Original Article
Food Science and Technology

ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.5327/fst.00390

Enhanced mate tea (*Ilex paraguariensis*): A novel blend with Brazilian native fruits (pitanga and jabuticaba) for health and flavor

Bruna Gomes das Virgens GOBBI[1], Sarah Nicolle Carvalho de LIMA[1], Natalia GATTO[1], Silvia Renata Machado COELHO[2], Naimara Vieira do PRADO[1], Américo WAGNER JÚNIOR[3], Luciano LUCCHETTA[1*]

Abstract

Mate tea (MT) (Ilex paraguariensis) can be consumed hot or cold, with the latter often enhanced with fruits, making it a popular choice for health-conscious consumers. This study aimed to develop a MT beverage combined with dehydrated pitanga (*Eugenia uniflora* L.) and jabuticaba (*Plinia trunciflora* O. Ber), both rich in nutrients. Different quantities of these fruits (up to 30%) were tested in combination with MT, analyzing parameters like total soluble solids (Brix), acidity, pH, color, total phenolic compounds, and tannins. The addition of jabuticaba and pitanga increased soluble solids, decreased pH, and raised acidity. Color changes were influenced by both fruits, with jabuticaba increasing luminosity. Although the standard MT had higher tannin and phenolic content, the addition of fruits still maintained significant levels of phenolic compounds, albeit reduced. Principal component analysis (PCA) highlighted MT's impact on phenolic composition, and overall, the addition of jabuticaba and pitanga improved the beverage's color and soluble solids content, despite a phenolic reduction.

Keywords: total phenolics; total tannins; color; Brazilian native fruits.

Practical Application: Yerba mate tea with native Brazilian fruits jabuticaba and pitanga, enriching its nutritional and sensory profile.

1 INTRODUCTION

Mate tea (MT) is made from the leaves of *Ilex paraguariensis*, a species native to South America and mainly grown in limited regions of Brazil, Paraguay, and Argentina. Following industrial processing, MT is commonly consumed through hot or cold infusion methods, known as "chimarrão," "chá-mate," and "tererê," respectively. Due to its rich chemical composition, comprising various organic and inorganic compounds, MT exhibits numerous bioactive components, particularly phenolics and flavonoids, which confer anti-inflammatory, antiviral, diuretic, and anticancer properties, thereby promoting human health (Bastos et al., 2007; Gerber et al., 2023).

Over the past decade, MT has emerged as the second most-consumed beverage globally, experiencing a 30% surge in consumption, trailing only water (da Silveira et al., 2017). This escalating consumption trend underscores a growing demand for formulations enriched with health-promoting properties (Heck & De Mejia, 2007; Vasconcellos et al., 2022). Innovative blends of teas, aimed at enhancing health and well-being, are becoming more popular, offering diverse flavors and medicinal attributes (Godoy et al., 2020; Valduga et al., 2019).

Similarly, phenolic compounds are abundant in various native Brazilian fruits, serving as vital sources of essential nutrients for human health (Brito et al., 2021; Mannino et al., 2020; Rodrigues et al., 2021). Among the Myrtaceae family, indigenous fruit-bearing plants boast an array of secondary compounds, known as bioactives. Jabuticaba (*Plinia trunciflora*) and pitanga (*Eugenia uniflora*) stand out among them, renowned for their delectable flavor profiles and high levels of phenolic compounds and antioxidant activity (Bagetti et al., 2011; Boger et al., 2022; de Lima et al., 2002; Migues et al., 2018; Munhoz et al., 2014; Pereira et al., 2018; Wagner Jr. et al., 2022). Flavonoids and anthocyanins, key constituents in these fruits, induce quinone reductase and demonstrate antigenotoxic and antimutagenic effects, concentration dependent, along with promising antitumor properties (Dametto et al., 2017; Düsman et al., 2017).

Pitanga is composed of 77% pulp, which is rich in carotenoids, flavonoids, and anthocyanins, as well as significant levels of calcium, phosphorus, and vitamin C, contributing to its potent antioxidant activity (de Lima et al., 2002; Paiva et al., 2023; Ramalho et al., 2019). Jabuticaba, with its medicinal potential, owing to its red and purple pigmentation, harbors phenolic

Received: Aug. 22, 2024.
Accepted: Sep. 9, 2024.
[1]*Universidade Tecnológica Federal do Paraná, Francisco Beltrão, PR, Brazil.*
[2]*Universidade Estadual do Oeste do Paraná, Francisco Beltrão, PR, Brazil.*
[3]*Universidade Tecnológica Federal do Paraná, Dois Vizinhos, PR, Brazil.*
*Corresponding author: lucchetta@utfpr.edu.br
Conflict of interest: nothing to declare.
Funding: Brazilian National Council for Scientific and Technological Development (CNPq).
Relevance of the work: We have developed a unique blend of mate tea infused with Jabuticaba and Pitanga, two underutilized yet nutritionally rich native Brazilian fruits. These fruits, often overlooked due to limited commercial exploitation, possess significant potential for enhancing both health benefits and flavor profiles in innovative food products.

compounds that aid in cancer prevention and other diseases (Brito et al., 2021; Mannino et al., 2020; Paiva et al., 2023; Rodrigues et al., 2021). Its peel is particularly rich in anthocyanins and fibers, which combat inflammation and oxidative stress and support gastrointestinal health.

Despite their nutritional richness, native Brazilian fruits like jabuticaba and pitanga face challenges in postharvest conservation, with a shelf life of merely 3–4 days. To capitalize on their nutritional benefits and address this limitation, there is a growing interest in developing healthy beverages offering unique flavors and forms. Leveraging the potential of MT, pitanga, and jabuticaba, this study aimed to formulate a beverage combining this infusion with these native Brazilian fruits.

