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Chemical characterization and sensory potential of Brazilian vanilla species

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Abstract – The objective of this work was to evaluate the chemical and sensory profile, as well as the acceptability, of Brazilian vanilla species. The evaluated vanilla species were *Vanilla planifolia*, *Vanilla chamissonis*, *Vanilla bahiana*, and *Vanilla pompona*. For this, the optimized descriptive profile methodology, consumer acceptance tests with extracts applied to teas and creams, and the analysis of mass spectrometry by gas chromatography were used. Volatile compounds, such as vanillin, anisyl acetate, 4-methyl guaiacol, *p*-cresol, benzyl alcohol, and 2,3-butanediol, were identified. The species *V. planifolia* and *V. pompona* exhibited a more intense vanilla aroma, floral aroma, fruity aroma, vanilla flavor, brown color, and sweet taste. In addition, *V. bahiana* showed a more intense woody attribute, while *V. chamissonis* showed less intense attributes. Vanilla tea from *V. pompona* had a better consumer acceptance. However, when the vanillas were applied to creams, there was an acceptance rate of over 80% of all samples. Brazilian native vanillas have different sensory and volatile profiles, besides potential for a high acceptance by consumers.

Index terms: flavoring, orchid, sensory attributes, sensory acceptance, volatiles.

Caracterização química e potencial sensorial de espécies brasileiras de baunilhas

Resumo – O objetivo deste trabalho foi avaliar o perfil químico e sensorial, bem como a aceitabilidade, de espécies brasileiras de baunilhas. As espécies de baunilhas avaliadas foram: *Vanilla planifolia, Vanilla chamissonis, Vanilla bahiana,* and *Vanilla pompona*. Para tanto, foram utilizados a metodologia do perfil descritivo otimizado, testes de aceitação de consumidores por meio da aplicação dos extratos a chás e cremes, e análise de espectrometria de massa por meio de cromatografia gasosa. Foram identificados compostos voláteis, tais como vanilina, acetato de anisila, 4-metil-guaiacol, *p*-cresol, álcool benzílico e 2,3-butanodiol. As espécies *V. planifolia* e *V. pompona* apresentaram maiores intensidades de aroma de baunilha, aroma floral, aroma frutado, sabor de baunilha, cor marrom e gosto doce. Além disso, *V. bahiana* mostrou maior intensidade do atributo amadeirado, enquanto *V. chamissonis* mostrou atributos com menor intensidade. O chá de baunilha da espécie *V. pompona* teve melhor aceitação pelos consumidores. Entretanto, quando as baunilhas foram aplicadas a cremes, houve aceitação por mais de 80% dos consumidores de todas as amostras. As baunilhas nativas brasileiras apresentam diferentes perfis sensoriais e de compostos voláteis, além de potencial para alta aceitação pelo consumidor.

Termos para indexação: aromatizante, orquídea, atributos sensoriais, aceitação sensorial, voláteis.

Introduction

Vanilla is an orchid species with edible fruit that comprises more than 110 species (Wilde et al., 2019). *Vanilla planifolia* Jacks. ex Andrews is one of the most commercialized species due to its sensory characteristics, such as its flavoring power (Brumano, 2019). Vanilla fruit are used to produce a natural extract that is widely used in the food industry, such as in bakery products, creams, chocolates, and ice cream production (Krasaekoopt & Jongyin, 2017; Schipilliti et al., 2017).

For the development of compounds responsible for its sensory and physicochemical characteristics, unripe vanilla fruit undergo a curing process, in which enzymatic and biochemical reactions occur (Hernández-Fernández et al., 2020). The most important volatile compound in cured fruit is vanillin, representing approximately 85% of the total volatile compounds found in vanilla fruit. (Krasaekoopt & Jongyin, 2017). Following vanillin, the predominant compounds include vanillic acid, p-hydroxybenzaldehyde, and p-hydroxybenzoic acid (Hernández-Fernández et al., 2020).

Due to the growing demand and limitations of vanilla supply, the spice ranks as the world's second most expensive commodity. For instance, in 2018, premium Madagascar vanilla reached US$600 per kilogram (Walton et al., 2000; Wilde et al., 2019). In Brazil, the lack of information and scientific studies on the commercial production, curing, and processing of vanilla contribute to a lack of knowledge and insufficient incentive for production (Brumano, 2019).

The use of native species is constrained by the insufficient knowledge and the cost-effectiveness of artificial vanilla (Silva et al., 2022). Nevertheless, Camilo et al. (2016), studied native species from the Brazilian flora and cataloged eleven species. Vanilla species *V. bahiana*, and *V. chamissonis* existing in the Atlantic Forest were also described as yielding economically important compounds (Oliveira et al., 2022). Therefore, food science and technology play a pivotal role in studying, understanding, and characterizing native vanillas, as the scarcity of projects and research is evident.

