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Formulation of Red Bean Meatballs as a Local Food Alternative: Increasing Protein and Fiber Using Design Expert D-Optimal

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ABSTRACT

Purpose of the study: The purpose of this study was to produce an optimal red bean-based meatball formula using the Design Expert D-Optimal method, with a focus on increasing protein and fiber content and reducing fat content to support food diversification based on local ingredients.

Methodology: The methodology of this study used red beans (Phaseolus vulgaris L.), Rose Brand cassava flour, and Segitiga Biru wheat flour. The tools included a Food Processor, digital scales, and texture analyzer. The analysis was carried out using the Kjeldahl method for protein, the Soxhlet method for fat, and Design Expert D-Optimal software was used for formula optimization.

Main Findings: The main results of this study indicate that the optimal formula for red bean-based meatballs consists of 52% red beans, 18% cassava starch, and 11% wheat flour. This formula has the highest protein content of 15.50%, crude fiber content of 2.84%, and a chewy texture that is preferred by panelists. The attributes of color, taste, and aroma achieved the best hedonic value in the organoleptic test.

Novelty/Originality of this study: The novelty of this research lies in the use of red beans as the main ingredient in making analog meatballs that are healthier, low in fat, and high in protein. In addition, the formula optimization method using Design Expert D-Optimal software provides a scientific approach to producing the best quality products, supporting local food diversification, and expanding the market potential of plant-based products in Indonesia.

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1. INTRODUCTION

Meatballs are one of the foods that are widely favored by Indonesian people because they have a distinctive and delicious taste. Meatballs are defined as products made from livestock meat mixed with starch and spices, with or without the addition of other food ingredients, and/or permitted food additives that are round or other shapes and cooked [1],[2]. Generally, meatballs are made from animal food ingredients such as beef, chicken or fish [3],[4]. The use of meat raw materials has a relatively expensive production price, especially beef [5]-[7]. Beef has a high saturated fatty acid content so it can increase the risk of heart disease and hypercholesterolemia [8]-[10]. Therefore, it is necessary to diversify food, one of which is making meatballs that are similar to beef meatballs but are not made from beef or can also be called analog meatballs.

Analog meatballs, or synthetic/imitation meatballs, are duplication products made from non-meat ingredients and serve as an alternative food product. These meatballs are ready to be consumed or processed and can help meet the protein needs of the Indonesian people [1],[11]. To make imitation meatballs that are high in protein and low in fat, nuts and cereals are usually used. The recommended beans are red beans [12]-[14]. Red beans are one type of legume that thrives in several regions in Indonesia [15]-[17]. Red beans are also called Phaseolus vulgaris L. Red beans are generally known by the public in making foods such as red bean pudding, red bean ice and red bean soup [18]-[20].

Red beans contain 60.01 g of carbohydrates; 23.58 g of protein; 0.83 g of fat and 24.9 g of crude fiber in every 100 red beans themselves is 3.22% -3.81%. g and the amino acid lysine as much as 1323 mg [21],[22]. While the level of dietary fiber in red beans also has benefits for the body such as strengthening the body's immunity, lowering blood cholesterol, and controlling blood glucose [23],[24]. Consuming red beans in sufficient quantities will supply the needs of the amino acids lysine and leucine in the body, according to recommendations from the Institute of Medicine's Food and Nutrition, one indicator of good quality protein is its leucine content of 76.16 mg per gram of protein [25]-[27].

The process of mixing ingredients in making meatballs affects the characteristics of the final product, including texture, taste, and nutritional content. Formula optimization is an important step to ensure that red bean-based meatballs have competitive quality with conventional meatball products [28]. For this reason, a scientific-based approach such as Design Expert D-Optimal can be used to determine the best formula [29]-[31]. Design Expert is software used to optimize formulas or processes through a statistical approach [32],[33]. The D-Optimal method allows researchers to design experiments efficiently, process data with high accuracy, and determine the combination of ingredients that produce the best response, such as protein, carbohydrate, crude fiber, and organoleptic attributes (color, taste, aroma, and texture) [34],[35].

Previous research focused on making analog patties based on beans and wheat flour, with analysis of the physical, chemical, and sensory content of the product, while the current research developed analog meatballs based on red beans using the formula optimization method through Design Expert with the D-Optimal approach. In previous research conducted by Novikasari et al., found that the highest water content in analog patties with a red bean base was 25.88% and the resulting fat content was 0.07% [36]. Previous studies have shown the potential of plant-based products as an alternative source of protein, but there is an imbalance in my previous studies where there has been no emphasis on increasing protein content and reducing fat in meatballs, as well as the use of technology to optimize formulas with high accuracy. So to fill this gap, this study was conducted with a focus on health, this study offers an alternative to meatballs that are healthier and based on local ingredients, which are important for food diversification and support the development of more nutritious products and can compete with conventional meatball products.

This study offers novelty by combining the use of red beans as the main ingredient and the use of the Design Expert method to produce meatballs that are not only healthy but also have a high desire value. This study also contributes to local food diversification, especially in the development of plant-based products that have broad market potential. The purpose of this study is to determine the optimal red bean-based meatball formula with the Design Expert program using the D-Optimal method. The purpose of this study is to produce an optimal formula for making red bean-based meatballs as determined by the Design Expert program using the D-Optimal method.

2. RESEARCH METHOD

2.1. Tools and Materials

The materials used in the process of making red bean meatballs are Koepoe-koepoe brand garlic powder, ice cubes, Kapal brand table salt, red beans (kidney beans) or cannellini beans obtained from plantations in the Rancaoray area, Bandung Regency, West Java, Maggi brand beef flavored flavor enhancer, Sodium Triphosphate (STPP) obtained from the Kimia Mart store, Segitiga Biru brand wheat flour and Rose Brand cassava starch. The materials used for analysis in the study were Aquadest, 0.1% Methyl Red Indicator (MM), Phenolptalein Indicator (PP), HCl, Starch, H2SO4, Na2S2O4, 95% Ethanol, Potassium Iodide, H3BO3, Luff Schorl. The tools used in the process of making red bean meatballs were Food Processor, Stove, Pan, Knife, Spoon, Cutting Board, Digital Scale, and Container. The tools used for analysis in the study were, Burette, Cup, Excictor, Filler, Clamp, Round-bottomed flask, Erlenmayer flask, Kjeldahl flask, Analytical Balance, Oven, Upright Cooler, Crucible Clamp, Pipette of the Same Size, Dropper Pipette, Pipette of the Same Size, and Stand.

2.2. Research methods

The research method to be carried out is divided into two stages, namely preliminary research and main research. The preliminary research to be carried out is divided into 2 stages, namely the first stage determines the formulation to be formulated in the design expert mixture d-optimal method with organoleptic test responses (Hedonic Test) and the second stage analyzes the raw materials to be used, namely Red Beans (Kidney Bean) with protein content responses, crude fiber content and carbohydrate content.

Table 1. Red bean-based meatball formulation (preliminary research to determine the basic formulation)

Formula 1		Formula 2		Formula 3		Formula 4	
Ingredients	(%)	Ingredients	(%)	Ingredients	(%)	Ingredients	(%)
Garlic Powder	0.25%	Garlic Powder	0.25%	Garlic Powder	0.25%	Garlic Powder	0.25%
Ice	15.00%	Ice	15.00%	Ice	15.00%	Ice	15.00%
Salt	1.00%	Salt	1.00%	Salt	1.00%	Salt	1.00%
Red Beans	50.00%	Red Beans	50.00%	Red Beans	50.00%	Red Beans	50.00%
Flavor Enhancer	0.25%	Flavor Enhancer	0.25%	Flavor Enhancer	0.25%	Flavor Enhancer	0.25%
Sodium Triphosphate (STPP)	2.50%	Sodium Triphosphate (STPP)	2.50%	Sodium Triphosphate (STPP)	2.50%	Sodium Triphosphate (STPP)	2.50%
Sago Flour	20.00%	Cassava Starch	20.00%	Corn Starch	11.00%	Corn Starch	11.00%
Wheat Flour	11.00%	Wheat Flour	11.00%	Cassava Starch	20.00%	Sago Flour	20.00%
Total	100.00%	Total	100.00%	Total	100.00%	Total	100.00%

In this study, the raw material components included in the fixed variables are garlic powder, salt, flavoring, sodium triphosphate (STPP) and ice cubes. Variables that change will be included in the formulation design settings because their values change in each formulation. In this study, the raw material components included in the variable variables are Cassava Starch, Wheat Flour and Kidney Beans with the number of variable changes of 81.00% of the total ingredients as seen from the remaining number of fixed variables, which can be seen in Table 2.

Table 2. Fixed and Variable Ingredients in Percentage Composition

No	Ingredients	Category	Percentage (%)
1	Salt	Fixed Ingredient	1.00%
2	Flavor Enhancer	Fixed Ingredient	0.25%
3	Ice	Fixed Ingredient	15.00%
4	Garlic Powder	Fixed Ingredient	0.25%
5	Sodium Triphosphate (STPP)	Fixed Ingredient	2.50%
	Total Fixed Ingredients		19.00%
6	Red Beans (Kidney Bean)	Variable Ingredient	50.00%
7	Cassava Starch	Variable Ingredient	20.00%
8	Wheat Flour	Variable Ingredient	11.00%
	Total Variable Ingredients		81.00%
	Overall Total		100.00%

The main research is a continuation of the preliminary research which aims to find the optimization of the selected formula from the preliminary research using the Design Expert D-Optimal method with chemical response and organoleptic response. Determining the optimum formula consists of four stages, namely the formula planning stage, the formulation stage, the analysis stage, and the optimization stage. The main research procedure using the Design Expert D-Optimal method that will be carried out is as follows:

1. In the application of the design expert D-Optimal mixture method, each material that is determined to be a variable that changes in the preliminary research is entered.
2. In the low and high columns, the limits of the variable that changes are entered based on the results of the Analysis

3. The number of responses to be analyzed in one desired unit is entered, for example in the form of % (percent) entered in the Name and Units columns. Continued in the next process by pressing the Continue button

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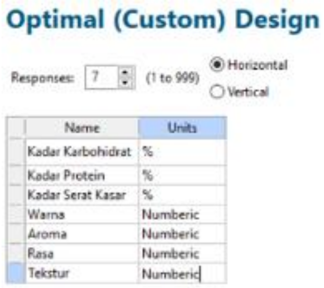
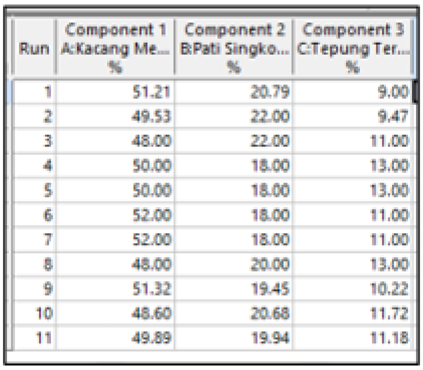


Figure 1. Stage 3 Optimization of Design Expert Program D-Optimal Mixture Method

4. From the results of the data input described in the steps above, a total of X formulas are produced (e.g.: 11 formulations) with Y variables (e.g. 3 variables, namely Kidney Beans, Cassava Starch, Wheat Flour).



