Optimization of biscuit formula based on denaturated whey protein concentrate and sweet potato flour in some protein and mineral concentrations

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Abstract. Biscuits are one of the food products that have low moisture content so that they have the potential to have a long shelf life and are suitable for use as emergency food products. There are several ingredients to make biscuits. Ingredients such as sweet potato flour and denatured whey protein concentrate are useful to fulfill macro nutrient needs, especially carbohydrate and protein content. In order to fulfill micro nutrient needs, mineral mix is added to emergency food. The amount of ingredients that added in biscuit will affect final product’s characteristics. Therefore, this research aims to determine the formulation of the addition of protein and mineral concentration which provides the characteristics of biscuit emergency food according to the standard. Some of the ingredients that added to the biscuit have their own characteristics which will affect the final results of the product. Hence, this research has hypothesis that the addition of mineral mix and denatured whey protein concentrate with optimal concentration can produces biscuit formulations that are accordance with the standard. In this research, Response Surface Method was employed to optimize response. The independent variable is the addition of denatured whey protein concentrate concentrations of 10%–15% and mineral mix concentrations of 2%–3.5%. The dependent variable is moisture content. The result of this experiment is protein and mineral with several concentration will not affected moisture content of biscuits.

1. Introduction

Indonesia is a country that has high potential for natural disasters. Natural disasters that occur will cause problems, especially the difficulty of getting proper food. The difficulty of getting a proper food will lead to a food crisis. It will impact on the nutritional availability of people in these disaster areas and will cause nutritional crisis [1]. Emergency food can be the solution of this case. Biscuits are one of the food products that have low moisture content so that they have the potential to have a long shelf life and are suitable for use as emergency food products. One of the emergency food requirements is adequate nutrition. In providing adequate nutrition, the addition of sweet potato flour is added to increase the carbohydrate content of the biscuits. The use of sweet potato flour as a complement to the macro needs of biscuits is because sweet potato flour has a high carbohydrate content. Sweet potato flour can be used as a substitute for staple food because it is an efficient source of calories [2].

As for fulfilling other macro needs, the addition of ingredients that have high protein content is carried out. In this research, the addition of denatured whey protein concentrate is used as an ingredient
that will add sufficient protein to the biscuits. Whey protein concentrate is whey obtained by separating processes such as precipitation, filtration, or dialysis [3]. Whey protein concentrate has a protein content (total solid) with a range of 34% to 85% [4]. Based on the research, denatured whey protein concentrate contains 52.28% protein. Protein will fulfilling macro needs, but also affect the palatability of the biscuits produced. The more protein added, the texture of a food will increase, so it will reduce the palatability of the product. This is because of the basic nature of the protein as forming the texture. The addition of minerals is expected to provide sufficient micro nutrients contained in biscuits. In addition, the addition of mineral is assumed to maintain the moisture content of the biscuits so that there is not much physical change and can extend the shelf life. The higher the concentration of humectant added, the moisture content of the product will be more stable because at high concentration the humectant will bind the water more strong [5].

In an effort to further adjust emergency food standards and have high palatability, modifications to the addition of protein and minerals assumed can affect the moisture content of the biscuits. The formulation was designed by Design Expert 10.0.1 to produce a combination of optimal protein and mineral concentration formulations for the response in the form of moisture content. The formulation design with the Design Expert 10.0.1 program begins with the determination of the independent factors in the form of protein and mineral concentrations and determines the minimum and maximum limits of the proteins and minerals used, then continues to determine the response.

2. Materials and methods

2.1. Materials

The main material used in this research were denaturated whey protein concentrate, mineral mix, and ingredients of biscuits included wheat flour, sweet potato flour, sugar, skim milk powder, baking powder, and chocolate powder. The equipment used in this research oven for moisture content analysis.

2.2. Response surface modelling (RSM)

This research was employed RSM and software of Design Expert (10.0.1) to optimized formulation of biscuit based on denaturated whey protein concentrate and sweet potato flour. Protein and mineral concentrate is used to be a factors in this research and applied in the software. The range of 2 factors were determined based on literature studied. Based on standard, protein minimum in emergency food is 10 g/100 g [3], and maximum protein in emergency food is 15 g/100 g [6]. Emergency foods made from full fat milk, sugar, vegetable oil, and peanut butter, 1.6% mineral mixtures are added [7]. Food products such as food aid in the form of biscuits were fortified with vitamin and minerals must have a maximum ash content of 3.5 g/100 g [3]. Based on literature studied, the ranges of protein concentration is 10–15% and mineral concentration is 1.6–3.5%. Design Expert program used Central Composite Design experimental plan. The plan mad 13 experiments with 5 central points (table 1). The response is moisture content and it determined with thermogravimetry method.