No studies were found using descriptive sensory tests for the sensory analysis of native vanillas; thus, the use of the optimized descriptive profile (ODP) methodology can be applied for a precise quantitative description of these vanillas (Minim & Silva, 2016), thereby contributing to the dissemination of scientific information on native vanillas.

The objective of this work was to evaluate the chemical and sensory profile, as well as the acceptability, of Brazilian vanilla species.

Materials and Methods

This research was approved by the Ethics Committee of the Universidade Federal de Viçosa (Protocol number 4,751,004).

Seven vanilla commercial samples of vanilla fruit from two Brazilian regions – located in the states of Bahia (BA) and Goiás (GO) –, which were obtained by cultivation or extractivism, were evaluated: *Vanilla planifolia* Jacks. ex Andrews in VPC_1 (cultivation, Una, BA, at -15.2881°S, -39.0764°W); *V. planifolia* in VPC_2 (cultivation, Nilo Peçanha, BA, at -13.6062°S, -39.1095°W); *V. chamissonis* Klotzsch in VCC_1 (cultivation, Una, BA, at -15.2881°S, -39.0764°W); *V. chamissonis* Klotzsch in VCC_2 (cultivation, Nilo Peçanha, Bahia, at -13.6062°S, -39.1095°W); *V. bahiana* Hoehne, in VBC_1 (cultivation, Una, Bahia, -15.2881°S, -39.0764°W); *Vanilla bahiana* Hoehne, in VBC_2 (extractivism, Alto Paraíso de Goiás, GO, at 14.1303°S, -47.5189°W), and *V. pompona* Schiede, in VPPE (extractivism, Alto Paraíso de Goiás, GO, at -14.1303°S, -47.5189°W).

In accordance with Brazilian laws and directives from the Genetic Heritage Board, this work was registered in the National Genetic Heritage Management System under number A19C071 (SisGen, 2023).

An enough amount of cured fruit (about 150 g) of each species was acquired and sent to the Embrapa Agroindústria de Alimentos laboratory. To obtain the extracts, the fruit were chopped into small pieces and added in a 1:5 (sample:solvent ratio). Therefore, 18 g of samples were used for each 100 mL of aqueous solution of grain alcohol at 54% (v/v). The flasks were manually shaken three times (at 8:00, 12:00, and 16:00 h) to homogenize the material, during three weeks, and they were protected from light, at 22 to 25ºC room temperature. The liquid was filtered into an amber bottle with a lid and stored under refrigeration, until the sensory analysis was performed according to the methodology adapted from the United States Pharmacopoeia (USP29-NF24) (USP, 2021).

For the analysis of volatile compounds, 0.5 g of vanilla pods was transferred to 4 mL flasks for solid phase microextraction. The samples were conditioned at 60ºC, for 60 min. A fiber of divinylbezene/carboxen/polydimethylsiloxane (DVB/CAR/PDMS) was exposed for 30 min to the headspace and, soon after, introduced into the chromatograph injector, heated at 250ºC for 3 min, for the desorption of the analytes (Brilhante et al., 2022).

The analysis of volatiles was performed on an Agilent 7890A chromatography coupled to an Agilent 5975C mass selective detector (Agilent, Wilmington, DE, USA), operated in electronic ionization mode (70 eV). The volatiles were desorbed in a heated injector at 250°C (splitless). Separation of the constituents was carried out in a capillary column of fused silica, with a stationary phase of 5%-phenyl-95%-methyl silicon HP-5MS, 30 m x 0.25 mm x 0.25 µm (Agilent, Wilmington, USA), using helium as carrier gas (1.0 mL min^{-1}). The oven temperature programming started at 40°C for 3 min, then varied from 3°C per min to 240°C. The transfer line, ionization source, and analyzer were maintained at 260ºC, 200°C, and 150°C, respectively. The scan rate (scan) was 3.15 scans per min. The analyzed mass range varied from 40 to 350 atomic mass units (Silva et al., 2020).

The identification of volatile constituents was carried out by comparing the obtained mass spectra with those from Wiley (McLafferty, 1994), NIST 11 (NIST, 2011), and Adams (2007), as well as by their linear retention indices (LRI) compared with data from the literature (Adams, 2007). LRI were calculated (Van Den Dool & Kratz, 1963) from the retention times of volatiles and those of a homologous series of *n*-alkanes (C_7-C_{26}, Sigma-Aldrich, São Paulo, SP, Brazil), injected under the same conditions as the samples, using pre-programmed Excel spreadsheets (Bizzo et al., 2020). A LRI divergence less than 10 units was considered a positive match. For the spectral libraries, the match for positive identification is above 80%.

