Nutrition & Food Science International Journal
ISSN 2474-767X

Research Article
Volume 10 Issue 1 - June 2020
DOI: 10.19080/NFSIJ.2020.10.555780

Nutri Food Sci Int J

Optimization and Development of Cashew Nut Beverage Based on Sensory Properties using Response Surface Methodology

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Submission: March 11, 2020; **Published:** June 15, 2020

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Abstract

This study aimed to develop and to optimize a cashew nut-based functional beverage based on its sensory characteristics. A 22 central composite rotated design with five repetitions on the central point was employed to evaluate the effect of juice and sugar contents on the acceptance of color, aroma, flavor, sweetness, thickness and overall impression of the beverage. Mathematical models explaining the behavior of the independent variables on the acceptance of all sensory attributes were obtained, with sugar concentration being the most influential factor. It was possible to combine the nutritional, functional and sensory characteristics of raw materials (cashew nut almonds, grape juice and prebiotic substances) used for the preparation of a beverage with high functional appeal. By means of the response surface methodology, a formulation with satisfactory acceptance was obtained, which must be added with 7% sugar and 37% grape juice.

Keywords: Acceptance; Functional foods; Nuts; Response surface methodology; Sensory analysis

Introduction

The response surface methodology is a method that has been widely used in recent years for the development of new products and it consists in evaluating of the relationship between a certain parameter, which is believed to be important to the product quality (response), and the variation sources under study (independent variables) [1]. During the development of a new product, it is of vital importance to evaluate the consumers' response still in the early stages, not only in the final product [2-4]. The response surface methodology, when used for sensory data interpretation, can be an important helping tool to obtain a formulation that achieves the maximum acceptance possible [5-8].

In Brazil, the beverage market and other lactose-free products is expanding rapidly, however, only the soy-based foods are already established in the market. In recent years, several studies have been conducted using various types of foods (soy, almonds, quinoa, rice, Brazil nuts) to obtain vegetal hydro soluble extracts and use them in beverage formulation [9-12]. Accordingly, a study by Rebouças et al. [7] demonstrated that the use of cashew nut almonds is a viable option for the development of beverages added with fruit juice, allowing to obtain a product with acceptable sensory quality.

The cashew nut almond has nutritional characteristics that make it an excellent raw material for obtaining vegetal hydro soluble extract to be used as a basis for the development of new foods and beverages. Its lipid fraction consists, mainly, of unsaturated, mono and polyunsaturated fatty acids [13], where are several bioactive substances (phenolic compounds, sterols and tocopherols) with antioxidant capacity [14]. Regarding protein contents, the cashew nut almond has all the essential amino acids to adults and schoolchildren [13], besides the mineral's magnesium, calcium, selenium, manganese, phosphorus and, in particular, iron [14].

Grape juice is a beverage much appreciated by the Brazilian consumer [15] that, besides sensory acceptance, has several substances capable to perform beneficial actions in the body, such as phenolic compounds and resveratrol, which have antioxidant activity [16]. In this sense, the use of grape juice in new products that combine their excellent functional and sensory characteristics with other foods containing proteins and good quality lipids, nutrients scarce in this fruit, seems to be very promising and valid.

The technological and nutritional characteristics of prebiotics of the inulin type make them a quite attractive ingredient for the development of functional foods, which have the potential to promote health through mechanisms not covered by conventional nutrition, restricting them only to health promotion and not to cure diseases [17].

Given the above, to combine the nutritional and functional characteristics of cashew nut almonds, grape juice and prebiotic substances seems to be a feasible alternative for the development of a functional beverage. Thus, this study aimed to use the response surface methodology to optimize the sensory attributes of a cashew nut almond-based functional beverage added with grape juice and prebiotic substances.

Materials and Methods

Materials

The following ingredients were used for the preparation of formulations: grape juice (pH = 2.99; 15.2ºBrix), cashew nut hydro soluble extract (CNH) (3.46g carbohydrates, 6.22g of lipids, 3.41g of protein, 0.35g of ashes, 3.6ºBrix, pH 6.56), sugar, oligofructose (2 to 8 monomers, Orafti P95) and inulin (degree of polymerization ≥10, GR Orafti). The CNH was obtained following the methodology describe by Rebouças et al. [7].

