Forest Systems
32 (1), e007, 14 pages (2023)
eISSN: 2171-9845
https://doi.org/10.5424/fs/2023321-19884
INIA-CSIC

RESEARCH ARTICLE

OPEN ACCESS

Traditional knowledge and use of wild mushrooms with biocultural importance in the Mazatec culture in Oaxaca, Mexico, cradle of the ethnomycology

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Abstract

Aim of study: To document for the first-time the biocultural knowledge related to the use, nomenclature, and classification of wild mushrooms by the Mazatec culture, cradle of the ethnomycology.

Area of study: Municipality of Eloxochitlán de Flores Magón and communities of San José Buena Vista and Agua Ancha, belonging to the state of Oaxaca, in southern Mexico.

Materials and methods: A total of 291 interviews were performed by using numerical ethnomycological methods, during the rainy seasons, between 2017 and 2021. Based on the knowledge of local experts, fungal specimens with biocultural relevance were collected. Socio-demographic information, knowledge of wild mushrooms and their usages, local nomenclature, culinary uses, and transmission of traditional knowledge were documented.

Main results: Paradoxically, this is the first ethnomycological study that addresses a complete study of fungi with biocultural importance in the ethnic group where ethnomycology emerged as a discipline. Previous studies related to mushrooms with Mazatec people focused exclusively on entheogenic mushrooms leaving aside paramount issues related to traditional mycological knowledge of the fungal local resources, including their edibility and cultural relevance. All interviewees consumed mushrooms, indicating high levels of mycophilia. Twenty-seven species, all of them having a native Mazatec name, were identified. Species of *Pleurotus*, *Auricularia*, *Cantharellus*, and *Schizophyllum* spp. showed the highest cultural value indexes.

Research highlights: Ethnomycological knowledge of Mazatec culture is prolific and related to local natural resources cosmovision, beliefs and traditions. Mycological knowledge is currently preserved among Mazatec people and it is still transmitted to new generations despite strong transculturation processes.

Additional key words: cosmogony; edible mushrooms; entheogenic mushrooms; ludic mushrooms; Mazatec biocultural heritage.

Abbreviations used: FM (frequency of mention); MI (mention index).

Citation: Ríos-García, U; Carrera-Martínez, A; Martínez-Reyes, M; Hernández-Santiago, F; Evangelista, FR; Díaz-Aguilar, I; Olvera-Noriega, JW; Pérez-Moreno, J (2023). Traditional knowledge and use of wild mushrooms with biocultural importance in the Mazatec culture in Oaxaca, Mexico, cradle of the ethnomycology. Forest Systems, Volume 32, Issue 1, e007. https://doi.org/10.5424/fs/2023321-19884

Received: 09 Oct 2022. **Accepted:** 01 Mar 2023.

Funding agencies/institutions	Project / Grant
National Council for Science and Technology (CONACyT)	PRONACES FOP07-2021-03 316198

Competing interests: The authors have declared that no competing interests exist.

This article belongs to the Special Issue **"Forests: Reservoirs of Global Mycocultural Heritage and Mycological Resources".** https://revistas.inia.es/index.php/fs/si1

Introduction

Fungi are a cosmopolitan group of organisms with high economic, ecological and cultural relevance. Due to their edibility and ceremonial use, mushrooms have had a sociocultural relevance around the world. Recently, there has been a growing trend to consider wild mushrooms as a valuable non-wood forest resource (Pérez et al., 2021a). In Mexico, knowledge related to the sustainable exploitation, management and use of wild mushrooms is a cultural heritage that dates back to pre-Hispanic times (Wasson, 1983; Guzmán, 2008; Moreno 2014, Pérez et al., 2021b). Traditional mycological knowledge in the country is extensive; however, its understanding in the 68 Mexican ethnic groups is far to be complete. In 1957 the world witnessed the rise of ethnomycology as a field of study, when Wasson & Wasson (1957) discovered the use of *Psilocybe* species as entheogens in ceremonial events which were part of the everyday life among members of the Mazatec culture in Oaxaca, Mexico. Subsequently, taxonomic, biochemical and ethnological studies received huge attention in that culture, linked exclusively to the knowledge of entheogenic fungi. Additionally, the isolation of the bioactive compounds that originate modifications of reality perceptions were explained by the influence of new indole compounds, called psilocybin and psilocin, on the human central nervous system (Heim & Wasson, 1958; Hoffman et al., 1959). Currently, ethnomycology is defined as the "area of ethnobiology that is responsible for studying traditional knowledge and the cultural and/or environmental manifestations and implications that derive from the relationships established between fungi and man through time and space" (Moreno et al., 2001).

The name "Mazatec" comes from the Nahuatl *mazatecatl*, which means "people of the deer"; this is an exonym given by the Nahuatl-speaking Nonoalca culture, related to the respect they felt for the deer and to the abundance of this animal in the forests they inhabit (Quintanar & Maldonado, 1999). The Mazatec people currently live in the north of the state of Oaxaca, and in some parts of Veracruz and Puebla states, in southern Mexico, with 237,212 native speakers, ranking tenth among the languages spoken in the country (INEGI, 2020). Despite the fact that ethnomycology, as a scientific discipline, was born with the studies of entheogenic fungi in the Mazatec culture, paradoxically to date a deep ethnomycological study linked to the traditional knowledge and the cosmogony of edible, medicinal or ludic mushrooms in this culture is lacking. The objective of the study was to carry out an ethnomycological study, using numerical ethnomycology methods for the first time, in order to document the use of wild mushrooms with biocultural importance within the Mazatec culture.

