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ORIGINAL PAPER

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TALINUM PANICULATUM (JACQ.) GAERTN. LEAVES – SOURCE OF NUTRIENTS, ANTIOXIDANT AND ANTIBACTERIAL POTENTIALS

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ABSTRACT

Background. The diet of most of the population is limited to a reduced number of plants, even in areas that have a varied and extensive diversity, such as Brazil. Unconventional Food Plants (UFPs) are plants considered exotic, native, and wild that grow naturally and can be used as food. Among these is *Talinum paniculatum* (Jacq.) Gaertn., which is widespread throughout Brazil and can be a potential source of nutrients. Due to the potential of utilization of UFPs in human food and the lack of studies regarding the composition of *T. paniculatum*, this study aimed to assess the nutritional value of *T. paniculatum* leaves, their antioxidant capacity, and their antimicrobial activity for possible use in food.

Materials and methods. The characterization of the leaves of *T. paniculatum* was carried out through analyses of proximal composition, color, ascorbic acid, mineral profile, and antinutritional factors showing the presence of condensed and hydrolysable tannins and nitrates in low concentrations. Solvents of water, ethanol, ethanol/water, methanol, methanol/water, methanol/acetic acid and acetone/water/acetic acid were used to evaluate the extraction yield of phenolic compounds, antioxidant capacity, and antibacterial activity of the extracts.

Results. High contents of protein (18.61 g 100 g^{-1}), insoluble dietary fiber (34.75 g 100 g^{-1}), ascorbic acid (81.03 mg 100 g^{-1}), magnesium, potassium, and calcium (649.600, 411.520 and 228.117 mg 100 g^{-1}, respectively) were observed. Extraction using the mixture of solvents of methanol/acetic acid showed the highest yield of phenolic compounds (432.73 mg EAG 100 g^{-1}) and antioxidant capacity using the DPPH assay (3144.92 mg 100 g^{-1}). *Bacillus cereus* growth was inhibited by the *T. paniculatum* extracts.

Conclusion. *T. paniculatum* leaves are a source of nutrients and their extracts have antioxidant and antibacterial potentials which can be used as supplements in food to improve one's health.

Keywords: *Talinum paniculatum*, nutritional factors, antioxidant capacity, antibacterial activity

INTRODUCTION

Biodiversity represents the forms of life on earth, such as animals, plants, and microbial species and their interactions with the ecosystems are essential for nutrition and survival human. Even with the emergence of agriculture, many people still rely on wild plants for food and their use is associated with particular wisdom and practices of communities, regions, and countries (WHO, 2015). Brazil is a country with great biodiversity with an abundance of fauna and flora that represent more than 20% of the total species on the planet (FAO, 2017). This variety provides options of wild species for use in foods as new sources of

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nutrients, medicine, and other products. These are mainly consumed by rural populations. Nonetheless, these species are barely exploited and, consequently, do not grant the country's agricultural development (Leal et al., 2018). Examples of wild edible plants consumed in Brazil are chicory (*Eryngium foetidum*) in the Northern Region, and mangarito (*Xanthosoma riedeianum*) and ora-pro-nobis (*Pereskia aculeata*) in the Southeast region (FAO, 2017). Wild edible plants have also been mentioned as Unconventional Food Plants (UFPs) and include native or exotic species, as well as cultivated and spontaneous ones. The most used parts are the fruits, seeds, roots, leaves, flowers, and stems (Leal et al., 2018). Among the UFPs described in the literature, attention should be paid to the species *T. paniculatum* (Jacq.) Gaertn., which is a weed species that spontaneously grows among cultivated plants, as well as on roadsides and wastelands. *T. paniculatum* is widely used in traditional medicine and as a food source and can show antimicrobial activity (Reis et al., 2015). Current studies are related to the medicinal power and phytochemical investigations of *T. paniculatum* (Tolouei et al., 2019) and few others on the characterization of *T. paniculatum* from Brazil can be found (Kinupp and Barros, 2008; Moura et al., 2020; Reis et al., 2015). *T. paniculatum* has shown the presence of nutrients such as proteins and a high content of minerals (magnesium, manganese, potassium, and iron) (Kinupp and Barros, 2008; Moura et al., 2020). The presence of compounds such as terpenes and phytosteroids can have antimicrobial activity and amino acids, nucleosides, chlorogenic acids, organic acids, and O-glycosylated flavone have ethnomedicinal properties (Reis et al., 2015; Tolouei et al., 2019). However, some secondary metabolites found mainly in fruits and vegetables have antinutritional factors, such as tannins, which is a group of phenolic compounds affecting protein utilisation and digestion, and miscellaneous substances, such as cyanogens and nitrate (Francis et al., 2001; Kinupp and Barros, 2008). Not all can be destroyed by thermal treatment and therefore must be identified. The use of *T. paniculatum* in food can be an important part of daily diets as a source of nutrients, serving as a supplement, and also improving health due to the presence of antioxidative compounds (Moura et al., 2020; Reis et al., 2015; Toluei et al., 2009). Assessing the nutrient content and bioactive compounds from unconventional crops may be an alternative to adding value to them by providing insight into the discovery of significant or high levels of specific nutrients or bioactive compounds that may improve market demand. Thus, this study aimed to assess the nutritional value of *T. paniculatum* (Jacq.) Gaertn. leaves, their antioxidant capacity and their antimicrobial activity for possible use in food.

