

Sensory Characterizations and Optimization of Cashew Apple Jam Formulations Using Baobab Powder as a Source of Pectin

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Abstract

Cashew processing in Côte d’Ivoire focuses only on the cashew nut, to the detriment of the apple. Only a very small proportion of the apple is processed into juice. The aim of this work is to enhance the value of cashew apples by transforming them into jam. Specifically, the aim was first to characterize the sensory properties of cashew apple jam formulations using baobab powder as a source of pectin and then to optimise the formulations. A Box-Behnken design with pH, Sugar, and Baobab as factors was used to model and characterize the jam sensory descriptors, and a multivariate analysis with SensomineR was used to characterize the jam formulations. The desirability function was used to optimise the formulations. The results show globally significant regressions at the 0.05 threshold for the sensory descriptors Gelling, Brilliance, Smell, Sweetness, and (-)Astringency, with the exception of (-)Salinity. The R² coefficients are greater than 80%. The factors studied could have effects on the sensory descriptors of cashew jam formulations. The Baobab had the main effect on the gelling, smell, and astringency of the jams. Brilliance depended on the added sugar. A product effect ($p < 0.001$) was observed for the descriptors Smell, Gelling, Brilliance, and Sweetness, as these allowed the panelists to find differences between the formulations. Optimum jam formulation can be achieved with 51.56% sugar and 2.12% Baobab at a pH of 3.15. Cashew apple jam using Baobab offers opportunities to add value to apples that have long been abandoned in the field. It would be important to find conditions for prolonged storage of this jam.

Keywords

Cashew Apple, Sensory Characterization, Jam Formulation, Area Design,

1. Introduction

Over the past decade, Côte d'Ivoire has seen a boom in cashew nut production, making it the world's leading producer of this commodity, with around 1.25 million tonnes expected by 2023 [1]. Côte d'Ivoire has undertaken efforts in cashew nut processing. The cashew nut processing rate reached 21.25% in 2022 [1]. Unfortunately, these processing efforts only concern cashew nuts and not cashew apples. However, only a very small proportion is processed into juice [2] [3]; its good nutritional values, such as its richness in juice (80% to 90%), reducing sugars (10.69 to 18.82 °Brix), vitamins C, B10, B1 and PP, antioxidants with a light flavour and acidity [4]-[7]. It also contains calcium, phosphorus, pectins (1%), and other nutrients, including 9% proteins, 4% lipids, and 8% cellulose [8]. Cashew apples are also high in triterpenoids and phenolics, which are important for inhibiting the bacteria that cause gastritis in humans [9]. Yet 90% - 95% of cashew apples are abandoned in fields in Côte d'Ivoire, despite the other virtually unexploited ways of adding value, such as processing into syrup, jellies, candied fruit, wine, alcohol, vinegar, compote, and jam [9]-[13]. Such local processing of cashew apples could, on the one hand, limit the need to import these food products, which are too expensive, and on the other, make them more accessible to different categories of consumers. Among these products, jam is one that allows the fruit to be consumed outside the harvesting season as a food product. Jam is a solid gel that is produced from the pulp of one or more fruits, mixed with sugar (sucrose), pectin, acid, and other ingredients (including preservatives, colourings, etc.) until a reasonably thick consistency is obtained that is firm enough to hold the fruit tissues in place [14] [15].

The jam should contain at least 40% fruit, and the expected total soluble solids content should not be less than 68%. Gelling agents, thickeners, and stabilisers are all essential in the production of jams, jellies, and marmalades. One of the most widely used gelling agents is pectin [16] [17]. Pectin controls the moisture or water content of the product. Pectin is naturally found in many tropical fruits, such as baobab pulp and cashew apples. Baobab pulp is soluble in water [18]. Reference [19] showed a high pectin content of 56.2%, and [20] confirms this trend with contents ranging from 43.93% to 54.99%, making this pulp a functional food ingredient. Several researchers [21]-[24] suggest that baobab pulp could be used to gel jams. Reference [24] found no significant differences between jams based on commercial pectins and those using baobab powder in terms of certain physicochemical parameters. Reference [25] formulated a jam based on residues from the extraction of ripe plantain juice using baobab powder as a source of pectin.

