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Food production potential of *Favolus brasiliensis* (Basidiomycota: Polyporaceae), an indigenous food

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Abstract

The Amazon region has shown commercial potential for native mushroom species, such as mushrooms produced by the Yanomami people, who already sell more than 10 Amazon species. Among the species collected and consumed by the Yanomami people is *Favolus brasiliensis* (Fr.) Fr. (Basidiomycota: Polyporaceae), which occurs naturally in tropical areas of Central and South America. Thus, the objective of this work is to carry out the bromatological characterization of *F. brasiliensis*, contributing to a better understanding of the nutritional and food potential, as well as registering the natural occurrence of the species in the Cerrado biome and in the state of Goiás. The *F. brasiliensis* mushrooms collected in the present study showed an average of 7.4% humidity, 27% crude protein, 1.5% ether extract, 17% crude fiber, and 1.7% mineral matter. Compared with other species of edible mushrooms, both wild and cultivated, the moisture content of *F. brasiliensis* (93.60%) is low for species of the genus *Pleurotus*. For example, the humidity varies from 87% to more than 90%, similar to that found in *Lentinus crinitus*, another mushroom native to Brazil and also consumed by the Yanomami people. Thus, *F. brasiliensis* has the potential to be used in human foods.

Keywords: edible mushrooms; indigenous; tropical polypore; Yanomami.

Practical Application: The search for native food sources increased with population growth. Here, we present a mushroom from the Cerrado biome, *Favolus brasiliensis*, which is edible and with nutritional potential for use in human food.

1 Introduction

Between 1978 and 2013, the global production of edible mushrooms increased 30 times, from one million to 34 million tons produced (Royse et al., 2017). The world market for edible mushrooms generates around 42 billion dollars annually, and for the year 2023, it is estimated that this value will reach US$62.2 billion (Research & Markets, 2017).

Estimates indicate that the number of species of fungi is between 2.2 and 3.4 million (Hawksworth & Lücking, 2017) however, a relatively low amount (~ 2,000) is recognized as safe for human consumption (Kalac, 2016). Although more than 350 species are currently collected and consumed as food, only twenty-five of them are widely grown commercially, and the main ones are *Agaricus bisporus*, *Lentinus edodes*, *Pleurotus* spp., and *Flammulina velutipes* (Valverde et al., 2015). In addition, 85% of global edible mushroom production is represented by only five genera: *Lentinula*, *Pleurotus*, *Auricularia*, *Agaricus*, and *Flammulina* (Prescott et al., 2018).

Brazil has about 5719 species of fungi already cataloged, and 2741 of these species are of the phylum Basidiomycota, being fungi that produce mushrooms. Despite this high number of already known species, the country is no exception to the world standard for commercial mushroom cultivation, and the main cultivated species are exotic. However, some examples of native species in the Amazon region have shown potential to be sold commercially, such as mushrooms produced by the Yanomami people, who already commercialize more than 10 Amazon species (Instituto Socioambiental, 2019).

Among the species collected and consumed by the Yanomami people is *Favolus brasiliensis* (Fr.) Fr. (Basidiomycota: Polyporaceae), which occurs naturally in tropical areas of Central and South America. The Yanomami people collect this species in a complex agricultural system known as "slash-and-burn agriculture". In the slash-and-burn system, an area of native forest is deforested, and the vegetable remains are burned with agricultural crops planted days after the burning. In approximately four years, the planting site begins to be abandoned and gives way to natural regeneration, giving rise to the "capoeira" (secondary forest formation), and it is during this period that *F. brasiliensis* is collected, growing on the decomposing trunks remaining from the burning (Coimbra & Welch, 2018).

The fact that it is produced and consumed by the Yanomami people in the Amazon rainforest gives *F. brasiliensis* food and production potential for commercial purposes (see Supplementary Material, a way to consume the mushroom). However, there are no records of the collection and consumption of this fungus in other biomes, such as the Cerrado, however, the potential is the same as that found in the Amazon Forest. In the state of Goiás, for example, no citations were found in the literature, even for the natural occurrence of this species (Brazilian Flora Group, 2018).

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Thus, this study intends, in addition to presenting the bromatological characterization of *F. brasiliensis*, to contribute to a greater understanding of the nutritional and food potential, as well as registering the natural occurrence of the species in the Cerrado biome and in the state of Goiás.

