



BIOLOGICAL ACTIVITIES, EXTRACTIVE METHODS AND PHYTOCHEMICAL CHARACTERIZATION OF *Alternanthera brasiliana*: A SYSTEMATIC REVIEW

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ABSTRACT

Introduction: *Alternanthera brasiliana*, commonly known as Penicillin, belongs to the Amaranthaceae family and is popularly used in the treatment of various pathologies due to its anti-inflammatory, antibacterial and analgesic properties and its inhibitory activity against the herpes simplex virus. Despite its empirical use, pharmaceutical industry investigations into the biological characteristics of this species have been limited.

Objective: Carry out a systematic literature review on the biological activities, types of extraction and chemical composition of *Alternanthera brasiliana*, aiming to provide an update on the state of the art of knowledge regarding the species, contributing to the scientific prospection of new drugs. Contribute to the development of drugs and expand understanding of the pharmacological properties of *Alternanthera brasiliana*.

Materials and methods: Therefore, the guiding question of this research was the following: Do the chemical components and biological properties identified in *Alternanthera brasiliana* have pharmacological actions? The adopted methodology comprises a systematic literature review, searching for articles in the PubMed, SciELO, Web of Science, EBSCO, SCOPUS and Science Direct databases, covering the period from 2003 to 2023. Studies that address the chemical composition and the biological properties of *Alternanthera brasiliana*, using analytical methods such as LC-MS and GC-MS.

Results: The main constituents identified were phenolic compounds, flavonoids, tannins, glycosides, saponins, alkaloids and terpenes. These compounds were mainly extracted from leaves using hydroalcoholic, aqueous, ethanolic and methanolic extracts. Its highlighted biological activities include anti-inflammatory, analgesic, antioxidant, wound healing and antimicrobial effects.

Conclusion: *Alternanthera brasiliana* shows promise as a source for the development of new medicines due to its chemical composition and biological properties.

Originality: This study offers perspectives for application in the development of pharmaceuticals and nutraceutical products.

Keywords: Penicillin, Phytochemistry, Pharmacological Actions, Therapeutic Actions.

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ATIVIDADES BIOLÓGICAS, MÉTODOS EXTRATIVOS E CARACTERIZAÇÃO FITOQUÍMICA DE *ALTERNANTHERA BRASILIANA*: UMA REVISÃO SISTEMÁTICA

RESUMO

Introdução: *Alternanthera brasiliana*, comumente conhecida como Penicilina, pertence à família Amaranthaceae e é popularmente utilizada no tratamento de diversas patologias devido às suas propriedades anti-inflamatórias, antibacterianas e analgésicas e à sua atividade inibitória contra o vírus herpes simplex. Apesar do seu uso empírico, as investigações da indústria farmacêutica sobre as características biológicas desta espécie têm sido limitadas.

Objetivo: Realizar uma revisão sistemática de literatura sobre as atividades biológicas, tipos de extração e composição química de *Alternanthera brasiliana*, visando fornecer uma atualização sobre o estado da arte do conhecimento em relação à espécie, contribuindo com a prospecção científica de novos fármacos.

Materiais e métodos: Portanto, a questão norteadora desta pesquisa foi a seguinte: Os componentes químicos e propriedades biológicas identificados em *Alternanthera brasiliana* apresentam ações farmacológicas? A metodologia adotada compreende uma revisão sistemática da literatura, com busca de artigos nas bases de dados PubMed, SciELO, Web of Science, EBSCO, SCOPUS e Science Direct, abrangendo o período de 2003 a 2023. Foram incluídos estudos que abordam a composição química e as propriedades biológicas de *Alternanthera brasiliana*, utilizando métodos analíticos como LC-MS e GC-MS.

Resultados: Os principais constituintes identificados foram compostos fenólicos, flavonóides, taninos, glicosídeos, saponinas, alcalóides e terpenos. Esses compostos foram extraídos principalmente de folhas por meio de extratos hidroalcoólicos, aquosos, etanólicos e metanólicos. Suas atividades biológicas destacadas incluem efeitos antiinflamatórios, analgésicos, antioxidantes, cicatrizantes e antimicrobianos.

Conclusão: *Alternanthera brasiliana* mostra-se promissora como fonte para o desenvolvimento de novos medicamentos devido à sua composição química e propriedades biológicas.