Given the advantages of cashew apples and Baobab, producers' lack of knowledge

of processing techniques for these fruits, apart from local beverages, limits the possible short- and long-term economic benefits of these two fruits. The development of processing techniques to produce a new product that is accepted by a large proportion of the population remains a major challenge. The production of cashew apple-based jams using Baobab as a source of pectin, without the use of colouring or preservatives, could therefore be a way of adding value to these local products and bringing financial benefits to producers. On the one hand, an experimental design could provide jam formulations tested by an expert panel and, on the other, quantify the influence of these ingredients (cashew apple and baobab) and their interactions in order to identify the best combination of them for the production of a quality jam [26]-[30]. The Box-Behken design was selected from the surface designs because, for the same number of factors, it requires fewer trials than centred composite designs. In addition, Box-Behken designs do not include defined points on the extreme parameters of all the factors, which may be more suitable for certain processes. Box-Behken designs can also be useful if the process validation domain is known. This is the case for jams where the main ingredients (sugar and pectin) must have a certain proportion in relation to the fruit and a specific pH in order to achieve a characteristic flavour and jelly texture. As pH is a difficult parameter to set, this design proposes three (3) levels, unlike the central composite design, which requires five (5).

The aim of this work is to carry out the sensory characterization of cashew apple jam formulations using Baobab as a source of pectin and to carry out sensory optimisation. To achieve this objective, a Box-Behken surface design was used to model and characterize the sensory descriptors, and multivariate analysis was used to characterize the jam formulations. Finally, a multi-objective optimisation was used to find the exact levels of factors leading to the best jams from a sensory point of view.

2. Materials and Methods

2.1. Plant Material

The plant material consisted of cashew apples collected from a farmer's plantation near Yamoussoukro, a town in central Côte d'Ivoire. These apples (red and yellow) were carefully separated from their nuts and transported to the laboratory in barrels.

2.2. Cashew Apples Pretreatment Method

Before pretreatment, the cashew apples were first sorted and rinsed three times with water. They were disinfected in a 100 ppm active chlorine solution for 30 min and rinsed again with water.

Pretreatment consisted of brining, followed by cold exposure of the products. The cashew apples were brined with their skins for one (1) day in 15 g/L NaCl before being frozen at a temperature of -4°C for six weeks as carried out by [31].

2.3. Setting Up a Box-Behken Design for the Preparation of Cashew Apple Jam Formulations

To produce the jam formulations after pre-treatment of the cashew apples, a Box-Behken surface design was used based on the following approach:

1) Factors and definition of the experimental range

Factors and their range were chosen based on data from literature and previous research carried out on jam formulations and include the proportion of added sugar (%), the quantity of baobab powder to provide additional pectin, and the pH measurement adjusted after the addition of citric acid or potassium hydroxide to control the acidity of the jam formulations (**Table 1**).

Table 1. Factor and experimental range of jam formulations.

Factors	Code	Low (-1)	High (+1)
Quantity of sugar (%)	S	40	60
Quantity of baobab powder (%)	B	0	5
pH	P	2.8	3.5

2) Sensory descriptors

Sensory analysis was used to extract the most appreciated jam formulation(s) using six descriptors: gelling, less salty flavour, designated by (-)Salinity, less astringent flavour, designated by (-)Astringency, sweetness, the brilliance of cashew apple jams, and smell of the cashew fruits.

3) Experiments

The matrix of experiments was obtained from the design-expert 13 software (**Table 2**). A total of 15 trials of jam formulations were carried out. The jam formulations obtained were identified by a product code.

Table 2. Design of experiments for cashew apple jam formulations.

Experiment (N°)	Product code	Factors code				Factors	
		P	S	B	pH	Sugar	Baobab
1	F670	-1	-1	0	2.8	40%	2.50%
2	F455	1	-1	0	3.5	40%	2.50%
3	F852	-1	1	0	2.8	60%	2.50%
4	F605	1	1	0	3.5	60%	2.50%
5	F550	-1	0	-1	2.8	50%	0%
6	F272	-1	0	1	2.8	50%	5%
7	F150	1	0	-1	3.5	50%	0%
8	F982	1	0	1	3.5	50%	5%
9	F409	0	-1	-1	3.15	40%	0%
10	F371	0	1	-1	3.15	60%	0%
11	F758	0	-1	1	3.15	40%	5%

Continued

12	F127	0	1	1	3.15	60%	5%	
13	F796	0	0	0	3.15	50%	2.50%	
14	F315	0	0	0	3.15	50%	2.50%	
15	F106	0	0	0	3.15	50%	2.50%	
					Level -1	2.8	40%	0%
					Level 0	3.15	50%	2.5%
					Level 1	3.5	60%	5%

4) Modelling sensory descriptors

The mathematical models for the sensory descriptors are second-order polynomial equations. The general equation for estimating the scores (Y) of the descriptors at the end of the sensory test is:

$$Y_{Descriptor} = a_0 + a_1P + a_2S + a_3B + a_{12}PS + a_{13}PB + a_{23}SB + a_{11}P^2 + a_{22}S^2 + a_{33}B^2$$

where Y is the response or score assigned to a descriptor, a_0 is the constant of the model, a_i (a_1, a_2, a_3) are the coefficients for the linear (first-order) term, a_{ij} (a_{12}, a_{13}, a_{23}) are the coefficients for the interaction terms, a_{ii} (a_{11}, a_{22}, a_{33}) are the coefficients for the quadratic (second-order) terms.

