




The influence of sensory attributes on overall liking by a gamma regression model: an analysis of Cerrado mixed fruits jams

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Abstract

Factors that influence the acceptability and preferences of consumers have been perceived as sensory attributes, such as color, appearance, flavor, and texture. Understanding which attributes are most important for overall liking would be helpful to establish meaningful criteria for product grading. Thus, in addition to the overall chemical and sensory qualities, it is important to appreciate which sensory attributes make a product pleasant or unpleasant to a consumer. In this context, the aim of this study was to evaluate the sensory attribute that contributes most to the overall liking by a gamma regression model using different formulations of mixed fruit jams made with Brazilian Cerrado fruits. Based on the proposed model, we concluded that appearance was the most important predictor of the overall liking of the assessors.

Keywords: Brazilian Cerrado fruits; simplex lattice mixture design; sensory attribute.

Practical Application: To appreciate which sensory attributes make a product pleasant or unpleasant to a consumer.

1 Introduction

Sensory properties are important factors in the determination of liking, and among the factors that influence the acceptability and preferences of consumers are sensory attributes, such as color, appearance, flavor, and texture (Concas et al., 2019). The sensory attributes play a major role in product acceptability by directly influencing the success of a product in the marketplace (Delahunty & Drake, 2004).

Moskowitz & Krieger (1995) investigated which sensory attributes are related to the acceptability of a product by consumers and whether all sensory attributes (flavor, appearance, etc.) have equal weight or have different weights in consumer preference. The authors emphasized that proper understanding of the attributes that are most important for overall liking would also be helpful for establishing meaningful criteria for product grading. According to Ritvanen et al. (2005), in addition to the overall chemical and sensory quality, it is important to appreciate which sensory attributes make a product pleasant or unpleasant to consumers.

Brazil has a wide biodiversity, and the Cerrado, which represents 25% of the Brazilian territory, houses most of these species, and the fruits of this biome are a source of bioactive compounds with functional properties beneficial to health, in addition to presenting unique sensory characteristics (Bailão et al., 2015; Souza et al., 2012a). Among its innumerable fruit trees, murici (*Byrsonima crassifolia* L. RICH), marolo (*Annona crassiflora* Mart.),

jenipapo (*Genipa americana* L.), sweet passion fruit (*Passiflora alata* Dryand), and soursop (*Annona muricata* L.) stand out.

Many fruit species of the Brazilian Cerrado are still unknown, and therefore, few are commercially available (Mattietto et al., 2010). These fruits are of a potential interest to the agroindustry and represent a possible future source of income for the local population (Almeida et al., 2011). One way to increase availability and add even more value to exotic Brazilian fruits is to create new products, such as jams, juices and jellies, to become an option for introduction into the national and international markets (Georgiev et al., 2014).

Given the wide variety of fruits in the Brazilian Cerrado, several products can be prepared from various fruit mixtures. These fruits are capable of producing jams, jellies and juices with different tastes and appearances. Mixed fruit jams combine the sensory and nutritional aspects of two or more fruits in the final product, and this market is gradually gaining prime space in the consumer market (Schiassi et al., 2018, Farias et al., 2019; Schiassi et al., 2019).

A gamma regression model is considered in which the mean of the response variable depends on the values of the regressor variates according to an exponential link function, which is an alternative to consider for variables that seem to be highly skewed. In this context, the aim of this study was to evaluate

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the sensory attribute that contributes most to the overall liking by a gamma regression model using different formulations of mixed fruit jams made with Brazilian Cerrado fruits.

2 Materials and methods

2.1 Materials

This study used the pulp of murici (*Byrsonima crassifolia* L. RICH), marolo (*Annona crassiflora* Mart.), jenipapo (*Genipa americana* L.), sweet passion fruit (*Passiflora alata* Dryand), and soursop (*Annona muricata* L.) and high-pectin methoxyl (Danisco, São Paulo (SP), Brazil), citric acid and sucrose.

