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Beverage of mate tea (*Ilex paraguariensis*) with pitanga (*Eugenia uniflora*) for enhanced sensory and nutritional benefits

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ABSTRACT

A novel beverage combining mate tea (Ilex paraguariensis) and pitanga pulp (Eugenia uniflora), a native Brazilian fruit, was developed to highlight local ingredients and create a healthy food product. Four formulations with varying proportions of mate tea and pitanga pulp were evaluated (F1: 100% mate tea, F2: 90% mate + 10% pitanga, F3: 80% mate + 20% pitanga, F4: 70% mate + 30% pitanga). Physicochemical, sensory, and color analyses were conducted, including parameters such as L*, a*, b*, Hue, chroma (C*), total phenolic content (TPC), and antioxidant capacity (TEAC). The addition of pitanga significantly altered the beverage's color, making it darker and redder, and enhanced sensory attributes by reducing bitterness and astringency. Formulation F2 achieved the highest sensory acceptance, offering a balanced flavor profile. While F1 had the highest TPC and TEAC values, pitanga addition slightly decreased these metrics without compromising the beverage's antioxidant properties. Principal Component Analysis (PCA) revealed that sensory acceptance strongly correlated with flavor and sweetness, while physicochemical attributes such as antioxidant capacity had limited influence. The combination of mate tea and pitanga pulp provides an innovative, functional beverage with a sustainable profile, balancing health benefits and consumer preferences, particularly in the F2 formulation.

Keywords: Yerba mate, Bioactive compounds, Antioxidant capacity, Native fruits, Sustainable innovation.

INTRODUCTION

Yerba mate (*Ilex paraguariensis*), a species of the *Aquifoliaceae* family, is a crop of fundamental historical and economic importance in southern Brazil and South America, where it is regarded as a cultural and economic icon.[1] An infusion prepared from its leaves, young branches, and occasionally stems provides a unique flavor and a diverse range of bioactive compounds associated with numerous health benefits.[2-5] Recent studies have emphasized the potential of different mate genotypes to enhance the quality of derived products.[6] The primary bioactive compounds in mate tea include polyphenols – such as chlorogenic acids, phenolic acids, and flavonoids –methylxanthines (caffeine, theobromine, and theophylline), and saponins.[4,7,8] These compounds are responsible for the beverage's antioxidant, anti-inflammatory, and stimulant properties.

Phenolic compounds and antioxidants are widely recognized for mitigating oxidative stress and conferring protection to organs such as the heart and liver.[9,11] Mate tea demonstrates cardioprotective properties, including the improvement of lipid profiles and vascular function, as well as the prevention of ischemia/reperfusion injury in ex vivo heart models, thereby reducing the risk of cardiovascular diseases.[12,13] Additional benefits involve body weight management and blood glucose regulation, with studies indicating a positive modulation of gut microbiota that supports digestive health.[14] The caffeine and other methylxanthines present in mate tea act as central nervous system stimulants and exhibit diuretic effects, promoting fluid elimination.[15-17]

The growing consumer demand for healthy alternatives has driven the development of ready-to-drink beverages based on mate tea, including blends with fruits.[18,19] The food industry continues to innovate in this expanding market segment by exploring novel formulations and processing technologies designed to preserve the sensory qualities and bioactive properties of mate tea.[20,21]

Native fruits from the Atlantic Forest represent promising ingredients for mate tea-based beverage formulations, owing to their distinctive nutritional and sensory profiles, which have attracted growing research and commercial interest. While many of these fruits are still harvested from wild populations, rising consumer awareness regarding the health benefits of diets rich in fruits and their derivatives, such as juices and herbal infusions, is stimulating market demand.[22,23]

As the world's third-largest fruit producer, with an annual output of 39.9 million tons, Brazil possesses remarkable biodiversity that includes numerous underutilized native species.[24,25] A notable example is Pitanga (*Eugenia uniflora* L.), a fruit characterized by its sweet-sour flavor and aromatic pulp, consumed fresh or processed into products such as jellies and liqueurs. Pitanga is a rich source of vitamins A and C, minerals, and bioactive compounds including phenolic acids and flavonoids. These components confer significant antioxidant and anti-inflammatory properties, which may contribute to the prevention of chronic diseases.[26-28]