MATERIALS AND METHODS

Collection and drying of *T. paniculatum* (Jacq.) Gaertn. leaves

The *T. paniculatum* (Jacq.) Gaertn. plant was collected (January 2019) from the Horticulture Sector at the School of Agronomy in the Federal University of Goiás (UFG) (16°35'45.9"S, 49°16'50.8"W). A sample of the complete plant was taken for identification at the Herbarium (UFG). The plants were washed in running water and sanitized using sodium hypochlorite solution (0.1 mL L^{-1}) for 15 min. The leaves were manually cut and dried in a forced air circulation oven (Tecnal, TE-394/3, Piracicaba, SP, Brazil) at 35 ±2ºC not to affect the bioactive compounds and improve efficiency with drying, which is faster and more homogeneous (Fig. 1). After drying, the plants were vacuum packed and stored at room temperature and protected from light until analysis was performed.

Proximal composition

The proximal composition was performed according to the Association of Official Analytical Chemists (AOAC, 2019) using method 930.04 for moisture, 930.05 for ash, 960.52 for nitrogen determination and 922.16 for determination of soluble and insoluble dietary fiber. The lipid content was quantified using the method of Bligh and Dyer (1959) using methanol. The carbohydrate content was estimated using the difference method, subtracting from 100 the values of moisture, ash, protein, lipids, and fiber. The total fiber content was quantified by adding up the soluble and insoluble dietary fiber contents. The results were expressed on as dry. The total energy value was calculated using the Atwater and Woods coefficients (1896).

