



Centesimal composition and physical-chemistry analysis of the edible mushroom *Lentinus strigosus* occurring in the Brazilian Amazon

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ABSTRACT

The centesimal composition and the physical and chemical analyses of *Lentinus strigosus*, an edible mushroom occurring in the Brazilian Amazon and produced in alternative substrates based on wood and agroindustrial residues, were evaluated. For this purpose, the C, N, pH, soluble solids, water activity, protein, lipids, total fiber, ash, carbohydrate, and energy levels were determined. The substrates were formulated from *Simarouba amara* Aubl. (“marupá”), *Ochroma pyramidale* Cav. Ex. Lam. (“pau-de-balsa”) and *Anacardium giganteum* (“cajuí”) sawdust and *Bactris gasipaes* Kunth (“pupunheira”) stipe and *Saccharum officinarum* (sugar cane bagasse). The results indicated that the nutritional composition of *L. strigosus* varied with the substrate of cultivation; the protein levels found in mushrooms grown in the different substrates (18 – 21.5%) varied with the substrate and was considered high; the soluble solids present in the mushrooms could have a relation with complex B hydrosoluble vitamins. *L. strigosus* could be considered as important food owing to its nutritional characteristics such as high protein content, metabolizable carbohydrates and fibers, and low lipids and calories content.

Key words: edible mushroom, nutritional value, minerals, protein, fibers.

INTRODUCTION

Several publications have highlighted the mushroom as food with high protein value, as a source of food fiber and vitamins as well as low lipids content (Chang and Miles 1989, Manzi et al. 1999, Sapata 2005). However, it should be noted that there is great variability in the nutritional composition of

mushrooms among the same species and between different species (Sturion and Oetterer 1995, Wang et al. 2001, Silva et al. 2002, Furlani 2004, Sapata 2005, Das and Mukherjee 2007). The variations could result from different factors such as: the mushroom species, strains, type of substrate used, maturation degree of the mushroom, type of storage, parts of the mushroom examined, and the conservation process (Andrade et al. 2008, Furlani 2004, Crisan and Sands 1978).

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When studying the viability of mushroom cultivation in alternative substrates, it is important to know the nutritional composition of the species grown in relation to such substrates. Many of the basidiomycete fungi that decompose wood and other lignocellulosic material are also edible fungi, like *Lentinus strigosus* (Schwein.) Fr., which can be used in the process of exploiting the residues owing to the special metabolic activity.

Many species of the genus *Lentinus* are considered as a primary decomposers of wood and other plant residues, and are known for their ability to be grown in various residues. Mushrooms of this genre, such as *L. Strigosus*, have been studied particularly regarding their cultivation in different residues (Lechner and Albertó 2007, Kadiri and Arzai 2004), although they have been rarely cultivated in the world. Nevertheless, there are no records in the scientific literature about the nutritional composition of *L. strigosus*.

Thus, the present study aims to evaluating the centesimal composition and the physical and chemical analyses of an *L. strigosus* strain occurring in the Brazilian Amazon, produced in substrates based on wood and agroindustrial residues.

MATERIALS AND METHODS

The study was carried out at the Coordenação de Tecnologia e Inovação (CTI) of the Instituto Nacional de Pesquisas da Amazônia (National Institute of Researches in Amazon - INPA), at the Analysis Laboratory of Soil and Plants of the same Institute, at the Fishing Laboratory and at the Analytical Center of the Universidade Federal do Amazonas.

The sawdust used in the preparation of the substrate were as follows: *Simarouba amara* Aubl. ("marupá"), *Ochroma pyramidale* Cav. Ex. Lam. ("pau-de-balsa"), and *Anacardium giganteum* ("cajuí"). The agroindustrial residues were: *Saccharum officinarum* (sugar cane) bagass and *Bactris gasipaes* Kunth ("pupunheira").

The choice of wood residues generation was based on their generation by the local timber industry. The agroindustrial residues were acquired from sugar cane juice micro industries and pupunheira stipe from the disposal of the palm production. The collection, drying, and preparation of the material were carried out at the CTI/INPA.

All the samples were dehydrated in a solar drier of the CTI/INPA and packaged separately in plastic tanks of 100 liters until the preparation of the substrate for the test with the fungus, according to Sales-Campos (2008).

After the cultivation, the mushroom samples were divided according to the origin of collection (substrate), and coded according to the residue in which the substrates were formulated: SIAMP-COG ("marupá"); SIAPB-COG ("pau-de-balsa"); SIACJ-COG ("cajuí"); SIAPP-COG ("pupunheira"); and SIACN-COG (sugar cane).