2.2 Source of fruit pulps

The pulps of jenipapo and murici were acquired from a fruit pulp processing company located in Uberlândia, Minas Gerais (MG), Brazil. The soursop pulp was obtained from a fruit pulp processing company located in Jarinu, SP, Brazil. These pulps were stored in sealed plastic bags, frozen and transported in Styrofoam boxes. The pulps of sweet passion fruit and marolo were processed at the Laboratory of Processing Plant Products, Federal University of Lavras (UFLA, Lavras, MG, Brazil), after the acquisition of fresh fruits from the north of Minas Gerais. These fruits were washed with tap water and then separated into peel, seed and pulp. The pulps were extracted manually with a knife, and the husk and seed were discarded. The pulps

were then beaten in a blender and after homogenization, were stored in sealed, plastic bags and frozen. All pulp was stored in a cold room at -18 °C.

2.3 Preparation of the jams

To process the jams, a blend of fruit pulps was made (according to Table 1) and sucrose was added. The proportion of sugar and fruit pulp used was 1:1 (w/w). The jams were processed in an open pan that was heated with a gas flame (Macanudo, SC, Brazil). Once boiling, 1.5% high-methoxyl pectin was added. After the soluble solids reached 75 °Brix, 6% citric acid (2%) was added and cooking was stopped. The percentages are expressed as percent weight.

The total soluble solids were determined using a portable refractometer model RT-82, and °Brix was measured at ± 25 °C. The hot jams were then poured into 250 mL sterile bottles, cooled in a container with water and ice and stored in a refrigerator at ± 7 °C.

2.4 Sensory analysis

Prior to performing the analysis, the project was approved by the local Ethics Committee (number 0018.0.461.000-11). An acceptance test was conducted based on the attributes of color, appearance, aroma, taste, and overall liking using a 9-point hedonic scale (1 = extremely dislike, 9 = extremely like) and the purchase intention test using a 5-point scale (5 = definitely

Table 1. Compositions of jam mixture samples in a simplex lattice mixture design.

Formulation	Jenipapo (%)	Marolo (%)	Murici (%)	Soursop (%)	Sweet passion fruit (%)
1	100	0	0	0	0
2	0	100	0	0	0
3	0	0	100	0	0
4	0	0	0	100	0
5	0	0	0	0	100
6	50	50	0	0	0
7	50	0	50	0	0
8	50	0	0	50	0
9	50	0	0	0	50
10	0	50	50	0	0
11	0	50	0	50	0
12	0	50	0	0	50
13	0	0	50	50	0
14	0	0	50	0	50
15	0	0	0	50	50
16	60	10	10	10	10
17	10	60	10	10	10
18	10	10	60	10	10
19	10	10	10	60	10
20	10	10	10	10	60
21	20	20	20	20	20

would buy the product, 1 = certainly would not buy the product) (Stone et al., 2012).

The test was conducted on 85 participants (50 women and 35 men) between the ages of 18 and 40 years. Panelists were selected based on their regular consumption of fruit jams and jellies. In the sensory evaluation, each panelist evaluated 21 formulations in five sessions spread over five consecutive days. In the first four sessions, four formulations were evaluated, and in the fifth and final session, five formulations were evaluated.

Samples of approximately 5 g of jam at refrigeration temperature (7 °C) were served in 50 mL cups in a balanced manner. These samples were coded with three-digit numbers selected from a table of random numbers. The test was conducted in individual booths under white light with adequate ventilation.

2.5 Experimental design

From the simplex lattice mixture design (Cornell, 1983), the proportion of fruit jenipapo (Z_1), marolo (Z_2), murici (Z_3), soursop (Z_4), and sweet passion fruit (Z_5) used in the preparation of the mixed fruit jams was determined. In total, 21 formulations were evaluated. The design with coded and experimental levels for these five factors is presented in Table 1.

