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Diversity and Biotopes of Edible Fungi in Ecological Zone II of Togo

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ABSTRACT

Background and Objective: Mushrooms are forest resources commonly used by local populations. This study contributes to the knowledge of the diversity of edible and medicinal wild mushrooms. This study aims to assess the diversity and distribution of edible fungi across various biotopes in Ecological Zone II of Togo. **Materials and Methods:** A systematic collection of fungi was carried out in the plant formations of Ecological Zone II of Togo. A macroscopic and microscopic description was made of each species to identify them. A Principal Component Analysis (PCA) was used to discriminate between the different species based on their biotopes at the 5% threshold. **Results:** Ninety-five edible mushrooms were identified. They are divided into eighteen genera and fifteen families. The most represented families were: *Russulaceae* (52 species), *Amanitaceae* (09 species), *Cantharellaceae* (09 species) and *Lyophyllaceae* (08 species). Some species were collected in Forests and Savannahs on five different substrates. Others were collected in fields and fallow land on four different substrates. **Conclusion:** Togo's Ecological Zone II is therefore a home to important edible and medicinal fungal species, most of which are not yet used in the agri-food and pharmaceutical industries.

KEYWORDS

Diversity, biotopes, behavior, edible and medicinal mushrooms

INTRODUCTION

Food insecurity is a growing problem in developing countries. To find a solution to this scourge, people are turning to nature, in particular by collecting and eating edible mushrooms, especially during periods of hunger[1]. This group of living beings represents the most diverse group in the living world[2]. Most of them live in symbiosis with ectomycorrhizal forest trees, notably *Isoberlinia* spp., *Uapaca* spp., *Berlinia grandiflora*, *Monotes kerstingii*, and *Afzelia africana*[3]. The higher the number of ectomycorrhizal forest trees, the higher the diversity of fungi. As a result, they participate in the regeneration and functioning of forest ecosystems[4]. *Termitomyces* are also symbiotic with termites[5]. These fungi (*Termitomyces*) are much appreciated in the dishes of tropical African populations, which are collected in large quantities and constitute a staple diet for local populations[6]. A high number of termite mounds is also a factor in the production of edible mushrooms. In addition, they are species provided free by nature or can be produced

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by agroforestry systems[7]. As such, they are considered to be foodstuffs in the fight against the problems of nutrition and food insecurity that are rife in tropical African countries[5]. In addition, more than a hundred species of mushroom are used in traditional medicine to treat a wide range of illnesses, including heart disease, diabetes, cancer, gonorrhoea, intestinal wounds, constipation, hypertension, sexual weakness and cardiovascular disorders[8,9]. Given the undeniable role played by fungi in people's lives, a number of studies have been carried out on these species in tropical Africa. To date, the number of taxa consumed is constantly increasing, and it is difficult to know exactly how many mushrooms are consumed by the various peoples of tropical Africa. However, a few studies have been carried out on the edibility of mushrooms in several regions in order to determine the number of mushroom species used by different peoples and their different uses[10-13]. In Cameroon, the work of Njouonkou *et al.*[14] has shown that ninety-four species of mushroom are used by people living near the rainforest of Southern Cameroon, while Ebika *et al.*[15] in Benin listed thirty-three species of wild mushroom commonly used by the Bariba, Gando and Yom people living near the Ouémé Supérieur classified forest. In Togo, the work of Maba *et al.*[16] inventoried the edible genera *Lactarius* and *Lactifluus* of West Africa and in particular, those of Togo, Kamou *et al.*[4] and Kamo *et al.*[17] showed the socio-economic importance of a number of edible ectomycorrhizal macromycetes for the Kotocoli, Bassar, and Kabyè peoples living along the Fazao-Malfakassa Park, Nadjombé *et al.*[18] and Magamana *et al.*[19] listed a number of species edible by the Tem and Kabyè populations living along the Alédjo wildlife reserve. Unfortunately, the information available on the edibility of mushrooms is still inadequate in Togo. Several species have been described, but their edibility status is uncertain. Other species are used by local populations but have not been described. This study aimed to make an inventory of the mushrooms used by the various peoples of Togo's Ecological Zone II with a view to their sustainable management.

MATERIALS AND METHODS

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[20]. This study was carried out in Ecological Zone II, which belongs to the Sudanian phytogeographical domain[21] 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. 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[22].

Methodology

Collecting edible mushrooms: 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, 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.

Data processing: Once the carpophores had been collected, each species was described according to the following criteria: Colour, shape, size, and appearance of the cap, blades, and lamellae or tubes and foot; ornamentation and consistency of the cap and foot (presence of scales, cones, a ring, fibrils); method of insertion of the blades in relation to the foot; consistency of the lamellae (firm or soft, velvety or viscous); characterization of the base (baggy or beaded, hairy or hairless, with or without agglomerated organic debris); consistency, colour, odour and flavour of the flesh; growth habit (solitary, in groups, in clumps, in troops, forming witches' circles), ecology (nearby trees, biotope, development on wood, grass, soil or a particular support). The macroscopic study was completed by microscopic examinations of the specimens. The microscopic examinations focused mainly on the spores, basidia, cystids, the possible presence of loops, the structure of the weft, and the structure of the pilose coat. Most of these anatomical elements were observed in solution of Rouge Congo Ammoniacal (composition see in 16) and drawn at x100 magnification using an Olympus CX21 microscope equipped with a clear chamber.

