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The relationship between leaf morphology on the chemical composition and antioxidant potential of *Campomanesia adamantium* (Cambess.) O. Berg tea

A relação entre morfologia das folhas na composição química e potencial antioxidante do chá de *Campomanesia adamantium* (Cambess.) O.Berg

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Campomanesia adamantium (Cambess.) O. Berg, commonly known as guavira, is a native Brazilian species of great socioeconomic relevance, due to the commercialization of its fruits and cultural importance, being officially recognized as the fruit symbol of the state fruit of Mato Grosso do Sul. Although it exhibits considerable genetic and morphological variability. This study investigated the influence of leaf morphology on the chemical composition and antioxidant potential of *C. adamantium* infusions. Leaves from seven wild individuals were collected and characterized based on length, width, mass, moisture content, and venation pattern. Chemical analyses quantified total phenolic compounds, flavonoids, and tannins, as well as antioxidant capacity (DPPH assay). Principal Coordinates Analysis (PCoA) grouped the samples into three morphological clusters: small leaves (samples 1, 3, and 6), narrow and elongated leaves (samples 2 and 5), and large leaves (samples 4 and 7). Principal Component Analysis (PCA) indicated a strong correlation between chemical composition and leaf morphology. The narrow and elongated leaves showed higher contents of phenolic compounds (210.47-220.13 µg GAE mL^{-1}), flavonoids (48.67-52.89 µg RE mL^{-1}), tannins (122.85-125.85 µg TAE mL^{-1}), and antioxidant potential (567.25-568.50 µg TE mL^{-1}). These results support the potential for selecting morphotypes with desirable traits for cultivation and commercial use, thus promoting the standardization and quality improvement of *C. adamantium*-based leaf products.
Keywords: guavira, Myrtaceae, polyphenols.

Campomanesia adamantium (Cambess.) O. Berg, popularmente conhecida como guavira, é uma espécie nativa do Brasil de grande relevância socioeconômica, devido à comercialização de seus frutos, e cultural, sendo reconhecida como fruto-símbolo do estado de Mato Grosso do Sul. Esta espécie possui alta variabilidade genética e morfológica. Este estudo investigou a influência da morfologia foliar na composição química e no potencial antioxidante das infusões de *C. adamantium*. Folhas de sete indivíduos silvestres foram coletadas e caracterizadas com base no comprimento, largura, massa, teor de umidade e padrão de nervuras. As análises químicas quantificaram compostos fenólicos totais, flavonoides e taninos, além da capacidade antioxidante (ensaios com DPPH). Na Análise de Coordenadas Principais (PCoA) observaram-se três agrupamentos morfológicos: folhas pequenas (amostras 1, 3 e 6), folhas estreitas e alongadas (amostras 2 e 5) e folhas grandes (amostras 4 e 7). A Análise de Componentes Principais (PCA) indicou uma forte correlação entre a composição química e a morfologia foliar. As folhas estreitas e alongadas apresentaram maior teor de compostos fenólicos (210,47-220,13 µg GAE mL^{-1}), flavonoides (48,67-52,89 µg RE mL^{-1}), taninos (122,85-125,85 µg ATE mL^{-1}) e potencial antioxidante (567,25-568,5 µg TE mL^{-1}). Esses resultados sustentam o potencial da seleção de morfotipos com características desejáveis para cultivo e uso comercial, promovendo, assim, a padronização e a melhoria da qualidade dos produtos à base de folhas de *C. adamantium*.
Palavras-chave: guavira, Myrtaceae, polifenóis.

1. INTRODUÇÃO

Campomanesia adamantium (Cambess.) O.Berg is a native shrub species of ecological, cultural, and economic relevance in Brazil. It is officially recognized as a symbolic fruit of the state of Mato Grosso do Sul [1]. Its fruits are harvested and commercialized for the production

of artisanal foods and beverages, particularly during the annual Guavira Festival held in Bonito, Mato Grosso do Sul [2].

