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Optimization of Blending Ratio of Seasoned Flour from Modified Cassava Flour, Sago Flour, and Cornstarch by D-Optimal Mixture Design Approach

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ABSTRACT

This study aimed to investigate the optimum ratio between modified cassava flour, sago flour, and cornstarch in order to improve the physicochemical and sensory qualities of seasoned flour. To achieve this objective, the D-optimal method in Design Expert software was used to create 16 formulas. The respective ranges for modified cassava flour, sago flour, and cornstarch were 37.5%–42.5%, 27.6%–32.5%, and 16.0%–20.0%. Furthermore, moisture content, water holding capacity (WHC), oil holding capacity (OHC), and sensory acceptance were analyzed. With a desirability value of 0.774, the predictive results showed that the optimal composition of 41% modified cassava flour, 31% sago flour, and 16% cornstarch produced the best results. According to physicochemical and functional analysis, the optimum seasoned flour formula had 8.06% moisture content, 6.32% ash, 2.67% protein, 0.40% fat, 80.31% carbohydrate, 5.01% resistant starch, 18.52% WHC, and 10.20% OHC.

Keywords: Autoclaving-cooling cycle, mixture design, modified cassava flour, optimization, seasoned flour

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INTRODUCTION

Seasoned flour is a food ingredient made from a mixture of flour and spices. Commercially available seasoned flour is generally made from composite flour, salt, spices, and other food additives. Meanwhile, packaged seasoned flour is often used for fried chicken or other fried food items as it saves cooking time. According to Isaskar et al. (2021), consumers prefer seasoned flour made from modified cassava flour to that made from wheat flour.

Composite flour was used as the base material for seasoned flour in this study. It is made from flours of cereals (corn, rice, and sorghum), tubers (cassava, sweet potatoes, and potatoes), which are high in carbohydrates, and legumes (soybeans), rich in protein. These ingredients may be used either alone or in combination with wheat flour (Seibel, 2006). Compared to wheat flour, composite flour offers higher protein content and more vitamins, making it a more nutritious option (Olaoye et al., 2006). The unique color, texture, and nutritional content of each component of composite flour can be considered a culinary advantage. Currently, composite flour is used in a wide variety of recipes around the world, particularly for cakes, bread, pastries, noodles, and pasta (Engindeniz & Bolatova, 2019).

A form of tuber potentially used as a functional food ingredient is cassava (*Manihot esculenta*), which can be modified to improve the functional properties of native starch. Native starch is considered negligible as the physical and chemical characteristics make it unsuitable for general use. A special treatment applied to starch to improve or alter certain properties is known as starch modification (Aparicio-Saguilán et al., 2005). In this study, cassava flour was used and modified using the autoclaving-cooling cycles method. The autoclaving-cooling cycles process involves a combination of heating using an autoclave, resulting in the complete gelatinization of starch (with the amylose fraction leaching out of the granules), followed by a low-temperature storage process that increases the retrogradation of starch through amylose crystallization (Sajilata et al., 2006). The modification process, involving repeated autoclaving-cooling cycles, increases the arrangement of amylose-amylose and amylose-amylopectin interactions and improves the formation of more perfect crystals, leading to higher levels of type 3 resistant starch (Leong et al., 2007). Cassava flour modified by autoclaving-cooling cycles has 6.44% moisture content, 1.78% ash, 2.76% protein, 0.10% fat, 85.34% carbohydrate, 67.31% starch, 24.22% amylose, 43.08% amylopectin, 4.45% resistant starch, 59.31 (%WT) white degree, 28.85% water holding capacity (WHC), and 10.20% oil holding capacity (OHC) (Rahman et al., 2017).

Corn (*Zea mays*), the third-most important grain crop in the world after rice and wheat, is processed to produce a wide range of food and industrial products, including starch, sugars, oils, beverages, and biofuels (Yu & Moon, 2022). A vital component often used in the food industry is cornstarch, which serves as a thickening, bulking, gelling, and water retention agent, as well as a colloid stabilizer (Singh et al., 2003). Even though excessive use of cornstarch can make fried food overly dense, it is known to improve crispiness when frying and can cause the food to break more easily when bitten (Perera & Embuscado, 2014).

Sago palm (*Metroxylon* spp.) is an important plant, particularly for the people of Southeast Asia and its surrounding regions (Indonesia, Malaysia, and Papua New Guinea), due to its wide range of uses (Konuma, 2018). Sago flour, processed from the tree trunks, has a competitive advantage in both yield and price compared to corn and cassava starch (Du et al., 2020). The composition is approximately 88% carbohydrates, with 21.4%–30.0% being amylose (Martinez et al., 2018). It has a higher swelling ability, lower enzyme digestibility than cornstarch, higher gelatinization temperature, and lower peak viscosity, thereby useful as a stabilizer (Achudan et al., 2020; Karim et al., 2008).