The incorporation of Pitanga pulp into food processes, such as drying or blending with cold mate tea-based beverages, represents a promising strategy for developing sensorially appealing and functional products.[21,29] This approach responds to the growing consumer demand for natural, minimally processed foods, including both fermented and non-fermented beverages, organic products, and other sustainable alternatives. Utilizing native fruits in beverage formulations enhances the valorization of Brazilian biodiversity while meeting these evolving market trends. These efforts are consistent with agroecological cultivation systems that prioritize environmental preservation.[30]

Therefore, this study aimed to develop and characterize a cold-infused mate tea beverage blended with Pitanga pulp. The objective was to promote the use of local agricultural products and encourage the consumption of healthy ingredients, thereby contributing to more balanced and sustainable dietary patterns.

MATERIALS AND METHODS

To prepare the mate tea beverages, yerba mate (*Ilex paraguariensis*) aged for six months and toasted was used to create the infusions, utilizing Guayakí Yerba Mate® brand leaves. The aging and toasting process followed quality standards established by the company (details proprietary). The samples were provided by the company itself (study partner). Pitanga pulp (*Eugenia uniflora*) was extracted from ripe fruits collected at the teaching orchard of UTFPR – Campus Dois Vizinhos. The fruits were washed under running water, sanitized with a sodium hypochlorite solution (200 mg L-1) for 15 minutes, and rinsed with potable water to remove residual sanitizer. The pulp was separated using an automatic depulper, resulting in a homogeneous pulp ready for beverage formulation. Was used a Industrial Fruit Pulper, model DES-60/1 Bivolt, from the Braesi brand.

Infusion and Formulation

Mate tea was prepared by infusing 6 grams of leaves in 100 mL of filtered potable water at 100°C for 15 minutes. After filtration through filter paper, fruit pulp was added according to the experimental design (Table 1). Was homogenized with a mixer before bottling. The beverages were hot-filled into glass bottles and refrigerated at 4°C for subsequent physicochemical and sensory analyses, conducted one week after processing.

Experimental Design

The experimental design included four formulations based on pre-tests that limited the proportion of fruit pulp to a maximum of 30%. A simple mixture design was employed (Table 1). The experiment was conducted with three independent replications per treatment (formulation). Measurements for all parameters – including physicochemical properties, color, phenolic content, and antioxidant capacity – were performed in triplicate.

Table 1. Experimental design based on proportions of mate tea and Pitanga pulp

Ingredients	Formulation (100 mL)			
	F1	F2	F3	F4
Pitanga Pulp	0	10	20	30
Mate tea	100	90	80	70

Physicochemical Analyses

The beverages were evaluated for physicochemical characteristics, including pH, total acidity (% acidity), and soluble solids (°Brix), following methods described by AOAC.[31] Instrumental color analysis was conducted using a colorimeter (Minolta CR-300). Parameters L*, a*, and b* were used to calculate Hue angle, chroma (C*), and total color difference (ΔE) using Equations, Eq. (1), (2) and (3). A color estimation (prospection) of the infusions was performed using color analysis software (*Research Lab tools*), utilizing L*, a*, and b* indices.

$$Hue = \tan^{-1}\left(\frac{b*}{a*}\right) \tag{1}$$

$$C* = \sqrt{a*^2 + b*^2} \tag{2}$$

$$\Delta E = \sqrt{(\Delta L*)^2 + (\Delta a*)^2 \ (\Delta b*)^2} \tag{3}$$

Total Phenolic Compounds

Total phenolic content was determined using a spectrophotometric method at 765 nm, measuring the reduction of Folin-Ciocalteu reagent.[32] A standard curve was prepared with gallic acid concentrations ranging from 50 to 500 mg L-1. Results were expressed using the standard curve equation in mg gallic acid equivalent (GAE) per 100 mL of beverage.

Antioxidant Activity

Antioxidant capacity was determined by reducing the stable DPPH radical, according to Brand-Williams et al.[33] Absorbance was measured at 517 nm before (A_0) and after 30 minutes of reaction (A_x). Results were expressed as TEAC µmol Trolox equivalent per mL of sample.

