ISSN: 2455-6939

Volume: 10, Issue: 04 "July-August 2024"

CATALOGING ECTOMYCORRHIZAL EDIBLE MUSHROOMS IN *BRACHYSTEGIA BOEHMII* TAUB. DOMINATED MIOMBO WOODLAND OF UPPER -KATANGA, RD CONGO

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DOI: https://doi.org/10.51193/IJAER.2024.10404

Received: 26 Jul. 2024 / Accepted: 05 Aug. 2024 / Published: 23 Aug. 2024

ABSTRACT

This study explores the variety of edible ectomycorrhizal mushrooms present in miombo woodlands, specifically those dominated by *Brachystegia boehmii* Taub, at Mikembo Sanctuary in Upper-Katanga, RD Congo. Species identification was based on macroscopic characteristics. Our discoveries enumerate twenty-eight species across five distinct families: Amanitaceae, Boletaceae, Cantharellaceae, Clavulinaceae, and Russulaceae. Russulaceae and Cantharellaceae are the most prevalent, representing 39% and 32% of the species found, followed by Boletaceae and Amanitaceae with 14% and 11% respectively. Clavulinaceae, with a single identified species, stands as the last represented family with 4%. The evaluation of the diversity of edible macromycetes basis of DNA sequencing will be the subject of our future studies.

Keywords: *Macro-fungi*, *Caesalpinioideae trees*, Zambesian Woodland

INTRODUCTION

Wild mushrooms serve as significant resources for local communities in sub-Saharan Africa, offering both food and medicinal properties, particularly during the rainy season, and providing income for impoverished farming communities (Parent and Thoen 1977, Boa 2006, Eyi-Ndong et

ISSN: 2455-6939

Volume: 10, Issue: 04 "July-August 2024"

al. 2011, Härkönen et al. 2015, De Kesel et al. 2017, Milenge and De Kesel 2020, Degreef et al. 2020, Kasongo et al. 2021, Mikobi et al. 2023). Both saprophytic and symbiotic wild fungi play an integral role in the regeneration and establishment of forest ecosystems (Mueller and Schmit 2007). Wild mushrooms, one of the most characteristic non-timber forest products (NTFPs) harvested from Upper-Katanga's miombo woodlands are frequently sold in large quantities along roadsides and in markets during the rainy season (Malaisse 1997, De Kesel et al. 2017, Kasongo 2017, Degreef et al. 2020, Kasongo et al. 2021). In Upper-Katanga, over 70% of the rural population uses NTFPs, including edible mushrooms (Degreef et al. 2020). A high number of fungi is used for consumption, with 78 species reported over the years (Malaisse 1997, De Kesel et al. 2017), and Kasongo et al. (2021) recently expanded this list through ethnomycological inquiries among the Bemba and Lamba people of Upper-Katanga.

Despite their importance in providing numerous goods and services to the people of Upper-Katanga, miombo woodlands face various anthropogenic pressures (Dikumbwa and Kisimba 2000, Campbell et al. 2007, Maquia et al. 2013, Muteya et al. 2022). Munyemba et al. (2010) indicated that the miombo woodland in the vicinity of the city of Lubumbashi is regressing at a rate of 2.7% per year. Muteya et al. (2022) identified five primary factors contributing to the disappearance of miombo: trees cutting for charcoal (the primary source of domestic energy for urban populations), forest land conversion to agriculture, mineral deposit exploitation, misuse of bush fires, and urban expansion due to population growth.

