

## PRODUCTION AND CHARACTERIZATION OF A FERMENTED BEVERAGE FROM PINEAPPLE (*Ananas comosus*) PEELS

## PRODUÇÃO E CARACTERIZAÇÃO DE UMA BEBIDA FERMENTADA UTILIZANDO CASCAS DE ABACAXI (*Ananas comosus*)

## PRODUCCIÓN Y CARACTERIZACIÓN DE UNA BEBIDA FERMENTADA UTILIZANDO CÁSCARAS DE PIÑA (*Ananas comosus*)



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### ABSTRACT

The objective of this work was to evaluate the use of pineapple peels in the production of a fermented beverage, contributing to the valorization of agro-industrial waste and the development of more sustainable food products. During fermentation, pH and °Brix analyses were performed at 12-hour intervals. The fermented beverage was analyzed for lactic acid bacteria counts and determination of coliforms at 35°C and 45°C, *Salmonella*, anaerobic mesophilic bacteria, and molds and yeasts. A sensory acceptance test and purchase intention assessment of the fermented beverage made with pineapple peels were conducted in comparison with a commercial fermented beverage. The results for sensory evaluation, and purchase intention of the two samples were subjected to analysis of variance (ANOVA) and Tukey's test at a 5% significance level. Fermentation time did not cause a significant difference ( $p < 0.05$ ) in °Brix and pH when the latter increased from 48 h to 72 h, and from 72 h to 96 h. The attributes of flavor, overall evaluation, and purchase intention showed a significant difference ( $p < 0.05$ ) between the fermented beverage evaluated and the commercial product. The fermented beverage with pineapple peels had higher scores and differed statistically ( $p < 0.05$ ) from the commercial product. The attributes of flavor and appearance showed a higher percentage of scores above 6, being within the acceptance range. However, purchase intention was considered low since only 21.67% of tasters would possibly buy the beverage. It was possible to obtain a fermented beverage with pineapple peels that is hygienically safe for human consumption, with the presence of lactic acid bacteria between  $10^8$  and  $10^9$  CFU/ml, indicating a possible probiotic activity.

**Keywords:** Circular Economy. Utilization of Agro-Industrial Waste. Upcycling. Sustainable Food Processing. Valorization of Agro-Industrial Waste.

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## RESUMO

O objetivo deste trabalho foi avaliar o aproveitamento das cascas de abacaxi na elaboração de uma bebida fermentada, contribuindo para a valorização de resíduos agroindustriais e para o desenvolvimento de produtos alimentícios mais sustentáveis. Durante a fermentação foram realizadas análises de pH e °Brix no intervalo de 12 horas. Na bebida fermentada foi realizada contagem de bactérias lácticas e determinação de coliformes a 35°C e 45°C, *Salmonella*, mesófilos anaeróbicos e bolores e leveduras. O teste de aceitação sensorial e da intenção de compra da bebida fermentada com cascas de abacaxi foi realizada em comparação com uma bebida fermentada comercial. Os resultados de avaliação sensorial e intenção de compra das duas amostras foram submetidos à análise de variância (ANOVA) e teste de Tukey a 5% de significância. O tempo de fermentação não ocasionou diferença significativa ( $p < 0,05$ ) nos °Brix e no pH quando este aumentou de 48 h para 72 h, e de 72 h para 96 h. Os atributos sabor, avaliação global e intenção de compra apresentaram diferença significativa ( $p < 0,05$ ) entre a bebida fermentada avaliada e o produto comercial. A bebida fermentada com cascas de abacaxi apresentou maiores notas e diferiu estatisticamente ( $p < 0,05$ ) do produto comercial. Os atributos sabor e aparência apresentaram maior porcentagem das notas acima de 6, estando dentro da faixa de aceitação. Contudo, a intenção de compra foi considerada baixa visto que apenas 21,67% dos provadores possivelmente comprariam a bebida. Foi possível obter uma bebida fermentada com cascas de abacaxi higienicamente segura para o consumo humano com a presença de bactérias lácticas entre  $10^8$  e  $10^9$  UFC/ml indicando uma possível atividade probiótica.

**Palavras-chave:** Economia Circular. Aproveitamento de Resíduos Agroindustriais. *Upcycling*. Processamento Sustentável de Alimentos. Valorização de Resíduos Agroindustriais.

