4% total starch content, with the resistant starch (RS) content and dietary fiber content being 17.5% and 14.5%, respectively.

Due to banana benefit, banana flour has been proposed as ingredient for breads (Pragati & Ravish, 2014), cookies (Agama-Acevedo et al., 2012) and food bar (Ekafitri et al., 2013, Lucas et al., 2020). Ekafitri et al. (2013) reported that banana flour can be used as a raw material for preparing food bar in combination with banana puree to improve the functional properties of food bars. Snack bars/ food bar considered as ready-to-eat food and are increasingly present in the diet of children (Lucas et al., 2020). Food bars are a type of biscuits in

Received 04 Mar., 2020

Accepted 01 Jun., 2020

¹Research Center for Appropriate Technology-Indonesian Institute of Sciences, Subang, West Java, Indonesia

*Corresponding author: dewi.desnilasari@gmail.com

the form of solid rod-shaped foods that are generally consumed by toddlers between meals (Ekafitri et al., 2013). Food bar made from banana can supply nutritional requirements as well as health benefits from inulin and FOS, dietary fiber and it can be served as good functional food bar for people of all age groups especially for toddlers. Therefore develop banana bar as functional product for toddlers need to be evaluated.

Furthermore, texture is an important parameter that contributes to overall product quality and acceptance of biscuits (Park et al., 2015). Starch is widely used as an ingredient in the manufacture of non-grain products to improve texture, appearance and stability (Horstmann et al., 2016). One type of starch that can be utilized for this purpose is potato starch. Potato starch contains 24.95% amylose (Mishra & Rai, 2006) and dietary fiber at a concentration of 1.3 g/100 g (Dhingra et al., 2012). On the basis of the above-described information, this study was conducted to investigate the potential of banana puree–banana flour–potato starch blends in the manufacture of food bars base on dietary fiber, inulin, potassium and texture using response surface methodology.

2 Materials and methods

2.1 Materials

The study materials included modified unpeeled banana flour ('Kepok' banana, *Musa acuminata*) and banana puree ('Ambon' banana, *Musa paradisiaca*) that were obtained from the local market (Subang, Indonesia). Other ingredients such as potato starch (Mr. Food), sugar (granulated cane, Gulaku), egg, milk powder, margarine (Forvita), emulsifier, baking powder (Koepoe-Koepoe) and salt were also purchased from a local supermarket (Subang, Indonesia).

2.2 Methods

Banana bar preparation

The ingredients used for preparing the banana bar included a mixture of banana puree, modified banana flour (made by ourselves)

and potato starch (Mr. Foods), which were optimized according to an experimental design with a maximum of 50% of recipe dough (Table 1). The other ingredients were 40 g sugar (granulated cane, Gulaku), 80 g egg (whole, fresh), 32 g milk powder (Dancow), 40 g margarine (Forvita), 4 g emulsifier (Koepoe Koepoe, expired date 17 December 2023), 3.6 g baking powder (Koepoe Koepoe expired date 17 December 2023) and 0.4 g salt (Kapal). Egg, sugar and emulsifier were mixed using an electric mixer at high speed until the mixture expanded. Milk powder was added and stirred until homogenous using a mixer (Phillips Mixer with Stand HR1559/40, Indonesia) at low speed. Banana puree was added and stirred until homogenous. Banana flour, potato starch, baking powder and salt were mixed thoroughly, added to the mixture and stirred until mixed well. Melted margarine was added to the mixture and mixed together to form dough. Portions of 300 g of the dough were then poured into an oiled baking dish (30 × 10 cm) and baked at 140°C for 30 min. The resulting cake was cut to size 2 × 10 cm and then baked again at 90°C for 2 h. Sample was stored in an aluminium foil bag for the further analysis.

Determination of inulin content

Inulin content was measured by high-performance liquid chromatography (HPLC) Agilent 1260 Infinity II (Agilent USA, Santa Clara) using an Agilent Hi-plex H (7.7 × 300 mm) column. The operating conditions were as follows: flow rate 0.6 ml/min, column temperature 60°C, refractive index detector and sample injection volume 10 µl. De-ionized water was used as a mobile phase was detected using water. Inulin extraction was performed according to the method described by Bekers et al. (2007) with some modification. Extracts were obtained by adding 10 ml of water to 0.1 g of samples. The slurry was placed in a sonicator for 30 min. The samples were centrifuged at 12,000 × g for 20 min. The resulting supernatant was filtered through a 0.2 µm membrane filter for HPLC analysis.

Determination of total dietary fiber (TDF) content

Total dietary fiber (TDF) content of the banana bar was determined using a combination of enzymatic and gravimetric

Table 1. Mixture components of the banana bar.

