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Optimization of the sensorial quality of Saka Saka, a dish made from cassava leaves

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The goal was to improve Saka Saka's sensory quality. The study analyzed Saka Saka samples by pre-treating cassava leaves, mixing ingredients, and optimizing color, odor, and taste. The data was analyzed using Minitab 17.3.1 software, with replicates varying. The sensory evaluation of Saka Saka samples showed acceptable characteristics, with scores ranging from 5 to 8. The most appreciated characteristic was color, followed by odor and taste. Garlic had a greater influence on color and taste. The study found that sugar and maggi broth components did not significantly influence smell or taste at tested doses. The optimal Saka Saka sample had scores ranging from 5 to 9, with the most appreciated quality characteristic being taste. The product contained 7.69% protein, 0.34% calcium, 0.09% magnesium, 0.013% iron and 0.12% phosphorus, confirming its nutritional importance.

Key words: Cassava leaves, sensorial, evaluation, optimization.

INTRODUCTION

Cassava leaves are a vital component of traditional diets worldwide, providing essential nutrients, protein, vitamins, and minerals (Latif and Müller, 2015). They are rich in vitamins A and C, iron, and calcium, and contribute to dietary diversity (Awoyinka et al., 1995; Montagnac et al., 2009). Cassava leaves are also culturally significant, being incorporated into traditional dishes and contributing to the preservation of knowledge and culinary heritage (de Oliveira Gonçalves et al., 2024; Ola and Adedayo, 2020). The large, green palmate leaves contribute to photosynthesis and nutrient cycling, making them a versatile component of diets (Scaria et al., 2024).

Cassava leaves are adapted to various environmental conditions and are crucial for food security in developing countries (Amelework et al., 2023; Cock and Connor, 2021). They are low in calories and carbohydrates, making them suitable for those seeking low-carbohydrate options (Latif and Müller, 2015). Cassava leaves are used in various global cuisines (Lancaster and Brooks, 1983).

Research on cassava leaves is ongoing, exploring its nutritional content, antioxidant properties, anti-inflammatory effects, potential cancer benefits, iron absorption, anemia prevention, gut health, immunomodulatory effects, metabolic health, and hepatoprotective properties (Mohidin et al., 2023). Cassava leaves contain anti-nutritional factors that can cause cyanide poisoning, kidney stones, reduced mineral

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bioavailability, iron deficiency, and protein digestion issues (Jamil and Bujang, 2016; Latif and Müller, 2015). Mitigation strategies include proper cooking, fermentation, a diverse diet, and public awareness campaigns (Sathischandra, 2022).

Cassava leaves undergo various processing techniques to improve their nutritional and sensory qualities. However, they face challenges in integrating into diets and economies, including post-harvest losses, cultural perceptions, and processing constraints.

The aim of optimizing the sensory quality of Saka Saka, a cassava leaf dish, is to improve color, odor and taste to meet consumer satisfaction.

MATERIALS AND METHODS

Fresh and young cassava leaves and ingredients were provided by the sellers from Total market in Brazzaville. The oven, Soxhlet apparatus, muffle furnace, UV-VIS spectrophotometer and Kjedhal instruments were available in the Laboratory of Agriresources Valorization at the National Polytechnique High School, Brazzaville.

The equipment and other materials used for mineral determination have been found at the National Research Institute for Exact and Natural Sciences at Pointe Noire.

Pre-treatment of cassava leaves

In order to prepare the Saka Saka samples for analysis, the cassava leaves were pre-treated. Thus, each sample of 300 g of shredded fresh leaves, cleaned beforehand, was washed three consecutive times with 200 ml fractions of drinking water and dried at 40°C for 1 h. The treated ground materials were mixed with the different combinations of ingredients in accordance with the experimental matrices.

Preparation of samples

Two experiments were performed to optimize the color, odor, and taste of Saka Saka cooked according to the previously optimized process (Alamu et al., 2021). For this purpose, two centered mixture designs increased with the points on the axes and with two components each were practiced to evaluate the combined effects of garlic and onion on one hand and sugar and maggi broth on the other hand on the color, odor, and taste of Saka Saka. The lower and upper levels of each component were set at 0 and 10 g, respectively, for a single total of 10 g. Each combination of components was mixed with 300 g of Saka Saka sample, 50 g of refined palm oil, and 600 ml of water. The five samples were fired simultaneously in the oven at 100°C for 1 h and 30 min.

Sensory evaluation of samples

All Saka Saka samples, including the prototype obtained after optimization, were evaluated for their color, odor, and taste by a panel of 8 to 10 non-experienced assessors. The assessors received, in addition to the samples, a paper towel, a glass of mineral water, five spoons, biscuits, and an evaluation form. They were asked to taste and appreciate the 5 samples on a hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely), passing through intermediate levels. Each assessor received five bread samples, corresponding to the different formulations.

Preparation of the prototype sample

This experiment consisted of preparing a stock of Saka Saka in accordance with the formulation optimized at the end of the previous tests. Samples of this formulation were then evaluated.

Characterization of the prototype sample

Determination of ash content

The ash content was obtained by dry ashing of 2 g of sample at 550°C in a muffle furnace overnight (Harris and Marshall, 2017). The product was weighed and its percentage calculated with respect to the fresh mass of the sample.

Determination of water content

The water content was determined by dehydrating the 5 g of sample at 105°C for 6 h (Joslyn, 1950). The mass of evaporated water was calculated by difference between the initial mass and the final mass of the sample. Its percentage was calculated with respect to the initial mass of the sample.

Determination of total lipids

Total lipids were determined by the Soxhlet method (Ellefson, 2017). Thus, the hexane extraction of these lipids was carried out from 50 g of sample previously dehydrated in a 125 ml Soxhlet for 16 h. The solvent evaporated, and the product was weighed. The percentage of lipids was calculated relative to the fresh mass of the sample.