Depending on the experimental results, statistical analysis based on an initial factor analysis (Hair et al., 2018) was used to describe the relationships of dependence on sensory attributes. After the identification of these variables was investigated, a generalized model (Jiang, 2006) that allows the identification of which sensory attribute (x) is more significant in predicting the expected value of the dependent variable (y) overall liking was used. This generalized model has a gamma distribution with a mean value $\mu > 0$ and a shape (nuisance) parameter $\nu > 0$, whereas $y \sim \text{Gamma}(\mu, \nu)$, if it has a density Function 1 (Mittlböck & Heinzl, 2002).

$$f(y) = \frac{1}{\Gamma(\nu)} \left(\frac{\nu}{\mu}\right)^\nu y^{\nu-1} \exp\left\{-\frac{\nu y}{\mu}\right\} y > 0 \quad (1)$$

A gamma regression is modeled using the reciprocal canonical link function $(\mu_i)^{-1} = x_i \beta$, $i=1, \dots, n$, where x_i is the vector of covariates and β is the parameter vector to be estimated with β_0 as the intercept and β_1, \dots, β_k as the parameters for the k covariates (Mittlböck & Heinzl, 2002). The iterated procedure weighted least squares (IWLS) algorithm was used in the statistics to numerically solve the maximum likelihood equations to estimate β in the proposed model. The diagnosis of influential observations in the estimates of model parameters is given in Function 2. This estimate, considering the dispersion parameter $\hat{\sigma}$ hat-values (h_i) for a generalized linear model, can be taken directly from the final iteration of the IWLS procedure and the approximation to the Cook's distance influence measure is

$$D_i = \frac{R_{pi}^2}{\hat{\phi}(k+1)} x \frac{h_i}{1-h_i} \quad (2)$$

R_{pi} Standardized Pearson residuals correct for the conditional response variation and for the leverage of the observations defined in Function 3

$$R_{pi} = \frac{Y_i - \hat{\mu}_i}{\sqrt{\hat{V}(Y_i | \eta_i)(1-h_i)}} \quad (3)$$

$V(Y_i | \eta_i)$ is the variance of the response given the linear predictor. Finally, the validation of the presented gamma model was made considering the Q-Qplot constructed from Standardized deviance residuals defined in R_{Di} (Function 4)

$$R_{Di} = \frac{D_i}{\sqrt{\hat{\phi}(1-h_i)}} \quad (4)$$

D_i , a deviance residual, is the square-roots of the case-wise components of the residual deviance, attaching the sign of $(Y_i - \hat{\mu}_i)$. For the model adjustment, the CORE TEAM software (R Core Team, 2018) was used.

3 Results and discussion

To investigate the dependence between the sensory attributes by using factor analysis, we obtained the factor loadings, which measure common aspects between the scores of the tasters (Table 2).

In this context, it is noted that the first factor (F1) has a strong correlation with all sensory attributes, whereas the second factor (F2) has a low correlation. Based on these results, we observe the existence of two contrasts, yielding two new variables called positive aspects of the panel (F1) and negative aspects of the panel (F2). The confirmation of these new variables can be verified by the high values of the communalities that suggest that all sensory attributes showed a significant contribution in the formation of factors (F1) and (F2).

The scores of known factors F1 and F2 by positive and negative aspects, respectively, are shown in a Biplot following the graph (Figure 1).

Table 2. Results of sensory analysis represented by Factorial Loadings and communalities.

Sensorial Attribute	Factorial Loadings		Commonality
	F1	F2	
Color	0.86	0.49	0.99
Appearance	0.85	0.45	0.93
Aroma	0.94	0.16	0.91
Taste	0.98	-0.18	0.99
Overall liking	1.00	-0.001	1.00
Purchase Intention	0.99	0.004	0.99
Variance	5.30	0.51	5.81
Variance (%)	0.88	0.08	0.97