Formulations	Variable levels			Real levels (%)		
	Banana puree (A)	Modified banana flour (B)	Potato starch (C)	Banana puree	Modified banana flour	Potato starch
1	0.50	0.50	1.00	15	20	15
2	1.00	0.00	1.00	20	15	15
3	1.00	1.00	0.00	20	25	5
4	1.00	0.50	0.50	20	20	10
5	0.50	1.00	0.50	15	25	10
6	0.00	1.00	1.00	10	25	15
7	0.67	0.67	0.67	16.67	21.67	11.67
8	0.83	0.83	0.33	18.33	23.33	8.33
9	0.83	0.33	0.83	18.33	18.33	13.33
10	0.50	0.50	1.00	15	20	15
11	1.00	0.00	1.00	29	15	15
12	0.00	1.00	1.00	10	25	15
13	0.33	0.83	0.83	13.33	23.33	13.33
14	1.00	1.00	0.00	20	25	5

methods (Association of Official Analytical Chemistry, 2007). Weigh duplicate 0.5 g samples into 400 ml tall-form beaker. Add 45 ml buffer solution pH 8.2 (MES-TRIS) stirred until homogeneous. Add 50 μ L α -amylase and incubate at 95-100 °C for 35 min in the shaker water bath. Cool solution to 60°C and rinse with 10 ml distilled water. Add 100 μ L protease (Merck) and incubate at 60 °C, 30 min. Adjust pH at 4.5 (4.1-4.6) using 0.561 N HCl, add 200 μ L amyloglucosidase (Merck) and incubate at 60 °C, 30 min. Let precipitate using 225 ml 95% ethanol preheated to 60°C at room temperature for 1 h. Filter using ash crucible filter paper no.42. Wash residue successively with two 15 ml portions of ethanol 78%, ethanol 95% and acetone. Dry in 70 °C vacuum oven or 105°C air oven. Cool in desiccator and weigh to nearest 0.1 mg or until constant weight. Analyze residue from one sample of set of duplicates for protein by Kjeldahl Method. Another duplicate was incinerate at 525 °C, 3 h. Cool in desiccator and weigh to nearest 0.1 mg or until constant weight. TDF was calculated using Equation 1 as follows:

$$TDF(\%) = \left[\frac{\text{weight residue} - \text{weight protein} - \text{weight ash}}{\text{weight sample}} \right] \times 100 \quad (1)$$

Determination of protein content

Protein content of the banana bar was analysed using a DuMaster protein analyser (DuMaster D-480, Buchi, Switzerland).

Determination of potassium content

Potassium content was measured by atomic absorption spectrophotometer (AAS, GBC 933 AA, Australia). Samples for AAS were prepared by using dry ash method. Samples were ashed in a muffle furnace at 450 oC for 3 h. The ash was dissolved with 5 ml of 6 N HCl then evaporated to about 1.0 ml on a hot plate. The solution was filtered using an ash-less filter paper, then it was diluted with distillate water to 50 ml and mixed thoroughly. The stock standard solution was made by dissolving potassium chloride/KCl (1.907 g) with distilled water using a 1000 ml volumetric flask. The standards were made by serial dilution. Air and acetylene were used as fuel for flame atomization of AAS. The potassium was detected at wavelength of 766.5 nm.

Textural properties of banana bar

Textural properties of the banana bar were analyzed in terms of hardness using a TA.XTPlus texture analyzer (Stable Micro System, Surrey, UK). A three-point bending rig (type HDP/3PB) was used to cut the samples after placement on base beams that were 4 cm apart. Compression strengths of the samples were measured under the following conditions: test mode, compression; test speed, 3 mm/s; target mode distance; distance, 5 mm.

Experimental design and statistical analysis

Statistical analysis and modelling of response variables were conducted using the Stat Ease Design Expert 7.0.0 software package (trial version). The simplex lattice design with a three-component mixture (banana puree (A), banana flour (B) and potato starch (C)),

in which the sum of the component proportions was equal to 50% (A + B + C = 50%), was used in this study. The optimum combinations of the components in the banana bar formulation were determined to produce the most acceptable product with the maximum acceptable chemical and textural properties.

The minimum and maximum limit levels of each component were initially investigated by conducting a preliminary study based on the acceptability of the banana bar texture. It was observed that the upper limit levels of banana puree, banana flour and potato starch were 20%, 25% and 15%, respectively; meanwhile, the lower limit levels of these components were 10%, 15% and 5%, respectively. This level was submitted in the Stat Ease Design Expert 7.0.0 and the result was the 14 formula that was shown in Table 1.

In this mixture design, the three components were evaluated by varying their levels (proportions) simultaneously and maintaining the total level (proportions) constant at 50%. The experimental design required 14 combinations of mixture components; the experimental design in terms of the actual levels is presented in Table 1. The physicochemical properties of the banana bar, such as inulin, dietary fiber, protein, potassium and hardness, were selected as the response variables.

