MINERAL COMPOSITION OF RAW MATERIAL, SUBSTRATE AND FRUITING BODIES OF *Pleurotus ostreatus* IN CULTURE

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SUMMARY

In a culture of a Pleurotus ostreatus *(oyster mushroom) strain, macro and micronutrients of the raw material and the initial and spent substrates were evaluated. Substrates were formulated with sawdust from* Simarouba amara *Aubl. and* Ochroma piramidale *Cav. ex. Lam., crushed* Bactris gasipaes *Kunth and crushed* Saccharum officinarum *(sugar cane). Samples were solubilized by means of acid digestion (nitric-peridrol). Ca, Mg, Fe, Cu, Zn and Mn were determined by atomic absorption spectrophotometry, Na and K by atomic emission, and P by colorimetry. The mineral composition of the fruiting body varied with the substrates, which made possible the production of a fruiting body rich in K, P, Mg and Fe. Potassium was the mineral with the highest content in the fruiting body in all substrates tested (36.83-42.18g·kg^{-1}). There was an increase of protein and mineral content in the spent substrate in relation to the initial one.*

Introduction

The cultivation of edible mushrooms has evolved in time and has become nowadays an activity of economical importance, mainly for the production of species of the genera *Agaricus, Pleurotus* and *Lentinula*. Their world production increase, especially *Pleurotus* spp., particularly occurred due to their ability to grow in different residues, such as sawdust and agroindustrial waste, a characteristic that made production economically viable. Such characteristics are relevant regards production, but mushrooms are also important regarding their nutritional aspect.

The type of substrate, the environmental conditions and the fungus species used in cultivation all have a large influence in the chemical composition of fruiting bodies. Variations occur mainly in relation to minerals and protein contents (Crisan and Sands, 1978).

There are few studies about the mineral composition of cultivated mushrooms (Strmisková *et al*., 1992; Vetter, 1994; Sturion and Ranzani, 2000). The adaptation of *Pleurotus* spp. strains to new residues requires knowledge of the cultivation process and the chemical composition of both substrate and fruiting body, more so as new formulations with wood and agroindustrial waste from the Amazon region are considered.

In general, the mineral elements necessary for the fruiting of the mushroom are the same required by any other cultivated plant, macro and micronutrients (Molena, 1986). P, K, Mg and S are the necessary macronutrients for the growth of several fungi (Miles and Chang, 1997). Molena (1986) included Ca as one of these elements. Kurtman and Zadrazil (1984) reported that minerals such as Na, Mg and Ca chlorides, stimulate mycelium growth, as well as the beginning of fruiting body formation.

Ca is a needed mineral for plants, but not so for most fungi, except for some ascomycetes in the formation of the perithecium and for certain basidiomycetes, such as *Cyathus stercoreus*, in the formation of the basidioma (Chang and Miles, 1989). According to Przybylowicz and Donoghue (1990), other supplements like limestone or $CaCO_3$, must be added to the cultivation medium to maintain a pH favorable to fungus growth during the last stages of decomposition, avoiding the increase in acidity caused by fungal metabolism.

K is available for the fungus usually in the form of phosphate (0.0001-0.0004M), thus providing two essential minerals for its metabolism (Chang and Miles, 1989). This mineral is very important because it is a co-factor of several enzymatic systems, being the most abundant macroelement in mushrooms (Chang *et al*., 1981; Chang and Miles, 1989; Vetter, 1990, 1994; Strmisková *et al*., 1992; Miles and Chang, 1997; Sturion and Ranzani, 2000; Wang *et al*., 2001; Zhang and Fadel, 2002).

Fe, Zn, Al, Mn, Cu, Cr and Mo are among the most studied and most essential micronutrients (trace elements) for the growth of many species of fungi (Molena, 1986; Miles and Chang, 1997). Some chemical elements that have been detected in the constitution of fungi, however, do not necessarily indicate any biological importance. It is hard to experimentally determine the necessary amount of these elements

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COMPOSICIÓN MINERAL DE LA MATÉRIA PRIMA, EL SUBSTRATO Y LOS CUERPOS DE FRUCTIFICACIÓN DE *Pleurotus ostreatus*

