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Influence of Volatile Acidity at Different Concentrations on the Sensory Profile of *Cachaça*

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ABSTRACT

Background and Objective: The chemical and sensory quality of *cachaça* is directly linked to the beverage's production process and the correct implementation of Good Manufacturing Practices. Volatile acidity affects not only the chemical quality but also the sensory quality of distillates, even when the levels are within legal limits. This study was designed to investigate the sensory effects of the gradual increase in volatile acidity in three commercial samples of unaged *cachaça*.

Materials and Methods: Three different concentrations of volatile acidity were used to observe sensory effects. A total of nine samples were analyzed. The evaluation of the nine samples at different volatile acidity concentrations was carried out in six separate sessions, also in triplicate. Standards of Identity and Quality were established to specify the limits of non-alcoholic volatile components, as well as organic and inorganic contaminants. The Quantitative Descriptive Analysis (QDA) results were analysed using one-way ANOVA for each attribute, considering the sources of variation: sample, trained assessor and interaction.

Results: Identical samples, however, with different acidity levels, exhibited distinct sensory profiles in the analyses. Cachaças with lower volatile acidity were associated with positive sensory attributes such as "velvety" and "sweet taste", while tasters perceived doped samples to have acetone and vinegar aromas, which could cause consumers to reject it.

Conclusion: Volatile acidity affects not only the chemical quality but also the sensory quality of distillates, even when the levels are within legal limits.

INTRODUCTION

Brazilian *cachaça* is a typical and exclusive sugarcane spirit with an alcohol content ranging from 38-45% v/v at 20°C. It is produced by distilling fermented sugarcane must with specific characteristics and up to 6 grams of sugars may be added per liter[1]. A Standard of Identity and Quality for *Cachaça* was established by the Ministry of Agriculture, Livestock and Food Supply (MAPA) in order to guarantee and protect consumer health. It specifies the maximum levels of non-alcoholic volatile components as well as organic and inorganic contaminants that can be present in the distillate[1]. The chemical and sensory quality of *cachaça* is directly related to the stages of its production process. In distillates, chemical risks occur mostly during fermentation or distillation, Once distillates are manufactured, the removal of chemical contaminants becomes difficult, or sometimes even impossible[2].

Volatile acidity of a product is determined by the concentration of acetic acid in the final product which is due to the presence of acetic bacteria competing with fermentative yeasts, causing an increase in the sensory acidity. The sensory quality of distillate is primarily rejected by consumers because of its high acidity[3]. According to Ordinance No. 539 of December 27, 2022, the volatile acidity limit for *cachaça* is 150 mg of acetic acid per 100 mL of anhydrous alcohol (aa). This concentration may be lower in some countries, which directly affect the export potential of *cachaça*.

The sensory properties of *cachaça*, as well as other distilled beverages are influenced by its chemical quality, such as volatile acidity. The aromatic bouquet of *cachaça* is directly related to volatile compounds derived from the raw material (sugarcane), the yeasts used, the fermentation conditions, distillation methods and aging, which is optional for *cachaça*[4]. In addition to the fermentation stage, the aging process can also gradually increase the concentration of acetic acid in the beverage through the oxidation of ethanol by acetaldehyde and organic acids extracted from wood[5].

Volatile acidity increases with the porosity of barrels, which varies depending on wood species and natural fibre structure, allowing more oxidation to occur[4]. As a result of prolonged and more intense reactions, exhaust barrels (i.e., those subjected to extensive use) can also lead to greater oxidation, which will increase the volatile acidity of the distillate[6].

This study aimed to investigate the sensory effects of increasing volatile acidity in three different commercial samples of unaged *cachaça* using the Quantitative Descriptive Analysis (QDA) methodology, with concentrations ranging from below to at the legal limit (150 mg/100mL aa).

MATERIALS AND METHODS

Sample collection: There was an agreement between three different *cachaça* brands to provide approximately two liters of mono-distilled white cachaça samples from the same batch, bottled for commercial sale. All samples complied with the parameters established by the *Cachaça* Identity and Quality Standards, including volatile acidity, were ready for commercialization.