In addition to the fruits, the leaves of *C. adamantium* are traditionally used in Brazilian ethnomedicine to treat inflammation, diarrhea, stomach disorders, and urogenital conditions [3]. Some of these traditional uses have been supported by pharmacological studies, which demonstrated anti-inflammatory and antinociceptive effects of ethyl acetate and aqueous extracts in *in vivo* models using mice [4]. The leaves of *C. adamantium* are commonly prepared as infusions or decoctions for medicinal tea [5]. In recognition of their traditional and potential therapeutic uses, the Brazilian Ministry of Agriculture and Livestock has included information on the use of *C. adamantium* leaves for tea preparation [6].

Recent studies have started to investigate the chemical composition and bioactive potential of *C. adamantium* leaf preparations, mainly as infusions or decoctions. In an infusion, boiled water is poured over the leaves, whereas in a decoction, the leaves are boiled together with the water. Castro et al. (2022) [5] reported that infusions contained higher levels of flavonoids and exhibited greater antioxidant activity compared to decoctions. Verdan et al. (2022) [7] demonstrated that incorporating aqueous extracts of *C. adamantium* leaves into craft beer enhanced its antioxidant potential. The antioxidant potential of aqueous extracts from C. adamantium leaves has been attributed to the presence of gallic acid [8]. Despite these promising findings, the leaves remain underutilized commercially, unlike the fruits, which are seasonally available from October to March; the leaves are available year-round [9].

However, the full exploitation of *C. adamantium* leaves faces a major obstacle: the species is still in the early stages of domestication and exhibits significant morphological and genetic variability [10]. Previous studies have reported at least three distinct leaf morphotypes depending on the geographical origin [11], and high levels of genetic diversity have been confirmed across different populations [12-14]. These findings suggest the existence of intraspecific variation that may affect not only physical traits but also chemical composition and biological properties.

The relationship between leaf morphology (a phenotypic trait) and the biosynthesis of secondary metabolites has been documented in other plant species [15-18]. For example, *Populus tremula* L. and *Tilia cordata* Mill. exhibit variations in protein content and dry mass associated with leaf form [15], *Solanum lycopersicum* Blanco displays differences in terpene profiles due to mutations in trichomes [16], *Echinacea purpurea* (L.) Moench shows altered phenolic and flavonoid contents depending on leaf shape [17], and *Camellia sinensis* (L.) Kuntze exhibits variations in polyphenol and alkaloid profiles among dried leaf samples from different suppliers [18].

These examples indicate that morphological traits, especially leaf dimensions and venation patterns, may correlate with metabolite profiles [15-18]. In this way, the morphology of leaves can be an indicator of quality for the plant, being a relevant mark in the process of domestication. However, in the case of *C. adamantium*, such a correlation has not been thoroughly investigated. Considering that phenolic compounds, flavonoids, and tannins, common in herbal teas, are key contributors to antioxidant properties [19], understanding this relationship is essential for standardizing leaf-based products.

In this context, it was empirically observed a variability of leaf shape in an experimental field of *C. adamantium*, despite the same conditions of cultivation. Based on this, a question arose: Is leaf morphological variation a viable criterion for selecting *C. adamantium* genotypes in tea-oriented domestication programs?

This preliminary study investigated whether morphological variability in the shape of *C. adamantium* is correlated with variations in chemical composition (including phenolic compounds, tannins, and flavonoids) and biological activities (antioxidant potential) in tea.

2. MATERIALS AND METHODS

2.1 Reagents and equipment

Folin-Ciocalteu reagent, (±)-6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), 2,2-diphenyl-1-picrylhydrazyl (DPPH), analytical standards of gallic acid, rutin, tannic

acid (Sigma-Aldrich, USA, purity ≥ 99%), aluminum chloride P.A., sodium carbonate P.A., methanol P.A., ethanol P.A. (Neon, Brazil).

Knife mill (Marconi, Brazil), Drying oven (TE-397/5, TECNAL, Brazil), UV/Vis spectrophotometer (UV-M51, BEL Photonics, Brazil).

