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# Comparative study of aqueous ultrasound-assisted extraction methods of bioactive compounds from Tarumã (*Vitex megapotamica*)

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**Abstract:** *Vitex megapotamica* (Tarumã) fruits are a potential source of phenolic compounds with relevant biological activities. This study compared ultrasound-assisted extraction (UAE) using a probe-type ultrasonic apparatus with conventional shaker extraction for the recovery of bioactive compounds from ripe Tarumã fruits. UAE extraction kinetics were evaluated at 5, 10, 15, and 30 min (90 °C, 60% amplitude). The extracts were evaluated for their highest total phenolic content (TPC), antioxidant, and anti-inflammatory activities. The TPC was obtained after 5 min of extraction, and this condition was selected for comparison with shaker extraction under the same parameters. UAE significantly increased phenolic recovery, reaching 1909.2 mg GAE 100 $g^{-1}$ of sample, whereas the shaker method yielded 1549.5 mg GAE 100 $g^{-1}$. Despite the higher phenolic extraction efficiency, antioxidant and anti-inflammatory activities did not differ significantly between extracts ($p > 0.05$). High-performance liquid chromatography analysis (HPLC) revealed ellagic acid as the predominant compound in the UAE extract, while myricetin was the major phenolic compound identified in the shaker extract. These results demonstrate that UAE is an efficient and rapid technique to enhance the recovery of phenolic compounds from Tarumã fruits, supporting its potential application in the development of bioactive extracts.

**Key words:** *Vitex megapotamica*, Phenolic compounds, Antioxidant activity, Anti-inflammatory activity, HPLC analysis, Ultrasound-assisted extraction.

## INTRODUCTION

The *Vitex megapotamica* plant, commonly known as Tarumã, is a fruit-bearing tree that belongs to the verbena family. It boasts a majestic canopy and can reach heights of up to 10 meters (Onofre et al. 2016). It is found in various Brazilian regions, predominantly in the Atlantic Forest of the southern region. The harvesting of fruits can occur between November and February. Ripe fruits are purplish in color and can be consumed fresh or turned into jelly (Campos et al. 2023).

Regarding traditional medicine, Tarumã leaves are used in the form of an infusion for therapeutic purposes. They have diuretic properties, blood-purifying, anti-inflammatory effects, and are applied as treatment of cardiovascular diseases (Bolson et al. 2015, Brandt et al. 2009, de Brum et al. 2013, Pires et al. 2018). On the other hand, the fruits properties have been studied little. However, current research indicates the presence of bioactive compounds with antioxidant, anti-inflammatory and antibacterial properties (Barboza et al. 2019, Monteiro et al. 2024a, b). Thus, Monteiro et al. (2024b) characterized the physical and

chemical parameters of the pulp of the Tarumã fruit, harvested at different stages of maturation (immature and mature), and concluded that the Tarumã can be a promising source of bioactive compounds, mainly the immature fruits.-

In this same topic, the research group also explored the extraction of bioactive compounds from the powdered pulp of the ripe fruit of the Tarumã (Monteiro et al. 2024a), evaluating several variables of the extraction process, such as pH, solid:liquid ratio, agitation, and temperature in an extraction time of 3 hours in an orbital agitator shaker. The study concluded that the best extraction condition was pH 5, solid:liquid ratio of 1:30, agitation at 100 rpm and temperature of 80 °C (Monteiro et al. 2024a).

Thus, bioactive compounds are phytochemicals naturally found in plant-based foods. Some studies suggest that they can play a role in modulating the body's metabolic processes, thereby improving health (Streda & Severo 2024). According to Huang & Chen (2022), nutraceutical functional foods and pharmaceuticals enriched with bioactive compounds can help reduce the risk of certain chronic diseases, as well as lessen their harmful effects. Bioactive compounds are found in a wide range of molecules, including carotenoids, flavonoids, carnitine, choline, coenzyme Q, dithiolthiones, phytosterols, phytoestrogens, polyphenols, and taurine (Shrinet et al. 2021).