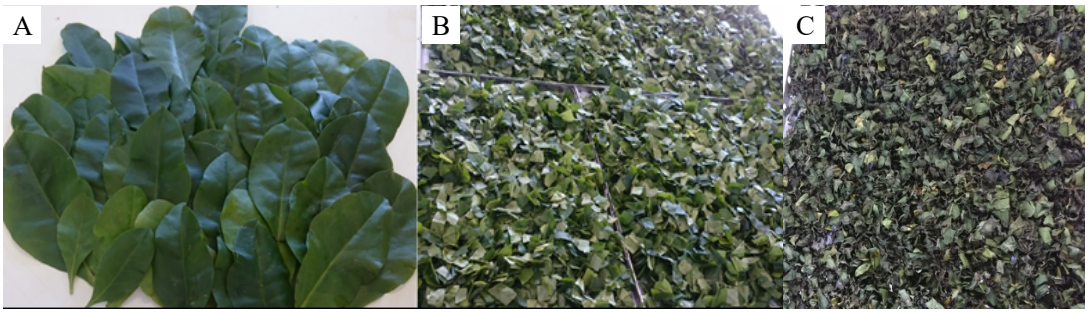

Fig. 1. Leaves of *T. paniculatum*: A – post-sanitization, B – post-cut, C – dry

Minerals and color

The mineral profile was measured by subjecting the samples to microwave digestion (Analytical Provision, DGT100 Plus, São Paulo, Brazil) at a power of 330W for 5 minutes and increasing to 800W for 8 minutes. The determination of minerals was performed using the Inductively Coupled Plasma Optical Emission Spectrometry – ICP-OES (Thermo Fisher Scientific, iCAP 6300 Duo, Massachusetts, USA) and the reading was taken using the axial configuration (Vista AX, Varian, Mulgrave, Victoria, Australia). The results were expressed in mg 100 g^{-1} of sample (Bezerra et al., 2018). The determination of color was carried out using the CieLab scale (L^*, a^*, and b^*) using a colorimeter ColorQuest II (Hunter-Lab, Reston, Virginia, USA), according to Paucar-Menacho et al. (2008) where L^* determines luminosity ($L^* = 0$ black and $L^* = 100$ white), and a^* and b^* determine chromaticity ($+a^*$ red and $-a^*$ green, $+b^*$ yellow and $-b^*$ blue). The saturation or chroma index (C^*) and the angular hue (h^*) were calculated using color parameters a^* and b^*.

Antinutritional analysis and ascorbic acid (vitamin C)

Tannin content was assessed through qualitative identification tests according to Saklani et al. (2012) with modifications. The tests were performed using the filtered extract obtained from the decoction of 5 grams of leaves in 100 ml of distilled water. For the precipitation test, about 2–5 mL was put into tubes by adding a few drops of the solutions: gelatin, ferric chloride reagent and lead acetate test's 10% in which precipitate formation and coloring indicate the presence of tannins and hydrolysable and condensed tannins. Hydrolysable and condensed tannins are evidenced by Stiasny reagent according to Benabdesslem et al. (2017), with modifications, by adding 15 mL of Stiasny reagent to 30 mL of the extract and submitting it to reflux for 30 min. In the presence of condensed tannins, a red precipitate is formed. The hydrolysable tannins were identified with the reaction of 10 mL of filtered extract saturated with 5 g of sodium acetate and the addition of 1 mL of solution of 1% $FeCl_3$ for the appearance of a blue-black tint. The Guignard test was used to detect cyanogenic compounds through a test using picro-sodium paper by observing the red coloring resulting from the reaction of hydrocyanic acid (HCN) with sodium picrate producing isopurpuric acid (Costa, 2001). The determination of nitrate was performed using the methodology proposed by Skoog et al. (1998) by reducing nitrate to nitrite reacting with sulphanilamide and α-naphthylamine measured in absorbance at 520 nm. The results were expressed as mg NO_3^- g^{-1} of sample. The determination of vitamin C was performed by the redox titration using iodine solution (UC, 2011) and the result was expressed in mg of ascorbic acid per mg 100 g^{-1}.

Preparation of different solvents for the determination of total phenolics, antioxidant and antibacterial activities

Seven different solvent combinations were studied to determine total phenolics and antioxidant activity according to the methodology proposed by Michiels et al. (2012), which are: water (W, 100%), ethanol (E, 100%), methanol (M, 100%), ethanol/water (EW, 70% : 30%), methanol/water (MW, 70% : 30%),

methanol/acetic acid (MAC, 99.5% : 0.5%), acetone/water/acetic acid (AWA, 70% : 28% : 2%). The four best solvents for the determination of total phenolics were utilized for the determination of antibacterial activity using concentrate extracts from 25 g of sample and 250 mL of solvent.

