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Evaluation of chemical and sensory composition of banana with cinnamon liqueur: effect of storage process

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Abstract

Banana (*Musa* sp.) fruits present a high sensory quality and are a source of sugars, minerals, vitamins, and pleasant aroma and flavor and represent a valuable raw material to liqueur production. The aim of this study was to investigate differences in the sensory, chemical, and characteristics of banana liqueurs elaborated by different concentrations of cinnamon (0.25, 0.5, and 0.75%), added as powder and bark form. The cinnamon (*Cinnamon cassia*) was used to improve the taste and aroma of liqueurs, verifying its effect after storage for 3 months in dark conditions. Physicochemical parameters were evaluated during the storage period of 3 months even as the colorimetric analysis and the sensory profile (assessed through quantitative descriptive analysis). All formulations tested showed parameters according to Brazilian legislation. The addition of cinnamon, mainly in powder and at a level of 0.75%, improves the banana liqueur sensory perception, in terms of taste and aroma, even after 3 months of storage.

Keywords: banana; liqueur; cinnamon; sensory quality; storage.

Practical Application: This study is original research that contributes to the knowledge of the chemical composition and storage process of liqueur produced from bananas and other fruits. Moreover, there was a possible evidence of the aroma and other sensory aspects of liqueurs, contributing to the quality of beverage industries during the storage process.

1 INTRODUCTION

Fruits are consumed either in raw form or after processing and conversion into various fruit-based products, are fundamental to all life, and add value to earth's biodiversity (Petrović et al., 2021) and exhibited a beneficial impact on human health (Sokoł-Łętowska et al., 2014). Banana fruits (*Musa* sp.) have wide acceptance due to their attractive flavor, composition rich in energy source of soluble sugars, as well as a source of minerals such as potassium and vitamins (Adão & Glória, 2005). Banana fruits contain phenolic compounds, carotenoids, flavonoids, biogenic amines, and low levels of phytosterols, in addition to being part of the diet of the different layers of the population and appearing on the table of Brazilians not only as dessert but also as food (FAO, 2005).

Brazil and Costa Rica have large plantations intended for foreign markets; however, part of the banana production does not meet the minimum standards for export, leading to a waste of 40–50% of the volume produced from the fruits (de Jesus Filho et al., 2018). Liqueur is a product obtained by mixing alcohol, water, sugar, and substances that provide them with aroma and flavor in appropriate measures, without fermentation (Viera et al., 2010). The high perishability of bananas is also well-known, entailing storage-related problems (de Jesus Filho et al., 2018). Thus, the processing of this fruit is an alternative way to avoid or reduce waste (Sampaio et al., 2013). Additionally, the production of liqueurs constitutes a good alternative to prevent the degradation of fruits, its processing requires simple technology, and the final product is commercialized at room temperature and has an extensive shelf life (Teixeira et al., 2005). During shelf life, several reactions can change the composition and sensory properties of liqueurs, improving their aroma, flavor, and acceptance (de Jesus Filho et al., 2018; Teixeira et al., 2005).

According to Brazilian legislation, liqueur is a beverage with an alcohol content from 15 to 54% v/v, at 20°C, and a proportion of sugar superior to 30 g/L, prepared with potable ethylic alcohol or simple distilled alcohol, both of agricultural origin, or with alcoholic beverages, added with extracts or substances of vegetable or animal origin, flavoring substances, dyes, and other additives (Brazil, 2009). Traditional liqueur products are made by mixing the distillate with sugar syrup that contains essences and herbs in small amounts, improving the aroma, flavor, and sensorial acceptance, in an appropriate combination of alcoholic content (Teixeira et al., 2007).

The aroma of banana liqueurs is one of the most important sensory attributes in determining quality and the volatile compounds that contribute most to the aroma of the banana are esters, followed by aldehydes, alcohols, and ketones (de Jesus Filho et al., 2018). However, the use of different substances can improve the aroma of liqueurs and their acceptance by consumers, for example, the use of cinnamon. Cinnamon (*Cinnamon cassia*) is used as a traditional medicine and is classified as a

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medicinal plant in many countries around the world (Kumar et al., 2012) and set different proportions of hydrocarbons, cinnamaldehyde, eugenol, *o*-methoxycinnamaldehyde, benzyl benzoate, coumarin, and cinnamyl alcohol (Gunawardena et al., 2015). In addition, cinnamon can potentially be an anti-inflammatory, antimicrobial, and antioxidant agent and has digestive properties (Han & Parker, 2017; Lee et al., 2005; Nascimento et al., 2022). The use of cinnamon in liqueurs can represent a good sensory and marketing alternative in the alcoholic beverage consumer market (Nascimento et al., 2022).

In this context, this study evaluates the sensory profile of six formulations of banana liqueur with different concentrations of cinnamon, added in powder and bark form, to assess the physicochemical composition, color parameters, and sensory effect of each formulation evaluating its evolution throughout the storage process of 3 months.

2 MATERIALS AND METHODS

2.1 Raw material and liqueur preparation

To prepare the liqueurs, bananas of the Chunkey variety (*Musa* sp.), cereal alcohol at 92% (v/v at 20°C), cinnamon, refined sugar, and potable drinking water were used. The bananas used were characterized according to the color index of the peel proposed by Von Loesecke (1950) and were in a maturity scale of 7 points, with yellow peel and brown spots. Cinnamon (*Cinnamomum cassia*) was purchased in the form of dry bark, which was processed and ground until becoming a powder form.