Sensory Analysis

Sensory evaluation was conducted after project approval by the UTFPR Ethics Committee for Research Involving Humans (CAAE 70057723.1.0000.0177). Samples underwent microbiological analysis to ensure safety, including mold and yeast counts and the absence of pathogens like Salmonella spp. and Escherichia coli. All samples were within safety limits and suitable for consumption.

To evaluate the acceptance of the mate tea beverage (*Ilex paraguariensis*) with Pitanga by the consumers, affective methods of preference were applied for the attributes Global Appearance, color, flavor, acidity, bitterness, astringency and order of preference. The hedonic scale of 9 points was used, starting with: I liked it very much (9) and disliked it very much (1). In the "ordering of preference" test, the panelists placed the formulations in a ranking from 1 to 4. The panel consisted of 71 untrained volunteers (approximately 50% male and 50% female), aged 20 to 50 years. All participants signed a free and informed consent form (FICF) according to Resolution 466/2012 of the Brazilian Ministry of Health.[34]

Data Analysis

Statistical analysis of the data was performed using Analysis of Variance (ANOVA), and the results were subjected to Tukey's test with a reliability of ≥ 95%. Principal Component Analysis (PCA) was conducted to evaluate the set of correlated and uncorrelated variables among the formulations, sensory analysis attributes, and physicochemical properties.[35]

RESULTS AND DISCUSSION

The incorporation of Pitanga pulp into the mate tea beverage significantly decreased the pH and increased the soluble solids content (°Brix) in a concentration-dependent manner (Table 2). These alterations are directly attributable to the intrinsic physicochemical properties of the pulp, which is characterized by high titratable acidity (mean of 1.2% in this study) and a moderate soluble solids content (10.2 °Brix). These values are consistent with both the authors' previous data and literature reports,[36-38] confirming that the observed changes result from the fruit component incorporation.

The modified physicochemical parameters positively influence the beverage's microbiological stability and potential consumer acceptance, as the balance between sweetness and acidity can enhance its appeal to consumers who prefer complex, refreshing flavor profiles.[36,39,40] Optimization of the final beverage formulation requires aligning instrumental analyses (acidity, °Brix, pH) with sensory evaluation to establish an optimal balance between chemical properties and consumer preference.

Addition of Pitanga pulp also significantly altered the beverage's color profile (Table 2), enhancing its visual appeal. Changes in color parameters, particularly decreased lightness (L) and increased redness (a), indicated a shift toward darker, redder tones characteristic of Pitanga's vibrant pigmentation.[36,41,42] The reduction in b* values (yellowness) further confirmed this shift toward red dominance. modifications in hue and chroma (C*) values reflected changes in tonality and color saturation.

These color alterations were expected, as Pitanga is known for its pronounced pigmentation, which correlates with its chemical composition and flavor profile, including higher antioxidant activity and perceived sweetness.[43] The use of natural colorants like Pitanga improves visual characteristics while simultaneously influencing flavor perception and consumer preference.

Table 2. Physicochemical variables and instrumental color of mate tea added with Pitanga (*Eugenia uniflora*)

Variables	F1	F2	F3	F4
Physicochemical				
pH	5.23a	4.43b	4.21bc	3.96c
TA	3.07c	5.40b	6.67a	7.33a
SS	2.47d	3.13c	3.83b	4.60a
Instrumental color				
L	33.84a	25.71c	28.88b	30.02b
a*	8.36d	17.34c	22.09b	24.84a
b*	19.33a	5.36d	9.16c	10.82b
Hue	66.60a	17.15c	22.52b	23.54b
C*	21.06c	18.15d	23.91b	27.10a

F1= 100% YM; F2= 90% YM +10% PIT; F3= 80% YM +20% PIT; F4= 70% YM +30% PIT. TA- Total acidity (%); SS-Solubles sólides (°Brix). Mean values in the same line followed by different letters indicate significant differences according to Tukey's test ($p < 0.05$).