Among the bioactive compounds extensively studied, the class of phenolic compounds stands out. These are secondary metabolites found in most plant tissues and are notable mainly for having high antioxidant properties (Monteiro et al. 2024a). This prevention of oxidative action is directly associated with the structures of phenolic compounds, which feature one or more hydroxyl groups attached to aromatic rings (De La Rosa et al. 2019). Hydroxyl groups present free radical scavengers, which are generated by the cellular autoxidation process, either through the donation of electrons, hydrogen atoms, or the chelation of metal cations (Montenegro-Landívar et al. 2021).

To obtain bioactive compounds from fruits, extraction is a crucial step, and selecting the right method is vital for optimizing the process. This optimization leads to significant time and resource savings, as well as maximizing the number of compounds extracted in the operation. Solvent extractions are the most widely used in the industrial chain. Green chemistry introduces the concept of using environmentally friendly solvents for the extraction of compounds of interest (Barba et al. 2016).

The efficiency of extraction depends on various factors. These include the type of sample, the compounds targeted for extraction, and their location within the sample. Other important parameters are the choice and polarity of the solvent, the extraction method, extraction time and temperature, pH, and the solvent-to-solute ratio (de Souza et al. 2014).

In recent decades, various methods have been explored with the aim of replacing conventional methods with more sustainable and efficient alternatives. Some of these alternative methods include ultrasound-assisted extraction, microwave-assisted extraction, pressurized liquid extraction, and supercritical fluid extraction (Osorio-Tobón 2020). It is important to emphasize that the probe-type ultrasonic apparatus is more adaptable and is considered more powerful than ultrasonic baths, as there is less dispersion of ultrasonic energy (Pingret et al. 2013). This probe-type ultrasonic apparatus is also widely known as a sonicator ou ultrasonicator (Shen et al. 2023).

Among the available techniques, probe-type ultrasound-assisted extraction was selected due to its efficiency in recovering bioactive compounds from Tarumã. This

method is based on acoustic cavitation, which involves the formation, growth, and collapse of microbubbles within the solvent. The implosion of these bubbles generates localized "hot spots" characterized by high temperatures and pressures, releasing intense energy into the surrounding medium. These conditions promote the disruption of plant cell walls and enhance solvent penetration into the cellular matrix, facilitating the release of intracellular compounds and improving mass transfer during extraction (Tiwari 2015).

Previous studies have highlighted the functional potential of *Vitex megapotamica* fruits, particularly due to their richness in bioactive compounds and associated biological activities (Monteiro et al. 2024a, b). However, comparative investigations evaluating the efficiency of different extraction techniques for recovering these compounds from Tarumã remain limited. Therefore, this study aimed to compare ultrasound-assisted extraction and conventional shaker-assisted extraction to identify the bioactive compounds present in Tarumã. Additionally, the total phenolic content as well as the antioxidant and anti-inflammatory activities of powdered pulp obtained from ripe Tarumã fruits were evaluated.

## MATERIALS AND METHODS

The chemical reagents and solvents used in this study were from commercial sources suppliers. The reagents Folin-Ciocalteu, gallic acid, sulfonamide, alpha-naphthyl ethylenediamine chloride (NED), 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), and 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (TROLOX) were purchased from Sigma-Aldrich, Merck Brazil. Sodium carbonate, potassium persulfate, ethyl alcohol, and citric acid were sourced from Biotec Comércio de Produtos para Laboratório, a Brazilian company.

Tarumã fruits were harvested between January and February of 2021, in the city of Faxinal dos Guedes, Santa Catarina. The fruits were selected at their ripe stage, featuring a dark purple color. Afterward, they were sanitized using a 200 ppm sodium hypochlorite solution for 15 minutes, the excess water was removed, and they were stored in polyethylene bags and kept frozen at -12 ± 1 °C in a standard freezer (CONSUL, CVU26E, Brazil) until the experimental activities began.