Run	Component 1 A:Kacang Me... %	Component 2 B:Pati Singko... %	Component 3 C:Tepung Ter... %
1	51.21	20.79	9.00
2	49.53	22.00	9.47
3	48.00	22.00	11.00
4	50.00	18.00	13.00
5	50.00	18.00	13.00
6	52.00	18.00	11.00
7	52.00	18.00	11.00
8	48.00	20.00	13.00
9	51.32	19.45	10.22
10	48.60	20.68	11.72
11	49.89	19.94	11.18

Figure 2. Stage 4 Formula Design for Making Red Bean-Based Meatballs

5. The results of the analysis of carbohydrate content, protein content, crude fiber content and organoleptic with color, taste and aroma attributes are entered in an empty table.

Table 3. Red Bean Based Meatball Formula (%)

Formula	Kidney Bean (%)	Cassava Starch (%)	Wheat Flour (%)	Salt (%)	Flavor Enhancer (%)	Ice (%)	Sodium Tripolyphosphate (STPP) (%)	Garlic Powder (%)	Total (%)
1	51.21	20.79	9.00	1.00	0.25	15.00	2.50	0.25	100
2	49.83	20.92	9.00	1.00	0.25	15.00	2.50	0.25	100
3	48.00	21.00	10.00	1.00	0.25	15.00	2.50	0.25	100
4	50.00	18.00	10.00	1.00	0.25	15.00	5.00	0.25	100
5	50.00	18.00	10.00	1.00	0.25	15.00	5.00	0.25	100
6	52.00	18.00	10.00	1.00	0.25	15.00	3.50	0.25	100
7	48.00	20.92	10.00	1.00	0.25	15.00	2.50	0.25	100
8	51.32	20.00	10.00	1.00	0.25	15.00	2.50	0.25	100
9	48.00	20.68	11.72	1.00	0.25	15.00	2.50	0.25	100
10	48.60	20.64	11.72	1.00	0.25	15.00	2.50	0.25	100
11	49.89	19.94	11.11	1.00	0.25	15.00	2.50	0.25	100

Table 4. Red Bean-Based Meatball Formula

Formula	Kidney Bean (Red Bean)	Cassava Starch	Wheat Flour	Salt	Flavor Enhancer	Ice	Sodium Triphosphate (STPP)	Garlic Powder	Total (g)
1	2564.5	1039.5	450	50	12.5	125	750	12.5	5000
2	2446.5	1100	473.5	50	12.5	750	125	12.5	5000
3	2400	1100	550	50	12.5	750	125	12.5	5000
4	2500	900	550	50	12.5	750	125	12.5	5000
5	2600	700	550	50	12.5	750	125	12.5	5000
6	2600	550	600	50	12.5	750	125	12.5	5000
7	2600	550	600	50	12.5	750	125	12.5	5000
8	2560	972.5	415	50	12.5	750	125	12.5	5000
9	2500	1100	450	50	12.5	750	125	12.5	5000
10	2500	1034	997	50	12.5	750	125	12.5	5000
11	2494.5	997	559	50	12.5	750	125	12.5	5000

2.3. Experimental Design

This study used a Completely Randomized Design (CRD) to evaluate the effect of 11 red bean-based meatball formulas on physical, chemical, and organoleptic characteristics. The independent variables in this study were differences in the composition of ingredients in each formula, consisting of variations in the amount of red beans, cassava starch, wheat flour, salt, flavoring, ice cubes, STPP, and garlic powder. The dependent variables included physical characteristics (texture and color), chemical (protein content, water content, fat content, and ash content), and organoleptic (taste, aroma, color, and texture). Meanwhile, the control variables included material quality standards, processing conditions such as temperature and time, and the tools used. Each formula was tested three times to ensure data reliability. Data analysis was performed using analysis of variance (ANOVA). If there was a significant difference, the Duncan Multiple Range Test (DMRT) was used to compare the treatments in detail. The hedonic scale criteria are presented in table 5 below

Table 5. Hedonic scale criteria

Scale	Parameter
1	Very Dislike
2	Do not like
3	Kinda Dislike
4	Kinda Like
5	Like
6	Really like

2.4. Research Procedures

This study began with the preparation of the necessary materials and tools. The main ingredients used include red beans, cassava starch, wheat flour, salt, flavoring, ice cubes, sodium triphosphate (STPP), and garlic powder. The red beans were soaked for 12 hours until they were soft, then boiled until cooked and pureed using a blender. All additional ingredients were weighed with high accuracy according to the specified formula. The equipment used in the study, such as meat grinders, blenders, analytical scales, drying ovens, and other laboratory test equipment, were sterilized and calibrated before use to ensure the accuracy and consistency of the results. After the ingredients were ready, the meatball making process began by mixing the pureed red beans with other additional ingredients, such as cassava starch, wheat flour, salt, flavoring, garlic powder, STPP, and ice cubes. This dough was kneaded using a meat grinder until all ingredients were evenly mixed. The dough was then formed into balls of uniform size, and the meatballs were boiled in boiling water until they floated, indicating that the meatballs were cooked. After that, the meatballs were cooled at room temperature and stored in a cold temperature (≤ 4°C) until ready to be tested.

Testing was carried out to evaluate the physical, chemical, and organoleptic characteristics of the meatballs. Physical tests included texture measurements using a texture analyzer to determine hardness and elasticity, and color measurements using a spectrophotometer to obtain L* (brightness), a* (redness), and b* (yellowness) values. Chemical tests included analysis of protein content using the Kjeldahl method, water content using the oven drying method, fat content using the Soxhlet method, and ash content through combustion in a furnace. In addition, organoleptic tests were carried out by involving 30-50 untrained panelists, who were asked to provide an assessment of the taste, aroma, color, and texture of the meatballs using a hedonic scale of 1-6 (1 = very dislike, 6 = very like).

The test results from each parameter were averaged and analyzed using statistical methods. Analysis of variance (ANOVA) was used to identify the significant effect of formula treatment on the results obtained. If there is a significant difference, further tests such as Duncan Multiple Range Test (DMRT) are carried out to determine the differences between treatments. The results of this study were interpreted to determine the best red bean-based meatball formula based on physical, chemical, and organoleptic characteristics.

3. RESULTS AND DISCUSSION

The results and discussion of this study are presented to analyze the effect of various red bean-based meatball formulas on the physical, chemical, and organoleptic characteristics of the product. The analysis was carried out based on data obtained from laboratory tests, including testing texture, color, protein content, water content, fat content, and ash content. In addition, the results of organoleptic tests involving untrained panelists were used to evaluate the level of consumer acceptance of the taste, aroma, color, and texture of the meatballs. The discussion focuses on significant differences between formulas and how the proportion of ingredients in each formula affects the overall quality of the meatballs. These results are expected to provide relevant information in the development of red bean-based meatball products as an alternative plant-based food.

3.1. Preliminary Research Results

The preliminary research conducted was the determination of the basic formula that could support the main research and the analysis of the raw materials used using the response of starch content, protein content, and fiber content. The basic formula was obtained from the results of trial and error with fixed variables, namely garlic powder, ice cubes, salt, flavoring, and Sodium Triphosphate (STPP). For variables that changed with the upper and lower limits, namely red beans 48.00% -52.00%, tapioca flour 18.00% -22.00%, and wheat flour 9.00% 13.00%. The selected formulation was carried out using a hedonic test as seen in Table 6.

Table 6. Selected formula using Hedonic Test

No	Ingredient Name	Percentage (%)
1	Red Kidney Beans	50.00%
2	Cassava Starch	20.00%
3	Wheat Flour	11.00%
4	Salt	1.00%
5	Flavor Enhancer	0.25%
6	Ice Cubes	15.00%
7	Sodium Triphosphate (STPP)	2.50%
8	Garlic Powder	0.25%

The selection of the selected formulation was carried out using a hedonic test with 30 panelists, so that the selected formula was the formula above.

Table 7. Results of Organoleptic Test Observations in Preliminary Tests

Formula	Attribute			
	Color	Flavor	Aroma	Texture
F1	4.30 (a)	4.13 (a)	4.21(a)	4.12 (ab)
F2	4.64 (b)	4.38 (a)	4.53(a)	4.70(b)
F3	4.22 (a)	4.07 (a)	4.19(a)	3.69(a)
F4	4.40 (a)	4.21 (a)	4.22(a)	4.26 (ab)

Based on table 7, it shows that the formula most preferred by the panelists is formula 2 with a composition of red beans, tapioca flour and wheat flour. Where the formula is preferred by the panelists because it has a chewy texture and a color that resembles meatballs in general. Furthermore, the results of the raw material analysis are displayed in table 8.