Originalidade: Este estudo oferece perspectivas para a aplicação no desenvolvimento de fármacos e produtos nutracêuticos.

Palavras-chave: Penicilin, Fitoquímica, Ações Farmacológicas, Ações Terapêuticas.

ACTIVIDADES BIOLÓGICAS, MÉTODOS EXTRACTIVOS Y CARACTERIZACIÓN FITOQUÍMICA DE *Alternanthera brasiliana*: UNA REVISIÓN SISTEMÁTICA

RESUMEN

Introducción: *Alternanthera brasiliana*, comúnmente conocida como penicilina, pertenece a la familia Amaranthaceae y se utiliza popularmente en el tratamiento de diversas patologías debido a sus propiedades antiinflamatorias, antibacterianas y analgésicas y su actividad inhibitoria contra el virus del herpes simple. A pesar de su uso empírico, las investigaciones de la industria farmacéutica sobre las características biológicas de esta especie han sido limitadas.

Objetivo: Realizar una revisión sistemática de la literatura sobre las actividades biológicas, los tipos de extracción y la composición química de *Alternanthera brasiliana*, con el objetivo de proporcionar una actualización sobre el estado del conocimiento sobre la especie, contribuyendo a la prospección científica de nuevos fármacos. Contribuir al desarrollo de fármacos y ampliar la comprensión de las propiedades farmacológicas de *Alternanthera brasiliana*.

Materiales y métodos: Por lo tanto, la pregunta que guió esta investigación fue la siguiente: ¿Los componentes químicos y las propiedades biológicas identificadas en *Alternanthera brasiliana* tienen acciones farmacológicas? La metodología adoptada comprende una revisión sistemática de la literatura, buscando artículos en las bases de datos PubMed, SciELO, Web of Science, EBSCO, SCOPUS y Science Direct, abarcando el período de 2003 a 2023. Estudios que abordan la composición química y las propiedades biológicas de *Alternanthera brasiliana*, utilizando métodos analíticos como LC-MS y GC-MS.



Resultados: Los principales componentes identificados fueron compuestos fenólicos, flavonoides, taninos, glucósidos, saponinas, alcaloides y terpenos. Estos compuestos se extraen principalmente de las hojas utilizando extractos hidroalcohólicos, acuosos, etanólicos y metanólicos. Sus actividades biológicas destacadas incluyen efectos antiinflamatorios, analgésicos, antioxidantes, cicatrizantes y antimicrobianos.

Conclusión: *Alternanthera brasiliana* se muestra prometedora como fuente para el desarrollo de nuevos medicamentos debido a su composición química y propiedades biológicas.

Originalidad: Este estudio ofrece perspectivas de aplicación en el desarrollo de productos farmacéuticos y nutracéuticos.

Palabras clave: Penicilina, Fitoquímica, Acciones Farmacológicas, Acciones Terapéuticas.

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1 INTRODUCTION

Medicinal plants have played a crucial role in the culture, medicine and diet of various societies throughout history. With scientific advances, phytotherapy has been increasingly valued, not only for its traditional use, but also as a source of empirical data that expands scientific and technological knowledge, driven by the search for new medicines and patents (Antonio et al., 2013). Currently, several compounds derived from plants are used in the treatment of numerous diseases, integrating both traditional and modern medicine systems (da Silva Miguéis et al., 2019).

In this context, native plants can provide a wide spectrum of applications that have not yet been explored, in addition to generating numerous economic, environmental and health benefits. *Alternanthera brasiliana* (L.), popularly known as terramycin, penicillin or benzetacil, belongs to the Amaranthaceae family. This perennial herbaceous species is native to Brazil, found in the north, northeast, southeast and south regions, thriving in well-drained and waterlogged soils (J. M. T. de Alencar Filho, Teixeira, et al., 2020). The genus *Alternanthera* comprises approximately 80 species, of which 30 occur in Brazil. Due to its broad therapeutic activity, *Alternanthera brasiliana* is widely used in folk medicine to treat various pathologies, including anti-inflammatory, antibacterial, antifungal, analgesic and herpes simplex virus inhibitory actions (Tracz et al., 2014). In addition, the plant has hepatoprotective properties, standing out as an important source of bioactive compounds (J. M. T. de Alencar Filho, Teixeira, et al., 2020).