## RESUMEN

El objetivo de este trabajo fue evaluar el aprovechamiento de las cáscaras de piña en la elaboración de una bebida fermentada, contribuyendo a la valorización de residuos agroindustriales y al desarrollo de productos alimenticios más sostenibles. Durante la fermentación, se realizaron análisis de pH y °Brix en intervalos de 12 horas. En la bebida fermentada se efectuó el recuento de bacterias lácticas y la determinación de coliformes a 35°C y 45°C, *Salmonella*, microorganismos mesófilos anaerobios, así como mohos y levaduras. La evaluación de aceptación sensorial y de intención de compra de la bebida fermentada a partir de cáscaras de piña se realizó en comparación con una bebida fermentada comercial. Los resultados de la evaluación sensorial e intención de compra de las dos muestras fueron comparados utilizando análisis de varianza (ANOVA) y teste de Tukey con un nivel de significancia del 5%. El tiempo de fermentación no ocasionó diferencias significativas ( $p < 0,05$ ) en los °Brix ni en el pH cuando este aumentó de 48 h a 72 h y de 72 h a 96 h. Los atributos sabor, aceptación global y intención de compra presentaron diferencias significativas ( $p < 0,05$ ) entre la bebida fermentada producida y el producto comercial. La bebida fermentada elaborada con cáscaras de piña presentó mayores puntuaciones y fué estadísticamente diferente ( $p < 0,05$ ) del producto comercial. Los atributos sabor y apariencia mostraron un mayor porcentaje de puntuaciones superiores a 6, situándose dentro del rango de aceptación. Sin embargo, la intención de compra fue considerada baja, dado que solo el 21,67% de los evaluadores probablemente comprarían la bebida. Fue posible obtener una bebida fermentada a partir de cáscaras de piña higiénicamente segura para el consumo humano, con la presencia de bacterias lácticas entre  $10^8$  y  $10^9$  UFC/mL, lo que indica una posible actividad probiótica.

**Palabras clave:** Economía Circular. Aprovechamiento de Residuos Agroindustriales. *Upcycling*. Procesamiento Sustentable de Alimentos. Valorización de Residuos



Agroindustriales.

## 1 INTRODUCTION

Hunger and food waste are two of the main challenges faced by Brazil, constituting a relevant paradox in the national scenario. Although the country produces about 140 million tons of food annually and is among the largest agricultural exporters in the world, there are still millions of people in a situation of food insecurity (Leonel et al., 2014). The increase in demand for fruits and vegetables is associated with population growth and changes in eating habits (Sagar et al., 2018).

The processing of fruits and vegetables is often associated with the generation of large volumes of waste, which can represent between 25% and 30% of the raw material *in natura* (Weyya et al., 2024). These residues constitute a rich source of bioactive compounds, dietary fibers, sugars, organic acids, and minerals, to which several health benefits are attributed, including antioxidant activities, among others (Sagar et al., 2018). The proper use of waste from vegetables can contribute to sustainable development, aiming to mitigate environmental impacts and promote human health through the incorporation of bioactive substances in food (Sagar et al., 2018).

Among the agro-industrial residues, pineapple has a high potential for use. The edible fraction of the fruit corresponds to a reduced portion of the plant, and approximately 77% of its composition (skin, stem, leaves, crown, and stems) is considered residue (Souza et al., 2021). During processing, these residues can represent between 40% (Ferreira et al., 2017) and 50% (w/w) of the fruit (Weyya et al., 2024). Pineapple peel stands out as one of the main by-products, with high nutritional value, with significant levels of minerals (4.74%) and fibers (17.92%). In addition, it is a source of compounds with antioxidant potential and can favor the growth of beneficial microorganisms, such as bacteria of the genus *Lactobacillus*, indicating potential application in products with functional characteristics (Nunes ; Silva, 2025).

Currently, the use of these residues in relation to the consumption of *fresh* and processed fruit is incipient. These are often disposed of in landfills or burned, contributing to negative environmental impacts (Diniz, 2017; Vieira et al., 2020). To date, the literature has focused mainly on the extraction of the enzyme bromelain and, secondarily, on the use of these residues for the production of phenolic antioxidants, organic acids, bioethanol, biogas and fibers. In addition, the sugar content present in these materials makes them suitable as a substrate for fermentation processes, enabling, for example, the production of vinegar (Roda et al., 2016).

In this context, the use of waste from the processing of fruits and vegetables, whether in the reformulation of traditional products or in the development of new products, presents

itself as a promising alternative to reduce environmental impacts (Ketnawa et al., 2012). Pineapple peels can be used in the production of fermented beverages, due to their sugar content, which serve as a substrate for microorganisms, resulting in the formation of bioactive compounds. An example is aluá (or aruá), a fermented, slightly acidic, low-alcohol beverage produced in different regions from raw materials such as pineapple, corn, rice, and bananas (Cerero-Calvo et al., 2022; Fernandes, 2021).

In view of the above, this work aimed to evaluate the potential of using pineapple peels in the elaboration of a fermented beverage, contributing to the valorization of agro-industrial residues and to the development of more sustainable food products

## 2 THEORETICAL FRAMEWORK

### 2.1 PINEAPPLE PRODUCTION, WASTE AND AGRO-INDUSTRIAL RECOVERY

Projections indicate a significant expansion of pineapple (*Ananas comosus* (L.) Merr.) production by 2030 (Vieira et al., 2020), following global trends in healthy food consumption. Brazil stands out as one of the world's leading producers, with production concentrated in the Northeast, North, and Southeast regions, responsible for the largest share of national production (EMBRAPA, 2018). The fruit and vegetable agroindustry is one of the main sources of organic waste generation, representing a significant environmental and economic challenge (Sagar et al., 2018).