To obtain the Tarumã powder, the fruits were removed from the freezer and left at room temperature for approximately 1 minute. Subsequently, the fruits were manually pitted using a knife, resulting in the pulp along with the peel, which in this study is referred to as the pulp. This sample was once again frozen in an ultrafreezer (ULT 335/710 D Vertical, Indrel, Brazil) for 48 hours at -86 °C and subsequently dehydrated at -60 °C under a vacuum pressure of 0.007 Pa in a lyophilizer (TFD5503, IIshin, Netherlands) for 48 hours. The freeze-dried pulp was ground using a conventional blender (Diamante 800, Britânia, Brazil) and homogenized by passing through a 32-mesh sieve (sieve number). The resulting powder was stored in metallic containers and kept frozen at −86 °C until analysis.

Regarding the sample preparation for the extraction processes, 8.66 g of Tarumã powder was mixed with 200 mL of distilled water. The solution was manually homogenized, and the pH was adjusted to 5.0 using a 0.1 M citric acid stock solution (Gomori 1955).

The ultrasound-assisted extraction process was performed using equipment featuring an ultrathermostatic bath with water recirculation (SL-152/10, SOLAB, Brazil) and a portable ultrasonic processor (sonicator) equipped with

an integrated automatic thermometer (UP200Ht, Hielscher, Germany). This device has a power rating of 200 W, operates at a frequency of 26 kHz, and includes an autoclavable titanium probe with a diameter of 14 mm. The amplitude was set at 60% (Boubechiche 2017, Torres-Valenzuela et al. 2020), the operating temperature was maintained at 90 °C, and the extraction times of 5, 10, 15, and 30 minutes were analyzed. The volumes of the solution were measured before and after extraction. The extraction was carried out in triplicate. The extracts were vacuum filtered (ME 1C 2016/07, Vacuubrand, Wertheim, Germany) and stored at -86 °C in an Ultrafreezer (ULT 335/710 D, Indrel, Londrina, Brazil) until the analyses were conducted.

The extraction in metabolic bath with Shaker agitation was performed by placed mixture in a Dubnoff metabolic bath with orbital shaker agitation (SL-157, SOLAB, Brazil), featuring time, temperature, and agitation control. The extractions were carried out in triplicate at a constant temperature of 90 °C, stirring at 100 rpm for a duration of 5 minutes (parameters set for comparison with the best results from the ultrasound -assisted extraction process). Subsequently, the extracts were vacuum filtered (ME 1C 2016/07, Vacuubrand, Wertheim, Germany) and stored at -86 °C in an Ultrafreezer (ULT 335/710 D, Indrel, Londrina, Brazil) until the analyses were conducted.

The determination of total phenolic compounds (TPC) was carried out according to Singleton et al. (1999) and Hiranpradith et al. (2025), with adaptations, a method widely applied in recent studies involving plant bioactive compounds (Shi et al. 2022, Umego & Barry-Ryan 2024). The phenolic compounds were quantified through spectrophotometry, using the Folin-Ciocalteu reagent. According to the method outlined, a 0.5 mL aliquot of the prepared Tarumã extract was added to 2.5 mL of a 10% Folin-Ciocalteu aqueous solution. Subsequently, the mixture was homogenized and left to stand for 5 minutes, after which 2 mL of 7.5% sodium carbonate was added to the mixture, and it was homogenized again. The solution was left to stand in the dark for 2 hours, at room temperature. The samples were prepared in triplicate. The absorbance was read at 760 nm, and the results were compared with the standard curve constructed with gallic acid. The results were expressed in gallic acid equivalents per 100 grams of sample (mg GAE 100 $g^{-1}$ of sample).

Antioxidant activity was determined using the ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)), radical scavenging method as described by Rufino et al. (2017), widely applied in recent studies (Xu et al. 2023, Nowak et al. 2022). Thus, 30 µL of Tarumã extract were added to test tubes containing 3 mL of the previously prepared ABTS radical solution. The mixture was homogenized and left to stand for 6 minutes. The absorbance was read at 734 nm in triplicate. A standard curve was constructed using the Trolox radical for comparison purposes, with the results being expressed in µM Trolox $g^{-1}$ of sample

The anti-inflammatory activity was quantified by the determination of nitric oxide (NO) radical scavenging, based on the method by Hazra et al. (2008) widely applied in recent studies (Mohammadi et al. 2024, Tischer et al. 2023). The absorbance of the mixture, consisting of the extract with sodium nitroprusside, 0.33% sulfonamide, and 0.1% alpha-naphthylethylenediamine chloride (NED), was read at 540 nm. The Trolox standard curve was used to determine the Trolox equivalent concentration, and the results were expressed in µM Trolox.$g^{-1}$ of sample.