2.4. Sensory Evaluation Method

A sensory evaluation was organised to characterize the 15 jam formulations over the course of a week. A batch of 4 to 5 pre-coded jam samples was served per session. A panel of 15 trained people from the laboratory staff generated the 6 descriptors mentioned above and tasted these products by filling out a descriptive test sheet.

2.5. Jam Preparation Method

The pre-treated cashew apples, free of any impurities, were cut into pieces. They were pre-cooked for 5 minutes without adding water, using the juice from the apples themselves. The apples are ground using a sieve mill. The jam is cooked by adding sugar and baobab powder to the apple in the proportions specified in the experimental design for approximately 7 to 10 minutes. The cooking time is checked using a refractometer. The jam is poured into glass jars at a temperature of over 90°C. Before packaging, the glass jars and their lids are sterilised in boiling water for around ten minutes. The jars of jam obtained are immediately closed and turned upside down so that the hot jam pasteurises the lid.

2.6. Statistical Analysis

Model evaluation tests for sensory descriptors were based on ANOVA and regression parameter analysis at the 5% threshold. Design Expert 13 software was used to process the experimental design data, in particular, the analysis of the statistical parameters of the regression for the characterization of the sensory descriptors

and to determine the optimal factor range.

The SensomineR package of the R software was used to carry out multivariate analysis to characterize the sensory characteristics of the jam formulations as proposed by [32].

The overall desirability (Dg), as proposed by [33], was calculated for each jam formulation as a function of the individual desirabilities (d_i) of the sensory descriptors according to the formula:

$$Dg = [d_1 \times d_2 \times \dots \times d_n]^{1/n}$$

where d_i is the individual desirability of sensory descriptor i , with $0 \leq d_i \leq 1$ and $0 \leq Dg \leq 1$; n , number of sensory descriptors.

3. Results and Discussion

3.1. Characterization of Sensory Descriptors of Cashew Jam Formulations

3.1.1. Analysis of the Regressions Relating to the Sensory Descriptors

The results of the analysis of variance (ANOVA) of the regression according to the surface design carried out to assess the model's significance in each sensorial descriptor of the jam formulations are presented in **Table 3**, together with the coefficient of determination (R^2).

Table 3. Results of the ANOVA of the regression of the models of the sensory descriptors of the jam formulations.

	Sources	SSD	DF	MS	F	p-value	R ²
Gelling	Regression	7.5	9	0.8331	20.76	0.002	0.9739
	Lack of fit	0.0278	3	0.0093	0.1071	0.949	
	Pure error	0.1728	2	0.0864			
Brilliance	Regression	10.28	9	1.14	3.21	0.030	0.8564
	Lack of fit	1.47	3	0.4897	3.84	0.214	
	Pure error	0.2551	2	0.1276			
Smell	Regression	7.29	9	0.81	6.94	0.023	0.9259
	Lack of fit	0.5586	3	0.1862	15.08	0.063	
	Pure error	0.0247	2	0.0123			
(-)Salinity	Regression	0.72	9	0.08	2.84	0.132	0.8363
	Lack of fit	0.108	3	0.036	2.19	0.329	
	Pure error	0.0329	2	0.0165			
Sweetness	Regression	15.19	9	1.69	10.48	0.009	0.9496
	Lack of fit	0.2148	3	0.0716	3.21	0.246	
	Pure error	0.0446	2	0.0223			
(-)Astringency	Regression	1.43	9	0.1591	13.11	0.006	0.9593
	Lack of fit	0.0525	3	0.0175	4.25	0.196	
	Pure error	0.0082	2	0.0041			

SSD: Sum of Squared Differences; DF: Degree of Freedom; MS: Mean Square; R²: Coefficient of Determination.

The coefficients of determination (R^2) are relatively high, exceeding 80%. It can be concluded that the variability observed in the sensory descriptors could be significantly explained by the regression models derived from the Box-Behken designs.

The p-values of ANOVA show that the regressions obtained are globally significant at the 0.05 threshold for the sensory descriptors Gelling ($p = 0.002$), Brilliance ($p = 0.030$), Smell ($p = 0.023$), Sweetness ($p = 0.009$) and (-)Astringency ($p = 0.006$) except for the (-)Salinity regression ($p = 0.132$). Overall, based on the regression results, the models obtained from the regressions give good predictions of sensory scores.