2.2 Collection and processing of the leaves

The leaves were collected (Access Register No A9CDAAE, the leaves 15/10/2018 in SisGen) in the Medicinal Plants Botanical Garden (*Horto de Plantas Medicinais*) – MPBG (22º11'44" S and 54º56'08" W, 430 m altitude) of the Federal University of Grande Dourados (UFGD), Mato Grosso do Sul, Brazil. The species was identified and deposited in the DDMS Herbarium under No. 4653. The specimens were of the same age (8 years) and were cultivated under the same soil, light, and water conditions. Seven representative specimens of different leaf morphologies were selected for the experiment. The collection occurred at 8:00h on 5 December 2023, just off the seven youngest leaves of each branch. The plants were beginning to flower out of season. The leaves were stored in plastic and immediately sent to the laboratory.

The leaves were cleaned with running water, and excess moisture was removed with a paper towel. The description of leaf morphology was performed based on Gonçalves and Lorenzi (2011) [20]. After this, 20 random leaves were selected to measure the length, width, and mass of the leaves. Three leaves were used in triplicate for moisture content measurement, dried in a drying oven without a circulation system until a constant mass was achieved at 50 ± 1°C in the oven. The other leaves were dried in a shaded place under a controlled temperature (24 ± 1 °C) and then crushed and sieved.

2.3 Preparation of tea

The tea was prepared immediately after being crushed and sieved using the infusion method. A portion of 500 ± 5 mg of leaves was placed in disposable nylon infusion filters (5x7 cm). Then, 200 mL of boiling water (95 ± 5 ◦C) was added to the *C. adamantium* leaves tea filters, maintaining contact for 10 min in a covered ceramic mug (420 cm^3). The teas were obtained in triplicate at a controlled temperature (21 ± 1 °C). In this way, the extraction concentration was 0.25% (w:v). The tea isn't standard in dry extract to simulate the popular consumption.

2.4 Analysis of total metabolite content

Analyses were carried out in triplicate for each extraction replicate in a temperature-controlled room (24 ± 2°C), and absorbance readings were taken in a UV spectrophotometer with a glass cuvette. Colorimetric reactions with analytical standards were used for quantification (Table 1).

Table 1: Information on colorimetric reactions for the quantification of total metabolites.

Class of compound	Reaction	Time (min)	λ (nm)	Analytical standard	Linear range (µg mL^{-1})	Reference
Phenolic compounds	0.1 mL of sample 0.5 mL of Folin-Ciocalteu 1.5 mL of $NaCO_3$ 20%*	120	760	Gallic acid	10-1000	[21]
Flavonoids	1 mL of sample 1 mL of $AlCl_3$ 2%	15	430	Rutin	10 e 50	[21]
Tannins	0.5 mL of sample 0.5 mL of Folin-Denis 0.5 mL of $NaCO_3$ 8%**	120	725	Tannic acid	0.5 e 80	[22]

*= Wait 1 minute before addition of $NaCO_3$ 20%; ** = Wait 3 minute before addition of $NaCO_3$ 8%.

The results of phenolic compound contents were expressed in mg gallic acid equivalent (AGE) per mL of tea, flavonoids in mg rutin equivalent (RE) per mL of tea, and tannins in mg tannic acid equivalent (TE) per mL of tea.

2.5 Inhibition of the 1,1-diphenyl-2-picrylhydrazyl radical

The used method was described by Silveira et al. (2018) [23], adapting the volumes without changing the proportions of the reactants. A portion of 51 µL of the sample was added to 2 mL of DPPH (1,1-diphenyl-2-picrylhydrazyl radical), waiting for the reaction for 15 minutes, and taking an absorbance reading on a spectrophotometer with a glass cuvette at a wavelength of 517 nm. The reaction was also carried out in Trolox solutions, at concentrations between 18 and 230 µmol L-1, resulting in a standard curve used to determine the concentration equivalent to Trolox per mL of tea. Distilled water was used as a negative control.

2.6 Statistical Analysis

All statistical analyses were performed on the R program [24]. Initially, the Shapiro-Wilk test was conducted to assess normality, and the homogeneity of variances among samples was analyzed.