The fruits were washed and sanitized (immersion in sodium hypochlorite solution, 200 ppm, for 15 min), peeled, weighed, and sliced (approximately 0.5 mm thick) manually. Subsequently, 700 g of banana was added in 1 L of alcohol (92%), forming the fixed base to formulations, and the extract was stored in glass containers, hermetically sealed, at room temperature (24.5±1°C), in the dark and filtered by the vacuum filter system after 15 days. Every 5 days, a gentle mixing was carried out, facilitating the extraction of aroma and flavor components. Refined sugar (50%) was dissolved in water, and the mixture was brought to heating (90°C, for 20 min). The syrup obtained was filtered (at room temperature), added to alcoholic banana maceration (proportion of 2:1, using 2 L of syrup for 1 L of alcoholic banana maceration), and remained for 5 days at room temperature (24.5±1°C).

Cinnamon was added to the liqueur in the form of powder and bark in the alcoholic maceration according to the formulations, using a permeable casing already prepared. Three formulations of banana liqueur were prepared with different concentrations of powdered and bark cinnamon of 0.25, 0.50, and 0.75% of the final liqueur volume. All formulations were produced in duplicate and remained for 10 days at room temperature and dark conditions.

After this period, a last vacuum filtration (using a laboratory scale system device with a filter diameter of 50 mm and a pore size of 1 µm) was performed, and the elaborated liqueurs were bottled in amber glass containers, sealed, and stored in a dark room and at room temperature for 15 days. After liqueur production, their physicochemical and sensory composition was checked, just after the liqueur production and after the period of storage (3 months). All formulations differed only by the different concentrations of powdered and bark cinnamon.

2.2 Analysis of physicochemical parameters

For each formulation, physicochemical analysis was carried out to characterize the composition of the liqueurs and their modifications during storage (maximum of 3 months). All parameters were carried out according to the AOAC methodologies (2005). The relative density was measured using a pycnometer, calibrated in relation to the mass of pure water at 20°C. Total sugars were evaluated by the Fehling method, and the sample was initially subjected to the clarification and hydrolysis steps (hydrochloric acid, for 15 min at 80°C) and was expressed in g/L. Acidity was determined by the titration method, based on the acid neutralization titration with a standardized 0.1 N NaOH solution, using the phenolphthalein indicator to the equivalence point and expressed in g of citric acid per 100 mL of sample. For the determination of pH, a digital bench pH meter (Gehaka, Rio de Janeiro, Brazil) was used. The total soluble solids (°Brix) were determined directly in a digital bench refractometer (Meter 2u, Movel Scientific Instrument, Ningbo, China). The dry extract (g/L) was calculated by weighing the residue after evaporating the water and alcohol by heating at 105°C until constant weight. The ashes (g/L) were calculated from the sample incineration residue.

The color of each formulation was determined by colorimetric analysis (UltraScan PRO, Hunter Lab, Reston, VA, USA) with the D65 lighting standard calibrated in the ultraviolet region. A total of 2 mL of each liqueur was added to a 2 mm glass cell. Three color parameters were evaluated: L*, a*, and b*. The value of a* characterizes coloring in the region from red (+ a*) to green (-a*), and the value b* indicates coloring in the range of yellow (+ b*) to blue (-b*). The L value provides the luminosity, ranging from white (L=100) to black (L=0). Chroma was calculated by the equation $C^*=(a^*2+b^*2)^{½}$ and the *h* angle (Hue) was calculated by the equation $h^*=\tan^{-1}(b^*/a^*)$. This procedure was carried out, with modifications, as proposed by Caner and Aday (2009).

2.3 Determination of ethanol and methanol content

For ethanol and methanol determination, gas chromatography equipped with a flame ionization detector (FID) was used, according to the methodology proposed by Wang et al. (2004), with modifications. The liqueur samples were diluted (1:4) in ultrapure water to a final volume of 10 mL. Consecutively, 500 µL of diluted samples, 500 µL of internal standard 2.75% (butanol) (Merck, Darmstadt, Germany), and 1 mL of ultrapure water were transferred to a headspace flask. The flasks were homogenized and incubated at a temperature of 70°C for 20 min. After the incubation time, 400 µL of the flask's volatile content was injected into the analytical system, manually. A GC-2010 PLUS system (Shimadzu, Kyoto, Japan) coupled to an Rtx-5 column 30 m×0.25 mm i.d., 0.25 μm (Restek, Bellefonte, PA, USA), was used. The injection temperature was adjusted to 150°C with a 1:10 split ratio and an injection pressure of 37.7 kPa. The FID temperature was maintained at 250°C. The column was initially held at 40°C, then increased to 240°C at 25°C/min, and held for 1 min, with a total runtime of 19 min. The analyses were performed in triplicate.

2.4 Copper determination

For the determination of copper (Cu) in liqueur samples, an atomic absorption spectrometer with flame atomization Shimadzu AA-7000 (Shimadzu) was used, equipped with a deuterium lamp for background correction and a hollow Cu cathode lamp (Hamamatsu, São Paulo, Brazil), as proposed by Navarro-Alarcon et al. (2007), with modifications. The instrumental conditions used were as follows: wavelength at 324.8 nm; lamp current at 8 mA; the flame type was air-acetylene; burner height at 7 mm; compressed air flow at 15 mL min^{-1}; and acetylene flow at 1.8 mL min^{-1}.