Table 8. Results of raw material analysis

Sample	Starch Content (%)	Protein Content (%)	Crude Fiber Content (%)
Red Beans	6.90	13.71	3.99

Based on the results of the analysis of starch content in table 8, it shows that the starch content contained in red beans is 6.90%. The carbohydrate content per 100 grams of red beans consists of 1.6% sugar, 2.7% dextrin, 35.2% starch, 8.4% pentose, 1.3% galactan and 0.7% pectin. The high carbohydrate content causes red beans to be a good source of energy of around 347 kcal per 100 grams. The difference in analysis results is due to the difference in the varieties of raw materials used, as well as the use of sample weights used during the analysis of carbohydrate content (starch). Starch is a glucose homopolymer with alpha-glycosidic bonds. Starch consists of two fractions that can be separated with hot water. The soluble fraction is called amylose and the insoluble fraction is called amylopectin. Amylose has a straight structure with alpha-(1.4)-D-glucose bonds, while amylopectin has branches with alpha-(1.4)-D-glucose bonds of 4-5% of the total weight.

Based on the results of protein analysis in table 8, it shows that the protein content contained in red beans is 13.71%. This is different from the research conducted by Sari who found that the protein content in red beans is 11.86% [37]. The difference in the results of this analysis is caused by the difference in the varieties of raw materials used and the method of protein analysis used. Protein is a food substance that is important for the body, because this substance functions as fuel in the body and also functions as a building and regulating substance. Determination of protein content using the Kjeldahl method is carried out based on the determination of nitrogen content, including other components containing nitrogen measured as protein nitrogen.

Based on the results of the crude fiber analysis in table 8, it shows that the fiber content contained in red beans is 3.99%. The crude fiber content in red beans is much higher than rice (0.2%), corn (1.65%), peanuts (1.4%). Crude fiber is the residue remaining from the hydrolysis of strong acids (H2SO4) and strong bases (NaOH). The results of crude fiber are used as an index of the presence of fiber in food ingredients, because generally in the results of crude fiber there are 0.2-0.5 parts of the amount of dietary fiber. Crude fiber levels that are too high are not good for digestion and can cause disruption of the digestive system, in contrast to dietary fiber which is actually the higher the food the better for the digestive process [38].

3.2. Main Research Results

This main research aims to find the optimal formula for the comparison between red beans, tapioca flour and wheat flour from the range of selected product formulations with the established formula. This study used a mixture design with the D-Optimal method. This design is used in research to see the effect of changes in component combinations to obtain a certain response so that it can produce an optimal formulation. The formula design with the Design Expert program begins with the determination of the raw material components used as fixed variables and changing variables and the total composition of the raw materials in the product. Based on the results of trial and error, the changing variables and the determination of the upper and lower limits in making red bean-based meatballs can be seen in table 9.

Table 9. Determination of upper and lower limits on the variable changes in red bean-based meatballs

No	Variables Changed	Lower Limit (%)	Upper Limit (%)
1.	Red Beans	48.00	52.00
2.	Cassava Starch	18.00	22.00
3.	Wheat Flour	9.00	13.00

Test variables/changing variables entered into the Design Expert program are red beans, tapioca flour and wheat flour with a total of 81.00% on the basis of the formula. Determining the upper and lower limits and entering chemical responses, as well as organoleptic responses. Based on the results of the Design Expert 13.0 program processing, 11 formulations were obtained which can be seen in Table 10.

Table 10. Recommended formulation of Design Expert Program

Formula	Variable Factors			Fixed Factors					Total (%)
	Red Bean (%)	Tapioca Flour (%)	Wheat Flour (%)	Garlic Powder (%)	Salt (%)	Ice (%)	Flavor Enhancer (%)	Sodium Triphosphate (STPP) (%)	
1	51.21	20.79	9.00	0.25	1.00	15.00	0.25	2.50	100
2	49.53	22.00	9.47	0.25	1.00	15.00	0.25	2.50	100
3	48.00	22.00	11.00	0.25	1.00	15.00	0.25	2.50	100
4	50.00	18.00	13.00	0.25	1.00	15.00	0.25	2.50	100
5	50.00	18.00	13.00	0.25	1.00	15.00	0.25	2.50	100
6	52.00	18.00	10.00	0.25	1.00	15.00	0.25	2.50	100
7	52.00	18.00	10.00	0.25	1.00	15.00	0.25	2.50	100
8	48.00	20.00	13.00	0.25	1.00	15.00	0.25	2.50	100
9	51.32	19.45	10.22	0.25	1.00	15.00	0.25	2.50	100
10	48.60	20.68	11.72	0.25	1.00	15.00	0.25	2.50	100
11	49.89	19.94	11.18	0.25	1.00	15.00	0.25	2.50	100

The formulation that has been recommended by the Design Expert Program is then made and analyzed in the form of chemical and organoleptic responses to obtain the best formulation that will be validated. The results of the analysis data for each response that has been entered into the program can be seen in table 11.

Table 11. Data Analysis Results in the Design Expert Program

Run	Component 1 A:Kacang Me... %	Component 2 B:Pati Singko... %	Component 3 C:Tepung Ter... %	Response 1 Kadar Protein %	Response 2 Kadar Serat K... %	Response 3 Kadar Karboh... %	Response 4 Warna Numeric	Response 5 Rasa Numeric	Response 6 Aroma Numeric	Response 7 Tekstur Numeric
1	51.21	20.79	9.00	14.13	1.84	18.59	4.3	4.47	4.37	4.27
2	49.53	22.00	9.47	12.38	1	15.24	4.4	4.17	4.2	4.03
3	48.00	22.00	11.00	11.56	0.93	13.05	4.5	3.97	4.1	3.6
4	50.00	18.00	13.00	13.13	1.49	17.43	4.23	4.4	4.3	4.23
5	50.00	18.00	13.00	13.31	1.5	17.46	4.17	4.42	4.37	4.27
6	52.00	18.00	11.00	15.5	2.84	19.48	4.1	4.67	4.57	4.63
7	52.00	18.00	11.00	15.44	2.78	19.88	4.07	4.63	4.53	4.6
8	48.00	20.00	13.00	11.06	0.91	12.95	4.57	3.87	4.03	3.5
9	51.32	19.45	10.22	14.44	1.95	19.08	4.27	4.57	4.4	4.5
10	48.60	20.68	11.72	11.88	0.96	13.92	4.47	4.03	4.17	3.67
11	49.89	19.94	11.18	12.88	1.46	15.88	4.33	4.2	4.27	4.13

Chemical response analysis includes analysis of carbohydrate content (starch), protein analysis, and analysis of crude fiber content. Starch is composed of amylose fractions (linear polysaccharides) and amylopectin (branched polysaccharides) in different ratios. Amylose is blue with iodine while amylopectin is red-violet. The determination of starch content is in principle by determining cupric oxide in solution before reacting with reducing sugar (blank) and after reacting with reducing sugar (sample) which is titrated using Na-Thiosulfate solution. In determining carbohydrate content, a reaction will occur where cupric oxide in the reagent releases iodine from KI salt in an equivalent amount. The following are the results of the carbohydrate content test (starch) that have been carried out on the 11 red bean-based meatball formulations, which can be seen in table 12.

Table 12. Results of Carbohydrate (Starch) Content Analysis of Red Bean-Based Meatballs

Formula	Carbohydrate (Starch) Content (%)
1	18,59
2	15,24
3	13,05
4	17,43
5	17,46
6	19,48
7	19,88
8	12,95
9	19,08
10	13,92
11	15,88

The polynomial model suggested by the Design Expert program for the analysis of the chemical response of the carbohydrate (starch) content test is linear. The ANOVA table shows that the F value of the model is 157.04 indicating that the significant model at level 2 which is marked by the P value prob>F "is <0.0001 less than 0.05. This shows that the combination of red beans, cassava starch and wheat flour provides a value on the response of carbohydrate (starch) levels that are significantly different or significant in the meatball formula. The F lack of fit value of 6.46 indicates that the lack of fit is not significant related to pure error. The lack of fit value that is not significant is a good sign because the model obtained is appropriate. The adjusted R^2 value for carbohydrate (starch) levels is 0.9690, with the predicted R^2 of 0.9529 with a difference of less than 0.2. The adeq precision value is 30.6187. Values greater than 4 indicate adequate signals. This model can be used to navigate the design space. The mathematical model equation for the analysis of chemical responses to starch content measurements is shown in the equation below.

Starch content score:

$$Y = 23{,}27\ A + 12{,}40\ B + 13{,}80\ C \quad \ldots(1)$$

Description:
A = Red Beans
B = Cassava Starch
C = Wheat Flour

The mathematical model equation above for carbohydrate (starch) content is a linear model, where the component that contributes the most to carbohydrate (starch) content is coefficient A (Red Beans). This is because the coefficient A (Red Beans) has the highest value, which is 23.27 when compared to other components. The more component A (Red Beans) is added, the higher the carbohydrate (starch) content in the product will be. The value that is considered to have an effect on the response is the one that has a plus (+) value, so from the equation above the other components are considered to have an effect on the response.

The graph of the normality of the internally studentized residuals of the carbohydrate (starch) content test results and the three-dimensional graph of the carbohydrate (starch) content test results obtained from the research results using the D-Optimal method can be seen in Figure 3.

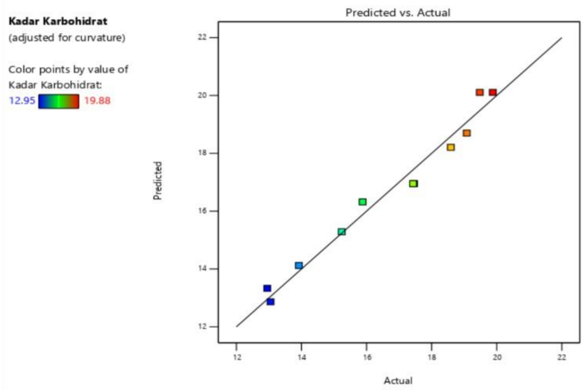


Figure 3. Graph of internally studentized residuals normality of carbohydrate (starch) content test results.

Based on Figure 3, it can be concluded that from the results of the analysis of 11 formulas, each point approaches the normal line, this shows that the model is in accordance with the assumptions of the ANOVA Design Expert program.