Physical and physicochemical characterizations were conducted using independent biological samples. Twenty randomly selected leaves were used for measurements of length, width, and mass. Moisture content measurements were performed in triplicate, and color was measured five times. For all subsequent analyses, tea infusions were prepared in three independent extractions (biological replicates). Each replicate was analyzed in triplicate (analytical replicates), totaling nine data points per sample per assay.

To compare the morphological parameters analyzed in the leaves, the Kruskal-Wallis test was applied with a 5% significance level, followed by Dunn's test using the FSA [25] and companion [26] packages, as the samples exhibited normality but lacked homogeneity of variances. Subsequently, Euclidean distance analysis was conducted using the vegan package [27], yielding a cophenetic correlation of 0.77. Principal Coordinates Analysis (PCoA) was then applied to analyze the similarity matrix of the morphological data using the "cmdscale" function with two axes.

For the chemical analysis and antioxidant potential results, a one-way analysis of variance (ANOVA) with a 5% significance level was applied, followed by Tukey's test. Principal Component Analysis (PCA) using Euclidean distance was also performed to check for cluster formation and to analyze the main parameters contributing to this result through the factoextra package [28]. Before this, a cophenetic correlation test was conducted as previously described, yielding a value of 0.89. Additionally, Pearson correlation tests were applied between the levels of phenolic compounds, flavonoids, tannins, and antioxidant potential.

3. RESULTS AND DISCUSSION

3.1 Morphology of leaves

The phenotypic plasticity of plant specimens is associated with genetic variability, representing the expression of the interaction between the environment and the species' genotypes, which enables the adaptation of the specimen to environmental adversities [29]. This variability has already been reported by Oliveira et al. (2018) [11], who described three morphotypes for *C. adamantium* leaves when collecting in different locations, with the leaf shape being elliptical, oblanceolate, oblong, obovate, and oval; the apex being acute; acute base, chordate, and subcordate and entire and slightly revolute edge, depending on the collection site. However, high variability was observed in the specimens collected, despite the environmental conditions and age of the specimens being standardized in an *ex-situ* cultivation under the same cultural treatments (Table 2).

Table 2: Morphology of the leaves of Campomanesia adamantium *specimens.*

Specimen	Format	Venation	Edges	Apex	Base	Photo
1	Elliptic	Eucamptodromous	Entire	Cuneate	Cuneate	
2	Elliptical-lanceolate	Eucamptodromous	Crenate	Cuneate	Attenuate	
3	Narrow-Elliptic	Eucamptodromous	Entire	Acute	Attenuate	
4	Narrow-oblong	Eucamptodromous	Crenate	Obtuse	Obtuse	
5	Narrow-Elliptic	Eucamptodromous	Entire	Acute	Acute	
6	Oblanceolate	Eucamptodromous	Entire	Cuneate	Acute	
7	Obovate	Eucamptodromous	Entire	Obtuse	Cuneate	

Eucamptodroma = Peninerveal nerve with marginal collecting nerve. *Photos proportional to the actual size of the leaves. Photos: Authors (2024).

The leaves showed variability in different morphological aspects (Table 2), probably being associated with a pleiotropic behavior resulting from the high genetic variability of the *C. adamantium* population. The study by Crispim et al. (2021) [14] in five different cities in Mato Grosso do Sul, Brazil, demonstrated high genetic variability among the *C. adamantium* populations in the municipalities.

Specimens 1, 3, and 6 had the smallest leaf widths, masses, and lengths ($p < 0.05$). The coefficient of variation differed for each sample, depending on the characteristic analyzed, with the most significant variability observed in length and width, as seen in specimen 5. Conversely, the variation in mass was most pronounced in specimen 1, and this specimen exhibits a notable variation in length. The specimens with the lowest variability were 7 for width, 2 for length, and 3 for mass. In this way, it is possible to verify that the variability of these characteristics fluctuated between the individuals in the sample group analyzed (Table 3). The high variability of the characteristics is also reinforced numerically, considering that their standard deviation for the population is greater than the variation of the specimens, except 5 for length.