Identification of specimens: 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.*[23], which was used to identify fungi of the genera *Amanita* and *Cantharellus*; the nomenclatures of Watling *et al.*[24], 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 15, 16, 17, Russula I, Russula II, Russula III by Meidl *et al.*[25]. The monographic flora of the genus *Lactarius* s. l. from tropical Africa Verbeken[26] was used to identify *Lactarius*, *Lactifluus* and *Russula*. The work of Yorou *et al.*[13]; Maba *et al.*[16] and de Kesel *et al.*[27] was used to complete the identification of the other species. The checklist was organized alphabetically by genus, species and family.

Statistical analysis of data: Microsoft Excel 2019 was used to calculate the frequencies of families and genera and to construct the spectra. Each frequency has been calculated[28]:

$$\text{Frequency (\%)} = \frac{n}{N} \times 100$$

Where:

n = Number of species belonging to the family or genus
N = Total number of species recorded

This same formula was applied to determine the percentages of the different groups of fungi and their substrates in forests, fields and fallow land. To determine the percentages (%) of edible fungi in relation to substrates, n = number of fungi collected on the substrate.

For the correlation analysis, linear correlation was chosen to establish the relationships between the variables. To this end, the variables (biotopes and edible species) were entered into the Excel 2019 spreadsheet, to obtain a data matrix. This database was used to draw up a dynamic cross-tabulation table between the edible mushroom species collected in forests and Savannahs and their biotopes, on the one hand, and between the edible mushroom species collected in fields and fallow land and their respective biotopes, on the other. Each of these tables was subjected to Principal Component Analysis (PCA) using Canoco for Window 4.5 software.

RESULTS

Diversity of edible mushrooms: Ninety-five species of edible and medicinal mushrooms have been identified. They were divided into eighteen genera and fifteen families (Fig. 1). Ninety species were identified to species level and five to genus level. The most represented families were: *Russulaceae* (55%) i.e., 52 species, *Amanitaceae* (10%) i.e., 9 species, *Cantharellaceae* (10%) i.e., 09 species and

