Available online on 15.04.2025 at http://jddtonline.info

Journal of Drug Delivery and Therapeutics

Open Access to Pharmaceutical and Medical Research

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Research Article

Medicinal Uses of Macromycetes Among Populations in Ecological Zone II of Togo

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Article Info:

Article History:

Received 24 Jan 2025
Reviewed 07 March 2025
Accepted 25 March 2025
Published 15 April 2025

Cite this article as:

Magamana E, Nadjombe P, Kamou H, Melila M, Agossou KE, Dourma M, Wala K, Guelly KA, Medicinal Uses of Macromycetes Among Populations in Ecological Zone II of Togo, Journal of Drug Delivery and Therapeutics. 2025; 15(4):98-107 *DOI: http://dx.doi.org/10.22270/jddt.v15i4.7075*

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Abstract

Objective : To comprehensively document the medicinal uses of macromycetes among the riparian populations of Ecological Zone II of Togo, with a view to their sustainable management.

Material And Methods : The mushrooms were collected from the vegetation formations of the ecological zone and then presented to the local riparian population. The medicinal mushrooms were identified by the local population, who specified the type of disease treated, the mode of use, and the dosage. For species identification, macroscopic and microscopic studies were conducted on each species, allowing for the determination of their names.

For statistical analyses, the R software was used for Correspondence Factor Analysis, and the Canoco software was used for PCA analyses.

Résultats : The bivariate analysis shows that the use of medicinal mushrooms is not linked to ethnicity (Chi-2 = 96.105; p = 0.106). The Correspondence Analysis (CA) reveals three groups of diseases : G1 (mild conditions) treated by the Tem and Kabyè, G2 (more severe pathologies) treated by the Bassar, and G3 (serious diseases such as cancer and diabetes) cited by the Nawdba and Moba. The Dim1 (42.7%) and Dim2 (25.8%) axes together explain 68.5% of the variance, highlighting a severity gradient of diseases. The PCA analysis shows that different populations exploit various fungal species to treat different diseases, with a single species capable of addressing multiple ailments. Six groups are distinguished based on their medicinal properties: G1 (*Termitomyces schimperi*, *Volvariella earlei*) linked to immunity and cancer, G2 (*Pleurotus sp.*) associated with diabetes, G3 (*Polyporus squarrosulus*) with asthma, G4 (*Ganoderma colossus*) with hormonal disorders, G5 (*Daldinia eschscholzii*) with ulcers, and G6 (*Phellinus sp.*) with cardiovascular diseases. *Ganoderma lucidum*, positioned at the center, appears to have a broad therapeutic spectrum.

Conclusion : The use of medicinal mushrooms transcends ethnic boundaries and adapts based on transmitted knowledge and encountered pathologies. PCA has identified the species with the highest therapeutic potential according to medical indications.

Keywords : Medicinal mushrooms, Ethnopharmacology, Principal Component Analysis, Ecological Zone II, Togo

1. INTRODUCTION

Macromycetes represent a fundamental biological resource for the traditional health practices of local populations, embodying an ethnopharmacological heritage at the intersection of empirical knowledge and therapeutic potential. These complex organisms, long overlooked by scientific research, are now emerging as key players in traditional medicinal practices and in the pharmacological potential of natural resources. The West African sub-region is distinguished by an exceptional ethnomycological richness, a result of the ecological and cultural diversity of its territories. Recent studies have progressively unveiled the complexity of the medicinal uses of macromycetes, revealing sophisticated therapeutic practices deeply rooted in local traditions.

In Ghana, Kwame[1] inventoried 48 fungal species used in the treatment of complex pathologies, demonstrating the precision and nuance of traditional medicinal knowledge. In Burkina Faso, eight (08) species of medicinal macrofungi are found in the city of Ouagadougou. These species are potential bioactive agents providing sources of medicine to the Burkinabe population[2]. In Niger, the work of Hama *et al.*[3] showed that macromycetes are used for treating various ailments and for wound disinfection. Research in Nigeria[4] and Cameroon[5] identified 45 and 42 species of fungi, respectively, with significant medicinal properties,

confirming the ethnopharmacological richness of the region. In Côte d'Ivoire, Yian *et al.*[6] deepened the understanding of medicinal applications, while Diop *et al.*[7] in Senegal highlighted the complex dimensions of macromycete use in traditional disease treatment. In Togo, studies by Kamou *et al.*[8, 9] revealed that macromycetes are widely used by local populations to treat various diseases and ailments.

Ecological Zone II of Togo emerges as a particularly promising field for investigation. Its unique ecological characteristics, combining diverse vegetation formations with a significant presence of ectomycorrhizal plant species, specific climatic conditions, and a rich cultural plurality, suggest an ethnomycological potential that remains largely unexplored. The rapid socio-economic transformations and the progressive erosion of traditional knowledge make this research all the more crucial. Every study documenting traditional medicinal practices contributes to preserving an empirical knowledge heritage threatened by the modernization of healthcare systems. The objective of this study is to comprehensively document the medicinal uses of macromycetes among the riparian populations of Ecological Zone II of Togo, with a view to their sustainable management.