Material and methods

Study area

The study was conducted in the communities of San José Buenavista and Agua Ancha, in the municipality of Eloxochitlán de Flores Magón. Both communities are located in the north of the state of Oaxaca, Mexico (Fig. 1). The study area

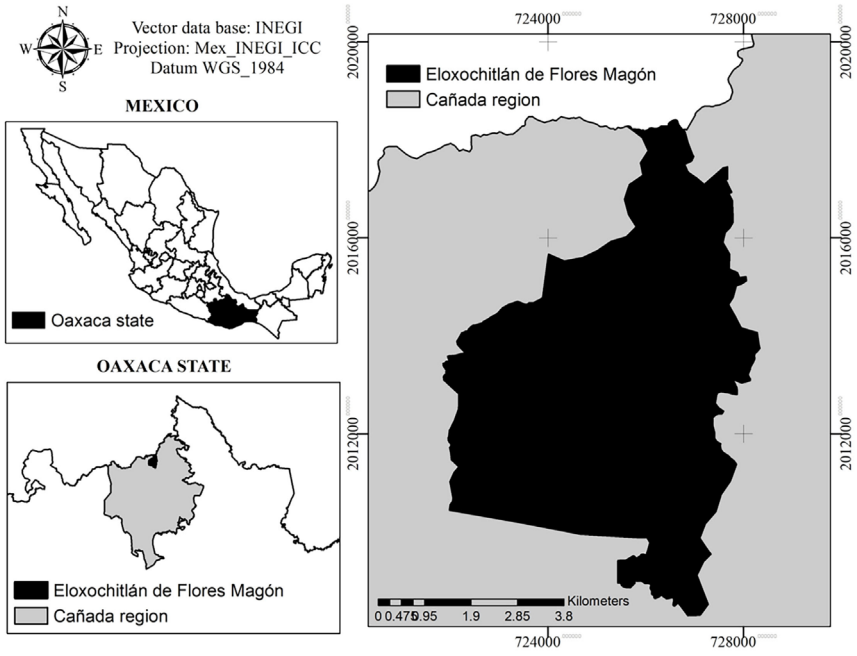

Figure 1. Location of the municipality of Eloxochitlán de Flores Magón, Oaxaca, Mexico.

Table 1. Mushrooms with biocultural relevance within Mazatec culture, common names, use, trophic group and ethnomycological indexes.

Taxa[1]	Mazatec name	English and Spanish (in brackets) translation	Use[2]	TG[3]	NM[4]	IM[5]	FM[6]
Armillaria mellea (Vahl) P. Kumm.	*Tjiɨn tsjín*	Milk fungus (Hongo de leche)	E	S	99	3.40	0.34
Auricularia angiospermarum Y.C. Dai, F. Wu & D.W. Li	*Tjiɨn chíká*	Ear fungus (Hongo de oreja)	E	S	274	9.42	0.94
Auricularia tremellosa (Fr.) Pat.	*Tjiɨn chíká*	Ear fungus (Hongo de oreja)	E	S	274	9.42	0.94
Auricularia nigricans (Sw.) Birkebak, Looney et Sánchez-Garcia	*Tjiɨn chíká nañá*	Dog ear fungus (Hongo de oreja de perro)	E, L	S	59	2.03	0.20
Calvatia cyathiformis (Bosc) Morgan	*Tjiɨn tsɑngɑ*	Sponge fungus (Hongo de esponja)	L	S	5	0.17	0.02
Cantharellus aff. confluens	*Tjiɨn ítá sinè*	Yellow oak fungus (Hongo amarillo de encino)	E	EC	18	0.62	0.06
Cantharellus cibarius s.l. Fr.	*Tjiɨn inì*	Red fungus (Hongo rojo)	E	EC	209	7.18	0.72
Cantharellus aff. violaceovinosus	*Tjiɨn chjɨ'ndɨ*	Purple mushroom (Hongo morado)	E	EC	35	1.20	0.12
Clavulinopsis fusiformis (Sowerby) Corner	*Jnǫ tsálá; Jnǫ nisen*	Lizard "milpa" (milpa de lagartija; Mouse "milpa" (milpa de ratón)	L	S	7	0.24	0.02
Daldinia sp.	*To'nchí*	Juicy and meaty ball (bola jugosa y carnosa)	E	S	209	7.18	0.72
Ganoderma zonatum Murrill	*Tjiɨn tája*	Hard mushroom (hongo duro)	L	S	13	0.45	0.04
Geastrum lageniforme Vittad.	*Tjiɨn chijo*	Dusty fungus (hongo de polvo)	L	S	3	0.10	0.01
Hydnopolyporus fimbriatus (Cooke) D.A. Reid	*Tjiɨn chroba tája*	Hard white fungus (hongo blanco duro)	E	S	47	1.62	0.16
Laetiporus sulphureus (Bull.) Murrill	*Tjiɨn akoǫn*	Hard hearted fungus (hongo de corazón duro)	E	S	139	4.78	0.48
Lentinus crinitus (L.) Fr.	*Tjiɨn xɑxín*	Fibrous fungus (hongo fibroso)	E	S	24	0.82	0.08
Panaeolus cyanescens Sacc.	*Chjɨngǫ tíndsó*	Shepherd (pastor)	M	S	1	0.03	0.00
Pleurotus albidus (Berk.) Pegler	*Tjiɨn chroban ntsǫkó*	White leg fungus (hongo blanco de pata)	E	S	19	0.65	0.07
Pleurotus djamor (Rumph. ex Fr.) Boedijn	*Tjiɨn chroba*	White fungus (hongo blanco)	E	S	283	9.73	0.97
Pleurotus opuntiae (Durieu&Lév.) Sacc.	*Tjiɨn chroba*	White fungus (hongo blanco)	E	S	283	9.73	0.97
Pleurotus sp.	*Tjiɨn chroba*	White fungus (hongo blanco)	E	S	283	9.73	0.97
Psilocybe caerulescens (Murrill)	*Tjiɨn kɨxó*	Landslide fungus (hongo de derrumbe)	M	S	55	1.89	0.19
Psilocybe cubensis (Earle) Singer	*Tjiɨn nanguiɨ*	Ground fungus (hongo de tierra)	M	S	236	8.11	0.81
Psilocybe mexicana R. Heim	*Tjiɨn nɨse*	Bird Fungus (hongo de pájaro)	M	S	31	1.07	0.11
Psilocybe yungensis Singer & A.H. Sm.	*Tjiɨn nɨse*	Bird Fungus (hongo de pájaro)	M	S	1	0.03	0.00
Schizophyllum commune Fr.	*Tjiɨn nɨse*	Bird Fungus (hongo de pájaro)	E	S	252	8.66	0.87
Schizophyllum radiatum Fr.	*Tjiɨn nɨse*	Bird Fungus (hongo de pájaro)	E	S	252	8.66	0.87
Ustilago maydis (DC.) Corda	*Tohíjé*	Ball of "jilote" (immature corn) (Bola de jilote)	E	P	218	7.49	0.75