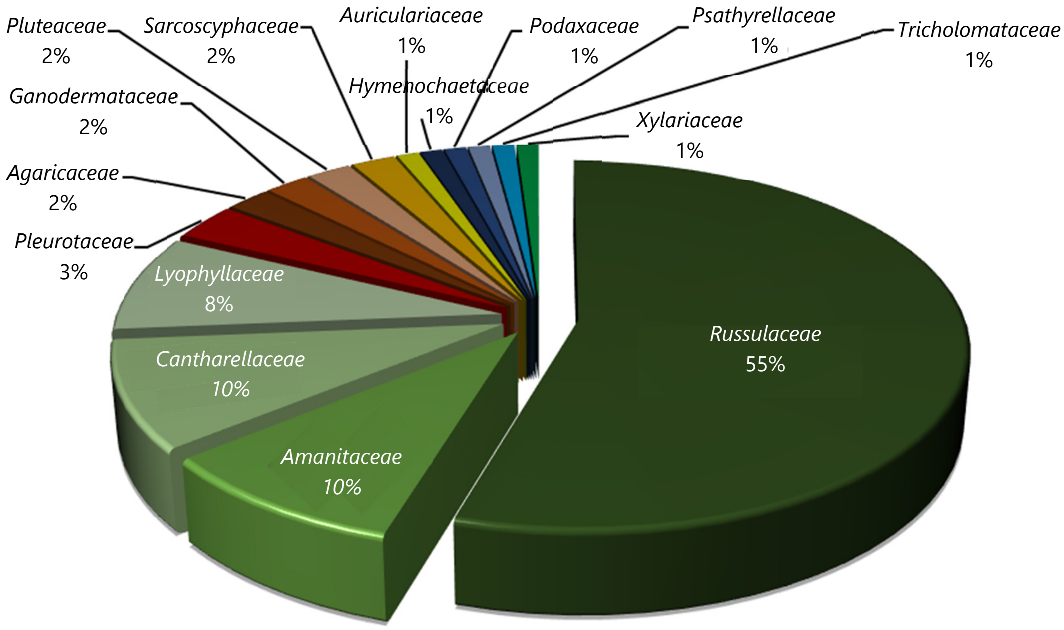

Fig. 1: Mycofloristic diversity at family level in Ecological Zone II of Togo

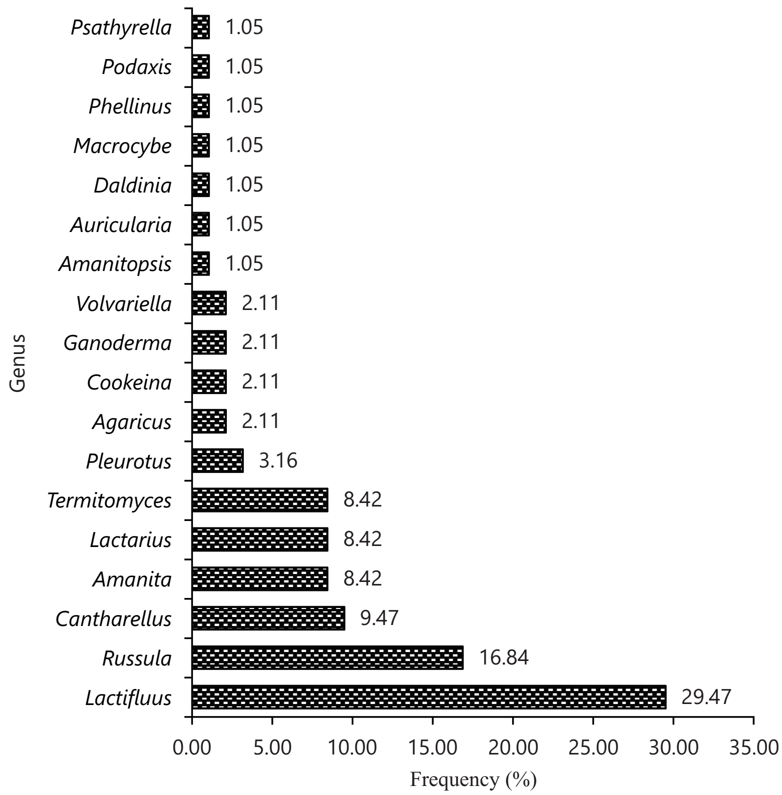

Fig. 2: Mycofloristic diversity at the genus level in Ecological Zone II of Togo

Lyophyllaceae (08%) i.e., (08) species. Six families were represented by a single species, each of which accounted for 1% of the species identified as edible. These were *Psathyrellaceae* (*Psathyrella tuberculata*), *Tricholomataceae* (*Macrocybe lobayensis*), *Xylariaceae* (*Daldinia eschscholtzii*), *Auriculariaceae* (*Auricularia cornea*), *Podaxaceae* (*Podaxis pistillaris*) and *Hymenochaetaceae* (*Phellinus allardii*).

The most represented genera were the genus *Lactifluus* (29.47%), i.e., twenty-eight species, and the genus *Russula* (16.84%), i.e., sixteen species (Fig. 2). The least represented genera were *Psathyrella*,

Table 1: Lifestyles of identified wild edible mushrooms

Species	Edible/medicinal	Behavior
Agaricus bingensis Heinem	Edible	Decomposer of litter or dead wood
Agaricus ochrascens Heinem, Gooss, Font	Edible	Decomposer of litter or dead wood
Amanita aff. vaginata (Bull.) Lam	Edible	Species in symbiosis with trees
Amanita aurea Beeli	Edible and medicinal	Species in symbiosis with trees
Amanita loosii Beeli	Edible	Species in symbiosis with trees
Amanita masasiensis Härkönen, Saarimäki & Mwasumbi	Edible	Species in symbiosis with trees
Amanita strobilaceovolvata Beeli	Edible	Species in symbiosis with trees
Amanita pulverulenta Beeli, Bull	Edible	Species in symbiosis with trees
Amanita subviscosa Beeli	Edible	Species in symbiosis with trees
Amanita rubescens Pers. s.l.	Edible	Species in symbiosis with trees
Auricularia cornea Ehrenb	Edible	Decomposer of litter or dead wood
Amanitopsis sp.	Edible	Species in symbiosis with trees
Cantharellus addaiensis Heinem	Edible	Species in symbiosis with trees
Cantharellus congolensis Beeli	Edible	Species in symbiosis with trees
Cantharellus densifolius Heinem	Edible	Species in symbiosis with trees
Cantharellus defibulatus (Heinem) Eystart. & Buyck	Edible	Species in symbiosis with trees
Cantharellus floridulus Heinem	Edible	Species in symbiosis with trees
Cantharellus platyphyllus Heinem	Edible	Species in symbiosis with trees
Cantharellus pseudomiomboensis de Kesel & Kasongo sp. nov	Edible	Species in symbiosis with trees
Cantharellus pseudocibarius Henn	Edible	Species in symbiosis with trees
Cantharellus rufopunctatus var. *rufopunctatus* (Beeli) Heinem	Edible	Species in symbiosis with trees
Cookeina sulcipes (Berk.) Kuntze	Medicinal	Decomposer of litter or dead wood
Cookeina tricholoma (Berk.) Kuntze	Medicinal	Decomposer of litter or dead wood
Daldinia eschscholtzii (Ehrenb.) Rehm	Medicinal	Decomposer of litter or dead wood
Ganoderma colossus (Fr.) C.F. Baker	Medicinal	Decomposer of litter or dead wood
Ganoderma lucidum (Leys. Fr.) Karst	Medicinal	Decomposer of litter or dead wood
Lactarius afroscrobiculatus Verbeken Van Rooij	Edible	Species in symbiosis with trees
Lactarius atro-olivinus Verbeken & Walleyn	Edible	Species in symbiosis with trees
Lactarius kabansus Pegler & Piearce	Edible	Species in symbiosis with trees
Lactarius medusae Verbeken	Edible	Species in symbiosis with trees
Lactarius miniatescens Verbeken Van Rooij	Edible	Species in symbiosis with trees
Lactarius saponaceus Verbeken	Edible	Species in symbiosis with trees
Lactarius subbalophaeus Maba	Edible	Species in symbiosis with trees
Lactarius tenellus Verbeken & Walleyn	Edible	Species in symbiosis with trees
Lactifluus annulatoangustifolius (Beeli) Buyck	Edible	Species in symbiosis with trees
Lactifluus annulatolongisporus Maba	Edible	Species in symbiosis with trees
Lactifluus cocosmus Maba	Edible	Species in symbiosis with trees
Lactifluus densifolius (Verbeken & Karhula)	Edible	Species in symbiosis with trees
Lactifluus edulis (Verbeken & Buyck) Buyck	Edible	Species in symbiosis with trees
Lactifluus emergens (Verbeken) Verbeken	Edible	Species in symbiosis with trees
Lactifluus fazaoensis Maba, Yorou & Guelly	Edible	Species in symbiosis with trees
Lactifluus flammans (Verbeken) Verbeken	Edible	Species in symbiosis with trees
Lactifluus flavellus Maba & Guelly	Edible	Species in symbiosis with trees
Lactifluus foetens (Verbeken & Van Rooij)	Edible	Species in symbiosis with trees
Lactifluus gymnocarpus (R. Heim ex Singer) Verbeken	Edible	Species in symbiosis with trees
Lactifluus gymnocarpoides (R. Heim ex Singer) Verbeken	Edible	Species in symbiosis with trees
Lactifluus guellii Maba	Edible	Species in symbiosis with trees
Lactifluus heimii de Kesel	Edible	Species in symbiosis with trees
Lactifluus knobsoides Maba	Edible	Species in symbiosis with trees
Lactifluus longibasidius Maba & Verbeken	Edible	Species in symbiosis with trees
Lactifluus longipes (Verbeken) Verbeken	Edible	Species in symbiosis with trees
Lactifluus longisporus (Verbeken) Verbeken	Edible	Species in symbiosis with trees
Lactifluus luteopus Maba	Edible	Species in symbiosis with trees
Lactifluus medusae Maba	Edible	Species in symbiosis with trees
Lactifluus melleus Maba	Edible	Species in symbiosis with trees
Lactifluus membranaceus Maba	Edible	Species in symbiosis with trees
Lactifluus nonpiscis (Verbeken) Verbeken	Edible	Species in symbiosis with trees
Lactifluus pectinatus Maba & Yorou	Edible	Species in symbiosis with trees
Lactifluus pimulus (Verbeken) Verbeken	Edible	Species in symbiosis with trees