Multiple regression analysis was used to generate polynomial models for the response variables. The best fitting model was verified according to the model significance, lack of fit and multiple correlation coefficients (R^2). The significance of each term was determined using an analysis of variance (ANOVA) with a level of significance of 95%. An effective solution was evaluated using a multiple response method termed as desirability value (Myers & Montgomery, 1995).

3 Result and discussion

3.1 Fitting for the best model

The effects of the three-component mixture (banana puree, banana flour and potato starch) on the contents of inulin, dietary fiber, protein and potassium and the hardness of the banana bar are shown in Table 2. ANOVAs were performed to determine the lack of fit and the significance of the model and the interaction effects of the independent variables on the dependent variables. The parameter used to select the model was based on nonsignificant lack of fit and the highest coefficient of determination (R^2). According to a previous study, the determination coefficient should be at least 80% to obtain a good fit model (Joglekar & May, 1987). However, Malcolmson et al. (1993) stated that an R^2 value of 80% is better for a preliminary study and mentioned that an R^2 value of 60% can also be used. Therefore, models with R^2 values >60% were used for prediction in this study.

The constant coefficients are shown in Table 2, and the equations for each of the response variables could be derived from the predicted values of each response variable. The linear model (Equation 2) was found to be the best fitted for evaluating the protein and potassium response of the banana bar; meanwhile, the quadratic model (Equation 3) appeared to be the best fitting model for assessing the dietary fiber and hardness response.

Table 2. The fitting model of the banana bar.

Coefficients	Response variables				
	Inulin (%)	Dietary fiber (%)	Protein (%)	Potassium (ppm)	Hardness (gf)
The model	Special cubic	Quadratic	Linear	Linear	Quadratic
Significance of the model (p)	0.0300 ^s	0.0324 ^s	0.0003 ^s	0.0009 ^s	0.0003 ^s
Lack of fit of the model	0.8709 ^{ns}	0.7640 ^{ns}	0.9399 ^{ns}	0.9800 ^{ns}	0.1613 ^{ns}
R-squared (R^2)	0.8033	0.7322	0.7665	0.7180	0.9213
Adj R-squared (Adj R^2)	0.6347	0.5469	0.7240	0.6667	0.8721
β_1	3.5331	1.1545	0.1634	6.0807	858.3675
β_2	1.8869	0.4265	0.1386	8.9861	-437.9938
β_3	4.4816	-2.6181	0.0713	2.2999	-256.7448
β_{12}	-0.2115	-0.0497	-	-	-6.32169
β_{13}	-0.3579	0.0446	-	-	-37.0601
β_{23}	-0.2505	0.0916	-	-	41.3821
β_{123}	0.0143	-	-	-	-

β_1 , β_2 and β_3 are the constant coefficients corresponding to the effects of banana puree, banana flour and potato starch, β_{12} is coefficient interaction banana puree and banana flour, β_{13} is coefficient interaction banana puree and potato starch, β_{23} is coefficient interaction banana flour and potato starch, and β_{123} is coefficient interaction banana puree, banana flour, and potato starch, respectively, in the model; ns: nonsignificant and s: significant at the 5% level ($p < 0.05$).

For assessing the inulin response, the special cubic model (Equation 4) was found to be the best fitting model.

$$Y = \beta_1 A + \beta_2 B + \beta_3 C \quad (2)$$

$$Y = \beta_1 A + \beta_2 B + \beta_3 C + \beta_{12} AB + \beta_{13} AC + \beta_{23} BC \quad (3)$$

$$Y = \beta_1 A + \beta_2 B + \beta_3 C + \beta_{12} AB + \beta_{13} AC + \beta_{23} BC + \beta_{123} ABC \quad (4)$$

where Y is the dependent variable (response variable); β_1 , β_2 , β_3 , β_{12} , β_{13} , β_{23} and β_{123} are the constant coefficients for each linear and interaction term in the predicted models; A, B and C are the levels (proportions) of each pseudo-component (banana puree, banana flour and potato starch, respectively). The R^2 values of all response variables were found to always exceed 60%, indicating an adequate proportion of variability as explained by the data. The results of ANOVA showed that all response variables were significantly ($p < 0.05$) influenced by the linear terms of the predicted models.

3.2 Effects of the three-component mixture on the physicochemical properties of the banana bar

The effects of the different amounts of banana puree, banana flour and potato starch on the physicochemical properties of the banana bar are presented in Table 2, according to the regression coefficient of the linear and second-order polynomials. To aid visualization, the contour plots for these response variables are depicted in Figure 1.

