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Influence of the Collection Site on the Chemical Composition and Potential Antioxidant and Photoprotector of Teas from the Leaves of *Campomanesia adamantium* (Cambess.) O. Berg

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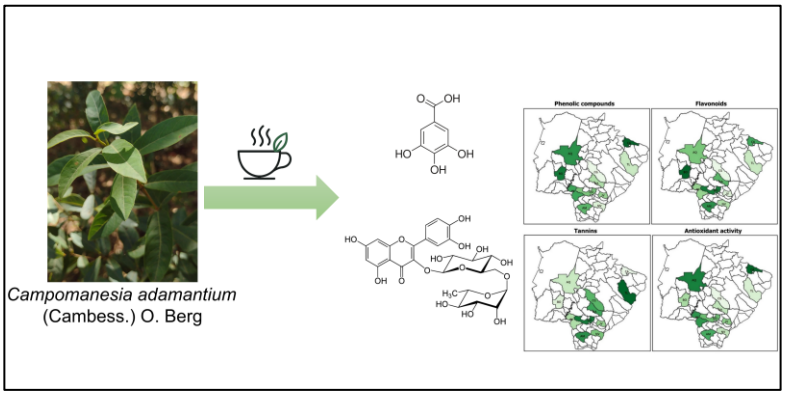
The need for alternative products that aid in the treatment of diseases is becoming increasingly common. As a result, medicinal plants present themselves as an alternative for the treatment and prevention of comorbidities. Within this context, *Campomanesia adamantium* emerges as a species of great interest in the Cerrado, with significant economic, cultural, and historical value in Mato Grosso do Sul. However, there is still a lack of studies evaluating its therapeutic potential. The secondary metabolites vary due to biotic and abiotic factors, which interfere with the therapeutic action of the plant. Therefore, the present study aimed to evaluate the variation in chemical composition and the antioxidant and photoprotective potential of teas made from the leaves of *C. adamantium* collected in eleven municipalities of Mato Grosso do Sul. The teas were prepared by infusion, at a ratio of 0.5% (w/v). Spectrophotometric methods were used to determine the levels of phenolic compounds, flavonoids, tannins, and antioxidant and photoprotective potential, as well as the determination of compounds by high-performance liquid chromatography. The results indicated variation in the chemical composition of the leaves concerning the municipalities of collection, which resulted in a variation in antioxidant potential between 11.5% and 87.2%. Intense or excessive exposure to UV-A and UV-B rays can cause health damage and premature aging; therefore, the samples presented an SPF higher than 13, classifying them in the categories of low and medium protection. Among the municipalities analyzed, the samples collected in the municipality of Cassilândia stood out, presenting higher levels of secondary metabolites and, consequently, the best potential, highlighting the region compared to the others.

Graphical abstract



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1. Introduction

Tea is among the most consumed drinks worldwide due to its flavor and aroma, and it has been used for therapeutic purposes since ancient times and continues to the present day. The therapeutic properties of teas result from the action of secondary metabolites and can be changed depending on the collection site, seasonality and part of the plant [1].

Secondary metabolites perform functions such as defense against pathogens, pollination, attracting pollinators, regulating growth, and responding to stress conditions, such as infections and ultraviolet radiation [1].

Brazil has many plant species, many of which have therapeutic and pharmacological properties. In this context, the Cerrado Biome stands out, characterized as the second largest biome in Brazil, in addition to being one of the main biomes in Mato Grosso do Sul (MS). Recognized as the tropical savanna, it is estimated that the Cerrado is home to around 12,000 species of plants, almost 5,000 of which are endemic, that is, exclusive to this region [2].

Among the native species of the Cerrado are species of the genus *Campomanesia*, traditionally known as guavira [3]. Plants of this genus stand out in the region due to their economic potential and are recognized by State Law No. 5,082 of November 2017 as a symbol of Mato Grosso do Sul.

In this scenario, *Campomanesia adamantium* represents economic and food value for the region, in addition to having its use driven by its presence in MAPA/MMA Ordinance No. 10 of July 21, 2021, which establishes a list of native socio-biodiversity species of food value, to sell in natura or their derivative products. This ordinance classifies *C. adamantium* as one of the plants that have food value, released for consumption, in which the bark of the stem and leaves can be used in teas and the fruit in natura or processed in the manufacture sweets, jellies, liqueurs, ice cream, juice, pie, pudding, yogurt, among other foods [4].

Considered a medicinal plant, *C. adamantium* presents a variety of secondary metabolites. A diverse number of bioactive compounds have already been observed in different parts of the plant, especially the leaves and parts of the fruit, such as the pulp and peel [5, 6, 7].