2. MATERIALS AND METHODS

2.1. Study area

Togo is a country in West Africa, situated between 6°06'N and 11°08'N North Latitude and between 0°09'W and 1°49'W East Longitude. It is bordered to the South by the Atlantic Ocean, to the North by Burkina Faso, to the East by Benin, and the West by Ghana. It has a surface area of 56,600 km^2, is 600 km long, and between 50 and 150 km wide. It is subdivided into five Ecological Zones[10]. This study was carried out in Ecological Zone II, which belongs to the Sudanian phytogeographical domain[11] and specifically covers the economic/administrative regions of Kara and part of Centrale. It lies between 9°00'N and 11°08'N Latitude and between 0°09'W and 1°49'W Longitude. It is bordered to the North by Ecological Zone I, to the East by Benin, to the West by Ghana, and to the South by Ecological Zones III and IV (Figure 1). It has a tropical Sudanian climate dominated by a long dry season and a long rainy season. Zone II is characterized by a mosaic of Sudanian Savannah-clear forest and dense dry forest corresponding to the Northern part of the Monts Togo. This Northern Mountain Region has two seasons: A rainy season from April to October and a dry season from November to March. The average total annual rainfall is around 1300 mm, with a maximum in August and September[12].

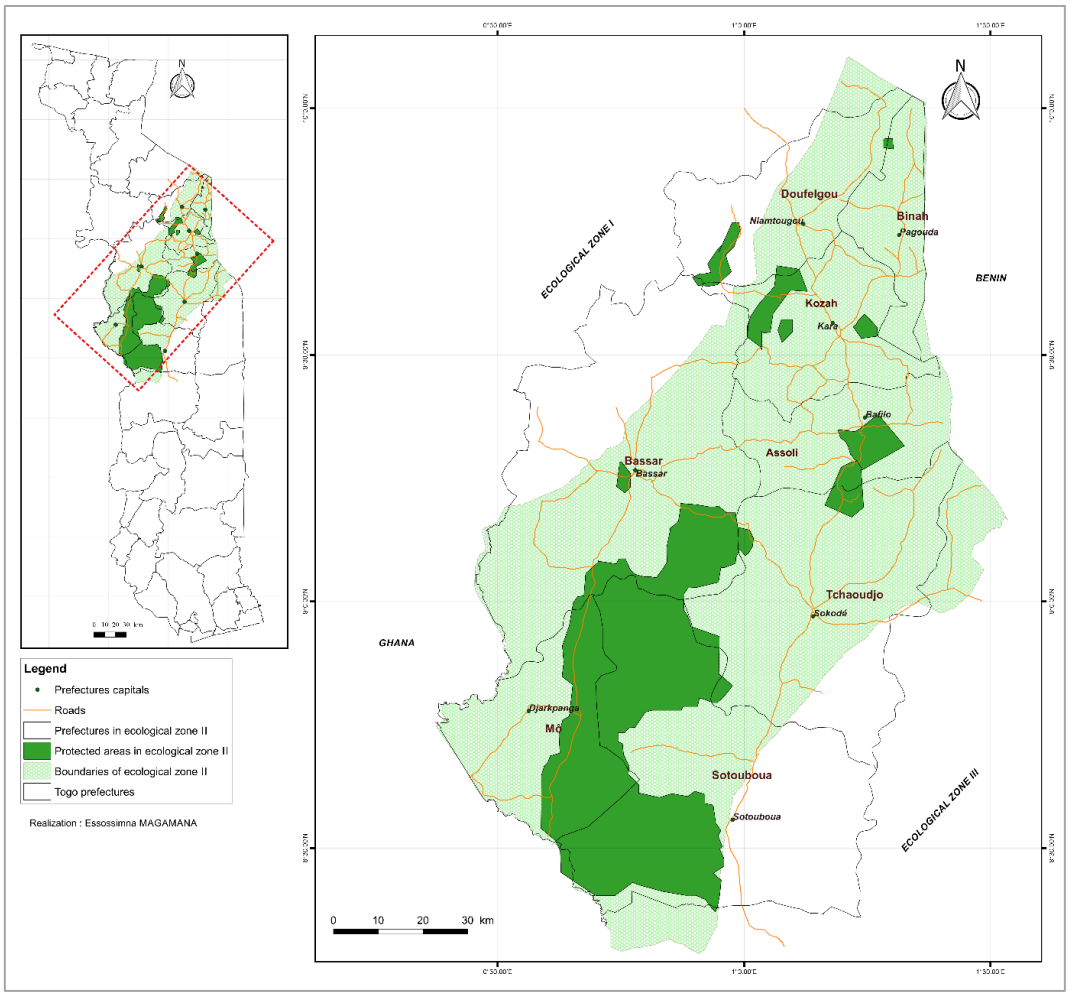

Figure 1: Map showing the location of the data collection area

2.2. Methodology

2.2.1. Wild Mushroom Collection

The mushrooms were collected from April to October, 2021 and again from April to October, 2022, a favorable period for the appearance of mushrooms. For the collection in the forest, a guide was chosen based on his motivation and his traditional mycological knowledge. Mushrooms were collected in open forests (Figure 2), gallery forests, fields, and fallow land (an example of an open forest with *Uapaca togoensis*). The mushrooms were carefully collected with a pocket knife, photographed, wrapped in ream paper, and placed in a basket. Fugitive characteristics were noted (presence of mucilage, ring, colour, odour, etc.); the different types of plant formations from which the wild mushrooms were collected, the host trees and different substrates, and the dates of the collection were noted. Species that were difficult to identify in the field were collected and identified at the Laboratory of Botany and Plant Ecology at Lome University. Each specimen was described in accordance with the fungi description.

Figure 2 : Open Woodland with *Uapaca togoensis*

2.2.2. Ethnopharmacological Surveys

Ethnomycological surveys were conducted among local populations in Ecological Zone II, selected based on their proximity to forests, plantations, fields, and fallows. The surveys were carried out using a structured questionnaire in the form of survey sheets or interview guides. Regarding the selection of ethnic groups, an exploratory study was conducted from March to December 2021 and from January to February 2022 to gather information on the predominant ethnic groups in Ecological Zone II, particularly those possessing medicinal knowledge of macromycetes. Based on the importance they attribute to fungi, five (5) ethnic groups were surveyed: Bassar, Tem, Kabyè, Nawdba, and Moba. In each