The digestion of liqueur samples (5 mL) was performed on a heating plate, using 1 mL of 3:1 hydrochloric acid solution (Fisher Chemical, Hampton, NH, EUA) and 65% nitric acid (Merck), respectively, at 110°C for 1 h. Afterward, the samples were cooled and transferred to 10 mL volumetric flasks, and the volume was completed with ultrapure water. The same preparation procedure was performed for a white sample (without liqueur). This was calculated by multiplying the standard deviation of 10 readings of the absorbance of the blank, divided by the slope of the curve, multiplied by 10, and added to the mean blank value (mg/L). The cooper calibration solutions used in the determinations by atomic absorption spectrometry were prepared by dilution in five different concentrations, starting from a reference solution of Cu 1000 mg/L (Merck) and prepared in the range of 0.1–1.5 mg/L.

2.5 Sensory analysis

Sensory analysis was performed at the Sensory Analysis Laboratory of Universidade Federal de Ciências da Saúde de Porto Alegre (UFCSPA), in appropriate and individual booths, under white light, away from noise and odors. The research project was approved by the Ethics Committee of UFCSPA (CEP/UFCSPA) (CAAE number: 06200619.3.0000.5345), and informed consent was obtained from each subject prior to their participation in the study.

The methodology used to define the sensorial profile of the liqueurs was the quantitative descriptive analysis (QDA), which was carried out by eight trained assessors and as described by Dutcosky (2013). The recruitment of participants was made through the distribution and filling out of questionnaires that identified the time availability of the evaluators, who had familiarity with sensory attributes and skills in using non-structured scales. In addition, it was taken into consideration the habit of consuming bananas and liqueur, age (over 18 years), and the health conditions of the participants. The judges had previous experience in the sensory evaluation of liqueurs and alcoholic beverages. Initially, the assessors were trained using the taste knowledge test, using different commercial liqueur formulations with banana flavors and the formulation of banana liqueurs tested with 0.50% of cinnamon powder to standardize perceptions and specific vocabulary and realized in four different sessions of training.

The formulations were evaluated by the trained panel (n=8) using individual booths, cups containing 20 mL of each liqueur formulation, served randomly and coded with random three-digit numbers and at room temperature. In addition, disposable 100 mL cups were also made available for drink disposal. In all sensory analysis sessions, participants received mineral water to clean the taste buds and avoid mixing flavors, causing exhaustion of taste between samples.

For the QDA test, the assessors established the intensities using an unstructured scale of 10 cm for each attribute and having quantitative expressions (anchors) on the left (which is equivalent to the starting point) with terms “weak” or “none” and the right (which is equivalent to the maximum point) with terms “strong” or “very.” Sensory attributes, derived from literature and assessors’ perception and described to all assessors, are shown in Table S1 of the Supplementary Material. The attributes were divided into groups, such as appearance (i.e., the presence of solid particles, apparent white sugar, and intensity of brown and yellow color), group of aromas (i.e., sweetness, alcoholic, banana, cinnamon, and fruity aroma), flavor group (i.e., sweet, alcoholic, banana, and cinnamon flavor), attributes of texture, and sensations (i.e., feeling of heat, acidity, astringency, and body).

2.6 Statistical analysis

For data obtained, means and standard deviation were calculated using triplicates. One-way analysis of variance followed by Tukey’s post-hoc test (95% of significance) was carried out to compare the difference between the means of the attributes of all assessors and of each liqueur sample obtained. Principal component analysis (PCA) was performed on data related to the sensory evaluation of liqueur formulations. All statistical tests were performed using the XLSTAT add-on software, version 2019.2.1.59219.

3 RESULTS AND DISCUSSION

within the scope of this study, a novel liqueur formulation based on banana and cinnamon was proposed at the pilot scale. In general, all formulations of banana and cinnamon liqueur presented similar parameters and were within Brazilian legal standards, demonstrating that the storage of 3 months in a much-reduced way modified the liqueur composition. On the contrary, the storage promoted changes in sensory aspects and modifications in the liqueur formulation profile.

3.1 Modification of physicochemical parameters

Table 1 shows the physicochemical characterization of banana and cinnamon liqueur formulations. All formulations showed adequate parameters and even in accordance with legal limits, even after a storage period of 3 months. The dry extract results varied in the means from 19.85 to 22.86 g/mL, and when

Table 1. Physicochemical characterization, ethanol, methanol, and copper of banana liqueurs with cinnamon powder and cinnamon in bark at initial storage and after 3 months. Means followed by the same letters in the column do not differ by Tukey's test (p>0.05). The standard deviations were calculated in triplicate.