Determination of minerals

Calcium and magnesium were determined by the versenate titration method (Banewicz and Kenner, 2002).

Phosphorus was determined by the colorimetric method using molybdate and ascorbic acid (Fogg and Wilkinson, 1958). Iron was determined by colorimetry (Siong et al., 1989).

Data analysis

The data were analyzed after deleting outliers from the raw data. The effects of the factors studied were examined by the analysis of variance at the 5% significance level and Pareto plots of the effects. The regressions were considered significant according to the plots of the residuals and the values of the regression coefficients. The data was processed using Minitab 17.3.1 software. To process the data in Minitab, we redesigned the experiments that prepared the samples. The only difference was the number of replicates, which this time was the product of the number of formulations and the number of assessors. We must point out that the incorrectly completed forms have been discarded (Chatterjee and Simonoff, 2013).

RESULTS

Effects of garlic and onion

The results of the sensory evaluation are shown in Table

Table 1. Scores of the odor of Saka Saka versus garlic and onion proportions.

Run	Garlic	Onion	Color	Odor	Taste	Run	Garlic	Onion	Color	Odor	Taste
1	0	10	7	6	6	18	5	5	7	7	7
2	0	10	5	6	1	19	5	5	7	6	5
3	0	10	5	6	4	20	5	5	7	7	6
4	0	10	6	5	4	21	7.5	2.5	7	7	6
5	2.5	7.5	7	7	7	22	7.5	2.5	7	7	3
6	2.5	7.5	8	7	3	23	7.5	2.5	9	6	8
7	2.5	7.5	5	5	1	24	7.5	2.5	7	6	2
8	2.5	7.5	6	6	5	25	10	0	7	7	6
9	2.5	7.5	7	5	5	26	10	0	8	6	3
10	2.5	7.5	8	6	5	27	10	0	5	6	5
11	2.5	7.5	7	7	5	28	10	0	6	8	5
12	5	5	7	7	7	29	10	0	8	8	6
13	5	5	8	7	3	30	10	0	9	6	8
14	5	5	8	7	1	31	10	0	8	8	6
15	5	5	6	6	6	32	10	0	6	6	6
16	5	5	5	6	6	33	10	0	7	6	6
17	5	5	6	7	6	34	10	0	7	7	5

Table 2. Regression parameters for the garlic and onion mixture.

Component	Characteristics	R-Sq (%)	R-Sq(pred) (%)	R-Sq(adj) (%)	Regression (%)	P (%)
Garlic	Color	23.54	6.46	18.27	Linear	0.006
	Odor	18.92	3.38	13.69	Linear	0.011
Onion	Taste	55.09	39.98	49.47	Quadratic	0.000

1. The scores vary between 5 and 8; that is, they are above average. It can be said that, on the whole, the samples were acceptable for the characteristics studied. The comparisons of the mean scores of the three characteristics were done by the ANOVA test, followed by the Tukey test, which gave a p value equal to 0.000, indicating the existence of at least one difference between the means at the 5% significance level. Color was the most appreciated characteristic, with an average score of 6.853, followed by odor (6.472) and taste (5.061).

Regression analysis for color, odor, and taste according to garlic and onion

The regression analysis gave the p values = 0.020, 0.011, and 0.002 < 0.05, respectively, for color, odor, and taste (Table 2). The values of R-squares were under 25% except for those with a taste that ranges between 40 and 55%.

Verification of regression hypotheses based on the garlic and onion mixture

The results of the analyses of the other regression assumptions are shown in Figures 1 to 3. It appears that the residuals follow a normal distribution in accordance with their alignment around the Henry line. They are randomly arranged according to the fitted values and do not show any particular trend according to the observations. The normality of the residual values was confirmed by the Anderson-Darling test, which gave a p value of 0.568 and 0.092>0.05, respectively, for color and taste, although that of odor was 0.007. However, the odor residual plots are similar to those of a normal distribution.

Normal probability plot: The points generally follow the straight line, it suggests that the data approximately follows a normal distribution, supporting the assumptions of statistical tests and models that require normality.

Fitted values versus residual plot: A well-fitting model should display a random scatter of points with no clear