locality, both indigenous and non-indigenous individuals were targeted for participation in the survey, following a random sampling approach. Respondents were engaged either individually or in focus groups, with no restrictions on age or gender. The survey questions were asked in French, and a local interpreter translated the questions and responses to allow participants to express themselves freely in their native languages, ensuring the accuracy of the collected data. All collected fungi specimens were presented to the local populations of each village, asking them first to sort out the fungal species they traditionally use for treating specific diseases. Subsequently, the names of these diseases, along with the corresponding fungal species utilized, were documented. Each identified species was labeled for taxonomic identification studies. The modes of administration and dosage for each treated condition were also recorded.

2.2.3. Macroscopic and Microscopic Description

After collecting macromycetes used in traditional medicine, their morphological characteristics were described based on the following criteria: cap color, shape, size, and texture; structure and appearance of gills, lamellulae, tubes, and stipe; ornamentation and consistency of the cap and stipe (presence of scales, warts, an annulus, or fibrils); attachment of the gills to the stipe; texture of the gills (firm or soft, velvety or viscous); characterization of the stipe base (saccate or swollen, hairy or glabrous, with or without aggregated organic debris); consistency, color, odor, and taste of the flesh; growth pattern (solitary, clustered, tufted, in troops, or forming fairy rings); and ecological aspects (proximity to trees, habitat, development on wood, grass, soil, or a specific substrate). The macroscopic study was supplemented by microscopic examinations of the specimens. The microscopic analysis primarily focused on spores, basidia, cystidia, the presence of clamp

connections, trama structure, and the composition of the pileipellis. Most of these anatomical features were observed using an Ammoniacal Congo Red solution.

2.2.4. Specimen identification

The identification of the fungi required a study of the macroscopic characteristics that could be directly observed in the field on fresh specimens and the microscopic characteristics that could be observed in the laboratory using a light microscope brand Olympus CX21. Identification was carried out down to genus/species level using the nomenclature of Strullu-Derrien *et al.*[13], which was used to identify fungi of the genera *Amanita* and *Cantharellus*; the nomenclatures of Watling *et al.*[14], which have been used to identify fungi of the genera *Termitomyces*, *Agaricus* and *Cantharellus*. The systematics and nomenclature of the Flore illustrée d'Afrique centrale, Fascicule [9, 15, 16,] Russula I, Russula II, Russula III by Meidl *et al.*[17]. The monographic flora of the genus *Lactarius* s. l. from tropical Africa Verbeken[18] was used to identify *Lactarius*, *Lactifluus* and *Russula*. The work of Yorou *et al.*[19] ; Maba *et al.*[16] and De Kesel *et al.*[20] was used to complete the identification of the other species. The checklist was organized alphabetically by genus, species and family.