Regarding the chemical composition of the ethanolic extract of *C. adamantium* leaves, flavonoids, phenolic compounds, tannins, and saponins were identified [8, 9]. Coutinho et al. [10] identified flavonones and chalcones in the methanolic extract of the leaves, these being: 7-hydroxy-6-methyl-5-methoxyflavanone, 5,7 dihydroxy-6-methylflavanone, 5,7-dihydroxy-8-methylflavanone, dimethylflavanone 2',4'-dihydroxy-6'-methoxychalcone, 5,7-dihydroxy-6,8 2',4'-dihydroxy-5'-methyl-6'-methoxychalcone and 2',4'-dihydroxy-3',5 ´-dimethyl-6´-methoxychalcone.

In aqueous extracts of *C. adamantium* leaves, glycosylated flavonols were identified, the main ones being dihexoside/quinic acid, myricetin O-pentoside, myricetin O-deoxyhexoside, quercetin O -pentoside and myricetin O-(O-galloyl) -pentoside [11]. The study conducted by Sá et al. [12] showed that the concentrated aqueous fraction of tannins from C. adamantium leaves had gallic acid and valoneic acid in its composition.

Castro et al. (2023) [9] reported the presence of gallic acid and rutin in leaf extracts using different concentrations of ethanol and water. Furthermore, recent studies also demonstrate the presence of gallic acid, catechin, and epicatechin in the methanolic extract of *C. adamantium* leaves [13].

Regarding the activities presented by *C. adamantium*, the antioxidant, photoprotective, anti-inflammatory and antimicrobial potential stands out [5, 9, 14, 15]. Furthermore, research has shown promising activities against cancer cells, confirming the potential use of the species [16, 17].

Given this and considering that the levels of secondary metabolites in plants vary according to biotic and abiotic factors, the objective was to evaluate the variation in the chemical composition and antioxidant and photoprotective potential of *C. adamantium* leaves teas collected in eleven municipalities in Mato Grosso do Sul.

2. Material and Methods

2.1 Reactives and instruments

UV/Vis spectrophotometer (Global Trade Technology, Brazil). High-performance liquid chromatograph (HPLC Shimadzu, Japan) with diode array detector (DAD). ODS HYPERSIL column (C-18, 150 mm long x 4.6 mm diameter, Thermo Electron Corporation, United States), freeze dryer (Alpha 1-2LD Plus, Christ, Germany). Gallic acid and rutin standards were purchased from Sigma-Aldrich, United States.

2.2 Material collection

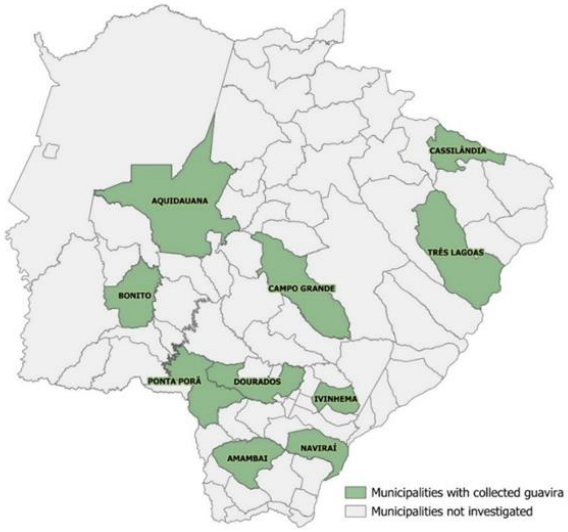

Fig. 1. Municipalities of *C. adamantium* collections in Mato Grosso do Sul. Source: Authors (2023).

The samples were collected in February 2023 from eleven municipalities in Mato Grosso do Sul. In each municipality, leaves were collected from five individuals, each with a planting age of 3 years (Figure 1). The collection was registered in the Brazilian government's National Genetic Heritage and Traditional Knowledge Management System (SisGen) under the code A4B1623.

2.3 Preparation of teas

Twenty grams of leaves from each sample were dried at room temperature and crushed in a blender for later preparation of teas. The samples were prepared to simulate the preparation of teas sold in sachets, which generally

contain 1 g of sample for 200 mL of water, which represents a concentration of 0.5% (m/v). Samples were prepared by infusion following the methodology of Catelan et al. [18]: the leaves were left in contact with water previously heated to 95–100 °C for 10 minutes in a closed container, then left in contact for 20 minutes at room temperature to carry out the filtration step. All extracts were filtered and subsequently lyophilized at -42 °C and under a vacuum of 0.045 mbr. The calculation of the extraction yield was carried out using the dry mass of the plant about the mass of the lyophilized extract. The humidity of the leaves was 75%.