This study used modified cassava flour, sago flour, and cornstarch as raw materials for making seasoned flour. These ingredients are abundantly available to the population in the study area. The differences in their properties and characteristics necessitate formula optimization to produce seasoned flour with good nutritional content, physical properties, and sensory acceptance. Design Expert is an effective method for optimizing the combination of test materials, requiring fewer resources than traditional methods (Zhong et al., 2007). One of the design options provided by Design Expert is D-optimal mixture, which aims to find the optimal formulation.

Previous studies on the development of seasoned flour used sword bean flour, wheat, and sago (Purwaningsih et al., 2021); fermented soybean flour and roasted *Moringa oleifera* seed flour (Omeje et al., 2021); sweet potato, rice, and tapioca flours (Alfani et al., 2019); corn flour (Christian et al., 2022); as well as jack bean flour, wheat flour, and sago flour (Purwaningsih et al., 2024). The development of seasoned flour using cassava flour, sago flour, and cornstarch is promising due to the ability to increase the use of local raw materials. Only a few studies have focused on the functional properties of flour and seasoned flour made from modified cassava flour, sago flour, and cornstarch (Rahman et al., 2017. This current study provided information on composite flour materials to increase the nutritional content of seasoned flour. Due to the limited investigations on seasoned flour formulation using optimization methods to obtain the optimal formulation, this study aimed to optimize the ratio of modified components to produce seasoned flour with improved nutritional value, as well as better physical and sensory properties.

MATERIALS AND METHODS

Materials

Cassava var. Manggu (*Manihot esculenta*), obtained at approximately 9 months of age from Tanjung Siang District, Subang Regency, served as the raw material for this experiment. Cornstarch, sago flour, baking soda, salt, pepper powder, garlic powder, flavoring, cooking oil, and chicken fillet were purchased from a local market in Subang Regency, Indonesia.

Seasoned Flour Preparation

The autoclaving-cooling cycle method was used to prepare modified cassava flour (Andriansyah et al., 2017). The first step involved weighing the materials according to the formulation. The ingredients (modified cassava flour, sago flour, cornstarch, and spices) were stirred until homogeneous, and the seasoned flour mixture was subsequently applied as a coating on fried chicken.

Chicken meat was cut into pieces weighing 5-6 grams. A wet batter for fried chicken, seasoned flour was prepared with a 25:75 ratio of flour to water. Chicken was coated by first dipping into the dry seasoned flour, then in the wet batter, followed by draining, and finally dipping back in the dry seasoned flour. The next step involved deep-fat frying at a temperature of 170°C for 5 minutes. The final stage was draining the oil.

Data Collection and Analysis

Sensory Evaluation

Evaluation was conducted hedonically on color, taste, texture, aroma, and overall acceptance, with a numerical assessment on a scale of 1–6, where 1 = very dislike, 2 = dislike, 3 = slightly dislike, 4 = slightly like, 5 = like, and 6 = very like. A total of 30 semi-trained panelists were selected and briefed on the six-point hedonic scale and its use prior to the assessment. Fried chicken was prepared, tossed with seasoned flour, placed on a white platter, and randomly coded. Subsequently, panelists were instructed to sip water between each sample test during the evaluation. Data from the sensory evaluation were analyzed using Analysis of Variance (ANOVA), and when significant, the Duncan test was applied.

Chemical Properties Analysis

The gravimetric method was used to determine the sample's moisture and ash content. Protein content was determined using the Kjeldahl method for crude protein analysis, with a conversion factor of 6.25 according to AOAC method 2001.11 (AOAC, 2005). Crude fat was determined by the Soxhlet extraction method according to AOAC method 920.39 (AOAC, 2005). Meanwhile, total carbohydrate content was determined using the "by difference" method.

Resistant Starch Analysis

Resistant starch was analyzed using a method from Kim et al. (2003) with minor modifications. An Erlenmeyer flask containing 0.5 grams of material was filled with 25 milliliters of 0.1 M pH 7 phosphate buffer solution, which was swirled to create a suspension. The sample was placed in the flask, and 0.1 milliliters of alpha-amylase enzyme was added. The Erlenmeyer flask was subsequently covered with aluminum foil and incubated for 15 minutes at 100°C in a water bath, with periodic stirring. After removal and cooling of the sample, 5 mL of 1 N HCl and 20 mL of distilled water were added. The flask was filled with 1 milliliter of 1% pepsin enzyme, covered, and heated to 40°C in a water bath for one hour. After removal, 5 mL of 1 N NaOH, distilled water, and 0.1 mL of beta-amylase enzyme were added to the flask. After sealing, the Erlenmeyer flask was incubated for one hour at 40°C in a shaking water bath. The mixture was filtered through filter paper, the residue was dissolved, and the starch content was determined.

Physical Properties

WHC and OHC were determined using methods from Adebiyi and Aluko (2011), with minor modifications. A 250 mg sample was dissolved in 5 mL of distilled water (or cooking oil). The suspension was kept at room temperature for 15 minutes, with shaking every 5 minutes. Furthermore, it was centrifuged for 15 minutes at 3,000 rpm. The volume of the separated distilled water (or separated cooking oil) was measured, and WHC (or OHC) value was calculated by dividing the volume of sediment by the volume of the suspension.