To prepare tea from the vanilla species, 0.4% (v/v) of vanilla extract was added to water (80°C) with 2% (m/v) sucrose, according to the methodology adapted from Januszewska et al. (2020). The teas were prepared one hour before the test, to avoid the loss of aromatic compounds, and served at a temperature close to 60°C.

The teas from the seven samples were evaluated using the optimized descriptive profile (ODP) methodology (Silva et al., 2012). The analyses were carried out in the Laboratory of Sensory and Technological Properties of Food of the Universidade Federal de Viçosa.

Thirty-one participants were recruited using a semistructured questionnaire, in order to obtain the minimum number of 16 evaluators required by the methodology. The recruitment was based on the time available to perform the sensory tests, demographics, health status, verbal creativity, and ability to use unstructured scales (Minim & Silva, 2016). The selection of evaluators was performed with a sequence of four discriminatory tests (triangular test) with two samples of vanilla tea, as follows: one sample at 0.2% natural extract of *V. planifolia*, and 2% sucrose; and the other sample at 0.2% of artificial essence of vanilla and 2% sucrose; prepared according to the methodology adapted from Januszewska et al. (2020). For the choice of these samples, tests were carried out with different dosages of extract and artificial vanilla essence, and pre-tests were also carried out, in order that samples could show differences for sensory characteristics, even with little variation. After checking the number of correct answers of each evaluator, 16 evaluators were selected, who presented the minimum percentage of 75% of correct answers to the tests (Minim & Silva, 2016).

The 16 selected evaluators used the descriptive terminology for the seven tea samples of vanilla extracts, based on a previous list (Minim & Silva, 2016). The sensory attributes that were part of the previous list were obtained from the work of Van Dyk et al. (2010), Januszewska et al. (2020), Bertelsen et al. (2021), and Oliveira et al. (2022). After the evaluation of the samples, the sensory attributes were defined for the description of vanilla extract teas.

The 16 evaluators were familiarized with the descriptive terms and their respective reference materials by familiarization sessions. The objective of those sessions was to standardize the form of evaluation and to clearly expose which sensory stimulus each term was referring to, in addition to anchoring the extremes of the 9 cm unstructured scale (weak and strong). In the optimized descriptive profile, the evaluators identify and define the intensity of the sensory attributes according to the evaluation scale (Minim & Silva, 2016).

Evaluations of vanilla tea samples were performed using the attribute-by-attribute protocol (Silva et al., 2012), associated with the presentation of reference materials, by which one attribute per session was evaluated. In each session, the evaluator received 3 samples (K = 3), according to the design of incomplete blocks, considering 3 replicates of evaluation of each sample (r = 3). It took 7 blocks (sessions) to allow all 7 samples (t =7) to be evaluated together, comparing the same pair of samples once (λ = 1). Samples coded with three random digits were presented in a randomized and balanced order to the evaluators. In addition to the vanilla samples, the evaluators received the reference materials (weak and strong) of the analyzed sensory attribute. In each session, the evaluators received a form organized by attribute, containing an unstructured scale of 9 cm (interval) associated with each sample. The evaluator was instructed to compare the samples with each other and with the references, before allocating the stimulus intensity on the evaluation scale.

The sensory profile of vanillas was represented by multivariate principal component analysis (order) and cluster analysis (centroid hierarchical cluster analysis) (Minim & Silva, 2016). The analyses were performed using the R software version 4.0.4.

To carry out the tea acceptance test, four vanilla samples were chosen (VPC_2, VCC_2, VBC, and VPPE), which were selected taking into account the groups formed by cluster analysis, the average intensity of the attributes, and the profile of volatile compounds. The analysis was carried out with 120 consumers, who were students and employees of the Universidade Federal de Viçosa. For the test, a 9-point-structured hedonic scale was used, ranging from 9-liked extremely to 1-disliked extremely. The four samples (VPC_2, VCC_2, VBC, and VPPE) were evaluated for global impression, and presented in a monadic and balanced way; all consumers evaluated all samples. Vanilla tea samples were prepared as described before. The teas were prepared one hour before the test, to avoid the loss of aromatic compounds, and served at a temperature close to 60°C.

The vanilla cream acceptance test was carried out with creams composed of sugar (25% m/v), corn starch [10% (m/v)], egg yolks (9% m/v), and butter (3% m/v). The vanilla extracts were added to each formulation at the same concentration (1% v/v). Therefore, four formulations were prepared with the same concentration of the vanilla extracts VPC2, VCC2, VBC, and VPPE, and the same concentration of all the other ingredients.