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RESUMEN

En un cultivo del hongo Pleurotus ostreatus *fueron analizados los macro y micronutrientes de la materia prima y de los sustratos inicial y residual (post-cosecha). Los sustratos analizados fueron formulados a partir de aserrín de de* Simarouba amara *Aubl. y de* Ochroma piramidale *Cav. ex. Lam., y de bagazos de* Bactris gasipaes *Kunth y de* Saccharum officinarum *(caña de azúcar). Las muestras fueron solubilizadas por digestón ácida (nítrico-peridol). Los elementos Ca, Mg, Fe, Cu, Zn y Mn fueron determinados por espectrofotometría de absorción atómica, Na e K por emissión atómica, y el P por colorimetría. La composición mineral del hongo varió con el sustrato de cultivo y los sustratos posibilitaron la producción de un hongo rico en K, P, Mg e Fe. El potasio fue el mineral de mayor contenido en el hongo en todos los sustratos ensayados (36,83-42,18g·kg^{-1}). Hubo un aumento del contenido proteico y de minerales en el sustrato residual en relación al inicial*

COMPOSIÇÃO MINERAL DA MATÉRIA PRIMA, DO SUBSTRATO E DOS CORPOS DE FRUTIFICAÇÃO DE *Pleurotus ostreatus*

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RESUMO

Foram analisados macro e micronutrientes da matéria-prima, do substrato inicial, residual (pós-colheita) e do cogumelo no cultivo do Pleurotus ostreatus*. Os substratos analisados foram formulados a partir de serragem de* Simarouba amara *Aubl. (marupá) e de* Ochroma piramidale *Cav. ex. Lam. (pau de balsa) e dos bagaços de* Bactris gasipaes *Kunth (pupunheira) e de* Saccharum officinarum *(cana-de-açúcar). As amostras foram solubilizadas mediante digestão ácida (nitrico-peridrol). Os elementos Ca, Mg, Fe, Cu, Zn e Mn foram determinados por espectrofotometria de absorção atômica, Na e K por emissão atômica, e o P por colorimetria. A composição mineral do cogumelo variou com o substrato de cultivo e os substratos possibilitaram a produção de um cogumelo rico em K, P, Mg e Fe. O potássio foi o mineral de maior conteúdo no cogumelo em todos os substratos testados (36,83-42,18g·kg^{-1}). Houve um aumento do conteúdo protéico e de minerais no substrato residual em relação ao inicial*

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because the tested element may be present in sufficient amounts, in impure form, in some ingredient of the growth medium or may be introduced by means of the inoculum. These elements are constituents or activators of several enzymes (Miles and Chang, 1997).

The content of mineral components of wood such as Ca, Mg, P, Si, K and others is normally low, and made up mainly of oxides. The ash content of wood is also considered low, varying between 0.2 and 1% dry weight (Browing, 1963).

The present study aims to analyze minerals from new substrates and from the fungus in relation to new growth substrates, so as to know the chemical composition of alternative substrates formulated with wood and agroindustrial wastes found in Amazon for the cultivation of *Pleurotus*, as well as the chemical composition of this strain in relation to the substrate on which it is grown, in order to better manage cultivation for future application in the growth of edible mushrooms in the region.

Materials and Methods

Samples

Samples were divided into raw material (analyzed separately), substrates (initial and spent) and the fruiting bodies harvested on the different substrates, described as follows:

Raw material: rice bran (RB); wheat bran (WB); corn bran (CB); bran mixture (BM) in the proportion of 60:20:20% for the respective brans; *Simarouba amara* Aubl. ("marupá") sawdust (MS); *Ochroma piramidale* Cav. ex. Lam. ("pau de balsa") sawdust (PB); ground stems of *Bactris gasipaes* Kunth ("pupunheira") palm tree (PP); and *Saccharum officinarum* (sugar cane) bagasse (SC).

Initial substrate, sterilized in autoclave previous to use, made up with the mixture of each sawdust or bagasse + brans mixture (BM). The codification employed for the initial autoclaved substrates (ISA) was ISAMP for ISA from "marupá" sawdust, ISAPB for ISA from "pau de balsa" sawdust, ISAPP from waste of the crushed stipe of "pupunheira", and ISASC from sugar cane bagasse.

Spent substrate (SS), resulting from the final process of the cultivation of *Pleurotus ostreatus* on the respective substrates mentioned above, codified as SSMP, SSPB, SSPP and SSSC.

Fruiting bodies, harvested on the respective initial substrates: ISAMP-MUSH, ISAPB-MUSH, ISAPP-MUSH and ISASC-MUSH.