Total phenolic compounds and antioxidant capacity

The content of phenolic compounds was determined for each of the extracts following the spectrophotometric method proposed by Chan et al. (2007). Test tubes containing 300 µL of each extract, 1.5 mL of 10% Folin-Ciocalteu reagent (v/v) and 1.2 mL of 7.5% (v/v) sodium bicarbonate solution were homogenized and allowed to stand for 30 min before absorbance was measured at 765 nm. The result was expressed as mg of gallic acid equivalents (GAE) per 100 g of sample. The calibration equation for gallic acid was $y = 0.0282x - 0.0078$ ($R^2 = 0.9991$). The antioxidant capacity was measured using the DPPH$^{\bullet}$ scavenging capacity assay (Chan et al., 2007) and the FRAP (Ferric Reducing Antioxidant Power) assay (Pulido et al., 2000), with modifications. For DPPH$^{\bullet}$ scavenging capacity assay, 1 mL of each diluted extract (200 µg/mL) reacted with 2 mL of DPPH (5 mg/250 mL methanol) for 30 min. The absorbance was measured at 517 nm and the radical scavenging activity was calculated as IC_{50} and expressed as Trolox equivalent (TE) in mg of Trolox per 100 g of sample obtained by ratio [($IC_{50\ (Trolox)}$ / $IC_{50\ (amostra)}$) × 10^5]. The IC_{50} of Trolox used for calculating TE was 0.0516 m mL^{-1}. For FRAP assay, the FRAP reagent (2.7 mL) was homogenized with an aliquot of 90 µL of each extract and 270 µL of distilled water. The mixture was incubated in a water bath at 37ºC for 30 min and the absorbance was measured at 595 nm. Results of the FRAP assay were expressed in µM of $FeSO_4$ per g of sample using the calibration equation for ferrous sulphate ($y = 0.001x + 0.0275$, $R^2 = 0.9905$).

Preparation of strains for antibacterial tests

Four different bacteria were used to assess the antibacterial activity of the extracts (item 2.6): *Bacillus cereus* (ATCC 11778), *Escherichia coli* (ATCC 25922), *Staphylococcus aureus* subsp. aureus (ATCC 25923) and *Salmonella enterica* serovar *Typhimurium* (ATCC 14028) from the collection of the Laboratory of Hygienic-Sanitary Food Control (LCHSA), UFG. The strains were prepared according NCCLS (2006) and the turbidity of microbial suspensions, cultured for 24 h at 36ºC, were adjusted in 0.9% sterile saline water according to a MacFarland standard (0.5).

Disk diffusion and macrodilution methods

The antibacterial activity was evaluated in the extracts at concentrations of 650, 455, 318.5, 223 and 156 mg mL^{-1} using the disc diffusion and macrodilution techniques described by NCCLS (2006). The results of disk diffusion were obtained by measuring the diameter of the halos and were considered as positive when the halo was greater than or equal to 9 mm (Smânia et al., 1995). In the Minimum Inhibitory Concentration (MIC), the inhibition of bacterial growth was observed macroscopically by the turbidity of the tubes (NCCLS, 2006). The minimum Bactericidal Concentration (MBC) was determined according to the methodology described by Mostafa et al. (2018). The results were expressed as 1 (no growth), 3 (light growth), 6 (moderate growth) and 9 (intense growth).

Statistical analysis

All the analyses were carried out in triplicate. The experimental data were submitted to an analysis of variance (ANOVA). The statistical significance between the treatments was analyzed using the Tukey's honestly significant difference (HSD) test ($p \leq 0.05$).

RESULTS

Proximal composition of *T. paniculatum* (Jacq.) Gaertn. leaves

Table 1 shows the proximal composition of the fresh leaves of *T. paniculatum* (Jacq.) Gaertn. The levels of proteins (18.61) were similar to those found by Moura et al. (2020) (18.90) in *in natura* leaves and stem of *T. paniculatum*, respectively. Lipid was higher (6.98) and ash content was lower (22.42) than leaves and stem with 2.98 for lipids and 28.69 for ash. Despite being from the same species, the leaves were harvested in different regions and times, which could justify the variability of nutrient content, which is influenced by season, soil, climate and leaf size and age (Babu et al., 2018). Compared with the leaves

Table 1. Proximal composition and total energy value of fresh leaves of *T. paniculatum* (Jacq.) Gaertn., kcal 100 g^{-1}

Component	Dry base g 100 g^{-1}	Acceptable Macronutrient Distribution Ranges (AMDR) and Adequate Intake (AI) for adults (Institute of Medicine, 2005)
Moisture	5.93 ±0.10	
Total carbohydrates	16.45 ±0.76	45–65%
Protein	18.61 ±0.47	10–35%
Lipid	6.58 ±0.11	20–35%
Soluble dietary fiber	1.19 ±0.24	5–10 g d^{-1}
Insoluble dietary fiber	34.75 ±0.66	15–25 g d^{-1}
Total dietary fiber	35.94 ±0.90	20–35 g d^{-1}
Ash	22.42 ±0.08	
Total energy value	199.46 kcal	

