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Brazilian endophytic fungi: biotechnological potential in evidence

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ABSTRACT

Plants play a key role in the ecosystem, especially in interactions with other living beings, including endophytic fungi. These fungi have a remarkable ability to produce bioactive compounds that resemble those present in their host plants. In this context, this study aims to present an overview of research carried out in Brazil on the biotechnological potential of endophytic fungi isolated from plants present in different Brazilian biomes. To achieve this goal, exploratory research was conducted in online databases and in open access published articles. The results indicate a concentration of investigations on prospecting endophytic fungi with metabolic potential in the Cerrado, Caatinga and Pantanal biomes. These endophytic fungi have a vast potential for the production of biomolecules with diverse applications in biotechnological processes, some of these fungi have the ability to produce metabolites with varied biological activities, including pharmacological properties, such as antitumor and antibiotics. However, it is important to note that these fungi are still poorly studied, and may be explored in relation to their potential for producing biomolecules.

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RESUMO

As plantas desempenham um papel fundamental no ecossistema, especialmente nas interações com outros seres vivos, entre eles os fungos endofíticos. Esses fungos apresentam uma notável habilidade para produzir compostos bioativos que se assemelham aos presentes em suas plantas hospedeiras. Neste contexto, este estudo visa apresentar uma visão geral das pesquisas desenvolvidas no Brasil sobre o potencial biotecnológico dos fungos endofíticos isolados de plantas presentes nos diferentes biomas brasileiros. Para alcançar esse objetivo, foi conduzida uma pesquisa exploratória em bases de dados online e em artigos publicados de acesso aberto. Os resultados indicam uma concentração das investigações sobre a prospecção de fungos endofíticos com potencial metabólico nos biomas Cerrado, Caatinga e Pantanal. Esses fungos endofíticos possuem um vasto potencial para a produção de biomoléculas com diversas aplicações em processos biotecnológicos, alguns desses fungos têm a capacidade de produzir metabólitos com atividades biológicas variadas, incluindo propriedades farmacológicas, como antitumorais e antibióticos. No entanto, é importante observar que esses fungos ainda são pouco estudados, podendo vir a ser explorado em relação ao seu potencial de produção de biomoléculas.

Palavras-chave:
Biomas.
Atividade Biológica.
Biodiversidade.
Propriedades Farmacológicas

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Introduction

Brazil is internationally recognized for its diverse biomes, which have extraordinary biodiversity (Maksic *et al.*, 2022). Each of these biomes has unique characteristics, including climate, soil and plant species, which are essential in preserving biodiversity and ecological balance (Magnusson *et al.*, 2018; Manhães *et al.*, 2018). The preservation of Brazilian biomes is fundamental, as they are home to a wide diversity of species, both fauna and flora, with emphasis on some endemic plant species (Martinelli *et al.*, 2021; Fernandes *et al.*, 2020), of great importance that are still little explored. Plants are a source of medicine for several communities, especially those located in regions far from urban centers (Leite *et al.*, 2021; Valli; Bolzani, 2019). Some plants are considered important therapeutic resources based on ethnocultural knowledge (Do Nascimento Magalhães *et al.*, 2019).

Over time, plants have developed complex mechanisms of adaptation to the environment, including symbiotic interactions with microorganisms. This resulted in the formation of a diverse microbiota that interacts symbiotically with host plants (Uroz *et al.*, 2019; Custodio *et al.*, 2022). These interactions occur at various levels and involve different organisms, such as bacteria, fungi and even viruses (Losi; Gaertner, 2021) that can colonize different parts of plants, such as roots, stems, leaves, flowers and seeds (Trivedi *et al.*, 2020), establishing a mutualistic relationship beneficial to both.

Symbiotic microorganisms play important roles in the health and well-being of host plants. A good example is some bacteria that have the ability to fix nitrogen and can provide a vital supply of this compound to plants. (Martins Da Costa *et al.*, 2020; Soumare *et al.*, 2020). Furthermore, other microorganisms can help plants absorb nutrients from the soil more efficiently, improving their resistance to diseases and environmental stresses, also contributing to the production of beneficial chemical substances that promote plant growth and development. On other hand, plants provide an environment conducive to the growth and reproduction of symbiotic microorganisms.