The mushrooms of each type of substrate were homogenized and dried in stove with circulating air at 55°C. They were then crushed in Willey knife mill and packed in sealed bottles and kept under refrigeration for further evaluation of the centesimal composition and the physical and chemical analyses.

pH DETERMINATION

The pH determination of the mushrooms was done using a potentiometer, previously calibrated with buffer 7 and 4, following the methodology recommended by the AOAC (1997). A total of three repetitions per sample (3 g) were carried out. The material was diluted in distilled water followed by reading in a Tecnal digital potentiometer.

DETERMINATION OF ORGANIC CARBON CONTENT

The organic carbon was determined by the Walkley Black method, according to Mendonça and Matos (2005). For this purpose, 0.01 g of the sample was used, instead of 0.5 g, owing to the large amount of carbon present in the sample. The amount of carbon

was determined by its oxidation in humid way (dichromate + sulphuric acid) and the maximization of oxidation was obtained by external heating. The result was obtained by two complementary formulas:

$$A = [(V_{ba} - V_{am})(V_{bn} - V_{ba}) / V_{bn}] + (V_{ba} - V_{am}), \text{ where:}$$

V_{ba} = volume spent in the titration of the white control with heating;

V_{bn} = volume spent in the titration of the white control without heating;

V_{am} = volume spent in the titration of the sample

$$\% C = \frac{(A) (\text{molarity of ferrous sulphate}) (3) (100)}{\text{Mass of the sample (mg)}}$$

3 = result of the ratio between the number of moles of dichromate that react with iron, multiplied by the number of moles of dichromate that react with carbon, multiplied by the atomic mass of carbon (12);

100 = unit of percentage.

DETERMINATION OF TOTAL NITROGEN AND PROTEIN

The Kjeldahl was employed for the analysis of total nitrogen, which involved three steps: digestion, distillation, and titration (Malavolta et al. 1989, AOAC 1997), by using the following formula:

$$\text{Nitrogen\%: } (V \times 0.0014 / M) \times 100$$

where,

V = Volume of H_2SO_4 spent in titration, mL

M = Mass of the sample (g)

For the conversion of nitrogen into protein the following formula was used, considering that 100 g of protein contains an average of 16% of nitrogen:

$$\text{Protein\%} = \text{N\%} \times 4.38 \text{ for the mushrooms}$$

WATER ACTIVITY

The water activity (A_a) in the mushrooms was determined using a Pawkit water activity analyzer with a technical calibration and adjustment certificate (Braseq 2005).

The water activity is represented by the formula $A_a = P / P_0$ (Maltini et al. 1993, Eira 2003).

Refractometry was used for measuring the refraction index of the sugar solution containing the mushrooms. The samples were homogenized and diluted in a small amount of distilled water, and large particles were discarded. One to two drops were transferred to the prism of the refractometer and read in the scales in Brix degree (Carvalho et al. 2002).

DETERMINATION OF HUMIDITY AND DRY MASS CONTENT

The moisture content of the samples cited was determined by the dissection method in stove at $105^\circ C$ until constant mass was achieved. One gram of each grinded sample (three repetitions per sample) was weighed with a precision of 0.01 mg in analytical balance in crucibles; the material was dried in stove at $105^\circ C$ for four hours. The crucibles were then transferred to a dissector with silica and left for cooling until environment temperature. Subsequently, they were weighed and the operation was repeated until constant mass. Humidity was expressed by the following formula:

$$U \% = \frac{M_1 - M_2}{M_1} \times 100$$

U = Percentage of humidity

M_1 = initial mass of the sample

M_2 = final mass of the sample

Dry mass was calculated as $MS\% = 100 - U$

LIPIDS

The dissected samples were submitted for extraction with mixtures of cold solvents by the Bligh and Dyer method in triplicates. The solvents used in this technique were chloroform, methanol, and water. The sample was mixed with the solvents, and the chloroform stage contained the lipids. This stage was separated after the evaporation of the chloroform. The amount of lipids was obtained by weighing and the results were expressed in grams per 100 g of the sample (Carvalho et al. 2002).

TOTAL FIBER

The total fiber content was determined by the Weende method (AOAC 1997). The fat was removed, and the samples were weighed around 2 g in triplicates and submitted to acid digestion. All samples were adapted to a Tecnal TE 146/8-50 and TE 146/5-50 fibers determinator system. In a second step, the samples were submitted to alkaline digestion, in a 1.25% NaOH solution. The results were expressed in grams of total fiber by 100 g of samples.