	Cinnamon concentration (%)	Dry extract (g/mL)	Ashes (g/L)	Acidity (g/L citric acid)	pH	Soluble solids (°Brix)	Sugars (g/L)	Density (g/mL)	Ethanol (%)	Methanol (mg/L)	Cu (mg/L)
Cinnamon powder	0.25	22.5^{ab}±0.35	1.67^{b}±0.01	1.42^{b}±0.01	4.65^{a}±0.01	30.5^{a}±0.43	300.5^{a}±0.53	0.35^{ab}±0.02	24.90^{b}±0.003	0.015^{a}±0.0000511	nd
	0.50	22.86^{a}±0.25	1.20^{a}±0.01	1.35^{d}±2.22	4.75^{a}±0.01	30.86^{a}±0.26	300.8^{a}±0.62	0.39^{ab}±0.07	24.98^{b}±0.008	0.017^{a}±0.0000457	nd
	0.75	22.8^{a}±0.08	1.61^{a}± 0.01	1.39^{bc}±0.01	4.87^{a}±0.01	30.53^{a}±0.38	300.5^{a}±0.38	0.40^{ab}±0.05	24.76^{b}±0.011	nd	0.0105^{a}±0.0002
Cinnamon powder after 3 months	0.25	20.17^{ab}±2.16	1.59^{a}±0.01	1.42^{b}±0.01	5.04^{a}±0.01	31.76^{a}±0.20	301.7^{a}±0.20	0.39^{ab}±0.001	23.28^{b}±0.113	0.015^{a}±0.0000457	nd
	0.50	19.85^{b}±0.15	1.63^{b}±0.01	1.42^{b}±0.01	5.02^{a}±0.01	30.63^{a}±1.08	300.6^{a}±1.08	0.40^{ab}±0.05	20.53^{a}±0.138	nd	nd
	0.75	19.96^{ab}±0.5	1.71^{b}±0.02	1.42^{b}±0.01	5.00^{a}±0.01	31.36^{a}±0.05	301.3^{a}±0.50	0.43^{ab}±0.009	21.08^{a}±0.132	0.023^{a}±0.0000430	0.0103^{a}±0.0002
Cinnamon in bark	0.25	21.73^{ab}±0.20	1.57^{a}±0.02	1.37^{cd}±0.01	4.85^{a}±0.01	31.26^{a}±0.05	301.3^{a}±0.50	0.37^{ab}±0.07	28.46^{c}±0.041	0.020^{a}±0.0000421	nd
	0.50	21.76^{ab}±0.20	1.61^{a}±0.01	1.42^{b}±0.01	4.74^{a}±0.01	31.73^{a}±0.29	301.7^{a}±0.29	0.31^{ab}±0.07	25.97^{b}±0.018	0.023^{a}±0.0000430	nd
	0.75	22.13^{ab}±0.12	1.19^{a}±0.01	1.42^{b}±0.01	4.67^{a}±0.01	31.43^{a}±0.38	301.4^{a}±0.38	0.29^{b}±0.07	25.01^{b}± 0.009	0.021^{a}±0.0000190	0.0137^{a}±0.0002
Cinnamon in bark after 3 months	0.25	21.07^{ab}±1.36	1.67^{a}±0.01	1.5^{a}±0.01	4.89^{a}±0.01	31.46^{a}±0.09	301.5^{a}±0.15	0.48^{a}±0.04	24.68^{b}±0.046	0.023^{a}±0.0000430	nd
	0.50	21.68^{ab}±0.74	1.57^{a}±0.00	1.47^{a}±0.03	5.08^{a}±0.01	31.53^{a}±0.05	301.5^{a}±0.50	0.44^{ab}±0.01	23.96^{b}±0.083	0.021^{a}±0.0000190	nd
	0.75	20.85^{ab}±0.59	1.62^{b}±0.02	1.5^{a}±0.03	5.02^{a}±0.01	31.5^{a}±0.14	301.5^{a}±0.14	0.44^{ab}±0.003	22.62^{b}±0.212	0.014^{a}±0.0000511	0.0136^{a}±0.0001

nd: not detected in the sample or below the calculated quantification limit of method (0.01 mg/L for ethanol and copper).

comparing the formulations before and after storage time, a decrease was verified, only using cinnamon powder (Table 1). This reduction was around 10, 13, and 12% to formulation with 0.25, 0.50, and 0.75% of cinnamon powder, respectively. This difference could be explained by the fact that, with a longer infusion time, several substances can be oxidized, polymerized, and precipitated (Alamprese & Pompei, 2005).

In all the formulations of liqueurs produced, reduced levels of ash were found, ranging from 1.19 to 1.71 g/L, with no significant difference among samples (p>0.05). Regarding total acidity, the average values ranged from 1.37 to 1.5 g/L in citric acid, and storage few interferes with the acidity of liqueurs. The acidity level in liqueurs, as well as the other parameters are related to the raw material and ingredients used in the formulation. The banana Chunkey variety used has higher acidity than other varieties, and the alcoholic degree of the alcohol used in the infusion and the amount of syrup may have influenced it. From a sensory point of

view, acidity has a strong influence, as the lower the presence of acids in fruit liqueurs, the more pleasant and the better the product will be for the consumers' taste (Almeida et al., 2012).

For pH (from 4.65±0.01 to 5.08±0.01), content of soluble solids (ranged from 30.5±0.43 to 31.76±0.20 °Brix), density (0.29±0.07 to 0.48±0.04 g/mL), and sugars (from 300.5±0.53 to 310.7±0.29 g/L), the formulations did not differ statistically from each other after storage time (3 months) (Table 1). This effect on pH values was verified in walnut liqueurs after 90 days of storage (Alamprese & Pompei, 2005) and banana liqueur found an average pH value of 4.78 (Teixeira et al., 2005), very close to that found in the formulation with 0.50% of cinnamon powder at time zero. Related to the soluble solids and sugar of liqueurs, the levels are very related to the infusion quantity of sugar used and the raw materials employed. A carrot liqueur with orange obtained a value of 30° Brix (Passos et al., 2013), like the values found in banana and cinnamon liqueur, as found in camu camu liqueurs (over 33° Brix) and pineapple (Viera et al., 2010). The values of soluble solids content are within the standards required by law; for the sugar content, it must be above 30 g/L and liqueur formulations can be classified as "Fine" because it ranges between 100 and 350 g/L of sugars (Brazil, 2009).

It was found that, during storage, fruit ingredients undergo transformations, and the color and composition of liqueurs change (Sokoł-Łętowska et al., 2014). Moreover, the transformation of raw materials and the extraction of different substances from solids to liquid phase are verified during the storage process, modifying some parameters of liqueurs composition (Alamprese & Pompei, 2005; Senica et al., 2016; Sokoł-Łętowska et al., 2014). The differences in liqueur parameters were probably due to the presence of different amounts of cinnamon, the extraction of its properties was evident in the dependence on the extraction source, and they were visible in the composition of the alcoholic and soluble solids contents. This effect was verified in banana and cinnamon liqueurs, mainly in dry extract, acidity, color, and sensory profile. On the contrary, several differences found might be related to the conditions of the extraction procedure (i.e., time of extraction) or to the intrinsic characteristics of plant material, such as origin and season (Rodríguez-Solana et al., 2021).