The methodology of Dutra et al. (2017) was used to identify the phenolic compounds

in the extracts of Tarumã ripe fruit by high performance liquid chromatography (HPLC). A chromatograph equipped with a Shimadzu ODS-A reverse-phase column (4.6 mm, 250 mm, 5 µm) and a photodiode array detector (SPD-M10AVp, Shimadzu Co., Kyoto, Japan) was used. The chromatographic separation was carried out using a gradient elution composed by (A) water/2% acetic acid (v/v) and (B) acetonitrile: methanol in a 2:1 (v/v) ratio. The sequence was as follows: 90% A at 0 minutes, 88% A at 3 minutes, 85% A at 6 minutes, 82% A at 10 minutes, 80% A at 12 minutes, 70% A at 15 minutes, 65% A at 20 minutes, 60% A at 25 minutes, 50% A from 30 to 40 minutes, 75% A at 42 minutes, and 90% A at 44 minutes. The eluent flow rate was maintained at 1.0 mL $min^{-1}$, the column temperature was kept at 40 °C, and the volume of sample injected for each analysis was 20 µL. The total time for each analysis run was 50 minutes.

The calibration was performed using an external calibration curve, with the injection of seven different concentrations (0.01; 0.03; 0.05; 0.1; 0.25; 0.5, and 1.0 mg $mL^{-1}$). The compounds were identified based on their retention time, and quantification was based on the areas of the peaks detected and interpreted by the Class-VP® software. The patterns of gallic, protocatechuic, vanillic, caffeic, p-coumaric, and ferulic acids were examined as phenolic acids, and catechin, rutin, and myricetin as flavonoids.

The statistical analysis was performed using STATISTICA 14 software (Trial Version), through variance analysis (ANOVA) and Tukey's mean comparison test at a 95% significance level ($p<0.05$).

## RESULTS AND DISCUSSION

### Total Phenolic Compounds, Antioxidant Activity, and Anti-inflammatory Activity

The kinetic study of extraction is an important tool for determining the optimal extraction conditions. Figure 1 shows the mean results for the extraction of total phenolic compounds. The highest concentration of TPC was identified at a 5-minute extraction time, with a content of 1922.8 mg GAE 100 $g^{-1}$ of sample. In ultrasound-assisted extraction the extraction time is significantly reduced compared to conventional techniques (Monteiro et al. 2024a), owing to enhanced solvent diffusion, rapid saturation of the medium, and the efficient disruption of the cell wall caused by the cavitation effect (Ghule & Desai 2021). The high frequency generated by the sonicator produces a vibratory effect on the plant cell, facilitating its rupture. This promotes a diffusion process of the extraction solvent into the cellular matrix, making it easier to extract the bioactive compounds of interest (Boeira et al. 2018).

On the other hand, prolonged extraction times were associated with a reduction in TPC recovery. Phenolic compounds are highly susceptible to environmental factors such as temperature, oxygen, and light, which may accelerate their degradation and consequently lead to lower extraction yields (Shi et al. 2022). According to the literature (Bin Mokaizh et al. 2024), although longer extraction times generally result in higher extract yields, there is a risk of degradation of the active components. Furthermore, prolonged extraction time, particularly with the aid of sonic cavitation, increases the penetration of the solvent into the plant matrix (Bin Mokaizh et al. 2024).

