



Research Article

Volume-06|Issue-05|2026

Optimizing The Sensory Quality of Saka-Saka and Ntoba Mbodi: A Mixture Design Study and Analysis of Cassava Varieties

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Article History

Received: 23.06.2026

Accepted: 03.08.2026

Published: 05.10.2026

Citation

Chanel, K. T. O. Fanny, G. P. & Bertin, M. (2026). Optimizing The Sensory Quality of Saka-Saka and Ntoba Mbodi: A Mixture Design Study and Analysis of Cassava Varieties. *Indiana Journal of Agriculture and Life Sciences*, 6(5), 8-11.

Abstract: Saka-saka and ntoba mbodi are two emblematic traditional dishes of the Republic of the Congo, both prepared from cassava leaves. The aim of this study was to evaluate the effects of three traditional condiments—carbonized plantain peel, *Tiliacora funifera*, and *Triclisia gillettii*—on the sensory quality of saka-saka, as well as the effects of three cassava varieties (sweet, bitter, and rubber cassava) on the sensory quality of ntoba mbodi. A centred simplex mixture design with three components was applied to saka-saka, whereas a one-way ANOVA was used for ntoba mbodi. Sixteen assessors evaluated saka-saka, and ten assessors evaluated ntoba mbodi, using a nine-point hedonic scale to assess colour, odour, and taste.

The most appreciated sensory attribute of saka-saka was colour (mean score = 7.14). Condiment 1 (carbonized plantain peel) achieved the highest sensory scores for colour (7.65), odour (8.43), and taste (8.24), with the maximum desirability value ($D = 1.00$). For ntoba mbodi, a significant preference for the sweet cassava variety was observed for odour ($p = 0.002$) and taste ($p = 0.013$). However, no significant difference was found in terms of colour ($p = 0.108$). These results provide a scientific basis for the standardization and potential industrialization of these traditional cassava-based products.

Keyword: Cassava; saka-saka; ntoba mbodi; sensory evaluation; mixture design; optimization; traditional condiments

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INTRODUCTION

Against a backdrop of globalization and rapid population growth, ensuring food security and promoting the diversification of agricultural products have become major challenges for developing countries, particularly in Africa (FAO, 2019). The Republic of the Congo is a major producer of cassava (*Manihot esculenta* Crantz), which is widely processed into traditional products such as saka-saka (pounded cooked cassava leaves) and ntoba mbodi (fermented cassava leaves). These preparations constitute an important component of local diets owing to their nutritional value and desirable organoleptic properties (Mabossy-Mobouna & Malaisse, 2021). The preparation of saka-saka traditionally relies on several indigenous condiments, notably carbonized plantain peel (*Musa paradisiaca* L.), *Triclisia gillettii* Oliv., and *Tiliacora funifera* (Miers) Oliv. leaves, which are valued for their ability to improve the flavor, texture, and visual appearance of cassava leaf dishes. Despite their extensive use in Congolese culinary practices, the scientific characterization of these condiments and their contribution to sensory quality remain poorly documented.

Regardless of their cultural and nutritional importance, the quality of these products remains uneven, owing to the variability of raw materials and the

artisanal processing methods. Such variability hinders the control of sensory attributes (colour, odour, taste) and constitutes a barrier to standardization and industrialization (Diallo et al., 2013). Cassava leaves are rich in nutrients, with approximately 27% protein, 10.7% lipids, and appreciable mineral content on a dry weight basis (Busson & Bergeret, 1958)

— some characteristics, such as bitterness from cyanogenic compounds and a fibrous texture, may reduce acceptability (Oloya et al., 2023).

The optimization of formulations using experimental design, especially mixture designs, is a robust methodology for identifying ingredient combinations that improve sensory attributes in fewer trials (Hinkelmann, 2015). Sensory evaluation is a codified scientific discipline and constitutes the main tool for measuring the acceptability of traditional food products and for driving their development (ISO 5492, 2008).

The overall objective of this study was to analyse and improve the sensory quality of saka-saka and ntoba mbodi. The specific objectives were: (1) to determine the sensory preferences of consumers; (2) to assess the impact of traditional condiments and cassava varieties on sensory quality; and (3) to optimize the

proportions of ingredients in order to standardize production.

MATERIALS AND METHODS

Biological Material

Three types of cassava leaves were used: two varieties of *Manihot esculenta* Crantz, one bitter and one sweet, and one variety of *Manihot carthagenensis* subsp. *glaziovii* (commonly known as rubber cassava). The following condiments were tested with saka-saka: (1) carbonized green plantain peel (*Musa paradisiaca* L.), (2) *Tiliacora funifera* leaves, and (3) *Triclisia gillettii* leaves. All raw materials were purchased at the Texaco market in the 5th district of Ouenzé, Brazzaville.

