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Mini-review: Brazilian fungi diversity for biomass degradation

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ABSTRACT

Brazil houses over 10% of the total number of known species on Earth, with a great diversity of plants and fungi. The collection, isolation, identification and conservation of filamentous fungi with relevance to agriculture, pharmaceutical, food and biotechnological industries in Biological Resource Centers (CRBs) is very important to the development of a nation's scientific and technological infrastructure. In Brazil, 36 fungal collections are registered in the database of International Collections. Several federal and state programs have encouraged the formation of a researcher's network in order to study natural resources and the nation's biodiversity. In this context, Brazilian researchers have been on the frontiers of knowledge, investigating the enzymatic systems from native filamentous fungi with potential for biomass degradation and biotechnological application. In this review, we address recent progress in Brazilian fungal research, focusing on the identification and study of fungi and enzymes with potential for biomass degradation and application in bioenergy.

1. Introduction

Brazil spans 8.5 million km^2, most of it located between Tropic of Capricorn and the equator, displaying several climatic zones. These climatic differences lead to great ecological variations, forming distinct biogeographical zones or biomes: Amazon, the world's biggest rainforest (which spans 49% of the territory); Pantanal (1.7%), the biggest flood plain; Cerrado (23.9%), with savannahs and woods; Caatinga (9.9%), with semiarid forests; Pampas' meadows (2%); and the Atlantic rainforest (13%). Brazil also has a coastline of 3.5 million km^2, which includes ecosystems such as coral reefs, dunes, mangroves, lakes, estuaries and swamps (IBGE, 2010). The diversity of biomes results in a great richness in flora and fauna: Brazil houses over 10% of the total number of known species on Earth, with a great diversity of plants and fungi, as well as animals (Alho, 2008).

It has been estimated that there may be from 1.5 to 5.1 million of fungal species in the world and about 100,000 species have been described (Hibbett et al., 2011). Lewinsonh and Prado (2005) estimated the total number of fungal species known (13,090–14,510) and predicted (150,300–263,900) to occur in Brazil.

There is no register of the total number of fungal species native of Brazil that have been identified or collected in all country. In the book "Catálogo de Plantas e fungos do Brasil" (Catalogue of plants and fungi from Brazil) (Forzza et al., 2010), there is register of 78 orders, 924 genera and 3608 species of fungi, and in the website "Fungos do Brasil" (Fungi from Brazil) (Minter and da Silva, 2007, www.cybertruffle.orguk/brazfung, access on 03/28/2013), 4325 species of Brazilian fungi are registered.

Geopolitical, economic, and employment concerns have promoted researchers, entrepreneurs, and legislators to focus on harnessing the potential of lignocellulosic feedstock for biotechnological application. The carbohydrate skeleton of plant cell walls needs to be depolymerized into simpler sugars for their application in industrial process, including ethanol production. The role of lignocellulolytic enzymes in the degradation of the plant cell wall is very important and cellulase accounts for nearly 20% of the total world enzyme market. In order to satisfy the market demand for cellulases, fungal microorganisms (*Hypocrea jecorina*, *Aspergillus niger* and *Fusarium* sp.) or bacteria (*Cellulomonas* sp., *Bacillus* sp.) are being employed (Chandel et al., 2012).

Here, we address recent progress in the Brazilian fungal research with a focus on identification and study of fungi and enzymes with potential for biomass degradation and application in bioenergy production.

2. Fungi collections

The Earth's biological resources are vital to humanity's economic and social development. In 1992, the Convention on Biological Diversity (CBD) established an strategic plan for Biodiversity 2011–2020. Amongst the strategic goals were: (i) to enhance the benefits to all from biodiversity and ecosystem services and (ii) to enhance implementation through participatory planning,

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knowledge management and capacity building (Convention on Biological Diversity, http://www.cbd.int/idb/, access on 03/29/2013).

Studies on fungal diversity have varying estimates. As the numbers differ greatly between 1.5 million species (Hawksworth, 2001), 3.5–5.1 million species (O'Brien et al., 2005) or 712,000 species (Schmit and Mueller, 2007) in the world. Filamentous fungi have traditionally been used to produce various substances of relevance to pharmaceutical, food and biotechnological industries; they have proved to be extremely useful to produce industrially applicable primary and secondary metabolites such as peptides, enzymes, organic acids and antibiotics (Lange et al., 2012).

The CBD gives sovereign rights to the country of origin and aims at fair and equitable benefit sharing, especially with regard to the country of origin in the case of successful economic exploiting of these genetic resources. The establishment of Biological Resource Centers (CRBs), which contain collections of culturable organisms (microorganisms, plants, animals, human cells, etc.), replicable parts of culturable organisms (genomes, plasmids, viruses, cDNA, etc.), non-culturable viable organisms, cells and tissues, as well as databases and bioinformatic resources related to these collections, is very important as key components of the scientific and technological infrastructure of a country.