Table 1: Continue

Species	Edible/medicinal	Behavior
Lactifluus rubiginosus (Verbeken) Verbeken	Edible	Species in symbiosis with trees
Lactifluus sudanicus Maba & Guelly	Edible	Species in symbiosis with trees
Lactifluus togoensis Maba	Edible	Species in symbiosis with trees
Macrocybe lobayensis (R. Heim) Pegler & Lodge	Edible	Decomposer of litter or dead wood
Phellinus allardii (Bres.) Ryv	Medicinal	Decomposer of litter or dead wood
Pleurotus sp.	Edible	Decomposer of litter or dead wood
Pleurotus squarrosulus Mont	Edible	Decomposer of litter or dead wood
Pleurotus tuber-regium (Fr.) Fr	Edible	Decomposer of litter or dead wood
Podaxis pistillaris (L.Pers.) Morse	Medicinal	Decomposer of litter or dead wood
Psathyrella tuberculata Smith	Edible	Decomposer of litter or dead wood
Russula aff. annulata Heim, Buyck	Edible	Species in symbiosis with trees
Russula cellulata Buyck, Bull	Edible	Species in symbiosis with trees
Russula compressa Buyck	Edible	Species in symbiosis with trees
Russula congoana var. *congoana* Patouillard, Bull. Soc. Mycol	Edible	Species in symbiosis with trees
Russula cyclosperma Buyck, Bull	Edible	Species in symbiosis with trees
Russula fissurata Buyck, Bull	Edible	Species in symbiosis with trees
Russula ingens Buyck	Edible	Species in symbiosis with trees
Russula liberiensis Sing. Pap. Michigan	Edible	Species in symbiosis with trees
Russula ochrocephala Buyck	Edible	Species in symbiosis with trees
Russula oleifera Buyck	Edible	Species in symbiosis with trees
Russula pseudocarmesina Buyck	Edible	Species in symbiosis with trees
Russula sp.[1]	Edible	Species in symbiosis with trees
Russula sp.[2]	Edible	Species in symbiosis with trees
Russula sp.[3]	Edible	Species in symbiosis with trees
Russula subfistulosa var. *subfistulosa* Buyck	Edible	Species in symbiosis with trees
Russula testacea Buyck	Edible	Species in symbiosis with trees
Termitomyces clypeatus	Edible	Symbiosis with termites
Termitomyces fuliginosus R. Heim	Edible	Symbiosis with termites
Termitomyces letesti R. Heim	Edible	Symbiosis with termites
Termitomyces medius R. Heim & Grassé	Edible	Symbiosis with termites
Termitomyces microcarpus (Berk. & Br.) Heim	Edible	Symbiosis with termites
Termitomyces robustus Beeli	Edible	Symbiosis with termites
Termitomyces schimperi Heim	Edible	Symbiosis with termites
Termitomyces striatus Beeli & Heim	Edible	Symbiosis with termites
Volvariella earlei Shaffer	Edible	Saprotrophs
Volvariella volvacea (Bull) Singer	Edible	Saprotrophs

Amanitopsis, *Daldinia* (*Daldinia schscholtzii*), *Macrocybe*, *Podaxis*, *Auricularia* and *Phellinus*, each representing 1.05%.

Groups of edible mushroom species: Three groups of edible fungi collected were categorized according to their lifestyle (Table 1). These are saprotrophs, symbionts and parasites. The symbiont group was the most represented (74%), followed by saprotrophs (24%) and parasites (2%). Figure 3, shows the proportions of edible fungi groups according to their lifestyle.

Biotopes in which edible mushrooms have been collected in forests and savannahs: The representation of species on the factorial plane along axes 1 and 2 of Principal Component Analysis (PCA) showed the distribution of species according to the biotopes in which they were collected in forest and savannah. The species were scattered along the two axes, revealing four groups (Fig. 4). These are group G1: Edible mushrooms collected only in gallery forests, group G4: Mushrooms collected only in open forests, group G2: Mushrooms collected in both gallery forests and open forests and group G3: Mushrooms collected only in savannahs (Table 2). The groups (G1 and G2) were correlated with axis 1 while the groups (G3 and G4) were correlated with axis 2. Axis 1 contains 70.30% of the information on the biotopes of edible fungi and axis 2 contains 87.40% of the information on the different species of edible fungi.