The results in Figure 1 focus on the positive and negative aspects of the consumers show that the attribute appearance (X_1) is correlated with the variable color. The correlated variable color was discarded, and it was assumed that only the variable appearance was adjusted for overall liking. The aroma (X_2) and taste (X_3) variables were considered in adjusting the model because they are independent variables. The variable, purchase intention, was not considered in the model because it is correlated with the overall impression (the dependent variable selected). In this context, we considered the Gamma distribution, justified by the asymmetry in the response variable overall liking (Figure 2), to set up the model range with the following specification: Y_{ij} is the observed response of the i^{th} assessor for the variable overall liking, and X_j for $j = 1, 2, 3$ refers to the responses for the variables appearance, aroma and taste, respectively. Thus, assume Y_{ij} is approximately $\Gamma(\mu_{ij}, \varphi)$ with the systematic given by $\log(\mu_{ij}) = \alpha + \beta_1 X_{1j} + \gamma_1 X_{1j}^2$, given that β_j and γ_j denote the effects of linear and quadratic j^{th} sensory attribute, respectively, and μ_{ij} .

To identify the sample that provided a greater influence over the estimates of the model parameters, the first adjustment

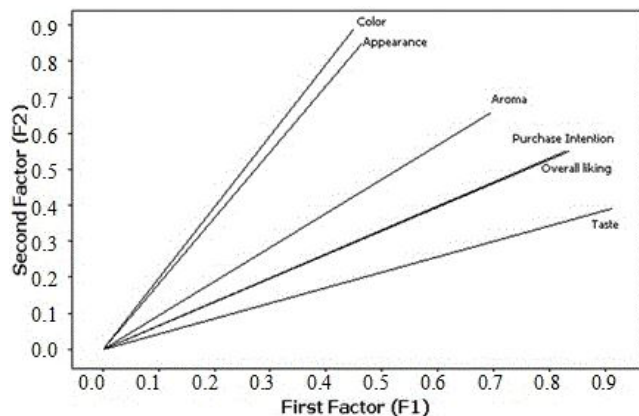


Figure 1. Biplot of sensory attributes.

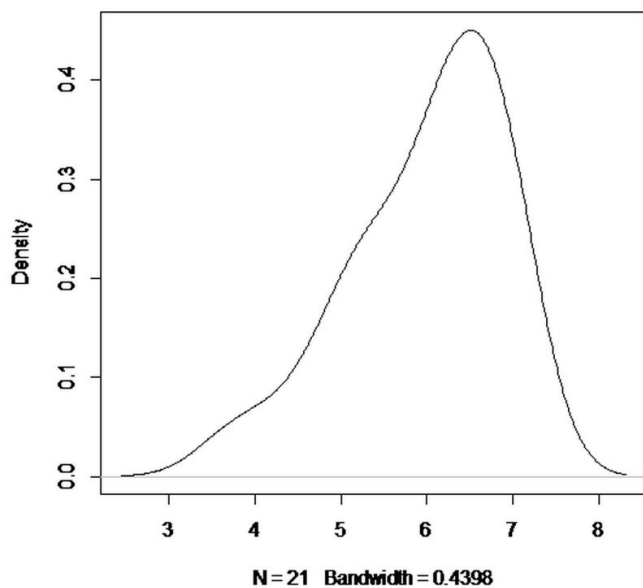


Figure 2. Density of response variable global aspect.

was made considering all of the observations. The results of the diagnosis are illustrated in Figure 3a and 3b.

It can be observed that the sample 1 with the values defined in appearance = 4.350, aroma = 4.125, and taste = 3.337, was identified as a point of leverage (Figure 3a) and an influential observation (Figure 3b). Thus, there is statistical evidence to state that the presence of this sampling observation influences the estimates of the parameters of the fitted model. The sample represented by a formula with 100% of jenipapo fruit stood out compared to the others; this was expected because this fruit has a characteristic and pronounced flavor and aroma (Souza et al., 2012a), and an acidic, slightly sweet pulp (Souza et al., 2012b), which is often not well accepted by consumers. In addition, features such as the brown color of the fruit pulp, are not very attractive (Silva et al., 2001).

Based on the results of the observations associated with the sample diagnosis, given the identification of sample 1 (appearance = 4.350, aroma = 4.125 and taste = 3.337), and the discrepancy (Figure 3a) and influence observation (Figure 3b), we proceeded with the analysis of estimates of model parameters in two situations: 1 - with all the sample observations; 2: Withdrawal of sample 1 in this context. The results are presented below in Table 3.