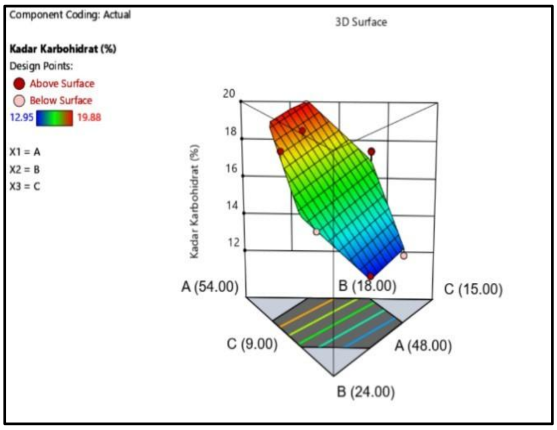


Figure 4. Three-Dimensional Graph of Carbohydrate (Starch) Content Test Results

Based on Figure 4, the three-dimensional graph of the interaction relationship between the components of the product contained in the raw materials can be seen from the color and surface. The blue color indicates the lowest carbohydrate (starch) content analysis results, while the red color indicates the highest carbohydrate (starch) content analysis results. The lowest carbohydrate (starch) content value is 12.95% with a combination of red bean formula of 48.00%, cassava starch of 20.00% and wheat flour of 13.00%. The highest carbohydrate (starch) content is 19.88% with a combination of red bean formula of 52.00%, cassava starch of 18.00% and wheat flour of 11.00%. Protein is an important food substance for the body because it functions as a building substance and a regulating substance and can also act as a source of energy.

Protein is composed of amino acids containing the main elements C, H, O and N. Protein is a polymer compound composed of amino acids as its monomers [39]-[41]. Amino acids are compounds that have ≥ 1 carboxyl group (-COOH) and ≥ 1 amino group (-NH2), one of which is located on the C atom next to the carboxyl group. The following are the results of the protein content test that has been carried out on the 11 red bean-based meatball formulations, can be seen in table 13. Chemical response analysis of protein content testing from 11 meatball formulations obtained protein content values of 11.06% -15.50%. The lowest protein content value is shown in formula 8 while the highest protein content value is shown in formula 6. The average value for protein content analysis is 13.25 with a standard deviation of 0.1437. Formulas 4 and 5 have a difference of 0.18% while formulas 6 and 7 have a protein content difference of 0.06%.

Table 13. Results of protein content analysis of red bean-based meatballs

Formula	Protein Content (%)
1	14,13
2	12.38
3	11.56
4	13,13
5	13.31
6	15.50
7	15.44
8	11.06
9	14.44
10	11.88
11	12.88

Of the 11 formulations, the protein content in the red bean meatball product produced is in accordance with the quality requirements of the combination meat meatball regulated by SNI 2014, which is a minimum of 8.00% (b/b). This red bean meatball product contains the lowest protein of 11.06% and the highest is 15.50%. The polynomial model suggested by the design expert program for the analysis of chemical responses to protein content testing is quadratic. The ANOVA table shows that the F value of the model is 216.83 at the 5% level, the P value is <0.0001, so "prob> F" or P is less than 0.05. This shows that the combination of red beans, cassava starch and wheat flour provides a value on the protein response that is significantly different in the meatball formula.

So that the value of the response can be used for the optimization process to obtain a product with optimum characteristics. The F lack of fit value of 3.16 indicates that the lack of fit is not significant related to pure error. The lack of fit value that is not significant is a good sign because the model obtained is appropriate. The adjusted R2 value is 0.9908 while the predicted R2 value is 0.9522, where the difference between the two values is less than 0.2. The adeq precision value is 40.7399, this value is greater than 4 which indicates that the signal is adequate. This model can be used to navigate the design space. The mathematical model equation for the analysis of protein content test responses can be seen below: Protein content score:

$$Y = 17{,}86\ A + 11{,}66\ B + 10{,}86\ C - 3{,}82\ AB - 0{,}0867\ AC + 0{,}2570\ BC \qquad ...(2)$$

Description:
A = Red Beans; B = Cassava Starch; C = Wheat Flour

The mathematical model equation above for protein content is a quadratic model, where the component that contributes the most to protein content is coefficient A (Red Beans). This is because coefficient A (Red Beans) has the highest value, which is 17.86 when compared to other components. The more component A (Red Beans) is added, the higher the protein content in the product will be. The values that are considered to have an effect on the response are those that have a plus (+) value in the model equation, so from the equation above, the components that have a negative (-) value are considered to have no effect on the response.

Based on the equation above, it can be concluded that components A (Red Beans), B (Cassava Starch), and C (Wheat Flour) have a significant effect on the protein content of the product. The interaction of components AB, AC, decreases the response value of protein content while the interaction BC increases the protein content in the product. The graph of the normality of the internally studentized residuals of the protein content test results and the three-dimensional graph of the protein content test results obtained from the research results using the D-Optimal method can be seen in Figure 5.

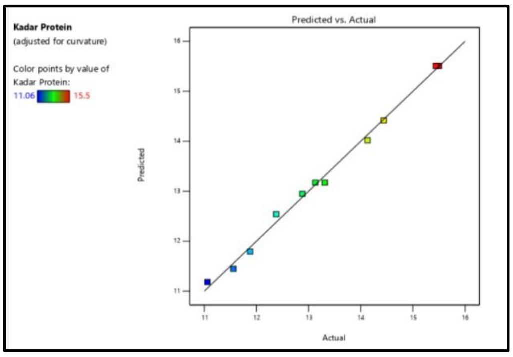


Figure 5. Graph of Internally Studentized Residuals Normality of the Results of the Content Test

Based on Figure 5, it can be concluded that from the results of the analysis of the 11 formulas, each point approaches the normal line, this shows that the model is in accordance with the assumptions of the ANOVA Design Expert program.

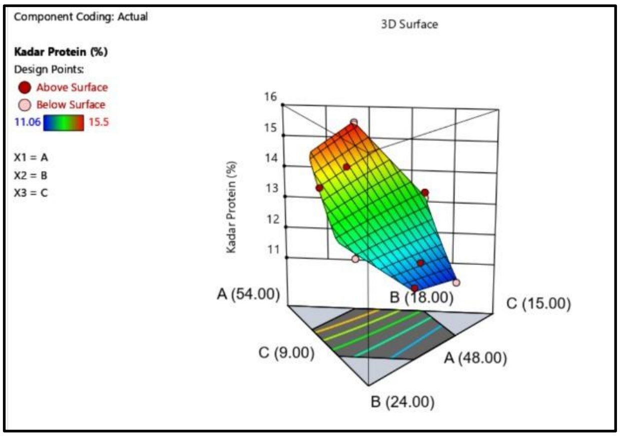


Figure 6. Three-Dimensional Graph of Protein Content Test Results

Based on Figure 6, the three-dimensional graph of the interaction between the components of the product contained in the raw materials can be seen from the color and surface. The blue color indicates the lowest protein content analysis results, while the red color indicates the highest protein content analysis results. The lowest protein content value is 11.06% with a combination of red bean formula of 48.00%, cassava starch of 20.00% and wheat flour of 13.00%. The highest protein content is 15.50% with a combination of red bean formula of 52.00%, cassava starch of 18.00% and wheat flour of 11.00%.

Crude fiber is a compound that cannot be enzymatically degraded so that it cannot be absorbed by the digestive organs of humans or animals. The crude fiber content in a food ingredient or product can be used as a parameter for the amount of dietary fiber content in it. The crude fiber content in a food ingredient can be used as an index of dietary fiber content because generally in crude fiber is found 0.2-0.5 parts of the amount of dietary fiber.

Analysis of crude fiber content is carried out through 2 steps, namely defating (removing fat using a fat solvent) and digestion (dissolving using acids and bases in a closed state at high temperatures). Fiber content that is too high is not good for digestion and can disrupt the digestive system, in contrast to dietary fiber which is actually the higher the better for the digestive process. The following are the results of the crude fiber content test that has been carried out on the 11 red bean meatball formulations, which can be seen in table 14. Analysis of the chemical response of the crude fiber content test of the 11 meatball formulations obtained a crude fiber content value of 0.91% - 2.84%.

The lowest value is shown by the 8th formulation while the highest value is shown by the 6th formulation. The average value for the results of the crude fiber content analysis is 1.61 with a standard deviation of 0.0894. In the same formulation, namely formulations 4 and 5, the difference in fiber content is 0.1% while in formulations 6 and 7 the difference in fiber content is 0.06%.

Table 14. Results of Crude Fiber Content Analysis of Red Bean-Based Meatballs

Formula	Crude Fiber Content (%)
1	1,84
2	1,00
3	0,93
4	1,49
5	1,50
6	2,84
7	2,78
8	0,91
9	1,95
10	0,96
11	1,46

The polynomial model suggested by the Design Expert program for the analysis of fiber content response is special quartic, but the statistical value in the Predicted R2 is not defined or does not meet the requirements so that it is necessary to adjust the model / change the model for the response of crude fiber content. For the model used in the response of crude fiber content becomes quadratic. The ANOVA table shows that the F value of the model is 120.34 indicating that the significant model at the 5% level indicated by the value of "prob> F" is <0.0001 less than 0.05.

This shows that the combination of red beans, cassava starch and wheat flour provides a significantly different or significant taste attribute value in the meatball formula. The F lack of fit value of 13.72, indicates that the lack of fit not significant value is related to pure error. The lack of fit not significant value is a good sign because the model is appropriate. The adjusted R2 value for testing fiber content is 0.9835 while the predicted R2 value is 0.9609 where the results of both differences are less than 0.2. Adeq precision value is 28.4700, this value is greater than 4 which means it shows adequate signal. This model can be used to navigate design space. The mathematical model equation for chemical response analysis of protein content testing can be seen below.
Crude fiber content score:

$$Y = 4{,}59\ A + 0{,}7832\ B + 0{,}7442\ C - 4{,}17\ AB - 2{,}35\ AC + 0{,}6788\ BC \quad ...(3)$$

Description:
A = Red Beans; B = Cassava Starch; C = Wheat Flour

The mathematical model equation above for crude fiber content is a quadratic model, where the component that contributes the most to crude fiber content is coefficient A (Red Beans). This is because coefficient A (Red Beans) has the highest value, which is 4.59 when compared to other components. The value that is considered to have an effect on the response is the one that has a plus (+) value in the model equation, so from the equation above, the component with a negative (-) value is considered to have no effect on the response.