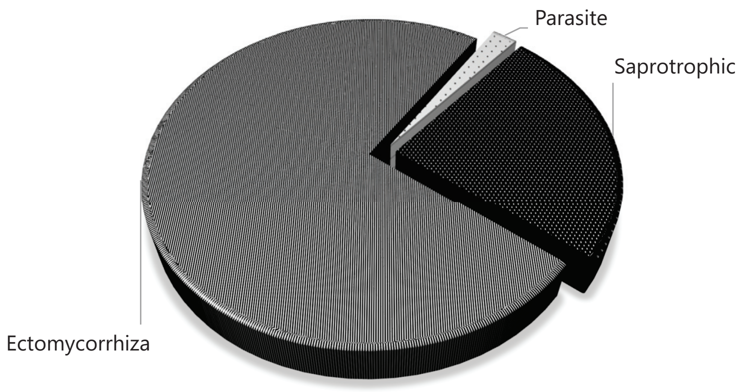

Fig. 3: Ecological groups of edible fungi

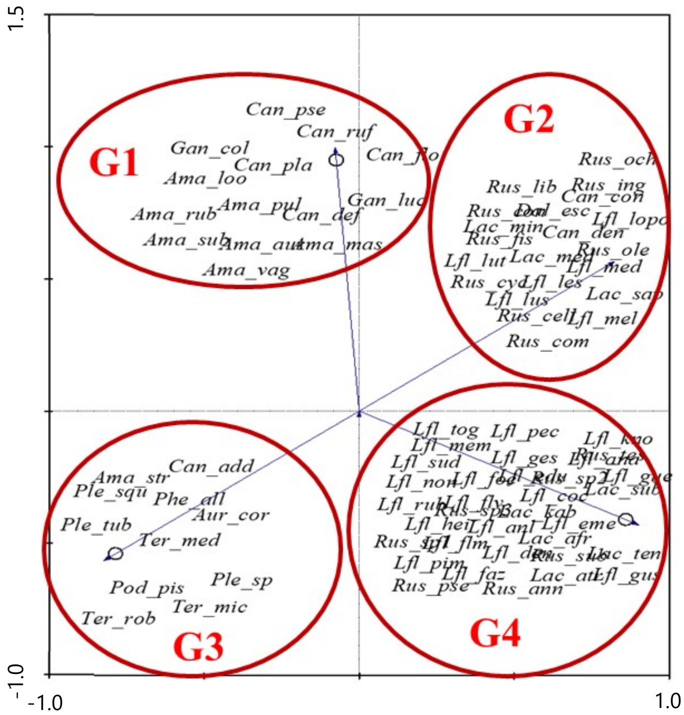

Fig. 4: Representation of forest and savannah species on the factorial plane of PCA axes 1 and 2

G1: Can_pse: *Cantharellus pseudocibarius* Fr., Can_ruf: *Cantharellus rufopunctatus* var. rufopunctatus (Beeli) Heinem, Can_def: *Cantharellus defibulatus* (Heinem.) Eyssart. & Buyck, Can_flo: *Cantharellus floridulus* Heinem; Can_pla: *Cantharellus platyphyllus* Heinem., Gan_col: *Ganoderma colosus* (Fr.) C.F.Baker, Gan_luc: *Ganoderma lucidum* (Leys. Fr.) Karst, Ama_loo: *Amanita loosii* Beeli, Ama_pul: *Amanita pulverulenta*, Ama_sub: *Amanita subviscosa* Beeli, Ama_mas: *Amanita masasiensis* Härkönen, Saarimäki & Mwasumbi, Ama_sub: *Amanita subviscosa* Beeli, Ama_vag: Amanita aff. vaginata (Bull.) Lam, G2: Rus_ochr: *Russula ochrocephala* Buyck, Rus_lib: *Russula liberiensis* Sing. Pap. Michigan, Rus_ing: *Russula ingens* Buyck, Rus_cyc: *Russula fissurata* Sanon & Buyck, Rus_com: *Russula compressa* Buyck, Rus_cel: *Russula cellulata*, Rus_ole: *Russula oleifera* Buyck; Rus_fis: *Russula fissurata* Sanon & Buyck, Can_con: *Cantharellus congolensis* Beeli., Can_den: *Cantharellus densifolius* aff., Lfl_med: *Lactifluus medusae* (Verbeken) Verbeken, Lfl_mel: *Lactifluus melleus* Maba, Lfl_lut: *Lactifluus luteopus* (Verbeken) Verbeken, Lac_med: *Lactarius medusae* Verbken, Lac_min: *Lactarius miniatescens* Verbeken Van Rooij, Lac_sap: *Lactarius saponaceus* Verbeken, G3: Ama_str: *Amanita strobilaceovolvata* Beeli, Can_add: *Cantharellus addaiensis* Heinem, Ple_squ: *Pleurotus squarrosulus* Mont., Phe_all: *Phellinus allardii*, Aur_cor: *Auricularia cornea* Ehrenb, Ple_tub: *Pleurotus tuber-regium* (Fr.) Fr, Ter_med: *Termitomyces medius* R. Heim & Grassé, Ter_rob: *Termitomyces robustus* R. Heim, Ter_mic: *Termitomyces microcarpus* (Berk. & Br.) Heim., Pod_pis: *Podaxis pistillaris* (L.Pers.) Morse, G4: Lfl_tog: *Lactifluus togoensis* Maba, Lfl_pec: *Lactifluus pectinatus* Maba & Yorou, Lfl_kno: *Lactifluus knobsoides* Maba, Lfl_sud: *Lactifluus sudanicus*, Lfl_hem: *Lactifluus hemii*; Lfl_faz:, Lfl_pim: *Lactifluus pimulus* (Verbeken) Verbeken, Lfl_eme: *Lactifluus emergens* (Verbeken) Verbeken, Lfl_gue: *Lactifluus guellii* Maba, Lac_kab: *Lactarius kabansus* Pegler & Piearce, Lac_afr: *Lactarius afroscrobiculatus* Verbeken Van Rooij, Rus_ann: *Russula* aff. *annulata* Heim, Buyck., Rus_pse: *Russula pseudocarmesina* Buyck