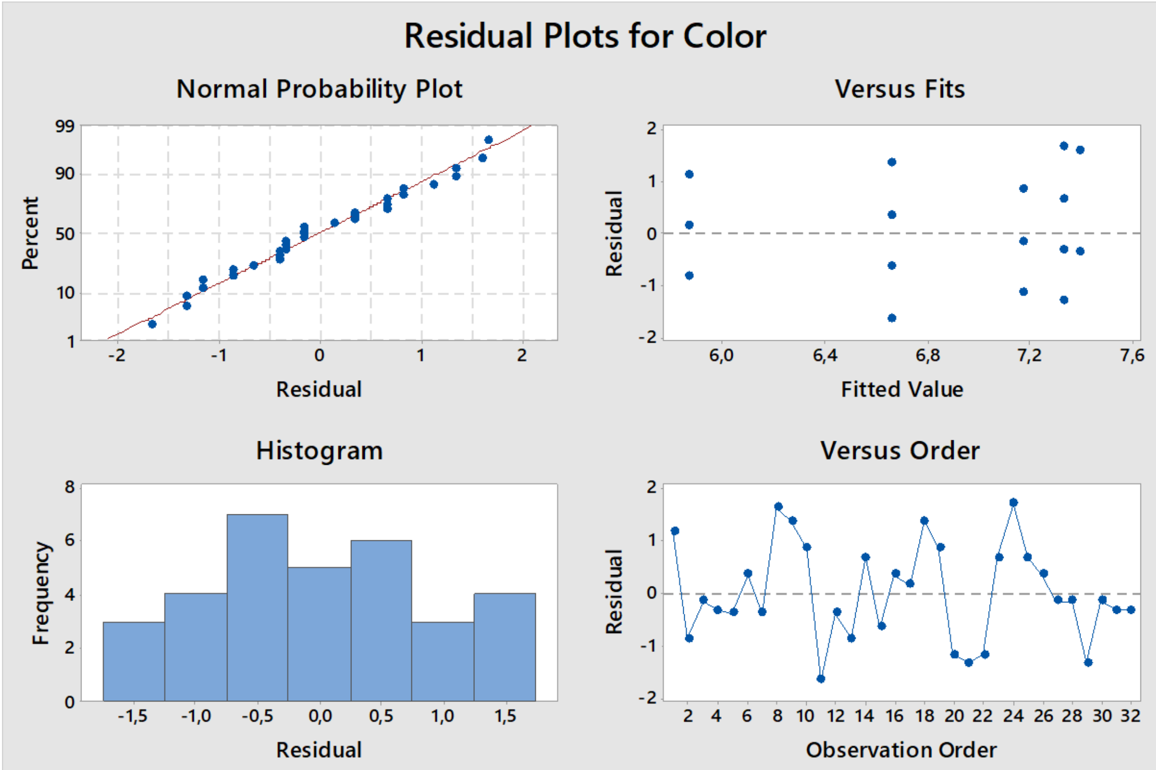

Figure 1. Residuals plot for color with garlic and onion.

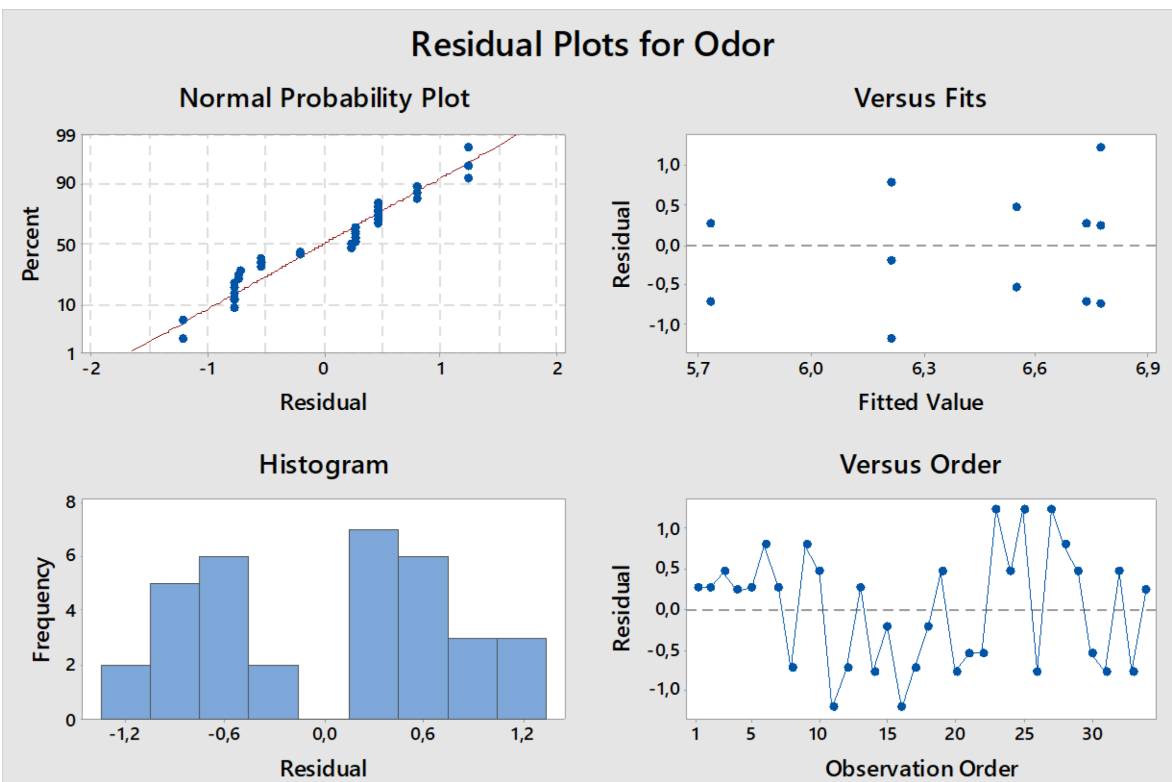

Figure 2. Residuals plot for odor with garlic and onion.