Based on the equation above, it can be concluded that components A (Red Beans), B (Cassava Starch), and C (Wheat Flour) have a significant effect on the crude fiber content of the product. The interaction of components AB and AC decreases the response value of crude fiber content while BC increases the response value of crude fiber content. The graph of the normality of internally studentized residuals of the crude fiber content test results and the three-dimensional graph of the crude fiber content test results obtained from the research results using the D-Optimal method can be seen in Figure 7.

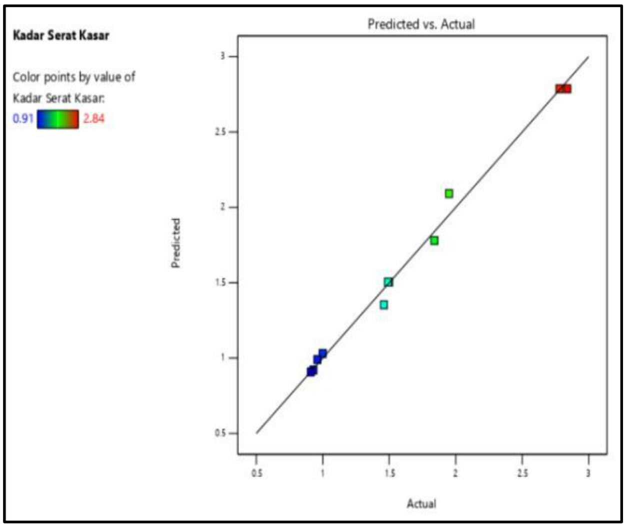


Figure 7. Graph of Internally Studentized Residuals Normality of Crude Fiber Content Test Results

Based on Figure 7, it can be concluded that the results of the analysis of 11 formulas for each point approach the normal line, this shows that the model is in accordance with the assumptions of the ANOVA Design Expert program.

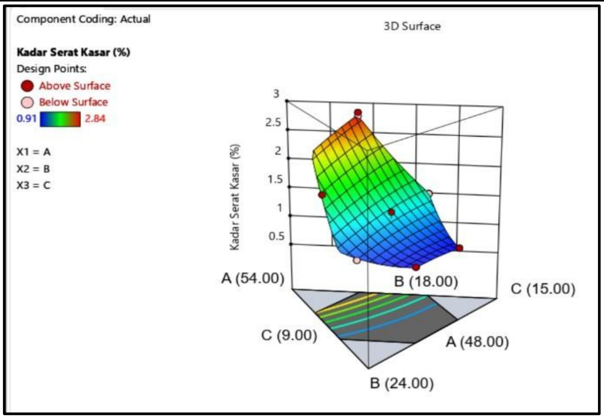


Figure 8. Three-dimensional graph of crude fiber content test results

Based on Figure 8, the three-dimensional graph of the interaction relationship between the components of the product contained in the raw materials can be seen from the color and surface. The blue color indicates the lowest crude fiber content analysis results while the red color indicates the highest crude fiber content analysis results. The lowest crude fiber content value has a value of 0.91% with a combination of 48.00% red bean formula, 20.00% cassava starch and 13.00% wheat flour.

The highest crude fiber content is 2.84% with a combination of 52.00% red bean formula, 18.00% cassava starch and 11.00% wheat flour. Organoleptic response analysis is by hedonic test with color, aroma, taste and texture assessment attributes. Visually, the color factor appears first and sometimes also determines the acceptance of a product. A product with a good texture, delicious and nutritious is sometimes not accepted if the color it has deviates from the color it should be. The color of food products can change during cooking due to the loss of some pigments caused by the release of cell fluid during the processing process. Thus, the intensity of the color produced will decrease [42].

The following are the results of the hedonic test of color attributes that have been carried out on the 11 red bean meatball formulations, which can be seen in table 15. The analysis of the organoleptic response of the hedonic test of the 11 meatball formulations obtained a color attribute value of 4.07 - 4.57 indicating that the panelists gave a rather liking assessment. The lowest value is shown by formula 7 while the highest value is shown in formula 8. The average value of the color attribute test is 4.31 with a standard deviation of 0.0294. In formulas 4 and 5 there is a difference of 0.06% while in samples 6 and 7 there is a difference of 0.03%.

Table 15. Results of Hedonic Test Analysis of Color Attributes of Red Bean-Based Meatballs

Formula	Color
1	4.30
2	4.40
3	4.50
4	4.23
5	4.17
6	4.10
7	4.07
8	4.57
9	4.27
10	4.47
11	4.33

Of the 11 color formulas produced, the color difference is not too far. The color of the meatballs produced is caused by a non-enzymatic browning reaction between vegetable protein containing amino acids and reducing sugars. Starch from flour can be broken down into reducing sugars which, when in direct contact with vegetable protein, will accelerate the color change. If the flour is heated, the complex compound will give a darker color to the product. The polynomial model suggested by the Design Expert program for the analysis of the organoleptic response of hedonic testing with color attributes is quadratic.

The ANOVA table shows that the F value of the model is 60.79 at the 5% level, the P value is 0.0002, so "prob> F" or P is less than 0.05. This shows that the combination of red beans, cassava starch and wheat flour provides a significantly different taste attribute value in the meatball formula. The lack of fit value of 0.6147 indicates that the lack of fit is not significant related to pure error. The lack of fit value that is not significant is a good sign because the model obtained is appropriate.

The Adjusted R^2 value is 0.9676 and the Predicted R^2 value is 0.8954, where the results of both have a difference of less than 0.2. The Adeq Precision value obtained is 21.6993, which is greater than 4 and indicates an adequate signal. This model can be used to navigate design space. The mathematical model equation for the analysis of the organoleptic response of the hedonic color attribute test can be seen below.
Color attribute value score:

$$Y = 4{,}14\ A + 4{,}36\ B + 4{,}49\ C + 0{,}3267\ AB - 0{,}7740\ AC + 0{,}4943\ BC \quad \ldots(4)$$

Description:
A = Red Beans; B = Cassava Starch; C = Wheat Flour

The mathematical model equation above for the color attribute is a quadratic model, where the component that contributes the most to color is the coefficient C (Wheat Flour). This is because the coefficient C (Wheat Flour) has the highest value, namely 4.49 when compared to other components.

The values that are considered to have an effect on the response are those that have a plus (+) value in the model equation, so that from the equation above, the components that have a negative value (-) are considered to have no effect on the response. Based on the equation above, it can be concluded that components A (Red Beans), B (Cassava Starch) and C (Wheat Flour) have a significant effect on the organoleptic response of the color attribute, the interaction of the AB component increases the organoleptic response value on the color attribute, the interaction of the AC component decreases the organoleptic response value on the color attribute and the interaction of the BC component increases the organoleptic response value on the color attribute. The graph of the normality of the internally studentized residuals of the results of the organoleptic test of the color attribute and the three-dimensional graph of the hedonic test of the color attribute obtained from the results of the study using the D-Optimal method can be seen in Figure 9.

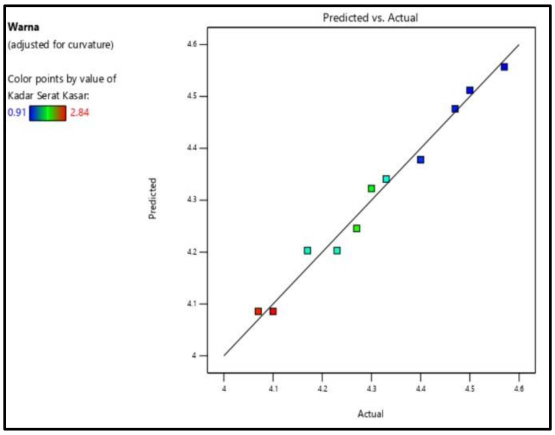


Figure 9. Graph of Internally Studentized Residuals Normality of Color Attribute Hedonic Test Results

Based on Figure 9, it can be concluded that from the results of the analysis of 11 formulas, each point approaches the normal line, this shows that the model is in accordance with the assumptions of the ANOVA Design Expert program.

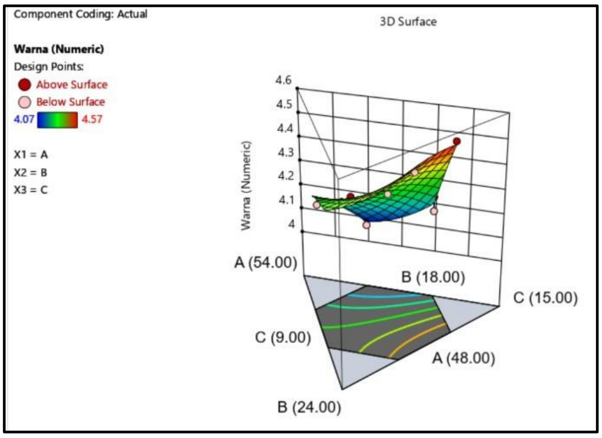


Figure 10. Three-Dimensional Graph of the Color Attribute Hedonic Test

Based on Figure 10, the three-dimensional graph of the interaction relationship between the components of the product contained in the raw materials can be seen from the color and surface. The blue color indicates the lowest color attribute test results while the red color indicates the highest color attribute test results. The lowest color attribute value is 4.07 with a combination of formulas of 52.00% red beans, 18.00% cassava starch and 11.00% wheat flour while the highest color attribute value is 4.50 with a combination of formulas of 48.00% red beans, 20.00% cassava starch and 13.00% wheat flour. Taste is a quality attribute of a product which is usually an important factor for consumers in choosing a product. The taste of food generally does not only consist of one taste but is a combination of various integrated ones so that it creates a complete food taste. Food ingredients contain 4 basic flavors. The influence between one flavor and another depends on its concentration. If one component has a higher concentration than the other components, that component will be dominant. If the concentration difference is not too large, then there is a possibility of a combined taste or all of these components can be felt sequentially. The following are the results of the hedonic test of taste attributes that have been carried out on the 11 red bean meatball formulations, which can be seen in table 16.