In this context, it becomes crucial to not only continue documenting and publishing ethnomycological knowledge but also to shed light on the specific forest types required by these fungi. Degreef et al. (2020) highlighted the significant role of miombo woodland as a primary driver of ectomycorrhizal fungi based ecosystem services in tropical Africa. For Upper-Katanga, De Kesel et al. (2017) provided insights into the occurrence, diversity, phenology, and natural productivity of edible fungi associated with *Julbernardia globifora*, *Julbernardia paniculata*, *Uapaca kirkiana*, and *Marquesia macroura*. In this contribution, we shift our focus to miombo woodland dominated by *Brachystegia boehmii*, an ectomycorrhizal tree species highly exploited for charcoal production due to its calorific power. This overexploitation threatens the survival of ectomycorrhizal fungi. By illustrating the potential loss of useful associated fungi due to environmental destruction, we aim to provide compelling arguments for the sustainable management of the miombo ecosystem. The objective of this study is to establish the first list of species of ectomycorrhizal fungi associated with the Brachystegia boehmii-dominated Miombo woodland.

ISSN: 2455-6939

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MATERIALS AND METHODS

The study was conducted in Mikembo Sanctuary, where miombo woodland dominated by *Brachystegia boehmii* is present (Useni et al. 2017, 2020). This forest reserve is situated 35 km northeast of Lubumbashi, residing on the Lubumbashi peneplain at an altitude of 1230 m, characterized by poor, acidic, leached lateritic Ferralsols. It is part of the Zambezi endemic region (White 1965) and is geographically positioned at these coordinates: 11°28.771'–11°29.025' South latitude, 27°39.743'–27°40.366' East longitude. The region experiences a marked rainy season from October to April, receiving 1000–1230 mm/m² per year. The average daily temperature ranges from 14.2–24.6°C, with minimum temperatures between 6–14°C and maximum temperatures between 25–32°C (Malaisse 1997, Saad et al. 2012).

We selected the *Brachystegia boehmii* dominated miombo woodland using a physiognomic approach. Three permanent 30 × 30 m plots were established within this plant formation. We assessed the diversity and relative abundance of ectomycorrhizal tree species present within the plots (Table 1). We estimated tree height, distinguishing between small trees (less than 3 m tall) and large trees (greater than 3 m tall). We calculated the relative tree abundance (RA) using the formula: RA = (Number of trees of species/Total number of trees of all species) ×100. We marked trees adjacent to plot boundaries (with a slash) and recorded the geographic coordinates of the plots using a GPS (Garmin Gecko). The coordinates were: S 11°22, 23' – E 27°40, 220', 1185m; for Plot 2: S 11°28, 22' – E 27°40, 219', 1192m; and for Plot 3: S 11°28', 21.6' – E 27°40, 220', 1191m.

Table 1: Distribution and relative abundance of tree species in the examined vegetation type. Highlighted value indicates the preponderance of characteristic species within the investigated formation. RA stands for Relative Abundance.

Type of forest	***Brachystegia boehmii* woodland**		
Trees Height (m)	**<3m**	**>3m**	**RA**
Albizia antunesiana Harms	-	3	1.4
Brachystegia boehmii Taub.	4	176	**83.72**
Dalbergia boehmii Taub.	-	2	0.93
Diplorhynchus condylocarpon (Muel. Arg.) Pichon	-	8	3.72
Julbernardia globiflora (Benth.) Troupin	-	2	0.93

Monotes katangensis (De Wild.) De Wild	1	1	0.93
Uapaca pilosa Hutch.	7	9	7.44
Uapaca sansibarica Baill.	1	1	0.93
Total			**215**

Fruiting bodies were collected during the rainy season from January to April 2021. We established three 30×30 m plots and adopted a survey technic involving successive passes along parallel bands each 1m wide to prevent omissions. During these surveys, we systematically collected, sorted by species, and counted all visible fruiting bodies. We took a referencial image for each species. Species identification was carried out using the book 'Edible Fungi of Upper-Katanga (DR. Congo)' (De Kesel et al. 2017). Macroscopic characteristics such as cap and stipe color, cap diameter, lamella shape, presence of scales or spores, odor, the presence or absence of a ring or volva, taste, etc., were used for species identification. After documenting these characteristics, we photographed the specimens, numbered, dried, and stored them in minigrip bags labeled with referencial numbers.