The concept of *food waste valorization* has gained prominence in the scientific literature, being defined as the set of strategies aimed at converting food waste into products with higher added value, including functional ingredients, bioproducts, and bioenergy (Galanakis, 2012; Mirabella et al., 2013). Fruit residues are recognized as rich sources of bioactive compounds, such as phenolics, carotenoids, dietary fibers, and organic acids, which have antioxidant, antimicrobial, and anti-inflammatory properties (Sagar et al., 2018). In this way, the reuse of these materials represents an opportunity for the development of functional and sustainable foods.

Inadequate management of this waste can generate relevant environmental impacts, including soil and water contamination, in addition to the emission of greenhouse gases (Borges, et al., 2025). On the other hand, its valorization contributes to the transition from a linear production model to a model based on the circular economy, in which waste is reintegrated into the production system (Geissdoerfer et al., 2017).

In the Brazilian context, public policies such as the National Solid Waste Policy (PNRS) and initiatives aimed at low-carbon agriculture reinforce the importance of valuing agro-industrial waste (Borges, et al., 2025).

## 2.2 POTENTIAL OF PINEAPPLE PEEL IN THE ELABORATION OF FERMENTED BEIDAS

In general, pineapple has about 89.9% water, 0.3% proteins, 0.5% lipids, 5.8% carbohydrates, 3.2% fibers and 0.3% minerals (Borges et al., 2004). Studies indicate that the peel may have higher levels of nutrients than the pulp. According to Gondim et al. (2005), 100 g of pineapple peel contains approximately 76.95 g of moisture, 1.51 g of protein, 11.04 g of lipids, 6.85 g of fiber and 2.90 g of carbohydrates, in addition to minerals such as calcium (123.94 mg), potassium (236.70 mg), iron (2.18 mg) and magnesium (26.24 mg), evidencing its high nutritional value. The content of dietary fibers and minerals is especially noteworthy, which play a fundamental role in the maintenance of human health, being associated with the regulation of intestinal transit, the prevention of chronic diseases and adequate metabolic functioning. In addition, the presence of phenolic compounds gives the peel antioxidant properties, expanding its potential for application as a functional ingredient. Several studies have explored the use of pineapple peel and other residues in different technological applications such as juice production (Borges et al. (2004; Imandi et al. (2008), ethanol (Tanaka et al., 1999), bromelain (Ketnawa et al., 2012), and flour (Ketnawa et al., 2010; Leonel et al., (2014) contributing to the aggregation of value to by-products reducing environmental impacts.

Regarding the application in fermentation processes, pineapple peel has particularly favorable characteristics, such as high fermentable sugar content, adequate moisture and the presence of bioactive compounds. Other authors have also highlighted the potential of this material and specifically of the peels as a substrate for different fermentation routes, obtaining various products such as alcoholic beverages (Paixão et al., 2018), a beverage similar to aluá (Teixeira, 2018), wine (Herrera, 2011) and vinegar (Reyes, 2015). Fermentation is a biotechnological process widely used for food preservation and transformation, involving the action of microorganisms that convert organic substrates into compounds of interest (Cerero-Calvo et al., 2022). In addition to increasing the shelf life of foods, fermentation can improve their sensory and nutritional characteristics.

Fruit-based fermented beverages have gained prominence due to their functional potential, especially due to the presence of beneficial microorganisms and bioactive metabolites (Marco et al., 2017). Lactic fermentation, in particular, is widely used in the production of functional foods, as lactic acid bacteria contribute to microbiological stability and can exert beneficial health effects (Freire et al., 2021; Reis et al., 2021). In this sense, fermentation emerges as a sustainable strategy for the valorization of these materials, allowing the obtaining of products with higher added value.

Among the traditional beverages obtained from the fermentation of pineapple residues, tepache stands out, a Mexican beverage with a characteristic sensory profile and functional potential, poorly characterized, produced from the spontaneous fermentation of the fruit peel (Sarmiento et al., 2022; Silva, 2023; Leite, 2022). Recent studies indicate that fermented beverages based on agro-industrial waste can represent a promising alternative for the development of sustainable foods, aligning technological innovation, valorization of by-products, and health promotion (Galanakis, 2012; Marco et al., 2017).