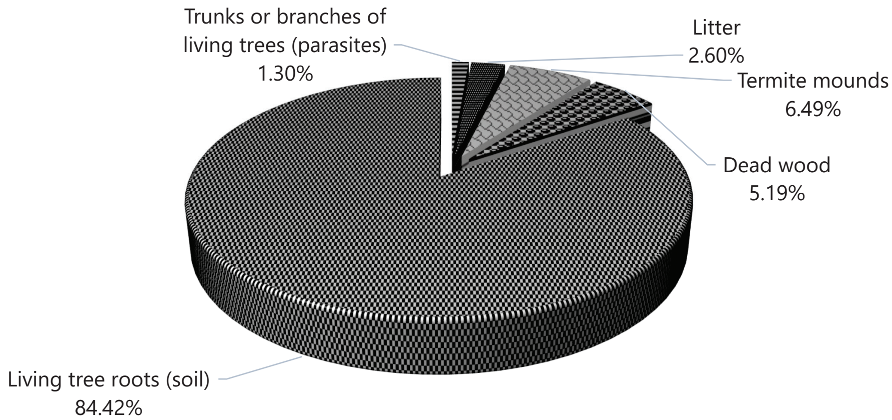

Fig. 5: Substrates of edible and medicinal mushrooms in forests and savannahs

Table 2: Edible mushrooms in the different groups of PCA in forests and savannahs

Group	Species
Group 1 (G1)	*A. loosii*, *C. platyphillus*, *C. rufopunctatus*, *A. vaginata*, *A. rubescens*, *G. lucidum*, *A. pulverulenta* and *C. defibilatus*
Group 2 (G2)	*R. compressa*, *R. ochrocephala*, *R. cyclosperma*, *C. congolensis*, *D. eschscholtzii* and *L. saponaceus*
Group 3 (G3)	*Pleurotus* sp., *T. robustus*, *C. addaiensis*, *T. microcarpus* and *P. pistillaris*
Group 4 (G4)	*R. annulata*, *L. rubiginosus*, *L. flammans*, *L. togoensis* and *L. guellii*

Table 3: Examples of edible fungi in the different groups of PCA in fields and fallow land

Group	Species
Group 1 (G1)	*T. clypeatus*, *T. striatus*, *P. pistillaris*, *T. schimperi*, *T. robustus* and *T. letestui*
Group 2 (G2)	*Russula* sp., 1, *R. compressa*, *R. ochrocephala*, *P. tuber-regium*, *P. squarosulus* and *R. congoana*
Group 3 (G3)	*P. tuberculata*, *G. lucidum*, *G. colosus* and *P. allardii*
Group 4 (G4)	*V. volvacea*, *V. earlei*, *A. ochrascens* and *M. lobayensis*

Substrates on which edible mushrooms have been collected in forests and savannahs: According to Fig. 5, edible mushrooms grow on five different specific substrates in forests and savannahs. These are the roots of living trees (soil), on which the majority of mushrooms were collected (84.42%) in the forests and savannahs; followed by termite mounds (6.49%) and dead wood (5.19%). Few edible mushrooms were collected from litter (2.60%) and from the trunks or branches of living trees (1.30%).

Biotopes in which fungi were collected in fields and fallow land: The representation of species on the factorial plane along the canonical axes 1 and 2 of PCA showed that the distribution of species according to the biotopes in which they were collected in the fields and fallows. The species were scattered along the two axes, revealing four groups (Fig. 6). These are group G1: Edible mushrooms collected on termite mounds, G2: Edible mushrooms collected on the dead wood of *Parkia biglobosa* or the living wood of *Afzelia africana* or the living wood of *Burkea africana*, G3: Edible mushrooms collected on the living stipe of *Elaeis guineensis* and group G4: Edible mushrooms collected on the rotten or living wood of *Elaeis guineensis* (Table 3). The groups (G2 and G3) were correlated with axis 1 while the groups (G1 and G4) were correlated with axis 2. Axis 1 contains 74.90% of the information on the biotopes of edible fungi and axis 2 contains 87.10% of the information on the different species of edible fungi.

Substrates on edible wild mushrooms are collected in fields and fallow land: According to Fig. 7, edible fungi were collected on four different specific substrates in the fields and fallow land. These were dead wood (38.89%), soil (33.33%) and termite mounds (22.22%). Few edible wild mushrooms were collected on living wood (5.56%) in these fields and fallows.