RESULTS

Species of ectomycorrhizal fungi associated with the *Brachystegia boehmii*-dominated Miombo woodland.

We identified twenty-eight species that belong to five families: Amanitaceae, Boletaceae, Cantharellaceae, Clavulinaceae, and Russulaceae. The families Russulaceae and Cantharellaceae had the highest representation, with 39% (11 species) and 32% (9 species), respectively. They were followed by Boletaceae and Amanitaceae, which accounted for 14% (4 species) and 11% (3 species), respectively. Conversely, the Clavulinaceae family was the least represented, making up only 4% (1 species) of the species identified in the open forest with *Brachystegia boehmii* (Tables 2).

International Journal of Agriculture and Environmental Research

ISSN: 2455-6939

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Table 2: List of species of ectomycorrhizal fungi

Taxon name	***Voucher Specimen***	**Family**
Afroboletus luteolus (Heinem.) Pegler & Young	BK135	Boletaceae
Amanita afrospinosa Pegler & Shah-Smith	BK128	Amanitaceae
Amanita loosii Beeli	BK114	Amanitaceae
Amanita mafingensis Härk. & Saarim	BK121	Amanitaceae
Boletus spectabilissimus Watling	BK118	Boletaceae
Cantharellus afrocibarius Buyck & V. Hofst.	BK130	Cantharellaceae
Cantharellus addaiensis Henn.	BK125	Cantharellaceae
Cantharellus congolensis Beeli	BK138	Cantharellaceae
Cantharellus mikemboensis De Kesel & Degreef	BK124	Cantharellaceae
Cantharellus platyphyllus Heinem.	BK110	Cantharellaceae
Cantharellus ruber Heinem.	BK126	Cantharellaceae
Cantharellus humidicola Buyck & V. Hofst.	BK139	Cantharellaceae
Cantharellus symoensii Heinem.	BK117	Cantharellaceae
Cantharellus miomboensis Buyck & V. Hofst.	BK132	Cantharellaceae
Clavulina albiramea (Corner) Buyck & Duhem	BK112	Clavulinaceae
Lactarius kabansus Pegler & Piearce	BK127	Russulaceae
Lactarius tenellus Verbeken & Walleyn	BK136	Russulaceae
Lactifluus densifolius (Verbeken & Karhula) Verbeken	BK131	Russulaceae
Lactifluus edulis (R. Heim ex Singler) Verbeken	BK129	Russulaceae
Lactifluus gymnocarpoides (Verbeken) Verbeken	BK120	Russulaceae

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Lactifluus gymnocarpus (Verbeken & Karhula) Verbeken	BK119	Russulaceae
Lactifluus velutissimus (Verbeken) Verbeken	BK140	Russulaceae
Russula compressa Buyck	BK113	Russulaceae
Russula congoana Pat.	BK141	Russulaceae
Russula cellulata Buyck	BK115	Russulaceae
Russula roseoviolacea Buyck	BK134	Russulaceae
Afrocastellanoa ivoryana (Castellano, Verbeken & Thoen) M.E. Sm. & Orihara	BK137	Boletaceae
Mackintoshia persica Pacioni & C. Sharp, 2000	KB111	Boletaceae

DISCUSSION

Methodology for Harvesting Sporophores

Our *Brachystegia boehmii* plots in Upper-Katanga were located in the same Sanctuary (Mikembo) where De Kesel et al. (2017) conducted an inventory of miombo woodland plots dominated by either *Julbernardia globifora*, *Julbernardia paniculata*, *Uapaca kirkiana*, or *Marquesia macroura*. In these plots, the belowground diversity of soil fungi, including ectomycorrhizal fungi fungi, was determined by using metabarcoding analysis of soil samples. This method revealed much higher diversity than what was measured using only aboveground fruiting bodies (Tedersoo et al. 2014; supplementary data). Indeed, NGS-based belowground estimation of ectomycorrhizal fungi diversity using soil samples tends to yield higher diversity results. However, since our research questions are not solely ecological, we argue that our purpose does not necessarily require collecting mantles from mycorrhized roots (Mesfek et al. 2021) or environmental sampling (Tedersoo et al. 2014). While our method might have overlooked a significant fraction of ectomycorrhizal fungi diversity, our focus in the context of useful fungi is primarily on the exploitable fraction of the taxa - that is, taxa producing material that people can actually collect and use. Although the harvesting and quantification of fruiting bodies in plots can be laborious, sustained effort over a longer period (2–3 years or more) will allow for a better understanding of phenology and the factors affecting it (both biological and climatological).