3.2 Alcohol, residual methanol, and copper content

The concentration of methanol in the samples was determined and proved to be below the legal limits (maximum 20 mg/100 mL). The low amount of methanol in the formulations (Table 2) showed its high quality not only in terms of taste and aroma, where their presence can cause an olfactory aggressiveness, but also it is highly harmful to the consumer's health even in small quantities (Cardoso et al., 2003). In the human body, methanol is oxidized to formic acid and later to carbon dioxide, causing severe acidosis (decrease in blood pH), affecting the respiratory system, which can lead to coma and even death (Fonger et al., 2000). Methanol is considered a toxic alcohol, naturally present in alcoholic beverages in quantities lower than the other components (Cardoso et al., 2003).

Regarding ethanol content, differences were detected by the storage process, and a lower decrease in alcohol content was verified, but the formulations remained within the considerable limits for liqueurs, according to the current legislation.

Table 2. Average values and standard deviations of color parameters from banana liqueurs with cinnamon powder and in bark at the initial time of storage and after 3 months. Means followed by the same letters in the column do not differ by Tukey's test (p>0.05).

	Cinnamon concentration (%)	L	a*	b*	Chroma	h
Cinnamon powder	0.25	72.85^{cd}±0.22	72.85^{cd}±0.22	72.85^{cd}±0.22	72.85^{cd}±0.22	72.85^{cd}±0.22
	0.50	73.39^{bc}±0.29	-1.36^{cd}±0.01	6.04^{f}±0.04	19.17^{f}±0.27	-1.35^{d}±0
	0.75	69.43^{f}±0.24	-1.05^{a}±0	10.96^{d}±0.02	60.64^{d}±0.27	-1.48^{fg}±0
Cinnamon powder after 3 months	0.25	70.10^{f}±0.17	-1.79^{e}±0.01	9.08^{e}±0.12	42.84^{e}±1.10	-1.38^{de}±0
	0.5	67.70^{g}±0.03	-1.59^{de}±0.00	13.78^{b}±0.10	96.21^{b}±1.38	-1.46^{fg}±0
	0.75	65.44^{h}±0.17	-1.10^{ab}±0.02	16.76^{a}±0.12	141.06^{a}±2.00	-1.51^{g}±0
Cinnamon in bark	0.25	74.41^{a}±0.16	-1.27^{abc}±0	1.71^{ij}±0.06	2.27^{i}±0.09	-0.93^{ab}±0.02
	0.50	73.94^{ab}±0.32	-1.36^{cd}±0.016	1.68^{j}±0.02	2.35^{i}±0.02	-0.89^{a}±0.01
	0.75	74.10^{ab}±0.41	-1.34^{bcd}±0.22	1.96^{i}±0.01	2.82^{i}±0	-0.97^{b}±0.01
Cinnamon in bark after 3 months	0.25	71.44^{e}±0.16	-1.70^{e}±0.016	5.27^{g}±0.10	15.33^{g}±0.58	-1.26^{c}±0
	0.50	72.51^{de}±0.19	-1.59^{de}±0.024	4.28^{h}±0	10.46^{h}±0.37	-1.21^{c}±0.05
	0.75	68.48^{g}±0.12	-1.58^{de}±0	11.43^{c}±0.06	66.65^{c}±0.69	-1.43^{ef}±0

This decrease was verified mainly, using cinnamon in powder, comparing the initial and the end of the storage period. Different alcohol contents used in the preparation of the extracting solution influenced the taste and overall impression of the banana liqueurs, and the combinations between the alcohol and sugar content produced banana liqueurs with different sensory, physicochemical characteristics and purchase intention (de Jesus Filho et al., 2018). No differences were observed comparing the formulations with different cinnamon content, except formulation with 0.25% of cinnamon in bark (28.46±0.041%).

Copper is one of the undesirable metals in beverages, and contamination by copper ions is considered an obstacle to exports (Marinho et al., 2009). Brazilian law limits the copper content in distilled beverages to 5 mg/L, although, in this concentration, copper cannot be considered toxic, its presence contributes to emphasize the acid flavor (Cardoso et al., 2003).

3.3 Color analysis

The color parameters of formulations were evaluated based on the variables L, a*, b*, chromaticity (Chroma), and angle *h*. All color parameters presented differences ($p \leq 0.05$) among the samples, as shown in Table 2. All formulations showed an appearance with high brightness. The L value varied from 65.44 to 74.41, indicating high luminosity. However, after the storage period (3 months), there was a decrease in the L value in all formulations ($p \leq 0.05$). This decrease was higher when comparing the formulations of liqueur with cinnamon in the form of powder than in the form of cinnamon in bark, with a decrease of approximately 5.53 and 4.27%, respectively. Figure 1 shows the appearance and visual color of banana and cinnamon liqueurs.

The variables a* and b* ranged from -1.05 to -1.79 and 1.69 to 16.76, respectively; thus, the formulations showed a greenish-yellow color, as demonstrated in Figure 1. The formulation with 0.75% of powder cinnamon, after 3 months of storage, showed a more intense yellow color, with a brown and less greenish tint (lower value of a*), in addition to the significant reduction in luminosity. This same formulation showed a decrease in the greenish-yellow color when compared with the formulation with 0.75% of cinnamon in bark after storage time (Figure 1). This result was possibly influenced by the hydroalcoholic extraction technique of the bioactive compounds present in cinnamon, such as proanthocyanidins, which provide some sensory aspects to foods such as bitter taste and astringent sensation, due to their ability to bind and precipitate salivary proteins (Bennick, 2002; Hofmann et al., 2006).