2 Materials and methods

2.1 Area characterization

The site where the specimen was collected is an agroforestry system located in the Brazilian Cerrado in the municipality of Goiânia, Goiás. The site was developed in the middle of 2017 with planting of agricultural species, such as coffee (*Coffea arabica* L.), cassava (*Manihot esculenta* Crantz), maize (*Zea mays* L.), yam (*Dioscorea sp.*), taioba (*Xanthosoma sagittifolium* Schott), ginger (*Zingiber officinale* R.), and banana trees (*Musa* spp.). Previously, the area was a forest (secondary forest) already containing arboreal species of more than ten years of development, some species being the following: jatobazeiro (*Hymenaea courbaril* L.), guapeva (*Pouteria torta* (Mart.) Radlk.), Aroeira (*Myracrodruon urundeuva* Allemão), Mango trees (*Mangifera indica* L.), cajazeiras (*Spondia* spp.), and cedar (*Cedrela fissilis* Vell.). In initializing the implementation area of the agroforestry system, timber was harvested from the following: mango trees, guapuruvueiro (*Schizolobium parahyba* (Vell.) Blake), banana trees, teak (*Tectona grandis* L. f.), and eucalyptus (*Eucalyptus* spp.), for deposition in the soil, aiming at protection and decomposition to provide nutrients.

After three years of implantation during the rainy season (mid-January), mushrooms began to appear in the different types of wood arranged in the soil. It is understood that the mushroom is only the reproductive part of the fungus and would probably present its vegetative development within dead wood. Several species of fungi and mushrooms were found growing in the locality; however, *F. brasiliensis* presented greater abundance among the mushrooms. From the choice of the specimens, the species was determined through the comparison of photos and with bibliographic material (Coimbra & Welch, 2018). The area is the same as where the *Lentinus critunus* have already been found and studied by our research group in previous work (Silva-Neto et al., 2019).

2.2 Species determination

Macro and microscopic characteristics were used for taxonomic determination of the collected material. The morphological analysis of the specimens of *F. brasiliensis* was performed using rehydrated basidiomes, according to the usual methodology for macrofungi (Largent & Thiers, 1977; Largent et al., 1977). The sections were rehydrated in 3% KOH and stained with phloxin when necessary, observed under an optical microscope with 1000× magnification, and photographed using a digital camera, while measurements were taken by using the Piximètre software, version 5.9 R 1532 (Henriot & Cheype, 2012). The species was determined by consulting the specific literature on the group, as well as comparing images deposited in online repositories (Sotome et al., 2012; Coimbra & Welch, 2018; Cui et al., 2019).

For the determination of macronutrients and micronutrients, 20 grams of mushrooms were collected for chemical analysis in the laboratory. After drying, the material was analyzed for characterization of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, manganese, sodium, organic matter, iron, copper, zinc, cobalt, and molybdenum (Calil et al., 2013), as well as bromatological analysis with characterization of moisture, protein, ether extract, and fibers (Silva & Queiroz, 2006; Santos et al., 2009).

After the pre-drying procedure, the sample was ground in an analytical mill with a 1 mm sieve, and the dry mass was determined by placing them in an oven at 105 °C for 24 hours, determining the total dry matter after calculations. The mineral matter (MM) was determined by the following method: after pre-drying 5 g of the ensiled material, the samples were placed in porcelain crucibles and taken to the oven to burn the organic material at a temperature ranging from 200 °C to 600 °C for a period of four hours, again to determine the total mineral matter after the calculations (Silva & Queiroz, 2006).

For the nitrogen content, the Kjedahl steam distillation apparatus was used, and the crude protein (CP) content was calculated using the conversion factor of 6.25, according to the Association of Official Analytical Chemistry (2000) and Santos et al. (2009). The analysis of total digestible nutrients (TDN), lignin, cellulose, and hemicellulose was carried out according to the methodology described by Santos et al. (2009) and Silva & Queiroz (2006).

3 Results and discussion

The genus *Favolus* was initially proposed by Palisot de Beauvois in 1805 in order to accommodate *F. hirtus* P. Beauv., and this genus was later adopted as a subgenus of *Polyporus*. In 1828, the mycologist Elias Magnus Fries, based on specimens collected in Brazil, described a genus also named *Favolus* (Fries, 1828), with the species type *F. brasiliensis* (Fr.) Fr. with *Favolus* Fr. being the currently accepted genus by taxonomy. For a long time, *Favolus* Fr. was considered synonymous with *Polyporus*, especially due to its morphological characteristics. Sotome et al. (2012) determined, based on molecular evidence, that *Favolus* Fr. should continue as an independent taxon. In addition, the authors defined *Neofavolus* Sotome & T. Hatt. in order to accommodate new species reported to *Favolus*. Both genders were segregated from the broad “Favolus clade” and have been accepted by the scientific community ever since (Zhou & Cui, 2017; Cui et al., 2019).