2.4 Evaluation of chemical composition

After lyophilization of the aqueous extracts, all samples were prepared at a concentration of 1 mg mL^{-1}. The analyses were carried out for the 5 individuals collected in the previously mentioned municipalities, and all tests were carried out with 5 replicates per sample.

2.4.1 Exploratory analysis by molecular absorption in the UV/Vis region

Scanning was carried out with a spectrophotometer in the ultraviolet and visible region (UV-Vis) with a concentration of 1 mg mL^{-1} at wavelengths from 200 to 800 nm, with a reading interval of 5 nm, using the MetaSpec Pro software, in a quartz cuvette.

2.4.2 Content of phenolic compounds, flavonoids, and tannins

The content of phenolic compounds was determined based on the Folin-Ciocalteau colorimetric method Djeridane et al. [19]. For this method, 0.5 mL of Follin-Ciocalteau reagent (1:10 v/v) and 1000 µL of distilled water were added to 100 µL of each sample, waiting 1 min. The addition was made of 1500 µL of 20% aqueous sodium carbonate solution. The solution was left protected from light to react for 120 min. The reading was carried out on a spectrophotometer at a wavelength of 760 nm. For quantification, an analytical curve was prepared with gallic acid (a = 0.0008; b = 0.0015; R^2 = 0.9875) as standard at concentrations 10–1000 µg mL^{-1}, and the result was expressed in mg of the equivalent of gallic acid (AGE) per g of lyophilized extract.

Determining flavonoid content followed the methodology proposed by Djeridane et al. [19]. To every 1000 µL of each sample, 1000 µL of 2% aluminum chloride in methanol solution was added. The solution was reacted for 15 min, and the reading was taken on a spectrophotometer at a wavelength of 430 nm. Rutin at a concentration of 10–50 µg mL^{-1} was used as a reference for quantification (a = 0.0019; b = 0.0105; R^2 = 0.9990), and the result was expressed in mg of rutin equivalent (RE) per g of lyophilized.

The tannin content was determined by the Folin-Denis spectrophotometric method, with tannic acid as reference, according to Pansera et al. [20], with adaptations in volumes, without changing the proportions. Initially, 0.5 mL of Foli-Denis reagent was added to 0.5 mL of the sample, shaking and waiting 3 minutes. Sequentially, 0.5 mL of 8% (m/v) sodium carbonate was added, homogenizing and waiting for the reaction to take place for 2 h in the dark for later reading, in which the absorbance was measured at a wavelength of 725 nm. For quantification, tannic acid (a = 0.03837; b = 0.009; R^2 = 0.99826) was used at a concentration of 0.5–80 µg mL^{-1}, and the result was expressed in mg tannic acid equivalent (ATE) per g of lyophilized extract.

2.4.3 Composition analysis by high-performance liquid chromatography with diode array detector (HPLC-DAD)

The chromatographic profile of the samples was determined on a liquid chromatograph (HPLC) with a diode array detector (DAD). The injection volume was 100 µL at a flow rate of 1 mL min^{-1}. The mobile phase consisted of ultrapure water 0.1% formic acid (solvent A) and 100% methanol (solvent B) with a gradient elution program of: 0 min 5% B; 10 min 7.5% B; 15 min 10% B; 15.50 min 35% B; 22 min 55% B; 35 min 67% B; 50 min 67.65% B; 52 min 5% B maintaining this proportion until 52.5 min. A time of 3 minutes between injections was determined to stabilize the system. The samples and the mobile phase were filtered with a 0.45 µm filter and then degassed using an ultrasonic bath before performing the analysis.

The analytical standards, gallic acid and rutin, were injected under the same conditions used in the samples. The chromatographic peaks were confirmed by comparing their retention time (RT) and molecular absorption spectra in the UV region.

Compounds were quantified using the external standard method with analytical curves at concentrations of 1-1000 µg mL^{-1}. The results of the linear regression of the analytical curves were expressed in µg/mg for gallic acid (a =-547.09; b =259777; r^2 = 0.9890; λ = 215 nm) and rutin (a = 278673; b = 33975; r^2 0.9874, λ = 215 nm). The signal-to-noise ratio estimated the limits of detection and quantification and was 0.07 and 0.23 µg mL^{-1} for gallic acid and 0.13 and 0.43 µg mL^{-1} for rutin, respectively.