In addition to the type of solvent, the solid-solvent ratio, the particle size of the solid, the temperature, pH, and the extraction time play an important role in increasing the efficiency in the extraction of proanthocyanidins (Rajha et al., 2014) and can influence the color of liqueurs. When the cinnamon was added in powder form, the solid-solvent ratio was increased, the solid precipitation was favored, and the color parameters were modified (Figure 1). Regarding the color of liqueurs, as shown in Figure 1, the addition of cinnamon modified the visual color, becoming more intense and with greater perception of brown color, according to the dose of cinnamon used, and, in powder form, this behavior was more evident. Probably, the powder form of cinnamon promotes the extraction of different compounds that increase the color of liqueurs; moreover, the oxidation process during storage may have led to the increase in brown coloration, as described previously (Rajha et al., 2014; Rodríguez-Solana et al., 2021; Senica et al., 2016).

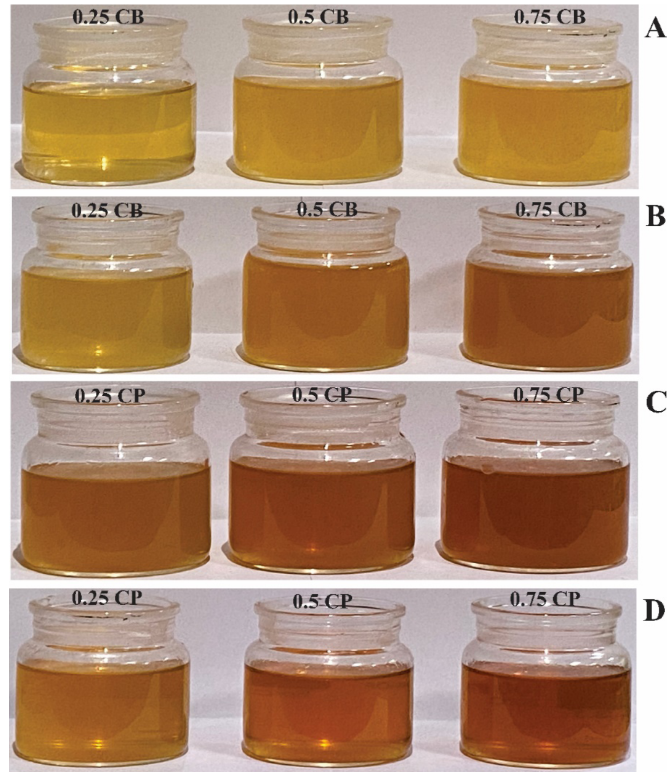


Figure 1. Appearance and color of different formulations of banana liqueurs with different concentrations of cinnamon (i.e., 0.25, 0.50, and 0.75%), earlier and after the storage of 3 months. (A) Formulations with cinnamon in bark form (CB). (B) Formulations with cinnamon in bark form (CB) after 3 months. (C) Formulations with cinnamon in powder (CP). (D) Formulations with cinnamon in powder (CP) after 3 months.

Chroma (C*) is a quantitative parameter of color intensity, and a higher chroma refers to a greater color saturation perceptible by the human eye (Pathare et al., 2013). The C* value calculated for formulations with cinnamon powder ranged from 2.27 to 141.06, with the highest value found in the formulation with 0.75% cinnamon powder and after 3 months of storage. The lowest value of C* (2.27) was detected in the liqueur with 0.25% cinnamon in bark. This formulation showed a yellow color more intense (b* value of 16.76, the highest value of all formulations) and, consequently, a reduced L value, resulting in an opaque liqueur. The formulations containing cinnamon in bark had lower C* values (from 2.27 to 66.65) and showed a light-yellow color (lower b* values), but the result was a formulation with greater brightness.

In this way, the addition of cinnamon changed the color of liqueurs, which was demonstrated in all formulations, and the modification was related to the increase in the cinnamon amount added. The main change was verified in the L value, which was decreased and influenced the perception of samples' luminosity and brightness during sensory analysis. This effect was evidenced using cinnamon in the form of powder. The powder cinnamon on liqueur formulations, in addition to providing greater extraction of flavor and aroma compounds, leads to greater turbidity, which may have been responsible for the decrease in the value of L and the other color parameters evaluated. This effect was evidenced in visual perceptions of liqueurs (Figure 1). However, there was an increase in the value of C*, showing that cinnamon increases the color of the formulations, especially when added in powder form.

