

Proximate and Mineral Evaluation of Six Edible Wild Mushroom Species from the Nahuatl Region of the State of Mexico

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ABSTRACT

Objective: To evaluate the nutritional and mineral content of six species of edible wild mushrooms, from a Nahuatl region in the State of Mexico.

Design/methodology/approach: Standard analytical techniques were used to determine moisture content, partial dry matter, ash, crude protein, crude fat, and mineral composition of six edible wild mushroom species.

Results: The edible wild mushrooms exhibited high moisture content, ranging from 87.0% to 91.6%. The highest dry matter content was found in *Lyophyllum decastes*. *Hypomyces macrosporus* showed the highest ash content, with a value 2.22 times greater than that of *Lactarius deliciosus*. Regarding protein content, *Infundibulicybe gibba* had the highest percentage of crude protein among the species analyzed.

Limitations on study/implications: The production of sporomes of edible wild mushrooms is subject to environmental conditions, mainly rainfall.

Findings/conclusions: Edible wild mushrooms are a valuable source of nutrients and easily accessible to the Indigenous communities living in the forests of the State of Mexico. Additionally, there was a conspicuous nutritional variation among the different species studied.

Keywords: food, environment, forest, beneficial, ectomycorrhiza, fungi.

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INTRODUCTION

Wild mushrooms are an important forest resource and play several essential roles in forest ecosystems, such as decomposers, mycorrhiza formers, and pathogens. In addition, they serve as a food source (Mleczek *et al.*, 2021). Edible mushrooms have served as a food source for humans for over a thousand years (Jacinto-Acevedo *et al.*, 2021).

It is estimated that there are 2,189 species of edible wild mushrooms worldwide (Li *et al.*, 2021). Their commercial and culinary importance lies primarily in their organoleptic properties, such as aroma and flavor. In addition, they are rich in protein and fiber, contain essential amino acids, and have a low lipid content (Rugolo *et al.*,



2022). Many edible wild mushrooms have also been reported to contain significant amounts of minerals such as magnesium, calcium, sodium, iron, zinc, selenium, among others (Khumlianlal *et al.*, 2022). Mexico harbors a high diversity of wild mushroom species. The presence of temperate forests dominated by gymnosperms and angiosperms across the national territory supports the development of approximately 200,000 fungal species (Jiménez *et al.*, 2013). It is estimated that around 450 species are consumed and 350 are used in traditional medicine by the various Indigenous groups inhabiting the country (Perete & Velázquez, 2023). It is particularly evident that many Indigenous communities in Mexico possess extensive knowledge to distinguish edible mushrooms from toxic ones (Torres-Gómez *et al.*, 2023). Mexico ranks as the second country in the world with the greatest diversity of edible wild mushrooms, following China (Pérez-Moreno *et al.*, 2021). In addition to their consumption, gathering communities generate income by selling them in markets and local fairs (Molina-Castillo *et al.*, 2023). Several studies have shown that nutritional content and bioactive compounds may vary even among mushrooms of the same species (Jacinto-Acevedo *et al.*, 2021). The consumption of edible wild mushrooms has contributed to the well-being of various cultures since ancient times due to their high nutritional value (López-Hernández *et al.*, 2022). There are reports of wild mushroom commercialization in traditional markets such as the one located in Ozumba, State of Mexico, where at least 90 species are traded and designated with more than 100 local names (Pérez-Moreno *et al.*, 2018). The objective of this study was to evaluate the nutritional content through a proximal analysis of moisture, dry matter, protein, total fat, and mineral content in six species of edible wild mushrooms from a Nahuatl region in the State of Mexico.

MATERIALS AND METHODS

Study Site

The mushrooms were obtained from the local market in the municipality of Ozumba de Alzate, State of Mexico. The municipality of Ozumba is inhabited by an Indigenous ethnic group of Nahuatl origin. The mushrooms were identified based on key ethnomycological knowledge, and taxonomic identification techniques were also applied (Bautista-Bautista *et al.*, 2024).

Nutritional Content

Moisture and Dry Matter: Sixty grams of fresh mushrooms from each species were weighed in triplicate and placed in 120-milliliter vials. Subsequently, they were freeze-dried using a FreeZone 6 lyophilizer (Labconco®). Moisture loss was recorded. For dry matter determination, one gram of the lyophilized sample was weighed and placed in an oven (Feliza®) at 180 °C for 8 hours.

Total Ash Determination: This technique was performed using the incineration method (Gómez-Flores *et al.*, 2019).

Protein Determination: Crude protein was determined using the micro-Kjeldahl method (AOAC, 2005). The methodology followed was that described by Gómez-Flores *et al.* (2019).

Crude Fat Determination: Two grams of lyophilized sample were weighed and placed in a cellulose cartridge, which was then mounted in the Goldfish extraction device. Fat extraction was performed using 100 ml extraction flasks (Labconco®) containing 30 ml of petroleum ether (Meyer Cat. 1290-41®).