The p-values of the lack of fit for all the sensory descriptors are not significant because they are greater than 0.05. Consequently, the adjustment errors and the pure errors could be of the same order of magnitude. We deduce that the errors committed by the use of the sensory descriptor regression models are not significant.

From the above analyses, we conclude that the regression models obtained explain the scores provided by the expert panel well. Thus, the factors (Sugar, Baobab, and pH) used in the experimental designs could have various effects on the sensory descriptors and, consequently, on the sensory quality of the formulations proposed to the panel.

3.1.2. Effects of Factors on Sensory Descriptors for Jam Formulation

Table 4 presents for each sensory descriptor the significance of the linear, interaction, and quadratic effects due to the variation factors (pH, Sugar, Baobab). The relevance of these effects on the descriptors is assessed by the significance of the p-values of the coefficients associated with the factors.

Table 4. Types of effects and model coefficients for sensory descriptors.

Effects	Factors	Gelling		Brilliance		Smell		Salinity		Sweetness		Astringency	
		Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value
Linear	A (pH)	0.708	0.000	0.027	0.898	0.069	0.590	0.069	0.294	-0.236	0.157	0.125	0.0238
	B (% Sugar)	-0.277	0.011	0.944	0.006	-0.194	0.168	0.055	0.392	1	0.000	0.194	0.004
	C (% Baobab)	0.430	0.001	0.166	0.458	-0.763	0.001	0.097	0.162	-0.152	0.330	0.125	0.023
Interaction	AB	-0.388	0.011	0.138	0.656	-0.416	0.050	0.083	0.366	0.222	0.318	-0.194	0.016
	AC	-0.25	0.049	0.694	0.048	0.222	0.249	0.000	1.000	-1.083	0.002	-0.166	0.029
	BC	0.111	0.317	-0.083	0.787	0.194	0.306	-0.083	0.366	-0.222	0.318	-0.361	0.001
Quadratic	A²	-0.097	0.393	0.106	0.741	0.527	0.031	0.231	0.045	-0.458	0.045	0.018	0.759
	B²	-0.347	0.020	-0.449	0.201	0.166	0.391	-0.185	0.047	-0.152	0.497	-0.064	0.309
	C²	-0.097	0.393	0.106	0.741	0.250	0.218	-0.212	0.050	-0.458	0.043	-0.148	0.049

In bold are the coefficients and p-values of the significant effect types. Coef. = coefficients.

Analysis of **Table 4** and **Table 5** shows that the factors could have linear,

interaction and quadratic effects on the sensory descriptors.

Table 5. Model expressions for sensory descriptor scores for jam formulations.

Sensory descriptor	Model expressions with significant coefficients
Gelling	$Y_{\text{Gelling}} = 7.2 + 0.708A - 0.278B + 0.403C - 0.389AB - 0.347B^2$
Brilliance	$Y_{\text{Brilliance}} = 6.815 + 0.944B + 0.694AC$
Smell	$Y_{\text{Smell}} = 5.667 - 0.764C - 0.417AB + 0.528A^2$
(-)Salinity	$Y_{(-)\text{Salinity}} = 8.370 + 0.231A^2 - 0.185B^2 - 0.212C^2$
Sweetness	$Y_{\text{Sweetness}} = 7.889 + 1.083AC - 0.458A^2 + 0.458C^2$
(-)Astringency	$Y_{(-)\text{Astr.}} = 8.519 + 0.125A + 0.194B + 0.125C - 0.194AB - 0.167AC - 0.361BC - 0.148C^2$

In terms of Gelling, all the linear effects are predominant compared with the quadratic and interaction effects. The three factors studied were all significant, with highly significant effects ($p < 0.01$) for pH and Baobab. Analysis of the regression coefficients for these two factors suggests that increasing them would increase Gelling. According to [34], the quantity of critical acid influences the final gelling of the jam. As Baobab is rich in pectin, an increase in pectin would favour an increase in gelling or consistency. This increase in gelling with that of citrus pectin is also observed in [35] [36] and [34]. There are also significant interactions, namely pH-Sugar and pH-Baobab. Thus, the scores attributed to Gelling do not depend mainly on a single factor but on the levels taken by each of them. A significant quadratic effect was observed for the sugar factor.

At 50% sugar, the contour plots (Figure 1) of all responses show that the region of Gelling descriptor scores above 7.5 could be observed at all levels of the Baobab factor but only for pH levels relatively higher than 3.1.