The analysis of the organoleptic response of the hedonic test of the 11 meatball formulations obtained a taste attribute value of 3.87 - 4.67 indicating that the panelists gave an assessment of rather dislike to rather like. The lowest value was shown by formula 8 while the highest value was shown in formula 6. The average value of the taste attribute test was 4.31 with a standard deviation of 0.0619. In formulas 4 and 5 there was a difference of 0.02 while in samples 6 and 7 there was a difference of 0.04.

Table 16. Results of Hedonic Test Analysis of Taste Attributes of Red Bean-Based Meatballs

Formula	Taste
1	4.47
2	4.17
3	3.97
4	4.40
5	4.42
6	4.67
7	4.63
8	3.87
9	4.57
10	4.03
11	4.20

The polynomial model suggested by the Design Expert program for the analysis of organoleptic responses of hedonic testing with taste attributes is linear. The ANOVA table shows that the F value of the model is 95.82 at the 2% level, the P value is <0.0001 then "prob> F" or P is less than 0.05. This shows that the combination of red beans, cassava starch and wheat flour provides a significantly different taste attribute value in the meatball formula. The lack of fit value of 9.88 indicates that the lack of fit is not significant related to pure error. The lack of fit value that is not significant is a good sign because the model obtained is appropriate. The Adjusted R^2 value is 0.9499 and the Predicted R^2 value is 0.9217, where the results of both have a difference of less than 0.2. The Adeq Precision value obtained is 24.0117, which is greater than 4 and indicates an adequate signal. This model can be used to navigate the design space. The mathematical model equation for analyzing the organoleptic response of hedonic testing of taste attributes can be seen below.
Taste attribute value score:

$$Y = 5{,}01\,A + 3{,}85\,B + 4{,}02\,C \qquad \ldots(5)$$

Information:
A = Red Beans; B = Cassava Starch; C = Wheat Flour

The mathematical model equation above for the taste attribute is a linear model, where the component that contributes the most to the taste attribute is the coefficient A (Red Beans). This is because the coefficient A (Red Beans) has the highest value, which is 5.01 when compared to other components. The more component A (Red Beans) is added, the stronger the taste of the red bean-based meatballs will be. The value that is considered to have an effect on the response is the one that has a plus (+) value, so from the equation above the other components are considered to have an effect on the response. Based on the equation above, it can be concluded that components A (Red Beans), B (Cassava Starch) and C (Wheat Flour) have a significant effect on the response of the taste attribute. The graph of the normality of the internally studentized residuals of the organoleptic test results of the color attribute and the three-dimensional graph of the hedonic test of the taste attribute obtained from the results of the study using the D-Optimal method can be seen in Figure 11.

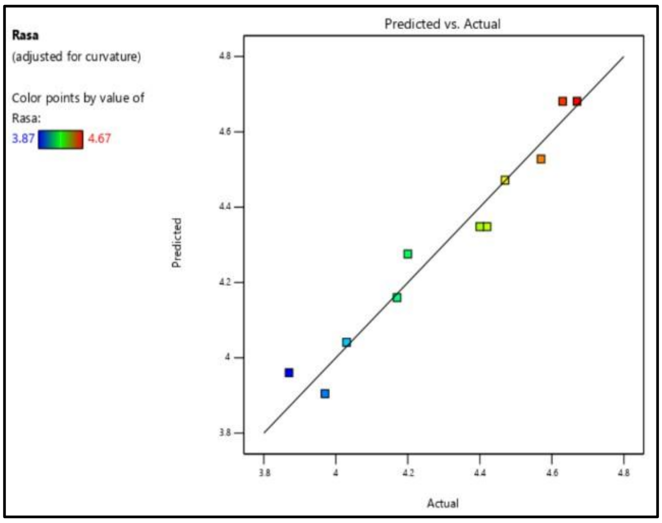


Figure 11. Graph of Internally Studentized Residuals Normality of Taste Attribute Hedonic Test Results

Based on Figure 11, it can be concluded that from the results of the analysis of 11 formulas, each point approaches the normal line. This shows that the model is in accordance with the assumptions of the ANOVA Design Expert program.

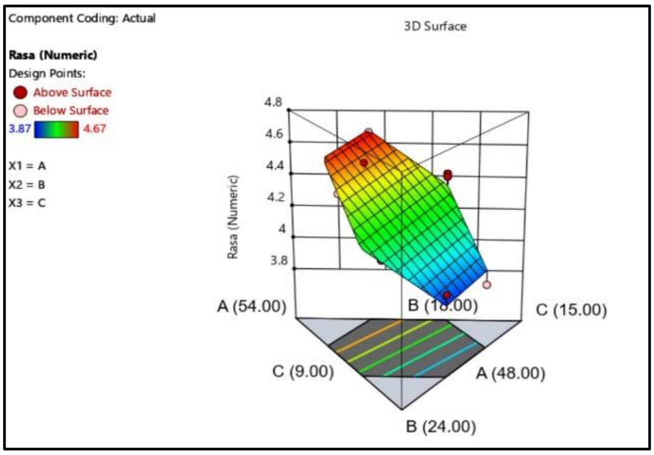


Figure 12. Three-Dimensional Graph of Hedonic Test of Taste Attributes

Based on Figure 12, the three-dimensional graph of the interaction relationship between the components of the product contained in the raw materials can be seen from the color and surface. The blue color indicates the lowest taste attribute test results while the red color indicates the highest color attribute test results. The lowest taste attribute value is 3.87 with a combination of formulas of 48.00% red beans, 20.00% cassava starch and 13.00% wheat flour while the highest taste attribute value is 4.67 with a combination of formulas of 52.00% red beans, 18.00% cassava starch and 11.00% wheat flour. The aroma of a food ingredient or food product can determine the taste of the food.

Fragrant, sour, rancid and burnt are a mixture of four odors received by the nose and brain [43]. Stated that aroma is a value contained in the product and can be enjoyed by consumers [42], [44]. The sense of smell greatly influences the hedonic aroma test. The following are the results of the hedonic test of aroma attributes that have been carried out on the 11 red bean meatball formulations, which can be seen in table 17. The analysis of the organoleptic response of the hedonic test of the 11 meatball formulas obtained an aroma attribute value of 4.03 - 4.57 indicating that the panelists gave a rather liking assessment. The lowest value is shown in the 8th formula while the largest aroma attribute value is shown in the 6th formula. The average value for the aroma attribute test is 4.30 with a standard deviation of 0.0405. In the same formulation, 4 and 5 have a difference of 0.07 and samples 6 and 7 have a difference of 0.04.

Table 17. Results of Hedonic Test Analysis of Red Bean-Based Meatball Aroma Attributes

Formula	Aroma
1	4.37
2	4.20
3	4.10
4	4.30
5	4.37
6	4.57
7	4.53
8	4.03
9	4.40
10	4.17
11	4.27

The polynomial model suggested by the Design Expert program for the analysis of the organoleptic response of hedonic testing with aroma attributes is linear. The ANOVA table shows that the F value of the model is 83.28 at the 2% level, the P value is <0.0001, so "prob> F" or P is less than 0.05. This shows that the combination of red beans, cassava starch and wheat flour provides a significantly different aroma attribute value in the meatball formula. The F lack of fit value of 1.01 indicates that the lack of fit is not significant related to pure error.

The lack of fit value that is not significant is a good sign because the model obtained is appropriate. The adjusted R^2 value is 0.9427 and the Predicted R^2 value is 0.9042, where the results of both have a difference of less than 0.2. The Adeq Precision value obtained is 22.5178, which is greater than 4 and indicates an adequate signal. This model can be used to navigate the design space. The mathematical model equation for the analysis of the organoleptic response of hedonic testing of aroma attributes can be seen below..

Aroma attribute value score:

$$Y = 4{,}73\ A + 4{,}01\ B + 4{,}13\ C \qquad \ldots(6)$$

Description:

A = Red Beans; B = Cassava Starch; C = Wheat Flour

The mathematical model equation above for the aroma attribute is a linear model, where the component that contributes the most to the aroma attribute is the coefficient A (Red Beans). This is because the coefficient A (Red Beans) has the highest value, which is 4.73 when compared to other components. The more component A (Red Beans) is added, the stronger the aroma of the red bean-based meatballs will be.

The value that is considered to have an effect on the response is the one that has a plus (+) value, so from the equation above the other components are considered to have an effect on the response.

Based on the equation above, it can be concluded that components A (Red Beans), B (Cassava Starch) and C (Wheat Flour) have a significant effect on the organoleptic response of the aroma attribute.

The graph of the normality of the internally studentized residuals of the aroma attribute hedonic test results and the three-dimensional graph of the aroma attribute hedonic test results obtained from the research results using the D-Optimal method can be seen in Figure 13.

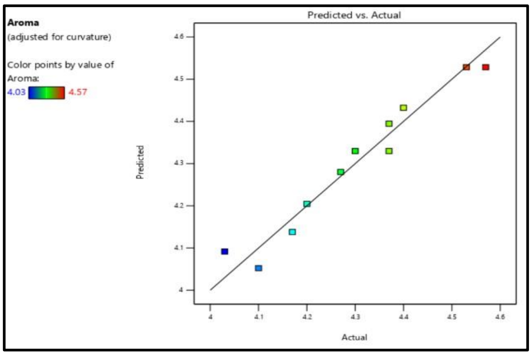


Figure 13. Graph of Internally Studentized Residuals Normality of Aroma Attribute Hedonic Test Results

Based on Figure 13, it can be concluded that from the results of the analysis of 11 formulas, each point approaches the normal line, this shows that the model is in accordance with the assumptions of the ANOVA Design Expert program.