To prepare the cream, half of the sugar [12.5% (m/v)] was first added to 1 L of whole milk and maintained under stirring for about 1 min, for the perfect dissolution of the ingredients and, then, they were heated until boiling. The other half of the sugar, the yolks, and starch were mixed in a dry way, until obtaining a homogeneous mass, which was added to the milk with sugar and heated again for about 5 min, to obtain the cream. Butter was added shortly after the cream was ready, without heating. The cream was stored under refrigeration (8-10ºC) for approximately 15 hours. After cooling, the creams were shaken to obtain the cream texture, and the extracts were added about one hour before the sensory tests were performed. The execution of the hedonic test for the vanilla cream was performed as the vanilla tea acceptance test.

The sensory profile of vanillas was represented by multivariate principal component analysis (PCA) and cluster analysis (centroid hierarchical cluster analysis) (Minim & Silva, 2016). The analyses were performed using the R software version 4.0.4.

The results of the acceptance test by hedonic scale were analyzed by frequency distribution and by internal preference map, through the analysis of the principal components, and also the cluster analysis (centroid hierarchical cluster analysis), using the software R version 4.0 .4 and Microsoft Excel.

Results and Discussion

There were differences between the studied vanilla species in relation to the identified volatile compounds (Table 1). This difference is influenced by the growing conditions, the curing process, and the genetic characteristics of the plant. The curing process involves four main steps: heat treatment, transpiration, drying, and conditioning (Van Dyk et al., 2010). In unripe fruit, vanillin is not volatile and is present in its glycosylated form called glucovanillin. During the curing process, hydrolysis occurs through the action of glycosidases, culminating in the release of aromatic compounds, and the most abundant ones in the species *V. planifolia* is vanillin (Delgado et al., 2021).

More than 300 compounds have already been identified in cured vanilla fruit (Hernández-Fernández et al., 2020). In the present study, for the *V. bahiana*

Table 1. Volatile compounds identified in fruit of vanilla species from Brazil

Compound	Intensity[(1)]								
	IR_{cal}	IR_{lit}	VPC_1	VPC_2	VCC_1	VCC_2	VBC	VBE	VPPE
acetic acid	*	645	+	-	+	-	+	-	+
2,3-butanediol	799	785	+	+	+	+	+	+	+
furfural	833	828	+	+	+	+	+	+	+
p-xylene	867	864	+	-	+	-	-	-	+
estryene	890	895	+	-	+	-	-	+	-
methoxy-phenyl-oxime	912	913	+	+	+	+	+	+	+
benzaldehyde	958	952	+	+	-	-	-	-	+
1-octen-3-ol	980	974	-	+	-	-	-	+	+
2-pentyl-furan	991	984	+	+	+	+	+	+	+
p-methyl-anisole	1018	1015	-	-	+	+	-	-	+
benzyl alcohol	1032	1026	+	+	+	+	-	-	+
p-cresol	1075	1071	-	+	+	-	+	+	-
o-guaiacol	1087	1087	+	+	+	+	+	+	+
nonal	1103	1100	+	-	-	-	-	+	-
phenylethyl alcohol	1111	1107	-	+	+	-	+	-	+
methyl octanoate	1123	1123	+	-	+	-	+	+	-
4-ethyl-phenol	1165	1166	-	-	-	-	+	-	-
octanoic acid	1177	1167	-	+	-	-	++	++	-
methyl salicylate	1177	1190	-	+	-	-	++	++	-
methyl-chavicol	1177	1195	-	+	-	-	++	++	-
ethyl octanoate	1177	1196	-	+	-	-	++	++	-
4-methyl guaiacol	1190	1190	+	+	-	+	-	-	+
p-guaiacol	1217	1234	-	-	-	-	-	+	-
3-phenyl-propanol	1227	1231	-	+	-	-	-	-	+
3,4-dimethoxy-toluene	1238	1240	-	-	-	-	-	+	-
p-anisaldehyde	1250	1247	+	+	+	++	+	+	+
p-anisic alcohol	1280	1279	+	+	+++	+++	++	++	+++
4-vinyl-guaiacol	1311	1313	+	+	-	-	-	-	-
methyl decanoate	1324	1326	-	-	-	-	+	+	-
eugenol	1357	1356	-	+	-	+	-	-	-
decanoic acid	1369	1364	-	-	-	-	-	+	-
methyl *p*-methoxy-benzoate	1370	1371	+	-	-	-	-	-	+
(*Z*)-ethyl cinnamate	1375	1376	-	-	-	+	-	-	-
(*E*)-methyl cinnamate	1381	1376	+	+	+	+	-	+	+
4-hydroxy-benzaldehyde	1385	1355	+	-	-	-	-	-	-
vanillin	1394	1394	+++	+++	+	+	++	+	+
anisyl acetate	1418	1412	-	-	+	+	+	+	+
ethyl anisate	1448	1450	-	-	+	+	+	+	-
(*E*)-ethyl cinnamate	1463	1465	-	+	+	+	-	+	+
methyl vanillin	1480	1475	-	-	-	-	-	-	+
methyl dodecanoate	1522	1524	+	+	-	-	+	+	-
lauric acid	1568	1665	-	-	-	-	+	-	-
ethyl dodecanoate	1592	1594	-	+	-	-	+	+	-
hexadecane	1596	1600	+	-	-	+	-	-	+
heptadecane	1695	1700	+	-	-	+	-	-	+
ethyl tetradecanoate	1722	1722	-	-	-	-	+	+	-
benzyl benzoate	1761	1759	-	-	-	-	+	-	-
4-hydroxy-benzyl hexanoate	1796	*	+	-	+	+	-	-	+
nonadecane	1896	1900	+	-	-	-	+	+	-
methyl palmitate	1923	1921	-	-	-	-	+	+	-
eicosane	1996	2000	+	+	-	-	+	-	+
ethyl linoleate	2158	2162	-	-	-	+	-	-	-
ethyl oleate	2167	2171	-	-	+	-	-	-	-
docosane	2195	2200	+	-	-	-	-	-	-
tetracosane	2394	2400	+	+	+	-	-	+	-