2.2.5. Statistical analysis of the data

The data collected from local populations were entered and cleaned in the Excel 2019 spreadsheet. For the Correspondence Analysis, a pivot table was created between the variable "Species" and the variable "Diseases treated." The resulting data matrix was submitted to the Canoco software for PCA. The spectrum of relative frequencies of diseases treated using macromycetes and the Correspondence Analysis (CA) between the diseases treated based on ethnic groups were performed using R 4.4.3 software.

3. RESULTS

3.1. Diseases treated in ethnic groups through the use of macromycetes

The bivariate analysis showed that there is no correlation between the diseases treated and the ethnic groups (Chi-2= 96.105; p=0.106). Knowledge of mushroom-based pharmacopoeia is not related to ethnicity. The Correspondence Analysis (CA) highlights, through Figure 3, the relationships between different diseases (in red) and ethnic groups (in blue). The main axes, Dim1 (42.7%) and Dim2 (25.8%), together explain 68.5% of the total variance, meaning they capture a large portion of the information contained in the data. The Dim1 axis seems to differentiate the conditions along a severity gradient, ranging from mild diseases to more severe pathologies. The Dim2 axis, on the other hand, could distinguish groups based on ethnicity or specific underlying causes.

Three main groups (G1, G2, and G3) are identifiable on the graph. Group G1 (circled in green) includes relatively common and mild diseases such as constipation, tension, gonorrhea, and abscesses. These conditions are often associated with minor infections or health issues related to nutrition and hygiene. These diseases are generally treated by the Tem and Kabyè peoples using mushrooms. Group G2 (circled in blue), on the other hand, includes more severe conditions such as fibroids, internal bleeding, and unhealable wounds, which usually require more complex medical management. These are more frequently treated by the Bassar people using mushrooms. Finally, group G3 (circled in black) consists of serious diseases such as cancer, anemia, diabetes, and breast swelling in women, often linked to hormonal or metabolic imbalances. These diseases were more frequently cited by the Nawdba and Moba as diseases treated using mushrooms

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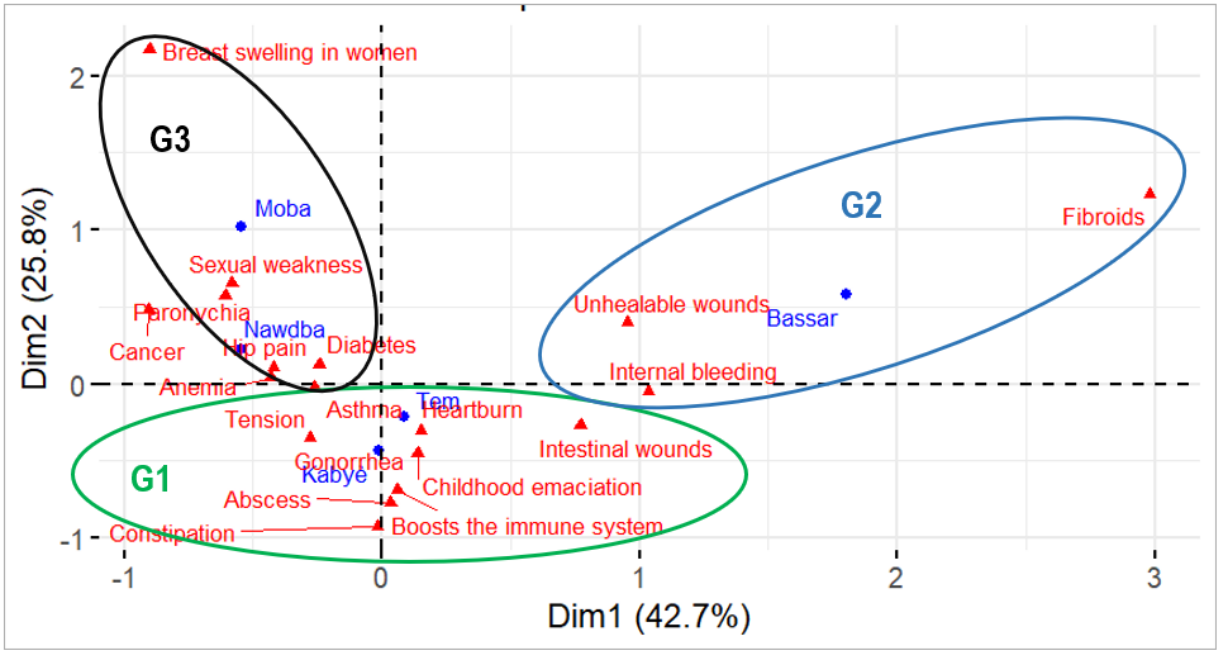

Figure 3: Correspondence Analysis between Ethnic Groups and the Therapeutic Use of Mushrooms

The analysis of the survey results showed that nineteen (19) diseases were treated within the different surveyed populations through the use of macromycetes. Among these treated diseases, heartburn, incurable wounds, anemia, diabetes, hypertension, and hip pain were the most frequently cited (Figure 4).