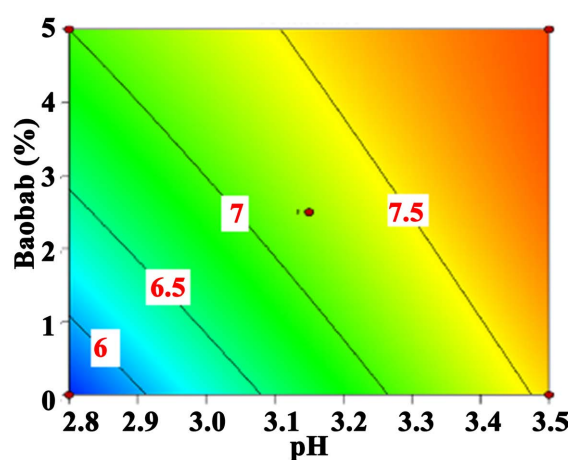


Figure 1. Contour plots for gelling scores in the Baobab-pH plane (at 50% sugar).

The Smell descriptor is highly influenced by the negative linear effect of the

Baobab factor (coef. = -0.764 ; $p = 0.002$). The increasing addition of this factor would therefore reduce the scores for the smell of apple jam. The existence of a significant pH-sugar interaction shows that the smell of cashew apple jam does not depend on Baobab alone, but on pH and sugar levels. The pH factor had a significant quadratic effect.

At 50% sugar, the contour plots (**Figure 2**) of all responses confirm that the scores for the descriptor Smell of apple jam seem to decrease with increasing Baobab level for a given pH.

Scores above 7 were observed in regions of low Baobab levels ($<0.6\%$) with pH levels below 2.9 or above 3.4.

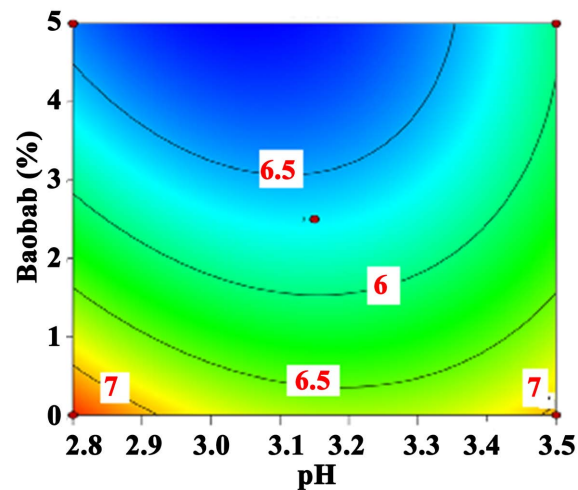


Figure 2. Contour plots for smell scores in the Baobab-pH plane (at 50% sugar).

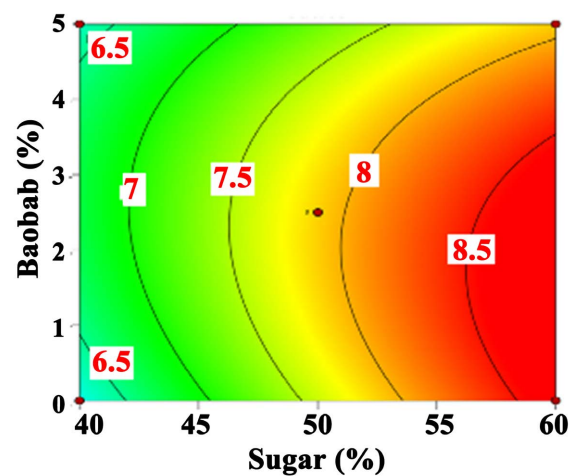


Figure 3. Contour plots for sweetness scores in the Baobab-sugar plane (at pH 3.15).

The scores for the Sweetness descriptors were highly influenced by the positive linear effect of the Sugar factor (coef. = 1.000 ; $p = 0.001$). Analysis of the regression

coefficient for the Sugar factor suggests that the increasing addition of this factor would, therefore, increase the sweetness scores for cashew apple jam [35]. However, there was a highly significant interaction effect between the pH-Baobab factors (coef. = 1.083; $p = 0.003$). This would mean that sweetness scores would depend not only on the sugar factor but also on pH and baobab levels. Significant quadratic effects on sweetness were observed for the pH and baobab factors.

At pH 3.15, the contour plots (Figure 3) of all responses seem to confirm the above information. Sweetness scores did increase with the addition of fixed levels of Baobab. The relatively high sweetness score region (>8) is observed for sugar levels that are relatively higher than 52% (Figure 3).