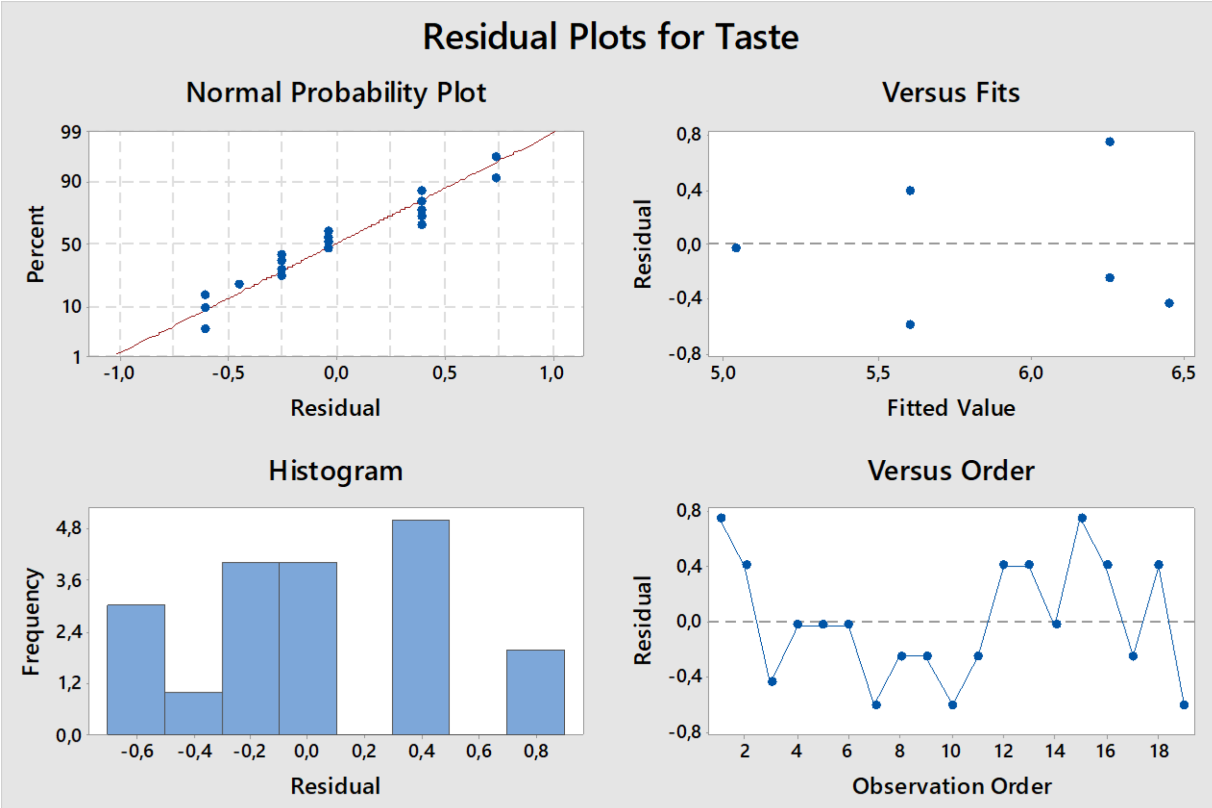

Figure 3. Residuals plot for taste with garlic and onion.

pattern or trend, indicating the model's assumptions are met.

Residuals versus order plot: Random scatter indicates random model errors, systematic patterns suggest missing important factors, and autocorrelation in time series analysis suggests the model does not account for temporal dependencies in data.

Histogram of residuals: A bell-shaped curve indicates normality and predictability.

Modeling and optimization of the three characteristic scores with garlic and onion

The results led, in accordance with the values of the coefficients found, to the writing of the following model equations:

z;

$$Y_2 = 0.677123X_1 + 0.573253X_2 + 0.0118237X_1X_2 ;$$

$$Y_3 = 0.733198X_1 + 0.586591X_2 + 0.0228140X_1X_2;$$

where Y_1, Y_2, and Y_3 represent respectively the adjusted scores of color, odor, and taste, and X_1, and X_2 being the garlic and onion proportions, respectively.

Although the interaction effects were not significant for color and odor, we included them in the models to have better R-squared values.

The optimization results are as shown in Figures 4 to 6 and resumed in Table 3. We observed that garlic had more influence on the three characteristics. A mixture of 81% garlic and 19% onion made it possible to obtain an overall appreciation score of 6.89.

The vertical red lines on the chart represent the current factor settings. The numbers at the top of a column indicate the current factor level settings (in red). The blue horizontal lines and numbers represent responses relative to the current factor level.

Effect of sugar and maggi broth mixture on taste

The results of the scores for the three characteristics color, odor, and taste are shown in Table 4. It can be seen that the maximum scores of 8 and a minimum of 4 were reached for certain samples. The majority of scores, 44 out of 48, were above 5. The product was accepted by assessors. The comparison of mean scores using the ANOVA gave a p value equal to 0.164, which indicates the absence of a significant difference between the

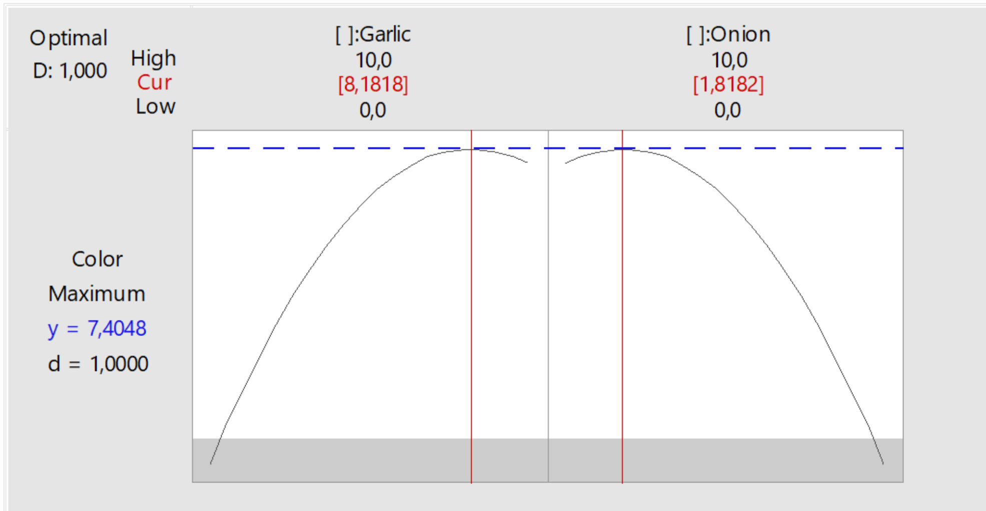

Figure 4. Optimization plot for color with garlic and onion.