[(1)]Intensity, low (+); medium (++); high (+++); not detected (-). Tentative identification (*). IR, retention index.

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species (VBC and VBE), 4-ethyl-phenol, octanoic acid, methyl salicylate, methyl-chavicol, and ethyl octanoate were found as major compounds. In the species *V. chamissonis* (VCC1, VCC2) and *V. pompona* (VPPE), the major identified compounds were *p*-anisic alcohol in both samples, and *p*-anisaldehyde in the *V. chamissonis* sample (VCC2). The species *V. planifolia* (VPC_1 and VPC_2) showed a greater occurrence of vanillin, and the species *V. chamissonis* (VCC_1 and VCP_2, and VBE) showed the lowest vanillin content.

Volatile compounds belong to different chemical categories and are produced at different concentrations, thus, the combination of compounds present in vanilla fruit will give the unique and characteristic aroma of each species. It is important to note that a compound does not need to be the most abundant to be perceived or contribute to the sensory profile (Oliveira et al., 2022). Pérez-Silva et al. (2006) reported that compounds such as guaiacol, 4-methyl guaiacol, acetovanillone, vanillyl alcohol and *p*-anisaldehyde, which are found in small amounts in *V. planifolia*, are perceived as intensely as vanillin.

The extractivism samples did not follow a production pattern and did not receive the initial heat treatment, differently from the cultivated ones, that were subjected to the Bourbon method and Madagascar's standard. These factors are among those that contributed to the difference in the volatile profile of the samples under study, since the heat treatment step aims to stop the vegetative life and allows of a contact between enzymes and substrates (Havkin-Frenkel & Frenkel, 2006; Van Dyk et al., 2010). In a study on the influence of the curing process on the sensory characteristics of vanilla, Van Dyk et al. (2010) found that blanching with water, followed by transpiration at 35–45°C and drying, produce cured fruit with excellent appearance and aromatic profile, with higher concentrations of compounds related to sweet, floral, fruity, and vanilla aromas.

The compounds found in the studied species were related in the literature to descriptor attributes that characterized the descriptive sensory profile of vanillas, as follows: anisyl acetate present in VPPE, responsible for the fruity aroma; 2,3-butanediol, identified in all samples, qualified by floral aroma; *p*-cresol identified in VPC_2, VCC_1, VBC, and VBE, perceived as woody; and 4-methyl-guaiacol present in VPC_1, VPC_2, VCC_2, and VPPE, described as sweet and woody. Vanillin, responsible for vanilla and sweet aromas, predominated in samples VPC_1 and VPC_2. Benzyl alcohol identified in samples VPC_1, VPC_2, VCC_1, VCC_2, and VPPE was related to floral and sweet aromas, and *p*-anisaldehyde present in sample VCC_2 was qualified as sweet (Pérez-Silva et al., 2006; Januszewska et al., 2020; Yeh et al., 2021).

According to Hernández-Fernández et al. (2019), it is important to note that even some compounds with a lower concentration than vanillin are responsible for the phenolic, sweet, balsamic, woody, and vanilla notes. Brunschwig et al. (2012) claims that the characteristics of vanilla depend on the genetics of the plant, as well as on the growing and curing methods, and on techniques applied in each region or country. These factors might have impacted, for instance, the distinctions between *V. bahiana* species in the states of Bahia and Goiás. Variables like cultivation practices, climate, and soil composition could have potentially contributed to the regional variations observed in the chemical and physical characteristics of Brazilian vanillas.