Experimental Design

A mixed centered simplex design of three components, generated using Minitab 17.3.1, was used to study the effect of condiments on the sensory quality of saka-saka. Formulations had a total of 60 g where component levels were constant from 0 to 60 g. This design resulted in seven mixtures, including three pure blends (60 g of a single condiment), three binary blends (30 g of two condiments each), and one balanced ternary blend (20 g of each condiment). The sample preparation was done in one replicate and the data analysis was performed in 16 replicates (corresponding to the number of assessors).

Preparation of Condiments and Products

Condiment Preparation

Plantain peels (condiment 1) were separated from the pulp, washed, carbonized over hot charcoal, cooled at room temperature (30 min), ground to a powder, and subjected to three successive wash-decantation cycles (50 g of powder per extraction; supernatants were pooled). Leaves of *Tiliacora funifera* (condiment 2) and *Triclisia gillettii* (condiment 3) were washed, chilled at 4 °C for 15 min to facilitate grinding, ground (50 g), and subjected to the same three-cycle extraction protocol.

Saka-Saka Preparation

The bitter variety of cassava leaves was sorted, washed, and mechanically ground. The resulting paste was washed three times (200 mL of drinking water per wash, pressed through muslin cloth) to reduce the cyanogenic compound content. The paste (300 g per sample) was dried in an oven at 40 °C for 1 h, mixed with condiments according to the experimental matrix, combined with base ingredients (palm kernel oil, salt, sugar, garlic, Maggi seasoning), and cooked at 100 °C for 1 h 30 min.

Ntoba Mbodi Preparation

Leaves of three cassava varieties were stripped from their stems, washed, chopped, and conditioned in a covered container for 24 h, then moistened by water spraying and wrapped in banana leaves for natural fermentation at room temperature for 3 days. The

fermented leaves were cooked at 100 °C for 20 min with standardized ingredients: fermented cassava leaves (200 g), water (150 g), bell pepper (27 g), vegetable oil (30 g), palm oil (20 g), salt (10 g), okra (20 g), garlic (30 g), spring onion (30 g), onion (80 g), and peanut paste (20 g).

Sensory Evaluation

Sixteen untrained assessors evaluated the saka-saka samples and 10 evaluated those of ntoba mbodi. The attributes assessed were colour, odour, and taste, rated on a nine-point hedonic scale (1 = "dislike extremely", 9 = "like extremely"). Between samples, assessors rinsed their mouths with mineral water and cleansed their palates with plain crackers.

Statistical Analysis

A one-way analysis of variance (ANOVA, $\alpha = 0.05$) was performed to compare ntoba mbodi scores among the three cassava varieties. After removal of outliers, condiment data were analysed using mixture regression models (linear and quadratic). With the goal of maximizing scores (lower bound = 6; target = 7), response optimization was performed using the composite desirability method. All analyses were conducted with Minitab 17.3.1.

RESULTS AND DISCUSSION

Mixture Design for Saka-Saka Condiments

Overall Sensory Appreciation

A total of 112 trials were conducted, yielding hedonic scores ranging from 4 to 9. Overall mean scores were 7.14 for colour, 6.44 for odour, and 6.40 for taste. ANOVA showed that the 95% confidence intervals for mean colour scores did not overlap with those for odour and taste, indicating a significant difference between these groups of attributes. Colour was therefore the most appreciated sensory characteristic of saka-saka across all condiment formulations. This result supports the reported importance of visual appearance in the acceptability of cassava leaf preparations (Mabossy-Mobouna & Malaisse, 2021).

Mixture Regression Models

The mixture regression model parameters are shown in Table 1. All linear models (colour, odour) and a quadratic model (taste) were statistically significant ($p < 0.001$). Coefficients of determination were $R^2 = 65.6\%$, 54.2% , and 68.6% for colour, odour, and taste, respectively, indicating that the models explain a substantial proportion of the variability in the responses. For pure blends, regression coefficients consistently ranked condiment 1 highest (8.24 for colour, 8.39 for odour, and 8.79 for taste), systematically above condiment 2 (5.53; 4.92; 5.05) and condiment 3 (7.53; 6.95; 7.26). The binary blend of condiments 1 and 3 showed antagonistic interactions, with negative interaction coefficients for odour (-2.31) and taste (-8.13), indicating that the combination of these two condiments decreased acceptability compared to the

respective pure blend averages. these negative interactions indicate sensory incompatibility between carbonized plantain peel, *Tiliacora funifera*, and

Triclisia gillettii, likely owing to differences in their aromatic profiles.