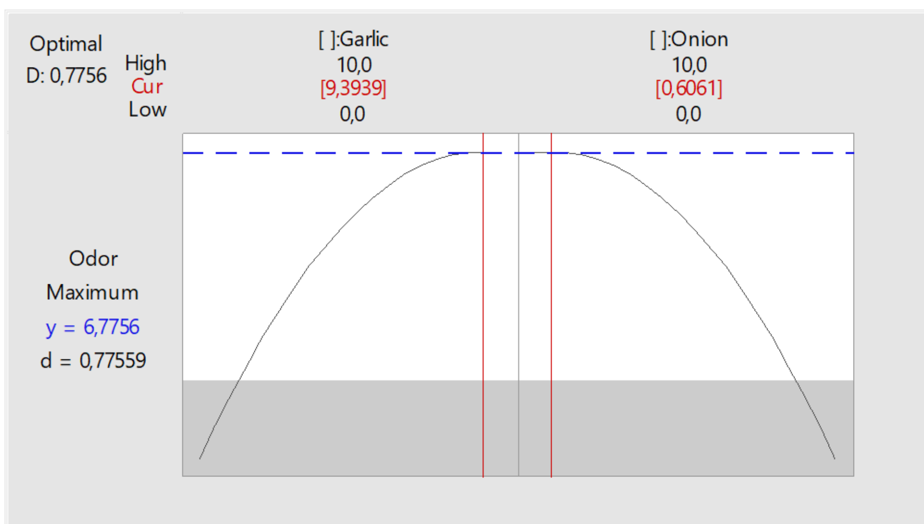

Figure 5. Optimization plot for odor with garlic and onion.

means at the 5% level of significance. However, taste was relatively the most appreciated characteristic, with an average score of 6.938, followed by color (6.750) and odor (6.313).

Regression analysis for mixtures: Color, odor, and taste as a function of sugar and maggi

The results of the regression analyses shown in Table 5 gave a p value equal to 0.264, above the significance level of 5% for odor. This means that the sugar and maggi broth components did not influence the odor of Saka Saka at the doses tested. In addition, the interaction effect between these two components had no significant effect (p = 0.336). The coefficients of determination were also low (R squared = 18.52%, R squared (Pred) = 0.00%, and R squared (adj) = 5.98%). On the other hand, the p-values for the linear and quadratic regressions were equal to 0.000<0.05 for color and taste, indicating significant regressions. Similarly, the interactions between the two components had significant effects on color (p = 0.000) and taste (p = 010). The coefficients of determination values for the regressions were also high and equal to R squared = 92.59%, R squared (Pred) = 89.84%, and R squared (adjust) = 91.45% for color, and R squared = 83.12%, R squared (Pred) = 75.20%, and R squared (adj) = 80.52% for odor.

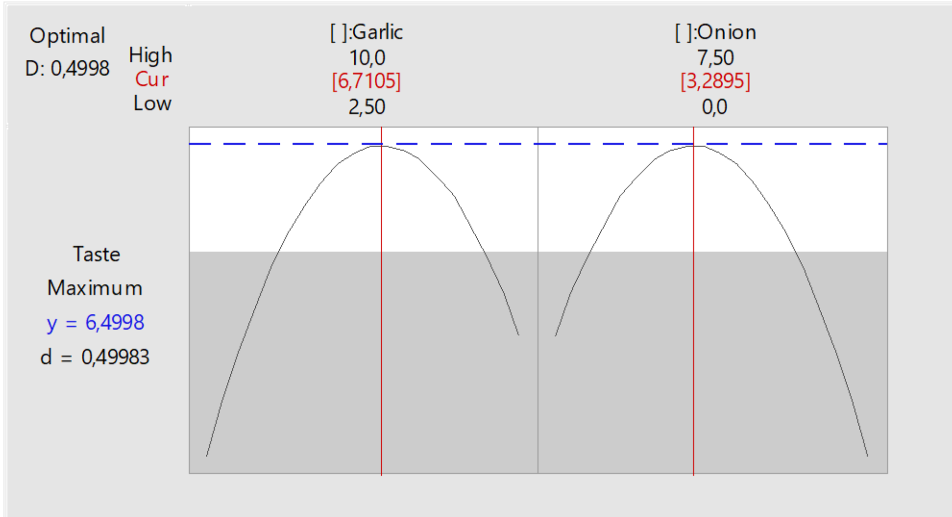

Figure 6. Optimization plot for taste with garlic and onion.

Table 3. Optimization of Saka Saka color, odor, and taste with garlic and onion.

Characteristics	Garlic	Onion	Score
Color	8.1818	1.8182	7.4048
Odor	9.3939	0.6061	6.7756
Taste	6.7105	3.2895	6.4998
Mean	8.0954	1.9046	6.8934
Percentage	80.954	19.046	-

The models fit the data well and can predict responses effectively.

Verification of color regression assumptions based on sugar and maggi mixtures

In accordance with the residual value plots presented in Figure 7, the validation hypotheses of the applicability of the least squares method are not verified. The points of the normal probability plot do not align around the Henry line. This is confirmed by the p value of the Anderson-Darling test, which is less than 0.005. The residual plot versus order also shows a cyclic trend, indicating that the variables are dependent. So, the regression of the color versus maggi broth and sugar was rejected.

Verification of taste regression hypotheses based on sugar and maggi broth mixtures

The residual value diagrams shown in Figure 8 as well as the result of the Anderson-Darling normality test (P = 0.055>0.05) confirm that: the residual values are normally distributed; the variables are independent since the residual values do not show any particular trend either according to the fitted values or to the observations.

Modeling and optimization of color and taste scores with sugar and maggi

The equations for the color and taste score regression models are written as follows:

$$Y_1 = 0.605556X_1 + 0.605556X_2 - 0.04444444X_1X_2$$

$$Y_2 = 0.422222X_1 + 0.805556X_2 + 0.0511111X_1X_2\ ;$$

where Y_1 and Y_2 represent the respective scores of color and taste and X_1 and X_2 are the respective proportions of sugar and maggi broth.

In accordance with the result of the optimization given in Figures 9 and 10, it appears that a mixture of 4,94949 g of sugar and 5,05051 g of maggi makes it possible to predict a color score of 7, and a mixture of 1.2121 g of

Table 4. Color, odor, and taste scores for Saka Saka assigned by the assessors.