This interaction between the different microbiota is carried out symbiotically with the host plants and plays a role in the health and functioning of ecosystems (Trivedi *et al.*, 2020), and can help in different areas such as agriculture and food production, as they can be explored to improve crop efficiency, reduce the use of chemical fertilizers and pesticides, helping to develop sustainable agriculture (Fenibo *et al.*, 2021; Kuila; Ghosh, 2022).

Knowledge about these interactions is based on discoveries resulting from observation of the environment interactions between species. In symbiotic interactions, microorganisms have the ability to induce or produce primary metabolites, conferring several advantages on plants (Bolívar-Anillo *et al.*, 2020; Kumar *et al.*, 2021). Such as endophytic fungi that have a high capacity to produce bioactive metabolites with potential for use in biotechnological processes. Some of these compounds demonstrate promising activities in various processes and applications, including the pharmaceutical, food and biofuel industries (Gupta *et al.*,

2020). The potential of these metabolites may be directly related to the phytochemicals produced by plants, resulting from the interaction between endophytes and their hosts.

In a way, the mutualistic relationship between host plants and endophytic fungi occurs through the restriction of the plants and the growth of the fungi. While the latter use various mechanisms to gradually adapt to the environment they live in, their survival and reproduction being possible thanks to an evolved enzyme system and biotransformation potential, which allows them to transform complex compounds (Baron; Rigobelo, 2022; Sharma *et al.*, 2023).

Recent studies have shown that endophytic fungi are capable of producing large number of important secondary metabolites (Vasundhara *et al.*, 2019; Cheng *et al.*, 2022; Pacheco-Tapia *et al.*, 2022), previously known only in plants, such as Taxol, a drug used in the treatment of cancer, by the endophytic fungus *Taxomyces andreanae*, isolated from the plant *Taxus brevifolia* which also produces this substance, suggesting that endophytes have acquired the ability to produce in vitro the same substances present in their hosts (Kuriakose *et al.*, 2020). In this sense, the present study aims to present an overview of research carried out in Brazil on the biotechnological potential of endophytic fungi isolated from plants present in different Brazilian biomes.

Materials e Methods

Nature of research

This is an exploratory descriptive review, developed on bibliographical research, preferably on articles published in periodicals and available online. A preliminary search was carried out, in which the search keywords were determined and virtual data search databases were consulted Scholar Google and Scielo. For this purpose, the terms “biomes AND Brazil AND endophytic fungi AND secondary metabolites”, both in Portuguese and English, considering the period between 2018 to 2022.

To delimit the research, article inclusion criteria were adopted, which consisted of selecting only articles published in magazines available online, as long as they were relevant to the topic in question. In order to compose the database for this article, a selection process was carried out based on the analysis of the abstracts, keywords and area of knowledge of the articles considered.

The descriptive exploratory review as a methodology allows for a comprehensive and detailed analysis of a given topic, leading to new discoveries and insights, which can lead to the observation and identification of gaps on the topic that can still be explored. The descriptive review provides support to deepen knowledge about a specific subject or phenomenon researched, providing a more elaborate discussion of different aspects that result in the

construction of more solid knowledge (Snyder, 2019; Xiao; Watson, 2019; Palmatier *et al.*, 2018).

Data analysis

The articles were read and the data compiled with Excel 2019 software, as well as the graphs.