[1] Nomenclature is based in *Index Fungorum* (http://www.indexfungorum.org/). [2] E, edible; L, ludic; M, medicinal (Use). [3] TG, trophic group based mainly in Rinaldi et al. (2008) and Comandini et al. (2012): S, saprotroph; EC, ectomycorrhizal; P, parasite. [4] NM, number of mentions. [5] IM, index of mention. [6] FM, frequency of mention.

is located between the geographical coordinates 18°09' and 18°15'N, and 96°50' and 96°55'W at 1460 m.a.s.l. According to Köppen's classification, modified by García (2004), there are two predominant climate types in the area: (A)C(m) (semi-warm sub-humid), with average temperatures above 18°C and abundant summer rains, and (A)C(fm) (temperate semi-warm humid) with rains all year, with a temperature of -3°C in cold months and an average temperature above 18°C. Based on Rzedowski's (2006) classification, the predominant types of vegetation in the municipality are mountain cloud forest and evergreen tropical forest. In the mountain cloud forest, the presence of *Liquidambar styraciflua*, *Pinus teocote*, *Quercus* spp., and species of the families Orchidaceae, Bromeliaceae, Cyatheaceae y Piperaceae was recorded. Meanwhile in the evergreen tropical forest, the vegetation included *Brosimum alicastrum*, *Quercus* spp., *Licania platypuss,* and *Manilkara zapota.*

Biocultural analysis

A field study was conducted during the rainy seasons from 2017 to 2021. A total of 291 non-structured, semi-structured, and structured interviews were carried by using the "snowball" technique (Sandoval, 2002). The following information was obtained from the conducted interviews: i) socio-demographic data disaggregated by gender, age, language, inhabitants per household, level of schooling, and economic activities; ii) known wild fungi, including information about their usages, local naming, local classification, ecology, morphology and their conceptualization of a fungus; iii) transmission mechanisms of mycological knowledge; iv) methods for mushroom picking; v) traditional culinary use; vi) mushroom poisoning; and vii) relationship among fungi and wild fauna. All mentioned fungi in the interviews were inventoried according to the methods proposed by Ruan et al. (2004), Garibay et al. (2006), Burrola et al. (2012) and Domínguez et al. (2015). The method consisted in recording all the traditional names in Mazatec language of the organisms that the interviewees consider to be mushrooms. Along with the names, drawings and verbal detailed descriptions were requested to the interviewees; and when necessary mushroom photographs were used. Finally, the identity of the species was confirmed with fresh samples collected in the field for all species. In order to select the people to be interviewed, two techniques were used: i) "snowball", which consists of identifying people with deep traditional ethnomycological knowledge; afterward asking to this people if they knew other people which also had broad mycological knowledge; then we contacted this new people (Sandoval, 2002), and ii) randomly within the study community, knocking from door to door, assuming that knowledge related to the mycological resource in the community was widely distributed. To recognize the taxonomic identity of the fungi mentioned in the interviews, the methodology proposed by Garibay et al. (2006) and Burrola et al. (2012) was used, which consists of using picture sets of fungi from the region and also to gather fresh specimens along with the local expert people from the studied community.

To establish an importance score for the wild mushrooms used by the community inhabitants, we used the *Frequency of Mention Index* proposed by Garibay et al. (2007) which was directly obtained from the free list of fungi known in each of the interviews. Mention Index (MI) was obtained by dividing the number of mentions of a fungus by the number of informants and multiplying this number by 10. The frequency of mention (FM) was obtained by dividing the number of total mentions of a fungus by the number of informants.

Additionally, fresh specimens were collected with the collaboration and expertise of local inhabitants or were purchased at the local markets of the studied region. Collected mushrooms were photographed and their macro- and micromorphological features were described. Taxonomic identification was performed by using specific literature (Anderson & Ullrich, 1979; Largent et al., 1980; Guzmán, 1983; Torres et al., 2015; Herrera et al., 2018; Fang et al., 2021; Rodríguez et al., 2022). The scientific nomenclature of specimens was based on *Index Fungorum* (http://www.indexfungorum.org). Dehydrated labelled specimens were deposited in the Mycological Collection of the Microbiology Area of the Postgraduate College (COLPOS) in Montecillo, State of Mexico. Mazatec language writing and its translation was carried out with the support of local translators and specialized dictionaries of the linguistic variant of Eloxochitlán de Flores Magón (Cházarez, 2012; Avendaño & Agee, 2013; Avendaño et al., 2013).

Results

In the present study, 291 interviews of persons from different dwellings were conducted, which constitute a sample of 30% of the total population in the study community. In the 291 dwellings considered in the study, 1,271 persons reside. The average number of inhabitants per house was 4 ±2.33, with the minimum number of inhabitants being one and the maximum 14. Of the total number of interviewed people, 55% were women and 45% were men. The average age was 48 and 50 years for women and men, respectively. The minimum age was 15 years old, whereas the maximum age was 92 years old. Interviewed people showed low educational level: 57% did not attend elementary school or dropped it out, 25% concluded elementary school, 13% concluded middle school and 5% attended any educational level higher than middle school. All of the interviewees spoke Mazatec, of which 89% were bilingual i.e., Spanish and Mazatec speakers, and 11% were only Mazatec speakers. Additionally, we identified that in the central area of the community an eroding process of the

Figure 2. Fungi with biocultural importance. a) *Daldinia* sp. b) *Auricularia nigricans* and *Armillaria mellea*. c) "Honguera" (mushroom gatherer) and granddaughter cleaning mushrooms in order to cook them. d) Mushrooms of the genus *Cantharellus* known as *tjiin ítá*. e) *Pleurotus* spp. f) *Clavulinopsis fusiformis*, called mouse "milpa" (*jnǫ nisen*) or lizard "milpa" (*jnǫ tsálá*). g) Example of good practice of transporting edible wild mushrooms using leaves and allowing spore dispersal. h) Collection of *Pleurotus* spp. in a plastic bag.

original language is occurring at accelerated rates, compared to the peripherical zones which are surrounded by primary vegetation.