Run	Sugar	Maggi	Color	Odor	Taste	Run	Sugar	Maggi	Color	Odor	Taste
1	0	10	6	6	8	9	5	5	7	6	8
2	0	10	6	7	8	10	5	5	7	6	8
3	2.5	7.5	7	7	8	11	7.5	2.5	7	6	6
4	2.5	7.5	7	7	9	12	7.5	2.5	7	7	5
5	2.5	7.5	7	6	8	13	7.5	2.5	7	7	6
6	2.5	7.5	7	6	7	14	7.5	2.5	7	6	6
7	5	5	7	7	8	15	10	0	6	5	4
8	5	5	7	6	7	16	10	0	6	6	5

Table 5. Regression parameters for the sugar and maggi mixture.

Component	Characteristics	R-Sq (%)	R-Sq(pred) (%)	R-Sq(adj) (%)	Regression (%)	P (%)
Sugar	Color	92.59	89.84	91.45	Quadratic	0.000
	Odor	18.52	0.00	5.98	Regression	0.264
Maggi	Taste	83.12	75.20	80.52	Quadratic	0.010

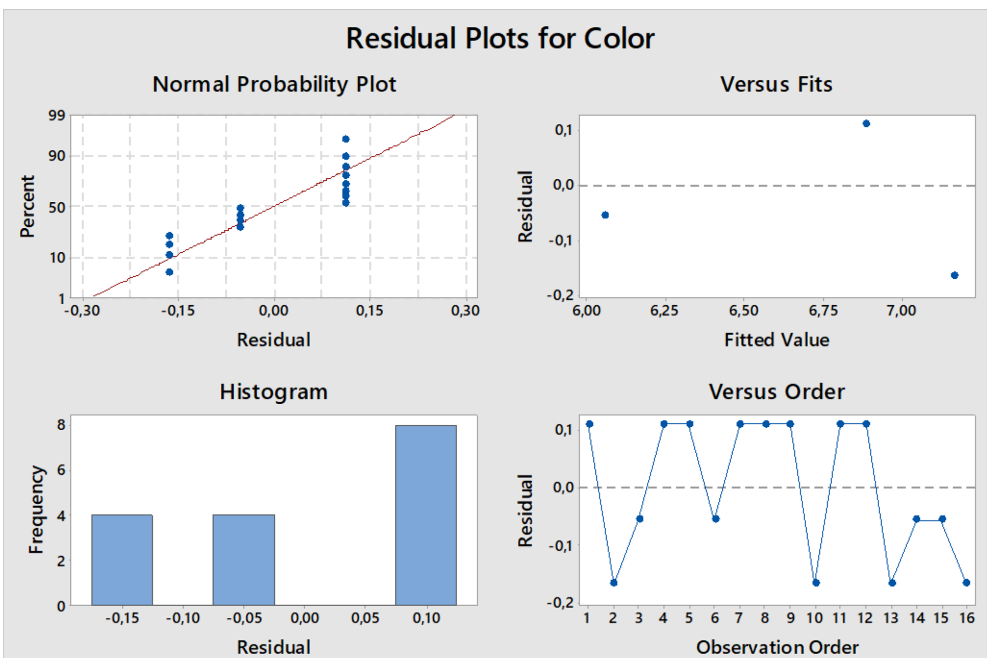

Figure 7. Residual plots for color with sugar and maggi.

sugar and 8.7879 g of maggi predicts a taste score of 8.

Optimal formulation

The results led us to develop the optimal formulation shown in Table 6.

Confirmation of optimal formulation

Sensory evaluation

The results of the sensory evaluation of the optimal Saka Saka sample, prepared based on the formulation resulting from the previous experiments (Table 6), are

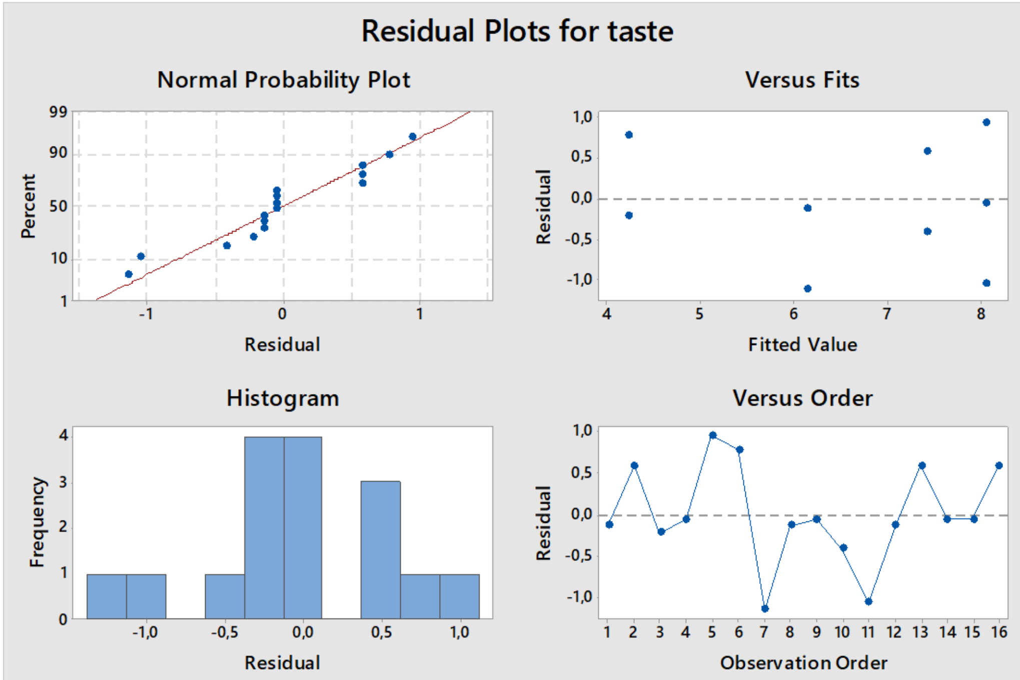

Figure 8. Residual plots for taste with sugar and maggi.