Mean ±standard deviation of three repetitions and four replicates.

of Ora-pro-nobis (*Pereskia aculeata* Miller), which have been reported to have high protein content and levels of total dietary fiber, the protein content found in the present study was similar to the one found by Silva et al. (2014) in the flour of leaves of Ora-pro-nobis (17) and the content of total dietary fiber was higher, at 35.94 and 8.66, respectively. A high content of total dietary fiber was also found in *in natura* leaves of *Curcuma longa* L. (34.47), which are considered as other UFPs with a possible sustainable use (Braga et al., 2018). The total carbohydrate was lower than that found in turmeric leaves and Ora-pro-nobis flour. Plants, except cereals and some legumes, show low concentrations of carbohydrates and lipids that are derived from oilseed sources (Wiesner et al., 2017). According to the Institute of Medicine (2005), based on a 2000 kcal diet, the AMDR for protein is 10–35% of calories and 20–35% of total fiber content per day. Thus, the protein content observed in dry leaves corresponded to 8.21% of the AMDR and the total dietary fiber to 100% of the total fiber content, over 100% of the insoluble fiber and about 20% of the soluble fiber of AI. *T. paniculatum* leaves can be considered to be rich in fiber (min 6 g/100 g) and protein (min 12 g/100 g) (Brasil, 2012).

Mineral analysis and color determination

Tables 2 and 3 show the element analysis and the leaf color parameters of *T. paniculatum*.

The highest contents of elements found in the leaves of *T. paniculatum* were magnesium, potassium, and calcium, with values of 649.6, 411.5 and 228.11 mg 100 g^{-1}, respectively. Sodium (79.062 mg 100 g^{-1}) and manganese (30.575 mg 100 g^{-1}) were also found in significant values. Magnesium, potassium, and calcium contents were lower than those found in *T. paniculatum* as reported by Kinupp and Barros (2008) (2100 mg 100 g^{-1} of magnesium, 6800 mg 100 g^{-1} of potassium, and 1300 mg 100 g^{-1} of calcium); sodium and manganese contents were higher (15.1 and 27.55 mg 100 g^{-1}, respectively). Moura et al. (2020) obtained higher amounts of calcium (1.06%), potassium (7.79%), magnesium (0.85%) and sodium (0.18%) but lower amounts of iron (126.75 µg 100 g^{-1}) and manganese (96.9 µg 100 g^{-1}). The difference in mineral contents is related with cultivation conditions, such as composition of the soil, climate of the region and the agricultural practices employed there (Moura et al., 2020). Some minerals, such as calcium, magnesium, sodium, and potassium are required in larger amounts than others because of the balance of electrolytes in the human body (Wiesner et al., 2017)

Table 2. Mineral composition and ascorbic acid content of *T. paniculatum* dry leaves

Element	Wavelength nm	Sample mg 100 g^{-1}	Dietary Reference Intakes – DRI mg d^{-1} (Institute of Medicine, 2005)
Mg	280.270	649.600 ±3.896	320
K	766.490	411.520 ±10.921	4 700
Ca	315.887	228.117 ±5.218	1 200
Na	588.995	79.062 ±2.861	1 300
Mn	257.610	30.575 ±0.019	1.8
Ba	455.403	14.246 ±0.269	14
Fe	259.940	7.599 ±0.028	8
Sr	407.771	5.825 ±0.049	2
Zn	213.856	3.105 ±0.008	8
B	249.773	1.895 ±0.015	20
Li	670.784	1.10 ±0.001	1
Cu	324.754	0.794 ±0.004	0.9
Ni	221.647	0.156 ±0.006	1
Ascorbic acid	–	81.03 ±0.43	45

Data expressed as mean ±SD.