Analyzing the sensory map of the descriptive profile of the vanilla tea samples, it can be observed that the first two main components together explained 96.21% of the total variation of the data, which is considered adequate to represent the dispersion of the samples and interpretation of the results (Figure 1). It can be seen that the first principal component explained a high percentage of the variation in the data (87.61%). Therefore, only one dimension will be considered in the interpretation of the descriptive map; the vertical dispersion will be disregarded, since the second main component explained a small proportion of the data variation (8.6%).

All sensory attributes, except for, sweet taste, showed a significant, positive correlation at 5% probability with the first main component. In the cluster analysis, there was the formation of three distinct groups. The 1st group was formed by the vanilla species VPC_1, VPC_2, and VPPE, which showed the greatest intensity of the attributes, vanilla aroma, floral aroma, fruity aroma, vanilla flavor, brown color, and sweet taste. The 2nd group was composed of samples VCC_1, VCC_2, and VBE which showed presented low intensities of these attributes. The 3rd group contains the VBC sample, which showed a higher intensity of the woody aroma attribute, medium intensities of vanilla flavor, buttery flavor, vanilla aroma, floral aroma, fruity aroma, and low intensity of brown color and sweet taste.

Oliveira et al. (2022) studied the samples VCC_1, VCC_2, VBC, and VBE, referring to the species *V. chamissonis* and *V. bahiana*, and they employed the gas chromatography-olfactometry (GC-O); their results showed higher concentrations of compounds that were associated with descriptors such as honey, weak vanilla, and cloves, among others that contributed to the difference between these species for *V. planifolia*, being a factor that may explain the differences between the species in this work. According to these authors, the compounds are responsible for the distinct characteristics of each species, for which they can be appreciated.

However, the species *V. planifolia* and *V. pompona* showed the highest intensity of the attributes vanilla aroma, floral aroma, fruity aroma, vanilla flavor, brown color, and sweet taste, and volatile compounds such as vanillin, anisyl acetate and 4-methyl-guaiacol, which are responsible for the perception of the vanilla, sweet, and fruity aromas. The species *V. bahiana*, cultivated in the state of Bahia, contained a greater intensity of the attribute woody aroma. In this sample, the compounds *p*-cresol and 4-methyl guaiacol were identified, which are related to the woody aroma; however, the species *V. chamissonis* and *V. bahiana*, from Goiás state, showed less intensity for these attributes.

Regarding the vanilla flavor, *V. planifolia* from Una (BA region), and *V. pompona* contained, the highest intensity for this characteristic. The species *V. pompona* contained a sensory profile similar to that of the *V. planifolia* VPC_1 and VPC_2. According to Maruenda et al. (2013), the species *V. pompona* has been treated as a promising crop, due to the attractiveness of its aromatic profile.

In the preference map of acceptance of vanilla teas, the first two principal components explained most of the variance of the samples for acceptability (70.21%). Therefore, the first two principal components are sufficient to discriminate the samples for acceptance (Figure 2). Each point on the graph represents the correlations between a consumer's acceptance data and the first two principal components.

The vanilla tea samples were separated into three distinct groups by cluster analysis. The 1st group was formed by VCC_2 and VPC_2; the 2nd one, by the VPPE; and the 3rd group, by the VBC. These clusters suggest

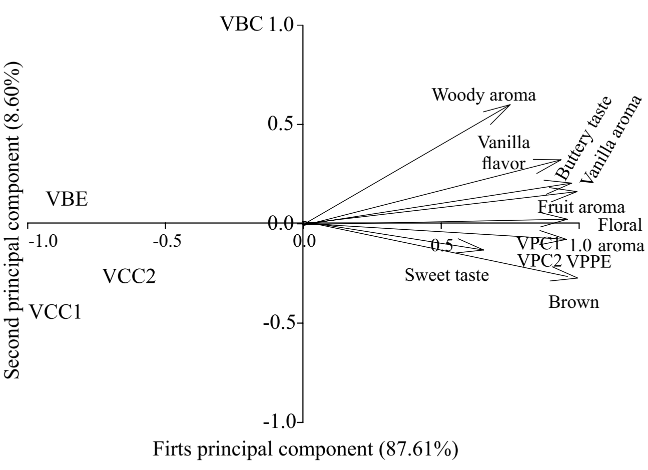

Figure 1. Sensory map of tea samples of Brazilian vanillas and their cultivation regions (Bahia and Goiás states): VPC1, *Vanilla planifolia* (Una, BA,); VPC2, *V. planifolia* (Nilo Peçanha, BA); VCC1, *Vanilla chamissonis* (Una, BA); VCC2, *Vanilla chamissonis* (Nilo Peçanha, BA), VBP, *Vanilla bahiana* (Una, BA); VBE, *Vanilla bahiana* extractivism (Alto Paraíso de Goiás, GO); VPPE, *Vanilla pompona* extractivism (Alto Paraíso de Goiás, GO).