Experimental design and beverages preparation

A 22 central composite rotated design with five repetitions on the central point (Table 1) was used to evaluate the effects of sugar and juice contents (independent variables) on the sensory acceptance.

Table 1: Experimental design used for the formulation of beverages (uncoded and coded values).

Formulations	Uncoded values		Coded values	
	Juice (%)	Sugar (%)	Juice (X1)	Sugar (X2)
F1	20	4	-1	-1
F2	20	8	-1	1
F3	40	4	1	-1
F4	40	8	1	1
F5	16	6	-1.41	0
F6	44	6	1.41	0
F7	30	3	0	-1.41
F8	30	9	0	1.41
F9 (CP)	30	6	0	0
F10 (CP)	30	6	0	0
F11(CP)	30	6	0	0
F12 (CP)	30	6	0	0
F13 (CP)	30	6	0	0

(CP): Central point

For the formulation of the beverages, a CNH concentration complementary to the concentration of juice established by the experimental design (Table 1) was used in order to fulfill the 100% liquid volume. The amount of sugar (v/v) added to the mixture of CNH and juice followed the experimental design, plus 3% (v/v) of the mixture of inulin and oligofructose in a 50:50 proportion, in order to complete the 200 ml volume. The addition of a mixture of prebiotic substances aimed a better functional effect, since the action of oligofructose appears to primarily occur in the proximal colon [18], while the inulin acts in the distal colon [19].

The ingredients were homogenized at a rotation of 900 rpm for 1 minute, and then, the beverage was packaged in 200mL polystyrene bottles. Soon after this, the beverages were submitted to a heat treatment in a thermostatic bath at 65 °C for 2 minutes, cooled and kept in refrigeration (7 °C).

Sensory evaluation

The evaluation of sensory acceptance of the developed formulations was performed with 130 untrained panelists, mostly females (76.03%), aged between 18 and 25 years (79.23%) and undergraduate students (72.30%). The panelists were selected according to their regular consumption of cashew nut almonds and grape juice. A portion of, approximately, 25mL of each sample was served chilled (7 °C) in plastic cups coded with three-digit random numbers in a monadic way. The evaluation was performed in sensory laboratory using individual cabins under artificial daylight lighting. The order in which the samples were

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served followed an incomplete balanced block design, where each panelist tasted 4 out of the 13 tested formulations [20].

To evaluate the acceptance of the sensory attributes color, aroma, flavor, sweetness, thickness and overall impression, it was used the nine-point hedonic scale (9 = like extremely; 1 = dislike extremely).

This study was approved by the *Comitê de Ética em Pesquisa of the Universidade Federal do Ceará*, which regulates research involving humans, with the number 873.769.

Data analysis

The effect of the concentration of grape juice and sugar on the acceptance of sensory attributes was established using mathematical models by means of second order equations (Equation 1). In the equation, Y corresponds to the attribute, β_0 is the constant, X_1 and X_2 the independent variables (grape juice and sugar), and β_1, β_2, β_{11}, β_{22}, β_{12} are the regression coefficients (linear, quadratic and interaction).

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{11} X_{21} + \beta_{22} X_{22} + \beta_{12} X_1 X_2 + \text{Error} \quad - (1)$$

The ANOVA of the models was performed to evaluate the quality of adjustment and significance of the linear, quadratic and interaction effects. The coefficient of determination (R_2), the adjusted coefficient of determination (R_2 adjusted) and the analysis of the lack of adjustment were used to evaluate the models' quality, and the response surface graphs were generated. The association between the sensory attributes analyzed was determined by Pearson's correlation coefficients (r). All analyses were performed using the statistical software Statistica version 7.0.

Results and Discussion

In general, the formulations reached hedonic scores around 5.0 (neither dislike nor like) and 6.0 (slightly liked), except for the color attribute, where formulations added with low juice contents reached averages referring to the scale rejection region (score of 1 to 4) (Table 2).

For all evaluated attributes, it was possible to obtain a satisfactory mathematical model ($p < 0.05$), with no significant lack of adjustment ($p > 0.05$), which shows that the model error and its replicates (central points) were low, and that it can be used for prediction purposes.