Eighty-two percent of the women dedicate most of their time to household tasks, but depending on the time of the year, they undertake additional activities, such as removing wild plants from the milpa (referred to as a Mesoamerican agroecosystem of food production whose main crops are corn [*Zea mays*], beans [*Phaseolus vulgaris*] and pumpkins [Cucurbitaceae family]), corn or coffee harvest. Meanwhile, 93% of men are mainly dedicated to agricultural activities and occasionally to construction activities. And only 18% and 7% of the interviewed women and men, respectively, work in other activities not related to the agriculture, including for example merchants or professional jobs. All the interviewed people declared consuming wild mushrooms, 84% collect them, and 16% buy them when they are offered directly at their houses or in the local markets. These results demonstrate a high degree of mycophilia among the local population.

Traditional knowledge

Twenty-seven species of wild fungi with biocultural relevance were collected and identified within the study community (Table 1), of which 18 are edible, five have medicinal usages, and five are used for ludic purposes (one of the species has two different uses). The name to identify fungal species is the word "*tjiin",* which means "mushroom" (or "thick") followed by an adjective or noun. Fungal species are classified into three groups according to their attributed use: i) edible species are named *tjiin ra ma chine,* or "mushrooms that can be eaten", ii) medicinal species are called *tjiin ra ma xkii*, which literally means mushrooms that "make you feel good", "make you feel warm inside" or "medicinal mushrooms", and iii) species that do not have any particular relevance are named *tjiin ra siskajinná* or *tjiin ska*, which literally means "mushrooms that drive you crazy" or "crazy fungi".

The fungal species mentioned by the interviewed people are classified into six ethnotaxons that correspond to:

i) white fungi (*tjiin chroba*) including *Pleurotus* spp. and *Hydnopolyporus fimbriatus,* ii) ear fungi (*tjiin chiká*) including *Auricularia* spp.; iii) oak fungi (*tjiin itá*) including *Cantharellus* spp. and *Laetiporus sulphureus*; iv) medicinal mushrooms (*tjiin xkii*) including *Psilocybe* spp. and *Panaeolus cyanescens;* v) "hard texture fungi" (*tjiin tája*) including *Ganoderma* spp., *H. fimbriatus* and *Lentinus crinitus*; and vi) dust fungi (*tjiin chijo*) including *Geastrum lageniforme* and *Calvatia cyathiformis*.

The importance of mushrooms for the community inhabitants lies in their edible value. A significant percentage of people (42%) mentioned that mushrooms are a better food than meat or any other food; some others mentioned that mushrooms have a good taste (25%), others did not provide any answer (23%), few mentioned their medicinal usages (6%) and very few (4%) said that mushrooms were beneficial to the earth and nature, or that they were not relevant. Among community inhabitants, mushrooms are conceptualized differently; 42% consider that mushrooms are plants, even when Mazatec language distinguishes plants from mushrooms and has different words for each of them; 19% ignore what a mushroom is, and did not provide an answer to this question; and 9% define a mushroom as "…*something that emerges from the forest tree trunks, being the trunk itself that takes that form…".* Interestingly 26% of interviewed people conceive fungi with some fascinating interpretations for example as: "… *the juice or the soul of the trees", "a juice coming from the earth", "something that is born from a root or plant", "an animal", "a medication", "a putrid stick", "dry leaves", "bugs", "the hard outer covering of the trees that turns into a mushroom", "something that came from an animal", "a decomposer plant (because is something that decay dead trees)", "something that came from the heart of the trees", "a pest from the trees that grow in there", "something that came from mother earth", "butterflies debris that turns into mushrooms", "plants which are from the family of lichens", "a seed", "manna (an edible food that God sent to the Israelites according to Christian people)", "soul in purgatory (according to Catholic religion, it refers to the souls of the dead who are in purgatory)" and "a kind of orchid".*

The traditional knowledge used to identify wild edible mushrooms is transmitted by oral tradition from adults to children (Fig. 2c). As well, the exchange of mycological knowledge is a bidirectional process that takes place when a new nuclear family (created when new members are added to a family, either from community members or people from other cultures) is created. Knowledge transfer includes identification of the type of substrate where a specific mushroom grows, vegetation types where some mushrooms can be found, forest mushroom species with high biocultural importance, seasonality, and traditional names. In addition, people use to communicate some procedures to identify if a wild mushroom is edible, such as tasting a small mushroom fragment and if it has an unpleasant or peppery (spicy) taste, then it is not edible. A small proportion of interviewed people (2%) recommend rubbing a piece of garlic on the fungus and if it turns black, it demonstrates that is not an edible mushroom. However, is important to note that this last procedure is not scientifically accurate and might cause either gastrointestinal mycetism or be lethal.

Wild mushrooms are picked up in nearby forests and sometimes also in coffee plantations. When the collection of wild edible mushrooms is abundant, and they are not used for sale, people use to give a small amount of them to their relatives or neighbors as a gift which strengthens the social relationships among the community members. Regarding picking practices, 56% of interviewees use techniques that promote the fructification of sporomes in subsequent years. These techniques consist of picking mature specimens and leaving part of the stipe on the ground, preventing mycelium disturbance. Conversely, a smaller number of people use inadequate harvesting practices that may impact the presence of sporomes in subsequent years. These practices include pulling sporomes out from the stipe base, thus carrying the soil and the mycelium with them. Another relevant aspect that may affect the sporome fructification in subsequent years is their transportation method. People prefer transporting wild mushrooms using broad leaves or traditional hampers called "chitates" (*inchjro*). This transport method is an appropriate harvesting practice because it promotes spore dispersion (Fig. 2g). However, wild mushrooms are sometimes also carried out in plastic bags or buckets, that prevent sporome spore dispersal (Fig. 2h).

