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The production of *Pleurotus sajor-caju* in peach palm leaves (*Bactris gasipaes*) and evaluation of its use to enrich wheat flour

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Abstract

The aim of this study was to evaluate of *Pleurotus sajor-caju* production in peach palm leaves and the addition of different fractions of mushroom powder to wheat flour to increase its nutritional value without changing its characteristics. The best yield (48.4%), biologic efficiency (4.5%), and Pr (0.36 g/day) values were obtained using 20% inoculum fraction and 10% rice bran fraction. The *Pleurotus sajor-caju* fruiting body cultivated under these conditions had the following composition in 100 g: 29.91 g (carbohydrates), 42.92 g (proteins), 1.24 g (lipids), 15.93 g (fibers), 7.42 g (ashes), 1.6 g (phosphorus), 2.7 g (potassium), 8.73 mg (iron), 23.75 mg (sodium), 0.34 mg (thiamine), and 0.57 mg (riboflavin). The wheat flour with mushroom powder had reduced sugar content, but it did not have increased fat content. The fiber, protein, phosphorus, potassium, iron, and riboflavin contents were increased mainly when 10% mushroom powder was added to the wheat flour**.** Furthermore, this flour does not undergo drastic alterations in its physicochemical characteristics such as in moisture, wet gluten, color, and falling number.

Keywords: nutritional value; wheat flour; mushrooms.

1 Introduction

The cultivation and extraction of hearts of palm produce large amounts of waste, and according to Soto et al. (2005), only a small part of it is commercialized in the form of canned hearts of palm (estimated to be less than 10% of the palms); thus, most of the palm trees remain in the soil after extraction.

The incorporation of non-decomposed organic matter in the soil implicates in the humification process, prompting intense microbial activity leading to a temporary nitrogen deficiency, which is consumed by the microorganisms to the detriment of the plants (Medina, 1990). Furthermore, the cultivation of peach palms for the production of hearts of palm is intensive (5000 to 6600 plants/ha), and the crops occupy the most diverse agro-bioclimatic regions (Bovi, 2000).

One feasible way of minimizing this probable environmental impact is by making better use of the cultivation using alternative approaches that could increase revenue for the producer while using the same space. This agroecological waste consists of lignocellulosic plant matter, which could be used as a renewable source of substrate for biological conversion into microbial biomass of high nutritional value (Philippoussis, 2009).

The *Pleurotus* genus of the class Basidiomycetes belongs to a group known as "white rot fungi" since they produce a white mycelium and degrade lignin and cellulose (Carvalho et al., 2010). Its cellulolytic enzyme complex contains enzymes such as cellulase, ligninase, cellobiase, laccase and hemicellulase (Kong, 2004). However, as far as its cultivation is concerned, it is known that nutrient restriction limits mushroom growth (Carvalho et al., 2010) and that the inoculum fraction has a significant influence on the productive parameters yield and biological efficiency (Bhatti et al., 2007).

The fruiting bodies (mushrooms) of the *Pleurotus* genus are appreciated not only for their taste, but also for their high nutritional value. They have large amounts of high quality protein, essential amino acids, various vitamins and minerals, as well as low fat and calorie contents (Kakon et al., 2012). Rampinelli et al. (2010) found that the fruting bodies of *Pleurotus djamor* are a source of P and K, in addition to having low sugar content and not containing fat. They can contribute to the intake of vitamins B_1 and B_2.

Furthermore, the *Pleurotus* genus has attracted great interest from the scientific community for having medicinal properties capable of modulating the immune system, exhibiting hypoglycemic and antithrombotic activities, reducing blood pressure and blood cholesterol, and for having anti-inflammatory, anti-microbial, and anti-tumor actions (Chang & Miles, 2004). Polysaccharides synthesized by *Pleurotus*, including the β-glucans, are considered primarily responsible for their therapeutic properties (Zong et al., 2012).

Nevertheless, mushrooms are not part of the traditional diet of the Brazilian population (Bett & Perondi, 2011), which is evidenced by their low consumption (around 30-60 g per inhabitant) when compared to that of other countries such as France (2 kg/inhabitant), US (1.6 kg/inhabitant), Italy (1.3 kg/inhabitant), and Germany (3.5 kg/inhabitant). About 60% of the production in Brazil is consumed as fresh mushrooms, and the other 40% is used by the food processing industry (Kasuya et al., 2005). On the other hand, consumers have been searching for good quality products that offer natural sources of vitamins (Furlani & Godoy, 2007). The belief that health depends on nutrition has resulted in the need

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to adopt healthy eating habits in order to prevent diseases, which should include the entire Brazilian population, based on foods containing the nutrients needed to ensure good health (Sichieri et al., 2000).

