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Graduation Special Project

Identification of Wild Edible Mushrooms of Uyuca Biological Reserve with Productive Potential

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Abstract

Production systems to provide food for the population are mainly comprised of animal husbandry and vegetable crop production. On the other hand, edible mushrooms represent the future of food security and human development due to their high nutritional potential. Currently, there are many gaps with respect to wild species available as candidates for mushroom production in Honduras. The objective of this project is to document in an identification manual the wild edible mushroom species available at the Uyuca Biological Reserve and identify those with the greatest productive potential for commercialization with the evaluation of variables such as: peak fruiting months, months of appearance, protein content, shelf life, palatability, quantity of flesh, prices, and medicinal properties. Additionally, determine the ideal months for harvesting edible species in the reserve. The documentation and identification of the species was carried out by means of systematic transects of an area of 400 m^2 with photographs and the iNaturalist platform. Likewise, an extensive literature review of each species was carried out to obtain information on the different variables and protein tests were conducted based on dry mass using the Kjeldahl methodology. Finally, with the classification of each variable by means of scales based on Likert methodology, it was determined that the species *Cantharellus cibarius, Fistulina hepatica, Lactarius deliciosus, Lactarius indigo and Amanita jacksonii* have the greatest commercial potential. On the other hand, the months mainly marked by the seasonality of edible mushroom species are June and October.

Key words: Identification, manual, mushrooms, seasonality.

Resumen

Los sistemas productivos para proveer a la población de alimentos están conformados principalmente por la cría de animales y la producción de cultivos vegetales. Por otro lado, los hongos comestibles representan una excelente alternativa para impulsar la seguridad alimentaria y desarrollo humano por su alto potencial nutricional. Actualmente, hay muchos vacíos con respecto a especies silvestres disponibles como candidatas a la producción de setas en Honduras. El objetivo de este proyecto es documentar en un manual de identificación, las especies silvestres de hongos comestibles disponibles en la Reserva Biológica del Uyuca e identificar aquellas con mayor potencial productivo para la comercialización con la evaluación de variables como: meses de fructificación, presencia anual, contenido de proteína, vida anaquel, palatabilidad, cantidad de carne, precios y propiedades medicinales. Adicionalmente, determinar los meses ideales de recolección de especies comestibles en la reserva. La documentación de las especies se llevó a cabo por medio de transectos sistemáticos de un área de 400 m^2 con fotografías y se identificó con la plataforma "iNaturalist". Así mismo, se realizó una extensa revisión literaria de cada especie para obtener la información de las distintas variables y se condujeron pruebas de proteína a base de masa seca con la metodología Kjeldahl. Finalmente, con la clasificación de cada variable por medio de escalas basadas en la metodología Likert se determinó que las especies *Cantharellus cibarius, Fistulina hepatica, Lactarius deliciosus, Lactarius indigo* y *Amanita jacksonii* poseen mayor potencial comercial. Por otra parte, los meses principalmente marcados por la estacionalidad de especies de hongos comestibles son junio y octubre.

Palabras clave: Estacionalidad, hongos, identificación, manual

Introduction

Fungi are a crucial part of ecosystems; they provide balance and make nutrients in organic matter available for other organisms. In other words, they are nutrient recyclers. Some fungi have evolved symbiotic mycorrhizal relationships, that are helpful in agricultural applications that improve production. Others revolutionized medicine. For instance *Penicillium notatum* is responsible for saving millions of human lives (Nabors, 2011). Still, mushrooms often go unnoticed, despite their potential not just as food but as medicine or even for tourism. In other words, mushrooms represent potential for local and global development.

As the human population increases exponentially, satisfying food demand in the future becomes more challenging. The annual increment of land required to maintain demand for meat is the principal source of biodiversity loss on the planet. However, fungi constitute one important alternative by which protein can be supplemented. Mushrooms´ dry weight is significantly composed by protein. Okigbo and Nwatu (2015) showed that some respondents of Anambra State in Nigeria used edible mushrooms as meat substitute, to thicken soups, as well as for medicinal purposes. These are a good option not just for a population that doesn´t have access to meat, but for people interested in reducing the impact of meat consumption on the environment and climate. Mushroom cultivation provides access to protein for consumers with negligible land areas required for production. According to Poore and Nemecek (2018) the area of land required to produce a kilogram of beef is around 300 m^2 and for a kilogram of pork requires 15 m^2. Mushrooms, on the other hand, can yield 45 kg per m^2 of land (Celik & Peker, 2009).

As mentioned, some species are not only available for nutritional purposes but are of medical importance. *Trametes versicolor* is an edible mushroom that has generated great interest in research because of its immune activating bioactivity in association with fermented substrate (Benson et al., 2019).

Incorrect identification and subsequent consumption of mushrooms can lead to intoxication. Even though little research has been conducted to explore mushroom poisoning, there is evidence of a study which used a 21-year sample in Northern Italy. Through those years, 443 cases were discovered, 92% of these were affected by simple gastrointestinal toxicity and three pregnant women needed to be carefully observed and 20 were classified as severe. There was an outstanding patient whose liver required a transplant for consuming *Amanita phalloides* (Cervellin et al., 2018). Furthermore, according to Erenler et al. (2016) some other symptoms that could be linked with mushroom poisoning are hypertension, tachycardia and arrhythmia, which may be dangerous for people who suffer any type of heart disease.

Is not surprising that Mexico has strong cultural ties with fungi, since its forests have high diversity and abundance in the presence of ancient cultural traditions. According to Villareal and Pérez- Moreno J. (1989) there are 204 edible identified mushrooms species in Mexico. What is more, Perez-Moreno et al. (2018) mentioned that half of those are commercialized in local sales. People who sell mushrooms tend to take advantage of additional forest products such as medicinal plants and local fruits.

Guatemala is another country with cultural richness that maintains indigenous traditions. Mushrooms, as in Mexico, fulfill an important role in their indigenous culture. A study conducted by Bran et al. (2003) expanded the data base of edible mushroom species with 21 new registered with help of identification guides and lab tests, documenting presence of at least 70 edible species in the country. However, according to Morales et al. (2010) 83 edible mushrooms where identified in the region, and at least 30 species where consumed in Tecpán. In this research, species with the most economic importance were identified such as: *Boletus edulis* (USD 13.33 per pound), *Cantharellus cibarius* and *Craterellus lateritius* (USD 5.33 per pound), the group *Amanita caesarea*, and *A. garabitoana* (USD 2.67 per pound) on local markets. Other papers reference the connection between mushrooms and people with more detailed and less structured instruments of data gathering as present in Morales (2001) where the identification of these species is determined by macroscopic characteristics, mostly by color. In the same study, mushroom morphology is known by population in their native language which is kagchiquel.

Honduras also possesses culture related to mushrooms consumption. Nonetheless, the frequency and popularity of this diet varies regionally. One species commonly known as "choros" (*A. caesarea complex*) is commercialized and served in regions inhabited by Lenca people. Despite this, there is still a lot of ignorance around the identification of local mushrooms. A study conducted by Sarmiento and Fontecha (2013) surveyed 106 consumers and collectors of mushrooms in Intibucá and La Paz known for traditions of mushroom consumption. These individuals were shown 101 locally collected mushrooms and only identified eight as edible and 10 as inedible with the rest unknown. The same research revealed that most of intoxication deaths, 95%, were caused by the genus Amanita.

In fact, there is little information about mushrooms identification in Honduras. Identification practices are employed informally, and this skill is being lost through generations. An illustrated catalog is needed, to expand this knowledge and to remark on differences between species that may be difficult to determine for consumers. Having a formal document with local species identities may be helpful in further research about chemical properties and opportunities for cultural learning preservation and even the development of products related with medicine and food industry. Beyond just compiling a list of edible species, it is going to be seek individual properties and their potential for cultivation and commercialization.

