

Review article: studies of fungi in the state of amazonas, brazil in the last 10 years

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Resumo

Os fungos são seres eucariontes, uni ou multicelulares e estão presentes em nosso dia a dia, tanto na fabricação de alimentos como na proliferação de doenças. A ocorrência dos fungos do filo Basidiomycota é encontrada com maior frequência na floresta, pois são nestes lugares que os fungos encontram as condições que melhor garantem as suas necessidades fisiológicas, agindo como principais decompositores da matéria orgânica. O presente trabalho tem como objetivo realizar análise de produção sobre fungos no Amazonas. A revisão consistiu em analisar artigos científicos, dissertações e tese na área da micologia na região amazônica disponíveis nas bases de dados PubMed, Scielo, Lilacs, Sciencedirect e Google Acadêmico, nos idiomas inglês e português. A coleta de dados, utilizou como critério de inclusão o período de publicação entre 2008 e 2018, o critério de exclusão foram as palavras-chaves que não estivessem de acordo com as análises propostas pelos critérios das publicações. Verificou-se que todos os trabalhos relacionados sobre fungos estão publicados em revistas científicas nas áreas de ensino (dois), saúde (cinco) e meio ambiente (quatro), com destaque nos fungos *Candida*, *Aspergillus* e *Penicillium*. A Floresta Amazônica tem sido pouco investigada, principalmente em relação a pesquisas com fungos o que torna urgente o conhecimento sobre a diversidade dos fungos principalmente em áreas da Amazônia brasileira, onde a mesma precisa ser mensurada.

Palavras-chave: Basidiomicetos; Micologia; Amazônia

Abstract

Fungi are eukaryotic beings, uni or multicellular and are present in our daily lives, both in the manufacture of food and in the proliferation of diseases. The occurrence of fungi of the phylum Basidiomycota is most frequently found in the forest, as it is in these places that fungi find the conditions that best guarantee their physiological needs, acting as the main decomposers of organic matter. The present work aims to carry out production analysis on fungi in Amazonas. The review consisted of analyzing scientific articles, dissertations and thesis in the field of mycology in the Amazon region available in the databases PubMed, Scielo, Lilacs, Sciencedirect and Google Scholar, in English and Portuguese. The data collection used the publication period between 2008 and 2018 as the inclusion criterion, the exclusion criterion was the keywords that were not in accordance with the analyzes proposed by the publication criteria. It was found that all related works on fungi are published in scientific journals in the areas of teaching (two), health (five) and the environment (four), with emphasis on the fungi *Candida*, *Aspergillus* and *Penicillium*. The Amazon Forest has been little investigated, mainly in relation to fungi research, which makes it urgent to know about the diversity of fungi, especially in areas of the Brazilian Amazon, where it needs to be measured.

Keywords: Basidiomycetes; Mycology; Amazon

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1 Introduction

The Amazon has a particularly important role in the conservation of biodiversity and in the economic and strategic scenarios of Brazil, consisting of the largest extension of continuous tropical rainforest within the nation, being characterized by a remarkable species richness and high rates of endemism (CAPOBIANCO et al., 2001). This forest is formed by a mosaic of habitats which are quite distinct: the ombrophilous (open and dense) forests, seasonal (deciduous and semideciduous) forests, montane refuges, pioneer formations, "terra firme", floodplain, "igapós", "campinaranas" and Amazonian savannas (MUSEU PARAENSE EMÍLIO GOELDI, 2007).

Regarding the environmental criteria, its importance is associated to its species variety, the abundance of fresh water, the carbon stock and the ability to transfer heat and steam to other regions. At the economic level, it contributes to the diversity of living organisms, mineral resources, agriculture, hydroelectric power, among others (PERCORPE, 2015) Although extensive areas still remain intact, the rate of forest loss is dramatic, especially in the "deforestation arch" along the southern and eastern edges of the Amazonas state. As a result, biodiversity loss and climate impacts are of major concern. The vastness of the remaining forests means that the potential impacts of deforestation on an ongoing basis are far more important than the severe impacts that have occurred to date (FEARNSIDE, 2005).