Determination of macro and micronutrients

The analyses of macronutrients (Ca, Mg, P and K) and micronutrients (Na, Fe, Cu, Mn and Zn) were carried out in triplicate, following the same protocol used for the analysis of soil and plants (Malavolta *et al*., 1989) in order to verify the presence of mineral compounds. Samples were dried and finely crushed in a Willey knife mill at the Department of Forest Products of the National Institute for Amazonian Research, for further digestion and analyses at the Laboratory of Soils and Plants Analysis of the same institute and of the Analysis Center of the Federal University of Amazonas.

Samples were weighed (0,5g), digested with nitric-perhydrol acid mixture and solubilized. Ca, Mg, Fe, Cu, Mn and Zn contents were determined by means of atomic absorption spectrophotometry, Na and K by atomic emission, and P by UV-visible colorimetry, all previously calibrated with standard solutions for each element (AOAC, 1997). Macronutrients (Ca, P, Mg and K) values were calculated

TABLE I
MINERAL COMPOSITION OF THE RAW MATERIAL ANALYZED

Raw material	Macronutrients				Micronutrients				
	Ca	Mg	P	K	Na	Fe	Zn	Mn	Cu
	g·kg^{-1}				mg·kg^{-1}				
RB	0.63 ±0.09	7.02 ±0.50	22.55 ±0.11	19.41 ±2.33	270.00 ±14.14	98.00 ±1.73	77.67 ±1.53	212.33 ±0.58	8.00 ±0.00
WB	1.03 ±0.03	4.01 ±0.08	11.72 ±0.11	10.63 ±0.18	380.00 ±14.14	146.00 ±4.36	109.67 ±0.58	151.33 ±0.58	13.33 ±1.53
CB	0.93 ±1.38	1.17 ±0.15	2.70 ±0.01	3.60 ±0.35	300.00 ±0.00	33.6 ±1.53	32.33 ±1.15	6.33 ±0.58	3.00 ±1.00
BM	0.52 ±0.20	6.09 ±0.08	9.71 ±0.22	15.01 ±0.36	305.00 ±5.23	98.33 ±0.58	91.00 ±0.00	192.33 ±0.58	8.33 ±0.58
MS	2.75 ±0.21	0.24 ±0.00	0.52 ±0.01	1.06 ±0.05	400.00 ±0.00	75.33 ±2.52	11.67 ±0.58	6.00 ±0.00	7.00 ±0.00
PBS	5.50 ±2.26	0.81 ±0.01	0.51 ±0.04	2.40 ±0.09	403.33 ±5.77	47.33 ±1.15	22.33 ±1.15	5.33 ±0.58	9.00 ±0.00
PP	2.97 ±0.64	1.25 ±0.01	3.27 ±0.01	9.77 ±0.09	290.00 ±0.00	63.67 ±3.21	97.33 ±1.15	5.33 ±0.58	12.00 ±0.00
SC	0.63 ±0.04	0.07 ±0.01	2.87 ±0.03	1.88 ±0.07	515.00 ±1.21	35.33 ±0.58	11.33 ±0.58	7.33 ±0.58	5.00 ±0.00

All values are mean (±SD) of three replicates.
RB: rice bran. WB: wheat bran, CB: corn bran, BM: bran mixture, MS: "marupá" (*Simarouba amara* Aubl.) sawdust, PBS: "pau de balsa" (*Ochroma piramidale* Cav. ex. Lam.) sawdust, PP: ground "pupunha" (*Bactris gasipaes* Kunth), SC: sugar cane (*Saccharum officinarum*) bagasse.

in g·kg^{-1} and micronutrients (Na, Fe, Cu, Mn and Zn), in mg·kg^{-1}.

Results and Discussion

According to Kurtzman and Zadrazil (1982), P. K, Fe and Mg are the most important minerals for the cultivation of *Pleurotus*. As confirmed in this study, they are naturally present in all of the raw materials used in the preparation of the cultivation substrate (Table I). Fe, Zn, Mn, Cu, Cr and Mo are among the essential and most studied microelements (trace elements) for the growth of many species (Molena, 1986; Miles and Chang, 1997).

The results related to macro and micro minerals analyzed in the different substrates, moistened and sterilized, are presented in Table II. These minerals were present in the raw material, as well as in all substrates tested, with higher amounts in the substrate formulated from residues of *Bactris gasipaes* Kunth (ISAPP), in agreement with the above authors. Cr, Mo and S were not analyzed in the present study.

The amount of macronutrients present in the initial substrates analyzed (Table II) followed the order Ca>K>P>Mg, while micronutrients followed the order Na>Fe (except for ISAPP and ISASC, in which Fe was higher than Na) >Mn>Zn>Cu. The presence of these minerals in the substrates tested reveal their importance for mushroom cultivation (Kurtzman and Zadrazil, 1982; Molena, 1986; Chang and Miles, 1989; Miles and Chang, 1997).