3.3 Inulin response of the banana bar

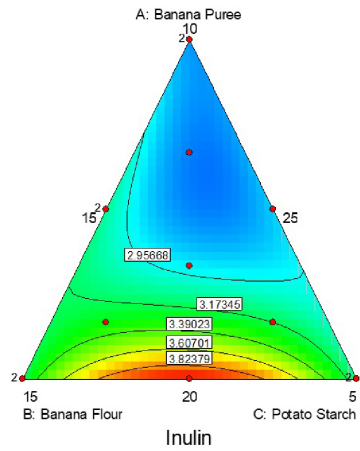
The inulin response is well fitted to the special cubic model with the determination coefficient ($R^2 = 80.33\%$). All components demonstrated positive contribution in increasing the inulin content of the banana bar; meanwhile, the interaction between the components exerted a negative influence. Analysis of the response surfaces (Figure 1a) suggested that a combination of a high banana puree concentration (20%) and moderate banana

flour and potato starch concentration (20% and 10%, respectively) produced banana bars with a higher inulin content.

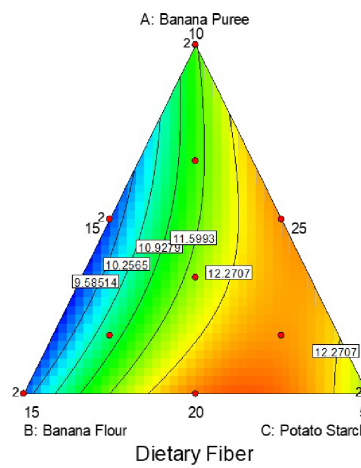
The inulin contents of banana puree, banana flour and potato starch were 0.30%, 0.28% and 0.10%, respectively. Similarly, an earlier study reported that *Nendran* banana puree had an inulin content of 1.02% (Shalini et. al, 2017). Inulin content in the banana bar varied from 2.57% to 4.10% Dry Matter. This content fulfils the requirement of inulin intake per day. Inulin and oligo fructose have been more frequently investigated in weaning foods consumed by toddlers. Multiple positive effects have also been reported, especially clinical effects that suggest an improved immune response, as indicated by a lower incidence of febrile episodes. Inulin and oligo fructose are bifidogenic and decrease the number of some pathogens. A study conducted by Saavedra and Tschernia performed in 1999 first reported the effect of oligo fructose (up to 3 g/d) in weaning foods consumed by toddlers attending daycare. It was observed that these otherwise healthy toddlers had softer stools, less emesis, regurgitation and perceived discomfort and, interestingly, fewer fever episodes. A similar recent analysis in toddlers attending daycare and taking 2 g/d oligo fructose for 3 weeks confirmed a protective effect against fever. These toddlers also had fewer infectious episodes requiring antibiotic treatment, fewer episodes of diarrhea and emesis and less flatulence. Fecal microbial analysis confirmed the suspected bifidogenic effect during supplementation (Veereman, 2007).

3.4 Dietary fiber content of the banana bar

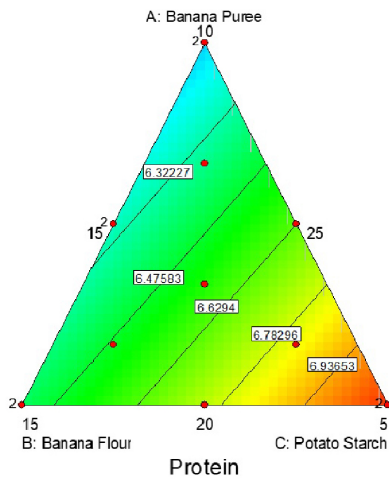
The quadratic model was obtained for assessing the dietary fiber content of the banana bar with a coefficient of determination (R^2) of 73.22%. The constant coefficients of the component indicated that the quantity of banana puree was the most dominant among the response variables, followed by banana flour (Table 2). In the contour plot of the dietary fiber response (Figure 1b), the highest values were found in the vertex and toward the edge of potato starch (C), whereas the lowest scores were found at the edge of banana puree (A). This result



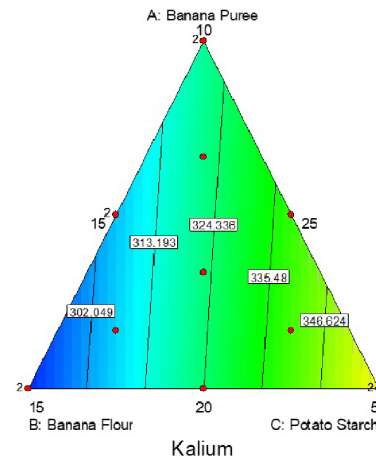
a) Inulin (%)



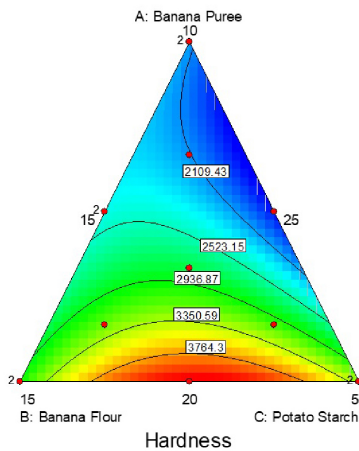
b) Dietary Fiber (%)



c) Protein (%)



d) Potassium (g/100g)



e) Hardness (gf)

Figure 1. Surface contour plots of the effects of processing components (A: banana puree; B: banana flour; C: potato starch) on the physicochemical properties of the banana bar: (a) inulin, (b) dietary fiber, (c) protein, (d) potassium and (e) hardness.

indicated that using banana puree or flour in the banana bar recipe increased the dietary fiber content of the final product.