Fungi are eukaryotic, heterotrophic organisms which obtain their food from organic matter or nourishing themselves as parasites from living hosts. These microorganisms influence human life by participating in beneficial or harmful processes. In general, the fungi include molds (or mildew) and yeasts. The molds are filamentous and multicellular whereas the yeasts consist of a single cell (TORTORA, 2012).

They are highly important organisms, being used in the production of foods such as fermented products and alcoholic beverages. Moreover, they contribute in the pharmaceutical industry, are present in the process of biodegradation and biological treatment of effluents, the production of enzymes of industrial interest and biotransformation. They are also of great agricultural and ecological relevance, as they maintain the balance of the environment by decomposing plant debris, degrading toxic substances, helping plants to grow and protecting themselves against enemies such as other pathogenic microorganisms. Finally, fungi are microorganisms of great biotechnological interest (ABREU et al., 2015).

The diversity of fungi and their occurrences vary according to the geographic location, in addition to the vegetation and climate, that there can be a change in the seasonality and speed of the winds of each region since the release of the spores that depend on favorable conditions provided for the environment. Most fungi are commonly considered aeroallergic and have a seasonal pattern of spore release (MENEZES, 2004).

One of the greatest scientific challenges of Brazil is to plan a territorial management system for the Amazon, the region that harbors the greatest biodiversity on the planet, and which takes into account both the conservation of its extraordinary natural resources and the promotion of social and economic development of the nearly twenty million inhabitants of this region. The solid scientific knowledge accumulated for decades by regional research institutions played an irrelevant role in this discussion (VIEIRA; SILVA; TOLEDO, 2005).

The knowledge about mycodiversity is still precarious and fragmented. According to Kirk et al. (2008) and Quevedo et al. (2012), the approximately 99.000 species of fungi studied to date represent only 6.6% of the estimated species for all ecosystems (about 1.500,000), which demonstrates that the vast majority of them have not yet been described.

According to Alfredo et al. 2012, cites that researchers, approximately 1.000 species of macrofungi have already been discovered in the Amazon and cataloged, but scientists estimate that in the world there are about 1.5 million species of fungi in total. Most of the unknown species would be in tropical forests, threatened by the destruction of habitats and the introduction of exotic species.

According to Gil (2008), a bibliographical research develops from books and articles by a systematic process through the method of scientificity, having as main objective to expose solutions to problems by the use of scientific procedures.

Marconi and Lakatos (2003) further complement the ideas of the above mentioned author, stating that the purpose of bibliographic research is to put the researcher in direct contact with everything that has been written, said or filmed about a certain subject, including conferences followed by debates that have been transcribed by means of publications or records.

Considering the information, the present study aimed to analyze the scientific production on fungi in the state of Amazonas, present in all areas of knowledge in different areas, namely, biotechnology, economic botany, pharmacology ecology, taxonomy. Using databases to build a bibliographic review referring to publications in the period of 10 years.

2 Materials and Methods

Data collection was carried out in the databases Pubmed, Scielo, Lilacs, ScienceDirect and Google Scholar in order to identify relevant articles, dissertations and theses in the field of mycology. The keywords used were: "Legal Amazon", "Fungi", "Basidiomycetes", "Southern Amazon", "Macrofungi", "Biodiversity", Mycology. The articles selected were written in Portuguese and English, between 2008 and 2018.

In this work, a literature review was conducted through a descriptive and exploratory research that aimed to analyze the material produced in the scientific investigations considering all stages, such as: concepts, techniques, results, discussions and conclusions, in order to verify articles published in national and international journals, since this type of study tries to explain a problem from theoretical references published in documents.

The historical method will subsidize the investigation of the bibliographic and documentary events that influenced the problem in the present.