The Main objective of this study is identifying edible mushrooms species with potential for propagation and commercialization in Uyuca Biological Reserve. There are three specific objectives: produce a catalog to identify wild edible species found on Uyuca, describe non-edible mushrooms species that share similarities with some edible individuals and remark on differences and finally, document seasonality of the species in question, palatability, percent of protein content, pharmaceutical properties.

Methods

Study Area

To collect a representative amount of data, periodic visits were made to Uyuca Biological Reserve. These visits cover June of 2022 to February of 2023. Observations were made primarily along existing trails emanating from the biological station. The reserve is located at 14 km North of Zamorano University main campus and at 15 km southwest to Tegucigalpa (Mora et al. 2013). The territory of the site is shared by two municipalities: San Antonio de Oriente, and Tatumbla, coordinates 87°04'56''W, 14°00'53''N y 87°03'49''W, 14°02'3''N. The buffer zone encompasses 1,300 to 1,700 masl, while the core zone 1,700 to 2,000 masl. The land is mountainous with abundant vegetation mostly broadleaf, pine and mixed forest.

Materials for Identification

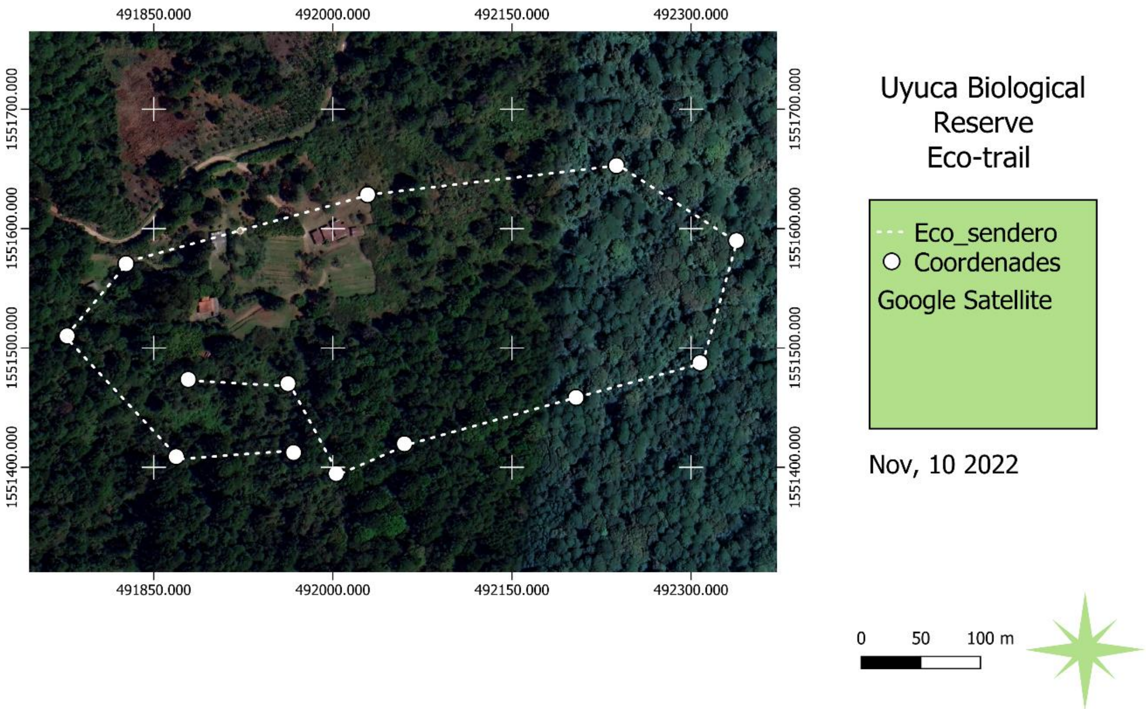
To document species, a camara was used to record different morphological characteristics. According to Laurie (2022) iNaturalist is a crowdsourced identification tool to share biodiversity as a common space of information. This platform also provided additional details once the species was labelled, such as seasonality, habitat, sometimes edibility or toxicity, its complete taxonomy, similar species and even history (frequency of observations of the species in the region).

Data Collection

To document all features of individuals, photographs were taken *in situ*. Photographs focused on features such as pileus and hymenium, which are decisive characteristics when determining the species. For the study, transects are used in a systematic way as shown in Figure 1. Randomization of transects was not conducted. With this method, reaching the data collection areas would be very difficult due to the irregular terrain. In addition, random transects would imply greater impact in the sensitive ecosystem with dense vegetation cover. These observations are documented by walking through existing trails of the reserve at a slow pace to be able to appreciate mushrooms on the ground, trees, and surroundings. The journey of the trail is shown in Figure 1.

Figure 1

Transects in Eco-trail, Uyuca Biological Reserve

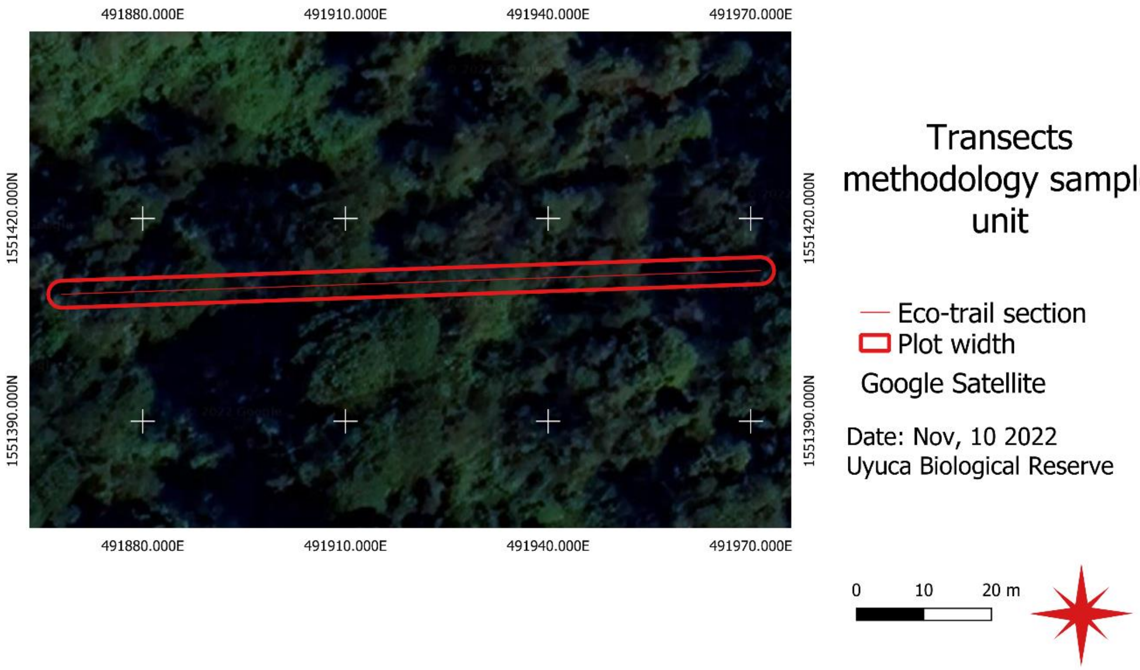


The length of transects was 100 m as shown in Figure 2. Shorter transects would be inefficient because of the reduced abundance of wild mushrooms at certain seasons. It is important to clarify that density and abundance of the fruiting bodies was not a variable studied in this research to find potentially edible species and assess their commercial potential. The length of transects was measured with "UTM Geo Map" app, marking several points in the route while walking. The primary purpose of the transect was to quantify length of the route and search effort. Subsequently, the marked points were inserted in the map of Figure 2 with QGis 3.16® program. After each photograph was taken, individuals were collected in a paper or cloth bag to preserve them as much as possible through the journey. Once trails are completed or return hour is reached, individuals collected in the bag are presented to Van Den Berghe, PhD., for preliminary identification and feedback of edible species he is familiar with. Individuals properly identified by this feedback were tasted to assess flavor.