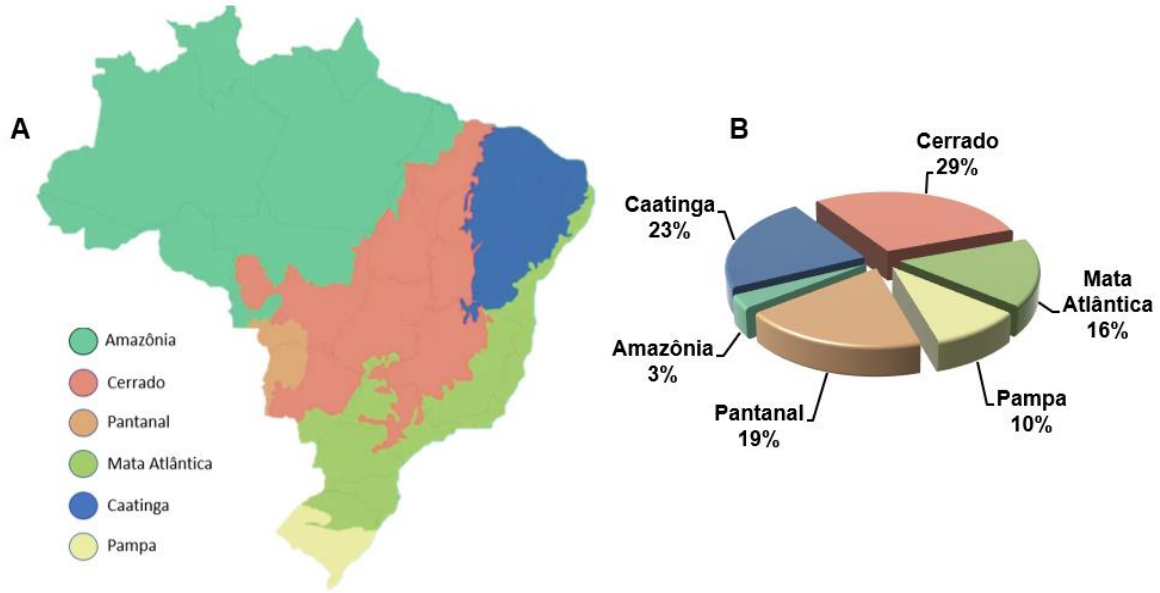
Results e Discussion

Brazil has the greatest biological diversity on the planet, housing biomes considered hotspots for the assessment and preservation of biodiversity. Some of these biomes, such as Mata Atlântica, Cerrado, Pantanal and Caatinga, are unique and present a singularity in their ecological complexity (Figure 1A). These biomes are among the most studied, as biodiversity is present in the fauna and mainly in the flora, with some plant species considered endemic. These plants may contain unique microbiota such as endophytic fungi.

Although endophytic biodiversity is rich and valuable, it is still poorly understood and explored, as highlighted by Dantas et al. (2021). In Brazil, it can be observed that research aimed at prospecting endophytic fungi with potential for the production of metabolites is concentrated in biomes Cerrado, Caatinga and Pantanal present 29, 23 and 19 % respectively (Figure 1B).

Figure 1.

Brazilian biomes and the panorama of research into prospecting endophytic fungi in Brazil.



Source: Prepared by the authors with research data (2023).

Caatinga is the largest dry tropical forest in South America, is located in northeastern Brazil. Despite adverse climatic conditions, such as irregular rainfall and high temperatures, it is home to a great diversity of plants, including endemic species. Its vegetation is mainly composed of cacti (De Andrade Vieira *et al.*, 2022). Studies indicate that this biome presents a remarkable fungal diversity, with the potential to produce bioactive compounds (Marinho *et al.*, 2019; Barbosa *et al.*, 2020).

Amazônia is the largest Brazilian biome, covers approximately 60% of the national territory, characterized by its hot and humid climate, with intense rain and high temperatures throughout the year (Ferreira; Reboita, 2022), displaying lush vegetation with endemic species of flora that provides the presence of endophytes, especially fungi, which develop and adapt to climatic conditions (De Oliveira Amaral *et al.*, 2022).

However, the biodiversity of endophytic microorganisms in this biome is still little explored. Mata Atlântica, which is present only in fragments, is known for its remarkable diversity of plants and animals, many of which are threatened with extinction (De Lima *et al.*, 2020). Large trees, palm trees, bromeliads and orchids are present in this biome (De Paula et al., 2020) which are environments conducive to the development of endophytes.