Table 3: Dimensions of the leaves of Campomanesia adamantium *specimens.*

Specimen	Width		Length		Mass	
	mm ± SD	C.V. (%)	mm ± SD	C.V. (%)	mg ± SD	C.V. (%)
1	56.82 ± 7.82^{a}	13.8	22.14 ± 3.64^{a}	16.4	244.60 ± 104.27^{a}	42.6
2	99.49 ± 12.30^{b}	12.4	36.27 ± 4.58^{bc}	12.6	856.70 ± 242.96^{b}	28.4
3	65.61 ± 8.59^{a}	13.1	20.87 ± 4.11^{ad}	19.7	279.00 ± 68.07^{a}	24.4
4	104.37 ± 15.27^{b}	14.6	49.35 ± 8.11^{bc}	16.4	798.20 ± 217.92^{b}	27.3
5	104.48 ± 20.78^{b}	19.9	34.52 ± 19.12^{b}	55.4	929.80 ± 245.06^{b}	26.4
6	51.76 ± 8.70^{a}	16.8	15.97 ± 3.58^{a}	22.4	156.50 ± 63.13^{a}	40.3
7	81.36 ± 9.98^{bc}	12.3	41.19 ± 6.66^{cd}	16.2	576.50 ± 165.55^{b}	28.7
Population	78.17 ± 24.14	30.89	32.28 ± 14.15	43.83	490.55 ± 340.16	69.34

SD = Standard deviation; C.V. = Coefficient of variation. Different letters indicate a significant difference ($p < 0.05$) by Dunn's test in the column.

To analyze the similarity between specimens, Principal Coordinates Analysis (PCoA) was applied (Figure 1), a non-parametric multivariate technique that transforms similarity distances into multidimensional coordinates to graphically demonstrate the relationship between samples.

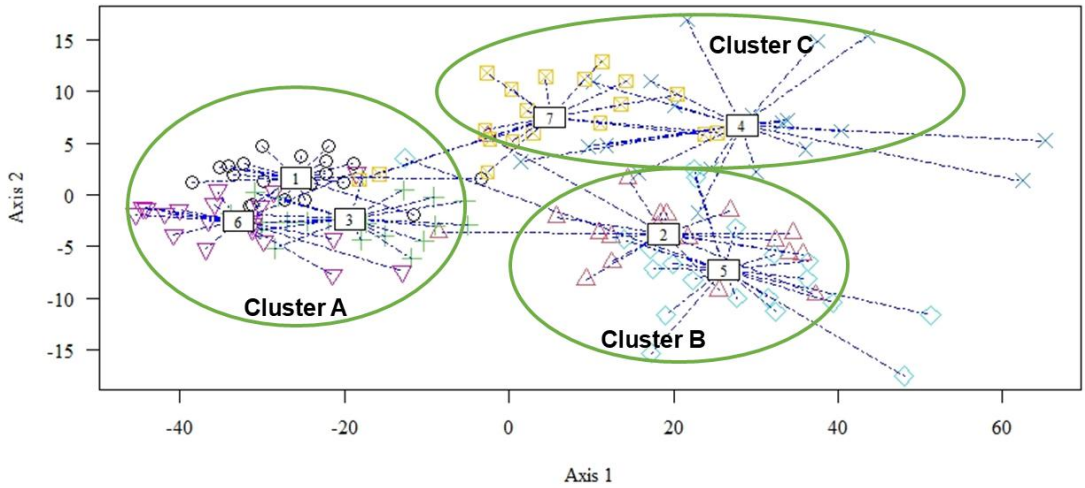

Figure 1: Principal Coordinate Analysis (PCoA) of the quantitative morphological characteristics of the Campomanesia adamantium *specimens' leaves.*

The analysis indicated the presence of three clusters. Cluster A is characterized by leaves with smaller widths and lengths; Cluster B is characterized by leaves of small width and great length, while samples 7 and 4 form Cluster C, characterized by large leaves. In this way, three leaf-shape groups were proposed in the analyzed sample group: small leaves (samples 1, 3, and 6), narrow and long leaves (samples 2 and 5), and large leaves (samples 4 and 7).

The moisture content of samples with small leaves was low, while samples with broad and large leaves were higher; however, the two specimens from the group with narrow and long leaves had different moisture contents (Figure 2).