Seasoned Flour Formula Optimization

After determining the variables to be mixed and their concentrations, the response to be measured was defined based on the product's components. Each response variable was analyzed using the Design Expert application to determine the D-optimal equation, which could be linear, quadratic, or cubic. These variables were used as a prediction model to ascertain the ideal formula. After processing each response variable according to the specified criteria, Design Expert provided solutions for several potential ideal formula responses. Desirability, a value between 0 and 1, was used to represent the target optimization value achieved. The closer the reaction to the value "1," the closer the formula is to the ideal point. Optimization was carried out to maximize the desirability value. Although the primary objective of formula optimization was to find the ideal mixture of various material combinations, achieving a desirability value of 1 was not the ultimate aim.

The lower and upper limits were selected using sensory tests to determine the formula to be optimized. According to Rahman et al. (2017), the sample selected based on sensory tests had a ratio of 40% modified cassava flour, 30% sago flour, and 18% cornstarch. These results were used to establish the upper and lower limits for the amounts of modified cassava flour, sago flour, and cornstarch, ensuring that the formulation was both optimized and met the required standards, as determined using the Design Expert program. The upper and lower limit data are presented in Table 1.

Table 1
Lower and upper limit data variable change

Variable Changed	Lower limit (%)	Upper limit (%)
Modified cassava flour	37.5	42.5
Sago flour	27.5	32.5
Cornstarch	16.0	20.0

In the preparation of seasoned flour, other ingredients were used as fixed variables and added to the dough. The concentration of these variables was not included in the experimental design. The ingredients included powdered spices (3% salt, 3% pepper powder, 2.5% garlic, 1% coriander, and 1.5% flavoring) and food additives (1% baking soda). The proportions of these additional ingredients were considered separately from the variable ingredients (modified cassava flour, sago flour, and cornstarch). The primary tool used to determine the optimal formulation and the relative percentage of each flour was Design Expert mixture design program with the D-optimal model.

RESULTS AND DISCUSSION

Determination of Seasoned Flour Formula Design

Based on the Design Expert program, 11 variations of the total flour composition were obtained without grouping, as part of an experimental design with 5 repetitions, resulting in 16 models of seasoned flour, as shown in Table 2. The results of physicochemical and sensory analysis of seasoned flour are presented in Table 3.

Table 2
Optimization design of seasoned flour formula using Design Expert

Formula	Modified cassava flour (%)	Sago flour (%)	Cornstarch (%)
1	40.0	29.9	18.0
2	38.9	29.1	20.0
3	42.3	29.7	16.0
4	42.5	27.7	17.8
5	37.5	30.8	19.7
6	38.9	32.5	16.6
7	38.9	32.5	16.6
8	40.4	27.6	20.0
9	42.5	27.7	17.8
10	40.7	31.3	16.0
11	40.4	27.6	20.0
12	38.7	31.0	18.3
13	37.5	32.4	18.1
14	41.0	28.5	18.5
15	37.5	30.8	19.7
16	42.3	29.7	16.0

Table 3
Input data from the response analysis results in Design Expert

Formula	Modified cassava flour (%)	Sago flour (%)	Corn starch (%)	OHC (%)	WHC (%)	Moisture content (%)	Sensory analysis				
							Color	Taste	Texture	Aroma	Over All
1	40.0	29.9	18.0	11.50	18.87	7.90	4.5	4.7	4.0	4.7	4.6
2	38.9	29.1	20.0	10.00	17.31	7.81	4.4	4.4	4.2	4.4	4.5
3	42.3	29.7	16.0	11.54	17.31	8.10	4.6	4.7	4.3	4.7	4.8
4	42.5	27.7	17.8	13.72	19.23	8.17	4.2	4.5	3.8	4.8	4.6
5	37.5	30.8	19.7	9.80	16.98	8.18	4.2	4.7	4.2	4.7	4.8
6	38.9	32.5	16.6	13.46	17.31	8.15	4.2	4.7	4.2	4.7	4.7
7	38.9	32.5	16.6	11.76	16.67	8.15	4.2	4.6	4.2	4.6	4.7
8	40.4	27.6	20.0	11.54	18.87	8.11	4.6	4.6	4.5	4.7	4.9
9	42.5	27.7	17.8	13.72	19.23	8.07	4.2	4.6	4.5	4.5	4.7
10	40.7	31.3	16.0	11.76	18.87	7.81	4.6	4.8	4.8	4.8	5.2
11	40.4	27.6	20.0	10.00	18.87	7.72	4.7	4.8	4.6	4.7	5.2
12	38.7	31.0	18.3	10.00	18.87	7.78	4.4	4.8	4.7	4.6	4.9
13	37.5	32.4	18.1	10.00	18.52	7.90	4.5	4.8	3.8	4.7	4.8
14	41.0	28.5	18.5	12.00	19.23	7.78	4.3	4.9	4.4	4.7	4.8
15	37.5	30.8	19.7	9.80	16.98	8.04	4.4	4.7	3.9	4.7	4.8
16	42.3	29.7	16.0	10.00	19.23	8.08	4.5	4.8	4.0	4.6	4.7