According to the research terms, it was possible to access ninety scientific articles. With the next step, the titles were read, in which only the scientific articles were selected, for the current time that they represent in terms of research.

This stage of the research is relevant, enabling us to know the investigations that were carried out regarding the studied subject, to support it theoretically and to acquire new ideas, providing the researcher a deeper vision about the subject (ARAÚJO; OLIVEIRA; ROSSATO, 2016), thus answering the questions. In addition, the qualitative and quantitative approaches were used.

The abstracts of the publications were read with the intention of ascertaining the relevance of the studies to the guiding question, research articles and systematic reviews, with full abstracts, were selected. Exclusion criteria were articles that did not address the main ideas to be exposed in the article, narrative review, theses, dissertations, book chapters, non-scientific publications.

3 Results and Discussion

In the period comprised of the last ten years, there were only 15 scientific publications, consisting of scientific articles, dissertations and theses related to the proposed theme. It could be observed that the most frequent 60% genera in the studies were the microfungi *Candida*, *Penicillium* and *Aspergillus* (Table 1).

Candida albicans is the most common pathogen in cutaneous and oropharyngeal candidiasis, but non-*albicans* species have increased in number and importance in vaginal and systemic candidiasis. The variability in behavior of different species of *Candida* prompted the development of fast and easy methods for their identification. Chromagar *Candida*® has been shown to be a sensitive and specific for presumptive identification of the most commonly isolated species of yeasts of the genus *Candida* (HOUNG et al., 1997; REX et al., 2000).

Candidiasis is characterized by a fungal process caused by the genus *Candida* spp., which is a natural constituent of the intestinal flora. Its increase may occur due to stress, incorrect use of antibiotics, changes in pH or due to immunosuppression. It mainly affects young birds and may also affect the older ones, causing depression, anorexia, and ingluvial impaction, occurring the formation of mucosal lesions with white and salient plaques. Animals can be infected by ingesting contaminated food and water, causing intestinal problems or by inhaling aerosols, causing respiratory illnesses. The treatment relies on the use of antifungals and on the elimination of the predisposing causes (SOUBHIA et al., 2008).

Species of the genus *Aspergillus* are found in several habitats and are known for their ability to produce a large numbers of secondary metabolites. Although they produce several metabolites that are harmful to humans and animals, the genus *Aspergillus* has great biotechnological potential and is widely used in the food and pharmaceutical industries (PALENCIA et al. 2010).

When ingested, foods contaminated with filamentous fungi permit the metabolites generated by the fungus to invade tissues or fluids of the host. Mycotoxins are produced in suitable environments, on adequate substrates and by specific fungal strains. Among the genera involved in the production of mycotoxins are *Aspergillus* and *Penicillium*. The *Aspergillus* sp and *Penicillium* sp species tend to contaminate food during drying and storage (SANTOS et al., 2016).

Among the Amazonian fungi, there are investigations reporting the production of compounds with activity against Gram-positive and Gram-negative bacteria (SOUZA et al., 2004; SILVA, 2010; TONIAL, 2010; SILVA et al., 2010; ATHAYDE, 2011; GARBIN, 2011; LIMA, 2011; SIQUEIRA, 2011) yeasts of medical interest (SILVA et al., 2010; TONIAL, 2010; GARBIN, 2011); phytopathogens (FIGUEIREDO, 2006; SIQUEIRA, 2011) and also with herbicidal activity (SANTOS et al., 2008).