2.5 Biological potentials of *C. adamantium* teas

2.5.1 Antioxidant activity

The antioxidant activity of the samples was evaluated using the DPPH (1,1-diphenyl-2-picrylhydrazyl) free radical method described by Capanoglu et al. [21]. For each 100 µL of the sample, 2000 µL of 0.004% DPPH was added, waiting for the reaction for 30 min in the light and reading on a spectrophotometer at a wavelength of 517 nm. The results were expressed in percentual of inhibition.

2.5.2 Photoprotective potential

The sun protection factor (SPF) was evaluated between 290 and 320 nm with a reading interval of 5 nm, based on the absorbances obtained in the exploratory analysis by molecular absorption in the UV/Vis region and the SPF was calculated according to Mansur et al. [22] Dutra et al. [23].

2.6 Statistical analysis

Statistical analysis was performed in R Studio software R Core Team, 2021. The normality and homoscedasticity of the samples were verified, where there was a lack of normality in the data. Sequentially, the Kruskal-Wallis non-parametric test was used to verify the presence of a significant difference of 5% between the samples with the "FSA" package [24]. After rejecting the hypothesis of the absence of variance between samples, Dunn's post hoc test was applied with 5% significance using the "companion" package [25]. Test correlation was performed using the "corrplot" package [26].

3. Results and Discussion

The results demonstrated that all teas prepared with samples

collected in the eleven municipalities had phenolic compounds, flavonoids, and tannins in their composition (Table 1). However, it is possible to note that there was significant variation using the Kruskall-Wallis test ($p < 0.05$), and the highest levels were presented in the samples collected in Cassilândia, on the other hand, the individuals collected in Campo Grande and Três Lagoas presented the lower levels of metabolites and consequently lower antioxidant and photoprotective potential (Table 1).

It is known that plants can be characterized as large factories for the production of bioactive compounds. In this scenario, such compounds are synthesized by them according to the adaptive conditions to which they are exposed, which may be related to biotic factors that can be caused by pathogens and abiotic agents such as radiation, temperature, rainfall, seasonality, among others [1].

The influence of abiotic factors, such as seasonal variation, has already been reported in the study by Coutinho et al. [5] with hexane, ethyl acetate, ethanolic, and methanolic extracts obtained by maceration of *C. adamantium* leaves. The results demonstrated that the beginning of spring increased the flavanones and chalcones content for samples collected in the same geographic region, confirming that seasonal variation and the plant's stage of development affect their constituents.

Regarding the potential presented by *C. adamantium*, the antioxidant potential stands out (Table 1, Figure 2). Studies report that this potential may be associated with phenolic compounds and flavonoids due to their ability to eliminate free radicals [27].

Table1. Contents of secondary metabolites and antioxidant and photoprotective potential present in teas obtained with *C. adamantium* leaves collected in municipalities in Mato Grosso do Sul.

Cody	Phenolic compounds (mg GAE g^{-1} ± SD)	Flavonoids (mg RE g^{-1} ± SD)	Taninns (mg TAE g^{-1} ± SD)	Antioxidant potential (% ± SD)	SPF ± SD
NA	217.59±47.60^{abc}	61.42±13.05^{ab}	82.88±7.20^{ab}	31.04±5.90^{bc}	14.21±1.20^{a}
AQ	380.84±42.43^{ab}	55.00±8.46^{ab}	59.60±5.92^{a}	73.90±12.97^{ab}	16.59±0.84^{a}
PP	335.66±68.60^{abc}	53.70±10.78^{ab}	61.12±8.80^{a}	66.078±10.27^{abc}	16.63±1.97^{a}
AM	317.71±61.79^{abc}	72.73±21.50^{ab}	84.31±16.35^{ab}	61.54±16.03^{abc}	15.29±0.47^{a}
NV	184.62±40.39^{bc}	52.11±11.07^{ab}	70.32±6.11^{ab}	31.04±5.90^{bc}	15.13±1.59^{a}
IV	256.41±47.19^{abc}	29.03±4.60^{b}	68.69±2.74^{ab}	51.16±10.36^{abc}	15.22±0.94^{a}
TL	213.09±41.87^{bc}	32.07±6.99^{b}	97.64±7.90^{b}	20.5±6.38^{c}	13.03±1.71^{a}
CA	468.99±45.73^{a}	63.92±21.84^{ab}	101.97±9.56^{b}	87.83±1.07^{a}	16.35±0.64^{a}
BN	438.5065±80.34^{ab}	87.39±9.16^{a}	132.0±8.41^{b}	38.41±8.58^{abc}	15.96±1.90^{a}
DO	305.20±16.43^{abc}	73.78±11.12^{a}	87.72±2.88^{ab}	54.29±13.98^{abc}	15.66±0.32^{a}
CG	452.29±29.82^{ab}	87.34±19.12^{a}	62.99±9.84^{ab}	69.64±3.36^{abc}	13.85±2.10^{a}

SD = Standard deviation; GAE = Gallic acid equivalent; RE =Rutin Equivalent; TAE = Tannic acid equivalent. Different letters indicate a significant difference ($p < 0.05$) in the two-sided t-test. NA = Nova Alvorada; AQ = Aquidauana; PP = Ponta Porã; AM = Amambai; NV = Naviraí; IV = Ivinhema; TL = Três Lagoas; CA = Cassilândia; BN = Bonito; DO = Dourados; CG = Campo Grande.