Figure 2

Sample unit, transect of Eco-trail

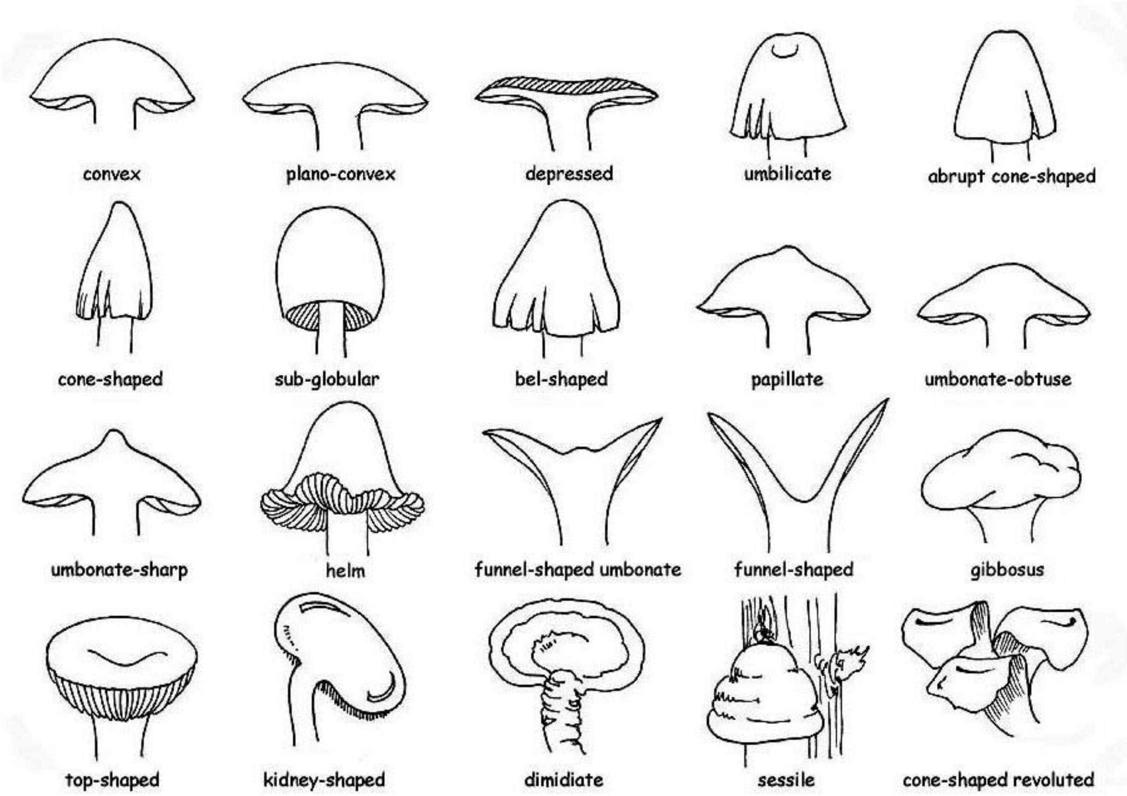
Main elements considered in identification besides pileus and hymenium were color, presence or absence of lamella, types of volva, fleshy or hollow foot, and consistency. There are



several shapes of pileus described in Figure 3. The presence of insects is a sign that can sometimes be used to determine edibility as well as bruise color as consequence of touching. Some mushrooms were tasted to be identified since some flavors are good indicators of its specie. However, no mushrooms were eaten until having a reliable identification.

Figure 3

Types of pileus in wild mushrooms (Pierluigi y Tullii, 2004)



Subsequently, all photos were uploaded to iNaturalist and with support of the community, mushrooms were identified. In parallel, literature is consulted to ensure the species are properly identified and to explore different properties that couldn´t be confirmed in situ. Once an identification is reached, an extensive and detailed literature review is conducted to describe additional characteristics of each species. In case of edibles that share similarities with non-edibles, they are mentioned to be aware of potential pitfalls and to exercise appropriate caution. For the literature review of each species included key words to search for different variables such as chemical composition, pharmaceutical properties, online prices, shelf life, protein content, edibility, toxicity, gastronomical significance, palatability, gourmet, culinary, etc.

Laboratory Analysis

Samples were collected for the laboratory; plastic bags were used to store dried samples of morphospecies. As mentioned, many mushrooms are delicate so special care was given to guarantee the flow of air and preservation. As shown in Figure 4, these were dehydrated using a food dehydrator for 24 h and stored to run tests on protein crude mass content.

Kjeldahl method was employed to determine crude mass protein content which functions based on organic nitrogen titration; this procedure reveals an approximate value of the protein richness of a food. The percentage of nitrogen is then multiplied by a conversion factor to protein. Before titration, it is necessary to dry the product according to AOAC 2001.11.

Figure 4

Samples before and after dehydration

Likert Scale Method

To determine candidate species for commercialization in Honduras considered different variables of every identified edible species which are:

Months of appearance (number of months with reports of the species divided by 12, the total of months in a year). As well as months of fruiting season (peaks on iNaturalist graphs per each species. These two variables were obtained with data base on the platform delimiting the area of Central America, as conditions in the region are similar. This geographical delimitation was established to be able to find tendencies.

Flesh quantity was described as scarce, moderate, or abundant based on qualified personal opinions´ related to gastronomical sciences. The same case is applied to palatability characteristics which determines the level of acceptancy based on the species´ flavor. Shelf life is an important characteristic if the main purpose of commercialization is based of fresh products. For this reason, it was considered during research. Crude dry mass protein content obtained by academic papers and conducted protein tests. Another variable that can give a clue about candidates is the availability of prices and online sales per kilogram. Last, but not least, the number of medicinal properties known under scientific evidence for each species. The more information available in this field, the greater the interest in the consumption of the mushroom.

All eight studied variables were required to be classified in the same format to determine candidates. This was accomplished by individual evaluation of each characteristic based of Likert scale. Numbers from 1 to 3 were associated to each variable to give a result, product of the sum of the evaluation of each characteristic. The five species with the best scores were determined as candidates for commercialization in Honduras. In this research, Likert method was a tool to evaluate the potential commercial development of these species related to studied variables.

The design of the assessment instrument was carried out under the basic concept of the instrument used by León-Carvajal during 2020 in research about community watershed stewardship. In addition, the rating scales were established based on vectorization by ranges evidenced in the literature and under the supervision of a professional with experience in the use of likert scales in research. Details of the applied values associated with the different ranges and qualitative characteristics can be found in the annex.