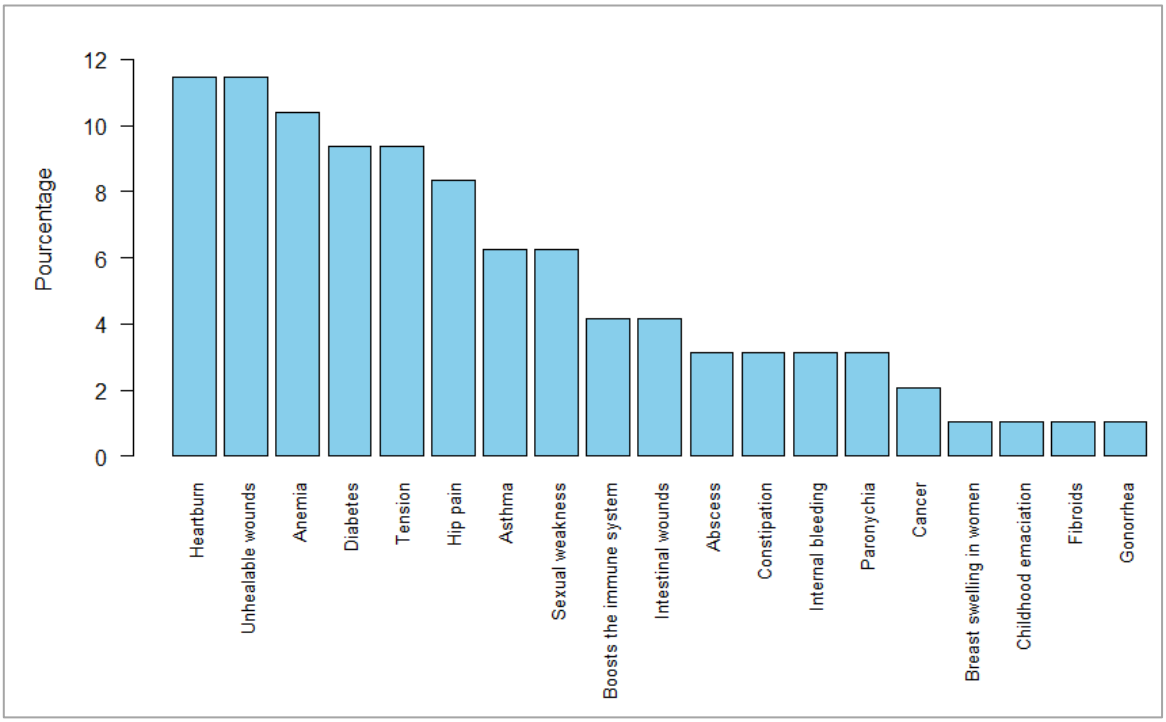

Figure 5: Frequency (%) of diseases treated with the use of macromycetes

3.2. Relationship Between Fungi and Therapeutic Use

Different populations do not exploit the same fungal species for the treatment of diseases. A single species can be used to treat multiple ailments. The Principal Component Analysis (PCA) presented in this graph highlights the relationships between different fungal species and their medicinal uses (Figure 6). PCA allows for dimensionality reduction of the data and visualization of the distribution of fungi based on their attributed therapeutic effects. The main axes structure these relationships, while the dark blue arrows represent the contributions of different medical conditions to the variance in the data. The fungi, represented by green dots, are positioned according to their associations with disease treatments.

The analysis of the graph reveals a distinct distribution of fungi according to their medicinal properties. Group 1 (G1) shows that *Termitomyces schimperi* and *Volvariella earlei* are strongly associated with boosts the immune systems and the treatment of cancer, constipation, and hip pain. This proximity suggests that they may contain bioactive compounds relevant for these applications. In Group 2 (G2), *Pleurotus* sp. and *Pleurotus tuber-regium* are primarily linked to the treatment of diabetes and sexual weakness, indicating their therapeutic potential in metabolic regulation and vitality stimulation. Nearby, Group 3 (G3) shows that *Polyporus squarrosulus* and *Termitomyces microcapus* are positioned closer to the center, suggesting that they have moderate effects on conditions such as asthma and gonorrhea.

The analysis of Group 4 (G4) shows that *Ganoderma colossus* is strongly correlated with the treatment of fibroids, internal bleeding, childhood emaciation, and breast swelling in women, indicating a potential interest for further studies on its hormonal or regenerative properties. Group 5 (G5) shows that *Daldinia eschscholzii*, located nearby, appears to be involved in the treatment of abscess, intestinal wounds and unhealable wounds, suggesting antibacterial or anti-inflammatory properties. Finally, in the lower right quadrant (Group 6), *Auricularia aurea*, *Polyporus allardii*, *Phellinus pistillaris*, and *Phellinus tuberculata* are associated with the treatment of heartburn, tension, ghonorrhea and asthma, suggesting potential beneficial effects on the digestive and cardiovascular systems.