Zhao et al. (2021) reported that the use of sonication can lead to the destruction of plant cell walls within time frames like those applied in this study. Therefore, there is an

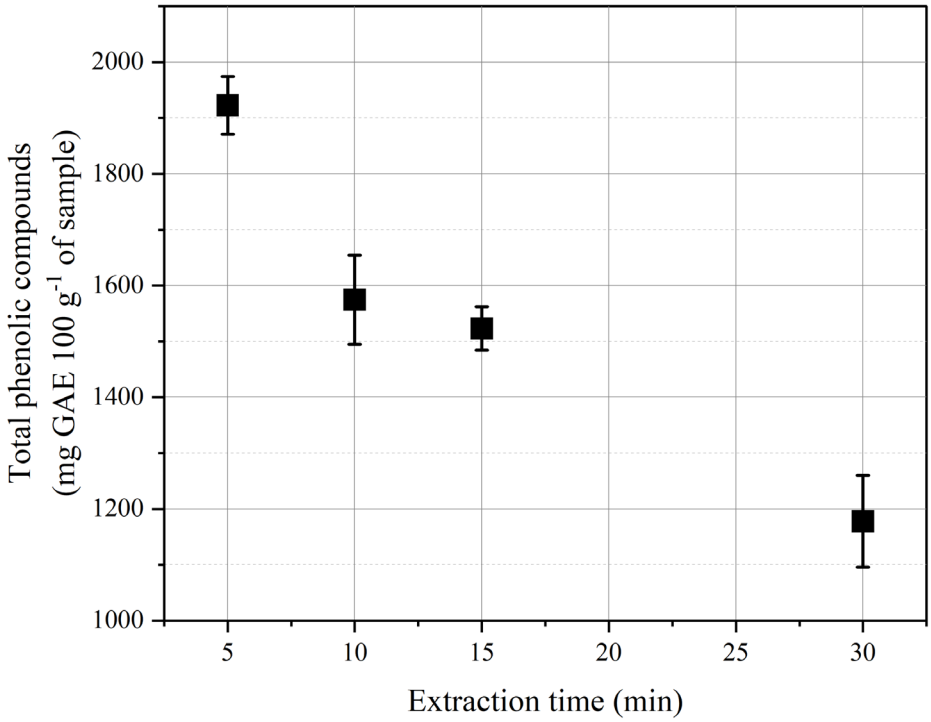


**Figure 1. Kinetics of total phenolic compounds (TPC) extraction from powdered Tarumã pulp using a sonicator. Note: sonicator power rating of 200 W, frequency of 26 kHz, 60% amplitude, the operating temperature was maintained at 90 °C.**

ideal extraction time beyond which the quality of the phenolic components present in the extracted sample may begin to decline, and thus, finding the right balance is essential to produce high-quality extracts (Liang et al. 2022). In addition to the influence exerted by the high power of ultrasound, high-frequency ultrasound equipment has the potential to generate a significant amount of free radicals, which lead to the degradation of polyphenols and consequent reduction of their biological activity (Shen et al. 2023).

About temperature, elevated values can be beneficial in relaxing of the plant tissues, swelling of the sample matrix by enhancing solvent uptake, weakening of bonds holding the phenolic compounds within the plant material, enhancing the permeability of the cells, reducing surface tension, and increasing the rates of diffusion in the sample matrix. However, elevated temperatures may result in the thermal degradation of certain phenolic compounds and encourage undesired reactions between these compounds and the sample matrix (Umego & Barry-Ryan 2024), through chemical or enzymatic reactions (Prasad et al. 2011, Hiranpradith et al. 2025).

Rodrigues et al. (2020) studied the extraction of bioactive compounds from camu-camu (*Myrciaria dubia*), a fruit native to the Amazon region, using a sonicator and water as solvent. They found the optimal conditions to be a duration of 5 minutes, a temperature of 60 °C, and an equipment amplitude of 30%, resulting in the extraction of 2579.8 mg of GAE. 100 $g^{-1}$ of sample for the analysis of total phenolics. Similarly, Aliaño-González et al. (2020) studied the blueberry (*Vaccinium corymbosum* L.) and also achieved the best extraction results within a duration of 5 minutes. In this study, the authors observed that during extraction periods exceeding 5 minutes, particularly after 20 minutes, there was a slight decrease in TPC values, likely due to the degradation of compounds.