ASH OR FIXED MINERAL RESIDUE

The ash content of a sample corresponds to the fixed mineral residue obtained after the decomposition of all the organic components. The analysis consisted in dissecting the samples, weighing around 1 g in triplicate, carbonization, and calcination in furnace, at 550°C. The results were expressed in % (AOAC 1997).

TOTAL CARBOHYDRATES

The total carbohydrates were calculated by difference (100 – total grams of humidity, protein, lipids, and ash), including fiber fraction. The result was given in percentage terms (LATINFOODS 2002, NEPA 2006).

AVAILABLE CARBOHYDRATES

These are metabolizable carbohydrates, which were calculated by difference and by excluding fiber fraction (100 – total grams of humidity, protein, lipids, ash, and fiber) (LATINFOODS 2002, NEPA 2006).

ENERGY

The total metabolizable energy is expressed in kilocalories (kcal / 100g), which was calculated by considering Atwater's conversion factors: (4 x g protein) + (4 x g carbohydrates [total carbohydrates – food fiber]) + (9 x g total lipids), as recommended by LATINFOODS (2002) and NEPA (2006).

RESULTS AND DISCUSSION

It was observed that the carbon contents of the mushroom presented close values even when grown in different residues (36.72 – 37.86%) (Table I). The mushroom grown in crushed sugarcane had 3.44% of N, while the production in the residue formulated from the residue of marupá had lower N content (2.81%). The results agree with the N values present in most of the mushrooms (2.27-5.13%), according to Chang and Miles (1989).

The soluble solids present in mushrooms were found to vary with the cultivation substrates (Table I). The values for SIAMP-COG, SIAPB-COG, SIAPP-COG, SIACN-COG, and SIACJ-COG were 1.82, 3.64, 3.64, 3.89, and 3.14%, respectively, with the highest content present in the mushroom grown in substrates made from sugar cane. It is possible that soluble solids' contents are also related to the presence of water soluble vitamins of the complex B, as mushrooms are sources of vitamins, especially those of complex B, ascorbic acid, and ergosterol, which transforms to vitamin D in the presence of ultraviolet light (Crisan and Sands 1978, Gunde-Cimerman 1999). However, analyses of the soluble solid contents regarding the content of the vitamins were not the objective of this study.

The pH values were found to be practically similar between mushrooms grown in the different substrates (5.39 - 5.73) (Table I), as well as the corresponding values to water activity (Aa) that ranged from 0.57 to 0.61. This is important for their conservation as low water activity makes microbial proliferation in the processed (dried and powdered) mushroom impossible, since microbial deterioration rate decreases as water activity is close to 0.60 and there is no microbial growth below that value (Eira 2003).

For the assessment of the protein content, the N conversion factor to protein used was 4.38 which takes into account the deletion of non-protean N from the chitin of the cell wall of fungi (Miles and Chang 1997), instead of 6.25 which is typically used for most food, avoiding protean super estimation.

TABLE I
Results of physical and chemical (soluble solids, pH, Aa), carbon (C), nitrogen (N) and C:N ratio analyses of *Lentinus strigosus* mushroom grown in different substrates.

<i>L. strigosus</i> grown in different substrates	C	N	C:N	Soluble solids	pH	Aa
	(%)	(%)	(%)	°Brix		
SIAMP-COG	(0.14) 37.86	(0.16) 2.81	(0.83) 13.47	1.82	5.39	0.58
SIAPB-COG	(0.21) 37.26	(0.06) 3.16	(0.15) 11.79	3.64	5.73	0.60
SIAPP-COG	(0.12) 36.86	(0.06) 3.29	(0.19) 11.20	3.64	5.41	0.61
SIACN-COG	(0.05) 37.04	(0.22) 3.44	(0.72) 10.77	3.89	5.47	0.57
SIACJ-COG	(0.04) 36.72	(0.03) 2.83	(0.11) 12.98	3.14	5.51	0.60

SIAMP-COG: Mushroom grown in the substrate with “marupá” sawdust; SIAPB-COG: with “pau de balsa” sawdust; SIAPP-COG: with grinded “pupunheira” stipe bagass; SIACN-COG: with crushed sugar cane; SIACJ-COG: with “cajuí” sawdust. Numbers in bold: average of three repetitions per analysis. Values between parentheses refer to standard deviation.

The protein levels found in mushrooms grown in the different substrates used in this study (18 - 21.5%) (Table II) are within the range reported for Miles and Chang (1997), compiled from various authors, and show that *Agaricus bisporus*, *Flamulina velutipes*, *Lentinus edodes*, and *Volvariella volvaceae* contain 23.9, 17.6, 13.4, and 21.2% of protein in dry basis, respectively. Andrade et al. (2008) found variations of 20-24.3% of protein for *L. edodes*. The author, however, used an N conversion factor of 6.25 for protein, thereby causing super estimation of protein for that mushroom, which would correspond to the range of 14–17% by applying the conversion factor of 4.38.