The incorporation of Pitanga pulp enhanced the sensory profile of the mate tea beverage by modulating acidity and sweetness, while also imparting a visually appealing color, which may collectively improve overall sensory acceptance. The addition of fruits rich in bioactive compounds, such as Pitanga, represents a viable strategy to improve the nutritional and antioxidant quality of tea-based beverages.[44,45]

Formulation F1 (100% mate tea) exhibited the highest total phenolic content (TPC), with a progressive reduction observed as Pitanga pulp was added ($p < 0.05$) (Table 3). Antioxidant capacity (TEAC) values followed a similar trend, with F1 showing the highest activity. Formulation F3 presented significantly lower TEAC (3.54 µM TEAC/mL), while F2 (3.75 µM TEAC/mL) and F4 (3.81 µmol TEAC/mL) did not differ significantly from F1. These results indicate that although Pitanga addition modestly reduces phenolic content and antioxidant capacity, the resulting beverages retain considerable antioxidant properties.

Table 3. Phenolic compound (TPC) and content and antioxidant capacity (TEAC) of mate tea added with Pitanga

Variables	F1	F2	F3	F4
TPC	596.98a	580.16ab	569.88ab	568.63b
TEAC	4.06a	3.75ab	3.54b	3.81ab

F1= 100% YM; F2= 90% YM +10% PIT; F3= 80% YM +20% PIT; F4= 70% YM +30% PIT; TPC: mg gallic acid equivalent (GAE) /100 mL; TEAC: µM Trolox equivalent (TEAC) /mL. Mean values in the same line followed by different letters indicate significant differences according to Tukey's test ($p < 0.05$).

Mate tea is notably rich in phenolic compounds, particularly chlorogenic acid and flavonoids, which contribute to its strong antioxidant activity.[5,46] Similarly, Pitanga contains bioactive compounds including phenolics and carotenoids, which exhibit health-promoting properties such as antioxidant and anti-inflammatory effects, though their concentrations vary depending on fruit maturity and origin.[47,48] Typical TPC values for mate tea range from 295 to 550 mg GAE/100 mL, with TEAC values between 300-400 μmol TE/100 mL, depending on preparation conditions.[9,49,50] Data from the authors' previous studies confirm that the raw material used herein falls within the upper end of this range, underscoring its high antioxidant potential. The concentration of these bioactive compounds correlates with mate tea's demonstrated ability to scavenge free radicals.[51-53]

Comparison with the literature confirms that formulation F1 yielded TPC and TEAC values in the upper reported range. Although Pitanga-containing formulations showed moderate reductions, their antioxidant profiles remained significant and comparable to other functional beverages. This preservation of bioactivity may be attributed to synergistic interactions between mate tea and Pitanga compounds.[47,54] Pitanga itself demonstrates moderate to high TPC (200–500 mg GAE/100 g) and TEAC (1.4–3.2 μmol TE/g) values, varying with maturity and growing region[36,55,56] The pulp used in this study exhibited values consistent with these literature ranges. It is noteworthy that certain health benefits associated with Pitanga, including anti-inflammatory effects, may compensate for slight reductions in antioxidant metrics, reflecting the complex interplay of its bioactive constituents.[56]

Sensory evaluation (Table 4) indicated significant differences among formulations in bitterness, flavor, and overall acceptance. Formulation F2 (90% mate tea + 10% Pitanga) received the highest scores for overall acceptance and flavor, establishing it as the most preferred product. In contrast, F1 received the lowest scores in these attributes, suggesting that the inclusion of Pitanga improves beverage palatability. Formulations F3 and F4, with higher pulp concentrations, also showed favorable acceptance, though they were less preferred than F2. Bitterness was perceived as lower in F2 and F3 compared to F1, which likely contributed to their enhanced acceptability.

Preference ranking of the mate tea formulations with Pitanga pulp corroborated the sensory acceptance results (Figure 1). Formulation F2 (90% mate tea + 10% Pitanga) was the most preferred among panelists. In contrast, F1 (100% mate tea) was the least preferred, with 52.11% of evaluations assigned the lowest preference score, confirming its reduced acceptability in terms of flavor and other sensory attributes. Formulation F4 (70% mate tea + 30% Pitanga) exhibited a broader distribution of scores, suggesting that while higher Pitanga content may mitigate the inherent bitterness of mate tea, it may not achieve an optimal flavor balance for most consumers. Formulation F3 (80% mate tea + 20% Pitanga) demonstrated moderate acceptance, receiving favorable ratings from 40.84% of participants at the third preference level.