Sample doping: In the initial samples (A, B and C) collected for volatile acidity analysis, the concentrations were well below the legal limit. Three different concentrations of volatile acidity were used to observe sensory effects: The initial concentration of each brand was 80 mg/100 mL of anhydrous alcohol and 150 mg/100 mL of anhydrous alcohol (the maximum permitted limit). The samples were then doped with P.A. acetic acid to reach the concentrations shown in Table 1. A total of nine samples were analyzed.

Sensory panel: Volunteers who expressed interest in participating in the Sensory Analysis using the Quantitative Descriptive Analysis methodology underwent a pre-selection involving a questionnaire addressing health conditions, *cachaça* and other beverages consumption, time of availability, among other selection criteria, such as selection by sensory acuity: identification of basic tastes (sweet, salty, acidic, bitter and umami), in addition to a triangular test with two different samples of unaged *cachaça*.

Eighteen panellists were approved after the selection process. All panellists were between 20 and 54 years old, both male and female, non-pregnant, non-lactating, free from chronic illnesses, with no history of drug addiction and regular *cachaça* consumers (two to three times per month).

Quantitative descriptive analysis (QDA): The Quantitative Descriptive Analysis was led by a panel leader (moderator), who also served as the principal investigator of the present study. Sensory training was carried out to enhance the ability of panellists to consistently evaluate the sensory characteristics of the *cachaça* samples. In the first session of the training, the panellists examined basic tastes prepared by mixing distilled water with sucrose, sodium chloride, caffeine, citric acid and monosodium glutamate (corresponding to sweet, salty, bitter, sour and umami, respectively). The concentrations of the solutions used during sensory training are presented in Table 2.
separate sessions, also in triplicate.

The training was then divided into nine sessions, during which the panel identified the minimum and maximum levels of each attribute using a scale: “Extremely Weak” (1) to “Extremely Strong” (10). The following references were

Table 1: Final volatile acidity concentrations of the samples after doping

Sample	Initial acidity concentration (mg/100 mL aa)	Acidity concentration 1 (mg/100 mL aa)	Acidity concentration 2 (mg/100 mL aa)
Sample A	13.19	79.97	149.98
Sample B	5.67	78.92	150.02
Sample C	5.98	79.99	150.01

Table 2: Set of references of basic tastes and sensations used in sensory panel training[7]

Descriptor	Class	Reference	Concentration in distilled water at room temperature
Sweet	Basic taste	Sucrose	10 g/L
Salt	Basic taste	Sodium chloride	2 g/L
Bitter	Basic taste	Caffeine	0.3 g/L
Acid	Basic taste	Citric acid	0.3 g/L
Umami	Basic taste	Monosodium glutamate	0.6 g/L
Metalic	Sensation	Ferrous sulfate heptahydrate	0.01 g/L
Pungent	Sensation	Acetic acid	40 mL /200mL
Velvet	Sensation	Carboxymethyl cellulose	0.5 g /250mL

used: tear formation, vinegar and acetone aromas; salty, sweet, bitter, acidic and umami tastes; pungent, velvety and metallic sensations; and bitter, acidic and umami aftertastes (Table 2). The choice of attributes was based on the *Cachaça* and Sugar Cane Brandy Sensory Wheel[8]. The sensory analysis was approved by the Human Research Ethics Committee (CAAE: 81806624.2.0000.5395). Before starting the formal analysis, panellists performed a preliminary test with three samples, in triplicate, to ensure panel consistency. The evaluation of the nine samples at different volatile acidity concentrations (Table 1) was carried out in six

Subsequently, The QDA results were analysed using one-way ANOVA for each attribute, considering the sources of variation: Sample, trained assessor and interaction. Tukey's tests were then applied to each attribute, at a 5% level of significance[9]. QDA results were also analysed using Principal Component Analysis (PCA), based on a correlation matrix. Statistical analyses were performed using XLSTAT software (2021.3.1.1159) (Addinsoft).

RESULTS AND DISCUSSION

This study evaluated attributes based mainly on sensory characteristics found in the studies of Bortoletto[8] and Odello et al.[10] and are presented in Table 3.