F. brasiliensis (Figure 1) is a mushroom belonging to the Polyporaceae family, whose basidiomes have annual growth, present flabeliform morphology, laterally stipitate, glabrous and radially striated surface, with a hymenial surface composed of large and radially elongated pores, towards the stipe. It presents whitish color in cool conditions (Sotome et al., 2012; Cui et al., 2019). The *F. brasiliensis* mushrooms collected in the present study showed an average of 7.4% moisture, 27% crude protein, 1.5% ether extract, 17% crude fiber, and 1.7% mineral matter. Compared with other species of edible mushrooms, both wild and cultivated, the moisture content of *F. brasiliensis* (93.60%)

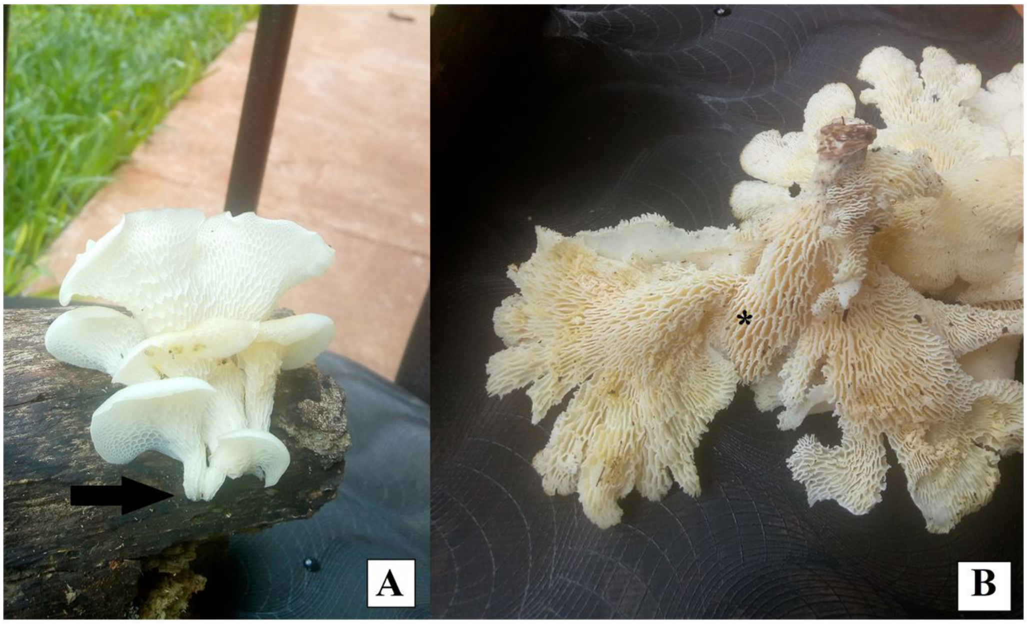

Figure 1. (A) Reproductive mycelium of *F. brasiliensis* on branches of guapuruvu (*Schizolobium parahyba*); (B) Top view of the reproductive mycelium of *F. brasiliensis*.

Table 1. Comparison between native and globally cultivated mushrooms and *F. brasiliense* in this study.

	Species	Moisture Content	Crude Proteina	Ether Extract	Crude Fibre	Mineral Matter	Reference
Wild	*F. brasiliensis*	93.60	27.00	1.50	17.00	1.70	Present study
	Agaricus abruptibulbus	93.30	20.30	--	8.85	--	Sudheep & Sridhar (2014)
	Termitomyces globulus	91.80	23.83	--	9.66	--	Sudheep & Sridhar (2014)
	Russula vesca	15.00	14.00	--	--	--	Singdevsachan et al. (2014)
	T. eurrhizus	7.00	22.83	--	--	--	Singdevsachan et al. (2014)
	Lentinula edodes	82.80	43.81	--	3.60	--	Ao & Deb (2019)
	Lentinus torulosus	80.97	27.31	--	--	--	Singdevsachan et al. (2013)
	Auricularia thailandica	80.75	12.99	--	4.62	--	Bandara et al. (2017)
	Lentinus crinitus	61.00	14.00	1.50	26.00	3.40	Silva-Neto et al. (2019)
Cultured	*Pleurotus ostreatus*	--	35.40	2.45	11.27	6.70	Carvalho et al. (2012)
	Lentinula edodes	79.78	4.40	--	--	--	Reis et al. (2012)
	Agaricus bisporus	--	37.88	--	10.31	11.98	Andrade et al. (2008)
	Agaricus blazei	88.00	39.80	--	9.65	7.75	Shibata & Demiate (2003)
	Pleurotus ostreatus	87.70	24.10	--	4.30	--	Duprat et al. (2015)
	Pleurotus sajor-caju	87.00	24.63	--	22.87	--	Alam et al. (2008)
	Pleurotus djamor	90.07	20.50	--	22.43	--	Rampinelli et al. (2010)

is high, for species of the genus *Pleurotus*. For example, the moisture content varies from 87% to more than 90%, and this is also notably similar in comparison with *Lentinus crinitus*, another mushroom native to Brazil and also consumed by the Yanomami people (Table 1).