### **3 METHODOLOGY**

#### **3.1 ELABORATION OF THE FERMENTED DRINK**

The process of making the fermented drink using pineapple peels was carried out according to Leite (2022), with some modifications. To make the syrup, 145g of granulated sugar and 1.5L of filtered water were mixed and boiled for 15 minutes. It was then cooled to room temperature. The pineapple was washed with a neutral detergent and with the aid of a brush, and the fruit was disinfected by immersing the fruit in a 200 ppm solution for 15 minutes. Then, the fruit was peeled manually, the peels along with the ginger, cloves and cinnamon were placed inside a previously washed and disinfected glass. Next, the syrup was added on top of the shells so that they were fully immersed. The container was closed with the lid, wrapped with aluminum foil and taken to the greenhouse (Ethik) at 30°C for 48 hours. After this period, the contents of the glass were sieved and the liquid transferred to plastic bottles. The bottles were kneaded manually to expel their internal air, favoring anaerobic fermentation in the following 48 hours of fermentation in the oven at 30°C. After this process, the fermented pineapple peel beverage was stored in the refrigerator until microbiological and sensory analyses were carried out (2.5 hours). The ginger was sanitized by immersion for 10 minutes in a solution of 0.3% alcohol vinegar. The glass and all the utensils used were washed with detergent and disinfected by immersion for 15 minutes in sodium hypochlorite solution (200 ppm).

#### **3.2 PHYSICO-CHEMICAL EVALUATION OF FERMENTED BEVERAGE**

The evaluation of pH and °Brix was carried out according to the physicochemical methods for food analysis of the Adolfo Lutz Institute (2008). pH and °Brix were measured in 12-hour periods, in triplicate. These two values were used to calculate the daily average.

### 3.3 MICROBIOLOGICAL EVALUATION OF THE BEVERAGE

All microbiological analyses were performed on the 10 replicates of the fermented beverage and all analyses were performed in duplicate. The analyses for lactic acid bacteria, coliforms at 35° C, coliforms at 45° C, *Salmonella* sp., Standard Count for heterotrophic anaerobic microorganisms mesophilic and molds and yeasts were carried out following the methodology of the Manual of methods of microbiological analysis of food and water by Silva et al., (2017).

### 3.4 SENSORY ANALYSIS

To perform the acceptance test, 60 untrained tasters were randomly recruited. For this, each taster received two samples of 25 ml each, the fermented pineapple drink and a commercial product called kombucha. The two samples were served in disposable cups coded with three-digit random numbers and submitted to sensory evaluation of the attributes: taste, color, appearance and global evaluation, using a structured nine-point hedonic scale where "1-disliked extremely", "2-disliked very much", "3-disliked moderately", "4-disliked slightly", "5-disliked/disliked", "6-liked slightly", "7-liked moderately", "8-liked it very much" and "9-liked it very much". The two samples were also evaluated, by the same tasters, regarding purchase intention using the structured scale where "1-certainly would not buy the product", "2- possibly would not buy the product", "3- maybe would buy / maybe not buy", "4-possibly buy the product" and "5-certainly buy the product" (MINIM, 2010; MEILGAARD et al., 2006). The sensory evaluation test was approved by the Research Ethics Committee (REC) under Protocol 5.922.453.

### 3.5 EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS

10 replicas of the fermentation of pineapple peels were prepared to carry out all microbiological and physicochemical analyses. The results of pH, °Brix, sensory acceptance and purchase intention were submitted to Tukey's test at 5% significance, and statistically evaluated through Analysis of Variance (ANOVA), using the Past program (Hammer, Ø; et al , 2001).

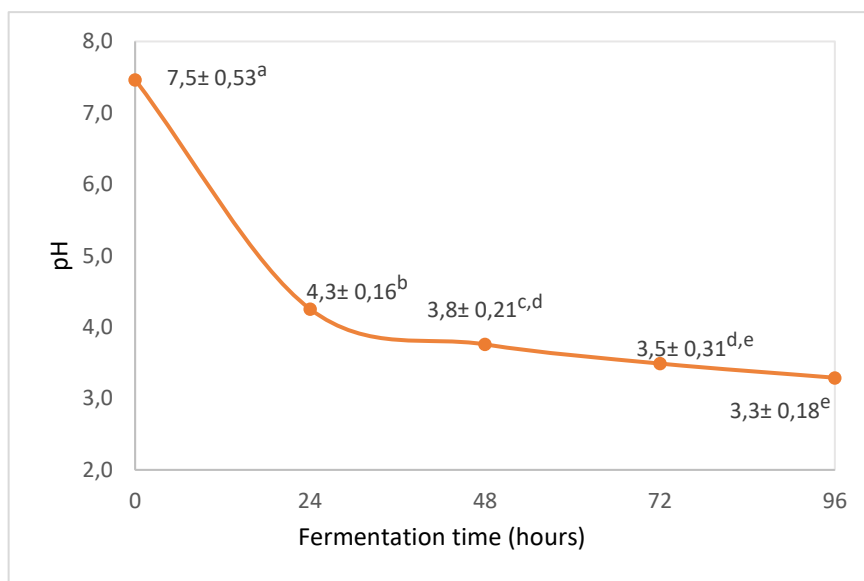
## 4 RESULTS AND DISCUSSIONS

### 4.1 PHYSICOCHEMICAL CHARACTERIZATION

Figures 1 and 2 show the mean values accompanied by their respective standard deviations for the pH and °Brix parameters.