The infusion of *Alternanthera brasiliana* leaves is traditionally used as a digestive, depurative and diuretic, while the maceration of the whole plant is used against constipation (J.



M. T. de Alencar Filho, Teixeira, et al., 2020). Phytochemical studies have identified several bioactive compounds in the aerial parts of the plant, such as phenolic compounds, terpenes, steroids, betalains, saponins, alkaloids and (Kumar et al., 2014) glycosides; Canesin de Oliveira et al., 2019)

Phenolic compounds mainly include flavonoids, such as luteolin, apigenin, and orientin, as well as tannins, which are known for their antioxidant and anti-inflammatory properties (Pereira et al., 2013). Terpenes, which include monoterpenes, diterpenes, and triterpenes, play significant roles in anti-inflammatory and analgesic activities (Facundo et al., 2012). Among steroids, β -sitosterol is notable for its anti-inflammatory and hepatoprotective properties (Kumar et al., 2014). Betalains, pigments such as betacyanins and betaxanthins, give the leaves their purple coloration and have antioxidant and anti-inflammatory activities (Canesin de Oliveira et al., 2019). Saponins contribute to antimicrobial and antifungal activities, while alkaloids are known for their analgesic and sedative properties (Pelisoli Formagio et al., 2012). Glycosides, including phenolic glycosides, have antioxidant and cardioprotective activities (Pereira et al., 2013).

The antibacterial activity of *Alternanthera brasiliana* is attributed to biologically active compounds, such as triterpenoids, phenolic compounds and pigments of the betalain class. (Kumar et al., 2014; Canesin de Oliveira et al., 2019). Chemical constituents such as flavonoids, betalains, hydrocarbons, hydrocarbon derivatives, oxylipins and triterpenes have been isolated and identified in the plant, highlighting its complex chemical composition and therapeutic potential (Trapp et al., 2015).

Medicinal plants are widely used in many parts of the world and represent a significant source of new bioactive molecules, with potential for the development of medicines, dietary supplements and cosmetics. The use of plant extracts in the treatment, cure and prevention of diseases is a promising practice of great scientific relevance. Understanding the chemical composition of plants is essential, as many health products have been developed from these plant substances. (Antonio et al., 2013; Da Costa et al., 2023)

The objective is to carry out a systematic literature review on the biological activities, types of extraction and chemical composition of *Alternanthera brasiliana*, aiming to provide an update on the state of the art of knowledge in relation to the species, contributing to the scientific prospecting of new drugs.



2 MATERIALS AND METHODS

This study was conducted using a qualitative literature review approach, systematically examining the chemical components and biological properties of *Alternanthera brasiliana*. The search for articles was performed in the PubMed, SciELO, Web of Science, EBSCO, SCOPUS and Science Direct databases, covering a 20-year period (2003-2023). Only articles that explicitly mentioned *Alternanthera brasiliana* in their titles, abstracts or keywords were included.

Database searches were performed using the combination of the following descriptors: “*Alternanthera brasiliana*” AND (chemical composition OR biological properties OR pharmacological activity). Searches were conducted in English, Portuguese and Spanish to ensure broad coverage of relevant studies.

Articles that met the following criteria were considered for inclusion: published between 2003 and 2023; studies that investigated the chemical composition, extraction methods and biological activities of *Alternanthera brasiliana*; review articles, in vitro and in vivo experimental studies.

Manuscripts that: did not explicitly address the species *Alternanthera brasiliana*; were duplicated in more than one database; did not provide sufficient data on the methods and results of phytochemical and biological analyses were excluded.

Article selection was performed in two stages. Initially, all titles and abstracts of the identified articles were reviewed to screen for inclusion and exclusion conditions. Then, the full texts of the selected manuscripts were obtained and reviewed in detail. Two reviewers conducted the blind inclusion and exclusion assessments. In case of disagreement, a third reviewer was consulted for intervention.

To ensure reproducibility, data extraction was standardized using a data collection spreadsheet. The following information was extracted from each study: Author(s), year of publication and country of study; plant parts used (leaves, stems, flowers, etc.); extraction methods (type of solvent, technique used, time and temperature of extraction); chemical composition (types and classes of bioactive compounds); analytical methods used (LC-MS, GC-MS, liquid chromatography, etc.); biological properties (anti-inflammatory, antioxidant, antimicrobial activities, etc.); main results and authors' conclusions.