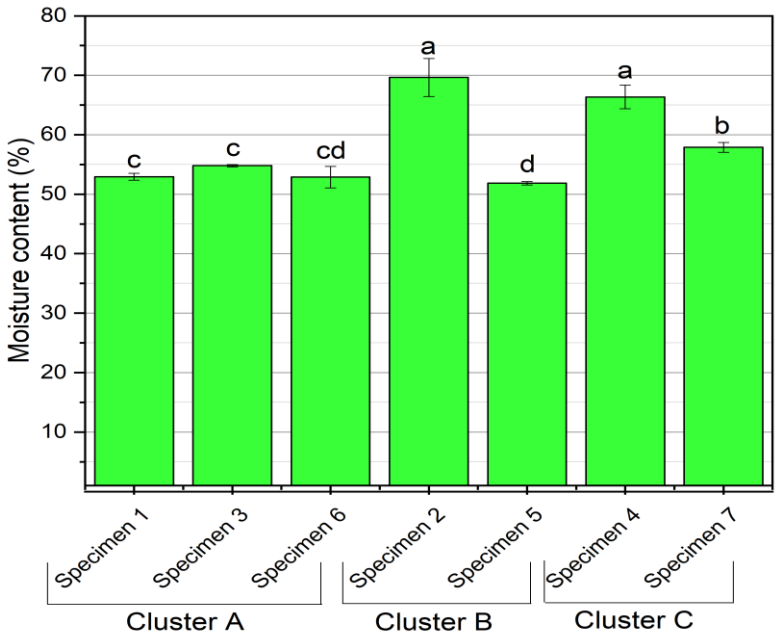

Figure 2: The moisture content of leaves of Campomanesia adamantium *specimens. Different letters indicate a significant difference ($p < 0.05$) by Dunn's test.*

The process of drying the leaves is essential for conserving the tea's raw material, as it increases shelf life and facilitates transportation, thus enabling commercialization [30]. Thus, cluster 1 stands out because of the lower moisture content. However, clusters 2 and 3 did not show a direct relationship with moisture content, with the specimens grouped in these clusters differing significantly from each other ($p < 0.05$).

3.2 Chemical composition of teas

The quantitative data regarding leaf shape showed that there was more significant variability in the population than in the tea preparation replica of each specimen. The specimens showed more significant variation concerning the content of phenolic compounds and flavonoids, with tannin content showing less difference (Table 4).

Table 4: Metabolite content of Campomanesia adamantium *leaves teas.*

Specimen (Cluster)	Phenolic compounds (mg GAE mL^{-1} ± DP)	C.V. (%)	Flavonoids (mg RE mL^{-1} ± DP)	C.V. (%)	Tannins (mg TAE mL^{-1} ± DP)	C.V. (%)
1 (A)	144.80 ± 5.42	3.7	39.93 ± 1.25	3.1	122.18 ± 5.03	4.1
2 (B)	210.47 ± 16.47	7.8	52.89 ± 2.68	5.1	122.85 ± 1.22	1.0
3 (A)	141.47 ± 10.37	7.3	39.54 ± 4.10	10.4	122.79 ± 2.48	2.0
4 (C)	106.13 ± 13.53	12.7	36.43 ± 4.32	11.9	120.35 ± 4.87	4.0
5 (B)	220.13 ± 16.29	7.4	48.67 ± 1.58	3.2	125.85 ± 1.29	1.0
6 (A)	152.13 ± 11.70	7.7	41.29 ± 0.97	2.3	123.01 ± 2.35	1.9
7 (C)	150.13 ± 10.54	7.0	31.39 ± 1.75	5.7	122.18 ± 1.82	1.5
Population	151.13 ± 41.32	27.3	40.03 ± 7.42	23.6	122.29 ± 3.50	2.9

A = Group of tiny leaves; B = group of narrow and long leaves; C = group of large leaves; SD = Standard deviation; C.V. = Coefficient of variation. Different letters indicate a significant difference ($p < 0.05$) by Tukey's test in the column.