2.3. Preparation of biscuit

Biscuits are dry food products made by baking dough containing basic ingredients of flour, fat or oil, with or without additional other food ingredients that are permitted. The additional ingredients that can be used include eggs, sugar, margarine, shortening, and emulsifiers [8]. Biscuit were prepared with different amount of denaturated whey protein concentrate and mineral mix. Butter and sugar were mixed at high speed for 10 minutes. Then added skim milk powder and egg yolks in the mixture, then mixed at low speed for 5 minutes. The ingredients such as whey protein concentrate powder, mineral mix, sweet potato flour, wheat flour, chocolate powder, and baking powder are mixed into the mixture and stirred until all the ingredients blended. The dough then sheeted by rolling pin and shaped with cake mold. The biscuits then were baked at 180 °C for about 20 minutes in a baking oven.
2.4. Moisture content analysis
The sample of biscuit weighed for 2 grams and then put it into a constant cup. Then it heated in the oven at 103 °C for 3 hours. The sample cooled in the desiccator and weighed. After that, the sample is reheated in the oven for 30 minutes, then cooled it in the desiccator and weighed it again. The treatment is repeated until it reaches a constant weight. The sample has reached the constant weight if the weight constantly differences of less than 0.2 mg. Weight reduction is the amount of water in the material. Moisture content can be determined by using equation 1.

\[
\text{Moisture content (\%)} = \frac{\text{loss weight (g)}}{\text{sample weight after heated}} \times 100\%
\]  

(1)

3. Result and discussion
3.1. Model analysis
The protein and mineral concentration of biscuit based on whey protein concentrate and sweet potato flour were analyzed by using responses surface modelling in Design Expert 10.0.1 to inform the effect of those factors to moisture content in biscuit. The program will expose several formulations to predict the optimum protein and mineral concentration in biscuit and to analyze the interaction of 2 factors to moisture content as the response of this research. The program also analyzed the data and determine suitable models for the response. The result of the program analysis are the displayed in a fit summary.

Table 1. Experimental design and data of protein and mineral concentration to water content using RSM.

| Run | Protein (%) | Mineral (%) | Moisture Content (%) |
|-----|-------------|-------------|----------------------|
| 1   | 12.5        | 2.75        | 15.55                |
| 2   | 12.5        | 2.75        | 15.55                |
| 3   | 10.7322     | 3.28033     | 15.05                |
| 4   | 10.7322     | 2.21967     | 12.13                |
| 5   | 12.5        | 2.75        | 15.66                |
| 6   | 12.5        | 2.75        | 10.36                |
| 7   | 14.2678     | 3.28033     | 12.18                |
| 8   | 10          | 2.75        | 14.83                |
| 9   | 12.5        | 3.5         | 9.84                 |
| 10  | 15          | 2.75        | 12.93                |
| 11  | 12.5        | 2           | 12.11                |
| 12  | 12.5        | 2.75        | 10.13                |
| 13  | 14.2678     | 2.21967     | 14.43                |

Table 2. Model summary statistics.

| Source     | Sequential p-value | Lack of Fit p-value | Adjusted R-squared | Predicted R-squared | Suggested |
|------------|--------------------|---------------------|--------------------|---------------------|-----------|
| Mean       | <0.0001            |                     |                    |                     |           |
| Linear     | 0.7335             | 0.8832              | -0.1279            | -0.4135             |           |
| 2FI        | 0.4955             | 0.8617              | -0.1867            | -0.4292             |           |
| Quadratic  | 0.4454             | 0.9020              | -0.2109            | -0.5794             |           |
| Cubic      | 0.7569             | 0.8010              | -0.5165            | -0.6901             | Aliased   |
Table 3. Analysis of variance (ANOVA)’s model.