The results of macro and micro minerals present in post-harvest or spent substrates (SS) are presented in Table III. Their concentrations follow the orders Ca>P>K>Mg for macro and Zn>Fe>Mn>Na>Cu micronutrients. These spent substrates underwent modifications in its composition, resulting in a different substrate composition from that of the initial one. According to Oliveira (2000) the degradation level varies with the genetic composition of the *Pleurotus* species used, besides physical, environmental, chemical and biological factors.

According to Rajarathmam and Bano (1989), cited by Sturion (1994), the reduction in the organic matter of the substrate is due to CO_2 and H_2O losses during the metabolism of the fungus, and also because of the removal of substances from the substrate for the construction of the fruit body. These losses are usually higher during the fruiting process than during mycelium development. The amino acidic nitrogen tends to increase due to the proteases activity justified by the loss of CO_2, as well as a progressive decrease of phenolic compounds if the incubation period is longer, due to the activity of the oxidant enzymes, secreted by *Pleurotus*, which degrade phenols (Rajarathmam and Bano, 1989).

Comparing data from Tables II and III the increased mineral composition of SS in relation to the of the initial substrate can be noticed for most elements, except for K, whose values were lower in all spent substrates, as well as P values of spent substrates SSMP and SSPB, which presented lower values than the initial substrate. Among micronutrients, Cu in SSPP and SSSC also revealed lower values than their respective ISA, before being decomposed by the fungus.

The relative increase of the mineral content in spent substrates was also verified in other studies (Zadrazil, 1978; Sturion, 1994; Oliveira, 2000; Silva *et al*., 2002), resulting from the cultivation of different *Pleurotus* strains in several agricultural residues. Ca was the element in the highest amount in SS, both in this study (Table III) and the cited ones.

TABLE II
MINERAL COMPOSITION OF INITIAL SUBSTRATES STERILIZED IN AUTOCLAVE (ISA)

Sterilized initial substrate	Macronutrients				Micronutrients				
	Ca	Mg	P	K	Na	Fe	Zn	Mn	Cu
	g·kg^{-1}				mg·kg^{-1}				
ISAMP	9.79 ±0.77	1.49 ±0.13	3.78 ±0.00	3.67 ±0.10	67.03 ±0.10	64.00 ±1.00	21.33 ±4.51	34.67 ±0.58	3.49 ±0.39
ISAPB	10.27 ±0.61	1.75 ±0.12	3.78 ±0.01	7.92 ±0.32	66.83 ±0.16	61.66 ±1.53	29.33 ±6.66	35.00 ±1.00	5.02 ±0.06
ISAPP	36.8 ±2.22	2.38 ±0.11	7.18 ±0.17	8.55 ±0.44	66.85 ±0.27	104.33 ±1.15	82.00 ±1.00	40.00 ±0.00	9.35 ±0.04
ISASC	8.42 ±0.02	1.49 ±0.01	3.55 ±0.01	3.35 ±0.03	41.15 ±1.37	67.67 ±0.58	32.00 ±2.00	37.33 ±1.53	9.94 ±0.98

All values are mean (±SD) of three repetitions per substrate in relation to each mineral.
ISAMP: initial substrate formulated from "marupá" (*Simarouba amara* Aubl.) sawdust, ISAPB: initial substrate formulated from "pau de balsa" (*Ochroma piramidale* Cav. ex. Lam.) sawdust, ISAPP: initial substrate formulated from grinded stipe of the "pupunheira" (*Bactris gasipaes* Kunth), ISASC: initial substrate formulated from sugar cane (*Saccharum officinarum*) bagasse.

TABLE III
MINERAL COMPOSITION OF SPENT SUBSTRATES: POST-HARVEST (SS)

Spent substrate (post-harvest)	Macronutrients				Micronutrients				
	Ca	Mg	P	K	Na	Fe	Zn	Mn	Cu
	g·kg^{-1}				mg·kg^{-1}				
SSMP	24.66 ±0.02	2.65 ± 0.03	3.63 ±0.01	2.90 ±0.02	79.34 ±9.43	213.33 ±1.53	426.33 ±0.58	123.00 ±1.00	8.20 ±0.52
SSPB	26.35 ±0.15	3.44 ±0.02	3.70 ±0.01	4.47 ±0.03	98.33 ±4.78	312.67 ±2.08	480.00 ±0.00	1117.67 ±1.53	7.43 ±0.27
SSPP	39.94 ±0.03	3.51 ±0.01	7.36 ±0.11	6.21 ±0.01	112.70 ±0.10	217.00 ±1.00	427.00 ±1.00	112.00 ±1.00	7.48 ±0.59
SSSC	25.14 ±0.02	2.47 ±0.03	3.80 ±0.01	2.31 ±0.01	121.03 ±0.42	178.00 ±1.00	355.00 ±1.00	125.67 ±1.53	40.46 ±0.43