Relevance of the work

We have developed a unique blend of mate tea infused with Jabuticaba and Pitanga, two underutilized yet nutritionally rich native Brazilian fruits. These fruits, often overlooked due to limited commercial exploitation, possess significant potential for enhancing both health benefits and flavor profiles in innovative food products.

2 MATERIALS AND METHODS

For this study, matured (6 months) and toasted MT (*Ilex paraguariensis*) were utilized in the infusion process (Guayaki Yerba Mate®), following a standardized procedure provided by the company (specific details restricted). The toasting and maturation processes adhere to a standardized raw material protocol for MT. Jabuticaba (JAB) (*Plinia trunciflora*) and pitanga (PIT) (*Eugenia uniflora* L.) fruits were sourced from the experimental orchard at the Universidade Tecnológica Federal do Paraná, Dois Vizinhos, Paraná, Brazil. Fruit harvesting was conducted at optimal ripeness.

The fruits were carefully selected, washed with running water, and sanitized in a sodium hypochlorite solution (200 ppm). For jabuticaba, only the peel was utilized, discarding other parts. Pitanga fruits were processed by removing the seeds. Subsequently, the jabuticaba peels and pitanga fruits without seeds underwent dehydration. Dehydration was carried out using a DAS dehydrator (Model DS800N) at a temperature of 50°C until the fruits reached an approximate moisture content of 10%. Following dehydration, the fruits were ground (particle size: 20–30 mesh), packed in plastic bags, and stored at -18°C until further use.

2.1 Experimental design

A mixture experimental design was employed, specifically the Design of Experiments for Limited Surface (STATSOFT INC, 2004), with the following variables: dehydrated jabuticaba peel and dehydrated pitanga pulp (Table 1). The standard infusion formulation used consisted of 100% matured and toasted MT. For formulations containing fruits, maximum quantities of up to 30% relative to the toasted MT were utilized. The minimum and maximum fruit limits were established in pretests as 0% and 30%, respectively.

For the preparation of the infusions (Table 1), 2 g of the formulation was utilized per 100 mL of filtered potable water at 100°C, steeped for 15 min. The beverages were then packed in hermetic plastic bottles and stored at 4°C for analysis.

2.2 Analysis of mate tea-based beverages

The beverages were assessed for physicochemical characteristics (percentage-based) through analyses of pH, total acidity, and soluble solids as per the methods described by the Adolfo Lutz Institute (IAL, 2008).

Instrumental color analysis was conducted using a colorimeter (Minolta CR-300). From the L*, a*, and b* parameters, the values of hue angle, chromaticity (C*), and total color difference (ΔE) were calculated using the provided Equations 1, 2, and 3. The color estimation (prospection) of the infusions was performed using color analysis software (Research Lab Tools), which employs the L*, a*, and b* indices. Also, a RGB color analysis was performed using the color analysis software (Research Lab Tools):

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

$$C* = \sqrt{a*^2 + b*^2} \quad (2)$$

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

Table 1. Mixture design for limited surfaces.

Formulations	Mixture design[a]				
	Original components (100%)			Pseudo components	
	Mate tea	X1	X2	X'1	X'2
Standard	100	0	0	-	-
F1	70	30	0	1	0
F2	70	22.5	7.5	0.75	0.25
F3**(C)	70	15	15	0.5	0.5
F4	70	7.5	22.5	0.25	0.75
F5	70	0	30	0	1

[a]X1 (jabuticaba – JAB)+X2 (pitanga – PIT) = 1 or 100%; C: Centroid; **Repetition; F: Formulation.

2.3 Analysis of bioactive compounds

The total phenolic content was determined using the Folin–Ciocalteu colorimetric method (Singleton et al., 1999). The results were expressed by the equation of the line derived from the calibration curve, in mg of gallic acid/100 g of fruit. The content of condensed tannins was determined using a methodology based on the reduction of the Folin–Dennis reagent (IAL, 2008). The reduction of the Folin–Dennis reagent in a basic medium by the tannins present in the sample produces an intense blue coloration, which is measured in the visible region with a spectrophotometer (760 nm). For the preparation of the standard curve, aliquots of 1–10 mL of standard tannic acid solution were pipetted into 100-mL volumetric flasks containing 75 mL of water. The reading was taken on the spectrophotometer at 760 nm. The result was expressed in tannic acid mg/L.

The methodology for determining individual phenolic compounds was adapted from Medic et al. (2021). The analysis was conducted using a high-performance liquid chromatography (HPLC) system, Thermo Scientific brand, Ultimate 3000 model, with a ultraviolet/visible (UV/VIS) detector. The column employed for phenolic compound separation was Promosil C18 5 μm (250×4.6 mm), operated at 25°C. The solvents used were as follows: Solvent A: water–0.1% phosphoric acid; Solvent B: acetonitrile. The gradient program: initially, the concentration of mobile phase B starts at 10% with a flow rate of 0.8 mL/min. At 5 min, the concentration increases to 20%, maintaining the same flow rate. By 35 min, the concentration reaches 25%, still at 0.8 mL/min. At 50 min, the concentration peaks at 80% with a flow rate increase to 1 mL/min. Finally, at 55 min, the concentration drops back to 10%, returning to the initial flow rate of 0.8 mL/min. The identification was performed by comparing retention times and standard spectra. The results were expressed in mg/L of sample.

Statistical analysis of the data was conducted using analysis of variance, and the results were subjected to Tukey's test with a confidence level of ≥ 95%. For the adjustment of linear models to construct ternary diagrams, Statistica version 10.0 (STATSOFT INC, 2004) and Jamovi (Jamovi, 2022). Principal component analysis (PCA) was performed to show a set of correlated and uncorrelated variables using the R package (R.CORE).