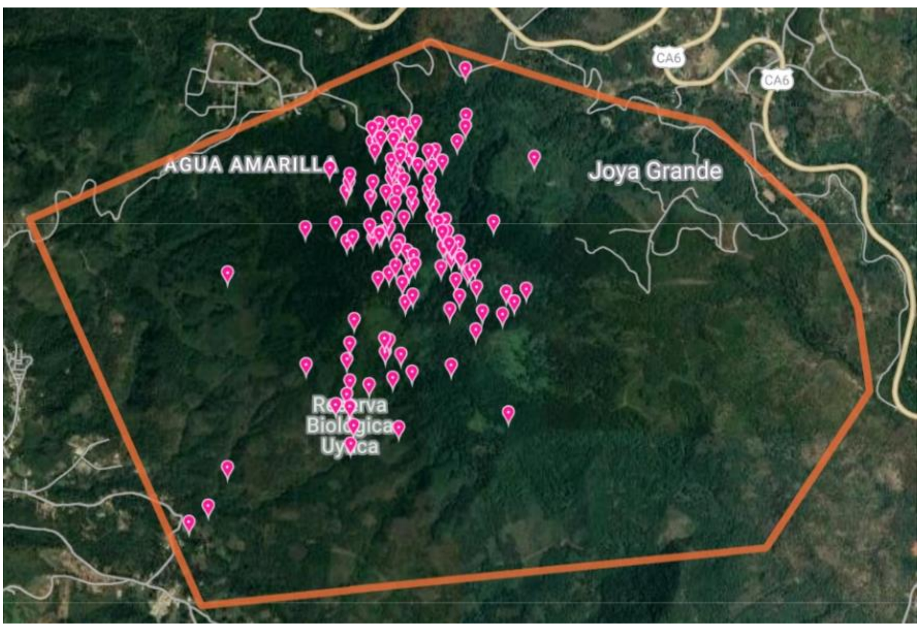
Study Design

The scope of the study is descriptive since it consists in collecting and detailing morphological characteristics of mushrooms with edible properties. No variables are controlled so it is non-experimental research. Descriptive statistics was applied to determine ideal months to look for and collect wild edible species, this information was based on seasonality references in iNaturalist. Standard Chao analysis are not appropriate for the purpose of the study since species completeness considers unknown areas of individuals in terms of edibility. An accumulation curve would include both edible and inedible species due to the lack of classified species in this category. This type of analysis would provide a significant margin of error and unreliable results.

For the analysis, existing data reports from iNaturalist was considered, which means community observations were included as part of the manual. The study is classified as longitudinal because data collected by other users and at different temporal contexts is contemplated. The spatial distribution of previously reported data can be seen in Figure 5.

Figure 5

Spatial distribution of Mushrooms observations in Uyuca Biological



Results & Discussion

Species Identification

Thirty-seven species of wild mushrooms in the Uyuca Biological Reserve have been identified and included. Of this number, 22 species were identified via field visits, while 15 species were added through existing reports in iNaturalist within the project "Reserva Biológica Uyuca" (Zamorano, Univ., Honduras).

It is worth noting that of these 37 species included in the manual, which can be seen in detail in the annexes 11 and 12, 32 are species with known edibility. On the other hand, three have unconfirmed edibility and two are toxic species that have been added because they have morphological characteristics that can be confused with edible species and their description is necessary to differentiate them.

During the identification of the fungi, important discoveries were made about the absence of certain species formerly believed to be present in the Central American region, such as the species *Amanita caesarea* and *Amanita phalloides*. For many years these names were mentioned in research that evidenced their availability in the forests of Mexico, Guatemala and even Honduras. However, these species were misidentified because of their similarities, and it was discovered that other fungi are found in the Central American region instead.

Species such as *Amanita haylyuy, Amanita jacksonii* and others are reported on "iNaturalist" as *Amanita caesarea section* since these have been confused with the original *A. caesarea* in the american region for years. Due to this, some research papers mention its supposed presence according to Castillo Godoy et al. (2019) in Honduras as well as in Guatemala according to Cáceres in 2011. According to a research, *Amanita phalloides* is present in Honduras and is the responsible for some intoxications. Nonetheless, there is not a single report of *A. phalloides* in Central America and with the help of community experts on iNaturalist it was determined that this species is only present in Europe (Castillo Godoy et al., 2019).

Kjeldahl Protein Content

Calculating the protein content of all the species found was not possible because analyzing all of them would have been far beyond the budget of this research. Because of this, the protein content of five species was analyzed in duplicate, except for one sample because there was not enough to collect 2 g. The rest of species protein content was obtained by consulting academic papers related to its chemical composition.

Several unidentified morphospecies were collected and dried for 24 h in a food dehydrator, the detail of its weight variation can be found on Table 1. Species dehydrated lost on average approximately 91% of their total weight. Then, six already identified species of interest were selected considering the proportion of sample available for testing.

Table 1

Weight reduction per species after 24 hours in the dehydrator

Specie	Fresh weight (lb)	Fresh weight (g)	Dry weight (g)	Difference (Fresh-dry)	% Dry weight/ fresh
Cantharellus cibarius	0.105	47.63	5.1	42.53	11%
Hydnum repandum	0.035	15.88	1.3	14.58	8%
Lactarius deliciosus	0.025	11.34	1	10.34	9%
Russula	0.045	20.41	2.88	17.53	14%
Amanita vaginata	0.085	38.56	3.06	35.50	8%
Morphospecies	1.37	621.42	36.75	584.67	6%
Pleurotus pulmonarius	0.975	442.25	36.51	405.74	8%

The procedure employed yielded values within the permitted ranges except for the acetanilide tubes, which is described in detail in Annex A. This may be due to various factors such as hydrochloric acid (HCl) concentration, equipment deterioration, boric acid (H_3BO_3) and Sodium hydroxide (NaOH) concentration. However, the possible key factor in these out-of-range values was the extensive time the prepared tubes spent at rest before being placed in the digestion process in the equipment, which amounted to a total of 29 days at rest. The reason for such extensive resting was the failure of the laboratory equipment and its repair. Despite this detail, the protein contents are a reliable clue to each species.

HCl concentration used for titration procedure was no 0.09 molar concentration, there was used for formula a factor of 6.25 to determine the result of protein content of each sample. The average of both results obtained per species was then calculated, apart from *H. repandum* since a duplicate was not performed in the procedure for this species, to obtain an approximate protein value for each species.

Values obtained from these tests showed to be very close in comparison with other papers, these values are shown in Table 2. For example, *Cantharellus cibarius* was found to have 20% in this *study compared* 21% protein (Karabi, 2017). The species *Hydnum repandum* had 27% of protein according to literature and got 25% with this procedure (Ertan, Ö. O. and Gulyavuz, H., 1993). *Lactarius deliciosus* had an aproximate result of 18% which is even higher than previously reported 17% (Xu et al., 2019). On the other hand, *Pleurotus ostreatus* protein has been evidenced to vary from 17 to 42% but resulted in 32% on the present study (Khan, 2010). Protein content of *Amanita subructilensens* and *Amanita vaginata* cannot be compared with other studies results since there is no a value reported for either species. There is more detailed information about HCL used during titration of each species in Annex B.

Table 2

Protein content according to dry mass.

Species	Weight g	Protein %
A. subructilensens	0.9325	42.91
A. vaginata	1.0004	23.56
C. cibarius	1.0017	19.64
H. repandum	0.9735	25.48
L. deliciosus	1.00155	17.70
P. ostreatus	1.00035	32.06

The statistics in relation to the protein content of the edible mushroom species identified in the Uyuca reserve showed an average value of 23.46% and a median of 22.81%. There is no value in the mode because there are no repetitions as witnessed in Table 3. There is a maximum value of protein content of 42.91% while the minimum value is 11%. There is a variance of 67.85, a standard deviation of 8.24 and a coefficient of variation of 0.23. All the previously mentioned values can be found in Annex E, pictures of the procedure followed for protein content determination are found on Annex F and G.