Water and Oil Holding Capacity

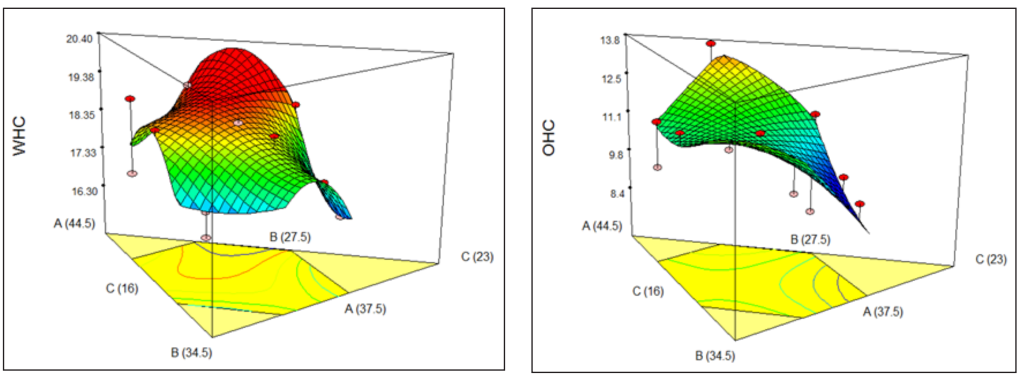
The ability of flour to retain water absorbed was measured by WHC. Smaller starch granules increased solubility and water absorption in flour, which was influenced by size and shape (Niba et al., 2001). The analysis showed that seasoned flour had WHC ranging from 16.67% to 19.23%. WHC value of this seasoned flour was lower compared to 22.06%–31.20% obtained from Herminiati et al. (2017). The results of the ANOVA test showed that the recommended model was a special cubic. The polynomial equation for WHC response is presented as follows.

$$\text{Water holding capacity (\%)}: Y = 13.25A + 12.14B + 4.17C + 24.42AB + 44.18AC + 37.85BC - 74.62ABC$$

Where:
A=Modified cassava flour
B=Sago flour
C=Cornstarch

Adding modified cassava flour, sago flour, and cornstarch significantly affected WHC of seasoned flour. Adding each flour component separately, as well as the two-component interactions (AB, AC, and BC), increased WHC value, confirmed by positive constant values. However, the interaction between the three components resulted in a decrease in WHC. Adding modified cassava flour had the most significant influence on increasing WHC, as it had the highest constant value.

A three-dimensional graph illustrating the interactions between the components is shown in Figure 1. Different response values are represented for each combination of formula components, based on the variation in surface height. The high areas corresponded to higher WHC response values, while the low areas corresponded to lower values.



(a) (b)

Figure 1. Three-dimensional graph of WHC and OHC: (a) WHC; (b) OHC

The ability of flour to retain the oil absorbed was measured by OHC. According to Adebowale et al. (2005), the ability to bind oil is influenced by the lipophilic groups coating the starch granules. The fat contents in starch, both in the granules and those covering the granules, created a hydrophobic surface, helping to bind oil components or other fats added externally. Therefore, the fat absorption capacity was influenced by the fat components in the starch granules. Flour with a high OHC value could absorb and retain more oil during frying. OHC measurements ranged from 9.8% to 13.72%. OHC value of this seasoned flour was lower compared to the 16.33% to 18.05% obtained by Herminiati et al. (2017). ANOVA test showed that the model for OHC response was quadratic. The polynomial equation for OHC response is presented as follows.

$$\text{Oil holding capacity (\%)}: Y = 12.85A + 14.01B + 3.85C - 8.59AB + 15.01AC + 2.08BC$$

Where:
A=Modified cassava flour
B=Sago flour
C=Cornstarch

Adding modified cassava flour, sago flour, and cornstarch significantly affected OHC of seasoned flour. Adding each flour component separately, as well as the two-component interactions (AC and BC), increased OHC, as confirmed by positive constant values. However, the interaction between AB components (sago flour and cornstarch) decreased OHC. Since sago flour had the highest constant value, its addition had a significant impact on increasing OHC.