The extracted data were qualitatively analyzed to identify patterns and trends in the chemical composition and biological properties of *Alternanthera brasiliana*. Biological activities were categorized based on the types of tests performed (in vitro or in vivo) and the



experimental models used. The chemical composition was grouped into compound classes (phenolics, terpenes, steroids, etc.) and related to the observed biological activities.

This review study did not involve experimentation with humans or animals and therefore did not require ethics committee approval. However, all reviewed studies that involved animal or human experimentation followed the ethical principles as stated by the original authors.

3 RESULTS AND DISCUSSION

The analysis of the selected articles revealed a total of 51 studies, of which 18 were excluded because they did not answer the guiding question, 4 were excluded because they did not present the species composition and 14 were duplicated in different databases. Thus, 15 studies were included in the final review (Table 1). The geographic distribution of the studies showed that 65% were conducted in Brazil, 30% in India and 5% in Nigeria, considering their areas of occurrence.

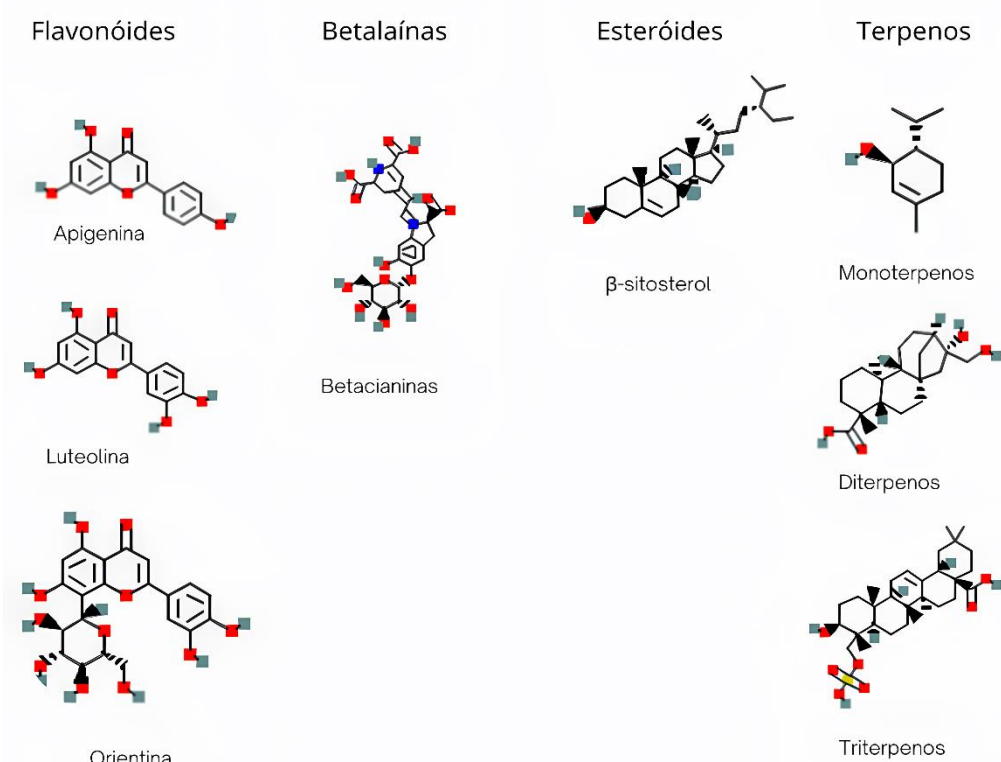
3.1. PHYTOCHEMICAL ANALYSIS AND EXTRACTION METHODS

Phytochemical analysis of *Alternanthera brasiliana* revealed a diversity of bioactive compounds, such as flavonoids, terpenes, steroids, saponins and alkaloids, identified mainly in the leaves and stems of the plant through methods such as LC-MS and GC-MS (Figure 1) (Facundo et al., 2012; Schneider-Teixeira et al., 2022; Pelisoli Formagio et al., 2012)



Figure 1

Alternanthera brasiliana extracts , according to studies available in the literature.



Source: (PubChem, 2024).