We were informed of 24 cases of mycetism during the interviews. Three of these cases were lethal. Regarding non-lethal poisoning cases (21), the symptoms were vomiting, stomach pain, rash, hallucinations, and gastroenteritis. Unfortunately, it was not possible to identify the species of fungi responsible for the poisoning because inhabitants only describe and know the fungus colour and, sometimes, the substrate where they grew. The oldest mycetism case among community inhabitants recorded in the interviews dates back to 1970. The interview said, "*My granny loved to eat wild mushrooms! One day, she went out looking… and saw some that looked tasty to eat. My mom told her that those mushrooms might hurt her because they did not look good to be eaten. My granny ignored her and prepared them as Tjiin chroba. She ate all of them herself. In the late afternoon, she was complaining of stomach pain and vomiting, but she recovered the next day. I think she removed all the bad stuff when she vomited. My mom scolded her and told her not to eat wild mushrooms carelessly".* The most recent mycetism case occurred in 2016 when a person, following the advice of someone, collected white wild mushrooms and ate them with the family. As a consequence of the poisoning, the family restricted their wild mushroom consumption to *Cantharellus* spp. and *Pleurotus* sp. Nowadays, the parent is the only person who

Figure 3. Examples of mycogastronomy of Eloxochitlán de Flores Magón, Oaxaca. a) "Tesmole" prepared with *Pleurotus* spp., b) *Auricularia tremellosa* with *Piper auritum* (known locally as "saint herb"); c) Toasted *Schizophyllum commune* and *Schizophyllum radiatum* with native maize and spaghetti; d) *Cantharellus* spp. with tomato sauce and onions; e) Roasted *Daldinia* sp.; f) "Tacos" with boiled *Schizophyllum commune* and *Schizophyllum radiatum*.

consumes *Pleurotus* sp. after a detailed inspection of the sporomes.

Mention index

According to the MI, the most important mushroom species for the inhabitants are *Pleurotus* spp. (MI=9.73) *Auricularia* spp. (MI=9.42), *S. commune* (MI=8.66) and *S. radiatum* (MI=8.66). The species with the lower MI correspond to *P. albidus* (MI=0.65) and *C.* aff. *confluens* (MI=0.62). Meanwhile, the most mentioned species for ludic use was *A. nigricans* (MI=2.03), whereas *G. lageniforme* obtained the lowest mentions (MI=0.10). *P. cubensis* (MI=8.11) was the most important species for medicinal purposes, because it is frequently used in ceremonies whose purpose is to heal people. *P. cyanescens* and *P. yungensis* (MI=0.03) showed the lowest MI. It is considered that *P. cyanescens* use is rare because it was only mentioned during one field trip accompanied by an "honguera" (name given in Spanish to women who gather wild mushrooms). *P. yungensis* is currently used only scarcely and one of the reasons is because it is considered necessary to use many sporomes to have an entheogenic effect. Additionally, this species is included in a single ethnotaxa together with *P. mexicana*, hindering the differentiation among them.

Edible mushrooms

There is a wide variety of culinary uses for wild mushrooms in the community of study. The dishes and their preparation are:

i) "Tesmole" a typical dish of the region (Fig. 3a), which is prepared using nixtamalized dough, achiote seeds (*Bixa orellana* L.), garlic (*Allium sativum* L.), onion (*A. cepa* L.), tomato (*Solanum lycopersicum* L.), and chilli (*Capsicum* spp.). Some people prefer not to use garlic and

Table 2. Prices of wild mushrooms consumed in the Mazatec community of Eloxochitlán de Flores Magón, Oaxaca.

Taxa	Mazatec name	Measurement unit	Price (USD$)	
			Minimum	Maximum[3]
Pleurotus spp.	*Tjiin chroba*	Jícara[1]	0.50	1.25
Pleurotus spp.	*Tjiin chroba*	kg	3.00	u
Schizophyllum spp.	*Tjiin nise*	Jícara	0.50	1.00
Ustilago maydis	*Tohíjé*	Piece	0.50	1.25
Armillaria mellea	*Tjiin tsjín*	Jícara	0.75	u
Laetiporus sulphureus	*Tjiin akoon*	Jícara	0.50	1.50
Auricularia tremellosa	*Tjiin chíká*	Jícara	1.00	u
Cantharellus cibarius s.l.	*Tjiin inì*	Jícara	0.75	1.50
Cantharellus aff. *confluens*	*Tjiin itá siné*	Jícara	1.00	u
Cantharellus aff. *violaceovinosus*	*Tjiin chji'ndi*	Jícara	0.50	u
Psilocybe caerulescens	*Tjiin kixó*	10 pieces	30.00	u
		Piece	0.25[2]	u
Psilocybe cubensis	*Tjiin nanguii*	Jícara	2.50	5.0
		Piece	0.25[2]	u
		Pair	1.75	u
		Pair (small sporomes)	2.50	u
		Pair (large sporomes)	7.50	u
		Four pairs	2.50	u
		Five pairs	5.00	u

[1] Jícara: local measurement equivalent to around one kilogram. [2] since 30 years ago. [3] u: unrecorded.

onion because they believe that mushrooms lose their flavor when these ingredients are added. Wild mushrooms used to prepare tesmole are *Pleurotus* spp. and *Cantharellus* spp.;

ii) Roasted mushrooms with "hoja santa" (*Piper auritum* K.) are prepared when the amount of collected mushrooms is limited. This dish is prepared by placing a base of "platanillo" leaves (*Heliconia* sp.) and then a base of "hoja santa" leaves. Subsequently, mushrooms, sliced onion, chilli and salt are added. Finally, all the ingredients are sprinkled with water, wrapped using the leaves and placed directly on the coals or on the griddle (Fig. 3b);

iii) Roasted mushrooms with salt (Fig. 3c) are prepared using *S. commune.* The mushrooms are soaked in salted water for 15 min and dripped out. Finally, they are roasted directly on the griddle;

iv) Mexican-style mushrooms (Fig. 3d) are prepared using garlic, onion, tomato and chilli. The mushrooms more frequently used to prepare this dish are *Pleurotus* spp. and the three species of *Cantharellus;*

v) Mushroom "tacos" are prepared by placing cooked mushrooms ("tesmole", roasted mushrooms or Mexican-style mushrooms) on a "tortilla" made from corn;

vi) Roasted mushrooms sprinkled with some salt (Fig. 3e). Collected mushrooms are cooked directly on the griddle and seasoned with salt. The species commonly used to prepare this dish are *Daldinia* sp., *L. crinitus*, and *Schizophyllum* spp., and

vii) Mushroom "tamales" are cooked using nixtamalized dough mixed with pig lard, and stuffed with "tesmole", Mexican-style mushrooms or *U. maydis*. If *U. maydis* is used, it must be previously cooked with garlic, onion and chilli. All the ingredients are wrapped using corn leaves or platanillo leaves and steamed in a pot.