The protein content shows the potential of the species under study, noting higher levels than those observed in some species of commercial cultivation, such as oyster mushrooms (*Pleurotus* spp.) and wild (*Agaricus abruptibulbus* Peck, *Termitomyces* spp., *Russula vesca*, *Auricularia thailandica*, *Lentinus crinitus* (L.) Fr.). The average crude fiber content found in the present study is similar to values compiled by Wang et al. (2014) for wild edible mushrooms found in China, being between 5% and 40%.

It is important to note that the studied mushrooms were collected in the wild, growing on mango tree trunks (*Mangifera indica* L.), and without the influence of artificially prepared substrates for cultivation. Commercial cultivation of several species is carried out on fortified substrates, or selected woods, which are factors that can influence the nutritional levels of mushrooms. Sales-Campos et al. (2011) observed that the nutritional composition of oyster mushrooms (*Pleurotus ostreatus*) varies depending on the substrate. Sales-Campos et al. (2013) also reported effects of the substrate on the nutritional contents of *Lentinus strigosus*, a naturally occurring mushroom in the Amazon. In addition to the substrate, other factors can influence the nutritional composition, such as species and their varieties, lineages, degree of maturity of the mushroom, parts of the mushroom examined, among others (Sales-Campos et al., 2013).

It should be noted that the mushrooms studied were found growing in low density wood (below 0.5 g/cm^3). This also occurs in Yanomami territory, where *F. brasiliensis* is found in fields, brushwoods, and dense forests as long as there are decomposing trunks, growing in woods such as that of embaúba, *Cecropia* spp. (Coimbra & Welch, 2018). This indicates the preference of this fungus for light dense woods. The same characteristic was observed for the mushroom *Lentinus crinitus* (L.) Fr., found in agroforestry systems in the state of Goiás by Silva-Neto et al. (2019), and the authors emphasize that information about the types of wood preferred by wild fungi are important for the development of suitable substrates for the commercial cultivation of these species. This suggestion must not, however, limit the possibility of tests with other substrates, whose composition directly influences the bromatological characteristics of the fungus. To date, no studies on substrates for the cultivation of *F. brasiliensis* have been found in the literature.

As in the previous work (Silva-Neto et al., 2019), the authors reinforce the potential for using mushrooms in agroforestry yards in the Brazilian Cerrado, notably *F. brasiliensis* in the case of this study. In this work, we collected a larger amount of *F. brasiliensis* than that collected from *L. critunus* previously. In this case, it was 100 g of fresh mushrooms, previously being about 20 g per 50m^2 in just one collection, and thus, one hectare of agroforestry yard could produce approximately 20 kg in a high estimate. If the current price of one tray of commercial mushrooms is around 10 reais per 100 g, a profit of 2.000 reais per hectare for a new commercial use of the production could be obtained, presenting results even better than for *L. crinitus*. In this sense, the collection of mushrooms would not be of just one species, and all the collected species could contribute together to the productivity of edible mushrooms in the areas.

F. brasiliensis, as well as *Lentinus crinitus,* is just one of the twenty species of mushrooms presented by the Yanomami people, being considered a very abundant mushroom by the group and not necessarily the most tasty or palatable. Many other mushrooms are preferred for food (Coimbra & Welch, 2018). New studies that value local and traditional knowledge of Brazil, especially the knowledge of indigenous communities, are important to recover knowledge about mushrooms, plants, and food, as well as valuing communities and positively influencing the maintenance of their territories and knowledge.

4 Conclusions

The *F. brasiliensis* mushroom, a mushroom native to Brazil and to the Amazon Forest but also occurring in the Cerrado biome, has bromatological characteristics similar to the mushrooms consumed by the population, being rich in proteins and minerals. Different aspects of cultivated mushrooms such as moisture can give particularities to the mushroom, being typical of wild mushrooms, as well as others found around the world.

In this work, the natural occurrence of an Amazonian mushroom in the Cerrado Biome is highlighted, which is already consumed by indigenous peoples. In the studied area, *F. brasiliensis* grows spontaneously in the agroforestry systems of the Cerrado and presents a possibility for its use within this agroecosystem.

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Supplementary Material

Supplementary material accompanies this paper.

Yanomami mushroom recipe.

This material is available as part of the online article from http://www.scielo.br/CTA