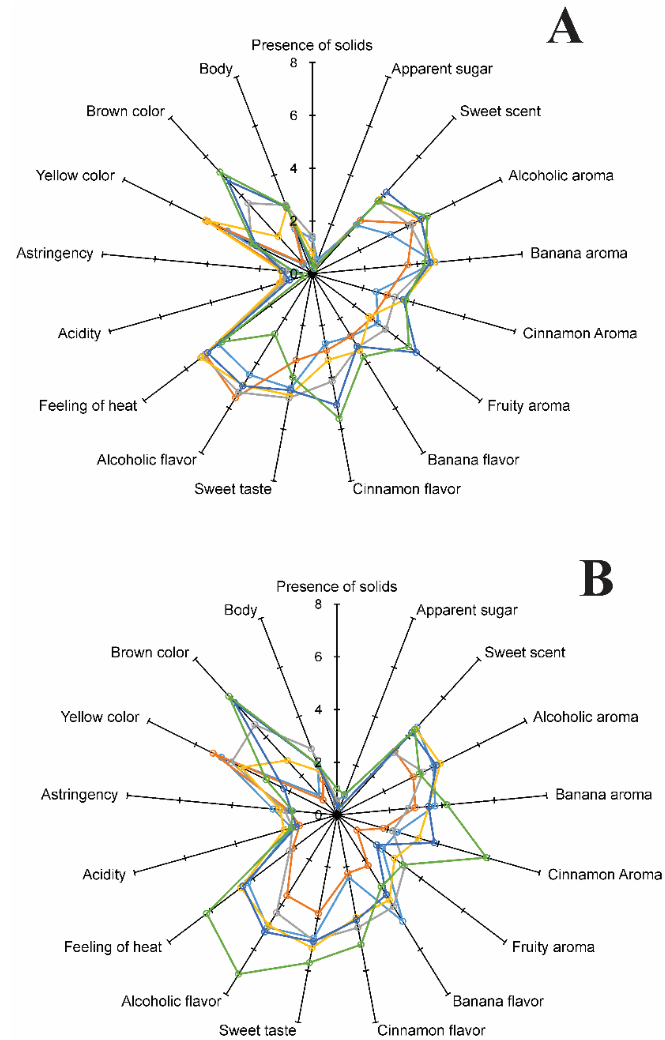
The results of C* presented for banana liqueurs, added in different concentrations of cinnamon in powder and bark, ranged from -0.89 to -1.51. The *h* is considered the qualitative attribute of color, with colors such as red and green, among others (Pathare et al., 2013). Temperature of storage, pH, oxygen, and other compounds, such as co-pigments, ascorbic acid, sugars, and their degradation products, also influenced liqueur color (Sokoł-Łętowska et al., 2014). As a result of cinnamon addition, evident alteration in the visual color of liqueurs was verified (increase in brown color and decrease in luminosity and brightness) mainly according to the dose and form of cinnamon used and to the effect of storage of 3 months.

3.4 Sensory analysis of formulations

The appearance, flavor, and aroma attributes of the liqueurs were evaluated, and these results of liqueur appearance are shown in Figure 1. The attributes with the highest intensity were the flavor and aroma attributes of cinnamon, sweetness, and banana. In addition, differences in sensory perception were detected after the 3-month storage period ($p \leq 0.05$). Banana liqueur was a great acceptance and purchase intention by consumers, mainly when prepared with lower alcohol content (19%) and intermediate levels of sugar (275 g/L) (de Jesus Filho et al., 2018).

Figures 2A and 2B show the sensory profile obtained for the different formulations of banana and cinnamon liqueur and the effect of the storage process. The intensity for the attributed presence of solid particles was higher in formulations of 0.25 and 0.75% of powdered cinnamon and after 3 months of storage. In addition, higher intensities were detected in formulations with a greater amount of cinnamon (0.75%). The fruity aroma was shown to be closely related to the banana aroma highlighted by the panel (n=8). In formulations with higher amounts of cinnamon, both powdered and in bark, the intensity of the fruity and banana aroma was higher (Figures 1 and 2). The greater intensity of the cinnamon aroma in the formulations and the lower intensity of the alcoholic aroma were detected in all formulations. In addition, the formulations with greater amounts of powdered cinnamon and after storage obtained greater intensities of fruity aroma, aroma, and banana flavor, aroma and flavor of cinnamon, and aroma and sweetish flavor. The enrichment with cinnamon changed the sensory characteristics due to its content of volatile compounds, especially cinnamaldehyde (Albak & Tekin, 2015).

After storage, the assessors had a greater perception of the brown color, as visualized in Figure 1. This effect of increasing the brown color was attributed to the presence of cinnamon,

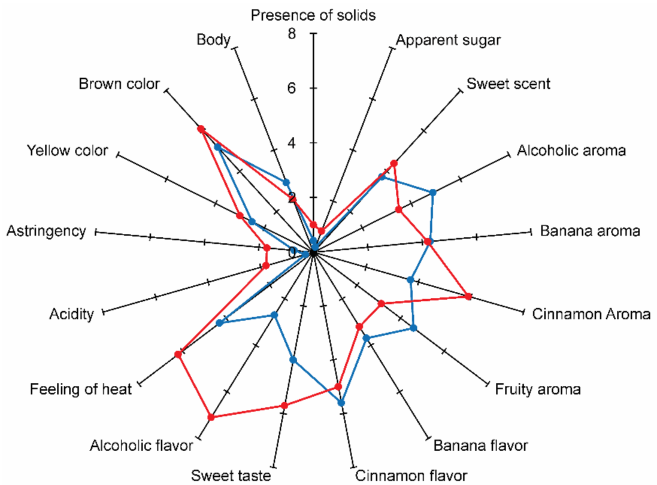


Light blue line: 0.25% CB; orange line: 0.50% CB; gray line: 0.75% CB; yellow line: 0.25% CP; dark blue line: 0.50% CP; green line: 0.75% CP.

Figure 2. Sensory profile and attributes of banana liqueur formulations with cinnamon powder (CP) and cinnamon in bark (CB) with different concentrations of cinnamon (i.e., 0.25, 0.50, and 0.75%) at the initial time of storage (A) and after the 3 months of storage (B) obtained by a panel of trained assessors.

mainly in the form of powder. The alcoholic flavor intensified; consequently, the sensation of heat was higher, and the perception of the aroma of cinnamon was intensified and more evident. For the formulation with 0.75% powdered cinnamon, the intensity of this attribute was 5.65±2.77, differentiating it from the other formulations ($p > 0.05$). The lower intensity of this attribute (2.89±1.52) was verified in the formulation with 0.25% cinnamon in bark form. The addition of cinnamon in powder form even after storage influenced other attributes such as sweetness and alcoholic flavor perception.