**Figure 1**

Variation in pH during fermentation of the drink made from pineapple peel over 4 days. The values represent mean  $\pm$  standard deviation ( $n = X$ ). Means followed by the same letter did not differ significantly from each other by Tukey's test ( $p > 0.05$ ).



Source: prepared by the authors.

The results show a reduction in pH and total soluble solids ( $^{\circ}$ Brix) throughout fermentation, indicating microbial metabolic activity. The pH decreased from  $7.5 \pm 0.53$  to  $3.3 \pm 0.18$  in 96 hours (Figure 1), with statistically significant differences between the times ( $p < 0.05$ ) from 0 to 48 hours. This acidification is associated with the production of organic acids, especially lactic acid, from the consumption of sugars by lactic acid bacteria and yeasts, evidencing the action of microorganisms such as *Lactobacillus* (Machado, 2020). Similar values were reported by Leite (2022), who observed pH lower than 4 after 48 h of fermentation in pineapple by-product beverages.

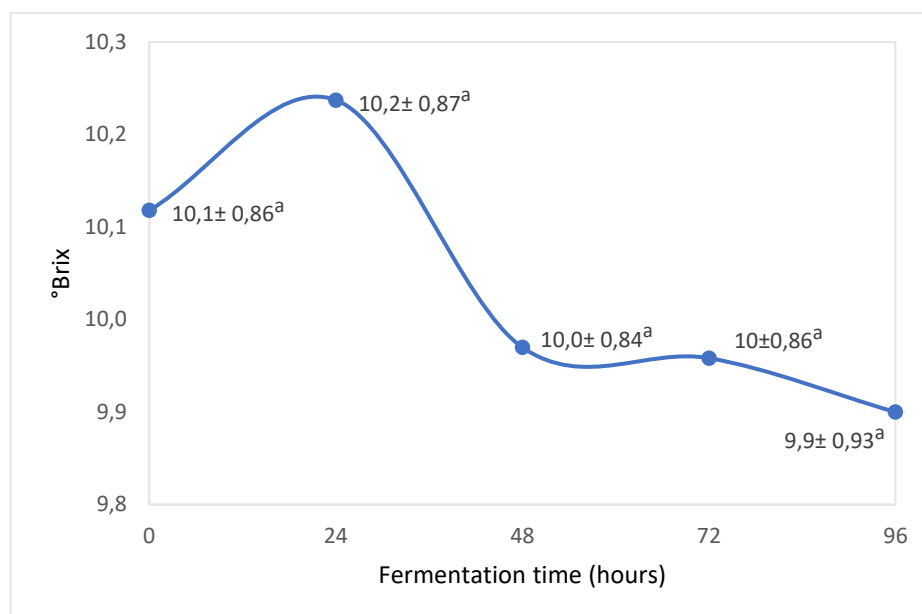
There was no statistically significant difference ( $p > 0.05$ ) between the  $^{\circ}$ Brix values, although a trend of reduction from  $10.1 \pm 0.86$  to  $9.9 \pm 0.93$  was observed at the end of the process (Figure 2), indicating the consumption of fermentable sugars. Similar results were reported by Sarmiento, et al., (2022), who observed a reduction to  $9.5$   $^{\circ}$ Brix after 72 h in tepache fermentation. The slight initial increase in  $^{\circ}$ Brix ( $10.2 \pm 0.87$  on the first day) may be associated with the release of soluble compounds from the substrate matrix in the initial stages of fermentation, before the predominance of microbial consumption.

In general, the significant reduction in pH associated with the tendency to decrease  $^{\circ}$ Brix confirms the occurrence of the fermentation process, and these parameters are influenced by the processing conditions (Leite, 2022) and widely used as indicators of microbial activity in fermented beverages, in addition to reflecting the production of

compounds of technological interest, such as organic acids and antimicrobial substances (Freire et al., 2021).

## Figure 2

Variation of soluble solids ( $^{\circ}$ Brix) during fermentation of the drink made from pineapple peel over 4 days. The values represent mean  $\pm$  standard deviation ( $n = X$ ). Means followed by the same letter did not differ significantly from each other by Tukey's test ( $p > 0.05$ ).



Source: prepared by the authors.

## 4.2 MICROBIOLOGICAL ANALYSES

The samples obtained after 96 hours of fermentation were submitted to microbiological analyses in order to determine the lactic acid bacteria count and to evaluate the hygienic quality of the spontaneously fermented beverage, through the quantification of indicator microorganisms as shown in Table 1.