3 RESULTS AND DISCUSSION

3.1 Physicochemical analysis

The addition of jabuticaba and pitanga fruits to the MT formulations increased soluble solids, reduced pH, and consequently increased acidity in the beverages (Table 2). Jabuticaba and pitanga contain a significant amount of acids in their composition, which contribute to the reduction of the beverage pH.

The relative proportion of organic acids in fruits and vegetables varies according to the degree of maturity and growing conditions (Seraglio et al., 2018). Jabuticaba and pitanga are acidic fruits, with pH below 3.5. Organic acids and other compounds influence the characteristic flavor of the fruit, which presents a sweet-acidic taste and aroma (Bagetti et al., 2011). The increase in soluble solids of the beverage occurred with the addition of native fruits, rising from 1.1 °Brix in the Standard beverage to up to 2.0 °Brix in formulations containing fruits. These changes were expected and may contribute to improving preservation conditions, sensory characteristics, and acceptability observed in the foods (Oliveira et al., 2023; Ruiz Rodríguez et al., 2021).

The addition of jabuticaba and pitanga fruits to the MT infusion altered the color indices (Table 3). The L* values underwent variations in formulations F1 and F5 with added fruits,

Table 2. Acidity, pH, and soluble solids indices in mate tea added with Brazilian native fruits (jabuticaba and pitanga).

Formulation	pH	Acidity (%)	Soluble solids (°Brix)
Standard	5.56 ± 0.14^{a}	0.59 ± 0.000^{b}	1.10 ± 0.173^{b}
F1	4.30 ± 0.01^{b}	1.21 ± 0.129^{a}	2.00 ± 0.000^{a}
F2	4.27 ± 0.05^{b}	1.52 ± 0.305^{a}	1.76 ± 0.252^{a}
F3	4.29 ± 0.08^{b}	1.27 ± 0.143^{a}	1.70 ± 0.339^{a}
F4	4.34 ± 0.01^{b}	1.32 ± 0.098^{a}	1.70 ± 0.265^{a}
F5	4.34 ± 0.00^{b}	1.21 ± 0.098^{a}	1.86 ± 0.231^{a}

Standard: 100% MT; F1: 70% MT+30% JAB; F2: 70% MT+22.5% JAB+7.5% PIT; F3: 70% MT+15% JAB+15% PIT; F4: 70% MT+7.5% JAB+22.5% PIT; F5: 70% MT+30% PIT. The results are expressed as mean ± standard deviation. The different lowercase letters indicate significant differences according to Tukey's test ($p < .05$).

Table 3. Color values of L*, C*, Hue*, and ΔE in mate tea beverage infused with Brazilian native fruits (jabuticaba and pitanga).

Amostras	L*	C*	Hue	ΔE	Color prospecting[#]
Standard	20.31 ± 3.91^{b}	33.01 ± 3.06^{a}	42.53 ± 5.29^{a}	38.78 ± 4.63^{ab}	
F1	29.44 ± 3.50^{a}	27.1 ± 8.50^{ab}	22.96 ± 0.51^{b}	42.45 ± 4.20^{a}	
F2	21.87 ± 0.35^{ab}	18.14 ± 0.24^{b}	4.45 ± 0.11^{c}	28.41 ± 0.41^{c}	
F3C	23.43 ± 2.09^{ab}	18.46 ± 3.18^{b}	11.40 ± 2.37^{c}	35.18 ± 9.39^{b}	
F4	24.11 ± 5.56^{ab}	25.57 ± 7.80^{ab}	42.19 ± 6.18^{a}	39.76 ± 2.67^{ab}	
F5	28.20 ± 1.73^{a}	28.00 ± 2.50^{ab}	47.58 ± 4.75^{a}	29.87 ± 3.44^{c}	

Standard: 100% MT; F1: 70% MT+30% JAB; F2: 70% MT+22.5% JAB+7.5% PIT; F3: 70% MT+15% JAB+15% PIT; F4: 70% MT+7.5% JAB+22.5% PIT; F5: 70% MT+30% PIT; [#]Color estimation (prospection) of the infusions using the L*, a*, and b* parameters with color analysis software (Research Lab Tools). The results are expressed as the mean ± standard deviation. The different lowercase letters indicate significant differences according to Tukey's test ($p < .05$).

indicating an increase in brightness. Chromaticity (C*) decreased, with these indices representing a measure of color intensity. Color estimation (Table 3) aids in demonstrating this behavior induced by the addition of fruits to the MT infusion.

Color is one of the key attributes that can affect the consumer perception of quality (Filho et al., 2008). Fruits are rich in phenolic compounds that confer coloration, such as anthocyanins, which belong to a subclass of flavonoids and are responsible for the red, blue, and purple coloring of fruits and vegetables, and they can interact with their environment (Burin et al., 2010; de Lima et al., 2002; Ramalho et al., 2019). The addition of fruits to MT may influence coloration due to the presence of substances that are natural acid–base indicators in MT (Fernandes et al., 2017). These substances can change color according to the pH of the solution, which can vary depending on the type and quantity of fruit added. Formulations containing fruits showed the highest levels of L*.

Anthocyanins can exhibit different colorations, which vary according to their diverse structural forms, and these can vary due to factors such as temperature, pH, and potential interactions with other chemical substances (Sato & Da Cunha, 2007). An increase in hydroxyl groups in the molecule makes the coloration more prone to blue, while additions to the number of methoxyl groups enhance the intensity of red (de Lima et al., 2002). With an increase in pH, there is a reduction in the number of conjugated double bonds, which, due to the protonation of the flavylium cation, are responsible for the increase in substance absorption (Bordignon et al., 2009). Consequently, there is a decrease in anthocyanin absorption, resulting in loss of coloration.