Comparing the estimates of the parameters of the model with a gamma distribution set to the two situations, one can observe that, keeping or deleting sample 1, the sensory attribute with the most significant response to the overall impression is verified by the magnitude of the estimates. Thus, the appearance attribute (X_1) has a higher contribution to the composition of the model used to predict the expected value of the overall impression. In terms of validating the quality of the fit of the model in both situations, the results shown in Figures 4a and 4b are presented.

In both cases (Figures 4a and 4b), the deviations are plotted within the confidence bands, and there is evidence for the model stating the distribution range used. The response has an overall print quality of fit desired.

We can observe that the appearance and its corresponding color attribute are important sensory factors. Color of foods greatly influences consumer preferences, and this trend can be observed in studies of Schiassi et al. (2018) and Schiassi et al. (2019). One of the main sensory parameters for the quality of foods is their color, and it is the first characteristic attracting consumer attention. Hence, it is considered a major feature for the assessment of food product quality (Martin et al., 2007).

In a study about consumer acceptance and appropriateness of meat substitutes in a meal context, Elzerman et al. (2011) concluded that the appropriateness seemed to be influenced by the appearance of the meat substitute-meal combination and less by flavor and texture.

The importance of color and appearance may be observed in several studies. Wei et al. (2012), for example, studied the relationship between color/appearance and sensory characteristics of expected levels. According to Wei et al. (2012), expectations and actual taste and flavor sensory characteristics are affected by food color and appearance, and according to this author

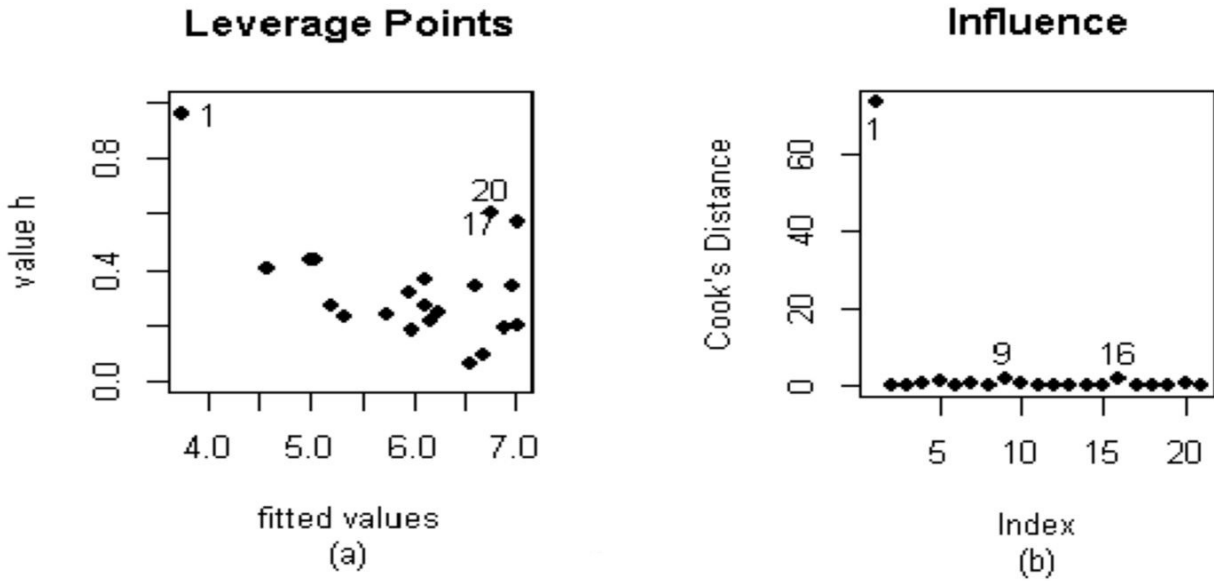


Figure 3. Diagnostic analysis of the model range set for the sensory data - point of leverage. (a) Diagnostic analysis of the model range set for the sensory data - influential observation (b).