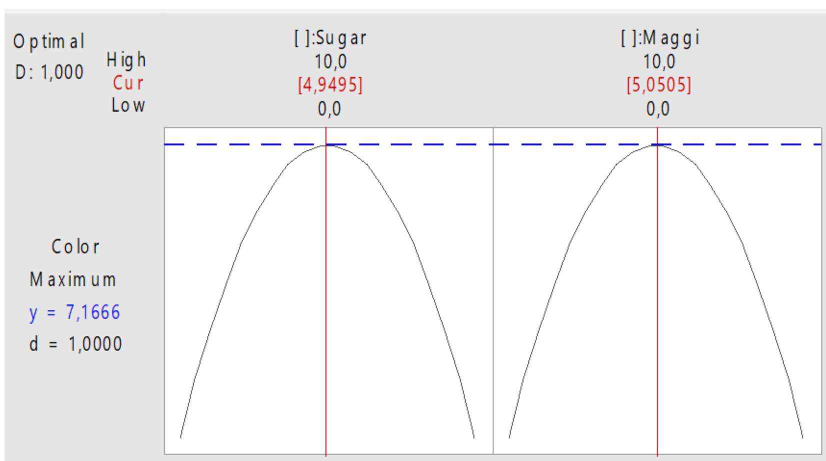

Figure 9. Optimization diagram of color.

given in Table 7. It appears that the scores vary from 5 to 9, with averages of 6 to 7. This wording was therefore accepted by the assessors. The results of the comparisons of the characteristic scores by the analysis of variance and the Tukey test are as shown in Figure 11 and Table 8. It can be seen that there was no significant difference between the means of the odor and color scores. On the other hand, there was a significant difference between the mean scores of these two characteristics and those of taste. The most appreciated quality characteristic was taste, with an average score of 7.707, followed by odor (6.817) and color (6.633). These findings confirm the predictions.

The intervals do not overlap and the error bars do no overlap, indicating significant differences between groups. Conversely, a significant overlap of intervals and error bars suggests similarities in group averages.

Physicochemical characteristics of the optimal formulation

The product obtained contained 7.69% protein, 0.34% calcium, 0.09% magnesium, 0.013% iron, and 0.12%

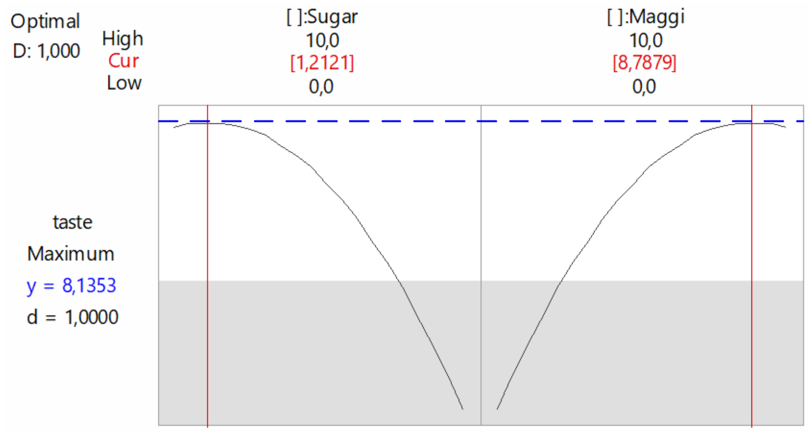

Figure 10. Optimization diagram of taste.

Table 6. Optimal formulation of Saka Saka with the ingredients studied.

Ingredients	Quantities (g)	Percentage
Saka Saka	300.000	30.748
Water	600.000	61.496
Palm oil	50.000	5.125
Salt	5.680	0.125
Sugar	1.212	0.582
Maggi	8.788	0.124
Garlic	10.000	1.025
Total	975.68	100.00

Table 7. Color, odor and taste appreciation scores of Saka Saka based on the optimized formulation.

Run	Color	Odor	Taste	Run	Color	Odor	Taste	Run	Color	Odor	Taste
1	7	6	7	21	4	5	8	41	3	7	7
2	7	6	7	22	6	7	8	42	2	5	7
3	7	7	8	23	8	8	9	43	7	7	7
4	7	5	9	24	8	8	9	44	6	6	9
5	7	8	9	25	6	9	9	45	7	8	6
6	7	8	9	26	8	8	8	46	4	8	9
7	8	5	6	27	9	9	9	47	7	3	7
8	7	7	7	28	7	9	7	48	6	5	6
9	9	9	9	29	8	8	9	49	8	7	7
10	4	7	6	30	9	9	6	50	8	5	9
11	7	6	8	31	6	9	5	51	8	5	6
12	3	6	8	32	8	4	9	52	8	7	8
13	6	7	4	33	7	8	6	53	8	5	9
14	5	7	6	34	6	6	6	54	9	9	9
15	7	8	8	35	6	6	9	55	7	8	7
16	8	9	7	36	6	8	9	56	5	4	8
17	7	8	9	37	6	8	9	57	9	8	6
18	6	8	8	38	7	8	9	58	5	5	9
19	7	3	8	39	9	8	9	59	6	2	
20	4	6	9	40	4	8	6	60	7	6	