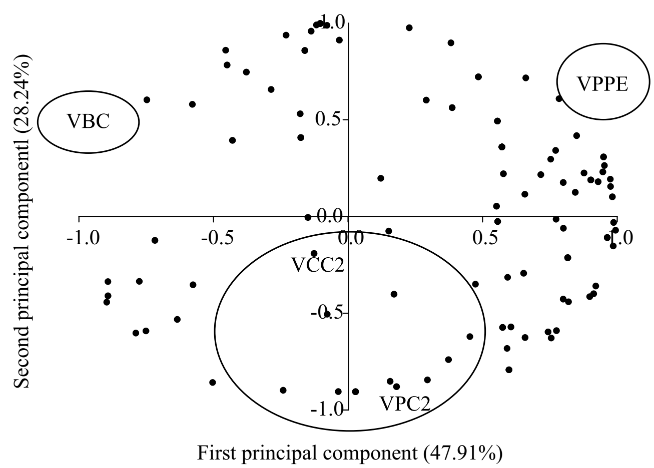

Figure 2. Dispersion of vanilla tea samples in relation to acceptance, and correlations of each consumer and the first two main components. Brazilian regions of vanilla cultivation: VPC_2, *Vanilla planifolia* (Nilo Peçanha, BA); VCC_2, *V. chamissonis* (Nilo Peçanha, BA); VBC, *V. bahiana* (Una, BA); VPPE, *V. pompona* extractivism (Alto Paraíso de Goiás, GO).

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that VCC_2 and VPC_2 do not differ for acceptance by consumers, while VBC and VPPE teas are isolated from the others, and the VPPE sample is the most accepted by consumers, while the VBC sample obtained the lowest acceptance.

Tea of the species *V. pompona* was accepted by more than 70% of consumers, while the VPC_2 sample was accepted by more than 60% of consumers, again indicating the potential of the *V. pompona* species when compared to *V. planifolia* (Figure 3). The greater acceptance of the VPPE and VPC_2 samples can be attributed to their sensory characteristics because, as seen in Figure 1, these samples contained a higher concentration of the descriptors of the attributes vanilla aroma, floral aroma, fruity aroma, vanilla flavor, brown color, and sweet taste, which may have influenced the consumers' preference for these samples.

Despite showing lower intensity of these attributes by the OPD profile analysis, the VCC_2 sample still obtained a better acceptance (58.83%) than the VBC sample (47.17%). This can be explained by the difference in the sensory profile of the VBC sample that is characterized by greater intensity of the woody attribute, and by the difference in its profile of volatile compounds.

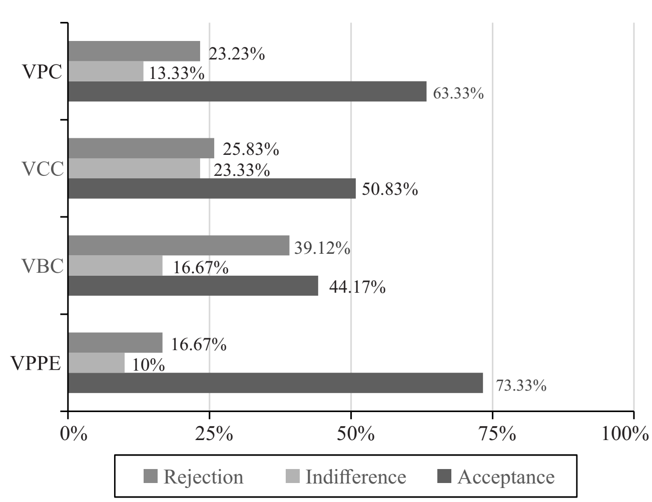

Figure 3. Frequency distribution of vanilla tea acceptance expressed as percentage. Brazilian regions of vanilla cultivation: VPC_2, *Vanilla planifolia* (Nilo Peçanha, BA); VCC_2, *V. chamissoni* (Nilo Peçanha, BA); VBC, *V. bahiana* (Una, BA); VPPE, *V. pompona* extractivism (Alto Paraíso de Goiás, GO).

Remarkably, the vanilla tea with the best acceptance by consumers was VPPE. Tea is the best way to assess the aroma characteristics of vanillas, without being influenced by the characteristics of other compounds, as it would happen in a more complex matrix.