Regarding to color, both the variable juice, in its linear and quadratic effect, and sugar, in its quadratic effect, were shown to influence on the acceptance of this attribute. By using equation 2, it was possible to obtain the response surface (Figure 1) which explains the behavior of the independent variables in the color acceptance. As observed, the increase on juice concentration leads to a greater color acceptance. Despite being an influential factor, sugar, as can be seen, exerted little influence on the acceptance of this attribute, where large variations in its concentration slightly altered the response obtained. One observes that it was possible to obtain a region of maximum color acceptance, where the juice concentration can vary between 30 and 44% and sugar around 5 to 7%.

$$\text{Color} = -12.48 + 0.64\text{Juice} + 2.34\text{Sugar} - 0.01\text{Juice}^2 - 0.20\text{Sugar}^2 - 0.0109\ \text{JuiceSugar}\ (R^2 = 0.98;\ R\text{adj.} = 0.97;\ P\text{-value (lack of fit)} = 0.16) \quad (2)$$

The formulations with higher juice concentrations and, as a consequence, with color nearest to the fruit juice, were the ones that had higher acceptance of color. Granato et al. [21] also found the same type of influence regarding the addition of guava juice on the color acceptance of soy-based desserts. In liquid foods, the individuals tend to prefer colors that comply with patterns stated in their memories (for example, orange juice with orange colors) [22]. Possibly, as this is a beverage added with grape juice, the panelists created an expectation, regarding the beverage color, which would be nearer to the characteristic color of this juice. The expectation and real perception regarding the various sensory attributes that compose the product can be directly affected by food color. The significant correlation (aroma r = 0.78; p = 0.002; flavor r = 0.62; p = 0.023; thickness r = 0.67; p = 0.013; overall impression r = 0.81; p = 0.001) between color and the other attributes, except for sweetness, exemplifies the influence that this attribute may have had on the acceptance of the other sensory characteristics of the beverage. (Table 2)

Table 2: Average results of sensory evaluation (n = 130 consumers).

Formulation	Uncoded and Coded Values		Sensory Attributes					
	Juice	Sugar	Color	Aroma	Flavor	Swetness	Thickness	Overall Impression
F1	20 (-1)	4 (-1)	3.2 ± 2.0	4.0 ± 2.0	4.3 ± 2.2	4.9 ± 2.1	5.1 ± 1.7	4.3 ± 2.0
F2	20 (-1)	8 (+1)	3.3 ± 2.1	4.9 ± 2.1	5.5 ± 2.4	6.3 ± 1.9	5.6 ± 2.2	5.3 ± 2.0
F3	40 (+1)	4 (-1)	5.9 ± 2.0	5.7 ± 1.7	5.5 ± 2.4	5.7 ± 2.4	5.8 ± 2.2	5.7 ± 2.1
F4	40 (+1)	8 (+1)	5.1 ± 2.3	4.9 ± 1.9	5.5 ± 2.2	5.3 ± 2.2	5.2 ± 2.4	5.7 ± 1.9
F5	16 (-1.41)	6 (0)	2.4 ± 1.8	4.8 ± 2.1	4.8 ± 2.5	5.1 ± 2.5	5.1 ± 2.5	4.6 ± 2.3
F6	44 (+1.41)	6 (0)	5.8 ± 2.3	5.4 ± 1.9	5.2 ± 2.4	5.7 ± 2.5	5.7 ± 2.3	5.6 ± 2.3

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F7	30 (0)	3 (-1.41)	3.9 ± 1.9	4.4 ± 1.5	3.8 ± 1.9	4.0 ± 2.0	4.4 ± 2.1	4.0 ± 1.9
F8	30 (0)	9 (+1.41)	4.2 ± 2.3	5.0 ± 1.7	5.2 ± 2.4	5.7 ± 2.3	5.8 ± 2.2	5.2 ± 2.2
F9	30 (0)	6 (0)	5.8 ± 2.0	5.0 ± 1.8	5.3 ± 2.8	6.0 ± 1.6	5.7 ± 2.0	5.6 ± 1.7
F10	30 (0)	6 (0)	5.9 ± 1.9	5.5 ± 1.5	5.3 ± 2.2	5.9 ± 1.8	5.7 ± 1.7	5.7 ± 1.7
F11	30 (0)	6 (0)	6.0 ± 2.0	5.8 ± 1.6	5.8 ± 2.1	6.4 ± 2.1	6.2 ± 1.8	6.0 ± 1.9
F12	30 (0)	6 (0)	6.2 ± 1.6	5.5 ± 1.6	5.5 ± 2.0	5.9 ± 1.7	5.9 ± 1.8	5.8 ± 1.6
F13	30 (0)	6 (0)	5.7 ± 1.9	5.5 ± 1.6	5.7 ± 2.3	6.4 ± 2.0	6.0 ± 1.9	5.9 ± 2.4