The dietary fiber content of the banana bar varied from 9.10% to 13.29%. The banana bar prepared using 15% banana puree, 25% banana flour and 10% potato starch had the highest dietary fiber content, whereas the lowest content was obtained by blending these ingredients at concentrations of 20%, 15% and 15%, respectively. Ripe banana and unpeeled banana flour have dietary fiber contents of 36.9%-49.7% Dry Matter (Emaga et al., 2007) and 15.52% Dry Matter (Bezerra et al., 2013), respectively.

It is known that dietary fiber intake affects the entire gastrointestinal tract from the mouth to the anus (Ötles & Ozgoz, 2014). Constipation negatively correlates with dietary fiber consumption, including childhood constipation. The baseline fiber intake of children (aged 3–17 years) was found to be 2 g/d. Increasing their fiber intake to 17 g/d could decrease the use of laxatives among children with severe developmental disabilities (Tse et al., 2000).

3.5 Protein content of the banana bar

According to Table 2, the protein value response is well fitted to the linear model. This model was able to explain 76.65% of all variance in the data. All components increased the protein content of the banana bar, among which banana puree and banana flour had a higher effect than potato starch. The contour plot (Figure 1c) demonstrated that the protein score was higher at the points closest to potato starch vertex, indicating that the use of banana puree and banana flour in the food bar formulation resulted in a higher protein content than that obtained using potato starch.

Proteins are vital to support tissue repair, growth and protection. The mean protein contents of the banana bar varied from 6.11% to 7.07% (Dry Matter). The highest protein content was obtained with blends of 20% banana puree, 25% banana flour and 5% potato starch, whereas the lowest protein content was produced from blends of 10% banana puree, 25% banana flour and 15% potato starch. This result is in close agreement with those of (Ho et al., 2016) (6.36% Dry Matter) and (Parn et al., 2015) who formulated fruit-based functional snack bars (2.22%-4.06%). In general, the protein content of a product depends on its composite material. However, the protein contents of ripe banana, unpeeled banana flour and potato starch were 7.9%–11% Dry Matter (Emaga et al., 2007), 4.33% Dry Matter (Bezerra et al., 2013) and 0.45% Dry Matter (Nadir et al., 2015), respectively.

3.6 Potassium content of the banana bar

Results of the statistical analysis indicated that the linear model significantly predicted the potassium content of the banana bar ($p < 0.05$). This model was able to explain approximately 71.80% of the observed variations and did not present a significant lack of fit ($p = 0.98$). As shown in Table 2, the potassium content of the sample showed a positive correlation with all the components, and banana puree appeared to be the most influencing among the response variables, followed by banana flour and potato starch. Higher potassium values were observed in the vertex of potato starch (C) and to some extent in the potato starch–banana puree

(AC) edge (Figure 1d). The potassium content of the banana bar decreased when the potato starch (C) concentration was increased and the banana puree–banana flour concentration was decreased in the sample recipe.

The potassium contents of all banana bars varied from 271.19 to 315.93 mg/100 g. The highest content was obtained when the banana bar was processed using 20% banana puree, 25% banana flour and 5% potato starch and the lowest potassium content was obtained when 20% banana puree, 15% banana flour and 15% potato starch were blended. The resulting high potassium content may have been contributed by the high potassium contents of ripe banana (385 mg/100 g) and unripe banana (460 mg/100 g) (Anyasi et al., 2013) and potato starch (413.91 mg/100 g) (Rahman et al., 2015). Potassium functions as an important electrolyte in the nervous system and also plays a role in osmoregulation.

3.7 Hardness of the banana bar

The R^2 value of the predicted model for assessing the hardness response was >0.90 , indicating that the quadratic model was relatively fit for the prediction purpose as shown in Table 2. Potato starch and banana flour had a negative effect on the hardness of the sample, whereas banana puree was the most dominant component that increased this response. However, the interaction between banana puree–banana flour (AB) and banana puree–potato starch (AC) had a negative influence on the hardness value of banana bar samples (Table 2). In the contour plot of the hardness response (Figure 1e), the hardness of the banana bar increased toward the banana flour edge (B) where the lowest scores were found at the vertex of banana puree (A) and to some extent in the potato starch–banana puree (AC) edge. It could be stated that the addition of banana puree to the recipe increased the hardness of the final product, whereas addition of potato starch and banana flour decreased the hardness.