Mineral composition of spent substrates: post-harvest (SS)
All values are mean (±SD) of three repetitions per substrate in relation to each mineral.
SSMP: spent substrate originating from "marupá" sawdust, SSPB: spent substrate originating from "pau de balsa" sawdust, SSPP: spent substrate originating from grinded stipe of the "pupunheira", SSSC: spent substrate originating from sugar cane bagasse.

Zadrazil (1978) analyzed minerals in the different development stages of *P. ostreatus* and author reports an increase of minerals (N, P, K, Ca and Mg) and ash contents in the substrate until the stage preceding fruiting (vegetative phase, in which the mycelium of the fungus stores nutrients for the fruiting body formation), followed by a slight decrease in N, K and P, showing a selective removal of nutrients towards the basidioma in the process of fruiting body formation. In spite of this, SS presented an increase of minerals contents in relation to ISA. The author mentions that the SS, rich in nutrients, presented high digestibility due to cellulose and lignin degradation, with increased solubility, consequently offering higher content of free sugars (glucose), which makes it useful as basis for the champignon compost, organic fertilizer and animal feed.

Rajarathnam and Bano (1992), studying basidiomycetes potentiality, report the increase of ash contents in SS, as a result of the constant use of organic matter by the fungus, from the incubation stage (vegetative growth) to the end of cultivation, making minerals release for the final substrate possible.

In the present work, although minerals have not been analyzed in the different growth stages of the fungus, a remarkable increase in their contents was found in the substrate decomposed by the fungus (SS). This characteristic is useful for the animal feed industry and for the formulation of organic fertilizers. There is abundant literature concerning the use of spent substrate resulting from the culture of *Pleurotus* as fertilizer for the production of vegetables (Maher, 1991), ingredient for animal food (Alborés *et al*., 2006) and cultivation substrate for other species of fungi (Silva *et al*., 2002).

Concerning the increase of minerals and ash contents in SS, it is relevant to emphasize the importance of additional studies to verify the causes of such high contents, much higher to the ones found in the initial substrate.

Table IV shows the mineral content in *P. ostreatus* fruiting bodies grown in the different substrates, characterizing *P. ostreatus* as a source of minerals, in accordance with Chang and Miles (1989), Miles and Chang (1997), Vetter (1990, 1994), Sturion and Ranzani (2000), Zhang and Fadel (2002) and Bernás *et al.* (2006).

Mushrooms are an important source of minerals which are removed from the substrate by the mycelium, being supplied during mycelium growth of the fungus and translocated to the fruit body during its formation process (Chang and Miles, 1989).

The mineral constituents of mushrooms are basically the same of superior plants. As in those plants, K is the most abundant mineral, followed by P and Mg, confirming literature data (Chang *et al*., 1981; Chang and Miles, 1989; Strmisková *et al*., 1992; Vetter, 1990, 1994; Sturion, 1994; Sturion and Oetterer, 1995; Miles and Chang, 1997; Sturion and Ranzani, 2000; Wang *et al*., 2001; Bernás *et al*., 2006). This finding is confirmed in Table IV, where K is the most abundant macronutrient in all the substrates tested, varying from 36.83 to 42.18g·kg^{-1}, followed by P (6.95-10.60), Mg (1.57-2.50) and Ca (0.34-0.60).

In the present work, K, P and Mg values of mushrooms cultivated in the several residues are superior to the ones presented by Vetter (1990) by and Sturion (1994), where the authors grew several strains of *Pleurotus* in different agricultural residues, as well as the results for K and Mg reported by Chang *et al.* (1981) and Vetter (1994), and the research conducted by Sturion and Ranzani (2000), in which the authors analyzed several commercial strains of *Pleurotus* grown in Brazil and, finally, the results reported by Wang *et al.* (2001) when they grew *P. ostreatus* in barley residue.