Flavonoids were the most frequently reported compounds, present in 85% of the studies analyzed. In addition, the GC-MS technique allowed the detection of several other classes of substances, including hydrocarbons, vitamin derivatives and phytosterols (de Alencar Filho Teixeira et al., 2020). Betalain pigments were also observed , with emphasis on betacyanins , responsible for the characteristic coloration of the leaves (Schneider-Teixeira et al., 2022).

The extraction methods used in the reviewed studies varied widely, significantly influencing the chemical composition of the extracts obtained. The maceration technique was identified in 80% of the studies, and the other techniques (hot maceration, acid digestion and hydrodistillation) together accounted for 20%. Regarding the solvents used, ethanolic extraction was the most common technique, used in 35% of the studies, followed by hydroalcoholic (23%) and aqueous (19%) extraction (Palisoli Formagio et al., 2012; Coutinho et al., 2018).

The choice of solvent and extraction conditions, such as temperature and time, proved to be crucial for the effectiveness in obtaining bioactive compounds, as demonstrated by the different yields and chemical compositions observed between studies (Schneider-Teixeira et al., 2022).



Table 1

Description of the chemical composition, part of the plant used and extraction method of Alternanthera brasiliana extracts .

Reference	Plant part	Extraction Method	Chemical Composition
(Pelisoli Formagio et al., 2012)	Stems and leaves	Aqueous (infusion)	Phenolic compounds, saponins, flavonoids, alkaloids, anthocyanins
(Pereira et al., 2013)	Sheets	Ethanolic (70%) (Maceration)	3-O robinobiosides of kaempferol and quercetin , β - sitosterol , stigmasterol
(Barua et al., 2012)	Sheets	Methanolic (Maceration)	Alkaloids, steroids , triterpenes
(Coutinho et al., 2018)	Sheets	Ethanolic (Maceration)	Luteolin , apigenin , orientin
(Facundo et al., 2012)	Flowers	Ethanolic (Maceration)	β -sitosterol-3-O- β -D- glucopyranoside , flavonoids
(Delaporte et al., 2005)	Sheets	Digestion	Macronutrients, micronutrients
(Brochado et al., 2003)	Sheets	Ethanolic (Maceration)	Kaempferol , quercetin
(Enechi et al., 2013)	Sheets	Ethanolic (Maceration)	Phenols
(Trapp et al., 2015)	Stems	Ethanol/ethyl acetate (Maceration)	Linoleic oxylipins
(Schneider-Teixeira et al., 2022)	Sheets	Aqueous (infusion)	Betacyanins , phenolic compounds grouped into hydroxycinnamic acids and flavones
(Alencar Filho, Sampaio, et al., 2020)	Sheets	Aqueous (infusion)	Flavonoids
(Das & Tribedi , 2015)	Sheets	Aqueous and methanolic	Saponins, cardiac glycosides, steroids, tannins, flavonoids
(Samudrala et al., 2015)	Sheets	Ethyl acetate (Maceration)	Alkaloids, glycosides, saponins, triterpenes, terpenoids, flavonoids
(Paliwal et al., 2023)	Sheets	Hydroalcoholic (Maceration)	Terpenoids, fatty acids, glycosides, alkaloids, phenols, flavonoids
(J. M. T. D. Alencar Filho et al., 2020)	Sheets	Ethanolic (Maceration)	Hydrocarbons (acids: linoleic, myristic , palmitic and stearic), phytosterols , diterpenes , triterpenes , vitamins, monoterpenes, carotenoids

In studies involving *Alternanthera brasiliana* , extraction techniques play a key role in obtaining bioactive compounds for subsequent analysis. The “maceration” extraction technique is a popular method due to its simplicity and efficiency in extracting a wide range of compounds, such as flavonoids, alkaloids, and terpenes. For example, Brochado et al. (2003) used maceration in ethanol for one week in the dark to isolate flavonoids, while Facundo et al. (2010) and Coutinho et al. (2018) employed maceration in ethanol at room temperature to obtain extracts rich in bioactive compounds.

In addition to traditional maceration, hot maceration can be used to accelerate the extraction process and improve the yield of certain compounds. Das and Tribedi (2015) applied hot maceration using a mixture of aqueous solvents and methanol (1:1) at 45°C, which facilitated the extraction of secondary metabolites, such as saponins, glycosides and flavonoids, in addition to improving the antimicrobial activity of the extracts obtained. This method is



especially useful when seeking to extract compounds that may be less soluble at room temperature conditions or that require specific conditions to be extracted effectively.