The hardness of the sample ranged from 1808 to 4182 gf. The banana bar prepared using 15% banana puree, 25% banana flour and 10% potato starch had the lowest hardness value. The hardness of commercial snack bar is 3936.39 gf, while the hardness of snack bar from modified sweet potato flour in previous study ranged between 1861.03–2275.16 gf (Sunyoto et al., 2019). In other previous research, the hardness of biscuits that prepared by the incorporation of sorghum and spirulina flours ranged between 1545.14 and 2298.14 gf (Chandra et al., 2015). Bolarinwa & Muhammad (2019) reported that the addition of potato starch to germinated brown rice flour decreased the hardness of the cookies. This is because starch can function as a hydrocolloid where it can bind with water and retain the moisture in the cookies. Cookies prepared with a higher concentration of protein flour had a harder structure because of the strong binding of starch and protein (Park et al., 2015).

3.8 Optimization of the basic formulation and verification of the model

The final objective of this study was to develop a banana bar that can improve the gastrointestinal function of toddlers. Hence, during the numerical optimization, the inulin and dietary

fiber responses were maximized, whereas other responses and material components were fixed in a range. The responses of inulin and dietary fiber values were assigned in the high relative importance of '5.' This was due to the fact that the inulin and dietary fiber contents of food are the most important attributes that influence in improving the gastrointestinal function of humans. The relative importance given to protein, potassium and hardness of the banana bar was '3.' Results of the optimization suggested that the banana bar prepared using 20% banana puree, 20.50% banana flour and 9.50% potato starch showed the best solution for this combination of variables with a desirability value of 0.923.

This recipe was used to produce banana bars, and all the response variables of the final product were analyzed. The predicted response values were compared with the experimental values of each response using the equations of the model. The predicted response values were inulin 4.89% Dry Matter, dietary fiber 12.86% Dry Matter, protein 6.78% Dry Matter, potassium 326.72 g/100g, and hardness 4123 gf. The experimental response values were inulin 4.16% Dry Matter, dietary fiber 12.14% Dry Matter, protein 5.80% Dry Matter, potassium 338.72 g/100g, and hardness 3805 gf. The response values of the experimental and predicted data were within the range of confidence interval and prediction interval. This indicated that the model can be used to optimize the basic formulation of food based on the mixture of banana and potato.

4 Conclusion

The simplex lattice mixture design approach was successfully used to obtain the best combination of banana puree, banana flour and potato starch to produce the banana bar. A combination of banana puree (20.0% w/w), banana flour (20.50% w/w) and potato starch (9.50% w/w) resulted in an optimum banana bar formulation. The optimum formulation had a desirability value of 0.923. This formulation could provide a nourishing snack for toddlers, including inulin content (4.16%), dietary fiber content (12.14%), protein content (5.80%), potassium content (338.72 g/100 g) and hardness (3805 gf).

Acknowledgements

All authors contributed equally in this research. This research was funded by the Ministry of Research, Technology and Higher Education of the Republic of Indonesia (INSINAS 2019). The author thanks to the Research Center for Appropriate Technology-Indonesian Institute of Sciences for the facilities to conduct this research.