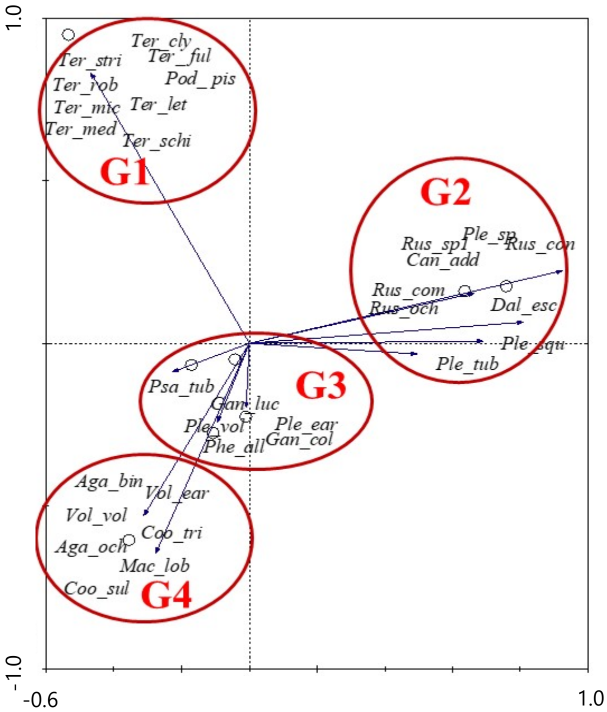

Fig. 6: Representation of field and fallow species on the factorial plane of PCA axes 1 and 2

G1: Ter_cly: *Termitomyces clypeatus*, Ter_ful: *Termitomyces fuliginosus* R. Heim, Ter_str: *Termitomyces striatus* Beeli & Heim, Ter_rob: *Termitomyces robustus* Beeli, Ter_mic: *Termitomyces microcarpus* (Berk. & Br.) Heim, Ter_sch: *Termitomyces schimperi* Heim, Ter_med: *Termitomyces medius* R. Heim & Grassé, Pod_pis: *Podaxis pistillaris* (L.Pers.) Morse, G2: Can_add: *Cantharellus addaiensis* Heinem, Ple_sp: *Pleurotus* sp., Ple_tub: *Pleurotus tuber-regium* (Fr.) Fr, Ple_squ: *Pleurotus squarrosulus* Mont, Dal_esc: *Daldinia eschscholtzii* (Ehrenb.) Rehm, Rus_com: *Russula compressa* Buyck, Rus_och: *Russula ochrocephala* Buyck, Rus_sp.[1]: *Russula* sp.[1], Rus_con: *Russula congoana* var. *congoana* Patouillard, Bull. Soc. Mycol, G3: Psa_tub: *Psathyrella tuberculata* Smith, Gan_luc: *Ganoderma lucidum* (Leys. Fr.) Karst, Gan_col: *Ganoderma colossus* (Fr.) C.F. Baker, Ple_vol: *Volvariella volvacea* (Bull) Singer, Ple_ear: *Volvariella earlei* Shaffer, Phe_all: *Phellinus allardii* (Bres.), G4: Vol_vol: *Volvariella volvacea* (Bull) Singer, Vol_ear: *Volvariella earlei* Shaffer, Aga_bin: *Agaricus bingensis* Heinem, Aga_och: *Agaricus ochrascens* Heinem, Gooss, Font.; Coo_tri: *Cookeina tricholoma* (Berk.) Kuntze, Coo_sul: *Cookeina sulcipes* (Berk.) Kuntze and Mal_lob: *Macrocybe lobayensis* (R. Heim) Pegler & Lodge

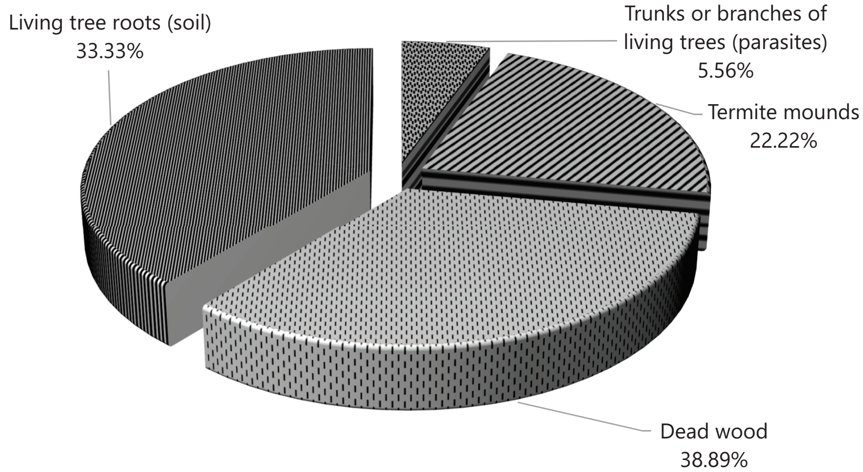

Fig. 7: Substrates of edible and medicinal wild mushrooms in fields and fallow land