Moisture Content

Products made with flour of high moisture content tended to clump and were more susceptible to microbial deterioration. In seasoned flour samples measured in this study, the moisture content ranged from 7.72% to 8.18%. This was lower than the moisture content of a composite of wheat, rice, green gram, and potato flour, ranging from 10.93% to 11.67% (Chandra et al., 2015). ANOVA test showed that the recommended model was quadratic. The polynomial equation for the moisture content response is presented as follows.

$$\text{Moisture content (\%)}: Y = 8.71A + 8.57B + 8.50C - 2.70AB - 2.67AC - 2.04BC$$

Where:
A=Modified cassava flour
B=Sago flour
C=Cornstarch

The analysis showed that the model was not statistically significant. The addition of modified cassava flour, sago flour, and cornstarch did not significantly affect the moisture content, likely due to their similar particle sizes and homogeneous mixing, which minimized variation in water-binding capacity. Adding each flour component separately increased moisture content, confirmed by positive constant values, while the interaction between components AB, AC, and BC decreased the moisture content. The polynomial model recommended by the Design Expert Program is a two-factorial interaction, but this model shows a very small Predicted R-Squared value, so it is necessary to do model reduction using backward elimination. Model reduction is done to eliminate the interaction of raw material components, because they are considered insignificant (do not meet $\alpha out = 0.1000$). Furthermore, the addition of modified cassava flour had the most significant influence on the increase in moisture content, as it had the highest constant value. A three-dimensional graph of moisture content response test results is presented in Figure 2.

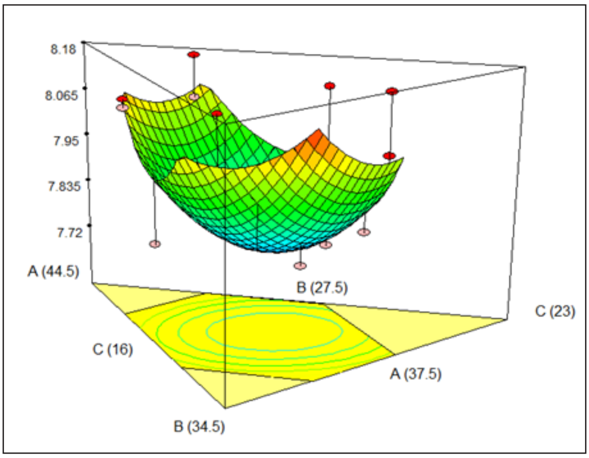


Figure 2. Three-dimensional graph of moisture content response

Sensory Evaluation

The results of the color response measurement produced values ranging from 4.2 to 4.7, showing that the panelists rated the color of the seasoned flour product as "slightly like" to "like." Based on the model analysis, the color response was cubic. The polynomial equation for the color response is presented as follows.

$$\text{Color: } Y = 2.86A + 2.30B + 11.64C + 8.09AB - 11.30AC - 10.60BC + 9.41ABC + 1.89AB(A-B) + 12.11AC(A-C) + 18.64BC(B-C)$$

Where:
A=Modified cassava flour
B=Sago flour
C=Cornstarch

The color response of seasoned flour was significantly affected by the addition of modified cassava flour, sago flour, and cornstarch. Adding each flour component separately, as well as the interaction between all three components (ABC), increased the color value, confirmed by a positive constant. However, the interaction between AC and BC components decreased the color value. The addition of cornstarch had the most significant influence on the increase in color value, as it had the highest constant value. Fried chicken products had a golden-brown color due to a non-enzymatic browning reaction, specifically the Maillard reaction.

Figure 3 shows the three-dimensional graph of the sensory evaluation and the interaction between the components. For each combination of formula components, the variation in surface height represented a different response value. The high areas corresponded to higher response values, while the low areas corresponded to lower response values.