The cultivation of *P. tuber-regium* was tested by Faside and Ekuere (1993) in banana leaf, corncob, cotton plant residue, and rice straw. The protein contents of the mushroom grown in the respective residues in dry basis were 16.8, 15.4, 15.1, and 13%. It was found that the protein content for the mushroom grown in banana straw was lower than the results presented for *L. strigosus* grown in wood and agroindustrial residues as well as that obtained in this research (Table II).

Silva et al. (2002) used three types of substrates for the cultivation of *P. pulmonarius*: residue made of cotton plant, sheets of citron grass, and a type of

forage plant. The protein levels for the substrates were 10.64, 7.87, and 7.55%, respectively.

In this study, the protein percentages of the mushroom grown in the corresponding substrates were 20.03, 16.90, and 26.82%, which present a higher protein value for the mushroom grown in the substrate of lower protein value (the Panicum maximum forage). Thus, in both cases, the results indicated that the highest protein content obtained in the mushroom did not correspond to the highest protein content of the cultivation substrate; a similar result was obtained in the study of Yildiz et al. (1998). The authors used different cereals' straw, and mainly sorghum as substrate with highest protein content (9%). The mushroom with highest protein content, however, was found to be that mushroom grown in peanut straw, the substrate with half of the protean value of sorghum straw (4.75%).

Several weeds were used isolated and mixed to rice straw for the cultivation of *P. ostreatus* originating in India (Das and Mukherjee 2007). The largest protein content was found to occur in the mushroom grown in Cassia sophera grass (10.85 mg.g⁻¹ of mushroom in fresh basis), although it was not the substrate promoting highest productivity.

As for lipid contents found in the mushroom grown in the different residues, the results were

TABLE II
Result of the centesimal composition of *Lentinus strigosus* in different substrates.

Mushroom per Substrate	Protein (N x 4.38) (%)	Lipids (%)	Total Fiber (%)	Ash (%)	Humidity		Dry mass (MS) (%)	Total Carbohydrate (%)	Available carbohydrate (%)	Total Metabolizable Energy (%)
					Fresh mushroom (%)	Dehydrated mushroom (%)				
SIAMP-COG	18.00	(0.05) 2.43	(0.64) 16.00	(0.38) 5.57	(0.78) 82.19	(0.17) 11.74	88.26	62.69	47.43	281.87
SIAPB-COG	20.00	(0.05) 2.39	(0.30) 14.25	(0.33) 5.47	(2.80) 83.38	(0.11) 12.45	87.55	59.95	45.70	283.32
SIAPP-COG	20.56	(0.08) 2.69	(1.57) 13.64	(0.17) 5.72	(1.63) 84.01	(0.40) 12.29	87.71	58.75	45.10	286.83
SIACN-COG	21.50	(0.03) 2.45	(2.87) 16.17	(0.62) 5.01	(1.55) 84.88	(0.32) 12.53	87.47	58.52	42.34	277.40
SIACJ-COG	18.00	(0.12) 2.50	(0.19) 13.00	(0.01) 4.19	(1.59) 81.36	(0.11) 12.53	87.47	63.10	50.42	294.92

SIAMP-COG: Mushroom grown in the substrate with “marupá” sawdust; SIAPB-COG: with “pau de balsa” sawdust; SIAPP-COG: with grinded “pupunheira” stipe bagass; SIACN-COG: with crushed sugar cane; SIACJ-COG: with “cajuí” sawdust. Numbers in bold: average of three repetitions per analysis. Values between parentheses refer to standard deviation.

found to be low (2.39 – 2.69%), as shown in Table II, and they are in agreement with several studies (Chang and Miles 1989, Sturion and Oetterer 1995, Miles and Chang 1997, Sapata 2005).

The fiber contents were found to vary with the cultivation substrate and were considered high, especially in SIACN-COG (16.17%) and SIAMP-COG (16%) (Table II). Andrade et al. (2008) grew *L. edodes* in logs of multiples species of *Eucalyptus* and found changes in fiber percentages ranging from 6.35 to 20.5% as a result of the influence of the wood species tested.

The ash content of the mushroom was found to vary from 4.19 to 5.72% (Table II). The highest ash content occurred in the mushroom grown in the pupunheira residue (palm tree stem), being in the range mentioned by Chang and Miles (1989) and according to, Manzi et al. (1999), Furlani (2004) and Sapata (2005). Andrade et al. (2008) obtained average percentages of ash in *L. edodes* grown in different species of *Eucalyptus* in the range of 2 to 5%.