Focusing on the prevention and control of nutritional disorders and diseases related to food and nutrition and since wheat is a staple food in the Brazilian diet, the Decree no. 344 (Brasil, 2002) has established that the addition of 4.2 mg iron and 150 mg folic acid per 100 g wheat flour is mandatory. Bread is an important basic foodstuff worldwide; therefore, it could be an excellent and convenient food item for protein fortification to improve people's nutritional well-being/health. Mushrooms are commonly used as food and can be added to food as a supplement in order to encourage and increase their consumption and provide beneficial health effects through various food products. Bread is consumed all over the world. Various food ingredients have been added to bread formulation to increase its diversity, nutritional value, and product appeal (Ulziijargal et al., 2013; Okafor et al., 2012; Tseng et al., 2010).

The literature on the fortification of wheat flour with mushrooms is scarce. Recently, Ulziijargal et al. (2013) evaluated the supplementation of wheat flour with mycelium. The authors found that when 5% of lyophilized mycelium of *Antrodia camphorata, Agaricus blazei, Hericium erinaceus,* and *Phellinus linteus* are added in the flour, the resulting bread was smaller in volume, lighter in weight, and darker in color. However, the substitution of 5% wheat flour for mycelium powder did not adversely affect the texture profile of the bread, and it was concluded that overall, the mushroom mycelium could be incorporated into the bread to provide it with beneficial health effects. Okafor et al. (2012) evaluated bread produced by replacing wheat flour with 5, 10, 15, 20, and 25% mushroom powder (*Pleurotus pulmonarius*). It was found that up to 10% of mushroom powder could be added to wheat flour without causing any adverse effect on the sensory properties of the bread. Tseng et al. (2010) used silver ear mushroom (*Tremella fuciformis* Berkeley) to substitute wheat flour to make bread. It was found that silver ear mushroom could be incorporated into bread to provide beneficial health effects.

Thus, the objective of this study was to evaluate the production of *Pleurotus sajor-caju* using peach palm leaves (agro industrial waste) as substrate with different inoculum and rice bran (nitrogen source) fractions. Furthermore, the fruiting bodies obtained under the best cultivation conditions were dried, processed into powder, and used to substitute 5 and 10% of wheat flour to increase its nutritional value.

2 Materials and methods

2.1 Microorganism and inoculum

Pleurotus sajor-caju CCB 019 was obtained from the Center for Basidiomycete Cultivation of the University of São Paulo. The strain was grown in wheat dextrose agar (WDA) medium (Furlan et al., 1997) and stored under refrigeration (4°C). Wheat grains were used as substrate and support to produce the inoculums. The grains were cooked, supplemented with $CaCO_3$ and $CaSO_4$ and sterilized in an autoclave at 121 °C, for 1 h. After the sterilization, they were inoculated with 8 mm diameter agar discs containing mycelium and incubated at 30°C in the dark for 15 days (Bonatti et al., 2004).

2.2 Fruiting body production

The experiments conducted for the production of *Pleurotus sajor-caju* using peach palm leaves are described in Table 1. The inoculum and rice bran fractions were defined according to preliminary results using intermediate values 10 and 5%, respectively (Experiment 5).

The peach palm leaves were ground into 2-5 cm particles and packed in raffia bags which were immersed in water for 12 h and then drained for approximately 2 h (Madan et al., 1987). Subsequently, 150 g (dry weight) were packed in transparent polypropylene autoclavable bags (28 x 40 cm), supplemented with 2, 5, or 10% of rice bran (Table 1) and closed while maintaining a vent filled with foam in order to allow moderate air exchange and avoid external contamination.

The aim of rice bran supplementation was to supply the necessary nitrogen for the growth of basidiomycete. Lignocellulosic wastes generally have low nitrogen content, 2.76% in peach palm leaves (Deenik et al., 2000), while rice bran has 4.58% (Sales-Campos et al., 2010). The plastic bags containing the substrate were homogenized and sterilized at 121 °C, for 2 h.