For comparative purposes, the best condition achieved in ultrasound-assisted extraction was applied to conventional extraction in a metabolic bath with Shaker agitation. The TPC content found (Figure 2) was higher in the ultrasound-assisted extraction method compared to the shaker extraction method ($p<0.05$). This result indicates that the cavitation effect on the cell wall of the sample was more effective than extraction using an orbital shaker. The use of the sonicator made the process more efficient and facilitated the diffusion of bioactive compounds from inside the cell into the solvent. According to Madrera & Valles (2020), sonicators are designed to be immersed and directly transmit ultrasonic intensity to the liquid sample, resulting in an increase in extraction yields.

Previous studies have proposed classifications for total phenolic content (TPC) in fruits based on values determined by the Folin–Ciocalteu method (Vasco et al. 2008). Fruits may be categorized as having low, moderate, or high phenolic content depending on the concentration of phenolic compounds expressed as gallic acid equivalents (GAE). Based on this approach, the TPC values obtained for Tarumã pulp in the present study can be considered high, indicating that both extraction methods were effective in recovering phenolic compounds. However, ultrasound-assisted extraction showed greater efficiency, as the TPC obtained using this technique was approximately 23% higher than that obtained with the shaker method. Similar variations in phenolic recovery depending on the extraction method have been reported in recent studies evaluating polyphenol contents in plant matrices (Vasco et al. 2008).

However, no significant differences were observed in the analyses of antioxidant and anti-inflammatory activities between the two extraction methods studied after statistical analysis ($p<0.05$) (Figure 2). The results suggest

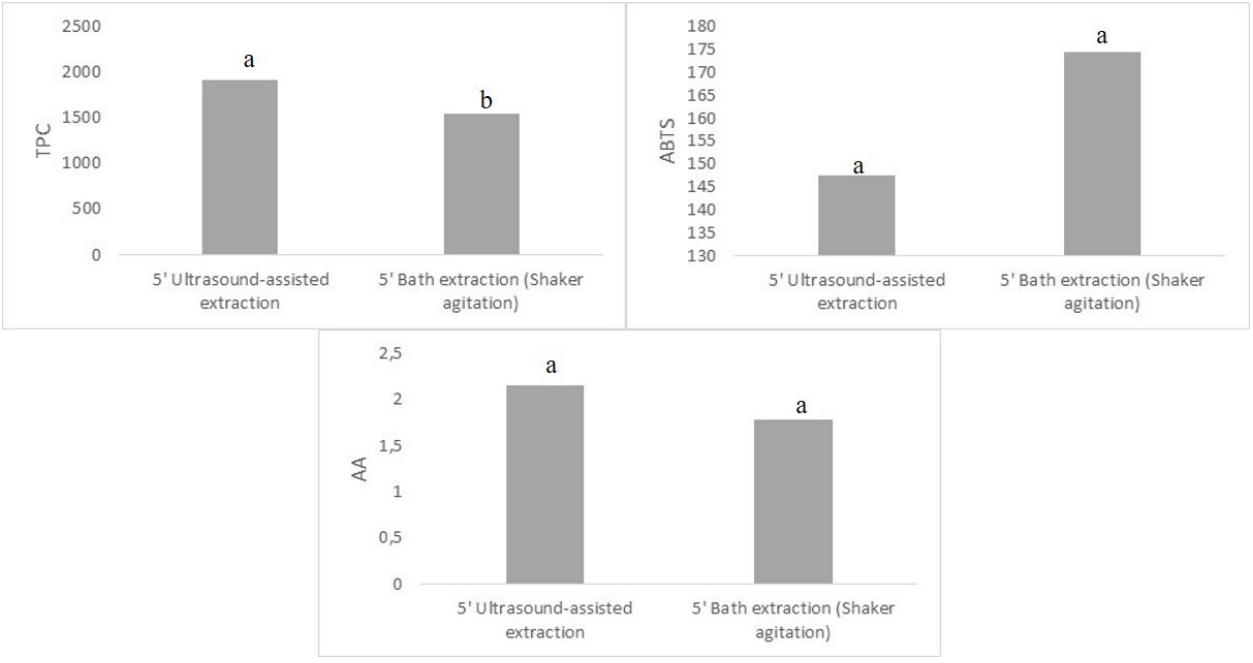


**Figure 2. Total Phenolic Compounds, Antioxidant Activity, and Anti-inflammatory Activity of Tarumã Pulp Powder. TPC: Total Phenolic Compounds (mg GAE 100 $g^{-1}$ of sample); ABTS: Antioxidant activity by the ABTS radical (µM TROLOX $g^{-1}$ of sample); AA: anti-inflammatory Activity: (µmol TROLOX $g^{-1}$ of sample). To each variable, the same letter does not statistically differ by the Tukey test at a 5% significance level.**

that the phenolic compounds responsible for the antioxidant activity were extracted in similar quantities across both extraction methods (Aliaño-González et al. 2020).