The aroma of the beverage was influenced by both juice concentration (linear effect), and sugar concentration (quadratic effect), besides the interaction effect between these two variables. Equation 3 shows that although the interaction between these variables is significant and with a negative effect (-0.0021), the influence exerted by this effect is very low, making it not possible to perceive clearly an increase on aroma acceptance due to a decrease in the variables concentration (Figure 1). However, a greater influence of juice, mainly with respect to its positive linear effect, is more clearly perceived. The positive quadratic effect of sugar concentration led to a greater acceptance with higher levels of sugar in the beverage. Regarding this attribute, it was not possible to obtain a region of optimization of acceptance.

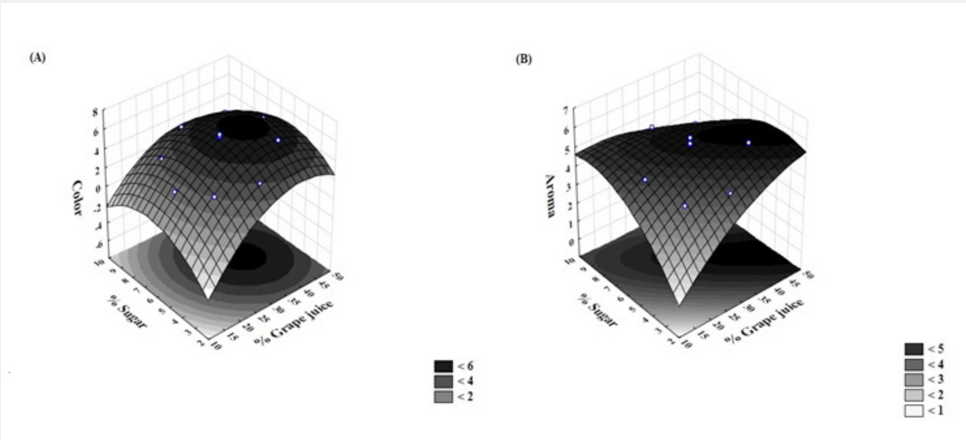

Figure 1: Effect of sugar and grape juice concentration on acceptance of color (A) and aroma (B).

$$\text{Aroma} = -4.713 + 0.286\text{Juice} + 1.736\text{Sugar} - 0.002\text{Juice}^2 - 0.086\text{Sugar}^2 - 0.0021\text{JuiceSugar} \quad (R^2 = 0.83;\ \text{Radj.} = 0.71;\ \text{P-value (lack of fit)} = 0.63.) \qquad (3)$$

Flavor was only influenced by sugar concentration on its linear and quadratic effect. Response surface was obtained using equation 4 (Figure 2), where it is possible to observe that the increase in sugar concentration leads to an increase in acceptance up to a maximum where, thereafter, a reduction in the response begins to happen. Through the graph, it can be observed that a wide range of variables concentration was obtained, leading to the maximum acceptance of flavor. It can be seen that a possible variation in juice concentration is much higher than in sugar concentration, precisely due to the lack of influence of this variable on the acceptance of flavor.

Formulations with lower juice concentrations were those that had lower aroma acceptance. Despite cashew nut almonds being a familiar product to the consumers who took part in this study, due to the fact that, at the time this study was conducted, there was no beverage based on this raw material available in the Brazilian market, possibly, this may have been one of the reasons for the low acceptance of the formulations with lower juice concentrations and, as a consequence, with an aroma nearest to that of an almond's. Rebouças et al. [7] also found the same behavior when evaluating the acceptance of the aroma of cashew nut almonds-based beverages added with passion fruit juice.

$$\text{Flavor} = -3.947 + 0.213\text{Juice} + 1.780\text{Sugar} - 0.002\text{Juice}^2 - 0.095\text{Sugar}^2 - 0{,}015\text{JuiceSugar} \quad (R^2 = 0.84;\ \text{Radj.} = 0.73;\ \text{P-value (lack of fit)} = 0.21) \qquad (4)$$