List of Fungi in *Brachystegia boehmii* Dominated Woodland

ISSN: 2455-6939

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Trees of the subfamily Caesalpinioideae, particularly *Brachystegia boehmii*, form ectomycorrhizae with several fungal species. In the *Brachystegia boehmii* dominated plots, we identified twenty-eight ectomycorrhizal forming fungal species. While we were unable to assess the exact relationship with *Brachystegia boehmii*, we found that this type of miombo woodland is home to a high diversity of ectomycorrhizal fungi. Most of the fungal species we found have also been identified in other plant formations (*Julbernardia paniculata, Uapaca kirkiana, Marquesia macroura* and *Brachystegia spiciformis*) (De Kesel et al. 2017). Some taxa are likely capable of associating with multiple host trees (Simlard et al. 1997). This aligns with the observations of Diédhou et al. (2005), who demonstrated that ectomycorrhizal fungi isolated from tropical forest trees are compatible with several host tree species. Preliminary results by Sanon et al. (1997) and Rivière et al. (2007) have also shown that many tropical fungi are multi-host. This multi-host symbiosis may be facilitated by a high degree of root interconnectivity among trees, which favors the exchange of mycelia between species. This fungal sharing is likely to be more prevalent between adult and young trees, with adults promoting the survival of younger trees by transferring carbon and other nutrients through mycelial networks between one or different tree species (Horton and Bruns, 2011).

High ectomycorrhizal fungi species diversity in our specific miombo woodland plots aligns with the findings of Kasongo (2017) and De Kesel et al. (2017). In the same area and over a three-year period, they found 42 ectomycorrhizal species in woodlands dominated by *Julbernardia globiflora*, 44 in *Julbernardia paniculata* woodlands, 38 in *Marquesia macroura* woodlands, and 28 in *Uapaca kirkiana* woodlands. All recorded fungal taxa belong to five families (Amanitaceae, Boletaceae, Cantharellaceae, Clavulinaceae, and Russulaceae), with the majority belonging to Russulaceae (39, 13%). Similar observations have been made in ectomycorrhizal fungi rich woodlands across tropical Africa (Parent and Thoen 1977, Högberg and Piearce 1986, Högberg and Alexander 1986, De Kesel et al. 2002, Degreef et al. 2016).

CONCLUSION

The objective of this study was to list the edible ectomycorrhizal fungi of the *Brachystegia boehmii*-dominated miombo woodland, a common yet often neglected type of miombo woodland. Despite the fact that fungal biodiversity can be measured in various ways, in an ethnomycological context, inventorying fruiting bodies (epigeous and semi-hypogeous taxa) seems to be a suitable and accessible method when compared to NGS methods. More studies are needed, but in just one year, we were able to inventory twenty-eight species of ectomycorrhizal fungi in this type of woodland. The families Russulaceae and Cantharellaceae are most represented. Globally, the latter family is sought after for its delicious species in the *Cantharellus* genus. In the *Brachystegia boehmii*-dominated woodlands of Upper-Katanga, this genus is represented by 9 species, which corresponds to 20% of all *Cantharellus* known to tropical Africa. In this context, the *Brachystegia*

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boehmii-dominated woodlands are ethnomycologically significant as providers of high-ectomycorrhizal fungi. DNA extractions and traditional knowledge related to ethnomycology and sustainable management of the miombo woodland will be integrated into our future research.

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