Although ultrasound-assisted extraction resulted in significantly higher total phenolic content (TPC) compared to the shaker method, this increase did not translate into a proportional enhancement of antioxidant activity. This apparent discrepancy may be explained by the fact that antioxidant capacity depends not only on the total concentration of phenolic compounds but also on their chemical structure, reactivity, and relative abundance in the extract. Structural features such as the number and position of hydroxyl groups, degree of conjugation, and presence of glycosidic substitutions can strongly influence the radical-scavenging capacity of individual phenolics. Moreover, the Folin–Ciocalteu assay used to determine TPC measures the overall reducing capacity of the sample and may react with non-phenolic reducing substances, which can lead to an overestimation of phenolic content (Pérez et al. 2023). In addition, antioxidant activity assays reflect the combined effect of all antioxidant molecules present in the extract, including non-phenolic constituents that may be present at similar levels in both extraction methods. Therefore, the comparable antioxidant activity observed between the two extraction techniques may be more closely related to the qualitative composition and synergistic interactions among antioxidant compounds rather than solely to the total phenolic concentration.

Torres-Valenzuela et al. (2020) used ultrasound-assisted extraction with an 11-minute duration and 60% amplitude on the sonicator and found an antioxidant activity content of 106.95 μM TROLOX.$g^{-1}$ in the peel of yellow pitaya (*Selenicereus megalanthus*), a value lower than that found in the present study for both tested extraction methods. On the other hand, Torma et al. (2019) published a study on seven genotypes of açaí (*Euterpe oleracea*) and observed that the values found for antioxidant activity ranged from 231.38 to 674.83 μM TROLOX.$g^{-1}$. This shows that the açaí species studied contained significantly higher amounts than those found in the Tarumã extract.

Ranjha et al. (2021) mention that it is crucial to assess the technical parameters of the equipment to be used in ultrasound-assisted extraction. It also indicates that the addition of agents such as ascorbic acid and ethanol can protect the compounds during cavitation, enhancing the extraction yields.

Each extraction technique is based on a specific principle, and the selection of the most efficient mass transfer mechanism is essential to ensure the effective transfer of target compounds into the solvent. Different extraction methods may therefore be applied depending on the characteristics of the compounds of interest to maximize extraction yield. Furthermore, process variables such as extraction time, temperature, solvent composition, and ultrasonic parameters must be carefully optimized to improve extraction efficiency while preventing oxidation or degradation of sensitive bioactive compounds (Yusoff et al. 2022, Che et al. 2024). For this reason, individual parameters should be systematically evaluated to determine optimal extraction conditions.

## High performance liquid chromatography (HPLC)

To identify the bioactive compounds in the Tarumã extract, high-performance liquid chromatography analyses were performed. The analysis covered both the extract obtained from ultrasound-assisted extraction and the extract obtained from conventional shaker extraction.

Table I lists the compounds identified in the Tarumã extract.

The Table I shows that ellagic acid was the primary compound identified in the sample extracted using an ultrasound-assisted. Notably, its value was statistically lower compared to the extraction performed with a shaker ($p<0.05$). The presence of free ellagic acid is associated with the degradation of ellagitannins during the sample preparation and extraction process. According to the literature, ellagic acid has chemopreventive effects and may inhibit the development of esophageal, liver, and lung cancers (Chauhan et al. 2024).