The presence of excessive acidity in *cachaça* and other distilled beverages is considered a serious production defect. Odello et al.[10] presented 20 commercial *cachaças* to a trained panel for sensory hedonic evaluation. Among these samples, a low level of acidity and pungency (burning sensation) was observed in the four most preferred cachaças. According to the same hedonic study, the least preferred *cachaças* presented accentuated characteristics of acidity, bitterness and pungency (burning sensation).

Conversely, it was determined that softness and smoothness, as well as velvety samples and sweet tastes, were positive indicators. Acidity, the main focus of this study, directly influences the sensory quality of the final product and at high levels, can result in consumer rejection[14]. Acetic bacteria are important for its formation which is amplified by aeration during fermentation[15,16].

Each of the sensory descriptors selected for the analyses was presented to the tasting panel during the training sessions using an intensity scale ranging from 1 (total absence of the characteristic) to 10 (extremely strong).

Using Principal Component Analysis (F1 and F2: 75.34%), Figure 1 illustrates which attributes were predominantly identified in each of the nine samples.

Regarding the visual aspect, tear formation was not directly correlated with any of the evaluated *cachaça* samples, suggesting that there may be no direct relationship between the viscosity of the sample and its volatile acidity content.

Both the Acetone and Vinegar aromas were more closely associated with samples A and C at 150 mg of acetic acid/100 mL of anhydrous alcohol (the maximum content permitted by law). Samples B and C (80 mg/100 mL aa), as well as sample B (150 mg/100 mL aa), also showed strong correlation with the aroma attributes investigated. In contrast, no proximity to these two aromas was detected in the original samples, which were not doped with acetic acid (Fig. 1).

Regarding basic tastes, the original samples A, B and C were associated with the sweet taste by the sensory panel. Sample A (80 mg/100 mL aa) showed the highest correlation with various basic tastes: salty, bitter and umami. In turn, samples A and B (both at 150 mg/100 mL aa) were

Table 3: Sensory descriptors used by the panel of tasters to evaluate the samples studied[11-13]

	Sensory attributes				
Visual	Tear formation				
Description	Intensity 0: water; Intensity 10: *Cachaça* with high tear formation				
Aromas	Acetone	Vinegar			
Description	Acetone aroma	Sour aroma, acetic fermentation			
Tastes	Sweet	Salt	Acid	Bitter	Umami
Description	Perception associated with the sweet flavor note, characteristic of an aqueous sugar solution	Perception associated with the salt flavor note, characteristic of an aqueous sodium chloride solution	Characteristic taste of aqueous citric acid solution	Characteristic taste of an aqueous solution of bitter substances	Characteristic taste of Monosodium Glutamate
Aftertastes	Acid	Bitter	Umami		
Description	Persistence of acidity in the mouth, tongue or throat after swallowing	Persistence of bitterness in the mouth, tongue or throat after swallowing	Persistence of Monosodium Glutamate in the mouth, tongue or throat after swallowing		
Sensations	Metalic	Pungent	Velvet		
Description	Perception associated with the metallic aroma note, characteristic of *cachaça* double-distilled in a stainless steel still	Perception of burning sensation in the nasal and oral mucosa	Feeling of fullness. The drink has a density, a "weight" in the mouth .		