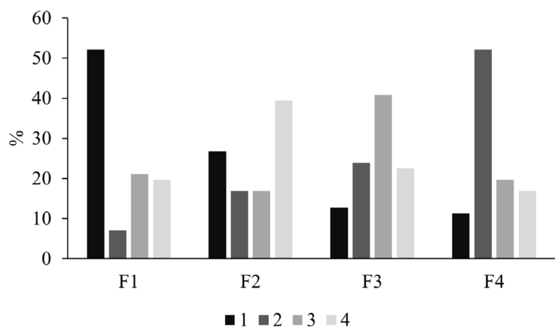

Figure 1. Order of preference in sensory evaluation results of mate tea added with Pitanga (*Eugenia uniflora*). F1= 100% YM; F2= 90% YM +10% PIT; F3= 80% YM +20% PIT; F4= 70% YM +30% PIT. Mean values expressed as a percentage in the order of preference. Ordering based on scores from least liked (1) to most liked (4).

Table 4. Sensory evaluation results (score) of mate tea with Pitanga (*Eugenia uniflora*)

Formulation	Astringency	Acidity	Bitterness	Flavor	Overall Acceptance
F1	4.55a	5.14a	4.24b	5.87b	4.65b
F2	5.41a	5.79a	5.75a	7.13a	5.76a
F3	5.17a	5.66a	5.30ab	7.01a	5.45ab
F4	4.62a	5.25a	4.93ab	5.68b	4.87b

F1= 100% YM; F2= 90% YM +10% PIT; F3= 80% YM +20% PIT; F4= 70% YM +30% PIT. Mean values in the same column followed by different letters indicate significant differences according to Tukey's test ($p < 0.05$).

Despite the significant increase in titratable acidity detected instrumentally, the panelists did not report perceptible differences in the sensory evaluation. This discrepancy can be attributed to three main factors: (i) the magnitude of the change may not have been sufficient to exceed the sensory detection threshold for acidity; (ii) other beverage attributes, such as the presence of bitter and astringent phenolic compounds from mate tea, may have masked the perception of acidity; and (iii) the natural sweetness from the soluble solids of the Pitanga pulp likely acted as a modulator, balancing the overall taste perception.

The improved sensory acceptance of mate tea beverages with Pitanga pulp may be attributed to reduced bitterness and enhanced flavor complexity, as supported by previous studies.(43) The incorporation of fruits into mate tea-based beverages can attenuate characteristic bitterness, thereby increasing palatability. The favorable flavor ratings of F2 and F3 align with research on fruit-added herbal infusions, where moderate fruit pulp concentrations generally yield higher sensory acceptance.(39)

The broader acceptance distribution of F4 may result from excessive acidity or excessive softening of the flavor profile, which may not appeal to all consumers. High fruit pulp concentrations can disrupt the sensory balance for certain consumer segments.(39,57) Thus, F2 appears to offer the optimal formulation for general acceptability, whereas F1, with its pronounced bitterness and unmodified flavor, was least preferred.

Principal Component Analysis (PCA) was performed to evaluate correlations between sensory and physicochemical variables across the different mate tea formulations with Pitanga (Figure 2). The first two principal components (PC1 and PC2) collectively explained 96.91% of the total variance, with PC1 accounting for 60.00% and PC2 for 30.91% of the variability.

The parameters of flavor and overall acceptance showed strong correlation and were positively grouped along PC1, indicating that formulations receiving high scores for these attributes were similarly rated for overall acceptability. Bitterness, astringency, and perceived acidity were also grouped in this region, though – as noted previously – they did not show significant differences among formulations ($p > 0.05$).