**Table 1**

*Standard plate count of molds and yeasts, lactobacilli, facultative aerobic heterotrophs and Most Probable Number (MPN) for total coliforms of the fermented beverage made with pineapple peels*

Sample	Molds and yeasts (CFU/ml)	Lactobacilli (CFU/ml)	Facultative aerobic heterotrophs (CFU/ml)	Total coliforms (MPN/ml)
1	2.9·10 <sup>5</sup> ±5.95·10 <sup>6</sup>	1.0·10 <sup>6</sup> ±1.64·10 <sup>9</sup>	3.93·10 <sup>4</sup> ±3.95·10 <sup>5</sup>	<3
2	1.78·10 <sup>6</sup> ±5.95·10 <sup>6</sup>	1.57·10 <sup>9</sup> ±1.64·10 <sup>9</sup>	9.50·10 <sup>5</sup> ±3.95·10 <sup>5</sup>	<3
3	1.13·10 <sup>6</sup> ±5.95·10 <sup>6</sup>	6.1·10 <sup>8</sup> ±1.64·10 <sup>9</sup>	5.30·10 <sup>4</sup> ±3.95·10 <sup>5</sup>	<3
4	1.92·10 <sup>6</sup> ±5.95·10 <sup>6</sup>	7.16·10 <sup>5</sup> ±1.64·10 <sup>9</sup>	2.37·10 <sup>3</sup> ±3.95·10 <sup>5</sup>	<3

5	1.28·107±5.95·106	5.12·109±1.64·109	3.44·105±3.95·105	<3
6	8.45·104±5.95·106	6.52·106±1.64·109	4.30·103±3.95·105	<3
7	6.0·105±5.95·106	2.47·108±1.64·109	6.05·105±3.95·105	<3
8	1.0·106±5.95·106	2.12·107±1.64·109	2.26·105±3.95·105	<3
9	1.46·107±5.95·106	2.14·108±1.64·109	1.0·106±3.95·105	<3
10	1.0·106±5.95·106	4.96·108±1.64·109	2.36·103±3.95·105	<3
<b>Average</b>	4,15·106	9,28·108	3,23·105	<3

Source: prepared by the authors.

It is important to note that there is no specific category in Brazilian legislation that establishes microbiological standards for fermented beverages made from pineapple peels. Thus, the category of "juices and other beverages submitted to technological processes for microbial reduction that require refrigeration" was adopted as a reference, according to Normative Instruction No. 60, of December 23, 2019, of the National Health Surveillance Agency (ANVISA). For this category, the maximum limit established for molds and yeasts is  $10^2$  CFU/mL. In the present study, the mean observed was  $4.15 \times 10^8$  CFU/mL, which is higher than the established limit. However, this extrapolation should be interpreted with caution, since yeasts are directly associated with the fermentation process, being able to develop in an acidic environment, a typical characteristic of acidophilic microorganisms. In this context, Aguilar (2022) highlights that *Saccharomyces cerevisiae* is one of the predominant yeasts in beverages such as tepache, contributing to its properties through the production of ethanol and  $\text{CO}_2$ .

Regarding the facultative aerobic heterotrophic microorganisms, the samples presented an average of  $3.23 \times 10^5$  CFU/mL. According to Silva et al. (2017), the mesophilic microorganism count is widely used as an indicator of raw material quality and hygienic-sanitary conditions during food production and preservation. However, in the present study, the interpretation of this parameter should be relativized, considering that yeasts also developed in this culture medium. Thus, this count was associated with the fermentative microbiota, and was not considered in isolation as an indication of hygienic quality.

The results for total coliforms and coliforms at 45 °C were lower than 3 MPN/mL in all samples, indicating the absence of these microorganisms. These parameters are widely recognized as indicators of fecal contamination and inadequate hygienic-sanitary conditions (Silva; Almeida; Baratela-Simm, 2017). Thus, the results obtained reinforce that the production process of the beverage took place under adequate hygienic-sanitary conditions, in accordance with the current legislation.

The lactic acid bacteria count showed an average of  $9.28 \times 10^8$  CFU/mL, showing high fermentative activity. According to Reis et al. (2021), foods with a probiotic claim should have concentrations between  $10^8$  and  $10^9$  CFU/mL of viable microorganisms. Although the values observed fall within this range, the lack of identification of the species and strains of lactic

acid bacteria prevents the attribution of probiotic properties to the drink, limiting this interpretation.

Lactic acid bacteria play a central role in the fermentation process, being able to inhibit the growth of undesirable microorganisms through the production of organic acids, hydrogen peroxide, alcohols, and other antimicrobial compounds (Silva, et al., 2020). Additionally, its action by homofermentative pathways, with the production of lactic acid and consequent reduction of pH, contributes both to the preservation of the food and to the improvement of sensory characteristics, such as flavor, aroma, and texture (Rodrigues, 2022).

Finally, it is noteworthy that the beverage was not subjected to heat treatment, which, on the one hand, preserves the microbiota present, but, on the other hand, requires the adoption of complementary conservation methods. In this sense, refrigeration plays a fundamental role in slowing microbial growth and controlling the advance of the fermentation process, contributing to the stability of the product (Granada; Zambiasi; Mendonça, 2004; Câmara, 2022).

#### 4.3 SENSORY ANALYSIS

The results of the sensory evaluation and purchase intention are presented in Table 2 and in Figures 3, 4 and 5. A significant difference ( $p < 0.05$ ) was observed between the samples for the attributes flavor, global evaluation and purchase intention, and the fermented beverage made with pineapple peels presented higher averages in these parameters.