Table 3. Color evaluation of fresh and dry leaves of *T. paniculatum*

*L**	31.94 ±1.64^{b}	41.61 ±0.99^{a}
*a**	5.89 ±1.05^{a}	1.26 ±0.55^{b}
*b**	15.04 ±2.85^{a}	5.21 ±0.76^{b}
*C**	16.15 ±3.01^{a}	5.39 ±0.75^{b}
H°	68.56 ±1.41^{b}	76.24 ±6.10^{a}

Data expressed as mean ±SD. Different letters on the same line indicate significant differences ($p < 0.05$) measured using the Tukey HSD test. *L**, *a**, *b** represent the chromaticity coordinates (*C**). The color parameters were converted to color angle, $H = \tan - 1b/a$, indicating the Hue (*H*) angle of the sample (0° or 360º – red, 90° – yellow, 180° – green, 270° – blue).

and the results of the present study suggest that *T. paniculatum* is a source of minerals. The magnesium content obtained in the present study was higher than the RDI reported by the Institute of Medicine (2005) with the RDI of potassium being 8.75% and of calcium 19.01%. It is worth noting that the levels of lithium (1.10 mg 100 g^{-1}), copper (0.794 mg 100 g^{-1}), and nickel (0.156 mg 100 g^{-1}) found in this study were lower or equal to the tolerable upper intake levels permitted and recommended by the Institute of Medicine (2005), which means that the leaves of *T. paniculatum* are safe to consume. All the results obtained from the color measurements were statistically significant ($p < 0.05$). Considering the *L***a***b** color difference of fresh and dry leaves, it is not possible to distinguish their color due to the low values of *a** and *b**. As for differences in chroma and lightness with drying process, the leaves became deeper in color, which might be related to the presence of chlorophyll and loss of water, which favors the concentration of this pigment (Ali et al., 2014). The results of the Hue angle indicate the tendency of *T. paniculatum* leaves to be yellow.

Antinutritional compounds and ascorbic acid (vitamin C)

The results of the analysis of antinutritional compounds are shown in Table 4.

Table 4. Antinutritional compounds in the leaves of *T. paniculatum*

Analyse	Condensed tannin	Hydrolyzable tannin	Cyanogenic compounds	NO_3^- mg g^{-1}
Result	+	+	–	0.38

+ – positive, – – negative.

Reis et al. (2015), in a preliminary phytochemical screening, identified tannins as a secondary metabolite in leaves extracted from *T. paniculatum*. The results of the analysis of antinutritional compounds showed the presence of condensed and hydrolysable tannins in the leaves. Condensed tannins cause astringency properties which are undesirable (Wiesner et al., 2017). The presence of nitrates, which are considered to be toxic compounds that can be found in plants, was observed in low concentrations (0.38 mg g^{-1} sample). Moura et al. (2020) assessed the cytotoxicity of an aqueous extract of *T. paniculatum* and observed no cytotoxicity. Tolouei et al. (2019) investigated the acute toxicological potential of *T. paniculatum* extract in female rats, which presented a significant increase in body weight gain and no decrease in food and water consumption, indicating that there was no toxic effect. The ascorbic acid content obtained from *T. paniculatum* leaves was 81.03 mg (Table 2), which was higher than that found by Moura et al. (2020), which was 18.4 mg.

Phenolic compounds and antioxidant capacity using different solvents

The total phenolic compounds and antioxidant capacity found in *T. paniculatum* leaves using different types of solvents are presented in Table 5. These solvents are often used for extracting phenolic substances and the properties of the extraction can affect the measure of the total phenolic content and antioxidant capacity owing to variations in polarity and the biochemical modifications of phenolics during the extraction (Michiels et al., 2012).

Among the extracts using a single solvent, the ethanolic extract presented the highest phenolic content (319.86 mg EAG 100 g^{-1}) whereas the lowest content was found in the aqueous extract (266.92 mg EAG 100 g^{-1}). The MAC mixture was the best solvent to extract phenolic compounds of all the solvents used, reaching 432.73 mg EAG 100 g^{-1}. The use of only one solvent did not provide an effective extraction of phenolic compounds. The combination of two or more solvents favors polarity interactions between them, leading to a more effective competition for solute solvation (Barchan et al., 2014). Moura et al. (2020)