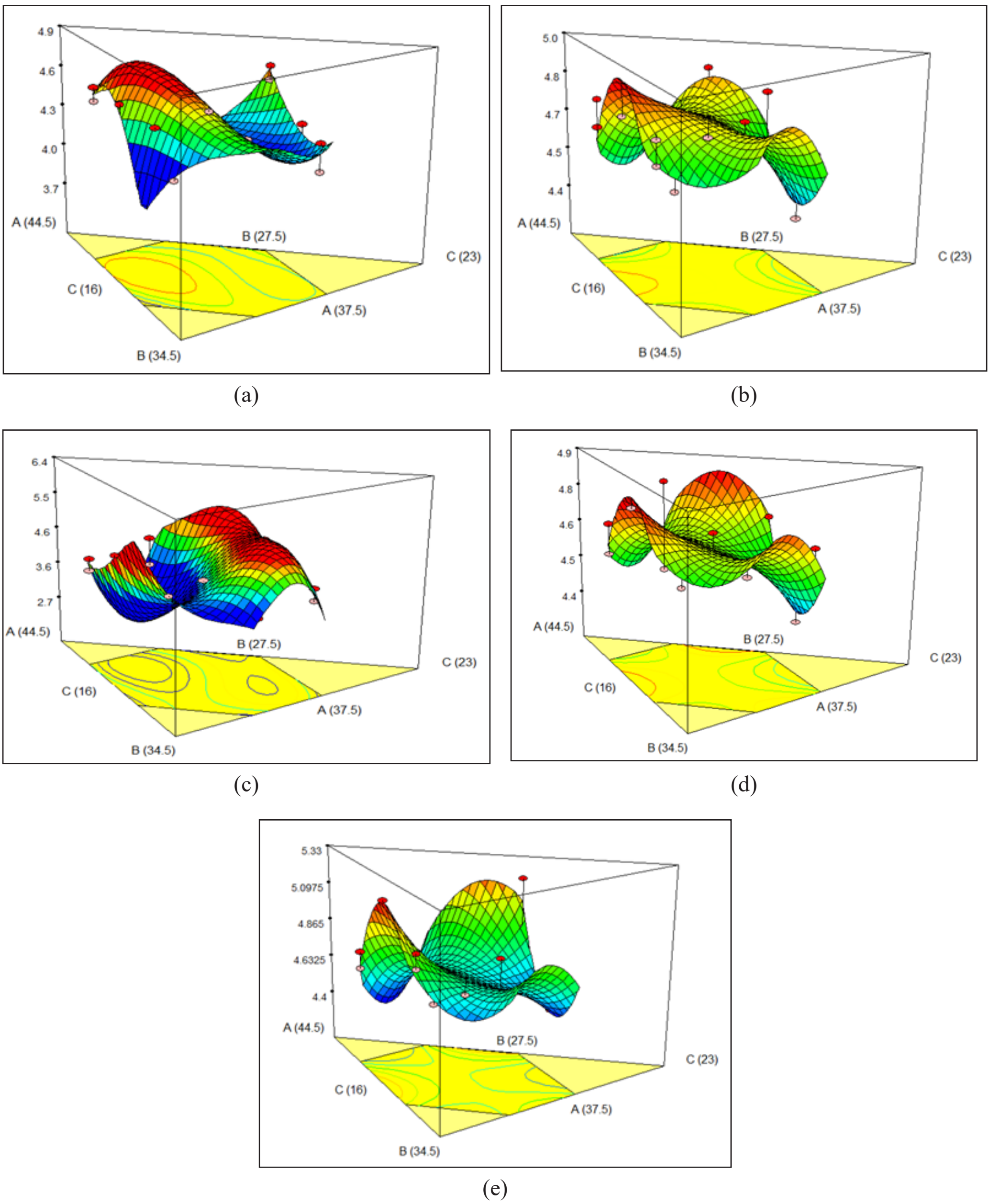


Figure 3. Three-dimensional graph of sensory evaluation: (a) color; (b) taste; (c) texture; (d) aroma; (e) overall

The results of the taste response measurement produced values ranging from 4.4 to 4.9. Fried chicken, coated with seasoned flour, tasted savory. Sensory acceptance value showed that panelists tended to rate the taste of fried chicken seasoned flour products more favorably. Based on the model analysis, the taste response was a special cubic. The polynomial equation for the taste response is presented as follows.

$$\text{Taste: } Y = 3.43A + 3.68B + 2.38C + 5.47AB + 7.62AC + 6.90BC - 17.16ABC$$

Where:
A=Modified cassava flour
B=Sago flour
C=Cornstarch

ANOVA test showed that the taste response of seasoned flour was not significantly affected by the addition of modified cassava flour, sago flour, or cornstarch. Adding each flour component separately increased the taste value, confirmed by a positive constant. However, the interaction between ABC components decreased the taste value. The increase in taste value was most significantly influenced by the addition of sago flour, which had the highest constant value.

Texture is a parameter that can be evaluated through the sense of taste (mouthfeel) or touch (handfeel). In this study, panelists only evaluated mouthfeel. In coated fried products, crispiness was influenced by the ability of the coating flour to absorb and retain water. Texture is closely related to a product's crispiness, a sensation associated with detecting small cracks in the mouth, often accompanied by the sound of food cracking or breaking (Van Vliet et al., 2007).

$$\begin{aligned}\text{Texture: } Y = {} & 8.52A + 3.51B - 29.57C - 5.81AB + 63.28AC + 69.17BC - \\ & 103.04ABC - 19.17AB(AB) - 67.22AC(A-C) - 52.46BC(B-C)\end{aligned}$$

Where:
A=Modified cassava flour
B=Sago flour
C=Cornstarch

ANOVA test showed that adding modified cassava flour, sago flour, and cornstarch did not significantly affect the texture response of seasoned flour. Adding flour components, A and B separately, as well as the interaction between components AC and BC, increased the crispy texture value, confirmed by a positive constant. Meanwhile, the interaction between components AB and ABC decreased the crispy texture value. The addition of cornstarch had the most significant influence on the increase in crispy texture value, as it had the highest constant value. The type of flour or oil and the seasoned flour ability to absorb and retain water were the main factors affecting the crispness of seasoned flour. The analysis showed that the OHC value of seasoned flour was lower than the WHC value. The higher the WHC, the greater the ability of the material to absorb and retain water. In products like seasoned flour or dough, high WHC allows the product to absorb more water or liquid, increasing the consistency or viscosity of the final product.

The emergence of food aroma was caused by the formation of volatile compounds that easily evaporate. The results of the aroma response measurement ranged from 4.4 to 4.8, confirming that the panelists generally liked the aroma of seasoned flour. Based on the analysis, the aroma response model was a special cubic. The polynomial equation for the aroma response is presented as follows.