3.2 Phenolic compounds

The study demonstrates variations in phenolic compounds and tannins according to the different concentrations of MT, JAB, and PIT (Figures 1A and B). The total phenolic content and total tannin content tended to decrease with the addition of fruits, although the levels are still considered high in all formulations (Silva et al., 2014) (Figure 1). This trend of reduction in the indices of these compounds due to the addition of dehydrated fruits was expected as MT is known for its significant levels of phenolic compounds and tannins (Frizon & Nisgoski, 2020), and the addition of fruit pulps or juices may dilute some of these indices. The formulation with 30% added jabuticaba exhibited higher values of total phenolic compounds compared to other fruit formulations. Jabuticaba demonstrates the highest values for phenolic compounds, anthocyanins, and antioxidant activity compared to other red-colored Brazilian native fruits, including "pitanga," "Araçá vermelho (*Psidium cattleyanum*), and "Cereja do rio grande" (*Eugenia involucrate*) (Munhoz et al., 2014).

Among the main phenolic compounds present in MT are flavonoids such as quercetin, rutin, kaempferol, and luteolin, and anthocyanidins such as cyanidin and delphinidin (Bastos et al., 2007; Bravo et al., 2007; El Khatib et al., 2023; Gawron-Gzella et al., 2021; Heck & De Mejia, 2007). In this study, some of these compounds (gallic acid, chlorogenic acid, delphinidin, myricetin, and rutin) were evaluated (Figure 2). The concentration of these compounds was higher in the standard formulation ($p < 0.05$), without the addition of fruits, following the trend observed in total phenolic content. The indices of individual compounds analyzed in this study did not show differences between the formulations with fruit ($p > 0.05$).

The response surface for individual phenolic compounds was better represented by the linear adjustment (Figure 3) and indicated that the addition of fruits contributed to lower

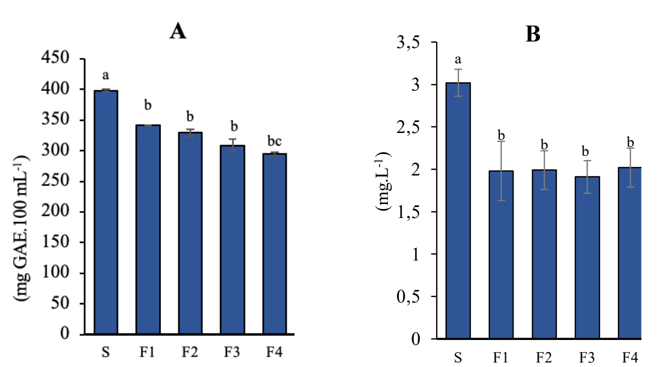

Figure 1. Total phenolic compounds and tannin content in beverage mate tea infused with jabuticaba and pitanga (Brazilian native fruits). Standard: 100% MT; F1: 70% MT+30% JAB; F2: 70% MT+22.5% JAB+7.5% PIT; F3: 70% MT+15% JAB+15% PIT; F4: 70% MT+7.5% JAB+22.5% PIT; F5: 70% MT+30% PIT. The different lowercase letters indicate the significant differences according to Tukey's test ($p < .05$).

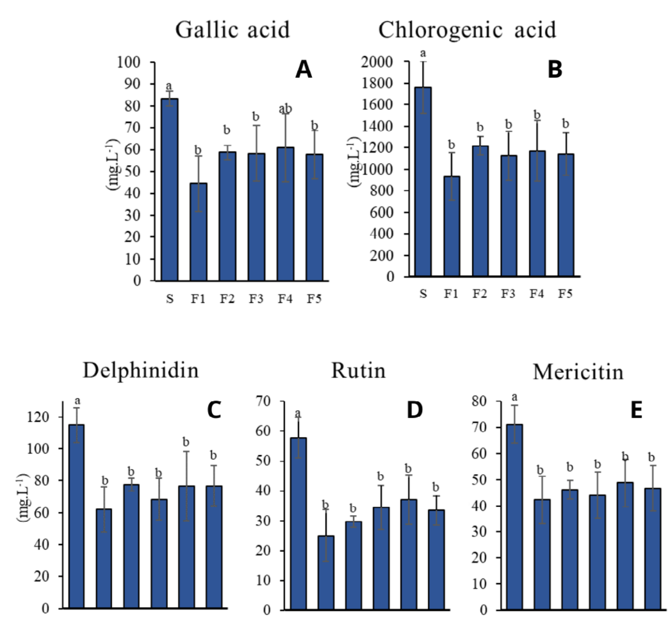

Figure 2. Content of individual phenolic compounds in beverage mate tea infused with jabuticaba and pitanga (Brazilian native fruits). Standard: 100% MT; F1: 70% MT+30% JAB; F2:70% MT+22.5% JAB+7.5% PIT; F3: 70% MT+15% JAB+15% PIT; F4: 70% MT+7.5% JAB+22.5% PIT; F5: 70% MT+30% PIT. The different lowercase letters indicate the significant differences according to Tukey's test ($p < 0.05$).

concentrations of the individual phenolic compounds analyzed in this study. Although the reduction tends to be smaller in beverages with the addition of PIT, this does not prove to be significant for the individual components. The interaction effects between phenolic compounds and fruit additives may influence their individual concentrations differently. For instance,