**Table 2**

*Sensory analysis and purchase intention of fermented beverage with pineapple peel and pineapple-flavored kombucha*

Attribute	Sample of fermented beverages	
	Drink made with pineapple peels	Kombucha
Flavor	5.85a	4.42b
Color	6.5a	6.8a
Appearance	6.48a	6.72a
Overall assessment	6.0A	5.0b
Purchase intention	2.93a	2.2b

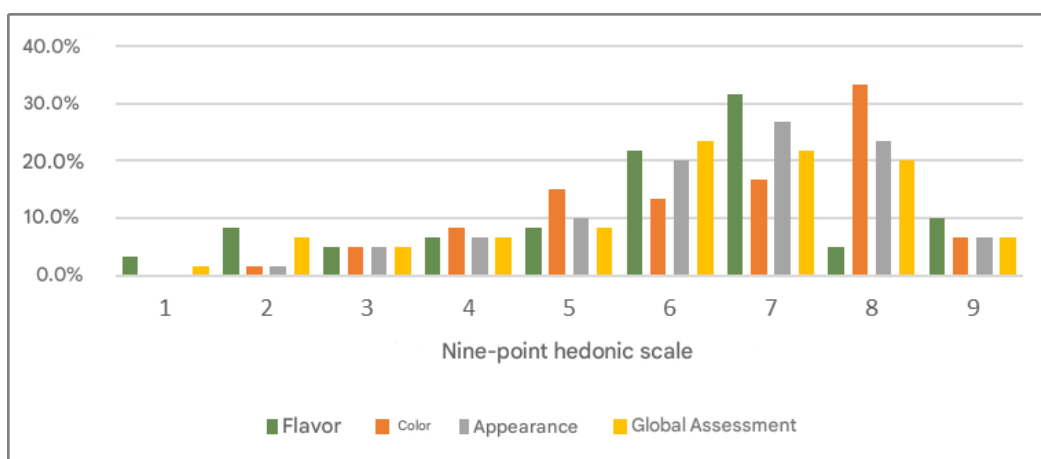
<sup>a,b</sup>. Means with the same letter do not present a significant difference ( $p < 0.05$ ).

Source: prepared by the authors

Although the score attributed to the flavor attribute was lower than 6 (I liked it slightly), the overall evaluation of the beverage developed in this study showed an average of 6, being in the acceptance range (Figure 3). This result suggests that, despite specific limitations in flavor, the overall perception of the product was positive, indicating potential for consumer acceptance.

**Figure 3**

*Percentage of scores per attribute for the fermented beverage sample*



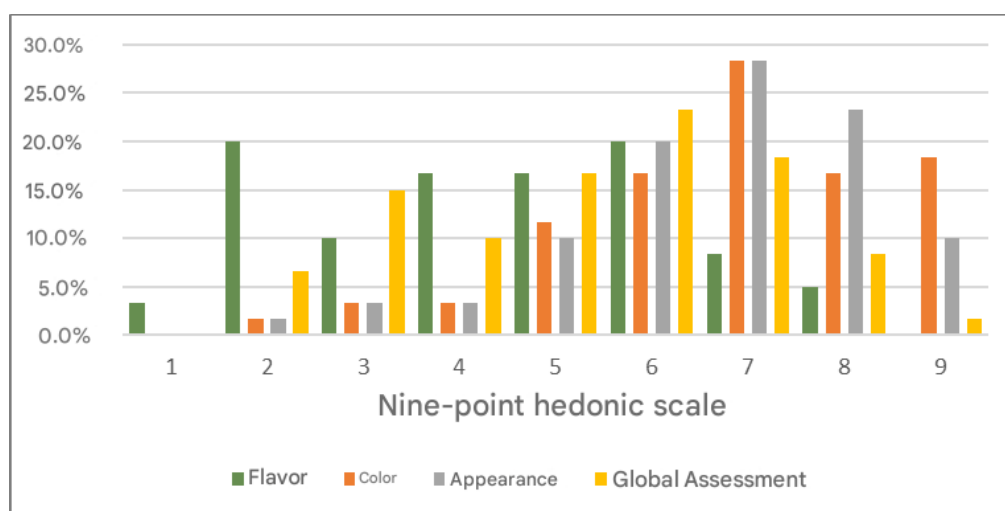
Hedonic scale: "1- I disliked it extremely", "2-I disliked it a lot", "3-I disliked it moderately", "4-I disliked it slightly", "5-I didn't like it/I didn't like it a lot", "6-I liked it slightly", "7-I liked it moderately", "8-I liked it a lot" and "9-I liked it very much".

Source: prepared by the authors.