The (-)Astringency descriptor scores all experience positive linear effects from the three factors studied, with a highly significant effect for the Sugar factor ($p = 0.004$). Increasing the pH, sugar, and Baobab levels would reduce astringency. However, a quadratic effect was observed for Baobab (Author). Significant interactions were observed between the three factors (Table 4 and Table 5). Thus, astringency scores do not depend mainly on a single factor but on pH-Sugar, pH-Baobab, and Sugar-Baobab interactions. Note that the Sugar-Baobab interaction is highly significant ($p = 0.001$).

At pH 3.15, the contour plots (Figure 4) of all responses show different regions of the (-)Astringency descriptor. In some regions (Baobab level $< 3.2\%$ and Sugar quantity $< 53\%$), the (-)Astringency descriptor scores seem to increase with the Baobab and Sugar factors (Author).

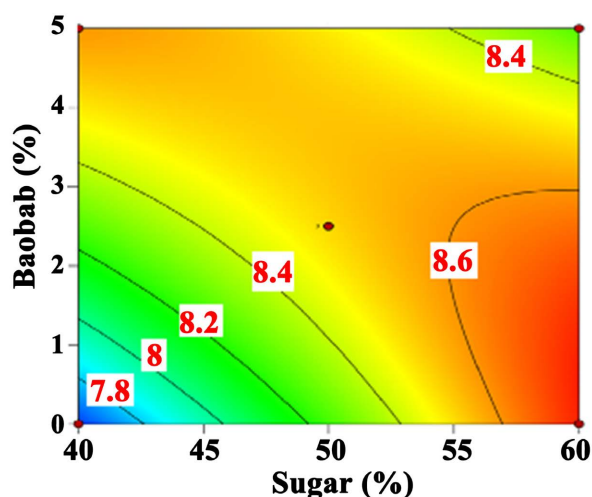


Figure 4. Contour plots for (-)Astringency scores in the Baobab-sugar plane (at pH 3.15).

Brilliance scores depend on the highly significant linear effect of the Sugar factor ($p = 0.006$). Thus, increasing the sugar level would increase the brilliance scores. A significant pH-Baobab interaction effect ($p = 0.064$) was observed. Brilliance would, therefore, not depend mainly on the sugar factor alone, but also on pH and baobab levels.

According to the contour plots of all responses (**Figure 5**), the Brilliance score varied very little with the fixation of the sugar factor, whatever the level of the baobab factor. On the other hand, for a fixed quantity of the Baobab factor, the brilliance score could increase with the increase in the sugar level. The addition of sugar could, therefore, increase the glossiness of the jams [14]. The region of brilliance scores higher than 7 is observed for sugar levels relatively higher than 50%.

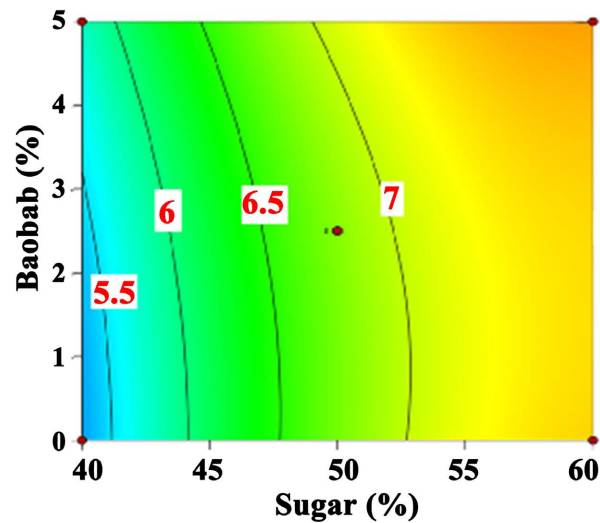


Figure 5. Contour plots for brilliance scores in the Baobab-sugar plane (at pH 3.15).

No linear effects were observed on (-)Salinity scores. The (-)Salinity scores depend significantly on the quadratic effects of all three factors studied (**Table 4**).

At 2.5% Baobab, the contour plots (**Figure 6**) of all responses, regions with (-)Salinity scores above 8.5 are observed for pH levels above 3.43 with Sugar levels above 43%, and for pH levels below 2.83 with Sugar levels between 45% and 43.5%.