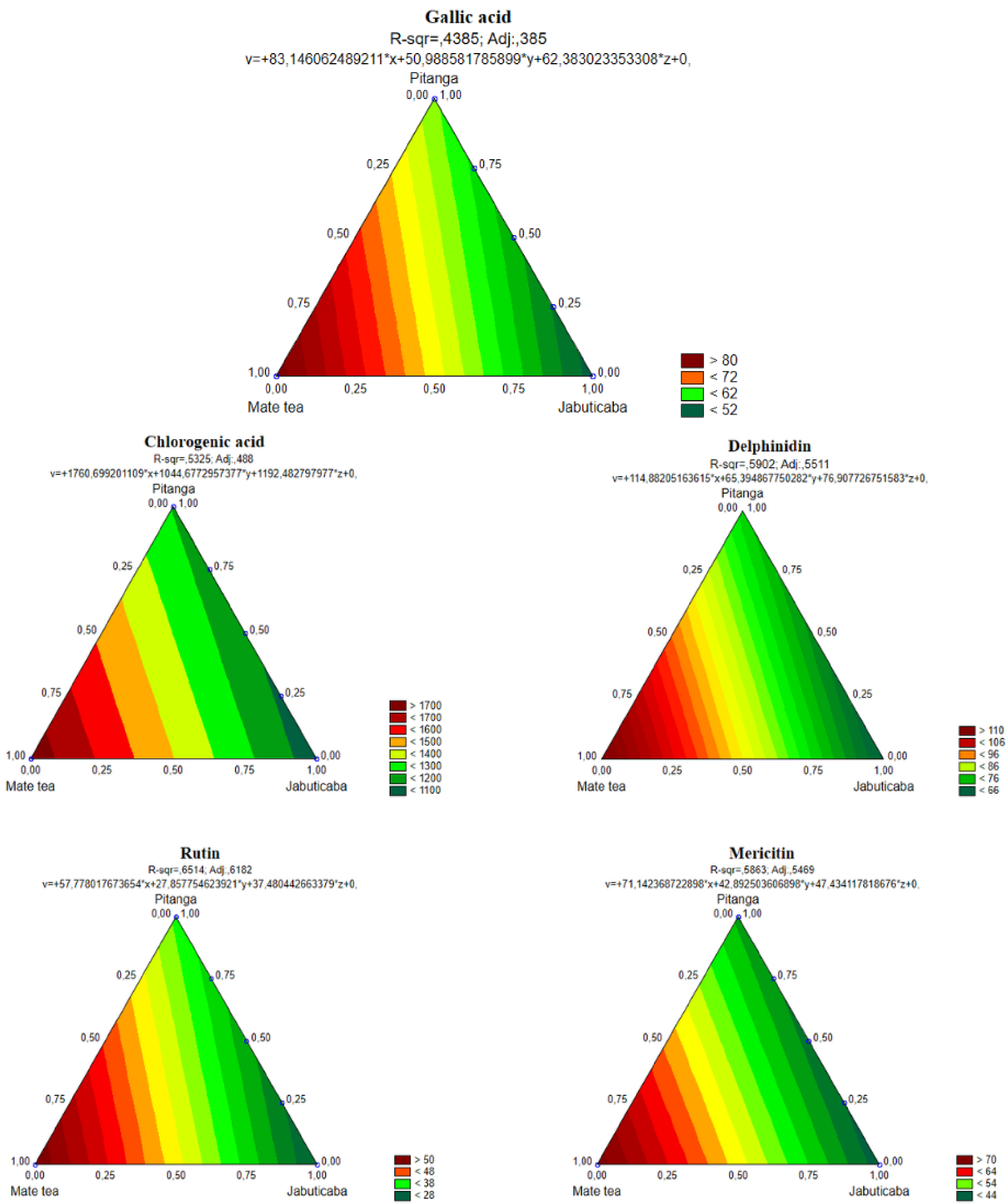

Figure 3. Ternary diagram of the response surface of the linear model of individual phenolic compounds (gallic acid, chlorogenic acid, delphinidin, myricetin, and rutin) in beverage mate tea infused with jabuticaba and pitanga (Brazilian native fruits).

certain phenolic compounds may have a higher affinity for specific fruit constituents, resulting in concentration variations. Additionally, the fruits' maturation stage can significantly impact the composition and concentration of phenolic compounds, as observed in previous studies (de Lima et al., 2002; Munhoz et al., 2014; Seraglio et al., 2018).

There is a positive relationship between total tannins, phenolic compounds, and specific ones with higher MT concentrations (Figures 1 and 2). In PCA, the first principal component (1) accounts for 64.8% of the variability among samples, while the second principal component (2) represents 20.8% of the total variability (Figure 4), meaning, together, they represent 85.6% of the total variability of the data, indicating good representativeness. Considering the physicochemical data, coloration, and phenolic compounds, a trend was observed for most compounds toward the standard group, MT without fruit, which has higher concentrations of total phenolic compounds, individual phenolics, and tannins.

The *hue*, chromaticity (C*), and total color difference (ΔE) parameters tended to be influenced by MT and pitanga. The addition of jabuticaba and pitanga showed to influence the L* coloration parameters, indicating a change in intensity (luminosity) of the coloration. This behavior was expected as in addition to the pigments brought by the fruits, the increase in acidity resulting from the addition of the fruits contributes to the color alteration, as described previously (Bordignon et al., 2009; Falk et al., 2014; Fernandes et al., 2017; Sato & Da Cunha, 2007). Regarding total phenolic compounds, the trend was for a lesser reduction with the addition of jabuticaba, while for individual phenolic compounds, there was a lesser reduction with the addition of pitanga, although not significant, as previously demonstrated (Figures 1 and 2).