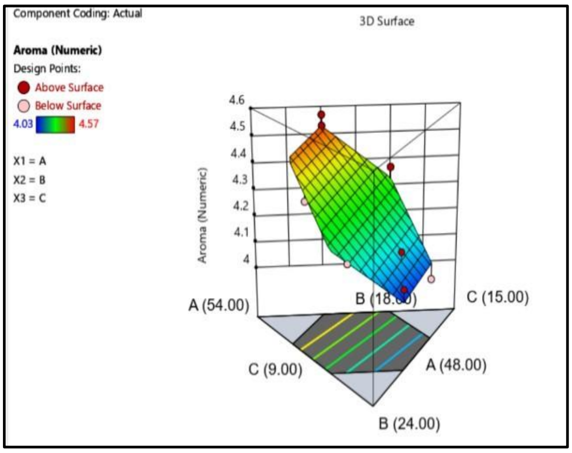


Figure 14. Three-Dimensional Graph of Aroma Attribute Hedonic Test Results

Based on Figure 14, the three-dimensional graph of the interaction between the components of the product contained in the raw materials can be seen from the color and surface. The blue color indicates the lowest aroma attribute test results while the red color indicates the highest aroma attribute test results. The lowest aroma attribute value is 4.03 with a formula combination of 48.00% red beans, 20.00% cassava starch and 13.00% wheat flour while the highest aroma attribute value is 4.57 with a formula combination of 52.00% red beans, 18.00% cassava starch and 11.00% wheat flour. Texture is the performance of a material when subjected to force [45], [46]. Texture can be expressed as deformation, namely the relative shift of a point or place when the material is subjected to force. Measurement of meatball texture can be expressed as softness, elasticity and deformation. The softness of meatballs is defined as the force that can be held until the material is damaged, where the smaller the force held, the softer the meatball texture will be. One of the factors that affects the softness of meatballs is water content. The chewiness of meatballs is determined by the use of flour. The texture of meatballs will be chewy if the water binding capacity is greater.

The texture of food can be determined by the content of water, fat, protein and carbohydrates. Changes in texture can be caused by the loss of water or fat, the formation of emulsions, carbohydrate hydrolysis, and protein coagulation [47], [48]. The texture test in this study was the chewiness tested using the sense of mouth, the composition of each different ingredient in each formulation causes different chewiness in the product. The following are the results of the hedonic test of texture attributes that have been carried out on the 11 red bean meatball formulations, which can be seen in table 18.

The analysis of the organoleptic response of the hedonic test of the 11 meatball formulas obtained a texture attribute value of 3.50 - 4.63 indicating that the panelists gave an assessment of rather dislike to rather like. The lowest texture attribute value is shown in the 8th formula while the largest texture attribute value is shown in the 6th formula. The average value for the texture attribute test is 4.13 with a standard deviation of 0.0573. In the same formulation, between 4 and 5 there is a difference of 0.04 and samples 6 and 7 have a difference of 0.03.

Table 18. Results of Hedonic Test Analysis of Texture Attributes of Red Bean-Based Meatballs

Formula	Texture
1	4.27
2	4.03
3	3.60
4	4.23
5	4.27
6	4.63
7	4.60
8	3.50
9	4.50
10	3.67
11	4.13

The polynomial model suggested by the Design Expert program for the analysis of the organoleptic response of hedonic testing with texture attributes is quadratic. The ANOVA table shows that the F value of the model is 93.76 at level 5, the P value is <0.0001 then "prob> F" or P is less than 0.05. This shows that the combination of red beans, cassava starch and wheat flour provides a significantly different texture attribute value in the meatball formula.

The F lack of fit value of 8.09 indicates that the lack of fit is not significant related to pure error. The lack of fit value that is not significant is a good sign because the model obtained is appropriate. The adjusted R^2 value is 0.9789 and the Predicted R^2 value is 0.9536, where the results of both have a difference of less than 0.2. The Adeq Precision value obtained is 27.2102, which is greater than 4 and indicates an adequate signal. This model can be used to navigate the design space. The mathematical model equation for analyzing the organoleptic response of hedonic testing of texture attributes can be seen below.
Texture attribute value score:

$$Y = 4{,}59\ A + 3{,}70\ B + 3{,}43\ C + 0{,}5084\ AB + 1{,}92\ AC - 0{,}1775\ BC \quad \ldots(7)$$

Description:
A = Red Beans; B = Cassava Starch; C = Wheat Flour

The mathematical model equation above for the texture attribute is a quadratic model, where the component that contributes the most to the texture attribute is the coefficient A (Red Beans). This is because the coefficient A (Red Beans) has the highest value, which is 4.59 when compared to other components. The value that is considered to have an effect on the response is the one that has a plus (+) value in the model equation, so from the equation above, the component with a negative (-) value is considered to have no effect on the response.

Based on the equation above, it can be concluded that components A (Red Beans), B (Cassava Starch), and C (Wheat Flour) have a significant effect on the organoleptic response of the product's texture attribute, the interaction of components AB and AC increases the organoleptic response value of the texture attribute while the interaction BC decreases the organoleptic response value of the texture attribute in the product. The graph of the normality of the internally studentized residuals of the hedonic test results of the texture attribute and the three-dimensional graph of the hedonic test results of the texture attribute obtained from the research results using the D-Optimal method can be seen in Figure 15.

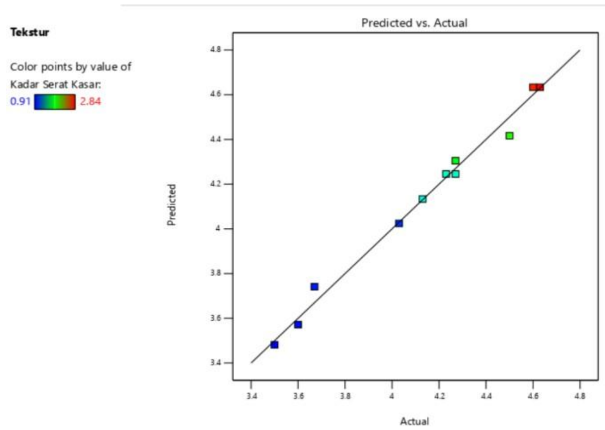


Figure 15. Graph of Internally Studentized Residuals Normality of Texture Attribute Hedonic Test Results

Based on Figure 15, it can be concluded that from the results of the analysis of 11 formulas, each point approaches the normal line, this shows that the model is in accordance with the assumptions of the ANOVA Design Expert program.

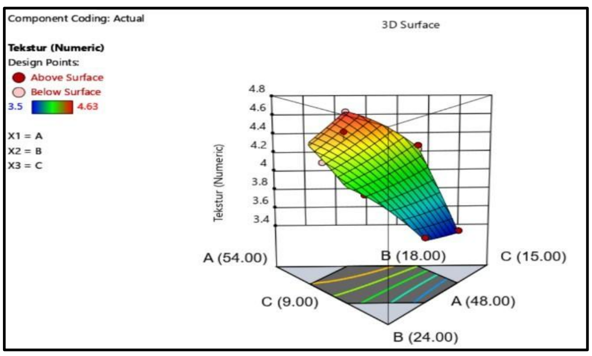


Figure 16. Three-Dimensional Graph of Texture Attribute Hedonic Test Results

Based on Figure 16, the three-dimensional graph of the interaction relationship between the components of the product contained in the raw materials can be seen from the color and surface. The blue color indicates the lowest texture attribute test results while the red color indicates the highest texture attribute test results. The lowest texture attribute value is 3.50 with a combination of formulas of 48.00% red beans, 20.00% cassava starch and 13.00% wheat flour while the highest texture attribute value is 4.63 with a combination of formulas of 52.00% red beans, 18.00% cassava starch and 11.00% wheat flour.

3.3. Determining the Optimal Formula

After the response analysis, the next stage is the formula optimization process carried out with the Design Expert Ver. 13 program. The formula optimization process is carried out to obtain a formula with the most optimal response. The most optimal response is obtained with desirability approaching 1. A desirability value approaching one indicates that the product formula has achieved the optimal formula based on the desired response variable. Conversely, a desirability index approaching zero signifies that the formulation is challenging to optimize according to its response variable [49].

In each research response, goal and importance are determined to determine the optimization objectives and weighting values. Goal determination is selected based on the desired value for each fruitful variable and response, namely in range, minimize, and maximize. Importance is selected with the level of importance of the weighting of each variable changing and the response starting from (+) to (+++++) [50], [51]. The higher the importance weight, the more important the weighting level. A large importance value will get the most optimum product, but it is difficult to get a high desirability value. The determination of goals and importance for each variable changes and the response can be seen in table 19.

Tabel 19. Goal dan Importance untuk Tahapan Optimasi Formula

Variable / Response	Goal	Lower Limit	Upper Limit	Importance
A : Red Beans	In range	48.00	52.00	3 (+++)
B : Cassava Starch	In Range	18.00	22.00	3 (+++)
C : Wheat Flour	In Range	9.00	13.00	3 (+++)
Protein Content (%)	Maximize	11.06	15.50	5 (+++++)
Crude Fiber Content (%)	In Range	0.91	2.84	3 (+++)
Carbohydrate Content (%)	Maximize	12.95	19.88	5 (+++++)
Color	Minimize	4.07	4.57	3 (+++)
Taste	Maximize	3.87	4.67	5 (+++++)
Aroma	Maximize	4.03	4.57	5 (+++++)
Texture	Maximize	3.50	4.63	5 (+++++)

Red beans are optimized with goal in range and importance level 3 (+++). Red beans in meatball products are expected to provide a high source of carbohydrates and protein in the product so that it can meet the nutritional needs of consumers even though it does not use animal protein in the product. Cassava starch is optimized with goal in range and importance level 3 (+++). Cassava starch in meatball products will increase water binding capacity so that it is expected to provide a chewy texture to resemble meatballs in general.

Wheat flour is optimized with goal in range and importance level 3 (+++). Wheat flour in meatball products is expected to provide a dense and compact texture to red bean meatball products. Protein content is optimized with goal maximize and importance level 5 (+++++). Protein is as important as other nutrients, it is expected that the resulting product has a high protein content so that red bean meatballs can replace meatballs with meat as the raw material.

Crude fiber content is optimized with goal minimize and importance level 3 (+++). Crude fiber is a compound that cannot be digested by the human digestive system. The type of crude fiber in red beans is alpha-galactoside. Where if it is too excessive it will cause bloating and diarrhea. Carbohydrate levels are optimized with the goal maximize and the level of importance 5 (++++). Carbohydrates are one of the sources of energy in the body, it is expected that red bean meatball products can contain high carbohydrates so that they can meet consumer energy needs.