Aroma: $Y = 3.76A+4.00B+2.90C+3.79AB+5.92AC+4.99BC-15.01ABC$

Where:
A=Modified cassava flour
B=Sago flour
C=Cornstarch

The addition of modified cassava flour, sago flour, and cornstarch did not significantly affect the aroma response of fried chicken seasoned flour. Adding flour components separately, as well as the interaction between AB, AC, and BC components, increased the aroma value, confirmed by a positive constant. However, the interaction between ABC components decreased the aroma value. The addition of sago flour had the most significant influence on increasing the aroma value because it had the highest constant value. Fried chicken coated with seasoned flour had a distinctive aroma due to the addition of pepper seasoning. The unique properties of pepper include its spicy taste and characteristic aroma. The distinctive aroma also comes from garlic, containing allicin, a chemical compound (Borlinghaus et al., 2021).

The results of the overall response measurement produced values ranging from 4.5 to 5.2, confirming the model to be cubic. The polynomial equation for the overall response is presented as follows.

Overall: $Y = 2.76A + 3.49B + 2.29C + 8.20AB + 10.59AC + 7.90BC - 30.02ABC$

Where:
A=Modified cassava flour
B=Sago flour
C=Cornstarch

Adding modified cassava flour, sago flour, and cornstarch significantly affected the overall response of fried chicken seasoning flour. Adding flour components separately, as well as the interaction between AB, AC, and BC components, increased the overall value, confirmed by a positive constant. However, the interaction between ABC components decreased the overall value. Sago flour had the most significant impact on the overall value increase, followed by modified cassava flour and cornstarch.

Optimization of Seasoned Flour Formula Using D-Optimal Method

The desirability value represents the desired optimization value that can be attained. A desirability index closes to 0 means it will be difficult for the crispy chicken seasoned flour formula to reach the optimal point based on response variables. Meanwhile, a desirability value close to 1 means seasoned flour formula can achieve the optimal formula according to the desired response variables. Using Design Expert program, the optimized components, goal values, limits, and importance at the formula optimization stage are presented in Table 4.

Table 4
Attributes and optimization criteria for seasoned flour formula

Component/ response	Goal	Lower Limit	Upper Limit	Importance
Modified cassava flour	*Maximize*	37.5	42.50	5 (+++++)
Sago flour	*is in range*	27.5	32.50	3 (+++)
Cornstarch	*is in range*	16	20.00	3 (+++)
OHC	*Minimize*	9.8	13.72	5 (+++++)
WHC	*Maximize*	16.67	19.23	5 (+++++)
Moisture content	*Minimize*	7.72	8.18	5 (+++++)
Color	Maximize	4.2	4.70	5 (+++++)
Taste	*Maximize*	4.4	4.90	5 (+++++)
Texture	*Maximize*	3.8	4.80	5 (+++++)
Aroma	*Maximize*	4.4	4.80	5 (+++++)
Overall	*Maximize*	4.5	5.20	5 (+++++)

The optimization stage provided one of the best formula solutions from several suggested formulas, with the highest desirability value of 0.774. The composition of the solution is presented in Table 5. Design Expert program recommended one formula solution with a desirability value closest to 1; hence, the formula could be used for the next test stage.

Table 5
Optimization stage formula solution

Modified cassava flour	Sago flour	Cornstarch	Desirability
41.00	31	16.00	0.774*
40.70	27.6	19.80	0.734
39.50	30.3	18.10	0.583

* The best formula

The best combination comprised 41% modified cassava flour, 31% sago flour, and 16% cornstarch, making up the chosen solution. With a desirability value of 0.774, this formula was expected to meet 77.4% of the optimization target. The formula was anticipated to achieve an organoleptic score of 4.6 for color, 4.9 for taste, 4.6 for texture, 4.8 for scent, and 5.2 for overall quality. It was also expected to have an OHC of 11.3%, WHC of 18.80%, and a moisture content of 7.96%. Figure 4 presents the three-dimensional graph of the optimum formula. In this graph, a low desirability value is represented by the low area, while a high desirability value is shown by the high area.

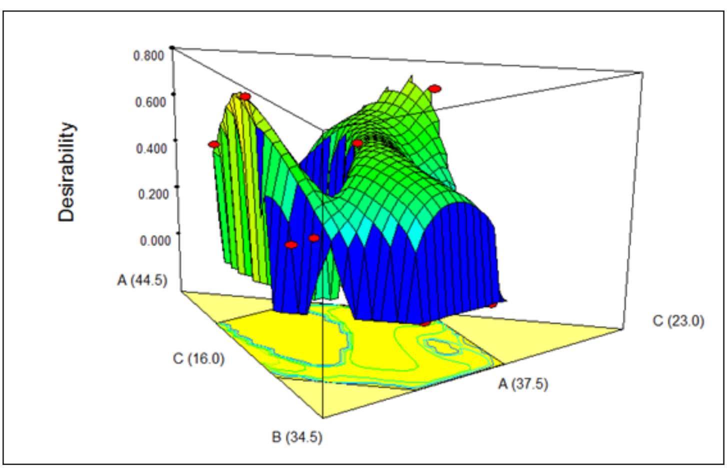


Figure 4. Three-dimensional graph of optimum formula

Verify Optimization Result Formula

The outcomes of the verification step and the predictions made for each response are presented in Table 6. Based on the verification, the data fell in the range predicted by Design Expert program. This was confirmed by the 95% confidence interval (CI) for

WHC, OHC, moisture content, and sensory attributes (color, taste, texture, aroma, and overall acceptance).