Table 3. Estimates of the generalized model considering the distribution range for the response for overall impression according to the sensory attributes selected by means of the factor analysis.

Parameter	Term	Situation 1 (all samples)	Situation 2 (excluding sample 1)
β_0	Intercept	-0.10	-1.90
β_1	Appearance (X_1)	0.37	0.71
β_2	Aroma (X_2)	0.005	0.30
β_3	Taste (X_3)	0.06	0.002
γ_1	X_1^2	-0.03	-0.05
γ_2	X_2^2	0.001	-0.02
γ_3	X_3^2	0.003	0.008

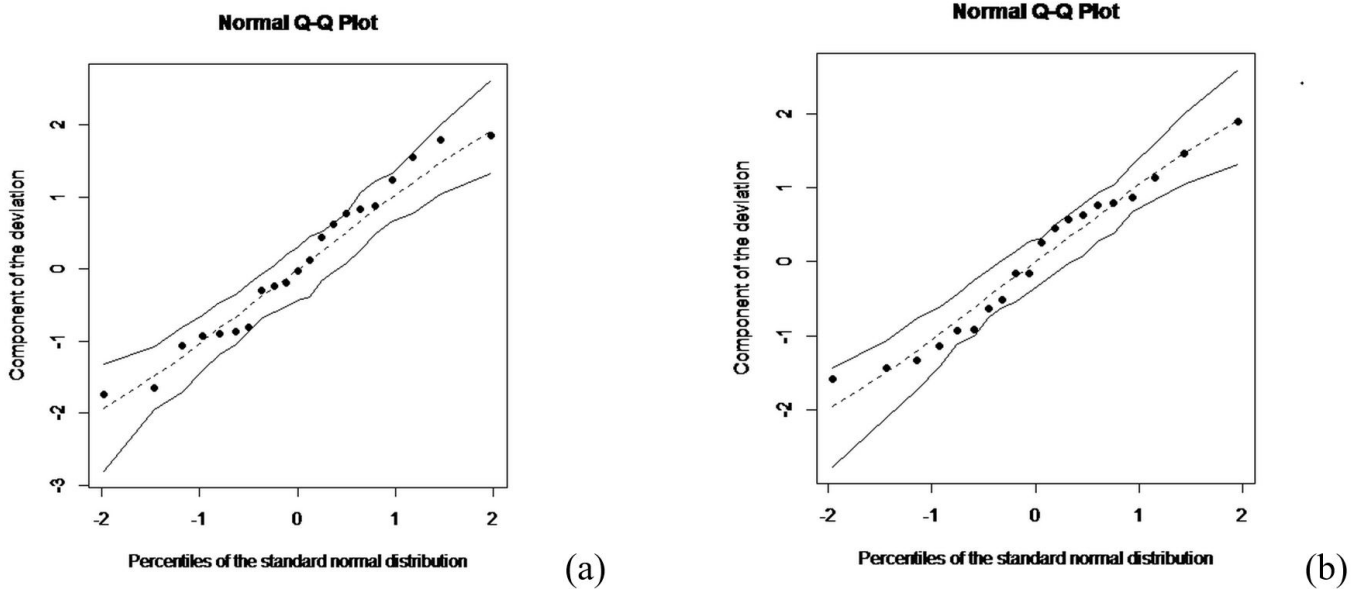


Figure 4. Chart of the envelope simulated considering the model range set for all observations (situation 1); (a) Chart of the envelope simulated considering the model range set for excluding sample 1 (situation 2) (b).

in many studies, it was found that color affected the expected and perceived levels of sensory characteristics. In general, they suggested that vivid colors tend to arouse stronger tastes or flavors than pale colors.

4 Conclusions

The proposed gamma regression model allowed us to infer that the attribute, appearance, showed a greater contribution to the prediction of the expected overall liking of the assessors.

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