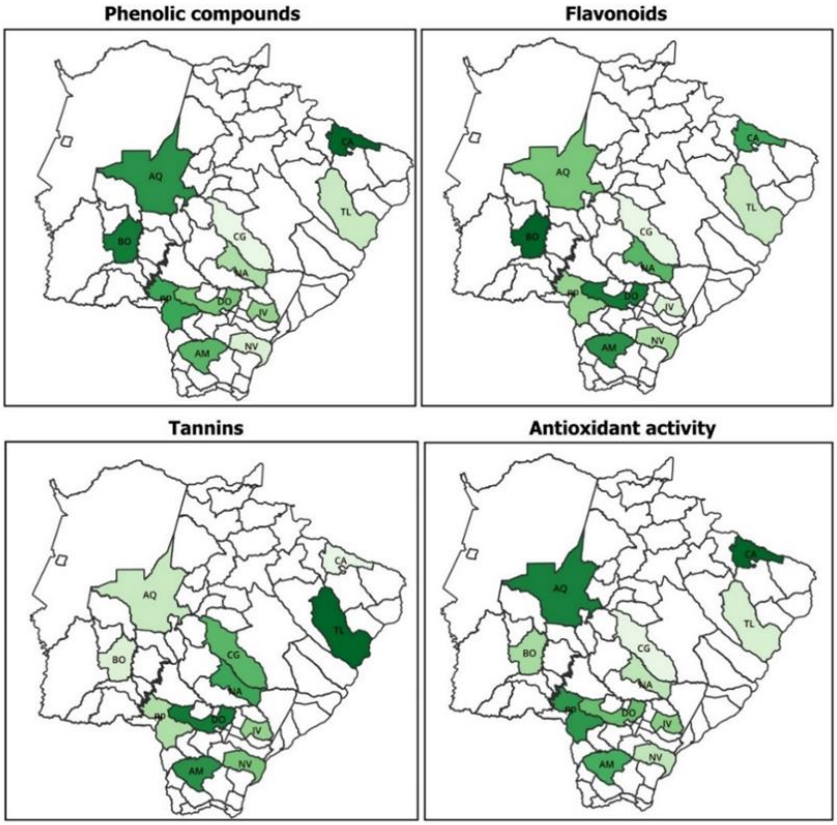

Fig. 2. Map of secondary metabolic intensity and antioxidant potential in different municipalities where the samples were collected. Source: Authors (2023).

The results obtained in the present study demonstrate a significant variation using the Kruskal-Wallis test ($p < 0.05$) between municipalities, which presented percentages of DPPH free radical inhibition between 11.5 and 87.2%. This variation can be observed in Figure 2, where the map expresses different shades of color to represent the data. Darker color indicates higher levels of secondary metabolites and greater antioxidant potential.

Regarding the DPPH• test, the antioxidant potential of the species has previously been reported in the study by Coutinho et al. [10], in which the methanolic extract of leaves collected in the municipalities of Bonito, Bela Vista, Dourados and Jardim exhibited an antioxidant potential of 52.0-92.2%. It was found that the highest antioxidant potential was obtained for samples collected in the municipalities of Cassilândia and Aquidauana, which also presented a content of phenolic compounds close to the content found by Catelan et al. [28] which was 477.99 ± 11.23 mg g^{-1}.Antioxidant activity is related to the structure of phenolic compounds and may vary according to the number of hydroxyl substituents in their constitution [29]. Controlling the number of reactive radicals helps prevent and treat various diseases [30]. In this way, antioxidants can stimulate cellular defenses and help prevent oxidative damage, delaying premature aging and improving quality of life [31].

However, the presence of phenolic compounds does not guarantee antioxidant potential since changes in the interaction with free radicals may occur depending on the phenolic compound present in the sample [32]. This situation was observed for samples collected in the municipality of Bonito, which, even with the high content of phenolic compounds, presented lower antioxidant activity than the others.