PCA also reveals that *Ganoderma lucidum* is positioned near the center, indicating a broad spectrum of medicinal effects. This observation suggests that this species may contain multiple bioactive compounds with interesting pharmacological properties.

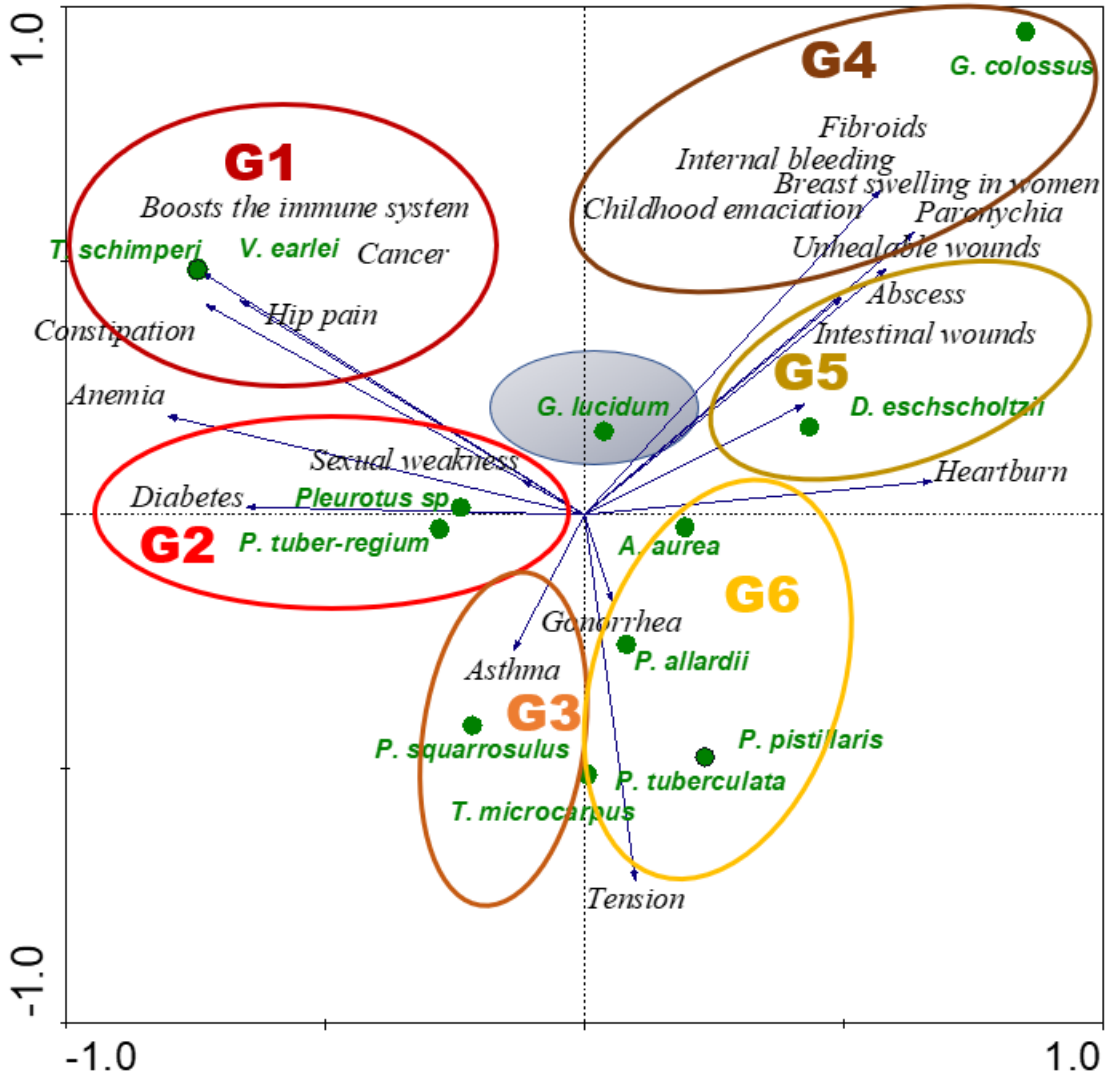

Figure 6: Relationship between mushroom species and therapeutic uses

3.3. Medicinal Usage and Dosage for Treating Diseases within Ethnic Groups

The medicinal usage and dosage used in the treatment of diseases shown in the PCA varied from one ethnic group to another. The details are provided in Table 1 below.