As for humidity, fresh mushroom obtained 81.36 to 84.88%, values considered as normal as mushroom is made up of about 90% water (Maziero 1990). The humidity of the dried mushroom was

found to range from 11.74 to 12.53, in agreement with the results of Oliveira et al. (1999) and Shibata and Demiate (2003) for dehydrated *A. blazei*.

The results of total carbohydrates (with fiber fraction included) for mushrooms SIAMP-COG; SIAPB-COG; SIAPP-COG, SIACN-COG, and SIACJ-COG were 62.69, 59.95, 58.75, 58.52, and 63.1%, respectively, and the highest results were found in the mushrooms grown in cajuí (SIACJ-COG) and marupá (SIAMP-COG) residues. This was probably owing to the high amount of total fiber (13 and 16%) present in the respective samples, which are part of the total carbohydrates, as well as owing to the lower levels in protein contained in those samples, which are lower percentages to be discounted in the total carbohydrate formula.

The available carbohydrate contents (carbohydrate from which fiber fraction is excluded) for samples SIACJ-COG and SIAMP-COG were 50.42 and 47.43%, respectively (Table II). It should be mentioned that the lowest percentages in proteins present in those samples (18%), consequently discounted in lesser percentage in the calculation of available carbohydrates, contributed to the higher value of those carbohydrates.

The total metabolizable energy was found to be higher similar to the percentage of available carbohydrate present in the sample, which was in a larger amount in SIACJ-COG with 294.92 Kcal. The results were found to be lower than those reported by Miles and Chang (1997) for *P. ostreatus*.

By analyzing samples in a general way, a wide variation in the protein, lipid, ash, total available carbohydrate, and energy contents was observed in the mushroom grown in all the cultivation substrates, which was in agreement with various studies (Fasidi and Ekuere 1993, Sturion and Oetterer 1995, Wang et al. 2001, Silva et al. 2002, Furlani 2004, Sapata 2005, Das and Mukherjee 2007).

In general, it is known that the highest nutritional composition of mushrooms is related to the pileum and not the stipe; this can be proven in the studies conducted by Shibata and Demiate (2003) with *A. blazei*, and the study by Akindahunsi and Oyetayo (2006) which confirmed that in relation to protein, lipids, ash and total carbohydrates in *P. tuber-regium*. The results found for pileum and stipe, respectively, for protein (13.8 and 7.8%), lipids (1.2 and 0.7%), ash (4.9 to 2.6%) and total carbohydrates (53.2 to 34%) were, however, lower than the same compositions presented by *L. strigosus* grown in the different substrates used in the present research, analyzing the mushroom as a whole (Table II).

The various sources consulted indicate that there is a wide variability in the centesimal composition of mushrooms, between the same species and between different species. Such results are in agreement with the observations of Furlani (2004) and Sales-Campos et al. (2009).

CONCLUSIONS

The nutritional composition of *L. strigosus* varies with the cultivation substrate.

Protein levels (18–21.5%) varied with the substrate and was considered high.

The soluble solids might have a relation with water soluble vitamins from complex B.

L. strigosus can be considered as important food owing to its nutritional features.

RESUMO

Avaliou-se a composição centesimal e análise físico-química do *Lentinus strigosus*, um cogumelo comestível de ocorrência na Amazônia brasileira, produzidos em substratos alternativos à base de resíduos madeireiros e agroindustriais. Com este objetivo, determinou-se C, N, pH, sólidos solúveis, atividade de água, proteína, lipídios, fibra total, cinzas, carboidratos e energia. Os substratos foram formulados a partir de serragem de *Simarouba amara* Aubl. (marupá), *Ochroma pyramidale* Cav. ex. Lam. (pau-de-balsa) e *Anacardium giganteum* (cajuí); e do estipe de *Bactris gasipaes* Kunth (pupunheira) e de *Saccharum officinarum* (cana-de-açúcar). Os resultados demonstraram que: a composição nutricional do *L. strigosus* variou com o substrato de cultivo; os valores de proteína encontrados nos cogumelos cultivados nos diferentes substratos (18 - 21,5%) variaram de acordo com o substrato, sendo considerados elevados; os sólidos solúveis presentes nos cogumelos podem ter relação com vitaminas hidrossolúveis do complexo B; o *L. strigosus* pode ser considerado um importante alimento devido suas características nutricionais: alto teor de proteína, carboidratos metabolizáveis e fibras; baixos teores de lipídios e de calorias.

Palavras-chave: cogumelos comestíveis, valor nutricional, minerais, proteínas, fibras

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