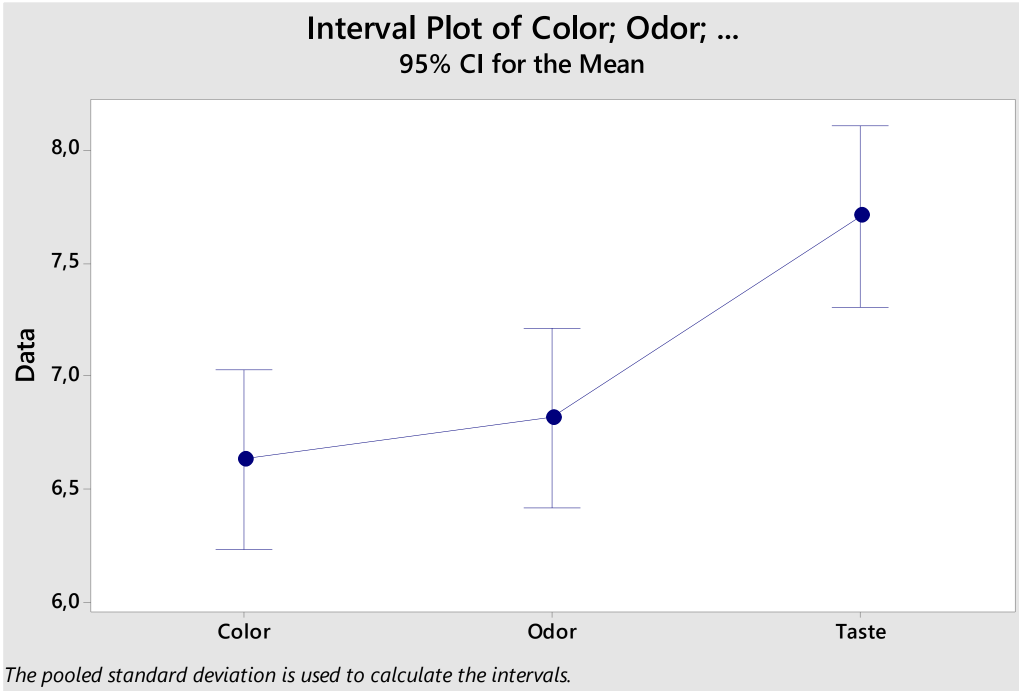

Figure 11. Diagram of color, odor, and taste intervals.

Table 8. Tukey pairwise comparisons.

Factor	N	Average	Grouping
Taste	58	7.707	A
Odor	60	6.817	B
Color	60	6.633	B

Means that not sharing a letter is significantly different.

Table 9. Values of physicochemical characteristics of the ideal Saka Saka.

Essay	Proteins (%)	Calcium (%)	Magnesium (%)	Iron (%)	Phosphorus (%)	Ash (%)	Humidity (%)
1	7.45	0.36	0.10	0.013	0.11	0,996	70.13
2	8.05	0.32	0.09	0.013	0.12	1,068	-
3	7.57	-	-	-	-	-	-
Average	7.69±0.32	0.34±0.03	0.095±0.01	0.013±0.00	0.115±0.01	1,032±0.051	70.13

phosphorus, in addition to known constituents that could not be identified (Table 9). This confirms the nutritional importance of this food.

DISCUSSION

Variations in the types and quantities of seasonings and spices impacted the sensory quality of Saka Saka. Onions and garlic significantly influenced the odor of Saka Saka, while sugar and maggi cubes significantly affected the taste. These ingredients are among the most cited in the literature on recipes of cassava leaf foods (Sanni, 2006; Sop et al., 2008; Bechoff, 2017; Wiczkowski, 2018).

The sensory evaluation of Saka Saka samples showed an average score of 6 to 7, with taste being the most appreciated characteristic. The optimal formulation was developed based on sensory evaluation, with no significant difference between odor and color scores. However, the mean scores for odor and taste were significantly different. The optimal formulation contained 7.96% protein, 0.34% calcium, 0.09% magnesium, 0.013% iron, and 0.12% phosphorus, with known constituents that could not be identified.

Saka Saka dishes can be improved to meet evolving consumer preferences and standards. Some authors have sought to improve the quality of dishes made from cassava leaves. For example, species, varieties, and processes of leaf treatment were studied (Mepba et al., 2007; Okoh et al., 2010; Umuhozariho et al., 2013; Mikolo et al., 2021).

Efforts are also being made to develop local spices. Several ingredients are used to improve the quality of cassava leaf dishes (Adadi et al., 2019). However, scientific data on their impact on the quality attributes of cassava leaf products are scarce (Kruger et al., 2020). Key areas for optimization include taste, texture, aroma, and visual appeal. Balancing flavors and seasoning can create a harmonious blend of savory, umami, and acidic notes. Optimizing cooking methods, processing techniques, and adding ingredients can create a smooth texture. Balancing the aroma with fresh ingredients and cooking methods can elevate the dish's fragrance. Optimizing color through ingredient selection and presentation techniques can also enhance the dish's appeal. Consistency in preparation methods is crucial for uniform sensory characteristics. Respecting cultural authenticity and nutritional integrity is essential, while incorporating wholesome ingredients and minimizing additives or unhealthy fats.

The product contained 7.69% protein, 0.34% calcium, 0.09% magnesium, 0.013% iron, and 0.12% phosphorus, confirming its nutritional importance. The values of the proteins are similar to those of the authors, such as Koubala et al. (2015). The values of the minerals are higher than those found by other authors. This can be explained by the spices added when preparing Saka Saka.

Conclusion

The study reveals that the combination of ingredients in Saka Saka significantly affects its sensory characteristics. The first combination of garlic and onion significantly influences the color, odor, and taste of the dish. A score of 8 was achieved with recipes containing 81% garlic and 19% onion. The flavor enhancer experiment with sugar and maggi broth showed that these ingredients significantly influence consumers' judgments of the Saka-Saka color and taste. The maggi cube broth significantly improves the taste score. The results led to the design of an optimal Saka Saka recipe, which was submitted for sensory assessment. The optimization predicted scores of 8.1 and 7.17, respectively, for taste and color. The results obtained with the prototype sample gave scores of 7.7 for taste and 6.6 for color. The designed formulation is rich in protein and minerals, providing an acceptable nutritional value. Contrary to housewives' practice, a mixture of 1/5 onion and 4/5 garlic improves the sensory quality of the dish.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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