| Source     | Sum of Squares | df | Mean Square | F Value | p-value Prob > F |
|------------|----------------|----|-------------|---------|-----------------|
| Model      | 0.0000         | 0  |             |         |                 |
| Residual   | 55.23          | 12 | 4.60        | 4.60    | 0.05            |
| Lack of Fit| 20.95          | 8  | 2.62        | 0.31    | 0.9279          |
| Pure Error | 34.27          | 4  | 8.57        |         |                 |
| Cor Total  | 55.23          | 12 |             |         |                 |

Table 1 shows the combination of 2 factors variables based on Design Expert 10.0.1 with the responses. Based on table 2, selected model for this research is mean. Table 3 shown that the lack of fit value from this model is 0.9279. The result indicated that the responses has compatibility with the model. It shown from the lack of fit value from this model is greater than 0.05 with F-value of 0.31. The result of not significant lack of fit is indicated that the model is good with the response. The predicted R-squared value is -0.1736, therefor the program will suggested mean model. A negative predicted R-squared means that the overall mean gives a better prediction for moisture content response. Because the selected model for this research is mean, the responses of the moisture content produced is only based on mean value. It means that there is no effect of adding protein and mineral concentration to moisture content in biscuit. The equation for this research is:

\[ y = +12.99231 \]

Figure 1 shows the effect of adding protein and mineral with several concentration to moisture content in biscuit. The result of the graph is a straight-field, it indicated that the response has the same value or considered not significantly different from each formulation. The form of the graph can be caused because the chosen model is mean, so that the moisture content response value is considered the same in each combination, where in the graph does not indicate the effect of adding several protein and mineral concentration to the moisture content in biscuit.

3.2. Optimization model

To optimize the model, the program has to set the criteria of 2 factors and the response. Protein and mineral as factor is set as maximize, then moisture content as the response is set as in range. The program
exposed several formulation with difference concentration of protein and mineral, but the same value of response and desirability. The response in every solution formulation is 12.992 with its desirability is 1.000. It occurred because the chosen model in this research is mean, so the program assumed that diversity of combination will not affected the response. All the solutions assumed will give a same value to the response. It was explained from equation 1 that the moisture content of the biscuit with every formulation is 12.992 and will not be affected by protein and mineral concentration. The result indicated that adding protein and mineral concentration with difference concentration will not affect moisture content in biscuit.

The results do not show any difference in each formulation can be caused by the use of denatured whey protein concentrate. Denatured whey protein concentrate loses its functional properties as a texture. This case because denatured whey reorganized its structure because of heat [4]. The reorganized structure of protein will cause whey denatured and decreased its solubility. Native whey has a good solubility as its functional properties. The high solubility is caused by magnitude of the hydrophilic surface in a native state, so it does not cause clumping or precipitation in the food system [9]. This change in functional properties of denatured whey protein concentrate has a positive effect if it added to some product, because it can produce the product that do not has extreme changes in its characteristic. The influence of mineral to biscuit’s moisture content is the influence of KCl, which is the highest concentration in the mineral mix, is one type of salt group humectant. The humectant will retain water in the product.

3.3. Validation model

After optimization, validation is done to determine the accuracy of the recommendations produced by the program with the actual value. The results showed that the results of the validation using 12.810% protein and 2.924% minerals produced biscuits with a moisture content of 9.95% and 10.08%. The response resulted in a validity value of 76.61% and 77.58%. Validation results showed presentation numbers in the range. The results indicate that the model used is valid.

| Name               | Goal     | Lower limit | Upper limit | Importance |
|--------------------|----------|-------------|-------------|------------|
| Protein (%)        | Maximize | 10.7322     | 14.2678     | +++        |
| Mineral (%)        | Maximize | 2.21967     | 3.28033     | +++        |
| Moisture Content (%) | In range | 9.84       | 15.66       | +++        |

Table 5. Validation of RSM.

| Protein (%) | Mineral (%) | Moisture Content (%) | Validity (%) |
|-------------|-------------|----------------------|--------------|
| 12.810      | 2.924       | 9.95                 | 76.61        |
|             |             | 10.08                | 77.58        |

4. Conclusion

Based on the results using response surface model with Design Expert 10.01, it can be stated that the addition of different protein and mineral concentrations will not affect moisture content of the biscuits. The equation for this model is:

\[ y = +12.99 \]

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