Castro et al. (2023) [31] studied 25 different commercial teas, obtaining values ranging between 4.80 and 322.80 mg GAE mL^{-1} for phenolic compounds and 9.05 and 85.88 mg RE mL^{-1} for flavonoids. In this sense, *C. adamantium* teas have relevant levels of these metabolites, compared to other commercial teas.

The presence of flavonoids has already been associated with the antioxidant potential in *C. adamantium* leaf tea [6, 8]. In the study by Castro et al. (2023) [8], the antioxidant potential of an aqueous extract of C. adamantium leaves was analyzed, revealing the presence of gallic acid, rutin, and 5,7-dihydroxy-6-methylflavanone, and identifying a correlation between gallic acid content and antioxidant potential.

3.3 Antioxidant activity

The antioxidant activity of *C. adamantium* leaves was explored by Castro et al. (2022) [5]. Based on this, how leaf morphology influences this property was examined. In addition, a relevant difference between Castro et al. (2022) [5] and the present work is the concentration used in infusion preparation, since 0.25% (w:v) instead of 2% (w:v) aims to have greater palatability, considering that high concentrations in the preparation of the infusion leave the product very bitter. This analysis allows us to understand whether lower preparation concentrations can be carried out without losing biological activity.

The antioxidant potential showed behavior consistent with the groups proposed in the morphological part. The most significant activity was observed for cluster B, followed by cluster A and, finally, cluster C (Figure 3).

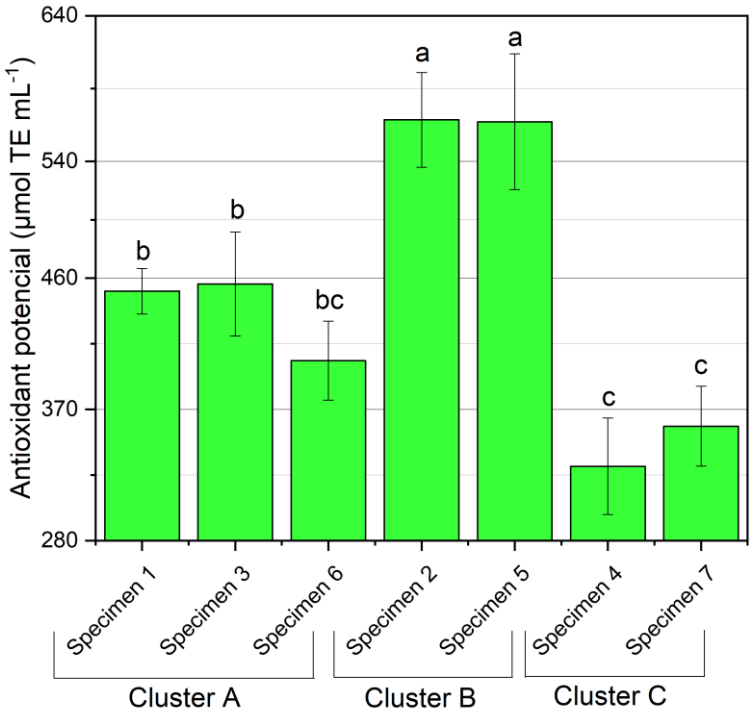

Figure 3: The antioxidant potential of Campomanesia adamantium *leaf teas. TE = Trolox equivalent. Using the Tukey test, different letters indicate significant differences ($p < 0.05$).*

When performing the principal component analysis (PCA), verifying the formation of the same cluster separation observed in the morphological part is possible. In this way, the shapes of the leaves are directly related to the chemical composition and antioxidant potential, considering that the same similarity was observed between the specimens in both situations. The separation was mainly due to dimension 1 (Dim1 = 85.6%), simultaneously, the impact of the tests on the PCA represented by the arrows shows that the levels of phenolic compounds, flavonoids, and tannins have increasing values from left to right; therefore, cluster B (narrow

and long leaves) is most associated with these characteristics, followed by cluster A (small leaves) and C (large leaves) (Figure 4). In addition, the intra-cluster chemical variation is concentrated in Dim2, representing only 10.9% of the samples' dissimilarity.