From the perspective of the antioxidant potential and its possible applications, the photoprotective potential was evaluated, in which ANVISA (2012) [33] determines a minimum SPF of 6 for sunscreens and 2 for multifunctional products. Products corresponding to SPF 6-14.9 fall into the low protection category, while SPF 15-29.9 corresponds to medium protection.

Given this classification, it is observed that the samples called NA, CG and TL were those that presented the lowest SPF, classifying them in the ANVISA category of low protection, on the other hand, the other samples presented SPF higher than 15, classifying them in the category from ANVISA of medium protection, which may be related to the high content of secondary metabolites (Table 1), highlighting the results presented in Figure 3 that demonstrate a positive correlation between the content of phenolic compounds and the antioxidant and photoprotective activity performed by the samples.

The photoprotective potential of Campomanesia leaf extracts has been explored in the literature. Catelan et al. [28] analyzed the SPF of extracts obtained by maceration with ethanol with leaves of *C. adamantium, C. guazumifolia, C. sessiliflora* and *C. xanthocarpa*. The results indicated that the formulations presented SPF values > 6, with the potential for photoprotective or multifunctional products.

The sun protection factor is directly associated with defense mechanisms against oxidative stress from reactive oxygen and nitrogen species, resulting from UVA and UVB radiation in contact with human skin [34]. However, the harmful effects caused by radiation can be minimized by using sunscreens and multifunctional products. Therefore, the observed activity may be related to the high content of phenolic compounds due to their ability to absorb ultraviolet radiation through electron resonance in aromatic rings [35].

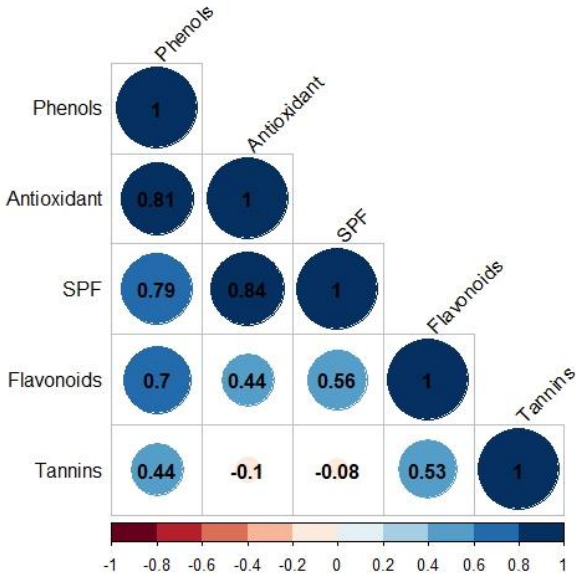

Fig. 3. Correlation between secondary metabolite levels and antioxidant and photoprotective potential of teas of *C. adamantium* leaves.

The antioxidant activity, together with the in vitro photoprotective activity presented by the extracts, are promising for future products in order to bring benefits to human health. However, this study indicates changes in the chemical composition of plants depending on the collection site, consequently altering their potential (Figure 2).

The UV spectrum indicated more intense absorption peaks between 200 and 400 nm with similar behavior (Figure 4 a-b). Castro et al. [9] observed in their studies with ethanolic, aqueous and hydroethanolic extracts of *C. adamantium* leaves bands close to 257 nm that corroborate the results found in the present study, as they demonstrate peaks in this region of the spectrum that indicate the presence of phenolic compounds.

In the HPLC-DAD analysis (Figure 5), rutin was identified (retention time 24.33 ± 0.21 min) for most municipalities, except the NV sample, which presented only gallic acid (retention time 1.71 ± 0.15 min).

The presence of gallic acid had already been reported in the study by Pascoal et al. [36], in which he quantified gallic acid in the ethanolic extract of *C. adamantium* leaves at a concentration of 29.98 ± 1.10 μg mg^{-1}. This acid is a biologically active molecule against oxidative stress, which may be related to the number of hydroxyl groups in the ring structure and its ability to increase the activity of enzymes such as: superoxide dismutase, catalase, glutathione reductase and glutathione peroxidase, in addition to present anti-inflammatory, antimicrobial, antitumor and anticancer properties [37-40].

Rutin has antioxidant, anticancer, antimicrobial and anti-inflammatory activities evidenced in the literature, boosting the use of such molecules in herbal medicines [41-44].

As described, gallic acid and rutin already have antioxidant potential, as evidenced in the literature, and these compounds can contribute to the antioxidant potential observed for *C. adamantium* teas. The study by Castro et al. [9] demonstrated that gallic acid correlates with the antioxidant potential for

extracts of *C. adamantium* leaves.