According to the information provided by the interviewers, *Daldinia* sp., *A. tremellosa* and *A. nigricans* are species that can be eaten raw. *Pleurotus* spp. and *A. tremellosa* can be consumed if they are previously tanned with salt. The preparation consists in wrapping the mushrooms using "hoja santa". Although *A. nigricans* is an edible species, only a small group of people consume it. Many interviewed people recognized it but did not consume it. Some others consider it non-edible.

Ludic uses

Ludic uses of wild mushrooms are diverse and not restricted to children, adults also play with mushrooms. Children used to play with *A. nigricans* by placing them behind their ears to make them resemble those of an animal. Chil-

dren and adults used to play with *G. lageniforme* and *C. cyathiformis* sporomes. The mushroom *G. lageniforme* is squeezed using the fingers or a small stick to see the spores come out. Ludic uses of *C. cyathiformis* depend on its maturity stages. Mature specimens are kicked or thrown to see the spores come out. As immature specimens resemble a cake, children use the mushroom to play as if they were cookers and they are slicing a cake. *G. zonatum* is a fungus that can be easily recognized in the forest due to its large size and abundance. It was mentioned during the interviews on several occasions but it was interesting that one person mentioned its use as an ornamental species in the garden.

Medicinal uses

The species used for medicinal purposes are *P. cubensis*, *P. caerulescens, P. cyanescens, P. mexicana* and *P. yungensis*. Among medicinal mushrooms, interviewees mentioned that small amounts of *P. caerulescens* produce very strong effects, in terms of hallucinations or "dreams". These mushrooms are consumed in a ceremony where some rituals are performed. These rituals are a syncretism between pre-Hispanic and Catholic cosmogonies. Before and after the ceremony, it is necessary to have certain kinds of self-care or to follow some specific recommendations for all family members. The ceremony is always performed at night. People who consume mushrooms consider them sacred and have a deep feeling of great respect and love for them. Sacred mushrooms are used for healing, to seek an answer to a better destiny, and to heal spiritually, emotionally or mentally. Medicinal mushrooms are also used to identify people who, through a strong feeling of envy toward another person, harm someone (cursing or wishing the worst to a person). The interviewed people mentioned that when they are having harsh times in their lives, they go with a local chaman in order to know if somebody is responsible for this. Then, they participate in a sacred ceremony where they consume the medicinal mushrooms and they experience clear visions where they are able to literally see the people who is trying to damage them. Some people even mentioned that they have to have an "spiritual fight" with this people during the ceremony in order to stop originating them some damage in their lives. Recreational uses for the genus *Psilocybe* were not reported by the interviewed people, who by the opposite expressed a deep respect for the sacred mushrooms.

Beliefs and costumes related to wild mushrooms

As an element of Mazatec cosmovision, there are customs and beliefs related to wild mushrooms. These beliefs associate various aspects of people's lives and the surrounding environment to wild mushrooms. Some beliefs relate mushroom abundance to different events. A fructification and abundance indicator for *Pleurotus* species is the moon. People think when the moon is visible during the day or when there is a crescent moon or full moon, the genus *Pleurotus* will fruit more abundantly (Fig. 2e). Events such as lightning in a rain or storm are associated with the fructification of the genera *Pleurotus* and *Psilocybe.* Regarding to climatic conditions, *L. sulphureus* is used as an indicator (bioindicator) of a colder winter. Some people believe that their presence or actions may influence the growth of wild mushrooms. When someone finds an immature edible mushroom, they usually pull their earlobe. It is believed that this action will allow the fungus to grow and reach its maturity stage; otherwise, the fungus will pass directly into a decomposing stage without reaching its maturity. Some interviewees mentioned that having sexual intercourse the day they consumed wild mushrooms or cooking the mushrooms with oil will affect the fructification or abundance of wild mushrooms in future times, especially for *Pleurotus* spp. Other beliefs are based on the idea that wild mushrooms may exert an influence on people's actions when consumed. There are some beliefs regarding *Daldinia* sp. (Fig. 2a), it is believed that people who consume large amounts of this fungus may lose their teeth. Some others believe that children born from women who consume large amounts of *Daldinia* sp. will cry a lot during their childhood. The crying of children is attributed to the noise produced by these mushrooms when cooking. However, people mentioned that crying children can be calmed by feeding them the same fungus. Finally, people believe that the possibility of encountering snakes (Suborder Serpents) instead of wild mushrooms is increased if a person exclusively decides to gather mushrooms or if a person points out that the taste of mushrooms is like eating meat. Specific phrases referring to the fungus as meat such as "this meat is delicious!" or "today we are going to eat meat" are considered an important factor that increases the finding of snakes. Additionally, some persons mentioned that *C. cibarius* s.l. is guarded by snakes. Some inhabitants used to tell a short legend about *C. fusiformis,* which is a non-edible fungus. This fungus is known as *jno tsálá* or *jno nisen* in the Mazatec language which means lizard "milpa" or mouse "milpa" (Fig. 2f). The legend mentions that lizards (suborder Lacertilia) or mice (*Mus* spp.) come out of their burrow to till the land and cultivate its own "milpa". In this case, the crop refers to the mushroom. The mice use to have their milpas on the ground and lizard on the stones. This legend, and beliefs, show the complex links and relevance of mushrooms in the cosmogony of Mazatec culture consequence of centuries of interactions between fungi and people.