According to Li and Chang (1982), cited by Chang and

TABLE IV
MINERAL COMPOSITION OF *Pleurotus ostreatus* MUSHROOM GROWN IN THE DIFFERENT SUBSTRATES

Mushroom per substrate	Macronutrients				Micronutrients				
	Ca	Mg	P	K	Na	Fe	Zn	Mn	Cu
	g·kg^{-1}				mg·kg^{-1}				
ISAMP-MUSH	0,47 ±0.06	2.50 ±0.02	7.40 ±0.17	39.68 ±0.66	154.00 ±16.97	151.00 ±1.73	118.00 ±1.00	23.00 ±1.00	11.69 ±0.05
ISAPB-MUSH	0.34 ±0.01	2.12 ±0.02	10.60 ±0.22	36.83 ±1.01	172.67 ±5.40	131.33 ±1.15	124.00 ±1.00	20.33 ±0.58	10.40 ±0.32
ISAPP-MUSH	0.57 ±0.04	1.57 ±0.01	9.74 ±0.13	42.18 ±0.43	181.90 ±2.12	115.67 ±1.15	82.00 ±2.65	16.00 ±0.00	9.10 ±0.31
ISASC-MUSH	0.60 ±0.03	2.12 ±0.02	6.95 ±0.28	41.52 ±0.74	194.40 ±8.20	123.00 ±1.00	96.00 ±1.00	20.67 ±0.58	10.39 ±0.27

All values are mean (±SD) of three repetitions per substrate in relation to each mineral.
ISAMP-MUSH: mushroom grown in substrate originating from "marupá" sawdust, ISAPB-MUSH: mushroom grown in substrate originating from "pau de balsa" sawdust, ISAPP-MUSH: mushroom grown in substrate originating from grinded stipe of the "pupunheira" ISASC-MUSH: mushroom grown in substrate originating from sugar cane bagasse.

Miles (1989), the K, P, Na, Ca and Mg contents of the fruiting body are responsible for 56-70% of its total ash contents, where K represents ~45%, which shows the abundance of this mineral in the mushroom. In the present study, K, P and Mg were found in higher amounts in the mushrooms than in the initial substrate, except for the Mg found in fruiting body harvested on *Bactris gasipaes* Kunth (PP) residue substrate, as can be seen comparing Tables II and IV. The same was verified by Bano and Rajarathnam (1988) for P, when they grew different species of *Pleurotus* in rice straw. P and K contents were also higher in the mushrooms than in the substrate in the works carried out by Zhang and Fadel (2002) when they grew *Pleurotus sajor-caju* in rice and wheat straw. Similar results were obtained with Mg and K by Sapata (2005).

The K translocation process in the basidioma appears to be very efficient, because the higher its content in the mushroom (Table IV), the lower its content in the corresponding spent substrate (Table III).

The Ca amount found corresponds to the lowest concentration in the present study (0.34-0.60g·kg^{-1}), in agreement with published results, except for *Pleurotus tuber-regium* (Akindahunsi and Oyetayo, 2006), where Ca content is higher than that of P.

Among micro minerals present in the mushrooms grown in the several substrates analyzed, Na was the one with the highest content in all substrates tested, varying from 154.00 to 194.40mg·kg^{-1}, followed by Fe (115.67–151.00mg·kg^{-1}), Zn (64.67-82.00), Mn (16.00-23.00) and Cu (9.10-11.69). Although Na presents the highest value among micro minerals, it is considered low concerning human diet, according to Sturion and Ranzani (2000). This fact makes this mushroom of interest in the treatment of patients with hypertension, added to the fact that it is rich in K.

For the same minerals analyzed, Strimisková *et al.* (1992) obtained the following values (mg·kg^{-1}) and order: Na (195.0) >Fe (90.3) >Zn (67.6) >Cu (15.1) >Mn (7.4). The order was basically the same as that in the present study, except for Mn, which was lower than Cu.

The chemical composition of the mushrooms varied according to the substrate in which it was grown, as was also detected in former studies (Chang *et al*., 1981; Sturion, 1994; Silva *et al*., 2002).

Conclusions

-- There was an increase of mineral content in the substrate decomposed by the fungus (spent substrate, SS), as a result of the use of organic matter by the fungus from the incubation stage (vegetative growth) to the end of cultivation allowing the release of minerals.

-- The highest content found in all substrates tested (ISAMP, ISAPB, ISAPP and ISASC) was that of K, varying from 36.83 to 42.18g·kg^{-1} and followed by P (6.95-10.60) and Mg (1.57-2.50).

-- The mineral composition of the mushrooms varied with the substrate.

-- The different substrates used in the present study produced mushrooms rich in K, P, Mg and Fe, important to human nutrition and health.

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