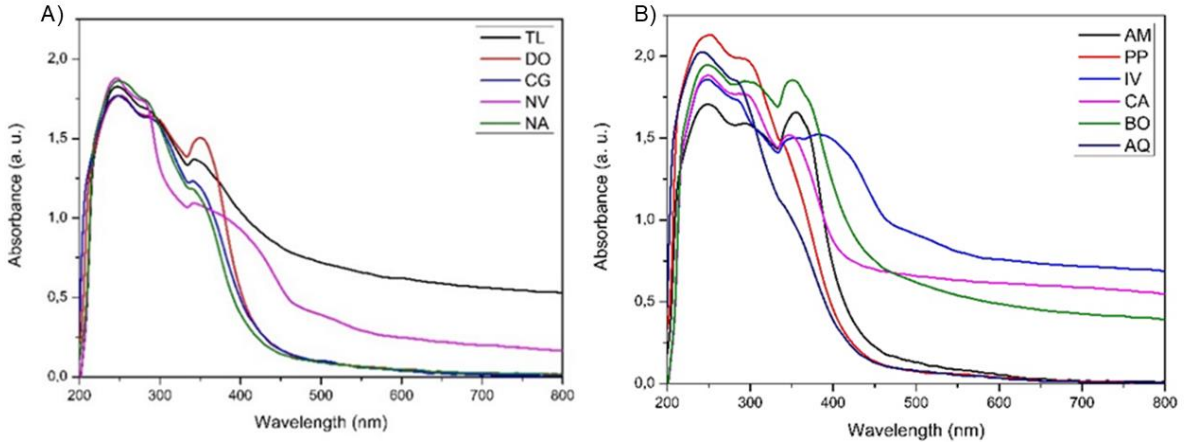

Fig. 4. Molecular absorption spectra of *C. adamantium* leaves collected in the municipalities of MS.

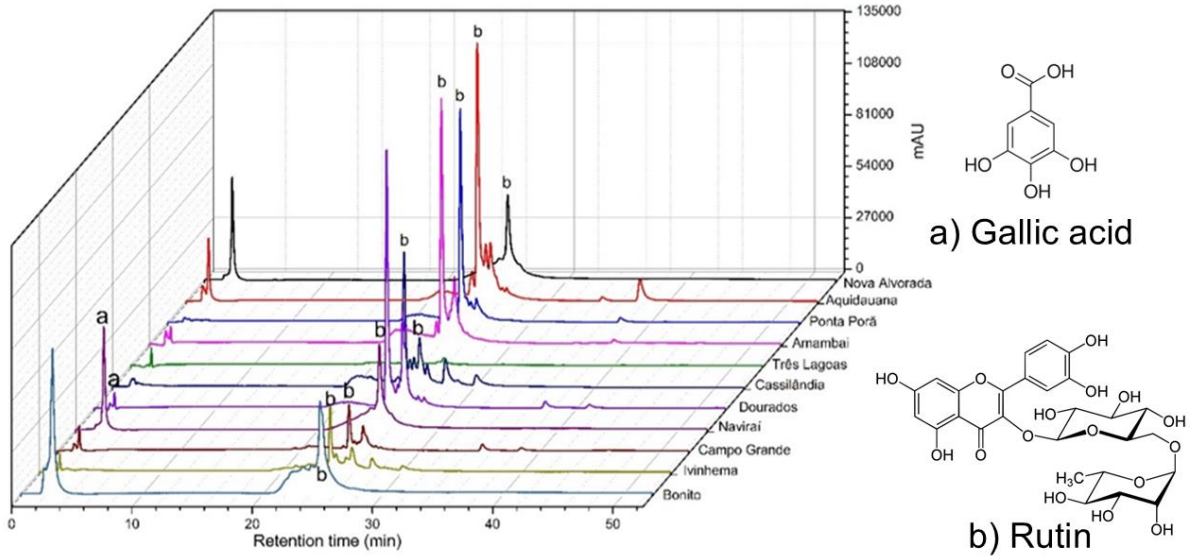

Fig. 5. Chromatogram of samples of *C. adamantium* leaves collected in the municipalities of Mato Grosso do Sul.

Table 3. Gallic acid and rutin contents in aqueous extracts of *C. adamantium* leaves collected in municipalities in MS.