Local knowledge related to mycophagy by animals

Forty-one per cent of interviewed people mentioned that they know that animals eat mushrooms. Mentions include mammals, insects, insect larvae, birds and reptiles. A total of

18 different species were identified. According to the (MI), the animals that use to eat mushrooms are larvae of different animals, colloquially known as "worms" (MI=1.55), reptiles of the Suborder Serpents (MI==1.17), birds (MI=0.65), armadillos (MI=3.34), fruit fly (MI=0.34), squirrels (MI=0.27), rodents (Cricetidae MI=0.21), tepezcuintle (*Cuniculus paca*, MI=0.17), Tlacuache (opossum, *Didelphis* sp., MI=0.14), slugs (Trigonochlamydidae, MI=0.07), raccoons (MI=0.07), skunks (*Conepatus* sp., MI=0.07), badgers (*Meles* spp., MI=0.07), and ants (MI=0.07). The animals with the lowest MI were goats (MI=0.03) and brocket deers (*Mazama temama,* MI=0.03). Some inhabitants use rotted fungus to feed their hens or sometimes they use cooked mushrooms to feed their dogs. A person mentioned that his cat used to eat repeatedly certain mushrooms that caused drunkenness.

Sale of mushrooms with biocultural importance

Wild mushrooms are commercialized from house to house and in the local markets. Among interviewed people, 19.5% dedicate to commercializing wild mushrooms. The species with higher commercial demand is *Cantharellus* spp., but the most traded and abundant species belong to the *Pleurotus* genus. *A. mellea* is the least traded fungus. The mushrooms are sold in containers, used as a unit of measurement called "jícaras", whose approximate volume is one litre. Each "jícara" of mushrooms has a price of 10 to 30 Mexican pesos, equivalent to USD$0.50 to USD$1.50 (Table 2). It is important to record that the prices of wild mushrooms have not changed significantly in the last 30 years (except for medicinal or entheogenic mushrooms). Additionally, cultivated *Pleurotus* sp. is sold at a price of up to 60 Mexican pesos per kilogram, equivalent to USD$3.00. However, people mentioned that wild mushrooms are of better quality and more nutritious compared to those cultivated. The commercialization of medicinal mushrooms is varied. The prices and the units to measure the number of mushrooms are diverse. They are sold by "jícaras", pieces, sizes, in pairs or the enough amount to carry out a ritual ceremony, according to the species. The prices of medicinal mushrooms have varied significantly. For example, 30 years ago, the price for *P. cubensis* and *P. caerulescens* was 5 Mexican pesos, equivalent to USD$0.25. Nowadays, the price of these mushrooms varies according to their abundance, seasonality and vendor, but their average price is 600 Mexican pesos, equivalent to USD$30.00 (Table 2). Another major aspect of wild mushrooms trade is their commercialization by brokers or "coyotes". These people are dedicated to commercialize manly *Cantharellus* spp. and *Psilocybe* spp.

Discussion

In this study, the traditional mycological knowledge of Mazatec indigenous people is documented for the first time. Although the Mazatec culture is considered the cradle of ethnomycology, few studies address their use of fungi, different from those with entheogenic use (Wasson & Wasson, 1957; Heim & Wasson, 1958; Guzmán, 1983; Rodríguez, 2017). These studies are far from describing the traditional mycological knowledge linked to their ancient relationship between mushrooms and humans in the Mazatec culture, which forms an important part of its cosmogony.

Mazatec culture classifies and recognizes fungi as a different group from plants and animals, similarly than other Mexican indigenous groups. For example, Zapotecs refer to the mushrooms as *beshia* (Garibay, 2009), Mixtecs as *xi'i* (Hernández et al*.,* 2016), Otomies as *yujo* (Montoya et al*.,* 2019), and Chinantecs as *ní¨t* (López et al*.,* 2017*,* 2020). The conceptualization of what a mushroom is among Mazatec people recorded in the present research showed a wide range of perceptions linked to their known natural resources. In different Mesoamerican cultures a rich meaning of definitions of the mushrooms have been reported. For example, in the Otomí ethnic group they are considered as "… *meat produced by the forest in the rainy season* …" (Lara et al*.,* 2013). A distinct conceptualization that involves the origin of mushrooms belongs to the Lacandon ethnic group. According to their oral tradition, their deity *Hacha'kyum* gave rise to the mushrooms that grow on sticks or land and they serve as food (Ruan et al*.,* 2021). Furthermore, mushrooms are also perceived as divine, autonomous, possessors of feelings and even anthropomorphized by the Wixaritari people (Haro et al*.,* 2019).

Since the knowledge is transmitted by oral tradition, the language and the traditional names of the mushrooms are a factor that preserves mycological knowledge within the Mazatec community (Turner et al., 2000; Burrola et al., 2012; Ruan et al*.,* 2021). Mazatec people use to collect wild mushrooms by cutting carefully their stipe base, a practice similar to that used by other indigenous groups, e.g., the Otomi group of Ocoyacac municipality in the State of Mexico (Domínguez et al*.,* 2015).

In relation to mycetism, it has been widely documented that the ingestion of species in the genus *Psilocybe* affects the central nervous system (e.g., Pomilio et al*.,* 2019). However, the Mazatec consider the symptoms originated by the consumption of these mushroom species as something beneficial in the healing process. We have to recognize that this is an alternative world vision of the western vision of how the world is perceived. In contrast, accidental poisonings due to confusion with edible species have been documented in the Tzotzil ethnic group (Ruan, 2018).

Based on the MI, more than 50% of the people interviewed recognized *Pleurotus* spp., *Auricularia* spp. and *S. commune* as the most important species. This is similar to what happen with the Lacandón ethnic group, where the species of greatest cultural importance are *P. djamor*, *Favolus tenuiculus*, *S. commune*, *Auricularia* spp. and *Oude-*

mansiella canarii (Ruan et al*.,* 2006; Ruan et al*.,* 2021). *S. commune* is also reported as a species of biocultural importance in markets of the coastal plain of the Gulf of Mexico (Ruan et al*.,* 2004). On the contrary, for the Zapotec group of Ixtlán de Juárez in Oaxaca, the genus *Pleurotus* has a MI of 0.421, which places it as a poorly recognized group of mushrooms, compared to *Amanita* sect. *caesarea* complex with a MI of 9.263 (Garibay et al*.,* 2007). Similarly, in Amanalco, state of Mexico, *Pleurotus* sp. is not a popular species for the population, reporting FMs of 0.07, 0.08 and 0.13 (Burrola et al*.,* 2012).