Inoculation was performed using a laminar air flow cabinet using 5, 10, or 20% inoculum on dry weight basis (Table 1). The incubation conditions used were: 30 °C in the dark for approximately 20 days, until complete mycelium colonization. Later, the induction of the fruiting bodies formation was achieved using perforated plastic bag (to increase air exchange) and light (270 lux) exposure for a period of 12 h per day. Temperature was kept around 28 °C and relative air humidity around 90% (Bonatti et al., 2004). Harvest point was defined through visual analysis (Sturion & Oetterer, 1995), when the edges of the pileus appeared flat in the stage prior to sporulation, as shown in Figure 1.

The fruiting bodies were harvested using a scalpel, weighed to determine the wet mass, and dehydrated at 40 °C for 24 h with forced air circulation (1370fx, SHEL LAB, Cornelius, USA) to determine the dry mass.

2.3 Production parameters

The experiments were performed with 7 replicates and were evaluated in terms of yield (Y % = fresh fruiting bodies mass x 100/dried initial substrate mass), biologic efficiency

Table 1. Experiments for the production of *Pleurotus sajor-caju.*

Experiment	Inoculum fraction (%)	Rice bran fraction (%)
01	5	10
02	5	2
03	20	10
04	20	2
05 (Control)	10	5

Figure 1. Harvest point of *Pleurotus sajor-caju.* Source: Primary.

(BE % = dried fruiting bodies mass x 100/dried initial substrate mass), and productivity (Pr – g/day = dried fruiting bodies mass/total cultivation time) (Holtz et al., 2009).

2.4 Sample preparation

Bunge Brasil (Joinville Mill – SC) provided the enriched wheat flour without mixed grains used in the experiments. The dried fruiting bodies were mixed and ground using a blender. These samples were dried to constant mass at 105 °C. The added mushroom powder was used to replace 5 and 10% w/w of wheat flour (Ulziijargal et al., 2013).

2.5 Analyses

The amount of total protein in wheat flour was estimated by the Kjeldahl macro method according to the 46-11A of AACC (American Association of Cereal Chemists, 1999), obtaining the total nitrogen content and later the protein content. The protein content in the mushroom powder was determined in the same way, considering that just 70% of nitrogen compounds found in mushrooms are digestible by the human body and using 4.38 as correction factor (Bonatti et al., 2004). The fat content was determined gravimetrically after continuous extraction of the samples with sulfuric ether in a Soxhlet apparatus, according to the method of the Instituto Adolfo Lutz (2005). The dietary fiber content was determined by the enzymatic/gravimetric 985.29 method of AOAC (Association of Official Analytical Chemists, 2005). The ash content was calculated based on the sample mass after incineration, according to the physicochemical method of the Instituto Adolfo Lutz (2005). The carbohydrate content was determined by difference, subtracting the sum of protein, fat, fiber, ash, and moisture from 100%, according to the Resolution no. 360, Anvisa (Brasil, 2003). The moisture content was determined by the difference between the weight of wet and dry samples at 105 °C until reaching constant weight, divided by the wet sample weight, times 100 (Association of Official Analytical Chemists, 2005). For the vitamin B_1 and B_2 analyses, an HPLC (Shimadzu) equipped with a C18 column (15 cm length and 5 μm particle size) and a fluorescence detector was used. The mobile phase used for B_1 and B_2 consisted of potassium chloride 0.038 $mol.L^{-1}$ and methanol. The Instituto Adolfo Lutz (2005) method was used for the measurements of phosphorus, potassium, and iron by atomic absorption spectrometry with flame. The sodium content was determined according to the method of ANFAL (Associação Nacional dos Fabricantes de Alimentos, 2005). The moisture (%), wet gluten (%), color (L*), and Falling Number (seconds) analyses were performed with the wheat flour without and with 5 or 10% mushroom powder (item 2.4). The wet gluten (%) determination was performed according to the AACC method 38-12 (American Association of Cereal Chemists, 1999) by washing the sample (10 g) with a 2% sodium chloride solution, followed by separation of gluten forming insoluble proteins (gliadins and glutenins) using the Glutomatic apparatus (Peter Instruments North America Inc., Reno, USA). The wet gluten percentage was obtained on 14% moisture basis by calculating the ratio of the total weight of wet gluten/g to 100% sample moisture. Luminosity (L*) was determined using a Minolta colorimeter, according to the AACC method 14-22 (American Association of Cereal Chemists, 1999). The Falling Number was obtained by measuring the ability of the alpha-amylase enzyme to liquefy a starch gel (in seconds), according to the AACC method 56-81B (American Association of Cereal Chemists, 1999).