For kombucha (Figure 4), it was observed that the color and appearance attributes concentrated 28.33% of the evaluations in "I liked it moderately", while the flavor attribute presented 20% of the answers in "I disliked it very much". In general, the sum of scores higher than 6 ranged between 13% and 63.3%, indicating greater variability in the sensory perception of this sample.

**Figure 4**

*Percentage of scores per attribute for the pineapple-flavored kombucha sample*



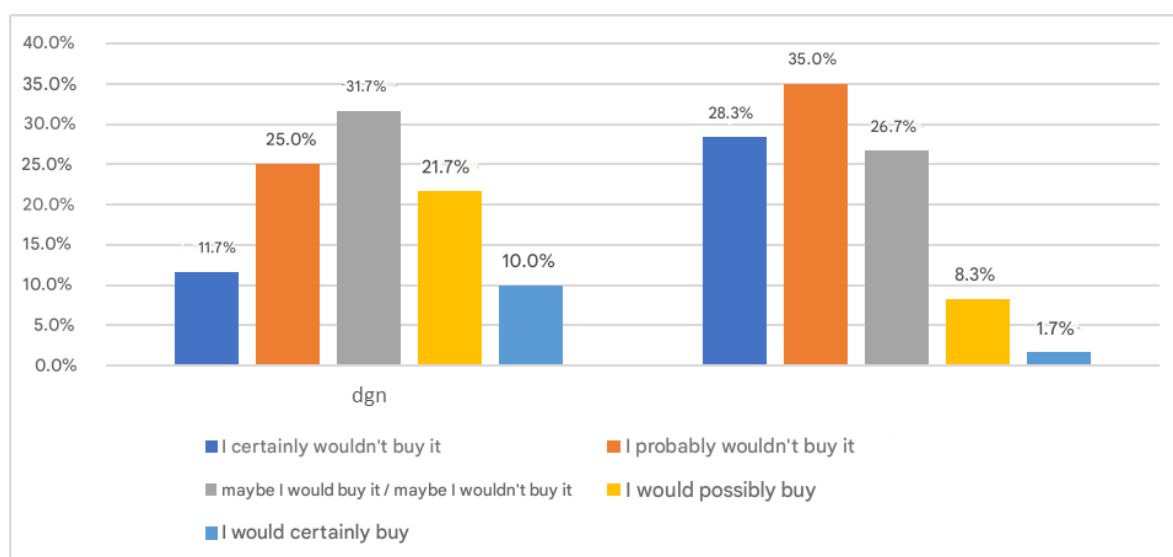
Hedonic scale: "1- I disliked it extremely", "2-I disliked it a lot", "3-I disliked it moderately", "4-I disliked it slightly", "5-I didn't like it/I didn't like it a lot", "6-I liked it slightly", "7-I liked it moderately", "8-I liked it a lot" and "9-I liked it very much".

Source: prepared by the authors.

The intention to purchase (Figure 5) showed that 31.67% of the tasters showed indecision regarding the purchase of fermented beverages made with pineapple peels. On the other hand, 35% of the evaluators indicated that they "would not possibly buy" kombucha. Although both samples showed low purchase intention, the beverage developed in this study showed superior performance, since 21.67% of the tasters indicated that they would "possibly buy" the product, while only 8.33% attributed this same evaluation to kombucha.

**Figure 5**

*Percentage of scores per attribute for the fermented beverage sample*



Source: prepared by the authors.

**It is possible that the limited familiarity of the tasters with this type of product influenced sensory perception.** Recorded observations, such as "I liked the sample of fermented beverage, it presented a citrus and gaseous flavor, very good" and "very tasty, sweet in the right measure, refreshing", indicate acceptance of typical sensory characteristics. On the other hand, comments such as "the drink had an acidic taste" and "I found the drink a little acidic", although pointed out as negative aspects, correspond to characteristics inherent to fermented beverages. Thus, it is likely that this factor has negatively influenced the results of acceptance and purchase intention.

## 5 CONCLUSION

It was possible to obtain a fermented beverage from pineapple peels with satisfactory hygienic-sanitary quality, evidenced by the absence of indicator microorganisms and the presence of lactic acid bacteria in concentrations of the order of  $10^8$  to  $10^9$  CFU/mL.

The beverage prepared in this study showed a significant difference ( $p < 0.05$ ) in relation to the commercial product kombucha in the attributes flavor, global evaluation and purchase intention, with averages of 5.85; 6.0 and 2.03, respectively, indicating better performance in these parameters.

Despite this, the intention to buy was considered low, since the largest portion of the tasters showed indecision about the purchase of the product, while a smaller proportion indicated the possibility of buying, although at a higher frequency than that observed for kombucha.

In this way, future studies can deepen the sensory evaluation and the intention to purchase the drink, in order to better understand its acceptance. In addition, future studies are needed to identify the species and strains of lactic acid bacteria present in the drink, enabling the evaluation of its probiotic potential.

Finally, the results obtained show the potential of using pineapple peels in the elaboration of fermented beverages, contributing to the valorization of agro-industrial residues and to the reduction of environmental impacts

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