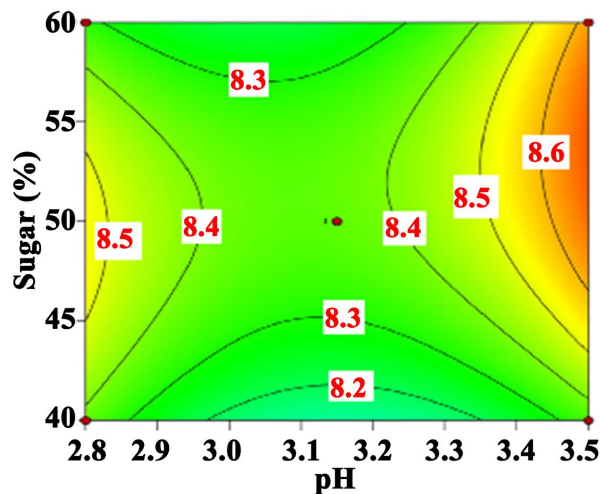


Figure 6. Contour plots for (-)Salinity scores in the sugar-pH plane (at 2.5% Baobab).

3.2. Sensory Characterization of Cashew Jam Formulations

Table 6 gives a summary of the results used to characterize the 15 jam formulations from the Box Behken design. Analysis of the p-values (F-test) in this table shows that there is a product effect for the sensory descriptors Smell, Gelling, Brilliance, and Sweetness, since these have F-test p-values of less than 0.05. We can, therefore, conclude that the panelists had a positive effect on the sensory descriptors Smell, Gelling, Brilliance, and Sweetness. Therefore, we can conclude that the panelists were able to find differences between the jam formulations for these four descriptors. Sweetness is the most discriminating sensory descriptor as it obtains the lowest F-test p-value ($3.92e-12$). No product effect was observed on the descriptors (-)Salinity and (-)Astringency ($p > 0.05$). We can, therefore, say that the panelists were unable to discriminate the 15 jam formulations on the basis of the descriptors (-)Salinity and (-)Astringency.

Table 6. Summary of multivariate analysis of sensory data for cashew jam formulations.

Formulations	Smell	Gelling	(-)Salinity	Brilliance	(-)Astringency	Sweetness
F409	7.333a	6.333	7.722	4.667b	7.556b	6.278b
F670	6.056	5.944b	8.111	5.722b	8.017	6.333b
F455	6.667a	7.833a	8.167	5.333b	8.556	5.5b
F982	6.167	7.944a	8.056	7.333a	8	5.167b
F550	6.889a	5.556b	8.222	7.722a	8	6.333b
F272	5.333b	6.889	7.944	5.611b	8.222	6.889
F150	6.889a	6.611	7.944	6.5	8.556	7.611
F371	6.444	5.833b	7.722	6.889	8.667	8.056a
F852	6.611a	6.056b	8.111	7.056	8.389	8.278a
F758	5.056b	7.222	8.111	6	8.556	6.778
F796	5.611	6.944	8.222	6.778	8.278	7.5
F315	5.5b	6.667	8.056	6.556	8.5	7.722
F106	5.611	6.86	8.278	6.5	8.389	7.889a
F127	5.167b	7.944a	8	7.833a	8.167	7.833a
F605	5.611	6.389	8.556a	7.333a	8.444	8.333a
Overall mean	6.06 ± 0.71	6.73 ± 0.75	8.08 ± 0.20	6.52 ± 0.90	8.28 ± 0.29	7.1 ± 1.0
P-valeur (F-test)	1.115e-09	5.75e-10	0.487	1.32e-09	0.068	3.92e-12

In a column, the letter “a” (blue cell) indicates scores significantly above the overall mean of the descriptor. The letter “b” (red cell) indicates scores that are significantly lower than the overall average of the descriptor. Cells with no indication show scores with no significant difference from the overall mean according to the t-test at the 0.05 threshold.

Table 6 presents both the jam formulations (in rows) and the sensory descriptors (in columns) according to an order of affinity or similarity generated by the SensomineR package of the R software [32] [37].

The table shows that the F409, F670, and F455 jam formulations have significantly lower Brilliance and Sweetness scores than their overall average. Jams F409 and F670 have low scores for (-)Astringency and Gelling respectively. Jams F127 and F605 are characterized in general by significantly higher score intensities, particularly for the descriptors Brilliance and Sweetness. These two jams, F127 and F605, have higher score intensities for Gelling and (-)Salinity, respectively. Overall, jams F796, F315, and F106 were not characterized by any significant sensory descriptor. Their scores were rather average, *i.e.*, not significantly different from the overall means of the descriptors.

In this work, the formulations showed no significant difference between them in terms of the descriptors (-)Salinity and (-)Astringency, except for the jam formulations F409 and F609. These formulations showed a low (-)Astringency score for F409 and a high (-)Salinity score for F605.

3.3. Optimal Choice of a Cashew Jam Formulation

3.3.1. Analysis of the Overall Desirability of Jams

The search for a set of factors leading to a better appreciation of the jam with optimum scores for each descriptor was carried out with the Design Expert 13 software based on the overall desirability of the formulations. **Table 7** shows the overall desirability results for the 15 experiments in the experimental design.