To better visualize the effect of storage, the sensory profile of the formulation with 0.75% powder cinnamon was compared, as presented in Figure 3. The formulation with 0.75% cinnamon powder showed the highest intensities ($p > 0.05$) of cinnamon aroma, as expected, even after storage. The storage effect was exhibited in the appearance, aroma, and flavor attributes of



Blue line: earlier storage time and red line: after 3 months.

Figure 3. Sensory attributes of banana liqueur with cinnamon in powder form at a concentration of 0.75% earlier and later the storage period of 3 months in dark conditions. The data were obtained with a panel of trained assessors (n=8).

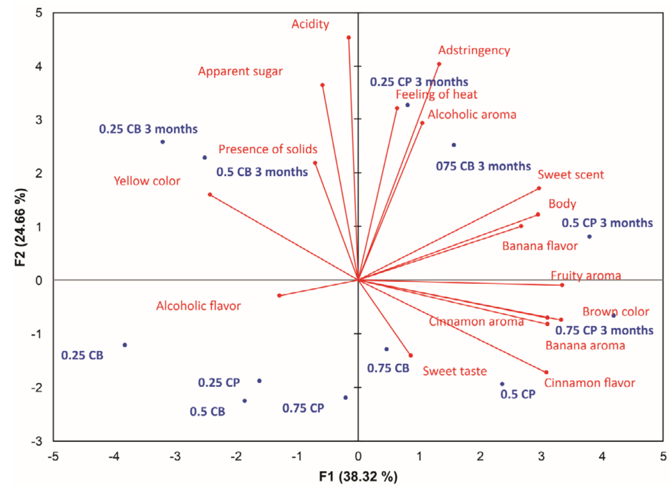


Figure 4. Bidimensional projection of the results obtained from the PCA in correlation matrix I and II for the sensory parameters of banana liqueur with different concentrations of cinnamon (i.e., 0.25, 0.50, and 0.75%) powder form (CP) and in bark form (CB) and earlier and after 3 months of storage.

the banana and cinnamon liqueur. The attribute of apparent sugar remained reduced, with a maximal value of 0.25±0.15. This visual attribute of liqueurs was reduced possibly due to the choice of the vacuum filtration method not only for the initial maceration but also for the syrup and the final liqueur, which reduced the presence of dirt and other possible sensory defects to the drink. After 3 months, the yellow color was reduced, and the brown color attributed to cinnamon was evidenced, as shown in Figure 1.

The flavors and aromas of both banana and cinnamon were displayed by the storage process; however, the alcoholic flavor perception was decreased (5.95±2.90 to 2.75±0.40). This effect of liqueur sensory attributes softened favoring the consumption and acceptance (de Jesus Filho et al., 2018; Teixeira et al., 2005). There was a small reduction in the sensation of warmth and the sweet taste perceived by the assessors, which can be explained by the presence of aromatic compounds from the cinnamon that raised the values of the attributes of sweet aroma based on the choice of the type of spice. The fruity aroma was not affected by the addition of cinnamon even with storage, which confirms that its presence, even in high quantities, did not negatively alter the base formulation (banana and alcohol), showing that it was possible to perceive the aroma of banana.

The PCA model developed for the samples of banana liqueur with cinnamon (Figure 4) showed that components 1 (i.e., fruity, sweetness, banana, cinnamon, banana flavor, cinnamon flavor, yellow, brown, and body color) and 2 (i.e., apparent sugar, alcoholic, feeling of heat, acidity, and astringency) were able to explain 62.99% of the total variation of the data, with 24.66% being explained by F1 and 38.32% by F2.

The attributes for astringency and alcoholic aroma proved to be important to characterize the formulation 0.25% cinnamon powder after 3 months of storage, as well as banana flavor and body in the characterization of the sample 0.50% cinnamon powder after 3 months of storage. The formulation of 0.75% cinnamon powder after storage was characterized by the brown color attributes, a feature of the highest amount of cinnamon, and the aromas of cinnamon and banana. In addition, the formulations with higher amounts of cinnamon (0.75 and 0.5%) had cinnamon and banana flavor and aroma as main components, even after the storage process. This effect was important, as it has a direct relationship to the sensory profile of the liqueurs produced and is more evident by the addition of cinnamon in the form of powder. On the contrary, formulations with less cinnamon added were characterized by alcoholic flavor and yellow color.

4 CONCLUSION

The formulation of banana liqueur with 0.75% of powder cinnamon, even after storage, showed greater intensity of sensory attributes such as brown color, cinnamon flavor and aroma, sweetish aroma, warm feeling, and alcoholic aroma, when compared with the other formulations. Regarding the composition, some differences were detected, which may be due to the amount of cinnamon, the maceration and production of liqueurs, and the effect of the storage process. Such results also influenced the response of the sensory panel to which this formulation showed greater intensity in different sensory attributes. All formulations of cinnamon banana liqueurs met the requirements of the current Brazilian legislation.

The elaboration of banana liqueur with cinnamon is feasible, which, in addition to having simple technology and being easily applied, even in small industries, has also proved to be a product of high sensorial quality and high durability. In addition to being a product that contributes to the reduction of food waste, it brings a new entrepreneurial possibility for producing families, contributing to the increase in family income.

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