Table 1: Studies on fungi of the state of Amazonas published between 2008-2018, Brazil

Authors	Year of publication	Journal	Genus/Species
PARREIRA, D.F.; NEVES, W.S.N.; ZAMBOLIM, L.	2009	Revista Trópica – Ciências Agrárias e Biológicas	<i>Strobilurus tenacellus</i>
ROSA, M.A.; MOHR, A.	2010	Experiências em Ensino de Ciências	<i>Penicillium</i>
SOARES, I.A.; FLORES, A.C.; MENDONÇA, R.P.; BARONI, S.	2011	Arquivo do Instituto de Biologia	<i>Phanerochaete chrysosporium</i>
ISHIKAWA, N.K.; ISLA, R.V.; CHAVES, R.S.; CABRAL, T.S.	2012	Ciência & Ambiente	<i>Geastrum, Phallus, Staheliomyces e Mutinus</i>
DONIZETE, R.; PIROTA, P.B.; TONELOTTO, M.; SILVA, P.; TREMACOLDI, C.R.; FARINAS, C.S.	2012	Ciência Rural	<i>Penicillium, Aspergillus</i>
NAVES, F.; SANTANA, D.P.; RIBEIRO, E.L.; MENEZES, A.C.S.;	2013	Revista de Ciências Médicas e Biológicas	<i>Candida albicans</i>
ABREU, J.A.S.; ROVIDA, A.F.S.; PAMPHILE, J.A.	2014	Revista UNINGÁ	<i>Aspergillus</i>
JOHAN, C.S.; CARVALHO, M.S.; ZANOVELLO, R.; OLIVEIRA, R.P.; BISOGNIN, T.M.; BARBOSA, N.B.V.; MORESCO, T.R.	2014	Ciência e Natura	<i>Saccharomyces cerevisiae</i>
RÊGO, C.M.; SANTOS, F.S.	2015	Revista Brasileira de Biociências	<i>Cladosporium, Penicillium, Aspergillus, Curvularia</i>
LAZAROTTO, M.; OLIVEIRA, L.S.; HAKAKAVA, R.; ZANATTA, P.; FARIAS, R.J.	2016	Floresta e Ambiente	<i>Trichoderma</i>
FERREIRA, J.S.; FERREIRA, A.S.	2017	Revista de Ensino de Ciências e Matemática.	<i>Marasmius sp</i>
TAKAHASHI, J.; LIMA, G.S.; LYRA, F.H.; HUGHES, A.F.S.; GONÇALVES, F.A.G.	2017	Revista Virtual de Química	<i>Penicillium, Aspergillus</i>
PEREIRA, A.M.; FERRARINI, A.; RODRIGUES, A.G.; ROMANO, L.H.	2018	Revista Saúde em Foco	<i>Cryptococcus gattii</i>

It is noteworthy the existence of many works being published which investigate fungi with biotechnological potentials all over the world. However, only a few studies have been published on fungi belonging to Amazon region, mainly the studies by Durán et al. (2002) Teixeira et al. (2012) in natural dyes. Therefore, knowledge about biodiversity and diversity in the Amazon is still restricted due to constant environmental changes, lack of financial resources and lack of qualified human resources to carry out collections in the area of mycology, which contributes to low scientific production in this area of knowledge. In this context, there is a need to increase the knowledge of the endogenous mycobiota of the Amazon, thus making it essential to assess the

fungus diversity of this region, even though the largest Brazilian biome the fungus still needs studies.

Thus, Nascimento (2014) and Silva; Malta (2016) state that new advances in this area demand time in research and planning. The development of biotechnology requires a strong academic and scientific basis and a productive sector capable of transforming this production into goods and services thus contributing to the gain or enhancement of desirable characteristics for the use of fungi.

Fungi are present in almost all environments of Earth, and the greatest diversity is found in the tropical regions of the world, whose hot and humid climate is favorable to their proliferation. Among the tropical biomes, the Amazon forest comprises the richest extant biodiversity, with a large number of plants, animals and microorganisms that are yet to be fully described, since these are considered cosmopolitan, being present in the different aquatic and terrestrial ecosystems, where they are frequently observed as saprobes and/or parasites of algae, macrophytes, invertebrates, amphibians, fungi and oomycetes (CALDERON et al., 2009; BLACKWELL, 2011; JERONIMO et al., 2014).