Hydrodistillation, on the other hand, is normally used to obtain essential oils, which are volatile compounds of interest in several pharmacological and cosmetic applications. Lopes et al. (2014) used hydrodistillation to isolate essential oils from *Alternanthera brasiliana*, a technique that stands out for its ability to extract volatile compounds efficiently and without significant thermal degradation. The choice of extraction method is crucial to ensure that the compounds of interest are extracted efficiently and stably, which directly influences the quality and application potential of the extracts obtained.

In studies of *Alternanthera brasiliana*, several chemical identification techniques were used to characterize the bioactive compounds present in the extracts. Among the most frequently employed techniques is High Performance Liquid Chromatography (HPLC), which was used in studies such as those by Facundo et al. (2010) and Coutinho et al. (2018) to separate, identify and quantify flavonoids and other polar compounds present in the extracts. HPLC is highly effective for the analysis of complex compounds, allowing precise separation and quantification of specific substances within plant extracts.

Another widely used technique was Gas Chromatography-Mass Spectrometry (GC-MS), particularly suitable for the analysis of volatile compounds, such as essential oils and fatty acids. Alencar Filho et al. (2019) employed GC-MS to identify 22 compounds in *Alternanthera brasiliana* extracts, of which 20 were reported for the first time in the species. This technique, together with Electrospray Ionization Mass Spectrometry (ESI-MS), which was used in combination with LC-MS/MS to identify specific flavonoids, stands out for its ability to provide detailed and accurate identification of a wide range of compounds.

In addition, Nuclear Magnetic Resonance (NMR) and UV-Vis Spectrophotometry have also played crucial roles in the structural elucidation and quantification of bioactive compounds. NMR was used by Brochado et al. (2003) and Facundo et al. (2010) to determine the molecular structure of flavonoids, providing detailed information about the chemical environment of the atoms. On the other hand, UV-Vis Spectrophotometry was used to quantify compounds such as flavonoids and phenolic acids, offering a simple and rapid technique for quantitative analysis. These combined techniques allow a comprehensive chemical characterization, fundamental to understand the pharmacological and biological properties of *Alternanthera brasiliana*.



3.2 BIOLOGICAL ACTIVITIES

The species *Alternanthera brasiliana* has been widely studied for its various biological activities, the most common being anti-inflammatory action, present in 67% of the reviewed studies. In addition, its antioxidant and antimicrobial properties, cited in 55% of the studies, reinforce its therapeutic potential against oxidative stress and infections. Although less frequent, antitumor and hepatoprotective activities were observed in 12% of the articles, while the sedative/anesthetic and nutritional effects were rarely reported, appearing in only 6% of the studies (Table 2). These properties highlight the pharmacological value of the plant and its possible applications in natural treatments.

Phenolic compounds, such as flavonoids, have been frequently associated with the anti-inflammatory and antioxidant activities of *A. brasiliana*. Studies by Enechi and Pereira (2013) highlight the effectiveness of extracts in neutralizing free radicals, while Coutinho et al. (2018) demonstrated a significant reduction in edema, between 35.57% and 64.17%.

Table 2

Biological activity and main results found of the compounds identified in the extracts of Alternanthera brasiliana, according to the systematic review carried out.