Table 3

Crude dry mass average protein content in wild edible mushroom species according to different sources

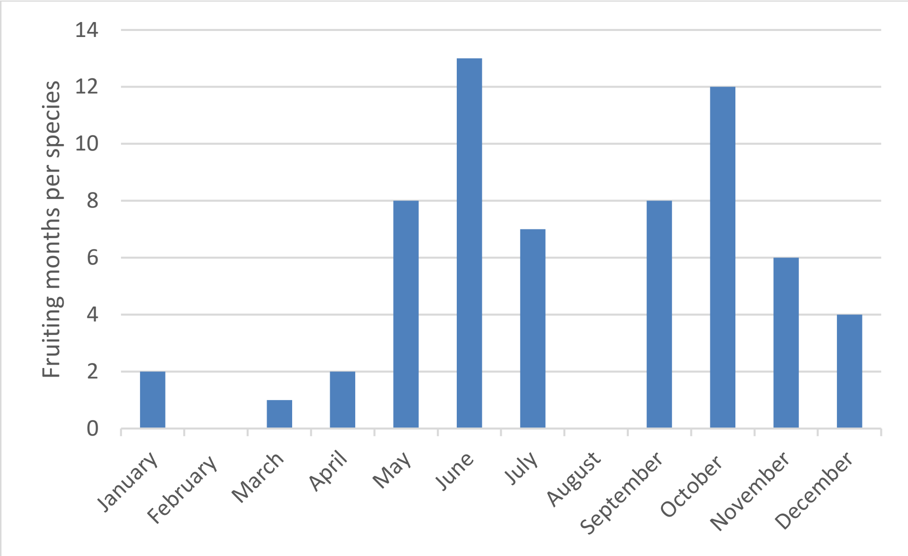
Species	Crude protein content %	Sources
Agaricus subrutilescens	42.91	Zamorano Laboratoty
Amanita jacksonii	27.45	(Román- Andrade, 2015)
Amanita vaginata	23.56	Zamorano Laboratoty
Cantharellus cibarius	24.04	Zamorano Laboratoty (Paraskevi, 2009) (Beluhan, 2011)
Cantharellus lateritius	21.92	(Karabi, 2017)
Favolus brasiliensis	27.00	(Silva-Neto et al., 2021)
Fistulina hepatica	22.05	(Manjula Rai et al., 2007) (Paraskevi, 2009)
Geastrum saccatum	37.05	(Guerra Dore et al., 2007)
Hydnum repandum	26.28	Zamorano Laboratoty (Ertan, Ö. O. and Gulyavuz, H., 1993)
Lactarius deliciosus	17.45	Zamorano Laboratoty (Xu et al., 2019)
Lactarius indigo	18.36	(Espejel- Sánchez et al., 2021) (León-Guzmán, 1997)
Laetiporus sulphureus	15.86	(Saha D, Sundriyal M, Sundriyal RC, 2014) (Petrovic, 2014) (Kovacs, 2015)
Pleurotus ostreatus	28.48	Zamorano Laboratoty (Beluhan 2011)
Pleurotus pulmonarius	17.00	(Khan MA, 2010)
Ramaria araiospora	11.00	(Ghosh et al., 2020)
Suillus granulatus	15.00	(Reis et al., 2014)

Months of Appearance and Peak Fruiting Months

Seasonality was determined thanks to the peaks represented in iNaturalist graphs that show trends in certain months of the year. These species-associated peaks are considered fruiting months when there is a higher probability of finding the species. Most of the wild edible mushroom species in Uyuca Biological Reserve are more likely to be found during June and October, which corresponds to the rainy season. On the other hand, mushroom peak fruiting months barely occur during January to April as seen in Figure 6, the same case corresponds to August. These months concur with low precipitation and humidity.

Figure 6

General seasonality of wild edible species found in Uyuca Biological Reserve



As described in Table 4, statistics showed an average of 1.84 (approximately 2 months) of fruiting per species. The median, the central value of fruiting months, is 2 months. While the mode, the most frequently repeated value, is 1 month. There is a minimum number of months of fructification of one and there are species in the reserve that have a maximum value of up to 4 months of fructification. There is a variance of 0.78, a standard variation of 0.88 and finally a coefficient of variance of 0.48. All these values can be seen in the table in Annex C.

In average wild edible species have two main months of fructification. However, there is a big variation in the number of fruiting months depending on the species. Some species such as *Amanita vaginata* and *Fistulina hepatica* in the wild produce fruiting bodies over a four-month season.

Table 4

Months with peak reports of each wild edible species found in Uyuca Biological Reserve

Species	Peak months of fruiting	*Species*	Peak months of fruiting
Agaricus subrutilescens	1	*Lactarius deliciosus*	3
Amanita hayalyuy	2	*Lactarius indigo*	4
Amanita jacksonii	3	*Lactfluus volemus*	1
Amanita vaginata	1	*Laetiporus sulphureus*	3
Aureoboletus betula	3	*Lycoperdon perlatum*	2
Boletus variipes	2	*Phylloporus leucomycelinus*	1
Cantharellus cibarius	1	*Pleurotus ostreatus*	1
Cantharellus lateritius	2	*Pleurotus pulmonarius*	2
Favolus brasiliensis	3	*Ramaria araiospora*	2
Fistulina hepatica	3	*Sparassis americana*	1
Geastrum saccatum	3	*Suillus granulatus*	2
Gymnopus dryophilus	1	*Tylopilus felleus*	2
Hydnum repandum	2	*Tylopilus leucomycelinus*	1
Hygrocybe coccinea	1	*Tylopilus rubrobrunneus*	1
Hygrocybe flavescens	1	*Xerocomellus chrysenteron*	1
Hygrocybe occidentalis	2	*Xerocomus subtomentosus*	2

Meanwhile fruiting peaks are months in which species reports soar, months of appearance considers the total of months in which a mushroom species is reported.

When it comes to months of appearance, in average, mushroom species available in the reserve are present during 4.63 months of every year. There is a median of four, the most repeated value among the sample is 1 month as described in Table 5. Some species may only be present during 1 month e.g. *H. repandum* in comparison with others like *Favolus brasiliensis* are reported in every month of the year. A variance of 11.08, a standard deviation of 3.33 months and a coefficient of variation of 0.72 were reported. All these values can be seen in detail in Annex D.

Table 5

Months of appearance of wild edible mushroom species

Species	Months of appearance	Species	Months of appearance
Agaricus subrutilescens	3	*Lactarius deliciosus*	6
Amanita hayalyuy	3	*Lactarius indigo*	12
Amanita jacksonii	6	*Lactfluus volemus*	1
Amanita vaginata	5	*Laetiporus sulphureus*	6
Aureoboletus betula	5	*Lycoperdon perlatum*	8
Boletus variipes	2	*Phylloporus leucomycelinus*	1
Cantharellus cibarius	1	*Pleurotus ostreatus*	5
Cantharellus lateritius	6	*Pleurotus pulmonarius*	9

Species	Months of appearance	Species	Months of appearance
Favolus brasiliensis	12	*Ramaria araiospora*	4
Fistulina hepatica	8	*Sparassis americana*	1
Geastrum saccatum	11	*Suillus granulatus*	2
Gymnopus dryophilus	7	*Tylopilus felleus*	4
Hydnum repandum	2	*Tylopilus leucomycelinus*	1
Hygrocybe coccinea	4	*Tylopilus rubrobrunneus*	1
Hygrocybe flavescens	7	Xerocomellus chrysenteron	1
Hygrocybe occidentalis	2	Xerocomus subtomentosus	2

Flesh Quantity

The size of the mushrooms is a relevant factor when selecting candidate species for cultivation. The nutritional value of mushrooms has a lot of potential, however, if a species is small sized it will complicate harvest even if large in number. Because of this, based on field visits and photographs found on the platform, exact and estimated values in centimeters were documented for the diameter of the pileus, the total length, and the type of flesh if it is considered thin or of a more robust nature. The above was useful in determining whether each species had scarce, moderate, or abundant flesh by means of assessment. The exact values of all species measured are found in Table 6.