2.6 Statistical analysis

All data obtained were submitted to the outlier rejection test (Dixon Q test) (Rorabacher, 1991). The results of the centesimal composition of the fruiting bodies and the wheat flour were expressed as means, and the results of the physicochemical analyses were submitted to analysis of variance using the Tukey Test with significance level of 5% (Anova).

3 Results and discussion

3.1 Evaluation of fruiting body production

Results of the Y (%), BE (%), and Pr (g/day) values are presented in Table 2.

Table 2 shows that there is no statistical difference in the Y of experiment 5 (control) in relation to the other experiments. The Biologic Efficiency (EB) of experiment 3 was higher (4.5 ± 0.3%) than that of the control experiment (3.3 ± 0.6%). The same was observed for Pr, which was higher in experiment 3 (0.36 ± 0.04 g/day) and lower in experiment 4 (0.21 ± 0.03 g/day) compared to that of the control (0.30 g/day).

When compared to the yield (Y), the biological efficiency (BE) is a more accurate parameter since it deals with the relationship between the dry fruiting body weight and the dry substrate weight, that is, without moisture interference. Thus, the best results for *Pleurotus sajor-caju* production in peach palm leaves in terms of Biological Efficiency (BE) and Productivity (Pr) were obtained using 20% (w/w) inoculum and 10% (w/w) rice bran (Experiment 3).

Castro et al. (2007) obtained 55.76% yield with *P. sajor-caju* cultivated in cotton textile waste with 10% wheat flour, and Patil (2012) obtained yield values of 84.56% in soybean straw.

Pleurotus sajor-caju had 48.4% yield (Experiment 3 – Table 2), similar to the results found for *P. ostreatus* (46.67%) banana straw (Furlan et al., 2008), and *P. pulmonarius* (43%) in corn straw (Oliveira et al., 2007). Biological efficiency values varying from 4.08 to 5.03% were found in literature (Bhatti et al., 2007; Holtz et al., 2009; Furlan et al., 2008), values that are similar to those found in this study (4.5%). Holtz et al. (2009) found productivity value of 0.37 g/day with *P. ostreatus* cultivated in cotton textile waste; this value is very close to that found in this study, 0.36 g/day.

3.2 Evaluation of nutritional potential

The production of edible dried and ground mushrooms from the drying and grinding of fruiting bodies can be an option for the nutritional enrichment of diets. One of the objectives of this study was to add wheat flour with 5 and 10% mushroom powder and evaluate its nutritional value and characteristics before and after the addition. Therefore, Table 3 shows the contents of carbohydrates, total fat, fibers, proteins, phosphorus, potassium, iron, sodium and vitamin in the mushroom powder of the fruiting bodies, the wheat flour, and the wheat flour with 5 and 10% mushroom powder (w/w), which were compared to the values as established in the Decree no. 27 of 13th January 1998 of Anvisa – National Agency of Sanitary Surveillance (Brasil, 1998), which approves the Technical Regulation in relation to Complementary Nutritional Information (statements related to nutrient contents).

According to Table 3, the mushroom powder can be considered a food containing sugars, but with low fat content, very low sodium content, high fiber content, proteins, phosphorus, potassium, iron, riboflavin, and source of thiamine. The wheat flour used in this study contained sugars, had low fat content, and high protein, iron, and thiamine content; it was a source of phosphorus and contained fibers, potassium, and sodium.

In general, the addition of with 5 or 10% mushroom powder did not change the classification of the flour when compared to the values according to Decree no. 27 of Anvisa (Brasil, 1998), except for the phosphorus content, which went from being a phosphorus source in the wheat flour to being excessive phosphorus content in the wheat flour with 5 or 10% mushroom powder.

However, the addition of wheat flour with 5 or 10% mushroom powder reduced the sugar content, but it did not increase the fat content, remaining similar to the flour without

Table 2. Mean values ± standard deviation obtained to study the effect of inoculum and rice bran fractions on Y (Yield), BE (Biologic Efficiency) and Pr (Productivity).