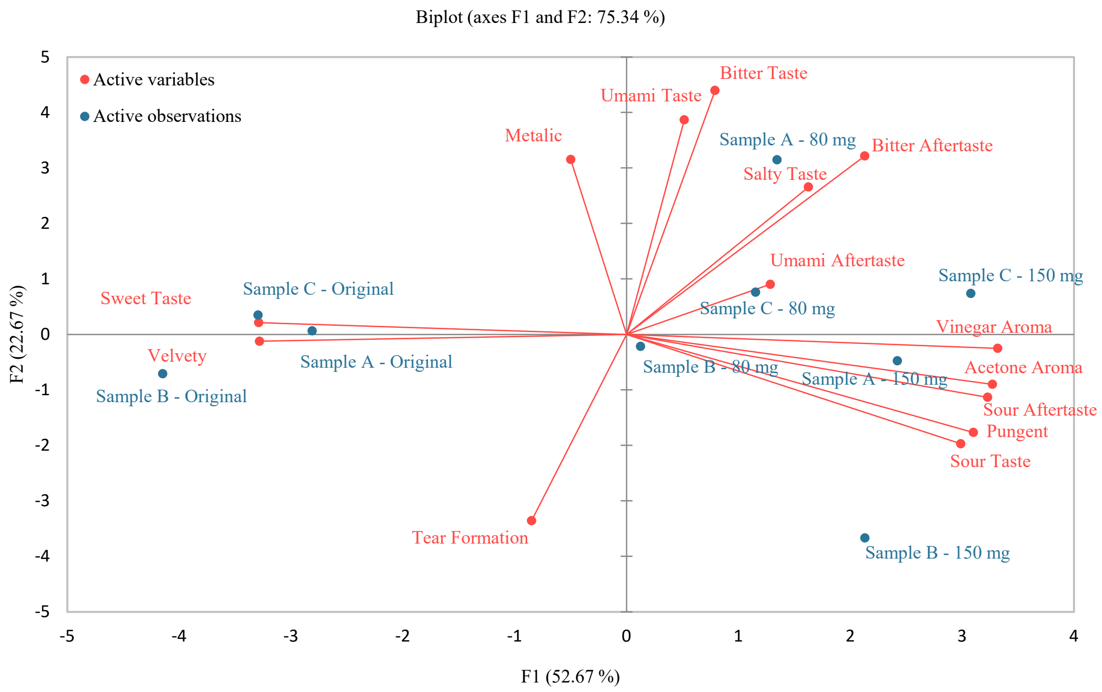

Fig. 1: Principal Component Analysis (F1 and F2: 75.34%) representing the attributes correlated with each sample evaluated

Table 4: Description of sensory attributes based on the result of the qualitative analysis

Samples	Acidity concentration (mg/100 mL aa)	Aromas	Taste	Aftertaste	Sensation
A1	13.19	-	Sweet	-	Velvet
A2	79.97	-	Salt, Umami, Bitter	Bitter	Umami
A3	149.98	Vinegar, Acetone	Sour	Sour	Pungent
B1	5.67	-	Sweet	-	Velvet
B2	78.92	Vinegar, Acetone	-	Umami	-
B3	150.02		Sour	Sour	Pungent
C1	5.98	-	Sweet	-	Velvet
C2	79.99	-	-	Umami	-
C3	150.01	Vinegar, Acetone	-	Sour	Pungent, Umami

more associated with the acidic taste. By observing the basic tastes in the graph, it is clear that samples with lower volatile acidity are more associated with sweetness, possibly due to the raw material (sugarcane) used in *cachaça* production. Clearly, the higher the acetic acid concentration in the sample, the more strongly it is associated with the acidic taste.

As for the aftertastes (acid, umami and bitter), sample A (80 mg/100 mL aa) was associated with the bitter aftertaste and sample C (80 mg/100 mL aa) was associated with the umami aftertaste. The acidic aftertaste was more closely associated with the samples containing the highest concentrations of acetic acid: B (150 mg/100 mL aa), C (150 mg/100 mL aa) and, mainly, A (150 mg/100 mL aa). The original samples did not show a direct relationship with any of the aftertastes evaluated in the present study.

Regarding sensations, the metallic sensation was most associated with sample A (80 mg/100 mL aa). The pungent sensation was mainly associated with samples A, B and C, all at a concentration of 150 mg/100 mL aa. The velvety sensation was associated only with the original samples, especially samples A and C. Table 4 shows the main attributes attributed to each of the samples.

From the Pearson Correlation Matrix (n -1), it was possible to generate the principal components analysis in order to correlate the attributes that would possibly be directly associated with each other (Table 5).

According to Table 5, some of the attributes showed high correlation, such as: The aroma of acetone was correlated with the aroma of vinegar (0.977), the acidic taste (0.972) and the pungent sensation (0.949) and indirectly correlated with the sweet taste (-0.950) and the velvety sensation (-0.943).