The acceptance of the beverage sweetness showed to be influenced by sugar concentration in its linear and quadratic effect and by the interaction between sugar and juice. By means of equation 5, it can be observed that, although the interaction between variables are significant and with a negative effect (-0.022), the influence exerted by this effect is very low, making it not possible to perceive clearly an increase in sweetness acceptance due to a simultaneous decrease in the variables

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concentration. On the other hand, the strong influence of sugar, mainly regarding its positive linear effect, is perceived by the obtained response surface (Figure 2). The gradual increase on sugar concentration leads to greater acceptance up to a certain level where, thereafter, the response begins to decrease (negative quadratic effect). The correlation between sweetness and flavor ($r = 0.92$, $p < 0.0001$) was significant and strong, which explains the results obtained and shows that the characteristics that compose this beverage flavor, sweetness was extremely important for the acceptance of this attribute.

$$\text{Sweetness} = -5.804 + 0.281\text{Juice} + 2.299\ \text{Sugar} - 0.002\text{Juice}^2 - 0.119\ \text{Sugar}^2 - 0{,}022\text{JuiceSugar}\ (R^2 = 0.83;\ \text{Radj.} = 0.71;\ \text{P-value (lack of fit)} = 0.15) \quad (5)$$

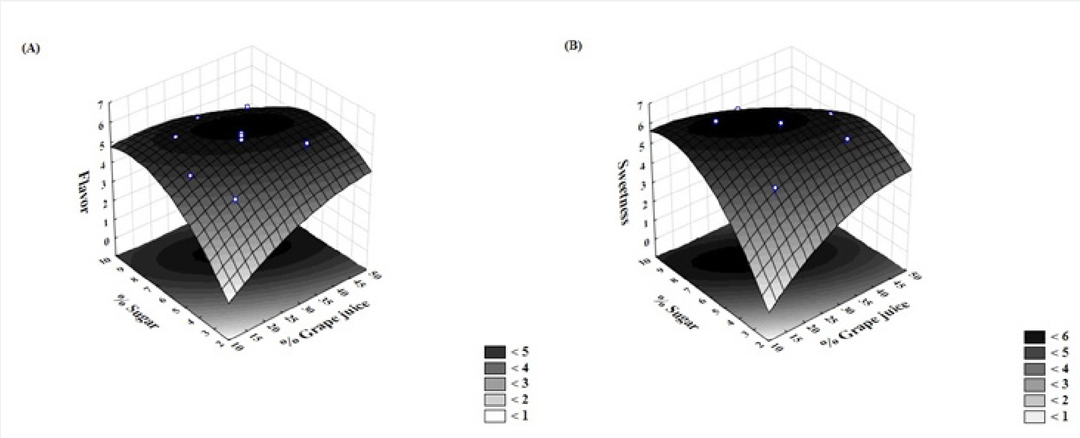

Figure 2: Effect of sugar and grape juice concentration on acceptance of flavor (A) and sweetness (B).

Despite having been an influencing variable for the acceptance of color and aroma, juice concentration did not influence flavor acceptance or the characteristic sweetness of the beverage. This means that, within the studied interval, the maximization of the acceptance of these attributes is obtained in practically all the range of juice concentration.

Regarding the acceptance of the beverage thickness, it proved to be influenced by sugar contents (linear and quadratic effect), by juice (quadratic) and by the interaction between the variables. From all the variables, the one that showed to exert greater influence on response was the sugar concentration (Equation 6) in its linear effect (+1.54). The positive linear effect led to an increase of acceptance due to the elevation of sugar concentration up to a certain point, around 8.0%, where, thereafter, acceptability begins to decrease due to the negative quadratic effect, as shown by the generated response surface (Figure 3).