References

- Abed, S. M., Ali, A. H., Noman, A., Niazi, S., Ammar, A.-F., & Bakry, A. M. (2016). Inulin as prebiotics and its applications in food industry and human health; a review. *International Journal of Agriculture Innovation and Research*, 5(1), 88-97. https://www.researchgate.net/publication/318900116_Inulin_as_Prebiotics_and_its_Applications_in_Food_Industry_and_Human_Health_A_Review
- Adeola, A. A., & Ohizua, E. R. (2018). Physical, chemical, and sensory properties of biscuits prepared from flour blends of unripe cooking banana, pigeon pea, and sweet potato. *Food Science and Nutrition*, 6(3), 532-540. <https://doi.org/10.1002/fsn.3.590>.
- Agama-Acevedo, E., Islas-Hernández, J. J., Pacheco-Vargas, G., Osorio-Díaz, P., & Bello-Pérez, L. A. (2012). Starch digestibility and glycemic index of cookies partially substituted with unripe banana flour. *LWT - Food Science and Technology*, 46(1), 177-182. <http://dx.doi.org/10.1016/j.lwt.2011.10.010>.
- Anyasi, T. A., Jideani, A. I. O., & Mchau, G. R. A. (2013). Functional properties and postharvest utilization of commercial and noncommercial banana cultivars. *Comprehensive Reviews in Food Science and Food Safety*, 12(5), 509-522. <http://dx.doi.org/10.1111/1541-4337.12025>.
- Association of Official Analytical Chemistry-AOAC (2007). *Official Methods of Analysis* (18th ed.). Gaithersburg: AOAC International.
- Badan Pusat Statistik – BPS. (2019). *Produksi tanaman buah pisang dari 2016-2018*. Jakarta: BPS.
- Bekers, M., Bekers, M., Grube, M., Upite, D., Kaminska, E., Linde, R., Scherbaka, R., & Danilevich, A. (2007). Carbohydrates in Jerusalem artichoke powder suspension. *Nutrition & Food Science*, 37(1), 42-49. <http://dx.doi.org/10.1108/00346650710726940>.
- Bezerra, C. V., Rodrigues, A. M. C., Amante, E. R., & Silva, L. H. M. (2013). Nutritional potential of green banana flour obtained by drying in spouted bed. *Revista Brasileira de Fruticultura*, 35(4), 1140-1146. <http://dx.doi.org/10.1590/S0100-29452013000400025>.
- Bolarinwa, I. F., & Muhammad, K. (2019). Functional properties, antioxidant activities and storage stability of cookies from germinated brown rice and rice-potato starch composite flour. *Pertanika Journal of Tropical Agricultural Science*, 42(2), 503-518.
- Borges, C. V., Maraschin, M., Coelho, D. S., Leonel, M., Gomez, H. A. G., Belin, M. A. F., Diamante, M. S., Amorim, E. P., Gianeti, T., Castro, G. R., & Lima, G. P. P. (2020). Nutritional value and antioxidant compounds during the ripening and after domestic cooking of bananas and plantains. *Food Research International*, 132, 109061. <http://dx.doi.org/10.1016/j.foodres.2020.109061>. PMID:32331671.
- Chandra, S., Singh, S., & Kumari, D. (2015). Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. *Journal of Food Science and Technology*, 52(6), 3681-3688. <http://dx.doi.org/10.1007/s13197-014-1427-2>. PMID:26028751.
- Desnilasari, D., & Lestari, N. P. A. (2014). Formulasi minuman sinbiotik dengan penambahan puree pisang ambon (*Musa paradisiaca* var *sapiantum*) dan inulin menggunakan inokulum *Lactobacillus casei*. *agriTECH*, 34(3), 257-265. <https://doi.org/10.22146/agritech.9453>.
- Dhingra, D., Michael, M., Rajput, H., & Patil, R. T. (2012). Dietary fibre in foods: a review. *Journal of Food Science and Technology*, 49(3), 255-266. <http://dx.doi.org/10.1007/s13197-011-0365-5>. PMID:23729846.
- Ekafitri, R., Sarifudin, A., & Surahman, D. N. (2013). Pengaruh penggunaan tepung dan puree pisang terhadap karakteristik mutu makanan padat berbasis-pisang. *Penelitian GIzi Dan Makanan*, 36(2), 127-134. <http://dx.doi.org/10.22435/pgm.v36i2.3998>. 127-134.
- Emaga, T. H., Andrianaivo, R. H., Wathélet, B., Tchango, J. T., & Paquot, M. (2007). Food chemistry effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. *Food Chemistry*, 103(2), 590-600. <http://dx.doi.org/10.1016/j.foodchem.2006.09.006>.
- Food and Agriculture Organization – FAO. (2020). *Banana market review: preliminary results 2019*. Rome: FAO.
- Ho, L. H., Tang, J. Y. H., Mazaitul Akma, S., Mohd Aiman, H., & Roslan, A. (2016). Development of novel "energy" snack bar by utilizing local Malaysian ingredients. *International Food Research Journal*, 23(5), 2280-2285.
- Horstmann, S. W., Belz, M., Heitmann, M., Zannini, E., & Arendt, E. (2016). Fundamental study on the impact of gluten-free starches