Experiment	Inoculum Fraction (%)	Rice bran fraction (%)	Mean ± standard deviation Y (%)	BE (%)	Pr (g/day)
1	5	10	31.4 ± 3.9*a*	2.9 ± 0.4*b*	0.21 ± 0.05*d*
2	5	2	45.8 ± 7.7*a*	3.4 ± 0.3*b*	0.27 ± 0.03*d*
3	20	10	48.4 ± 16.1*a*	4.5 ± 0.3*c*	0.36 ± 0.04*e*
4	20	2	34.4 ± 5.1*a*	3.2 ± 0.4*b*	0.21 ± 0.03*f*
5 (Control)	10	5	44.6 ± 12.2*a*	3.3 ± 0.6*b*	0.30 ± 0.03*d*

Different lowercase letters in the same column indicate that the means differed statistically according to the Tukey's test (P < 0.05) between experiment 5 (control) and the other experiments.

Table 3. Mean carbohydrate (sugars), total fat, proteins, fibers, phosphorus, potassium, iron, sodium, and vitamin values for the mushroom powder, wheat flour, and wheat flour with 5 and 10% mushroom powder and comparison with Decree no. 27 (Brasil, 1998) values.

Nutrients	*P. sajor-caju*/ According to Decree no. 27*	Wheat flour/ According to Decree no. 27*	Wheat flour with 5% *mushroom powder*/ According to Decree no. 27*	Wheat flour with 10% *mushroom powder* / According to Decree no. 27*
Sugars (g/100g)	29.9 / Contain	72.3 / Contain	70.2 / Contain	68.1 / Contain
Fat (g/100g)	1.2 / Low content	1.6 / Low content	1.6 / Low content	1.6 / Low content
Fibers (g/100g)	15.9 / High content	<0.50 / Not containing	0.79 / Not containing**	1.6 / Not containing**
Proteins (g/100)	42.9 / High content	12.4 / High content	13.9 / High content	15.5 / High content
Phosphorus (mg/100g)	1602.8 / High content	184.7 / Source	255.6 / High content	326.4 / High content
Potassium (mg/100g)	2722.6 / High content	437.5 / Not containing	551.8 / Not containing	666.1 / Not containing
Iron (mg/100g)	8.7 / High content	4.2 / High content	4.4 / High content	4.6 / High content
Sodium (mg/100g)	23.8 / Very low content	2.1 / Not containing	3.2 / Not containing	4.2 / Not containing
Thiamine (mg/100g)	0.34 / Source	0.67 / High content	0.65 / High content	0.64 / High content
Riboflavin (mg/100g)	0.57 / High content	<0.40 / Not containing**	0.028 / Not containing**	0.057 / Not containing**

*Sugars – Low content: Maximum of 5 g/100g. Not containing: Maximum of 0.5 g/100g. Total fat – Low content: Maximum of 3 g/100g. Not containing: Maximum of 0.5 g/100g. Fibers – Source: Minimum of 3 g/100g. High content: Minimum of 6 g/100g. Proteins – Source: Minimum of 10% of dietary reference intake (DRI) of reference/100g. High content: Minimum of 20% of DRI of reference/100g (Brasil, 1998). DRI = 50g (Brasil, 2005a). Na – Low content: Maximum of 120 mg/100g. Very low content: Maximum of 40 mg/100g. Not containing: Maximum of 5 mg/100g. Vitamins – Source: Minimum of 15% of DRI of reference/100g. High content: Minimum of 30% of DRI of reference/100 (Brasil, 1998). DRI Vitamin B_1 =1.2 mg, DRI Vitamin B_2 = 1.3 mg (Brasil, 2005a). Minerals – Source: Minimum of 15% of DRI of reference/100g. High content: Minimum of 30% of DRI of reference/100g (Brasil, 1998). DRI P = 700 mg, DRI Fe = 14 mg (Brasil, 2005a), DRI K = 4700 mg (National Research Council, 2005). **0% content considered in wheat flour.

the addition of mushroom powder. The contents of fiber, proteins, phosphorus, potassium, iron, and riboflavin were increased, mainly when 10% mushroom powder was added to the wheat flour. Regarding the sodium content, the contents in the wheat flour with 5 or 10% mushroom powder increased; however, they maintained the same classification according to the Decree no. 27 of Anvisa (Brasil, 1998), in other words, "products not containing Na".