The color attribute is optimized with the goal minimize and the level of importance 3 (+++). Color is the first parameter seen by consumers and can be the first reference used to assess food products. Therefore, color is a very important attribute in the formulation of a product. The lower the range produced, the more the color is preferred by consumers and is expected to have a color similar to meatball products in general.

The taste attribute is optimized with the goal maximize and the level of importance 5 (++++++). Taste plays an important role in determining whether the product is acceptable to consumers or not. The higher the range of taste produced, the more consumers will like the product. The aroma attribute is optimized with the goal maximize and the level of importance 5 (++++++). The aroma of food ingredients greatly determines the deliciousness of the food ingredients. Aroma can be recognized when steam is formed and the molecules of the aroma components must have time to touch the olfactory cell cilia and be transmitted to the brain in the form of electrical impulses by the olfactory nerve endings [52], [53]. Aroma is one of the important determining factors in a product, the higher the range produced, the more it is preferred by the panelists [54], [55].

The texture attribute is optimized with the goal maximize and the importance level 5 (++++++). Texture is the performance of a material when subjected to force. Texture can be expressed as deformation, namely the relative shift of a point or place when the material is subjected to force [56], [57]. Measurement of meatball texture can be expressed as softness, elasticity and deformation. The expected texture of the product is chewy and resembles meatballs in general.

From the optimization stage carried out, the design expert program recommends 1 selected formulation which can be seen in table 24, the optimal formulation is seen based on the desirability value closest to the number 1. The higher the desirability value indicates the higher the suitability of the meatball formula to achieve the optimal formula with the desired response variables. The resulting desirability value is greatly influenced by the complexity of the components, the range used in the components, the number of response components and the desired target in obtaining the optimal formula. The complexity of the number of components can be seen in the requirements for the amount of raw materials that are considered important and influential in determining the formulation. The amount of each raw material is determined in different intervals that will affect the desirability value. The wider the range, the more difficult it will be to determine a formula with high desirability. The more components and responses, the more difficult it is to achieve an optimal state so that the desirability value is lower. The desirability value in the selected formula is 0.982.

Table 20. Optimal formulation

Parameter	Value
Formula	1
Red Beans (%)	52.00
Tapioca Flour (%)	18.00
Wheat Flour (%)	11.00
Garlic Powder (%)	0.25
Salt (%)	1.00
Flavor Enhancer (%)	0.25
Ice (%)	15.00
Sodium Tripolyphosphate (%)	2.50
Garlic Paste (g)	0.25
Water Addition (mL)	155.1
Red Color (°H)	30.11
Yellow Color (°H)	27.9
Green Color (°H)	40.83
Aroma (Score)	4.82
Taste (Score)	4.88
Texture (Score)	4.92

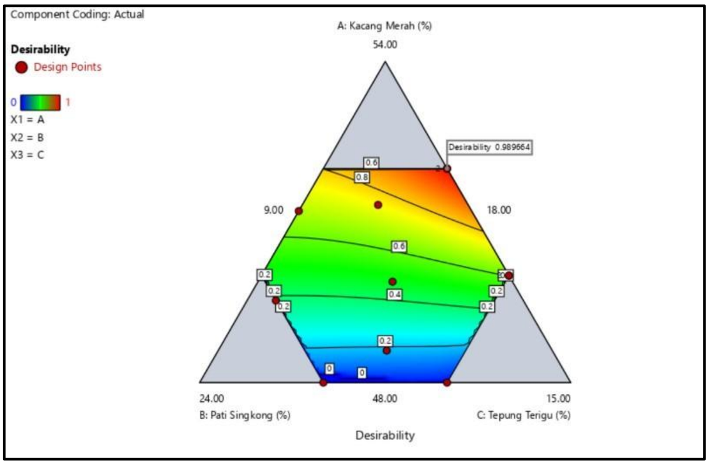


Figure 17. Desirability Graph of Optimal Red Bean Meatball Formulation

The selected formula solution is the optimum formula consisting of 52.00% red beans, 18.00% cassava starch, 11.00% wheat flour. This formula has a desirability of 0.982, which means that this formula produces a product that has characteristics in accordance with the optimization target of 98.20%. This formula is predicted to produce a protein content of 15.51%, a crude fiber content of 2.79%, a carbohydrate content (starch) of 20.11%, a color attribute value of 4.086, a taste attribute value of 4.681, an aroma attribute value of 4.528, and a texture value of 4.633.

3.4. Optimal Formula Validation Results

The optimum formula produced will be used in the manufacture of red bean meatball products which will then be reanalyzed using the same response as the response in the manufacture of the formula. The purpose of this test is to determine the actual value of the optimum formula so that it can be compared with the predictions given by the Design Expert program. In addition to predicting the response value of each formula solution given, the design expert program also provides a confident interval and prediction interval for each predicted response value at a significance level of 5%. Confidence interval is the standard error of the mean which helps overcome random errors from data obtained from the amount of data used. The more data used, the smaller the random error and range obtained. If you repeat the sampling without limits, the 95% CI that is built will contain the actual population average.

Prediction interval is a range that shows the expectation of the results of the next response measurement with the same conditions. If you repeat the sampling without limits, the 95% PI that is built will contain new observations. Thus, CI and PI must be compared to confirm that the verification results differ in the range indicating the value of the response accuracy. The range of CI values will be smaller than the range of PI values because PI measurements involve a variety of unknown sample variations for the description of future sample results with a certain level of confidence based on observations that have been observed. The results of the validation carried out along with predictions of each response can be seen in Table 21.

Table 21. Response Validation Results

Response	Analysis Results	Design Expert	95% CI Low	95% CI High	95% PI Low	95% PI High
Protein Content	15.69	15.51	15.2572	15.7556	15.0608	15,952
Crude Fiber Content	2.97	2.79	2.63224	2.94219	2.51009	3.06433
Carbohydrate Content	20.41	20.109	19.5527	20.665	18.9256	21.292
(Starch)	4.13	4.086	4.03473	4.13673	3.99454	4.17692
Color	4.67	4.681	4.60497	4.75698	4.51927	4.84267
Taste	4.57	4.528	4.47873	4.5782	4.42266	4.63427
Aroma	4.63	4.633	4.53364	4.73241	4,4553	4.81074

Based on table 21, it can be concluded that the validation data of chemical responses of protein content, carbohydrate content (starch), organoleptic responses of taste attributes and texture attributes meet the prediction of 95% Confidence Interval (CI). Validation of chemical responses of protein content, crude fiber content, carbohydrate content (starch), organoleptic responses of color attributes, taste attributes, aroma attributes, and texture attributes meet the prediction of 95% Prediction Interval (PI).

The results of this study have a significant impact on the field of plant-based food development both locally and globally. Locally, this study supports Indonesian food diversification by introducing red beans as the main raw material in making healthy, cheap, and nutritious analog meatballs. This innovation contributes to strengthening national food security through the utilization of abundant local raw materials and supporting healthy eating patterns of the Indonesian people. At the global level, this study is an important contribution to the trend of environmentally friendly plant-based food.

In line with previous studies that have the same goal in developing healthy plant-based meatball products by increasing nutritional content such as fiber and protein, while considering physical, organoleptic, and microstructural qualities. Previous studies used red lentil flour as an additional ingredient to increase fiber in chicken meatballs, while current research uses red beans as the main ingredient in the plant-based meatball formula. The results of previous studies showed that the addition of 9% red lentil flour produced chicken meatballs that were rich in fiber with an attractive color and acceptable to consumers [58]. Current research supports these results by showing that the use of red beans as the main ingredient is able to produce meatballs with a higher protein content (15.50%) and significant crude fiber (2.84%), with a texture and taste that is preferred by panelists. However, there is a major gap between the two studies. The previous study only focused on adding fiber to meat-based meatballs, while the current study expanded the innovation by making fully plant-based meatballs, which is more relevant to the trend of plant-based healthy food. In addition, the formula optimization method in the current study provides advantages over the conventional experimental approach in the previous study in ensuring product efficiency and quality.

The formula optimization method using the Design Expert D-Optimal approach provides a framework that can be replicated in the development of other plant-based products, enriching the literature on food technology. With a focus on reducing fat and increasing protein content, this research is relevant to the global need to provide healthy and sustainable food alternatives, in line with the global agenda on climate change and more responsible food production. The results of this study provide an important contribution to the development of plant-based food in Indonesia, especially in diversifying healthier protein sources [59], [60]. With the optimal formula produced, red bean meatball products have the potential to be a more nutritious and environmentally friendly alternative compared to meat-based meatballs, and can support the sustainability of the local food industry through the utilization of abundant local raw materials.

This study introduces an innovation in making analog meatballs based on red beans using a formula optimization method through the Design Expert D-Optimal approach. This innovation not only produces products that are high in protein and low in fat, but also supports local food diversification by utilizing red bean resources as an alternative main raw material, which has not been widely used in the development of similar analog products. This research is still limited to laboratory-scale testing, so it does not cover aspects of large-scale production and wider market testing. In addition, although formula optimization has been carried out, there is a possibility of variation in results if the raw materials used come from different varieties of red beans, which can affect the final characteristics of the product.

4. CONCLUSION

Based on the research that has been conducted, it can be concluded that the use of Design Expert software is able to produce an optimal formulation for red bean-based meatball products with a desirability value of 0.982. Initial analysis of red beans showed a carbohydrate content of 6.90%, protein 13.71%, and fiber 3.99%. Of the 11 formulations tested, one optimal formula was obtained with a composition of 52.00% red beans, 18.00% cassava starch, 11.00% wheat flour, 1.00% salt, 0.25% flavoring, 15.00% ice cubes, 2.50% Sodium Triphosphate (STPP), and 0.25% garlic powder. This formula produces a carbohydrate content of 20.11%, protein 15.51%, crude fiber 2.79%, and good organoleptic scores for color (4.086), taste (4.681), aroma (4.528), and texture (4.633). For further research, it is recommended to analyze the Water Holding Capacity (WHC) levels, test the shelf life with the right packaging and storage temperature, and evaluate the physical texture using a Texture Analyzer. In addition, the addition of artificial flavors with meat aromas and good fat ingredients, such as animal or vegetable fats, also needs to be done to improve the quality of the product to be more like conventional meatballs.

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