Cerrado, the second largest biome in Brazil, located in the center of the country, is recognized for its rich biodiversity and the occurrence of endemic species and plants that are more resistant to environmental conditions (De Oliveira Santana; Simon, 2022). Pantanal has plant species that are also more resistant to environmental conditions, since in this biome there are plains that are flooded during periods of the year (Dalmagro *et al.*, 2022). It is a biome rich in floristic biodiversity that presents species with a high capacity for tolerance to climatic conditions such as high temperatures and prolonged periods of drought (Júnior *et al.*, 2021), which can provide the presence of a specific endophytic microbiota with unique characteristics and which can produce distinct chemical or phytochemical compounds (Raimi; Adeleke, 2021), which are still little explored.

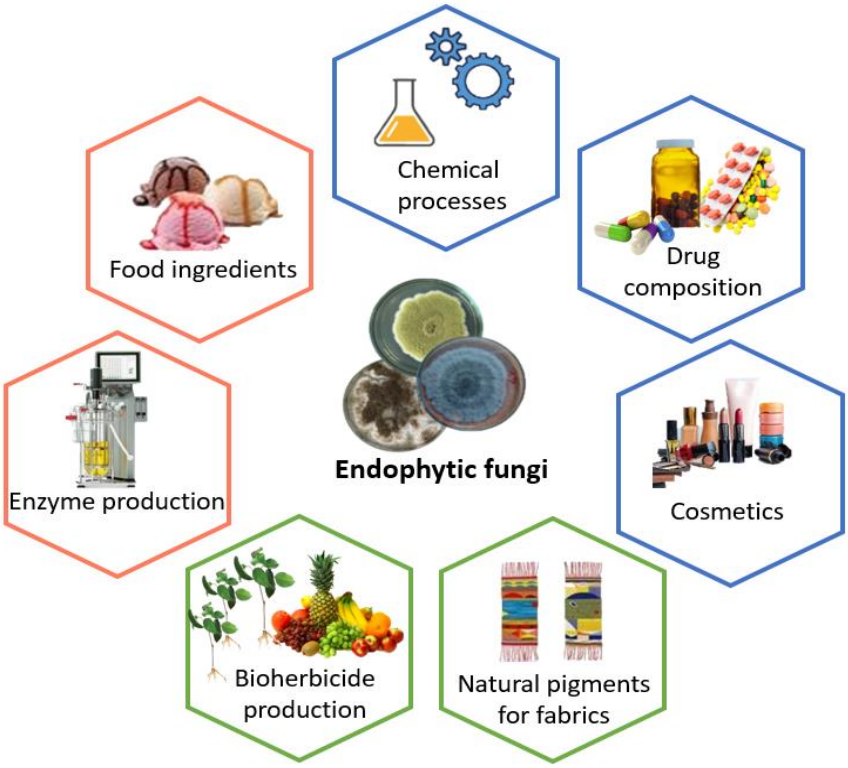
Endophytic fungi have vast potential for the production of biomolecules, which can have diverse biotechnological applications. These biomolecules can be used in several areas, such as in the manufacture of medicines, pigments used in food composition and in the textile industry, as well as in the manufacture of enzymes that are fundamental for different industrial processes. Furthermore, these fungi have the ability to synthesize phytochemicals that have great potential for use in modern agriculture. Endophytic fungi demonstrate to be a rich and versatile source of biotechnological resources with varied and relevant applications in different sectors (Figure 2).

Nowadays, recognition of the relevance of preserving the environment and biodiversity has gained increasing prominence. The perception that plants, microorganisms, animals and insects are potential sources of new bioactives has grown remarkably. These products, of natural origin, can be used in the development of new innovative pharmaceutical compounds,

opening promising horizons for obtaining new substances with wide applicability (Valli *et al.*, 2018; Calixto, 2019). Thus, through biotechnology, new perspectives have opened up for both the pharmaceutical industry and advancement in this field, which are intrinsically connected to the evolution of chemical processes and medical sciences. It is important to highlight that plants have assumed a fundamental role in this scenario, as highlighted Gonçalves and Romano (2018).