Table 6

Flesh classifying parameters for wild edible species in Uyuca

Species	Pileus diameter (cm)	Length (cm)	Type
Agaricus subrutilescens	6.2	4.8	Robust
Amanita hayalyuy	10.2	10.9	Robust
Amanita jacksonii	9.7	10.1	Robust
Amanita vaginata	5.1	10.4	Thin
Aureoboletus betula	1.8	5.8	Robust
Boletus variipes	10.9	6.1	Robust
Cantharellus cibarius	4.3	7.4	Robust
Cantharellus lateritius	5.2	6.1	Robust
Favolus brasiliensis	8.9	3	Robust
Fistulina hepatica	8.5	0.5	Robust
Geastrum saccatum	2.6	1.6	Robust
Gymnopus dryophilus	3.5	4.1	Thin
Hydnum repandum	5	5.1	Thin
Hygrocybe coccinea	2.6	2.8	Thin
Hygrocybe flavescens	2.1	2.9	Thin
Hygrocybe occidentalis	2.9	3	Thin
Lactarius deliciosus	7.6	9.2	Robust
Lactarius indigo	8.1	8.3	Robust

Species	Pileus diameter (cm)	Length (cm)	Type
Lactfluus volemus	5.3	8.1	Robust
Laetiporus sulphureus	10.6	2.2	Robust
Lycoperdon perlatum	2.5	3.4	Robust
Phylloporus leucomycelinus	4.5	5.1	Thin
Pleurotus ostreatus	7.7	9.2	Robust
Pleurotus pulmonarius	6.5	7.3	Thin
Ramaria araiospora	3	4.2	Thin
Sparassis americana	6.2	7.8	Robust
Suillus granulatus	5.6	1.7	Robust
Tylopilus felleus	8.3	10.4	Robust
Tylopilus leucomycelinus	4.5	5.9	Robust
Tylopilus rubrobrunneus	5.6	6.7	Robust
Xerocomellus chrysenteron	6.5	5.3	Thin
Xerocomus subtomentosus	5.2	6.1	Robust

Palatability

For a food product to be in demand, its availability throughout the year, its nutritional contribution and even, for more specific consumers, its environmental impact, are key characteristics. However, a food cannot be expected to appeal to consumers if it is unpalatable. Therefore, palatability must be included in the evaluation. Reviews from food science professionals and other valid sources were used as a reference to gather this information for as many species as possible as shown in Table 7. A sensory evaluation was not possible for species reported on the platform but not found during the present study.

Table 7

Palatability references per species

Species	Palatability/Quality	Sources
Agaricus subrutilescens	Good	(Wood & Stevens, 2020)
Amanita hayalyuy	Excellent	(Cáceres, 2011)
Amanita jacksonii	Excellent	(Cáceres, 2011)
Aureoboletus betula	Excellent	(McHugh, 2023)
Boletus variipes	Excellent	(Alonso-Aguilar et al., 2014)
Cantharellus cibarius	Excellent	(Bergo, 2012)(Henderson, 2020)
Cantharellus lateritius	Good	(Bergo, 2012)
Fistulina hepatica	Good	(Bergo, 2017)
Gymnopus dryophilus	Good	(Burrola, 2017)
Hydnum repandum	Excellent	(Wilde, 2012)
Hygrocybe flavescens	Indifferent	(Asociación Cultural "Baxauri" Kultur Elkartea Mikologia., 2022)
Lactarius deliciosus	Excellent	(Galán, 2013) (Laumont, 2023)
Lactarius indigo	Excellent	(Camacho, 2021)

Species	Palatability/Quality	Sources
Lactfluus volemus	Bad	(Asociación Cultural "Baxauri" Kultur Elkartea Mikologia)
Laetiporus sulphureus	Good	(Emberger, 2021)
Pleurotus ostreatus	Good	(Del Torres-Martínez et al., 2022)
Pleurotus pulmonarius	Good	(Im et al., 2020)
Ramaria araiospora	Good	(Y Aguilar-Cruz & M Villegas, 2010)
Suillus granulatus	Good	(Asociación Cultural "Baxauri" Kultur Elkartea Mikologia, 2023)
Tylopilus felleus	Bad	(Bergo, 2019)
Tylopilus leucomycelinus	Bad	(Bergo, 2019)
Tylopilus rubrobrunneus	Bad	(Bergo, 2019)
Xerocomellus chrysenteron	Bad	(Asociación Cultural "Baxauri" Kultur Elkartea Mikologia)
Xerocomus subtomentosus	Bad	(Wood, M., & Stevens, F.)

Shelf Life

One important consideration for most merchandisers, and consumers how long it can last before decomposition, or shelf life. In Table 8 there is information about different species shelf life available. Products with a very short shelf-life present problems for even getting them to market in the first place. On the other hand, there are many ways to extend shelf life that are still subject to research. However, when fresh produce is to be marketed, the alternatives are reduced. It is complicated to talk about the shelf life of wild mushrooms, since there is very little information available, especially if it is focused on fresh produce. Mushrooms have water in their composition, so their deterioration is fast. The shelf life of fresh mushrooms in refrigeration is generally four to seven days (Zalewska et al., 2018). Species shown with short shelf life and no reference of information in the chart are species with particularly fragile structure that evidenced deterioration with minimum manipulation at field visits.

Table 8

Shelf-life references information per species

Species	Shelf life	Source
Cantharellus cibarius	Extended	(Asociación Cultural "Baxauri" Kultur Elkartea Mikologia)
Fistulina hepatica	Extended	(Bergo, 2017)
Geastrum saccatum	Short	
Hydnum repandum	Short	(La Casa de las Setas)
Hygrocybe coccinea	Short	

Species	Shelf life	Source
Hygrocybe flavescens	Short	
Hygrocybe occidentalis	Short	
Lactarius deliciosus	Short	(Huang & Chen, 2016)
Pleurotus ostreatus	Short	
Pleurotus pulmonarius	Short	
Suillus granulatus	Short	(Ardón, 2007)
Xerocomellus chrysenteron	Short	

Prices

Prices obtained were not used for comparison with each other as doing so would imply a large margin of bias. The shown prices in Table 9 come from different countries and years. For this reason, the price is simply a parameter considered. Because it demonstrates the presence of market demand, while its absence was interpreted as market uncertainty.

Table 9

Prices of mushrooms found on online stores and other sources

Species	Price per kilo (USD)	Source
Amanita hayalyuy	46	(Cáceres, 2011)
Amanita jacksonii	46	(Cáceres, 2011)
Cantharellus cibarius	91	(Fungo, 2021)
Cantharellus lateritius	38	(Real fungi, 2021)
Fistulina hepatica	44	(Baldridge Farm)
Hydnum repandum	20	(Everything Mushrooms, 2017)
Lactarius deliciosus	40	(Galán, 2013)
Lactarius indigo	33	(Foraged, 2023)
Laetiporus sulphureus	65	(Etsy Canada)
Pleurotus ostreatus	12	(Field & Forest Products)
Pleurotus pulmonarius	10	(Indiamart)
Ramaria araiospora	40	(Y Aguilar-Cruz & M Villegas, 2010)
Sparassis americana	52	(Regalis Foods)
Suillus granulatus	20	(Made in China, 2022)

Pharmaceutical Properties

Undoubtedly, this last characteristic is of utmost importance for rearing potential since the pharmaceutical potential enters into a different realm. As described in Table 10, this can range from vitamins to the presence of bioactive components that reduce the risk of developing diseases such as diabetes or specific cancers.