High correlations were also observed between the acidic taste and other attributes, such as the aroma of acetone (0.972), the aroma of vinegar (0.939), the acidic aftertaste

Table 5: Principal component analysis of attributes and their respective correlations

Variables	Tear Formation	Acetone	Vinegar	Sweet Taste	Salt Taste	Bitter Taste	Acid Taste	Umami Taste	Bitter Aftertaste	Umami Aftertaste	Acid Aftertaste	Metalic	Pungent	Velvet
Tear formation	1	-0.057	-0.196	0.322	-0.009	-0.810	-0.020	-0.315	-0.686	-0.473	-0.045	0.040	0.109	0.224
Acetone	-0.057	1	0.977	-0.950	0.454	0.069	0.972	0.077	0.479	0.254	0.990	-0.217	0.949	-0.943
Vinegar	-0.196	0.977	1	-0.953	0.490	0.174	0.939	0.162	0.544	0.350	0.980	-0.140	0.907	-0.966
Sweet taste	0.322	-0.950	-0.953	1	-0.347	-0.226	-0.921	-0.058	-0.651	-0.425	-0.934	0.253	-0.867	0.954
Salt taste	-0.009	0.454	0.490	-0.347	1	0.413	0.268	0.692	0.453	0.034	0.410	0.559	0.264	-0.532
Bitter taste	-0.810	0.069	0.174	-0.226	0.413	1	-0.061	0.605	0.755	0.196	0.004	0.182	-0.128	-0.186
Acid taste	-0.020	0.972	0.939	-0.921	0.268	-0.061	1	-0.046	0.329	0.195	0.982	-0.384	0.959	-0.876
Umami taste	-0.315	0.077	0.162	-0.058	0.692	0.605	-0.046	1	0.384	-0.299	0.069	0.573	-0.094	-0.150
Bitter aftertaste	-0.686	0.479	0.544	-0.651	0.453	0.755	0.329	0.384	1	0.479	0.409	0.180	0.328	-0.637
Umami aftertaste	-0.473	0.254	0.350	-0.425	0.034	0.196	0.195	-0.299	0.479	1	0.252	0.110	0.165	-0.448
Acid aftertaste	-0.045	0.990	0.980	-0.934	0.410	0.004	0.982	0.069	0.409	0.252	1	-0.221	0.954	-0.934
Metalic	0.040	-0.217	-0.140	0.253	0.559	0.182	-0.384	0.573	0.180	0.110	-0.221	1	-0.306	0.060
Pungent	0.109	0.949	0.907	-0.867	0.264	-0.128	0.959	-0.094	0.328	0.165	0.954	-0.306	1	-0.844
Velvet	0.224	-0.943	-0.966	0.954	-0.532	-0.186	-0.876	-0.150	-0.637	-0.448	-0.934	0.060	-0.844	1

(0.982) and the pungent sensation (0.959). In contrast, sweet taste (-0.921) and velvety sensation (-0.876) were the descriptors most inversely correlated with the acidic taste.

The acidic aftertaste showed a similar behavior as the acidic taste when comparing their associated descriptors. Some descriptors did not show significant correlations with most other attributes, such as bitter taste, which was correlated only with the bitter aftertaste (0.755); metallic sensation, umami aftertaste and umami taste, which was correlated only with the salty taste (0.692).

Although, tear formation appeared to be uncorrelated with most attributes in previous analyses, the PCA presented in Table 3 revealed an inverse correlation with two other attributes: Bitter taste (-0.810) and bitter aftertaste (-0.686). This suggests that samples with more pronounced bitterness characteristics tend to show reduced tear formation.

CONCLUSION

Identical samples, however, with different acidity levels, exhibited distinct sensory profiles in the analyses. *Cachaças* with lower volatile acidity (original samples) were associated with positive sensory attributes such as “velvety” and “sweet taste”, while tasters perceived doped samples to have acetone and vinegar aromas, which could cause consumers to reject it.

In addition, some attributes showed strong positive correlations, such as acidic taste and pungent sensation in the same samples, while others were antagonistic, such as acidic taste and velvety sensation. These results demonstrate that the greater presence of volatile acidity in the distillate influences not only the acidic taste but also contribute to particular sensations, aromas and aftertastes in the beverage.

Future studies, including aged *cachaças*, may seek to map the expected aromatic profile resulting from the aging of beverages, during which volatile acidity also increases over the storage period.

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