Figure 2.

Potential for applicability in different processes.



Source: Prepared by the authors with research data (2023).

Furthermore, endophytes emerge as promising sources of natural products, as they have the ability to synthesize the same bioactive compounds present in the host plant (Kuriakose *et al.*, 2020). Some of these bioactive compounds may contain properties that can be used in different areas, suggesting that some bioactive compounds that were previously thought to be produced exclusively by plants can also be synthesized by these microorganisms (Hashem *et al.*, 2023; Rutkowska *et al.*, 2023).

Some endophytic fungi from different species are already under study and present metabolites with broad biological activity. Among the activities, the main ones are bioremediation, antioxidant activity, antimycotic, antibacterial and anti-inflammatory activity and allelopathy, in addition to considering the challenges and implications of these discoveries.

Some endophytic fungi studied have shown the production of metabolites with potential for application in biotechnological processes, as they present promising biological activity (Table 1).

Table 1.

Endophytic fungi with potential for application in biotechnological processes.

Fungus	Biological activity	Reference
Avicennia marina	Fungicide	Al Husnain *et al.* (2023)
Serendipita indica	Soil bioremediation Increased plant biomass	Liu *et al.* (2023)
Penicilluim commune, Penicilluim glaucoroseum, Aspergillus flavipes Fusarium chlamydosporum	Antioxidant activity	Hassane *et al.* (2022)
Mycoleptodiscus indicus, Penicillium citrinum, Humicola grisea	Antimycotic, antibacterial and anti-inflammatory activity	Andrioli *et al.* (2022)
Xylaria sp., X. venulosa, X. apiculata, Cladosporium halotolerans, Coriolopsis rigida, Myceli asterilia, Preussia sp., P. africana	Allelopathy	Fernandes *et al.* (2018)
Mycosphaerella sp.	Antitrypanosomic action	De Oliveira *et al.* (2018)
Dichotomophthora sp. Aspergillus nidullans	Antioxidant action and antiacetylcholinesterase potential	Alves *et al.* (2020)

Source: Prepared by the authors with research data (2023).

However, there are some factors that must be taken into consideration regarding the presence and production of bioactive compounds in endophytic fungi, since the same organism may not express the compound present in the host plant or the fungus may produce other distinct metabolites. This may occur due to the conditions of the environment in which the plant is located (Rutkowska *et al.*, 2023).

The characteristics and quantities of bioactive compounds produced by endophytic fungi are influenced by a number of factors, including soil quality, climate, ecological factors, plant characteristics and biodiversity (Abu Taher *et al.*, 2023). These variations have important

implications for the research and application of bioactive compounds of fungal origin in several areas, such as medicine and agriculture.

In recent years, many efforts have been employed to identify new molecules derived from natural sources that exhibit a range of clinical and pharmacological activities. This led to extensive research into organic substances synthesized by various plants and microorganisms growing in diverse habitats (Chandra *et al.*, 2020).

Conclusions

In Brazil, research on endophytic fungi with metabolite production potential is concentrated in the Cerrado, Caatinga and Pantanal biomes.

Endophytic fungi have high potential for the production of biomolecules for various biotechnological applications with high added value.

Despite the biological diversity present in Brazil, which is home to countless species of flora, there is a notable lack of studies related to endophytic fungi that inhabit plants. Specifically, there is a gap regarding the potential of these fungi to produce metabolites with commercial value and that can be used in the formulation of drugs, including antitumor drugs and antibiotics.

The results obtained so far highlight the importance of directing new research to analyze the interaction between endophytic fungi and the environment in which they are located. This approach can collaborate with advances in obtaining new compounds/biomolecules of natural origin that can have diverse applications in the field of biotechnology.

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