Color parameters (L* and hue) and bioactive compounds (antioxidant capacity and total phenolic content) were more closely associated with PC2, revealing a positive correlation among these variables. This suggests that formulations with higher phenolic content also possessed greater antioxidant activity, which is consistent with the known role of phenolic compounds as primary antioxidants. Soluble solids, titratable acidity, and the color parameters chroma (C*) and redness (a*) were associated with Pitanga pulp addition, indicating that although visual characteristics influenced product perception, their contribution to overall acceptance was less determinant than flavor-related attributes.(36,41) As anticipated, TEAC and TPC values were not directly correlated with the most appreciated sensory parameters (flavor and overall acceptance), as indicated by their distant positioning relative to these attributes in the PCA plot.

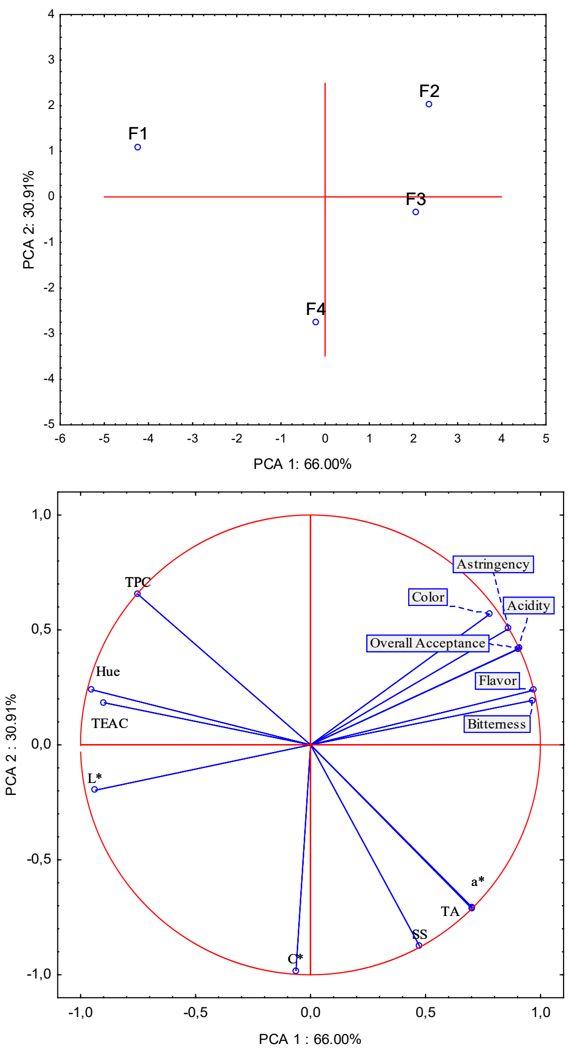

Figure 2. Principal component analysis (PCA) of compounds, physicochemical parameters, sensorial atributes and formulations in beverage Mate tea infused with Pitanga (*Eugenia uniflora*).

These findings align with prior results, where formulation F2 (90% mate tea + 10% Pitanga) was the most preferred, largely due to its smoother and more balanced flavor profile, accompanied by reduced bitterness and astringency.[58]

The PCA further underscores that overall acceptance was more strongly influenced by favorable flavor perception than by visual or physicochemical properties such as color or acidity.[59] In conclusion, the moderate incorporation of Pitanga pulp into mate tea significantly enhanced sensory acceptability by attenuating less desirable attributes like bitterness and astringency, while preserving visually appealing characteristics.[2]

CONCLUSION

The addition of Pitanga pulp to mate tea resulted in sensory improvements, particularly in overall acceptance and flavor, as demonstrated in formulations F2 (90% mate tea + 10% Pitanga) and F3 (80% mate tea + 20% Pitanga). Sensory analysis revealed that moderate Pitanga addition softens the flavor profile of mate tea without compromising desirable characteristics, such as acidity and pleasant taste, maintaining a balance between physicochemical and sensory attributes that favor consumer acceptance.

Principal Component Analysis (PCA) showed that variables such as flavor and overall acceptance positively correlated, while total phenolic content (TPC) and antioxidant capacity (TEAC) did not directly correlate with sensory acceptance, despite their high values. Thus, combining mate tea with Pitanga provided a beverage with a good balance between health benefits and sensory acceptance.

DATA AVAILABILITY STATEMENT

All datasets supporting the results of this study were used in this article.

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