Table 10

Medicinal properties witnessed on different studies conducted per mushroom species

Species	Medicinal properties	Sources
Amanita jacksonii	Vitamin C and riboflavin	(Román-Andrade, 2015)
Amanita vaginata	Bioactive components and antioxidant action	(Soumitra & Krishnendu, 2013) (Soumitra & Krishnendu, 2014)
Cantharellus cibarius	Carotenoids, tocopherols, vitamin C, flavonoids, etc.	(Muszyńska et al., 2016)
Fistulina hepatica	Antioxidants, organic acids, and phenolic compounds	(Fuentes-Antón, 2022) (Ribeiro et al., 2007)
Geastrum saccatum	Anti-inflammatory, antioxidant, and antidiabetic	(Pramod et al., 2021)
Gymnopus dryophilus	Immunomodulatory, anticancer, and antitumor properties	(Sarikurkcu et al., 2020)
Hydnum repandum	Active metabolites as renpadiol	(Takahashi et al., 1992)
Hygrocybe coccinea	Antitumor	(Ohtsuka et al., 1997)
Hygrocybe flavescens	Antitumor	(Ohtsuka et al., 1997)
Hygrocybe occidentalis	Antitumor	(Ohtsuka et al., 1997)
Lactarius deliciosus	Anti-inflammatory, antioxidant, anticarcinogenic	(Muszynska et al., 2013)
Lactarius indigo	Antibacterial pharmaceutical potential, inhibitor of carcinogenic	(Ochoa-Zarzosa et al., 2011)
Laetiporus sulphureus	Anticancer, antioxidant, anti-inflammatory, immunomodulatory, etc	(Jing-Wei Zhang et al., 2015) (Olennikov et al., 2011) (Seo et al., 2011)(Khatua et al., 2017)
Lycoperdon perlatum	Antimicrobial and antioxidant properties	(Akpi et al., 2017) (Novakovic et al., 2015)
Pleurotus ostreatus	Antiviral, antidiabetic, antioxidant, anticancer, antitumor, antihypercholesterolic	(Krishnamoorthy-Deepalakshmi, 2014)
Pleurotus pulmonarius	Antidiabetic properties	(Wahab et al., 2014)
Suillus granulatus	Antibacterial and antioxidant properties, vitamin E	(Reis et al., 2014)
Tylopilus felleus	Cytotoxic action for human breast cancer cells	(Defaye et al., 1988)

Final Evaluation

All the information previously presented with the help of laboratory tests and an extensive literature review was taken into consideration to perform an assessment based on the likert scale methodology. The results of which showed five species with the best summed score. Species whose variable information could not be evidenced were assigned a value of 0. Species with 70% or more scores were considered with productive and commercial potential.

As found in Table 11, the species with the best score was *Fistulina hepatica*, whose fields with the best scored variables were, number of peak months in fruiting, long shelf life compared to the average mushroom and a great variety of medicinal properties. In second place there is *Cantharellus cibarius* which obtained a high score in the variables of culinary quality or palatability, abundant flesh, shelf life and great variety of medicinal properties. In second place too, *Lactarius deliciosus* demonstrated superiority in palatability scores, flesh abundance and an extensive list of medicinal properties. On the other hand, *Lactarius indigo* with the same score has very good ratings in all the above-mentioned fields of *L. deliciosus* with the addition of high score in months of appearance. Finally, *Amanita Jacksonii in third place,* had good ratings in meat abundance, protein value and various medicinal properties. The complete version of data with both quantitative and qualitative variables can be found on Annex H. Meanwhile the complete version with values given by likert scales is on Annex I. The detailed given values for the use of the evaluation instrument are found on Annex J.

Table 11

Species evaluation.

Species	*F. hepatica*	*C. cibarius*	*L. deliciosus*	*L. indigo*	*A. jacksonii*
Months of appearance	3	1	2	4	2
Months of fruiting peaks	3	1	3	3	3
Flesh	2	3	3	3	3
Palatability/Quality	2	3	3	3	3
Shelf life	3	3	1	0	0
Crude protein content	2	2	1	1	2
Price per kilo (USD)	1	1	1	1	1
Medicinal properties	3	3	3	3	2
Species value	19	17	17	18	16

Conclusions

Thirty-seven species of mushrooms have been and are included in the manual. From these, 32 are species with known edibility. Three have unconfirmed edibility and two are toxic species that have been added because they have morphological characteristics that can be confused with edible species. There are at least two toxic species that share similarities with edible species in the reserve: *Amanita muscaria* and *Amanita flavoconia*, in addition to three other species whose edibility or toxicity has not been confirmed: *Aseroe rubra*, *Boletus ananas* and *Marasmiellus candidus*.

The species that showed the best qualification as commercial potential in function of presence, size, taste, medicinal properties, shelf life, protein content and the rest of studied variables were *Cantharellus cibarius, Fistulina hepatica, Lactarius deliciosus, Lactarius indigo* and *Amanita jacksonii.*

Wild edible mushroom seasonality occurs mainly in June and October. There is a dramatic decrease of reports in the month of August, probably affected by dry spell in Honduras.

Recommendations

To complement the missing information on the protein content of the species *Amanita hayalyuy, Aureoboletus betula, Boletus variipes,* and among other missing species to make a fairer comparison between species.

For future research requiring sampling of wild edible mushrooms in the Uyuca Biological Reserve, schedule data collection at least one year in advance during the months of June through October, otherwise availability is even more limited.

Study cultivation and propagation methods with different substrates for the wild edible mushroom species identified *Cantharellus cibarius, Fistulina hepatica, Lactarius deliciosus, Lactarius indigo* and *Amanita jacksonii.* In order to explore new food productive systems for development in Honduras.

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Annexes

Annex A

Established parameters showing the validity of the results by the method Kjeldahl

Tubes	HCL ml	Expected range
Control 1	0.2	0.2 - 0.3
Control 2	0.2	
Ammonium sulfate 17	20.8	20.98 - 21. 20
Ammonium sulfate 18	20.5	
Acetanilide 19	18.5	10.17 -10.16
Acetanilide 20	18.2	

Annex B

Laboratory tests samples´ dry weight, HCL used and resulted protein g/100 g

Species/Sample	**Tube #**	**HCL ml**	**Weight g**	**Protein**
A. subructilensens	9	50.9	0.9947	40.52
A. subructilensens	10	49.8	0.8703	45.30
A. vaginata	12	29.2	1.0005	23.04
A. vaginata	13	30.5	1.0003	24.08
C. cibarius	7	24.7	1.0015	19.45
C. cibarius	8	25.2	1.0019	19.83
H. repandum	11	31.4	0.9735	25.48
L. deliciosus	3	22.6	0.9996	17.81
L. deliciosus	4	22.4	1.0035	17.59
P. ostreatus	5	40.9	1.0002	32.35
P. ostreatus	6	40.2	1.0005	31.78

Annex C

Descriptive statistics of fruiting months peaks in wild edible mushroom species of the reserve

Variable: Months of fruiting peaks	
Mean	1.84
Median	2.00
Mode	1.00
Maximum	4.00
Minimum	1.00
Variance	0.78
Standard variation	0.88
Variation coefficient	0.48

Annex D

Descriptive statistics of months of appearance in wild edible mushroom species of the reserve

Variable: Months of appearance	
Mean	4.63
Median	4.00
Mode	1.00
Maximum	12.00
Minimum	1.00
Variance	11.08
Standard variation	3.33
Variation coefficient	0.72

Annex E

Descriptive statistics protein content in wild edible mushroom species of the reserve

Variable: Protein content %	
Mean	23.46
Median	22.81
Mode	Null
Maximum	42.91
Minimum	11.00
Variance	67.85
Standard variation	8.24
Variation coefficient	0.35