On the other hand, in the extraction process using a shaker, the primary compound extracted was myricetin, which proved to be statistically equivalent to the extraction results obtained with a sonicator. Myricetin, also identified in high quantities in the extracts analyzed for both extraction methods, is a flavonoid known for its anticancer action against various types of cancer (Zhou et al. 2019). The study by Coêlho et al. (2021) indicates improvements in hyperglycemia, insulin sensitivity, triglyceridemia, and hepatic steatosis in mice treated with myricetin. Another significant property of myricetin is its ability to chelate excess iron in the cytoplasm, preventing the accumulation of hydroxyl free radicals, which are responsible for aging and cell death (Mira et al. 2002).

It is also worth noting that the protocatechuic and chlorogenic acids, found in small quantities in the samples of extract obtained through ultrasound-assisted extraction, were not detectable in the chromatogram of the extract obtained by conventional extraction with orbital shaker agitation.

Thus, HPLC analyses showed no uniformity in compound identification among the extraction methods evaluated in this study. According to Hoffmann-Ribani & Rodriguez-Amaya (2008), the efficiency of hydrolysis can be influenced by many factors depending on the type of sugar attached to the flavonoid. These factors include the composition of solvents, extraction time, the concentration of acid used in the analysis, and the extraction temperature.

**Table I. Identification of Phenolic Compounds in Tarumã Pulp Extracts (μg $g^{-1}$ of sample).**

| Compound | Retention time (s) | Ultrasound extraction | Shaker extraction |
|---|---|---|---|
| **Gallic acid** | 3.941 | 17.76±1.02[a] | 19.41±1.89[a] |
| **Protocatechuic acid** | 4.862 | 14.44±0.35 | ND* |
| **Catechin** | 6.56 | 28.42±0.38[a] | 27.38±0.34[b] |
| **Chlorogenic acid** | 7.391 | 2.72±0.82 | ND* |
| **Caffeic acid** | 8.398 | 345.94±12.61[a] | 78.78±7.53[b] |
| **Coumaric acid** | 12.098 | 63.43±8.79[a] | 78.46±5.93[a] |
| **Rutin** | 18.802 | 117.34±4.2[a] | 142.97±4.32[b] |
| **Ellagic acid** | 19.069 | 457.71±26.06[a] | 642.09±7.80[b] |
| **Myricetin** | 20.803 | 411.71±32.08[a] | 849.30±112.1[a] |

**Values expressed as mean ± standard deviation. Means followed by the same letter on the same line do not statistically differ by the Tukey test at a 5% significance level. *ND: not detected or below the standard curve limit.**

Therefore, the compounds identified by HPLC suggest that the Tarumã fruit also has chemopreventive and antidiabetic properties, potentially offering a medicinal alternative in the prevention and treatment of certain diseases, as indicated by conventional medicine.

## CONCLUSIONS

The results of this study have shown promise across the tested variables for the extraction of bioactive compounds from Tarumã pulp using ultrasound-assisted extraction (UAE) with a sonicator and metabolic bath with orbital shaking (shaker). The extraction kinetics showed higher efficiency at a 5-minute extraction time using a sonicator, and the combination of a temperature of 90 °C and an amplitude of 60% extracted a greater quantity of phenolic compounds compared to extraction in a shaker under the same conditions of time and temperature. On the other hand, the results of antioxidant activity and anti-inflammatory activity did not show any statistical difference between the tested methods.

The high-performance liquid chromatography analyses showed a significant equivalence in the compounds obtained by the two extraction methods studied.

Therefore, both methods proved efficient in extracting active compounds from the Tarumã pulp. However, the use of UAE with a sonicator stood out, especially in terms of the high extraction of phenolic compounds in a short operation time, and also sustainability, as it uses a smaller volume of solvent and consumes less energy in the process than the shaker.

From an industrial perspective, ultrasound-assisted extraction shows promising scalability due to its reduced extraction time and lower solvent consumption compared with conventional methods. The increasing availability of industrial ultrasonic reactors also supports the potential application of this technology in large-scale processes for the recovery of bioactive compounds from plant matrices. However, further studies are required to evaluate operational parameters under industrial conditions, including energy efficiency, process optimization, and economic feasibility.

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**Data availability**

The data that support the findings of this study are available from the corresponding author upon reasonable request.