Okafor et al. (2012) observed that the supplementation of wheat flour with 10% mushroom powder (*Pleurotus pulmonarius*) increased the crude protein content significantly, from 9.7 to 13.14%, crude fiber from 0.3 to1.06%, and ash from 0.76 to 1.44%. They verified that the carbohydrate content in the wheat flour (75.94%) decreased in the wheat flour with 10% mushroom powder (71.07%). These results are similar to those of the present study (Table 3).

3.3 Physicochemical evaluation

Table 4 presents the results of moisture (%), wet gluten (%), color (L*), and *Falling Number* (FN) analyses conducted with the flour with and without 5 and 10 % mushroom powder.

One of the great concerns regarding flours is moisture control, which can have a direct influence on the quality of food during manufacture (Brasil, 2005b; Empresa Brasileira de Pesquisa Agropecuária, 2009). The Resolution RDC no. 263 of 22nd September 2005 (Brasil, 2005c) establishes that the moisture content of flours should have a maximum value of 15.0%. The results obtained for the flour without and with 5 or 10% mushroom powder (Table 4) show a maximum value of 14.0%, in other words, they meet legal specifications.

The gluten forming proteins are basically responsible for the functional properties of the wheat flour and are related to the strength of the flour (it represents the work deformation of the dough and indicates the bread-making quality of the flour) (Empresa Brasileira de Pesquisa Agropecuária, 2009). In Table 4, it can be observed that the gluten content in the wheat flour and the wheat flour with 5 and 10% mushroom powder showed no statistically significant difference with a 29.8% average of wet gluten. The results, therefore, show that wheat flour with mushroom powder maintained its bread-making quality. Table 4 also shows that the gluten content in the wheat flour and the wheat flour with 5 and 10% mushroom powder showed no statistically significant difference with a 29.8% average of wet gluten. Therefore, the results show that wheat flour with mushroom powder maintained its bread-making quality.

Mohammed et al. (2009) evaluated wheat flour and wheat breads supplemented with teff and concluded that breads supplemented with teff flour, up to a 5% level, are organoleptically and nutritionally acceptable. The authors found 28.6 % wet gluten in wheat flour; however, when 5% teff flour was added, this value decreased significantly to 21.6 %.

According to Kajishima et al. (2003), flour coloring is a prime factor for its acceptance or rejection. According to Decree no. 354 of July 1996 of Anvisa (Brasil, 1996), flour coloring must be white with light yellow, brown, or even gray tones. Furthermore, according to Embrapa Trigo (Empresa Brasileira de Pesquisa Agropecuária, 2009), although consumers prefer the whitest flours, they do not always offer the best quality for all final products. The luminosity measurement (L*) has a scale from zero (black) to 100 (white), that is, the closer to 100, the whiter the flour. In Table 4, it can be observed that the flour without the addition of mushroom powder showed a luminosity value of 92.3 (L*). However, the flour enriched with mushroom powder was darker, equivalent to 89.2 (L*) and 88.1 (L*) for flour with 5 and 10% mushroom powder, respectively. This color was expected, due to the dark color of the mushroom powder and its ash content (7.4 g/100g). Nonetheless, these results did not affect the product quality since it was nutritionally enriched (Table 3). Today, consumers search for products that can offer health benefits, especially for natural additives, ingredients, and foods (Gandra et al., 2008).

In a study conducted by Ulziijargal et al. (2013), in which 5 g of mycelium powder of *Antrodia camphorata, Agaricus blazei, Hericium erinaceus, and Phellinus linteus* were added to 95 g wheat flour (5%) and other ingredients for bread preparation, it was observed that the bread without the addition of mycelium had 70.68 (L*), and in the breads in which mycelium was added, the luminosity dropped to 62.45 (L*) with *Antrodia camphorata*, 54.84 (L*) with *Agaricus blazei,* 47.47 (L*) with *Hericium erinaceus,* and 66.64 (L*) with *Phellinus linteus.* The authors concluded that all breads supplemented with mycelium were slightly colored (brownish). The change in color in the bread supplemented with mycelium could be related to the original pigments of the mycelium and with the oxidation of the phenolic compounds of the mycelia during baking. However, the authors suggest that the brownish color could be attractive to the consumer. On the other hand, Tseng et al. (2010) evaluated bread with silver ear flour and found that the white bread showed 76.75 (L*), while the addition of 5% silver ear flour resulted in bread with less color 82.27 (L*).

Table 4. Mean ± standard deviation results obtained for wheat flour without and with 5 and 10 % mushroom powder.