DISCUSSION

The people of Togo's Ecological Zone II know and use mushrooms. These mushrooms are often collected in forests, savannahs, fields and fallow land. A total of 95 species of edible mushrooms have been identified as edible in this zone by local people. These results show that there is a high diversity of mushrooms consumed by the different peoples of Ecological Zone II. This diversity is thought to be linked to the ecological and climatic conditions that are conducive to the fruiting of edible and medicinal mushrooms. Most of the mushrooms were collected in forests. In these forests, certain species form a symbiosis with ectomycorrhizal species, while others are saprotrophs. This has already been pointed out by Kamou *et al.*[4] and Kamo *et al.*[17] during ethnomycological studies of local populations in the Fazao-Malfakassa National Park. According to these authors, the different groups of useful fungi occur in all ecosystems throughout Togo. Both saproptrophic fungi and ectomycorrhizal fungi are found in forests, savannahs, fields and fallow land. However, the presence of ectomycorrhizal fungi in the fields and fallow land in this study is linked to the presence of ectomycorrhizal species conserved by farmers in their fields and fallow land. These include *Afzelia africana*, *Prosopis africana* and *Daniella oliveri*. The presence of significant numbers of *Lyophyllaceae* is linked to the presence of termite mounds, which have been found almost everywhere in forests, savannahs, fields and fallow land, and which are favourable for the production of *Termitomyces* fungi. The enormous presence of decomposing parts of dead trees or even whole felled trees leaving decomposing residues and creating windfalls in the middle of the forest have been the source of the edible saprotrophic fungi collected in these areas. Saprotrophs live only on decomposing organic matter. Among the species of edible and medicinal fungi identified in this study, ectomycorrhizal fungi were found to be the most abundant. This large number of ectomycorrhizal fungi was linked to the presence of a diversity of ectomycorrhizal plants in Ecological Zone II, including *Afzelia africana*, *Uapaca* spp., *Isoberlinia* spp., *Monotes kerstingii*, *Azadiracta indica*, *Berlina grandiflora*. The diversity of edible and medicinal mushrooms observed in this study was linked to the dietary habits of local populations and the importance they attach to wild mushrooms. Similar studies were carried out among the Riparian population of the PNFM by Kamou *et al.*[4]. These authors reported 23 species of mushroom edible by the Kabyè and Bassar Riparian population of the PNFM. Similar studies have also been carried out in several regions of tropical Africa. In the miombo of Burindi and Rwanda, Degreef *et al.*[11] identified seventy-seven wild edible fungi, with ectomycorrhizal fungi dominating. In the rainforest of Southern Cameroon, ninety-four mushrooms have been identified as edible by the Bantu, Baka and Bagyeli pygmy peoples[14]. In the Democratic Republic of Congo, Madamo *et al.*[29] identified seventy-four edible mushrooms in the Hinterland community and among the city dwellers of Kikwit, with a predominance of *Cantharellaceae*, *Lyophyllaceae*, *Marasmiaceae* and *Polyporaceae*. In Côte d'Ivoire, N'douba *et al.*[6] identified ten edible mushrooms from the populations of the town of Daloa, while studies by Guissou *et al.*[10] identified eleven edible mushrooms also used in traditional pharmacopoeia by the populations of Gagnoa, Soubré and Abidjan. Soro *et al.*[30] identified twenty-one edible mushrooms that contribute to the economy of the Malinké, Lobi, Koulango, Oubi, Koyaka, Baoulé, Abron, Gouro, Mossi, Koyaka, Abbey, Agni and Ebrié peoples. In Benin, the work of Codjia and Yorou[31] identified twelve edible mushrooms among the Nagot, Holli and Fon. Fadeyi *et al.*[12] identified nineteen edible mushrooms among the Lokpa, Bètamaribè, Peuhls and Nagots living in the Kouffe Mountains Region. Ebika *et al.*[15] identified thirty-five wild edible mushrooms among the Bariba, Gando and Yom of the N'dali Region. The diversity of edible mushrooms in the different works varies from one country to another, from one region of a country to another but also according to the different peoples. This variability shows that the number of edible and medicinal mushrooms is great throughout tropical Africa.

In forests, as in fields and fallow land, mushrooms do not grow on the same substrate. In this study, in forests as in fields, the majority of edible and medicinal mushrooms were collected on the ground. The soil substrate here is simply a support for these mushrooms. In fact, edible fungi mycorrhise with ectomycorrhizal plants such as *Isoberlinia* spp., *Uapaca* spp., *Monotes kerstingii*, *Berlinia grandiflora*, *Afzelia africana* and other ectomycorrhizal species. The ectomycorrhizal fungi were generally collected on the root of the host plant, under the crown of the host plant or sometimes 50 m or more from the host plant. The same observations were made in Senegal[2] and Togo[4]. The work of Njouonkou *et al.*[14] showed that 21.30% of edible ectomycorrhizal fungi grow in the rainforest of Southern Cameroon. In their work, they showed that edible fungi establish mycorrhizae with certain plants such as *Afzelia*, *Berlinia*, *Brachystegia*, *Gilbertiodendron* and *Uapaca* spp. Edible fungi were also collected on the dead wood or branches of decaying trees. These are saprotrophic fungi, most of which are involved in the decomposition of plant debris in forests. In this way, edible fungi help to purify forests of their own waste, such as dead wood, dead leaves and dead branches and trees. Among these fungi is *V. volvacea*, which has generally been collected on decomposing *Ealeis guineensis*, after the extraction of palm wine. The same observation was made with the fungus *P. tuberculata*, which generally grows on the stump of *Parkia biglobosa*. Among these edible saprotrophs, three species were reported by Guelly *et al*.[32]. These are *V. volvacea*, *P. tuberculata* and *M. lobayensis*, which were collected in the grounds of the Lomé University Campus. Other species and those reported by Guelly *et al*.[32] were reported by Kamou *et al*.[4] and Kamo *et al*.[17] from the riparian population of the Fazao-Malfakassa National Park.

CONCLUSION

Togo's Ecological Zone II is an ectomycorrhizal plant zone par excellence. It is home to a diversity of fungi commonly used by local populations as food or alicaments. Most of these fungi form symbiotic relationships with ectomycorrhizal plants, helping to structure these forest ecosystems, regenerate them and ensure their sustainability. Fungi are therefore an essential component of these ecosystems.

SIGNIFICANCE STATEMENT

Mushrooms are one of the non-timber forest products exploited by local populations. Most of these species are collected from plant formations. Togo's Ecological Zone II is a prime area for ectomycorrhizal plants. It abounds in a wide variety of fungi that are exploited by local populations, especially during the welding season. The aim of this study was to compile an inventory of these edible mushrooms in order to provide consumers with better guidance. Ninety-five species of mushroom are eaten by local people and are also used in traditional medicine. However, not all of them were collected in the same plant formations. Some were collected only in forests and savannahs, others in fields and fallow land.

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