Annex F

Weight in pounds samples for protein content tests

Annex G

Laboratory nitrogen titration

Annex H

Wild Edible Mushrooms of Uyuca with all variables of study

Species	Annual presence	Months of fruiting	Flesh	Palatability/Quality	Shelf life	Crude protein content	Price per kilo (USD)	Medicinal properties
Agaricus subrutilescens	3	1	Moderate	Good	N/I	42.91%	N/I	N/I
Amanita hayalyuy	3	2	Abundant	Excellent	N/I	N/I	46	N/I
Amanita jacksonii	6	3	Abundant	Excellent	N/I	27.45%	46	Vitamin C and riboflavin
Amanita vaginata	5	1	Moderate	N/I	N/I	23.56%	N/I	Bioactive components and antioxidant action
Aureoboletus betula	5	3	Moderate	Excellent	N/I	N/I	N/I	N/I
Boletus variipes	2	2	Abundant	Excellent	N/I	N/I	N/I	N/I
Cantharellus cibarius	1	1	Abundant	Excellent	Extended	24.04%	91	Carotenoids, tocopherols, vitamin C, flavonoids, etc.
Cantharellus lateritius	6	2	Moderate	Excellent	Extended	21.92%	38	N/I
Favolus brasiliensis	12	3	Moderate	N/I	N/I	27.00%	N/I	N/I
Fistulina hepatica	8	3	Moderate	Good	Extended	21.50%	44	Antioxidants, organic acids and phenolic compounds
Geastrum saccatum	11	3	Scarce	N/I	Short	37.05%	N/I	Anti-inflammatory, antioxidant and antidiabetic
Gymnopus dryophilus	7	1	Moderate	Good	N/I	N/I	N/I	Immunomodulatory, anticancer, and antitumor properties
Hydnum repandum	2	2	Moderate	Excellent	Short	26.28%	20	Active metabolites as renpadiol
Hygrocybe coccinea	4	1	Scarce	N/I	Short	N/I	N/I	Antitumor
Hygrocybe flavescens	7	1	Scarce	Medium	Short	N/I	N/I	Antitumor
Hygrocybe occidentalis	2	2	Scarce	Medium	Short	N/I	N/I	Antitumor
Lactarius deliciosus	6	3	Abundant	Excellent	Extended	17.45%	40	Anti-inflammatory, antioxidant, anticarcinogenic
Lactarius indigo	12	4	Abundant	Excellent	N/I	18.36%	33	Antibacterial pharmaceutical potential, inhibitor of carcinogenic
Lactfluus volemus	1	1	Abundant	Bad	N/I	N/I	N/I	N/I
Laetiporus sulphureus	6	3	Moderate	Good	N/I	15.86%	65	Anticancer, antioxidant, anti-inflammatory, immunomodulatory, etc
Lycoperdon perlatum	8	2	Moderate	N/I	N/I	N/I	N/I	Antimicrobial and antioxidant properties
Phylloporus leucomycelinus	1	1	Moderate	N/I	N/I	N/I	N/I	N/I
Pleurotus ostreatus	5	1	Abundant	Good	Short	28.48%	12	Antiviral, antidiabetic, antioxidant, anticancer, antitumor, antihypercholesterolic
Pleurotus pulmonarius	9	2	Abundant	Good	Short	17%	10	Antidiabetic properties
Ramaria araiospora	4	1	Scarce	Good	N/I	11%	40	N/I
Sparassis americana	1	1	Abundant	Good	N/I	N/I	52	N/I
Suillus granulatus	2	2	Moderate	Good	Short	15%	20	Antibacterial and antioxidant properties, vitamin E
Tylopilus felleus	4	2	Abundant	Bad	N/I	N/I	N/I	Cytotoxic action for human breast cancer cells
Tylopilus leucomycelinus	1	1	Moderate	Bad	N/I	N/I	N/I	N/I
Tylopilus rubrobrunneus	1	1	Moderate	Bad	N/I	N/I	N/I	N/I
Xerocomellus chrysenteron	1	1	Moderate	Bad	Short	N/I	N/I	N/I
Xerocomus subtomentosus	2	2	Moderate	Bad	N/I	N/I	N/I	N/I

Annex I

Wild Edible Mushrooms of Uyuca evaluation

Species	Annual presence	Months of fruiting	Flesh	Palatability/ Quality	Shelf life	Crude protein content	Price per kilo (USD)	Medicinal properties	Species value
Agaricus subrutilescens	1	1	2	2	0	3	0	0	9
Amanita hayalyuy	1	2	3	3	0	0	1	0	10
Amanita jacksonii	2	3	3	3	0	2	1	2	16
Amanita vaginata	2	1	2	0	0	2	0	2	9
Aureoboletus betula	2	3	2	3	0	0	0	0	10
Boletus variipes	1	2	3	3	0	0	0	0	9
Cantharellus cibarius	1	1	3	3	3	2	1	3	17
Cantharellus lateritius	2	2	2	2	0	2	1	0	11
Favolus brasiliensis	4	3	2	0	0	2	0	0	11
Fistulina hepatica	3	3	2	2	3	2	1	3	19
Geastrum saccatum	4	3	1	0	1	3	0	3	15
Gymnopus dryophilus	3	1	2	2	0	0	0	3	11
Hydnum repandum	1	2	2	3	1	2	1	1	13
Hygrocybe coccinea	2	1	1	0	1	0	0	1	6
Hygrocybe flavescens	3	1	1	1	1	0	0	1	8
Hygrocybe occidentalis	1	2	1	0	1	0	0	1	6
Lactarius deliciosus	2	3	3	3	1	1	1	3	17
Lactarius indigo	4	3	3	3	0	1	1	3	18
Lactifluus volemus	1	1	3	0	0	0	0	0	5
Laetiporus sulphureus	2	3	3	2	0	1	1	3	15
Lycoperdon perlatum	3	2	2	0	0	0	0	2	9
Phylloporus leucomycelinus	1	1	2	0	0	0	0	0	4
Pleurotus ostreatus	2	1	3	2	1	2	1	3	15
Pleurotus pulmonarius	3	2	3	2	1	1	1	1	14
Ramaria araiospora	2	1	1	2	0	1	1	0	8
Sparassis americana	1	1	3	0	0	0	1	0	6
Suillus granulatus	1	2	2	2	1	1	1	3	13
Tylopilus felleus	2	2	3	0	0	0	0	1	8
Tylopilus leucomycelinus	1	1	2	0	0	0	0	0	4
Tylopilus rubrobrunneus	1	1	2	0	0	0	0	0	4
Xerocomellus chrysenteron	1	1	2	0	1	0	0	0	5
Xerocomus subtomentosus	1	2	2	0	0	0	0	0	5

Annex J

Likert scales for commercial and cultivation potential evaluation.

Variable: Month reports		Variable: Months fruiting peaks		Variable: Flesh quantity		Variable: Shelf life	
Original data	Value	Original data	Value	Original data	Value	Original data	Value
No information	0	No information	0	No information	0	No information	0
1 - 3 months	1	1 month	1	Scarce	1	Short	1
4 - 6 months	2	2 months	2	Moderate	2	Average	2
7 - 9 months	3	3 months or more	3	Abundant	3	Extended	3
10 - 12 months	4						

Variable: Palatability		Variable: Pharmaceutical properties		Variable: Protein content		Variable: Price evidence	
Original data	Value	Original data	Value	Original data	Value	Original data	Value
Bad/ No information	0	No information	0	No information	0	Registered prices	0
Indiferent	1	1 property	1	10 - 20%	1	No prices	1
Good	2	2 properties	2	21 - 30%	2		
Excellent	3	3 or more properties	3	31% or more	3		