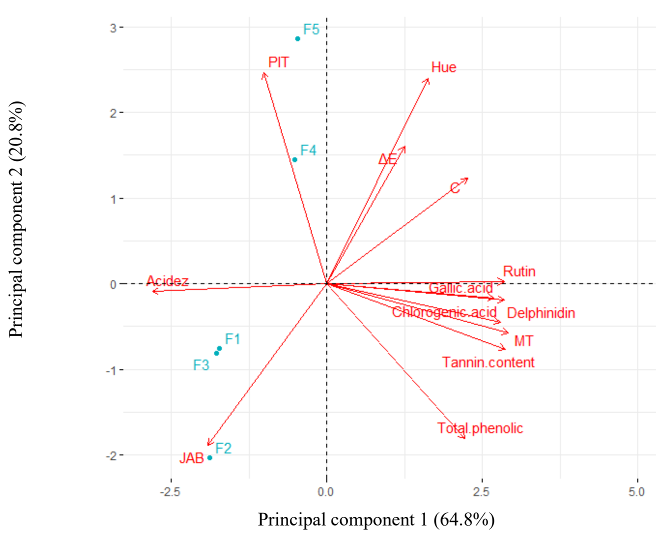

Figure 4. Principal component analysis (PCA) of compounds, physicochemical parameters, and formulations in beverage mate tea infused with jabuticaba and pitanga (Brazilian native fruits); Standard: 100% MT; F1: 70% MT+30% JAB; F2: 70% MT+22.5% JAB+7.5% PIT; F3: 70% MT+15% JAB+15% PIT; F4: 70% MT+7.5% JAB+22.5% PIT; F5: 70% MT+30% PIT.

4 CONCLUSION

The MT-based beverage with the addition of jabuticaba and pitanga resulted in increased beverage acidity and added characteristics such as coloration and soluble solids (sweetness). Regarding color parameters, the addition of fruits enhanced the brightness (L*) of the beverage (brighter colors), with a greater influence from pitanga. The alteration of chemical components such as acidity contributes to this positive color change, characteristic of the studied fruits. Furthermore, the addition of pitanga resulted in a smaller decrease in beverage chromaticity and hue. However, even though the addition of fruit led to a reduction in both total and individual phenolic compounds, the final beverage still contains high levels of these compounds due to the unique characteristics of each component.

ACKNOWLEDGMENTS

We would like to thank the Brazilian National Council for Scientific and Technological Development (CNPq), Araucária Foundation, Universidade Tecnológica Federal do Paraná, Guaiaki Yerba Mate®.

REFERENCES

Bagetti, M., Facco, E. M. P., Piccolo, J., Hirsch, G. E., Rodriguez-Amaya, D., Kobori, C. N., Vizzotto, M., & Emanuelli, T. (2011). Physicochemical characterization and antioxidant capacity of pitanga fruits (Eugenia uniflora L.). *Ciência e Tecnologia de Alimentos*, *31*(1), 147-154. https://doi.org/10.1590/S0101-20612011000100021

Bastos, D. H. M., Oliveira, D. M., Matsumoto, R. L. T., Carvalho, P. O., & Ribeiro, M. L. (2007). Yerba maté: pharmacological properties, research and biotechnology. *Medicinal and Aromatic Plant Science and Biotechnology*, *1*(1), 37-46.

Boger, B. R., Cavalli, K. F., Marquetti, C., Pinto, E. P., Tonial, I. B., & Lucchetta, L. (2022). Jabuticaba: características e aplicações tecnológicas. In A. Wagner Júnior, M. A. Danner & I. Citadin. *Jabuticabeiras* (pp. 266-293). EDUTFPR. Retrieved from https://editora.utfpr.edu.br/produto/jabuticabeiras/

Bordignon, C. L., Francescatto, V., Nienow, A. A., Calvete, E., & Reginatto, F. H. (2009). Influência do pH da solução extrativa no teor de antocianinas em frutos de morango. *Food Science and Technology*, *29*(1), 183-188. https://doi.org/10.1590/S0101-20612009000100028

Bravo, L., Goya, L., & Lecumberri, E. (2007). LC/MS characterization of phenolic constituents of mate (Ilex paraguariensis, St. Hil.) and its antioxidant activity compared to commonly consumed beverages. *Food Research International*, *40*(3), 393-405. https://doi.org/10.1016/j.foodres.2006.10.016

Brito, T. G. da S., Silva, A. P. S. da, Cunha, R. X. da, Fonseca, C. S. M. da, Araújo, T. F. da S., Campos, J. K. de L., Nascimento, W. M., Araújo, H. D. A. de, Silva, J. P. R. e, Tavares, J. F., Santos, B. S. dos, & Lima, V. L. de M. (2021). Anti-inflammatory, hypoglycemic, hypolipidemic, and analgesic activities of Plinia cauliflora (Mart.) Kausel (Brazilian grape) epicarp. *Journal of Ethnopharmacology*, *268*, 113611. https://doi.org/10.1016/j.jep.2020.113611

Burin, V. M., Falcão, L. D., Gonzaga, L. V., Fett, R., Rosier, J. P., & Bordignon-Luiz, M. T. (2010). Colour, phenolic content and antioxidant activity of grape juice. *Food Science and Technology*, *30*(4), 1027-1032. https://doi.org/10.1590/S0101-20612010000400030 da Silveira, T. F. F., Meinhart, A. D., de Souza, T. C. L., Cunha, E. C. E., de Moraes, M. R., Filho, J. T., & Godoy, H. T. (2017). Optimization of the preparation conditions of yerba mate tea beverage to maximize chlorogenic acids extraction. *Plant Foods for Human Nutrition*, *72*(2), 219-223. https://doi.org/10.1007/s11130-017-0613-6