The state of Oaxaca has a varied gastronomy in the ethnic groups who inhabit it. However, there are some common dishes among its different regions, and one of the most popular stews in this state is called "amarillo" or "tesmole". Mazatec people and other ethnic groups in Oaxaca prepare this stew. For example, in the Mixtec, Chinantec and Zapotec groups, *Hydnum repandum* s.l., *Cantharellus* spp., *Ramaria* spp., *Bovista* spp., *Agaricus campestris*, *Amanita* spp., among other species, are used in the preparation of this typical dish (Garibay et al*.,* 2007; Hernández et al*.,* 2016; López et al*.,* 2020).

Mushrooms with ludic use in different Mesoamerican cultural groups are a consequence of the ancestral interactions of human beings with their natural environment. For example, the fable referring to the growth of *C. fusiformis* as part of the "milpa" production system, shows the intricated and old relationships between humans, mushrooms and nature. The fable in this case is a type of literary genre used by the Mazatecs to express their perception of life and the description of the natural phenomena that surround them, as mentioned by Luna (2007). The use of *G. zonatum* as an ornamental piece among mazatecs, coincides with the similar use given to mushrooms of this genus by the Otomi people in Tlaxcala and Chinantec people in Santiago Comaltepec, Oaxaca (Montoya et al*.,* 2002; López et al*.,* 2020). In the municipality of Teapa, Tabasco, Mexico, people use *Auricularia* sp. as a toy, making cuts inside the basidiomata to make bags or balloons (Ruan et al*.,* 2004). On the other hand, in the Mixtec group of Santa Catarina Estetla, the use of mature stages of *Calvatia* sp. as balls for playing has been reported by Hernández et al*.* (2016).

In contrast to the current lack of knowledge of edible mushrooms among mazatec people, the ceremonial use of mushrooms of species belonging to the genus *Psilocybe* in this culture has been widely documented (Johnson, 1939; Wasson & Wasson, 1957; Guzmán, 2011, 2014; Rodríguez, 2017). In traditional Chinantec medicine, *P. yungensis* and *P. zapotecorum* are used to ask questions related to death, illness and when they are preserved in honey, one or two sporomes are usually consumed to recover energy (López et al*.,* 2020). In the Mixtec group in the state of Oaxaca, the use of entheogenic mushrooms has been documented in a codex written in the early XVIth century in Pre-Hispanic times. In the folios 24 and 25 of the Codex Vindobonensis Mexicanus I or Yuta Tnoho, a sacred ceremony is shown to be held among deities consuming entheogenic mushrooms before the first dawn (Hernández et al*.,* 2017). Other groups from the state of Oaxaca that use entheogenic mushrooms in traditional medicine are the Chatinos of San Juan Juquila and Yaitepec; the Mixes of San Juan Mazatlán, Santa María Coatlan and Santiago Zacatepec, and the Zapotecs of San Agustín Loxicha (Ramírez-Cruz et al*.,* 2006).

In Mexico, mycophagy of wild animals has been previously recorded, including for example squirrels and deers have been associated with the consumption of *Amanita* sect. *caesarea*, *Boletus edulis* s.l. and *Russula mexicana* (Hernández et al*.,* 2016). The Wixaritari and Mestizos of Villa Guerrero, Jalisco, Mexico, believe that mushrooms can be a source of food for humans and animals, although a wide variety of mushrooms eaten by animals may not be edible for humans (Haro et al*.,* 2019). For example, the Tsotsil group prefers not to consume edible mushrooms that have been bitten by an animal, since they consider that they can produce poisonings (Ruan, 2018). In the Mazatec culture there is a cosmogony that considers that if a snake is seen below a mushroom, it is a sign of the occurence of negative events, as it has also been considered by other Mesoamerican ethnic groups such as the Chinantec and Tsotzil cultures (López et al*.,* 2017; Ruan, 2018).

The development of sustainable strategies for collecting wild edible mushrooms, mycotourism in regions with high mycophilia such as the Mazatec region, the enhancement of local mycogastronomy, the cultivation of native species and the application of techniques to give added value to mushrooms represents a real alternative in the sustainable management of the forests of Mexico, which has not been used to date in the Mazatec culture despite its importance in rural sustainable development (Pérez-Moreno et al*.,* 2021a,b).

Conclusions

This study presents for the first time a formal ethnomycological study carried out from 2017 to 2021, using numerical ethnomycology, in the Mazatec culture, the cradle of ethnomycology. It presents an analysis which include species with edible, medicinal and ludic use. Previously, only the sociocultural importance and diversity of psychotropic mushrooms, mainly belonging to the *Psilocybe* genus, had been documented in this Mexican culture. Our study, highlight the biocultural importance of mushrooms by the interviewees, not only due to their entheogenic and medicinal use; but also as an important source of livelihood as a nutritious food, with higher quality than meat. Despite the enormous pressure of acculturation to which the Mazatec culture is currently exposed to, a remarkable mycophilia still survives. For example, all the people interviewed consume wild edible mushrooms. Through 291 interviews of native speakers of Mazatec, 27 mushroom species with biocultural im-

portance were identified. The species with the highest mention rate as food belonged to the genera *Pleurotus, Auricularia, Schizophyllum, Cantharellus* and *Daldinia*. *A. nigricans, G. lageniforme, C. cyathiformis*, *C. fusiformis, Pleurotus* spp. and *L. sulphureus* are important elements of the Mazatec cosmogony and are linked to local myths and fables. There is also a deep knowledge related to mycophagy carried out by mammals, insects, birds and reptiles in various species of local fungi that thrive in primary cloud forests and high evergreen forests, as well as secondary forests. This knowledge confirms the ancient complex interrelations between fungi, nature and society in the Mazatec culture. In addition, it was recorded a rich myco-gastronomy in the study region. It is important to strengthen local knowledge with local mycological workshops, mycological resource management strategies, and forest protection measures to preserve the ancient mycological knowledge and contribute to local sustainable development and food security.

Acknowledgments

The authors acknowledge the authorities of the municipality of Eloxochitlán de Flores Magón, Oaxaca for the permits and facilities provided. Likewise, the inhabitants and people interviewed are also acknowledged for their valuable participation, support and for sharing more than just their mycological traditional knowledge but their ancestral life cosmogony. Feliciano Cházarez Vargas, native speaker and reader-writer is thanked for his support in revision and correction of the writing of the Mazatec language.

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