Mineral Analysis: Nitrogen (N) was determined by the semi-micro Kjeldahl method (Bremner, 1965). Total phosphorus (P) and potassium (K) were determined following the method described by Allen *et al.* (1997). Micronutrients were evaluated using the ammonium acetate extraction method combined with flame photometry.

Statistical Analysis

Values were calculated as the mean of triplicate samples for each mushroom species. The data for the evaluated variables were subjected to analysis of variance and the Shapiro-Wilk normality test. When the data sets did not meet the normality criteria, square root or logarithmic transformations were applied to allow subsequent mean comparison using Tukey's test ($p \leq 0.05$) with the Statistical Analysis System software, version 9.00 (SAS, 2004).

RESULTS AND DISCUSSION

Six edible wild mushrooms with high biocultural importance in the studied area were identified: *Lactarius* aff. *deliciosus* (L.) Sf. Gray, *Infundibulicybe gibba* (Pers.) Harmaja, *Lyophyllum decastes* (Fr.) Singer, *Hypomyces lactifluorum* (Schwein.) Tul. & C. Tul., *Hypomyces macrosporus* Seaver, and *Cantharellus cibarius* s.l. Singer (Figure 1, d, e). Common names were provided by the collectors and vendors at the market (Figure 1, a, b, c). The identified species were previously reported by Pérez-Moreno *et al.* (2009) in the study area, who analyzed 150 mushroom species commercialized in the markets of the Izta-Popo National Park region.

The dry matter content varied among the species, with *C. cibarius* presenting the highest total dry matter (Figure 2). In general, mushrooms contain approximately 90% moisture and 10% dry matter (Assemie & Abaya, 2022). Neh *et al.* (2021) reported a dry matter increase of 17.77% in *Polyporus dictyopus* Mont. and 12.69% in *Auricularia polytricha* (Mont.) Sacc., compared to average values. These differences were attributed by the authors to fluctuations in environmental factors during growth and storage, which affect mushroom metabolism. Srikram and Supavanich (2016) stated that differences in dry matter are mainly due to the mushroom species, climatic conditions, growth substrates, and geographical distribution.

The ash content varied among the different species, with *H. macrosporus* showing the highest percentage, 2.22 times greater than that of *L. deliciosus* (Table 1). Srikram and Supavanich (2016) reported low ash percentages in both wild and cultivated edible mushrooms, with contents ranging from 0.27% to 2.56% in *Russula cyanoxantha* (Schaeff.) Fr.

Protein percentages varied, with *I. gibba* showing a significant difference ($P=0.05$), containing up to 2.6 times more protein than *C. cibarius* (Table 1). Previous studies have reported varied protein percentages; Agrahar-Murugkar and Subbulakshmi (2005) reported that *Lactarius quieticolor* (Romagnesi) had the highest percentage at 27.5%. Gunasekara *et al.* (2021) mentioned that differences in protein content and percentage may be due to various



Figure 1. Wild mushrooms: mushroom vendor (a); commercialization of edible mushrooms at the Ozumba market, State of Mexico (b, c); *Hypomyces lactifluorum* (d); *Hypomyces macrosporus* (e).

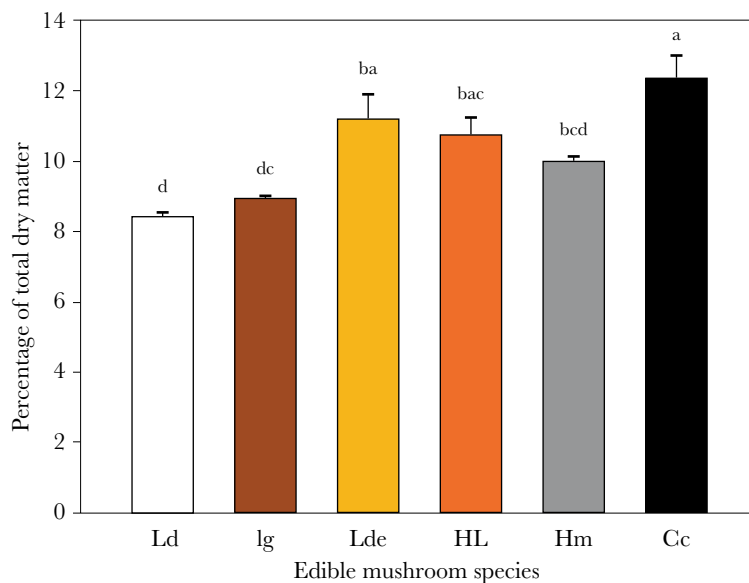


Figure 2. Total dry matter percentage of edible wild mushrooms. L=*Lactarius* aff. *deliciosus*, Ig=*Infundibulicybe gibba*, Ld=*Lyophyllum decastes*, Hi=*Hypomyces lactifluorum*, Hm=*Hypomyces macrosporus*, and C=*Cantharellus cibarius* s.l. Error bars represent the standard error of the mean (n=3). Means with different letters (a-d) above the bars are significantly different according to Tukey's test (P=0.05).

Table 1. Proximate composition of wild edible mushrooms.