- on the quality of gluten-free model breads. *Foods*, 5(2), 30. <http://dx.doi.org/10.3390/foods5020030>. PMID:28231125.
- Joglekar, A. M., & May, A. T. (1987). Product excellence through experimental design. Food product and development: from concept to the marketplace. In American Association of Cereal Chemists – AACC. *Cereal food world* (pp. 211). Minnesota: AACC.
- Khoozani, A. A., Bekhit, A. E. D. A., & Birch, J. (2019). Effects of different drying conditions on the starch content, thermal properties and some of the physicochemical parameters of whole green banana flour. *International Journal of Biological Macromolecules*, 130, 938-946. <http://dx.doi.org/10.1016/j.ijbiomac.2019.03.010>. PMID:30844459.
- Lucas, B. F., Priscila, A., Carvalho, L. F., Morais, M. G., Santos, T. D., Alberto, J., & Costa, V. (2020). Snack bars enriched with Spirulina for schoolchildren nutrition. *Food Science and Technology*, 40(suppl. 1), 146-152. <https://doi.org/10.1590/fst.06719>.
- Malcolmson, L. J., Matsuo, R. R., & Balshaw, R. (1993). Textural optimization of spaghetti using response surface methodology : effects of drying temperature and durum protein level. *Cereal Chemistry*, 70(4), 417-423.
- Maselkowski, S., & Olenius, K. (2014). *Global governance issues in banana trade*. Finland: Hanken School of Economics.
- Megala, P., & Hymavathi, T. (2018). Inulin and fructooligosaccharides incorporated functional fruit bars. *World Academy of Science, Engineering and Technology*, 59, 393-398.
- Mishra, S., & Rai, T. (2006). Morphology and functional properties of corn, potato and tapioca starches. *Food Hydrocolloids*, 20(5), 557-566. <http://dx.doi.org/10.1016/j.foodhyd.2005.01.001>.
- Müller, M., Canfora, E. E., & Blaak, E. E. (2018). Gastrointestinal transit time, glucose homeostasis and metabolic health: modulation by dietary fibers. *Nutrients*, 10(3), 1-18. <http://dx.doi.org/10.3390/nu10030275>. PMID:29495569.
- Myers, R., & Montgomery, D. (1995). *Response surface methodology: process and product optimization using designed experiments*. New York: John Wiley & Sons, Inc.
- Nadir, A. S., Helmy, I., Nashed, M., Abdelmaguid, W., Abozeid, M., & Ramadan, M. (2015). Original Research Article Modification of Potato Starch by Some Different Physical Methods and Utilization in Cookies Production. *International Journal of Current Microbiology and Applied Sciences*, 4(10), 556-569.
- Ötles, S., & Ozgoz, S. (2014). Health effects of dietary fiber. *Acta Scientiarum Polonorum. Technologia Alimentaria*, 13(2), 191-202. <http://dx.doi.org/10.17306/J.AFS.2014.2.8>. PMID:24876314.
- Park, J., Choi, I., & Kim, Y. (2015). Cookies formulated from fresh okara using starch, soy flour and hydroxypropyl methylcellulose have high quality and nutritional value. *LWT - Food Science and Technology*, 63(1), 660-666. <http://dx.doi.org/10.1016/j.lwt.2015.03.110>.
- Parn, O. J., Bhat, R., Yeoh, T. K., & Al-Hassan, A. A. (2015). Development of novel fruit bars by utilizing date paste. *Food Bioscience*, 9, 20-27. <http://dx.doi.org/10.1016/j.fbio.2014.11.002>.
- Pragati, S. I. G., & Ravish, K. (2014). Comparative study of ripe and unripe banana flour during storage. *Journal of Food Processing & Technology*, 5(11), 1-6. <http://dx.doi.org/10.4172/2157-7110.1000384>.
- Rahman, M. A., Ali, M. A., Hasan, S. M. K., & Sarker, M. (2015). Effects of peeling methods on mineral content of potato and development of potato based biscuit. *International Journal of Nutrition and Food Sciences*, 4(6), 669. <http://dx.doi.org/10.11648/j.ijnfs.20150406.21>.
- Roberfroid, M., Gibson, G. R., Hoyles, L., McCartney, A. L., Rastall, R., Rowland, I., Wolvers, D., Watzl, B., Szajewska, H., Stahl, B., Guarner, F., Respondek, F., Whelan, K., Coxam, V., Davicco, M. J., Léotoing, L., Wittrant, Y., Delzenne, N. M., Cani, P. D., Neyrinck, A. M., & Meheust, A. (2010). Prebiotic effects: metabolic and health benefits. *British Journal of Nutrition*, 104(Suppl. 2), S1-S63. <http://dx.doi.org/10.1017/S0007114510003363>. PMID:20920376.
- Scheid, M. M. A., Moreno, Y. M. F., Maróstica, M. R. Jr., & Pastore, G. M. (2013). Effect of prebiotics on the health of the elderly. *Food Research International*, 53(1), 426-432. <http://dx.doi.org/10.1016/j.foodres.2013.04.003>.
- Shalini, R., Abinaya, G., Saranya, P., & Antony, U. (2017). Growth of selected probiotic bacterial strains with fructans from Nendran banana and garlic. *LWT - Food Science and Technology*, 83, 68-78. <http://dx.doi.org/10.1016/j.lwt.2017.03.059>.
- Sunyoto, M., Andoyo, R., & Masitoh, E. (2019). Characteristics of high protein snack bar made of modified sweet potato flour. In *IOP Conference Series: Earth and Environmental Science* (Vol. 347, pp. 422-427). Bristol: IOP Publishing Ltd. <http://dx.doi.org/10.1088/1755-1315/347/1/012064>.
- Tse, P. W., Leung, S. S., Chan, T., Sien, A., & Chan, A. K. (2000). Dietary fibre intake and constipation in children with severe developmental disabilities. *Journal of Paediatrics and Child Health*, 36(3), 236-239. <http://dx.doi.org/10.1046/j.1440-1754.2000.00498.x>. PMID:10849223.
- Veereman, G. (2007). Pediatric applications of inulin. *The Journal of Nutrition*, 137(11), 2585S-2589S. <http://dx.doi.org/10.1093/jn/137.11.2585S>. PMID:17951508.