Table 1: Diseases or conditions treated by fungi and their methods of use within ethnic groups

Ethnic groups	Diseases	Methods of use	Dosage
Tem, Kabyè	Chest pain.	Drink the mushroom decoction.	Approximately 0.33 liters every morning
Nawdba, Kabyè	Paronychia	Dry the mushroom, then pound it into a fine powder. The obtained powder is mixed with red oil and simmered before applying drop by drop onto the wound.	Morning and evening after showering.
Bassar, Moba	Incurable wounds.	Grill the mushroom, then crush it. The obtained powder is stored and gradually applied to the wound.	Every morning and evening after bathing.
Kabyè, Tem, Bassar	Chest pain	Grind the sclerotium of the dried specimen into a powder and mix it with the porridge.	One spoonful of powder added to the porridge (3 times a day).
Kabyè, Tem, Bassar	Internal bleeding.	Dry the specimen, pound, and crush it to obtain a black powder. Take a spoonful of the black powder and mix it with a glass of alcohol. Once consumed, if the person suffers from internal bleeding, they will vomit all the bad blood.	Immediately after the accident.

Kabyè, Tem, Bassar	Incurable wounds.	Dry the specimen, pound it, then the obtained powder is mixed with Vitellaria paradoxa butter. The resulting paste is applied in small amounts to massage the wound. This disinfects the wound and subsequently promotes healing.	Twice a day (morning – evening).
Moba	Breast swelling in women.	Grill the mushroom and crush it. Then, grill the oil palm caterpillar after extracting the palm wine and crush it as well. Next, mix the two powders obtained. After mixing, add Vitellaria paradoxa oil to the mixture. This results in a pasty mass that is used to massage the breasts of the suffering mother.	Every evening before going to bed.
Bassar	Fibroids	Crush the mushroom, mix the obtained powder with *Tridax procumbens*, and crush everything together. Mix the mixture in lukewarm water. Filter it, and the filtrate is purged using a pump (for children) after a few minutes of physical exercise. After all this, the individual will automatically go to the toilet. It is during defecation that they will get rid of their fibroids. Subsequently, they will become pregnant immediately.	Once, if the procedure is successful.
Moba	Paronychia	Dry the mushroom, then pound it. Afterward, roast the obtained powder and crush it again. The final powder is mixed with Vitellaria paradoxa butter. The paste resulting from the mixture is brought to a boil. This mixture is applied drop by drop to the affected area.	Morning - Evening.
Tem, Kabyè	Abscess.	Grill the mushroom, then crush it to obtain a powder. The obtained powder is mixed with Vitellaria paradoxa butter until a pasty mass is formed. The resulting paste is then applied to the abscess.	Once a day (every morning).
Tem	Childhood weight loss	Add a few milligrams of the mushroom powder to the porridge or honey. Mix everything together and then give it to the child.	Every morning.
Tem, Kabyè, Nawdba	Anemia	Accompany your daily food with *Psathyrella tuberculata* in the form of animal meat.	Every day.
	Diabetes	Dry these small mushrooms, especially when they are in large quantities, and pound them to obtain a powder. The obtained powder is then stored in a box and used as an ingredient when preparing a new sauce.	With each new sauce for pasta or rice.
Tem, Kabyè, Nawdba	Heart pain.	Grind the dried specimen into a powder, then mix it with the porridge.	One spoonful of sclerotium powder added to the porridge (3 times a day).
Nawdba	Tension	Dry the mushroom, crush the dried specimen to obtain the powder. This is then mixed with honey. The resulting mixture is consumed like porridge or tea.	Every morning.
Kabyè		Dry the mushroom, then crush it to obtain a powder. The powder is mixed either with clean drinking water or with the porridge. The resulting beverage, when consumed gradually, treats high blood pressure.	
Tem	Gonorrhea.	Carbonize the specimen, then grind it into black powder. Mix this powder with red oil or palm kernel oil and apply it to the wound.	Clean the wound thoroughly, then apply the powder. After one to two weeks, the wound heals easily.

Kabyè, Tem	Diabetes	Grind the dried mushroom into a powder, then mix it with the porridge for each use. Alternatively, use the powder as an ingredient in the sauce.	Twice a day (Morning – Evening).
Kabyè, Tem	Tension		
Nawdba	Asthma.	Dry the mushroom, then crush the dried specimen to obtain the powder. This is then regularly mixed with the porridge.	Once a day (Morning).
Kabyè, Moba	Constipation	Simply accompany your pasta sauce with the mushroom once a day, and your constipation problem will be resolved within a week.	Once a day.
Nawdba	Anemia.	Prepare it like meat in sauce. Eat it like any other meat in sauce. It facilitates the development of erythrocytes, thus leading to an increase in blood in the body.	Lunch Dinner
Kabyè	Constipation	Simply accompany your pasta sauce with the mushroom once a day, and your constipation problem will be resolved within a week.	Once a day.
Nawdba	Hip pain.	A palm nut sauce with crushed *Ocimum basilicum* leaves, along with mushrooms of the *Volvariella* genus, is very effective against hip pain. After eating pasta with this sauce or simply drinking the sauce, the patient will go to the toilet. After doing so three times, they will be cured of their pain.	Once a day for three (03) days.
Kabyè	Boosts the immune system (gives strength).	Dry the mushroom, then crush it to obtain a powder. The powder is mixed either with clean drinking water or with porridge. The resulting beverage, when consumed gradually, treats high blood pressure.	Every morning at the usual time for morning tea.
Tem		Eat it like animal meat in sauce.	