Sample	Rutin content (mg g^{-1} ±SD)	Gallic acid content (mg g^{-1} ± SD)
NA	23.89 ± 9.47	ND
AQ	85.18 ± 14.03	ND
PP	55.86 ± 18.42	ND
AM	48.20 ± 10.18	ND
NV	ND	20.79 ± 1.74
IV	26.18 ± 10.17	ND
TL	ND	ND
CA	12.47 ± 6.10	ND
BN	27.63 ± 13.40	ND
DO	78.50 ± 21.01	ND
CG	26.23 ± 8.85	ND

ND: Not detected; Teor ± Desvio-padrão; NA = Nova Alvorada; AQ = Aquidauana; PP = Ponta Porã; AM = Amambai; NV = Naviraí; IV = Ivinhema; TL = Três Lagoas; CA = Cassilândia; BN = Bonito; DO = Dourados; CG = Campo Grande.

The AQ sample presented the highest content of rutin in its composition (Table 3), which may be related to the high antioxidant potential, as shown in Figure 3, where the content of phenolic compounds presented a positive relationship with the antioxidant and photoprotective potential played by the samples. Among the individuals analyzed for the municipalities of Bonito, Aquidauana, and Nova Alvorada, it was possible to identify and quantify rutin in 60% of the samples (Table 3).

Neither rutin nor gallic acid was identified in the TL sample (Table 3), whereas the samples from Nova Alvorada and Campo Grande showed lower levels of rutin than the other municipalities.

The results obtained by cluster analysis using the levels of phenolic compounds, flavonoids, and tannins showed variations between the municipalities where C. adamantium leaves were collected (Figure 3).

Sample collection was carried out during the summer, characterized by high rainfall in the cerrado [45]. Coutinho et al. [5] had already demonstrated in their study with organic extracts from *C. adamantium* leaves that seasonal variation leads to changes in the chemical composition of the plant, indicating that the influence of external factors generates the need for the species to adapt to the environment.

Kabubii et al. [46], through their study with the aqueous, ethanolic, and methanolic extracts of *Rosmarinus officinalis*, showed that in addition to the rainfall index, geographic

variation and the stage of development of the plant influence the chemical composition. The samples analyzed in the present study had an average age of 3 years. However, it is worth noting that due to the various collection municipalities, including reserves and villages, it was not possible to accurately determine the stage of development of each individual, which may explain the high standard deviation between the means of the collection municipalities (Table 2).

The study conducted by Crispim et al. [47] shows high genetic diversity in all *C. adamantium* populations from different municipalities, with geographically closer populations being more genetically similar.

Another important factor about the variability presented in the results is the type of soil present in each collection municipality. According to the Brazilian Soil Classification System (SiBCS), the municipality of Aquidauana has hydromorphic planosol soils, generally characterized by having a high concentration of clay and slow or very slow permeability [18].

The municipality of Bonito is located in the southwest region. It has red and red-yellow argisols, while Cassilândia, located in the Bolsão region, has red argisols in a large part of its extension, which are characterized by red to yellow colors and clayey texture, with moderate drainage and low levels of organic matter [48]. This municipality had a high level of phenolic compounds.

Ponta Porã and Amambai are located in the same region called South-border, which may explain the close values for the levels of secondary metabolites and biological potentials (Table 6). According to Santos et al. [48], except Aquidauana, Bonito and Cassilândia, the other municipalities have, in the majority of their extension, the soil of the red-oxisol type, which is characterized by great homogeneity of characteristics along the profile, have good drainage and dark red color due to to the significant presence of iron oxides, in addition, it can vary from low to high natural fertility and availability of micronutrients.

The soil variation between the collection municipalities may have affected the metabolite levels and consequently the antioxidant activity, and the best results obtained were for the samples collected in the municipality of Cassilândia, which has its territory completely covered by the Cerrado, while the samples collected in Campo Grande, they presented the lowest levels of metabolites and consequently antioxidant activity.

In relation to the photoprotective potential played by teas, it was possible to determine that the variation in the content of secondary metabolites did not affect the SPF results obtained, indicating that the collection site did not influence such activity, enhancing the use of teas for the development of future products that perform photoprotective function.

4. Conclusions

Considering the therapeutic potential played by *C. adamantium*, the present study demonstrates the influence of the sample collection site on the levels of secondary metabolites, causing a direct influence on the antioxidant potential played by the plant. The samples showed promising photoprotective potential for future applications in new products and it was determined that the municipality of Cassilândia presented the best results for the respective tea. This study shows that the place of cultivation changes the properties of the plant, suggesting that external conditions lead the plant to adapt to the environment, affecting the levels of secondary metabolites. Therefore, we conclude that a broader study regarding the change in composition and its effect on the plant's potential is recommended.

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Author Contributions

JKMS = Conceptualization, Validation, Investigation, and Writing - Original Draft; TLAC = Formal analysis, Investigation, Visualization, and Writing - Review & Editing; JBO = Formal analysis, and Software; CALC = Resources, Project administration, Funding acquisition, and Writing - Review & Editing.

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