Dametto, A. C., Agustoni, D., Moreira, T. F., Plaza, C. V., Prieto, A. M., Silva, T. G. A., Souza, F. O., Boralle, N., Maria Sorbo, J., Silva, D. H. S., & Soares, C. P. (2017). Chemical composition and in vitro chemoprevention assessment of Eugenia jambolana Lam. (Myrtaceae) fruits and leaves. *Journal of Functional Foods*, *36*, 490-502. https://doi.org/10.1016/J.JFF.2017.07.013

de Lima, V. L. A. G., Mélo, E. de A., & Lima, D. E. d. S. (2002). Fenólicos e carotenóides totais em pitanga. *Scientia Agricola*, *59*(3), 447-450. https://doi.org/10.1590/S0103-90162002000300006

Düsman, E., Almeida, I. V., Pinto, E. P., Lucchetta, L., & Vicentini, V. E. P. (2017). Influence of processing and storage of integral grape juice (Vitis labrusca L.) on its physical and chemical characteristics, cytotoxicity, and mutagenicity in vitro. *Genetics and Molecular Research*, *16*(2), gmr16029670. https://doi.org/10.4238/gmr16029670

El Khatib, K., Hadeer, R. A., Saad, A., Kalaydjian, A., Fayad, E., Mahfouz, Y., Dougnon, V., Daoud, Z., & Abdel-Massih, R. M. (2023). Determination of MIC, MPC, and MSW of Ilex paraguariensis against non-typhoidal Salmonella with identification of the mechanisms of resistance and pathogenicity factors. *Microbial Pathogenesis*, *174*, 105905. https://doi.org/10.1016/j.micpath.2022.105905

Falk, M., Rugraff, E., Narula, R., Wakelin, K., Andrijauskiene, M., Dumčiuvienė, D., Wang, X., Petit, M. L., Sanna-Randaccio, F., Sestini, R., Ghebrihiwet, N., Jin, F., Lee, K., Kim, Y.-K., Gachino, G. G., Mathew, A. J., Mukherjee, A., … & Choo, K. (2014). Elaboração de uma nova bebida a base de chá mate e néctar de jabuticaba, adicionada de néctar esferificado. *Research Policy*, *9*(2), 155-162.

Fernandes, C. E. F., Scapinello, J., Bohn, A., Boligon, A. A., Athayde, M. L., Magro, J. D., Palliga, M., Oliveira, J. V., & Tres, M. V. (2017). Phytochemical profile, antioxidant and antimicrobial activity of extracts obtained from erva-mate (Ilex paraguariensis) fruit using compressed propane and supercritical CO2. *Journal of Food Science and Technology*, *54*(1), 98-104. https://doi.org/10.1007/s13197-016-2440-4

Filho, G. L., De Rosso, V. V., Meireles, M. A. A., Rosa, P. T. V., Oliveira, A. L., Mercadante, A. Z., & Cabral, F. A. (2008). Supercritical CO2 extraction of carotenoids from pitanga fruits (Eugenia uniflora L.). *Journal of Supercritical Fluids*, *46*(1), 33-39. https://doi.org/10.1016/j.supflu.2008.02.014

Frizon, C. N. T., & Nisgoski, S. (2020). Color parameters to predict moisture and tannin content in yerba mate process. *Floresta e Ambiente*, *27*(2), e20180098. https://doi.org/10.1590/2179-8087.009818

Gawron-Gzella, A., Chanaj-Kaczmarek, J., & Cielecka-Piontek, J. (2021). Yerba mate—a long but current history. *Nutrients*, *13*(11), 3706. https://doi.org/10.3390/nu13113706

Gerber, T., Nunes, A., Moreira, B. R., & Maraschin, M. (2023). Yerba mate (*Ilex paraguariensis* A. St.-Hil.) for new therapeutic and nutraceutical interventions: A review of patents issued in the last 20 years (2000–2020). *Phytotherapy Research*, *37*(2), 527-548. https://doi.org/10.1002/ptr.7632

Godoy, R. C. B. de, Chambers, E., & Yang, G. (2020). Development of a preliminary sensory lexicon for mate tea. *Journal of Sensory Studies*, *35*(3), e12570. https://doi.org/10.1111/JOSS.12570

Heck, C. I., & De Mejia, E. G. (2007). Yerba mate tea (Ilex paraguariensis): A comprehensive review on chemistry, health implications, and technological considerations. *Journal of Food Science*, *72*(9), R138-R151. https://doi.org/10.1111/j.1750-3841.2007.00535.x

Instituto Adolfo Lutz (IAL) (2008). *Normas Analíticas do Instituto Adolfo Lutz. v. 1: Métodos químicos e físicos para análise de alimentos*. Retrieved from http://www.ial.sp.gov.br/ial/publicacoes/livros/metodos-fisico-quimicos-para-analise-de-alimentos

Jamovi, P. (2022). *Jamovi (Version 2.3) [Computer Software]*. Retrieved from https://www.jamovi.org

Mannino, G., Perrone, A., Campobenedetto, C., Schittone, A., Margherita Bertea, C., & Gentile, C. (2020). Phytochemical profile and antioxidative properties of Plinia trunciflora fruits: A new source of nutraceuticals. *Food Chemistry*, *307*, 125515. https://doi.org/10.1016/j.foodchem.2019.125515

Medic, A., Jakopic, J., Hudina, M., Solar, A., & Veberic, R. (2021). Identification and quantification of the major phenolic constituents in Juglans regia L. peeled kernels and pellicles, using HPLC–MS/MS. *Food Chemistry*, *352*, 129404. https://doi.org/10.1016/j.foodchem.2021.129404