Table 5. Total phenolic content and antioxidant capacity of *T. paniculatum*

Solvent	Total phenolics mg EAG 100 g^{-1}	DPPH mg TE 100 g^{-1}	FRAP µM of $FeSO_4$ g^{-1}
Water (W)	266.92 ±0.71^{g}	1 440.84 ±133.61^{c}	2 488.20 ±116.84^{f}
Ethanol (E)	319.86 ±0.32^{e}	1 967.30 ±236.34^{b}	4 004.08 ±75.80^{e}
Methanol (M)	276.63 ±0.37^{f}	2 964.81 ±86.52^{a}	5 650.74 ±94.52^{a}
Ethanol/water (EW)	421.11 ±0.83^{b}	1 177.61 ±157.35^{c}	4 467.62 ±13.24^{b}
Methanol/water (MW)	347.17 ±0.16^{d}	1 274.59 ±173.04^{c}	3 362.43 ±84.07^{c}
Methanol/acetic acid (MAC)	432.73 ±0.84^{a}	3 144.92 ±24.00^{a}	3 696.58 ±26.03^{d}
Acetone/water/acetic acid (AWA)	379.25 ±0.89^{c}	2 743.14 ±109.96^{a}	3 440.28 ±51.83^{de}

Data expressed as mean ±SD. Different letters in the same column indicate significant differences ($p < 0.05$) measured using the Tukey HSD test.

found total lower phenolic contents (27.46 mg EAG 100 g^{-1}) in aqueous extract of *T. paniculatum* than that found in the present study in aqueous solvent (266.92 mg EAG 100 g^{-1}). According to Tolouei et al. (2019), phenolic compounds can be in the cortex and in the vascular bundles of the stem of *T. paniculatum*. Reis et al. (2015) identified campesterol, stigmasterol, and sitosterol as the main phenolic compounds present in the leaves of *T. paniculatum*. When compared to other UFPs, the concentration of phenolic compounds in this study was higher than that obtained by Silva et al. (2014) in the methanolic extract of Ora-pro-nobis flour (120 mg EAG 100 g^{-1}). Regarding the DPPH method, the highest antioxidant capacities were obtained for the mixtures of MAC, M and AWA (3144.92, 2964.81 and 2743.14 mg TE 100 g^{-1}, respectively). The higher value of antioxidant capacity using the FRAP method was also observed in M (5650.74 µMol $FeSO_4$ 100 g^{-1}) unlike from that obtained for total phenolic. According to Chan et al. (2007), both methods measure the ability for hydrogen (DPPH) or electron (FRAP) donation and would explain the difference of values found in this study. Similarly to total phenolics, DPPH and FRAP also showed the lowest results for the aqueous extract.

Antibacterial activity

The results of the disk diffusion method showed no antibacterial activity in the EW and MW solvents, and in the MAC mixture. The extract obtained with AWA showed some antibacterial activity against *B. cereus* with a larger diameter of inhibition halo of 2 mm in 650 mg mL^{-1}, as shown in Table 6 and Figure 2.

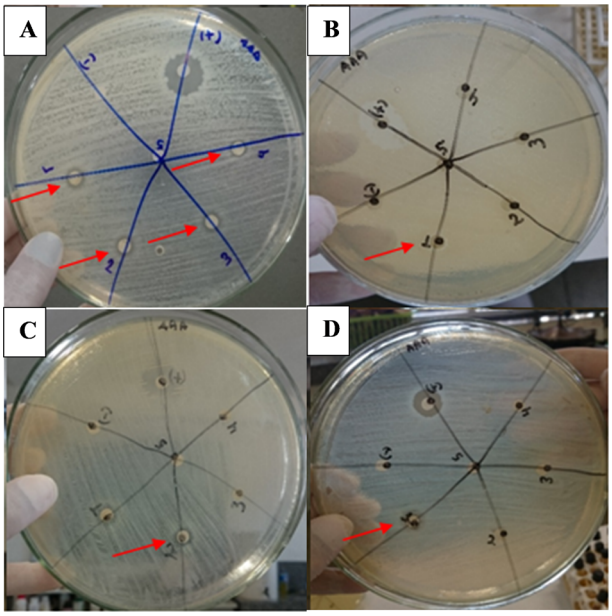

Fig. 2. Disc diffusion technique using AWA solvent in front of the: A – *B. cereus*, B – *E. coli*, C – *S. aureus*, D – *Salmonella*; + – 2% iodine solution, – – sterile distilled water; 1, 2, 3, 4 and 5 – extracts in the concentrations of 650, 455, 318.5, 223 and 156 mg mL^{-1}, respectively