In 2007, the Ministério do Meio Ambiente/IBAMA, through the Normative Instruction 160, creates the National Record of Biological Collections (CCBio) in order to gather the scientific collections from research institutions from Brazil, which constitute an information heritage regarding fauna, flora and genetics, important for conservation, studies, exploration and propagation of Brazilian species.

The establishment of the Brazilian Center of Biological Material (CBMB), an authorized center for storage of microorganisms with patent purposes, as part of the national policy for biotechnology development established by Decreto no 6.041/07 (Brazil, 2007), is ongoing and currently there is no second institution of the kind in all Latin America. Several collections from Brazilian institutions are registered on the World Federation for Culture Collections (WFCC, www.wfcc.info/home/, access in 03/28/13) (Table 1a) or on the Biodiversity Collection Index (www.biodiversitycollectionsindex.org/) (Table 1b). Other collections can be found at the Brazilian herbaria network (Sociedade Botânica do Brasil, www.botanica.org.br), SICOL data system (www.sicol.cria.org.br) and species link (www.splink.org.br), which are mostly collections from research centers and/or universities.

Enterprises such as INCT, "Herbário Virtual da Flora e dos Fungos" (Virtual Herbarium of Flora and Fungi) (www.inct.florabrasil.net/), species link (www.splink.org.br/), "Centro de Referência em Informação Ambiental" (Reference Center for Environmental Information) (CRIA, www.cria.org.br/), BIOTA/FAPESP – SinBiota (www.biota.org.br) – environmental information system of the State of São Paulo – and the information system for collections of biotechnological interest "Coleções de Interesse Biotecnológico" (SICol, http://www.sicol.splink.org.br/), have as a goal and strategy the propagation of electronic, public access information about the Brazilian biological resources centers and the biological collections, so that they serve as an integrated element of the diverse biological collections. However, several collections and subcollections do not have an online catalogue due to lack of resources, which limits the knowledge and propagation of their material and collected species.

3. Research

The systematic and organized study of the biodiversity of Brazil's native fungi should allow not only the collection and identification of species, but also bioprospecting. Hence, the diverse fungal collections from Brazil (Tables 1a and b) harbor an important biological material that can be explored, for example, to search for fungi capable of efficiently hydrolyzing biomass and to identify enzymes and genes of potential biotechnological interest.

Bioethanol, a product obtained by the fermentation of sugars present in sugar cane or corn, is a renewable clean product, whose utilization as fuel may contribute to the reduction of the greenhouse effect and air pollution, thus benefiting public health in the long term (Zaldivar et al., 2001). In the 1970s, Brazil started a program to substitute gasoline for ethanol; in this program, sugarcane was chosen as the feedstock to produce ethanol. However, only part of the biomass produced is used for bioenergy production; one-third of the plant is used for sugar production, one-third is bagasse, which is burnt for electricity production, and the

Table 1a
Selected Brazilian genetic resource collections.[a]

Acronym	WDCM number	Collection
BCCCp	WDCM 921	Brazilian Culture collection of Crinipellis perniciosa
CBMAI	WDCM 823	Brazilian Collection of Microorganisms from the Environment and Industry
CCB	WDCM 713	Coleção de Culturas de Basidiomicetos
CEMM	WDCM 880	CEMM – Centro Especializado em Micologia Médica
CG	WDCM 712	Collection of Fungi of Invertabrates
CM-UFMG	WDCM 1029	Collection of Microorganisms, DNA and Cells of Universidade Federal de Minas Gerais (UFMG)
CMM	WDCM 923	Culture Collection of Phytopathogenic Fungi Prof. Maria Menezes
CNEN-LABPC	WDCM 710	Laboratorio de Pocos de Caldas
COAD	WDCM 989	Coleção Octávio de Almeida Drumond
ESAP	WDCM 294	Instituto Zimotecnico-Z
Fiocruz/CCFF	WDCM 720	Coleção de Culturas de Fungos Filamentosos
Fiocruz/CFAM	WDCM 957	Coleção de Fungos da Amazonia
Fiocruz/CFP	WDCM 951	Coleção de Fungos Patogenicos
Fiocruz/CMRVS	WDCM 575	Coleção de Microrganismos de Referencia em Vigilância Sanitária
Fiocruz/CMT	WDCM 948	Coleção Micológica de Trichocomaceae
FTI	WDCM 716	Centro de Biotecnologia e Química – CEBIQ
IAL	WDCM 282	Núcleo de Coleção de Microrganismos
IALMIC	WDCM 717	Micoteca do Instituto Adolfo Lutz
IGESALQ	WDCM 902	Coleção Microorganismos
IMT	WDCM 718	Micoteca do Instituto de Medicina Tropical de São Paulo
IPT	WDCM 721	Agrupamento de Biotecnologia, Culture Collection of Microorganisms
Micoteca IAL	WDCM 869	Micoteca do Instituto Adolfo Lutz
MMBF	WDCM 942	Micoteca Mario Barreto Figueiredo

[a] Registered in World Federation for Culture Collections (http://www.wfcc.info/home/): Collection of Fungi.

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