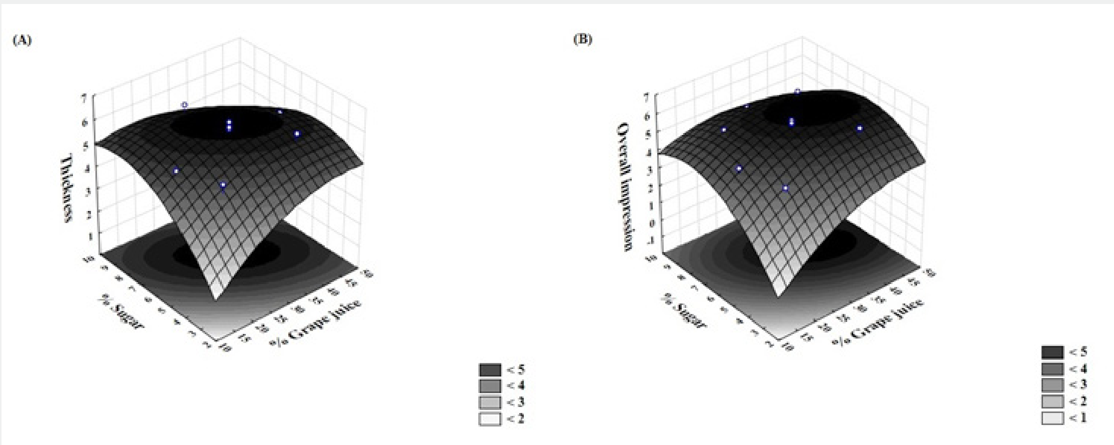

Figure 3: Effect of sugar and grape juice concentration on acceptance of thickness (A) and overall impression (B).

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$$Thickness = -2.814 + 0.234Juice + 1.54Sugar - 0.002\ Juice^2 - 0.085\ Sugar^2 - 0.013JuiceSugar\ (R^2 = 0.73;\ Radj. = 0.54;\ P\text{-value (lack of fit)} = 0.06) \quad (6)$$

It was observed that higher sugar concentrations resulted in a higher acceptance of the beverage thickness. Possibly, the increase in sugar concentration led to an increase of the beverage viscosity, due to higher contents of soluble solids, which resulted in wider acceptance of this sensory characteristic. A study by Lethuaut et al. [23] reported that the variation in sugar contents in dairy desserts caused a modification on the evaluation of oral texture, where higher concentrations of this ingredient caused an increase in intensity texture characteristics.

The overall impression showed to be influenced by the concentration of juice, sugar and the interaction between them. The response surface (Figure 3) obtained by equation 7 shows the greater influence of sugar concentration on global acceptance. The positive linear effects and negative quadratic effects of juice and sugar concentration showed, as well as in other attributes, that a higher concentration of each of these variables increases the acceptance to a certain point where, thereafter, it begins to decrease. It can be noted that it was possible to obtain an optimum region of acceptance concerning the concentration of the two variables, by adding juice ranging from 27 to 44% and sugar from 5 and 8% approximately.

$$Overall\ impression = -5.315 + 0.271\ Juice + 1.973Sugar - 0.003Juice^2 - 0.118Sugar^2 - 0.013\ JuiceSugar\ (R^2 = 0.91;\ Radj. = 0.85;\ P\text{-value (lack of fit)} = 0.07) \quad (7)$$

It stands out that all evaluated sensory attributes obtained a significant strong correlation with the overall impression (color: r = 0.80; aroma: r = 0.87; flavor: r = 0.96; sweetness: r = 0.85; thickness: r = 0.87), showing that the acceptance of all these attributes contributed to the final acceptance of the beverage in the same degree of importance.

Considering overall impression, it was influenced by both sugar concentration and juice content, although the latter has influenced in a lesser degree. Therefore, it is necessary to consider the concentration of both variables in order to obtain the product's greatest possible acceptance. The studied variables concentration range allowed to obtain optimal points for all attributes, except for the attribute flavor. Analyzing the response surfaces obtained, it is noticeable that the sugar concentration which allows maximum sensory acceptance is between 5 and 7%. Regarding juice, in almost all studied interval, it is possible to obtain higher averages. Thus, analyzing all response surfaces in order to contemplate the maximum acceptance achieved in all sensory attributes evaluated, it can be stated that the formulation added with 7% sugar and 37% juice allows to obtain a satisfactory acceptance of this beverage.

Conclusion

The variation on sugar concentration in the beverage was found to be the most influential factor in the acceptance of most sensory attributes analyzed. Through the use of the response surface methodology, it was possible to obtain a formulation with satisfactory acceptance, which must be added with 7% sugar and 37% grape juice. Thus, it was possible to combine the nutritional, functional and sensory characteristics of the raw materials used (cashew nut almonds, grape juice and prebiotic substances) to elaborate a beverage with high nutritional and functional appeal.

Acknowledgments

The authors wish to acknowledge Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for its scholarship and Beneo-Orafit for their support.

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