Analyzing the map of the results of acceptance of vanilla creams, the two components together explained 78.64% of the total variance of the acceptance data, thus the two components are considered sufficient to represent the dispersion of the samples, regarding acceptability (Figure 4). According to the cluster analysis, three groups were formed, as follows: the 1st one, formed by the VPC_2 and VPPE samples; the 2nd one, formed, by the VBC sample; and the 3rd one, by the VCC_2 sample. However, most consumers did not correlate with the main components, which suggests that there was no difference for despite having presented lower intensity of these attributes by the Optimized Descriptive Profile analysis the acceptance of vanilla creams.

Therefore, it is possible to observe by the frequency distribution analysis that all creams obtained acceptance above 80% (Figure 5), which shows that the application of vanilla extracts in the dessert cream favored the acceptance by consumers. This acceptance

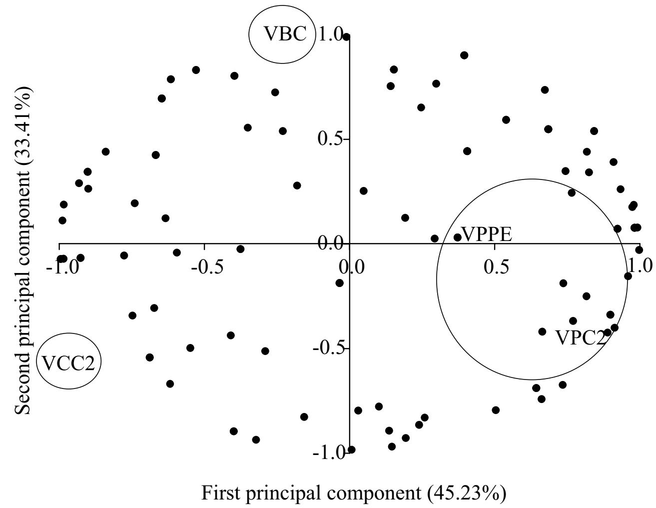

Figure 4. Dispersion of vanilla cream samples in relation to acceptance, and correlations of each consumer and the first two main components. Brazilian regions of vanilla cultivation: VPC_2, *Vanilla planifolia* (Nilo Peçanha, BA); VCC_2, *V. chamissonis* (Nilo Peçanha, BA); VBC, *V. bahiana* (Una, BA); VPPE, *V. pompona* extractivism (Alto Paraíso de Goiás, GO).

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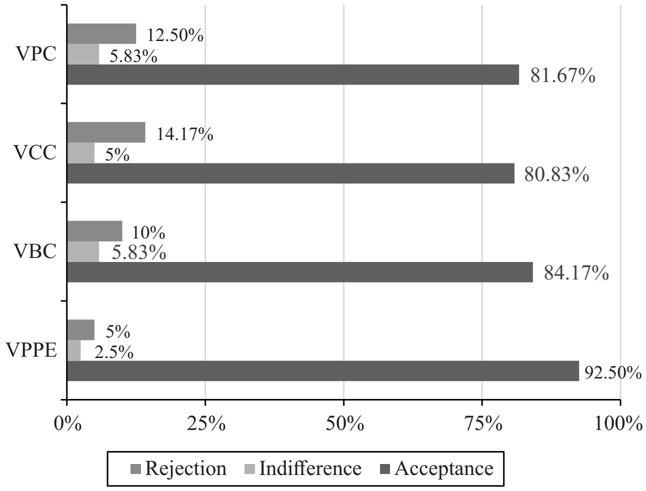

Figure 5. Frequency distribution of vanilla cream acceptance expressed as percentage. Brazilian regions of vanilla cultivation: VPC_2, *Vanilla planifolia* (Nilo Peçanha, BA); VCC_2, *V. chamissonis* (Nilo Peçanha, BA); VBC, *V. bahiana* (Una, BA), VPPE, *V. pompona* extractivism (Alto Paraíso de Goiás, GO).

suggests that Brazilian vanillas are well accepted when applied to a product commonly appreciated by the population, and that even species with a sensory profile with less intensity of attributes are accepted by most consumers.

According to Oliveira et al. (2022), each vanilla species will be appreciated for its specificities, according to the type of application and purpose. In the present work, the application of Brazilian vanillas to a product that normally has already good acceptance by the population showed the importance of evaluating these species when applied to a product, thus increasing the potential for the use of native vanillas by the food industry.

Conclusions

1. Brazilian vanillas show differences for volatile compounds composition, including vanillin, anisyl acetate, 4-methyl guaiacol, *p*-cresol, benzyl alcohol, and 2,3-butanediol.

2. Samples of *V. planifolia* and *V. pompona* from the regions Una and Nilo Peçanha (Bahia state), and Alto Paraíso (Goiás state) show superior intensities of the studied sensory attributes of vanilla, floral, and fruity aromas, vanilla flavor, brown color, and sweet taste.

3. Application of vanillas to cream results in an acceptance rate of over 80% for all species.

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