	Moisture (%)	Wet gluten (%)	Color (L*)	FN (s)
Wheat flour	13.1 ± 0.14 *a*	29.4 ± 0.16 *a*	92.3 ± 0.05 *a*	483.5 ± 4.95 *a*
Wheat flour with 5% mushroom powder	14.0 ± 0.28 *b*	29.8 ± 0.08 *a*	89.2 ± 0.28 *b*	457.5 ± 6.36 *b*
Wheat flour with 10% mushroom powder	14.0 ± 0.14 *b*	30.3 ± 0.49 *a*	88.1 ± 0.35 *c*	431.5 ± 3.36 *c*

Different lowercase letters in the same column indicate that the means differed statistically according to the Tukey's test ($P < 0.05$).

The Falling Number (FN) results obtained in the flour sample without the addition of mushroom powder was 483.5 s, and in the flour with 5 and 10% mushroom powder this number dropped to 457.5 and 431.5 s, respectively. Such decrease could be due to the fact that the mushroom powder showed a larger particle size than that of the flour, hindering the formation of hydrolyzed gel. However, the results are higher than those expected for bread-making.

According to Costa et al. (2008), flours with high FN values (minimum 250 s) are compatible with the wheat enhancer, which is preferred in mixture industries in different proportions with flours of low FN value for the purpose of improving the end quality of the product. On the other hand, FN values lower than 250 s are compatible with soft wheat flours, and these flours are more appropriate for bread-making. Low FN values can be related to high α-amylase activity so that the flours with high contents of this enzyme tend to produce low amounts of sticky products. These authors evaluated different domestic and imported wheat flours and verified FN values ranging between 64 and 223 (s) for domestic flours and between 293 and 430 (s) for imported flours. Mohammed et al. (2009) observed that the substitution of wheat flour for teff flour caused a significant increase in FN, indicating less amylase activity. In the present study, (Table 4) the FN decreased when the mushroom powder increased. This could be due to the fact that the *Pleurotus* genus has the ability to produce amylases (Souza et al., 2008).

In general, it was confirmed that wheat flour with 5 or 10% mushroom powder did not drastically change the physicochemical characteristics, such as moisture, wet gluten, color, and falling number, evaluated in wheat flour.

4 Conclusions

The best results in terms of Yield (48.4 ± 16.1%), Biological Efficiency (4.5 ± 0.3%), and Productivity (0.36 ± 0.04 g/day) were obtained using 20% inoculum fraction and 10% rice brand fraction.

The fruiting bodies of *Pleurotus sajor-caju* CCB 019 cultivated in peach palm leaves with 10% rice bran and 20% inoculum had 29.91 g/100g total carbohydrates, 42.92 g/100g proteins, 1.24 g/100g fat, 15.93 g/100g fibers, 7.42 g/100g ash, 1602.78 mg/100g phosphorus, 2722.58 mg/100g potassium, 8.73 mg/100g iron, 23.75 mg/100g sodium, 0.34 g/100g thiamine, and 0.57 mg/100g riboflavin. *Pleurotus sajor-caju* mushroom powder can be considered a food containing sugars, but with low fat content, very low sodium content, high fiber, protein, phosphorus, potassium, iron, and riboflavin content, and a source of thiamine.

The wheat flour with 5 or 10% mushroom powder reduced the sugar content, but it did not increase the fat content, remaining similar to the flour without the addition of mushroom powder. The fiber, protein, phosphorus, potassium, iron, and riboflavin contents were increased mainly when 10% mushroom powder was added to the wheat flour. With regard to the sodium content, the contents in the wheat flour with 5 or 10% mushroom powder increased, however, they maintained the same classification according to Decree no. 27 of Anvisa (Brasil, 1998), that is, "products not containing Na".

The finding that the wheat flour with 5 or 10% mushroom powder did not drastically change the physicochemical characteristics such as moisture, wet gluten, color, and falling number, together with the fact that the mushroom powder increased the nutritional value of the wheat flour, suggests that wheat flour with 10% mushroom powder provides nutritional enrichment without changing the characteristics evaluated. Furthermore, due to the fact that mushrooms are not part of the traditional diet of the Brazilian population, currently showing a consumption of just 30 g per inhabitant, the addition of wheat flour with mushroom powder may contribute to increase the consumption of mushrooms in the country, thus providing a positive impact on the health of the population.

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