Microorganisms are very important for the maintenance of the Amazon forest because they participate in the recycling of the components of nature via the biogeochemical cycles. The Amazonian soil is known to be poor in organic matter, and what guarantees the maintenance of the forest is the numerous microbial diversity present in the soil, which reuses the components of the plants and animals present in the environment, thus redistributing the primary elements among organisms and the environment (GADD, 2007; PETIT et al., 2009; SOUZA et al., 2011; MELO et al., 2012).

Since the fungus that led to the discovery of penicillin was a contaminant in the experiments of Fleming and the fungus from which cyclosporin was isolated came from a Norwegian soil, the potentials of new drugs could be anywhere. Therefore, the research groups are studying optimal conditions for the production of hypnophylin by the fungus *P. strigellus*, as well as searching for new antimicrobial metabolites produced by macrofungi (ISHIKAWA et al., 2012).

In scientific publications, the works are published in national health journals (since some species of fungi cause pathogenic diseases that can cause systemic diseases in different age groups) (RODRIGUES et al., 2010); education, because Kingdom Fungi is studied in elementary school programs (7th grade), according to the National Common Curricular Base (BNCC) (BRASIL, 1996); and environment, being present in ecological relationships between species (GUERRA et al., 2011).

The vast fungal diversity reflects an enormous potential to many fields. The economic and strategic benefits of using fungi are related to the discovery of species which are potentially exploitable in biotechnological processes for biological control; secretion of secondary metabolites, mycoparasitism, new antibiotics and therapeutic agents; probiotics, chemicals; enzymes and polymers for industrial and technological purposes; bioremediation of pollutants and bioleaching and ore recovery; description and improvement of new species. Other benefits include prognosis or prevention of emergent diseases in humans, animals and plants, and optimization of microbial capacity to fertilize soils/soil fertilization and clean-up the water (CANHOS; MANFIO, 2010; RODOVIDA; PAMPHILE, 2015).

The discovery of new active metabolites of microbial origin is a challenge which can bring substantial benefits. Fungi are essential for the health and prosperity of many terrestrial ecosystems, being also essential for their sustainability and biodiversity. In this context, it is necessary to emphasize the importance of biotechnology in obtaining several substances by means of the manipulation of fungi to obtain new technologies in order to benefit human health and environmental balance (ABREU et al. 2015).

Nascimento (2014) points out that new advances in this area demand time in research and planning. Thus, the development of biotechnology requires a strong academic and scientific basis and a productive sector that is capable of transforming this production into goods and services, thus contributing in gaining or enhancing characteristics which are desirable for the use of fungi.

Mushrooms, which were found in five publications in this study, have been used since ancient times for medicinal purposes to combat hemorrhages, cramps, wounds, asthma and other illnesses. Some Brazilian Indian tribes used *Pycnoporus sanguineus* (popularly known as "orelha-de-pau" in Brazil, with an intense red color) for wound healing. Researches indicate medicinal properties to several species of mushrooms, such as antiviral, antibacterial, antiparasitic, antitumor, antihypertensive, anti-atherosclerotic, hepatoprotective, antidiabetic, anti-inflammatory and immune system modulators (ABREU et al., 2015).

The genera *Penicillium* and *Aspergillus*, found in four publications in this study, are responsible for the degradation of food, biodeterioration and are pathogenic to humans and animals. These organisms are interesting not only because of their biotechnological potential but also for the economy due to its metabolic properties (MONTEIRO, 2012).

It is interesting to note that despite the Amazonian fungi are so large in numbers, only a few works were really developed using them for biotechnological purposes up to now.

4 Conclusions

Fungi are considered organisms that are comparatively more studied in Brazil. However, for the state of Amazonas, in the analyzed databases, only a few scientific records could be identified.

Despite the volume of information in the literature, this group presents a great diversity of species and deserves more attention.

The fungi possess potential regarding economic and medical interests, being also important for the environment and for Amazonian populations due to these being used in the traditional knowledge and in favor of science.

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