Table 7. Overall desirability of jam formulations.

Experiment (N°)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Formulation	F670	F455	F852	F605	F550	F272	F150	F982	F409	F371	F758	F127	F796	F315	F106
pH	-1	1	-1	1	-1	-1	1	1	0	0	0	0	0	0	0
Sugar	-1	-1	1	1	0	0	0	0	-1	1	-1	1	0	0	0
Baobab	0	0	0	0	-1	1	-1	1	-1	-1	1	1	0	0	0
Overall desirability	0.35	0.00	0.69	0.50	0.60	0.55	0.63	0.51	0.00	0.70	0.00	0.56	0.70	0.65	0.66

In bold, the selected overall desirabilities.

Analysis of these results (**Table 7**) shows null overall desirability (0) for jam formulations F455, F409, and F758. The sensory quality of these jam formulations was, therefore, judged unsatisfactory for the panel as a whole when the sensory descriptors were considered individually. As for the other jam formulations, they obtained overall desirabilities greater than zero (0). F670 jam obtained a relatively low overall desirability of 0.35. These last four jam formulations share a low level (-1) for the Sugar factor, *i.e.*, 40% Sugar. However, for these jams, the pH and Baobab quantity factors could vary.

Jams F852, F371, F796, F315, and F106 had overall desirabilities of 0.69, 0.70, 0.70, 0.65, and 0.66, respectively, which were the highest. Consequently, the sensory quality of these jams was judged to be satisfactory for the panel as a whole. Analysis of the factors used to produce these jam formulations reveals a particularity. None of them had a high pH (1), a low sugar level (-1), and a high baobab

level (1).

The jams F796, F315 and F106 are the same formulations because they represent the trials at the centre of the experimental design. Thus, on the basis of overall desirability, three (3) formulations (F852, F371, and F796) could be selected as being those that would best take into account the panel's preferences during the sensory evaluation sessions. These formulations are characterized by a pH level of between 2.8 and 3.15, a sugar content of between 50% and 60%, and a Baobab content of between 0% and 2.5%.

3.3.2. Analysis of the Optimal Range of Factors Using a Response Surface Design

Multi-objective optimization gives the optimum surface area at pH 3.15 (Figure 7).

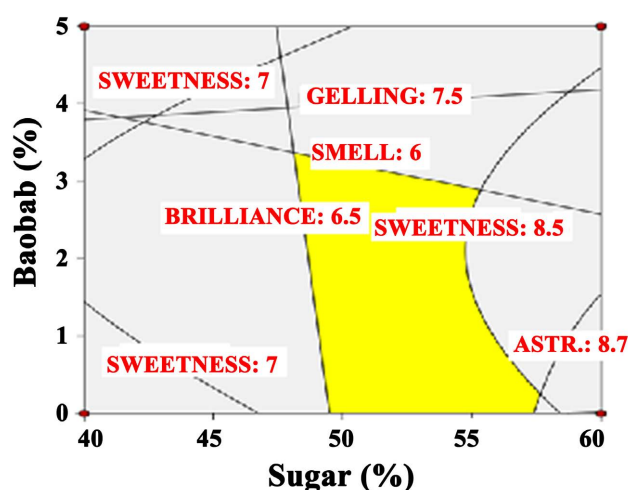


Figure 7. Optimum surface area at pH 3.15 for cashew jam formulations.

An optimal jam formulation can be achieved with 51.56% sugar and 2.12% Baobab at pH 3.15. With these conditions, the average scores for the sensory descriptors would be: Gelling 7; Brilliance 7; Smell 6.30; (-)Salinity 8.28; Sweetness 8.07; and (-)Astringency 8.43.

4. Conclusion

This study was carried out with a view to enhancing the value of the cashew apple in a jam, which has long been abandoned in plantations in favour of the cashew nut, which is of greater economic interest. The results of the cashew jam formulations using Baobab show that the sensory descriptors can be modelled. The Baobab has a significant effect on the gelling, smell, and astringency of the jams. Brilliance depends on the added sugar. The product-effect analysis shows that the formulations obtained can be characterized by at least one of the following descriptors: Cashew smell, Gelling, Brilliance, and Sweetness. An optimal cashew jam formulation that best satisfied the panellists was obtained. Cashew apple jam

using Baobab is a way of adding value to the apple that has long been abandoned. With the product effect of the descriptors, the manufacturer can make the jam according to the type of consumer. It would be important to find conditions for prolonged storage of this jam.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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