Table 6. Antibacterial activity of AWA extract using disk diffusion method

AWA extract, iodine solution and sterile water mg mL^{-1}	*B. cereus*	*E. coli*	*S. aureus*	*Salmonella*
650	2 ±0.7[a]	1.3 ±0.4[a]	0	0.3 ±0.4[a]
455	0.8 ±0.8[a]	0	0.7 ±0.9[a]	0
318.5	0.7 ±0.9[a]	0	0	0
223	0.3 ±0.4[a]	0	0	0
0	0	0	0	0
Iodo 2% (+)	9 ±0	9 ±0	8 ±0	8 ±0
Sterile water	0	0	0	0

Data expressed as mean ±SD. Different letters in the same column indicate significant differences (p <0.05) measured using the Tukey HSD test.

Table 7. Strain growth observed at the minimum inhibitory concentration (MIC) and the minimum bactericidal concentration (MBC) in MW, MAC and AWA extracts

Extract	Concentration mg mL^{-1}	*B. cereus*		*E. coli*		*S. aureus*		*Salmonella*	
MW	650	AC	1	C	–	C	–	C	–
	455	AC	1	C	–	C	–	C	–
MAC	650	C	–	C	–	C	–	C	–
	455	AC	1	C	–	C	–	C	–
AWA	650	AC	1	AC	9	AC	3	C	–
	455	AC	9	C	–	C	–	C	–

The first column shows the MIC results where: AC – no growth and C – bacterial growth; the second column the MBC column where: 1 – lack of growth, 3 – light growth, 6 – moderate growth, 9 – intense growth, – – not applicable.

Reis et al. (2015) reported a lack of inhibition of microbial growth of *B. cereus*, *E. coli* e *Salmonella typhimurium* at the maximum concentration (50 mg mL^{-1}) of the EW extract obtained by the percolation of *T. paniculatum* leaves and showed moderate antimicrobial activity against *Serratia marcescens* and *S. aureus.* All the strains grew in the presence of EW in the macrodilution technique. In general, leaf extracts of *T. paniculatum* showed a MIC of 455 mg mL^{-1} for *B. cereus* and 650 mg mL^{-1} for *E. coli* and *S. aureus* in AWA extract (Table 7). The antimicrobial activity of *T. paniculatum* leaves can be related with the presence of phytosterols such as campesterol, β-sitosterol, and stigmasterol (Reis et al., 2015). The results of MBC determination showed no growth of *B. cereus* in the mixture of MW at the highest concentrations or in the mixture of MAC at 455 mg mL^{-1} (Table 7). Thus, the MIC and MBC results were similar, which inhibited *B. cereus*. After performing MBC tests on the extract of the mixture of AWA, it could be observed that *B. cereus* had intense growth at a concentration of 455 mg mL^{-1}, but not at a concentration of 650 mg mL^{-1}. *E. coli* had an intense growth and *S. aureus* presented a light growth in the same extract (650 mg mL^{-1}).

Comparing the methods utilized in the present study, better results were obtained using the macrodilution methods regarding the evaluation of antimicrobial activity using agar diffusion, which was also observed by Reis et al. (2015). The solvents utilized are less polar and can restrict the diffusion of the extracts throughout the agar, which is more polar (Reis et al., 2015).

CONCLUSIONS

Talinum paniculatum (Jacq.) Gaertn. leaves are rich in protein, insoluble dietary fiber, ascorbic acid, and minerals such as magnesium, potassium, and calcium. Analysis of the antinutritional compounds showed no cyanogenic compounds and a low nitrate concentration, although the presence of tannins was shown. The highest yield extraction of phenolic compounds was obtained in the mixture of methanol/acetic acid (MAC), which also had the highest antioxidant capacity in the DPPH method, along with the mixture of acetone/water/acetic acid (AWA) and the methanol solvent (M). The latter also showed higher values using the FRAP method. The analysis of antibacterial activity showed that the leaf extracts inhibit bacterial growth, which was more effective in *B. cereus*. So, *T. paniculatum* leaves and their extracts could be used in food as a source of nutrients and antioxidant and antibacterial potentials.

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