	Ash (%)	Protein (%)	Total fat (%)
<i>L. deliciosus</i> (L)	4.77±0.03e	13.27±0.13b	1.49±0.13c
<i>I. gibba</i> (Ig)	6.45±0.01d	25.67±0.53a	3.57±0.07b
<i>L. decastes</i> (Ld)	9.64±0.01b	24.94±0.24a	6.19±0.27a
<i>H. lactifluorum</i> (Hl)	8.20±0.04c	13.08±0.23b	3.40±0.18b
<i>H. macrosporus</i> (Hm)	10.62±0.10a	14.46±0.44b	3.51±0.19b
<i>C. cibarius</i> (C)	9.59±0.16b	9.90±0.23c	2.75±0.05b

Values with the same letter in the same column are not significantly different according to Tukey's test ($P=0.05$). ±Standard error of the mean ($n=3$).

factors, such as intraspecific genetic variation and developmental stages. The protein fraction of wild edible mushrooms is characterized by significant concentrations of essential and non-essential amino acids. (Altaf *et al.*, 2020). The percentage of crude fat varied among the different species, with *L. decastes* presenting the highest fat content, showing significant differences ($P=0.05$), with up to 4.15 times more than *L. deliciosus* (Table 1). Gunasekara *et al.* (2021) reported wide ranges of crude fat percentages, with *Termitomyces* spp. recording a maximum value of 12.35%. The species *L. decastes* showed significant differences ($P=0.05$) in nitrogen (N) content, with 6.24%. The highest phosphorus (P) content was also recorded in *L. decastes*, with 8.88 g. Potassium (K) content ranged between 21.23 g and 9.34 g, with *C. cibarius* showing the highest K content (Table 2).

Table 2. Macronutrients in wild edible mushrooms.

	N (%)	P (g)	K (g)
<i>L. deliciosus</i> (L)	2.95±0.15b	2.72±0.67b	9.34±2.27b
<i>I. gibba</i> (Ig)	6.06±0.29a	7.97±0.09a	12.33±0.06b
<i>L. decastes</i> (Ld)	6.24±0.53a	8.88±0.24a	16.71±0.74ba
<i>H. lactifluorum</i> (Hl)	3.33±0.18b	3.58±0.04b	16.98±2.21ba
<i>H. macrosporus</i> (Hm)	3.05±0.03b	3.50±0.07b	17.46±2.53ba
<i>C. cibarius</i> (C)	2.35±0.11b	3.18±0.27b	21.23±1.99a

Values with the same letter in the same column are not significantly different according to Tukey's test ($P=0.05$). ± Standard error of the mean ($n=3$).

Table 3. Micronutrients in wild edible mushrooms.

	Ca (g)	Mg (g)	Cu (g)	Fe (g)
<i>L. deliciosus</i>	0.57±0.16b	0.74±0.18b	0.01±0.003d	0.04±0.011b
<i>I. gibba</i>	0.79±0.15ba	1.05±0.02ba	0.06±0.001ba	0.11±0.003a
<i>L. decastes</i>	0.65±0.02b	1.42±0.04a	0.05±0.002b	0.08±0.001ba
<i>H. lactifluorum</i>	1.17±0.11a	1.11±0.02ba	0.07±0.002a	0.09±0.021ba
<i>H. macrosporus</i>	0.55±0.06b	1.11±0.02ba	0.07±0.002a	0.10±0.008ba
<i>C. cibarius</i>	0.88±0.02ba	0.87±0.07b	0.04±0.004c	0.09±0.012ba

Values with the same letter in the same column are not significantly different according to Tukey's test ($P=0.05$). ± Standard error of the mean ($n=3$).

Fogarasi *et al.* (2020) reported that potassium is the element with the highest concentration in mushrooms. Neh *et al.* (2020) observed that wild mushrooms have high levels of phosphorus and potassium. Therefore, mushrooms are rich in mineral content and are an excellent source of minerals (Sifat *et al.*, 2020).

In this study, we report a high calcium (Ca) content in the fungus *H. lactifluorum* with 1.17 g. The highest magnesium (Mg) content was found in the species *L. decastes*. *H. lactifluorum* showed the greatest copper (Cu) content. We observed that the fungus *I. gibba* presented the highest concentration of iron (Fe). Krupodorova and Sevindik (2020) pointed out that mineral content can vary depending on the habitats where the fungi were collected. This study is one of the first to demonstrate the nutritional contribution of Mexican wild edible mushrooms to the diet of the people who consume them. The research shows that these mushrooms have a high mineral content, which contributes to the improvement of the diet and dietary diversification. Previously, it has been shown that wild mushrooms contain higher amounts of nutrients and minerals compared to cultivated mushrooms (Krupodorova and Sevindik, 2020).

CONCLUSIONS

The nutritional profile of the studied wild edible mushrooms was characterized by high protein concentrations, low fat levels, and interspecific variation in micronutrient composition. Dietary intake of these fungi provides significant nutrient supplementation to consumers, with heightened dietary relevance for ethnic populations utilizing them as traditional food sources. Consequently, they represent a nutritionally valuable non-timber forest product.

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