4. DISCUSSION

Correspondence Analysis (CA) shows that the studied ethnic groups treat different diseases using medicinal mushrooms, without a strong correlation between a specific ethnic group and a particular disease. This phenomenon reflects a broad and flexible transmission of ethnomedicinal knowledge rather than strict ethnic specialization.

Recent research confirms this trend. For example, the study by Afolabi *et al.*[21] on *Pleurotus tuber-regium* highlights its use in treating headaches, skin diseases, and male sexual disorders in various African cultures. This diversity of use aligns with the idea that mycotherapeutic knowledge is shared among ethnic groups and not restricted to a single group. Furthermore, the study by Saravanan *et al.*[22] on *Lentinus squarrosulus* demonstrates that this species is used to treat infections and reduce the risks of metabolic diseases. This perspective reinforces the findings from the CA, where certain metabolic diseases like diabetes and anemia are treated by different ethnic groups without major distinctions.

The grouping in clusters (G1, G2, G3) in the CA also reflects therapeutic trends already documented in the literature. Group G1, addressing mild diseases like constipation and hypertension, corresponds to common uses in traditional African medicine, often based on mushrooms with anti-inflammatory and digestive properties. Group G2, which includes more severe pathologies requiring more complex management, reflects the growing interest in mushrooms with regenerative and immunomodulatory effects, such as those from the *Ganoderma* genus. Finally, Group G3, which includes serious diseases like cancer and diabetes, aligns with research showing increasing interest in mushrooms rich in polysaccharides and bioactive compounds capable of modulating the immune system[23, 24].

Principal Component Analysis (PCA) revealed a distinct distribution of fungi based on their medicinal properties. Different populations do not use the same species of fungi in the treatment of diseases. This observation is confirmed by a study by Wasser[25], which indicates that the therapeutic uses of fungi vary based on local ethnomycological knowledge and medical traditions. The study emphasizes that species like *Ganoderma lucidum* are commonly used in traditional Asian medicine for their immunomodulatory and anticancer properties, while others, such as *Pleurotus* sp., are more popular in Africa and Latin America for their effects on metabolism.

The association of *Termitomyces schimperi* and *Volvariella earlei* with cancer treatment and immune enhancement is consistent with the work of Wasser *et al.*[25], which shows that some fungi contain polysaccharides and triterpenes with immunostimulant and anticancer effects. Similarly, *Pleurotus* sp. and *Pleurotus tuber-regium* linked to treatments for diabetes and sexual weakness confirm the work of Lindequist *et al.*[26]. These authors confirmed that several species of

Pleurotus contain β-glucans and other compounds that improve insulin sensitivity and can reduce hyperglycemia. The association of *Ganoderma colossus* with fibroids and hormonal disorders suggests the presence of compounds that regulate hormonal balance. According to Wang *et al.*[27], some fungi contain phytoestrogens that can modulate hormonal activity. PCA also revealed that *Ganoderma lucidum* is a species with multiple therapeutic uses. This observation aligns with the conclusions of Karunarathna[28], who describes this species as a "universal medicinal mushroom" used for reducing hypertension, modulating the immune system, providing liver protection, and treating oxidative stress.

5. CONCLUSION

In conclusion, these results reinforce the idea that the use of medicinal mushrooms transcends ethnic boundaries and adapts according to transmitted knowledge and encountered pathologies. Principal Component Analysis (PCA) helps identify species with the highest therapeutic potential based on medical indications. However, these associations stem from an exploratory analysis and need to be validated through in-depth biochemical and pharmacological studies. This approach provides valuable insight into the relationship between mushrooms and their traditional therapeutic uses, highlighting promising associations that deserve further investigation. Future research could explore the biochemical specificities of the mushrooms used to better understand their role in disease management. Additionally, targeted biological tests could help identify the active compounds responsible for their medicinal effects. Finally, a complementary study on the synergy between these mushrooms and other medicinal plants could enhance our understanding of their therapeutic properties.

Conflict of Interest : The authors declare no potential conflict of interest with respect to the contents, authorship, and/or publication of this article.

Author Contributions : All the authors contributed significantly to the drafting and preparation of this manuscript

Acknowledgments : None

Conflicts of Interest : None

Ethical approval : This study does not involve experiments on animals or human subjects.

Source of Support : Nil

Funding : Nil

Data Availability Statement : The data presented in this study are available on request from the corresponding author.

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