Activity	Reference	Description
Antioxidant and Anti-inflammatory	Enechi et al. (2013); Pereira et al. (2013); Kasthuri and Ramesh (2018); Alencar Filho et al. (2020); Brochado et al. (2003); Coutinho et al. (2018); Facundo et al. (2012)	Increasing concentrations of <i>A. brasiliana</i> extract inhibit the DPPH radical. Phenolics were effective in capturing free radicals. Leaf extracts have the ability to combat free radicals and oxidative stress. Development of a photoprotective gel with high efficacy against sun damage. Associated flavonoids anti-inflammatory and analgesic actions. Extract demonstrated anti-edematogenic effect, with edema reduction between 35.57% and 64.17%.
Antimicrobial	Pelisolí Formaggio et al. (2012); Das and Tribedi (2015); Trapp et al. (2015); Johan et al. (2010); Marchete et al. (2021); Coutinho et al. (2018)	Phenolic compounds and saponins attributed to antimicrobial properties. High activity against Gram-positive pathogens when aqueous and methanolic extracts were mixed. Identification of 17 oxylipins with antibiotic properties in the stem parts of the plant. Antifungal activity against <i>Paracocci</i> . Antimicrobial potential against multidrug-resistant bacterial strains.
Hepatoprotective	Paliwal et al. (2023)	Hepatoprotective effect of the hydroalcoholic extract highlighting terpenoids, fatty acids, glycosides, alkaloids, phenols and flavonoids.
Antitumor	Samudrala et al. (2015); Kasthuri and Ramesh (2018)	Potent antitumor activity of ethyl acetate extract, comparable to 5-fluorouracil. Cytotoxic activity of leaf extract against tumor cells in vitro.
Wound Healing	Barua et al. (2012); Santos et al. (2021)	Alkaloids and triterpenes contributed to wound healing.



Activity	Reference	Description
Nutritional	Delaporte et al. (2005); Schneider-Teixeira et al. (2022)	Potential as a nutritional supplement. Potential as a food coloring, maintaining stability and antioxidant activity during storage.

Regarding antimicrobial activity, the presence of saponins and alkaloids is indicated as the disruptive factor of microbial membranes. Studies indicate high activity against Gram-positive pathogens, in addition to relevant effects against multidrug-resistant bacterial strains (Das and Tribedi , 2015; Marchete et al., 2021). Antifungal activity was also recorded, especially against *Paracoccidioides brasiliensis* .

The hepatoprotective properties of the plant are attributed to terpenes and β - sitosterol , compounds that have demonstrated liver protection by modulating inflammatory and oxidative pathways (Paliwal et al., 2023). Furthermore, the ethyl acetate extract of *A. brasiliana* showed potent antitumor activity, comparable to 5-fluorouracil, with significant cytotoxic effects on tumor cells in in vitro studies (Kasthuri & Ramesh , 2018; Samudrala et al., 2015).

Finally, wound healing is another area of emphasis, where alkaloids and triterpenes present in the plant were effective in accelerating the healing of wounds and burns, as described by Barua et al. (2012) and Santos et al. (2021). The relationship between the chemical composition of *A. brasiliana* and its various biological activities reinforces its therapeutic potential in several areas of health, especially due to the presence of flavonoids and phenolics that confer its main medicinal properties.

3.3 GAPS, LIMITATIONS AND FUTURE PERSPECTIVES

Despite these promising findings, there are critical gaps in the knowledge about *Alternanthera brasiliana* that require further investigation. First, although preclinical studies have demonstrated diverse biological activities, it is essential to investigate the efficacy and mechanisms of action of the bioactive compounds in human clinical models to validate their therapeutic potential. Another factor is the synergistic interaction between the different bioactive compounds present in the plant and their combined effects, which have not yet been fully explored. Understanding these interactions may result in more effective therapeutic formulations. Furthermore, detailed studies on the safety and toxicity of *Alternanthera brasiliana* extracts are needed, especially for long-term or chronic use.

Alternanthera brasiliana is a potential source of new medicines and nutraceutical products. The development of new products should focus on the therapeutic properties of the



plant. Additional studies on the stability of betacyanins and their use as natural colorants in foods are also essential to ensure their effective application, preserving their antioxidant properties during storage.

4 CONCLUSION

This study systematically investigated the chemical components and biological properties of *Alternanthera brasiliana*, highlighting its therapeutic potential. Flavonoids, terpenes and alkaloids that exhibit antioxidant, anti-inflammatory, antimicrobial, hepatoprotective and antitumor properties were identified. These findings demonstrate that *Alternanthera brasiliana* has proven pharmacological actions, contributing significantly to the development of new drugs and expanding the understanding of its therapeutic potential.

To maximize the therapeutic applications of *Alternanthera brasiliana*, it is recommended to conduct clinical trials to validate the efficacy and safety of bioactive compounds in humans. It is crucial to investigate the interactions between different compounds to improve therapeutic formulations. In addition, the development of new pharmaceutical, nutraceutical and cosmetic products should focus on the therapeutic properties of the plant. Continued research on the stability of betacyanins to ensure their effective application as natural colorants in foods is essential, preserving their antioxidant properties during storage.

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