Table 6
Results of the verification stages

Response	Results		95% CI low	95% CI high	95% PI low	95% PI high
	Prediction	Verification				
OHC (%)	11.29	12.00	10.00	12.58	8.70	13.88
WHC (%)	18.80	18.52	17.64	19.96	16.92	20.68
Moisture content (%)	7.96	8.06	7.77	8.16	7.57	8.36
Color	4.59	4.6	4.40	4.78	4.31	4.88
Taste	4.92	5.0	4.73	5.12	4.61	5.24
Texture	4.59	4.5	4.08	5.10	3.81	5.37
Aroma	4.83	4.7	4.68	4.98	4.58	5.08
Overall	5.18	5.2	4.99	5.37	4.87	5.49

Characterization of Seasoned Flour Optimal Formula

Moisture, ash, protein, fat, carbohydrate (by difference), and resistant starch content, as well as WHC and OHC obtained from seasoned flour, were analyzed for optimization. Table 7 presents the results of the comprehensive proximate analysis of seasoned flour for crispy fried chicken.

Compared to seasoned flour from Alfani et al. (2019), seasoned flour from this study had a lower water content but higher fat, crude fiber, carbohydrate, and protein content. Seasoned flour from Omeje et al. (2021) had lower crude fiber, ash, and carbohydrate content but higher fat and protein content compared to this study.

Moisture content of seasoned flour met the requirements of the Indonesian National Standards (Badan Standardisasi Nasional, 1998), stipulating a maximum moisture content of 12%. However, the crude fiber content of seasoned flour did not comply with the standards, specifying a maximum crude fiber content of 1.5%. Protein, fat, and carbohydrate content of seasoned flour was not specified in the standards, but the components were suitable for meeting the body's calorie needs. Ash content of seasoned flour did not comply with the standards, also requiring a maximum ash content of 1.5%. The high ash content can be attributed to the addition of seasonings such as salt and baking soda, inorganic salts that remain as ash after ashing. To reduce the high ash content in food ingredients, it can be considered to use soaking methods, using additional ingredients (such as starfruit leaf extract), or choosing types of food ingredients with lower ash content.

The high WHC of seasoned flour allowed the retention of water absorbed during dough preparation. The relatively low OHC of seasoned flour enabled the dough to absorb only a small amount of oil during frying. The resistant starch content in seasoned flour was 5.01±0.01. This component was beneficial for the body, particularly the digestive system. Resistant starch formed a physical barrier that slowed the access of digestive enzymes to starch particles and could reach the large intestine without being altered. As a prebiotic, resistant starch has an advantage over FOS (fructose-oligosaccharides) and inulin because it can bind and retain water in stools, preventing constipation and flatulence, even when consumed in high amounts (Ozturk et al., 2011).

Table 7
Physicochemical and functional composition of optimized seasoned flour

Response	**Value (%)**
Moisture content	8.06±0.06
Ash content	6.32±0.08
Protein content	2.67±0.03
Fat content	0.40±0.00
Crude fiber content	2.24±0.07
Carbohydrate content	80.31±0.12
Resistant starch	5.01±0.01
Water holding capacity	18.52±0.00
Oil holding capacity	12.00±0.00

Commercial seasoned flour available in the market is made from wheat flour, which lacks high-quality protein due to a deficiency of lysine, and also has low dietary fiber content. In this study, seasoned flour was made without wheat flour, incorporating sago flour and cornstarch to improve nutritional content, particularly resistant starch and fiber content. Therefore, the use of non-wheat seasoned flour was expected to support the local food-based processing industry, as the import of wheat flour was crucial.

CONCLUSION

In conclusion, this study showed that a blend of 41% modified cassava flour, 31% sago flour, and 16% cornstarch produced the best seasoned flour formula, with a desirability value of 0.774. Moreover, the verification results showed that the selected formula had an overall assessment score of 5.2, with individual scores of 4.6 for color, 5.0 for taste, 4.5 for texture, 4.7 for scent, and WHC of 18.52%, along with a moisture content of 8.06%. The composition of the best formula for seasoned flour was 8.06% moisture, 6.32% ash, 2.67% protein, 0.40% fat, 80.31% total carbohydrates, and 5.01% resistant starch. WHC was 18.52%, and OHC was 10.20%. Based on analysis, the use of modified cassava flour, sago flour, and cornstarch produced an acceptable seasoned flour with good physical, chemical, and functional properties. Therefore, the combination of several types of flour into seasoned products was an effective method to increase acceptance and address the problem of malnutrition in the community.

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