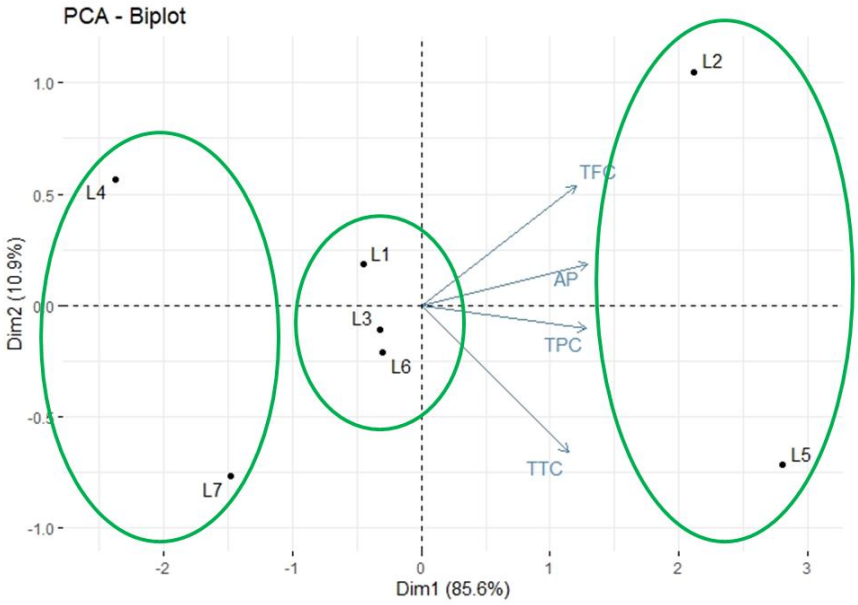

Figure 4: Principal component analysis (PCA) of tea leaf samples from different Campomanesia adamantium *specimens. TPC = Total Phenolic compounds; AA = Antioxidant potential; TFC = Total Flavonoids; TTC = Total Tannins.*

The antioxidant potential of *C. adamantium* leaves infusion was previously reported by Castro et al. (2022) [5]. These authors proposed that the flavonoids of this preparation can be associated with the antioxidant potential observed in the samples. Using the Pearson correlation test, a positive and significant correlation was found for the antioxidant potential and the levels of phenolic compounds ($r = 0.9083$; $p = 0.0046$) and flavonoids ($r = 0.9129$; $p = 0.0041$), while tannins showed a lower, albeit significant, correlation ($r = 0.7621$; $p = 0.0464$). This reinforces the hypothesis of Castro et al. (2022) [5] about the relationship between flavonoids and antioxidant potential in *C. adamantium* leaves infusion.

Phenolic compounds are known in the literature for their antioxidant capacity, due to the presence of the phenol group, which can donate hydrogen or accept electrons without breaking the aromatic structure, thus inhibiting radical formation [32, 33].

The results obtained demonstrate a clear relationship between the morphology, chemical composition, and antioxidant properties of *C. adamantium* teas within the studied population, reinforcing the relevance of domesticating to standardize the raw material and guarantee the quality of teas for commercialization.

4. CONCLUSION

C. adamantium leaves exhibited high morphological variability, even under controlled *ex-situ* cultivation conditions. The seven specimens were classified into three groups: small leaves (samples 1, 3, and 6), narrow and elongated leaves (samples 2 and 5), and large leaves (samples 4 and 7). The levels of phenolic compounds, flavonoids, tannins, and antioxidant potential mirrored this grouping pattern. The narrow and elongated leaf group showed the highest concentrations of phenolic compounds, flavonoids, and antioxidant activity. These findings reinforce the importance of domestication and selective breeding of this species to achieve greater uniformity in leaf traits, contributing to the standardization and quality of tea products derived from *C. adamantium*.

It is noteworthy that the antioxidant activity observed in the teas was obtained using a 0.25% (w/v) infusion, a relatively low concentration compared to values reported in the literature, which highlights the species' promising potential. Further studies are recommended to evaluate consumer acceptability and purchase intent regarding *C. adamantium* teas

5. ACKNOWLEDGMENT

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