Migues, I., Baenas, N., Gironés-Vilaplana, A., Cesio, M., Heinzen, H., & Moreno, D. (2018). Phenolic profiling and antioxidant capacity of Eugenia uniflora L. (pitanga) samples collected in different uruguayan locations. *Foods*, *7*(5), 67. https://doi.org/10.3390/foods7050067

Munhoz, P. C., Pereira, E., Schiavon, M. V., Santos, D. C. dos, & Vizzotto, M. (2014). Caracterização química de frutas nativas vermelhas: araçá vermelho, cereja-do rio-grande, pitanga e jabuticaba. In *Encontro Sobre Pequenas Frutas e Frutas Nativas do Mercosul* (pp. 134). Retrieved from https://www.alice.cnptia.embrapa.br/alice/handle/doc/987248

Oliveira, T. M. B. F. de, Guimarães, L. da C. R., Oliveira, R. L. B. de, Nunes, T. P., Pagani, A. A. C., Santos, J. dos, Santos, J. dos, Júnior, L. de S. R., & Silva, G. F. da. (2023). Desenvolvimento e caracterização de uma bebida láctea com adição de preparado da casca de Umbu (Spondias Tuberosa Arruda Câmara) e microcápsula pela técnica de gelificação iônica. *Observatório de la Economía Latinoamericana*, *21*(10), 15192-15216. https://doi.org/10.55905/OELV21N10-039

Paiva, Y. F., Figueirêdo, R. M. F. de, Queiroz, A. J. de M., Amadeu, L. T. S., Santos, F. S. dos, Reis, C. G. dos, Carvalho, A. J. de B. A., Lima, M. dos S., Lima, A. G. B. de, Gomes, J. P., Moura, R. L., Moura, H. V., & Silva, E. T. de V. (2023). Physicochemical aspects, bioactive compounds, phenolic profile and in vitro antioxidant activity of tropical red fruits and their blend. *Molecules*, *28*(12), 4866. https://doi.org/10.3390/molecules28124866

Pereira, E. dos S., Vinholes, J., Franzon, R. C. ., Dalmazo, G., Vizzotto, M., & Nora, L. (2018). Psidium cattleianum fruits: A review on its composition and bioactivity. *Food Chemistry*, *258*, 95-103. https://doi.org/10.1016/j.foodchem.2018.03.024

Ramalho, R. R. F., Barbosa, J. M. G., Ferri, P. H., & Santos, S. da C. (2019). Variability of polyphenols and volatiles during fruit development of three pitanga (Eugenia uniflora L.) biotypes. *Food Research International*, *119*, 850-858. https://doi.org/10.1016/j.foodres.2018.10.068

Rodrigues, L., Donado-Pestana, C. M., Moura, M. H. C., Rossi e Silva, R., Pessoa, É. V. M., & Genovese, M. I. (2021). Phenolic compounds from jaboticaba (Plinia jaboticaba (Vell.) Berg) ameliorate intestinal inflammation and associated endotoxemia in obesity. *Food Research International*, *141*, 110139. https://doi.org/10.1016/j.foodres.2021.110139

Ruiz Rodríguez, L. G., Zamora Gasga, V. M., Pescuma, M., Van Nieuwenhove, C., Mozzi, F., & Sánchez Burgos, J. A. (2021). Fruits and fruit by-products as sources of bioactive compounds. Benefits and trends of lactic acid fermentation in the development of novel fruit-based functional beverages. *Food Research International*, *140*, 109854. https://doi.org/10.1016/J.FOODRES.2020.109854

Sato, A. C. K., & Da Cunha, R. L. (2007). Influência da temperatura no comportamento reológico da polpa de jabuticaba. *Food Science and Technology*, *27*(4), 890-896. https://doi.org/10.1590/S0101-20612007000400033

Seraglio, S. K. T., Schulz, M., Nehring, P., Della Betta, F., Valese, A. C., Daguer, H., Gonzaga, L. V., Fett, R., & Costa, A. C. O. (2018). Nutritional and bioactive potential of Myrtaceae fruits during ripening. *Food Chemistry*, *239*, 649-656. https://doi.org/10.1016/j.foodchem.2017.06.118

Silva, N. A. da, Rodrigues, E., Mercadante, A. Z., & de Rosso, V. V. (2014). Phenolic Compounds and Carotenoids from Four Fruits Native from the Brazilian Atlantic Forest. *Journal of Agricultural and Food Chemistry*, *62*(22), 5072-5084. https://doi.org/10.1021/jf501211p

Singleton, V. L., Orthofer, R., & Lamuela-Raventós, R. M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. *Methods in Enzymology*, *299*, 152-178. https://doi.org/10.1016/S0076-6879(99)99017-1

STATSOFT INC. (2004). *Statistica data analysis system version 7.0.* (7.0).

Valduga, A. T., Gonçalves, I. L., Magri, E., & Delalibera Finzer, J. R. (2019). Chemistry, pharmacology and new trends in traditional functional and medicinal beverages. *Food Research International*, *120*, 478-503. https://doi.org/10.1016/J.FOODRES.2018.10.091

Vasconcellos, A. C. de, Frazzon, J., & Zapata Noreña, C. P. (2022). Phenolic compounds present in yerba mate potentially increase human health: a critical review. *Plant Foods for Human Nutrition (Dordrecht, Netherlands)*, *77*(4), 495-503. https://doi.org/10.1007/S11130-022-01008-8

Wagner Jr., A., Danner, M. A., & Citadin, I. (2022). *Jabuticabeiras*. EDUTFPR. Retrieved from https://editora.utfpr.edu.br/produto/jabuticabeiras/