Table 1. Mixture regression parameters for colour, odour, and taste of saka-saka

Attribute	p-value	R ² (%)	Adj. R ² (%)	β Cond.1	β Cond.2	β Cond.3	β C1×C3
Colour	< 0.001	65.6	61.1	8.24	5.53	7.53	+0.91
Odour	< 0.001	54.2	45.2	8.39	4.92	6.95	-2.31
Taste	< 0.001	68.6	61.3	8.79	5.05	7.26	-8.13

CI×*C3*: binary interaction term condiment 1 × condiment 3; β: regression coefficient; Adj. R²: adjusted coefficient of determination.

Saka-Saka Sensory Optimization

Through composite desirability optimization, the optimal formulation was found to consist exclusively of condiment 1 (60 g of carbonized plantain peel, with condiments 2 and 3 set to zero). Predicted sensory scores for this formulation were: colour = 7.65; odour = 8.43; taste = 8.24. The fitted model was found to meet the set optimization criteria simultaneously as indicated by the composite desirability (*D* = 1.00). for all three attributes, confirming the superiority of this formulation. These results indicate that the alkaline ash obtained from plantain peel positively contributes to the texture and flavour of saka-saka.

Effect of Cassava Variety on Ntoba Mbodi

Hedonic Scores by Variety

The descriptive statistics of assessor scores (Table 2) showed that the sweet variety was consistently superior across all attributes. The mean scores of the sweet variety for taste, odour, and colour were 8.3 ± 1.3 , 7.8 ± 1.5 , and 7.3 ± 1.6 , respectively, which were significantly higher than those of the bitter variety (taste: 5.1 ± 2.4 ; odour: 4.8 ± 2.3 ; colour: 5.2 ± 1.9) and the rubber variety (taste: 4.8 ± 2.8 ; odour: 4.3 ± 2.5 ; colour: 6.4 ± 2.8).

Table 2. Descriptive statistics of hedonic scores for ntoba mbodi (n = 10 per variety)

Variety	Attribute	N	Mean	SD	Min	Max
Sweet	Taste	10	8.3	1.25	5	9
	Odour	10	7.8	1.55	4	9
	Colour	10	7.3	1.64	4	9
Bitter	Taste	10	5.1	2.42	2	9
	Odour	10	4.8	2.25	1	8
	Colour	10	5.2	1.87	2	8
Rubber	Taste	10	4.8	2.78	1	9
	Odour	10	4.3	2.54	1	8
	Colour	10	6.4	2.76	1	9

SD: standard deviation; *Min*: minimum; *Max*: maximum

Analysis of Variance (ANOVA)

The ANOVA results (Table 3) indicated significant differences in odour (*p* = 0.002) and taste (*p* = 0.013) among varieties, but no significant difference in colour (*p* = 0.108). Analysis of 95% confidence intervals

showed that the sweet variety differed significantly from both the bitter and rubber varieties for odour and taste, while no significant difference was found between the bitter and rubber varieties. For colour, the 95% confidence intervals of the three varieties overlapped, indicating no perceptible difference among assessors.

Table 3. One-way ANOVA results for sensory attributes of ntoba mbodi

Attribute	p-value	Threshold α	Observation	Conclusion
Colour	0.108	0.05	$p > \alpha$	Non-significant difference
Odour	0.002	0.05	$p < \alpha$	Significant difference
Taste	0.013	0.05	$p < \alpha$	Significant difference

α : significance threshold.

The preference for the sweet cassava variety in ntoba mbodi is probably attributable to its lower content of cyanogenic compounds, which impart a residual bitterness to bitter varieties even after fermentation (Massamba & Trèche, 1995). The 3-day fermentation used in this study allows partial reduction of cyanogenic glycosides but not their complete elimination in bitter varieties (Tomlins et al., 2007). The rubber variety (*M. glaziovii*) presented a relatively better score for colour, but less acceptable for aromatic and gustatory profiles, which could be due to its particular biochemical composition.

CONCLUSION

This study identified and optimized the factors influencing the sensory quality of two traditional Congolese food preparations based on cassava leaves. Colour was the most appreciated sensory attribute for saka-saka, and the optimal formulation consisted exclusively of condiment 1 (carbonized plantain peel, 60 g), with predicted scores of 7.65 for colour, 8.43 for odour, and 8.24 for taste, and a maximum composite desirability of $D = 1$. The combination of condiments 1 and 3 (*Triclisia gillettii*) had an antagonistic effect, decreasing overall acceptability. The sweet cassava variety was significantly preferred for odour and taste in ntoba mbodi, while no significant difference in colour was detected among the three varieties tested.

These results constitute a provide preliminary scientific evidence for standardization and further development of these products. They open research perspectives on the biochemical characterization of traditional condiments, the mechanisms of ingredient interactions, and the optimization of fermentation and cassava detoxification processes. These results should be validated in larger-scale studies with representative consumer panels, in the context of innovative product development.

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