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Biociências

Use of agro-industrial wastes (banana pseudostem and onion waste) for the growth of *Pleurotus* spp.

Uso de resíduos agroindustriais (pseduocaule de bananeira e resíduo de cebola) para o cultivo de Pleurotus spp.

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Abstract: One possibility for the value addition of agro-industrial waste is its use for the growth of edible mushrooms of the genus *Pleurotus*. The objective of this work was to evaluate the productive parameters and nutritional value of *Pleurotus* spp. cultivated in agro-industrial wastes available in the northeastern region of the State of Santa Catarina. *Pleurotus ostreatus, Pleurotus sajor-caju* and *Pleurotus djamor* were cultivated using banana pseudostem and onion waste as substrates. Yield (Y%), biological efficiency (BE%) and productivity (Pr g/day) were evaluated. The fruiting bodies obtained from the substrate with the best Y% and BE% were analyzed for moisture, ash, carbohydrates, fibers, lipids and proteins. *P. ostreatus* has shown the highest Y% (126%) when cultivated in onion waste. *P. sajor-caju* also obtained the highest BE% (10,8%) and Pr (0.43 g/day) in onion waste. *P. ostreatus* cultivated in onion waste has shown higher amounts of carbohydrates (63.7%) and proteins (26.2%) than those observed in the literature, while the level of fat, fiber and energy value, when in banana pseudostem, were higher (7.4%, 14.7% and 402.4 kcal/100 g, respectively). The results showed that onion and banana pseudostem wastes are efficient substrates for the growth of *P. ostreatus* and *P. sajor-caju*.
Keywords: Biodegradable Wastes, Food Production, Functional Foods, Mushroom.

Resumo: Uma das possibilidades de agregar valor aos resíduos agroindustriais é utilizá-los no cultivo de fungos comestíveis do gênero *Pleurotus*. Sendo assim, o objetivo deste trabalho foi avaliar os parâmetros produtivos e o valor nutricional de *Pleurotus* spp. cultivados em resíduos agroindustriais disponíveis na região nordeste do Estado de Santa Catarina. *Pleurotus ostreatus*, *Pleurotus sajor-caju* e *Pleuroutus djamor* foram cultivados utilizando pseudocaule de bananeira e resíduo de cebola como substrato. Os corpos de frutificação do 1º e do 2º fluxo produtivo foram colhidos e os parâmetros de produção como rendimento (R%), eficiência biológica (EB%) e produtividade (Pr g/dia) foram avaliados. Além disso, os corpos de frutificação provenientes do substrato que promoveu o melhor rendimento foram avaliados em termos de umidade, cinzas, carboidratos, fibras, lipídios e proteínas. *P. ostreatus* apresentou o maior R% (126%) quando cultivado em resíduo de cebola. *P. sajor-caju* apresentou maior BE% (10,8%) e Pr (0,43 g/dia) quando cultivado em resíduo de cebola. *P. ostreatus* cultivado em resíduo de cebola apresentou quantidades superiores de carboidratos (63,74%) e proteínas (26,2%) em relação aos observados em literatura, quando cultivado em pseudocaule de bananeira o teor de gorduras, fibras e o valor energético foi aumentado (7,42%, 14,67% e 402,42 kcal/100 g, respectivamente). Os resultados mostram que os resíduos de cebola e pseudocaule de bananeira são substratos eficientes para o cultivo de *P. ostreatus* e *P. sajor-caju*.
Palavras-chave: Alimentos funcionais, Cogumelo, Produção de alimentos, Resíduo biodegradável.

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INTRODUCTION

The state of Santa Catarina is one of the main producers of bananas and onions in Brazil. The 2021 onion crop in Santa Catarina was 481,233 tons on 17,216 hectares, with a yielding 27,953 kg/ha. The 2022 banana crop produced 716,616 tons on 29,859 ha, with a yielding 24,000 kg/ha (Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina [Epagri], 2023). This large production generates a corresponding amount of agro-industrial waste. For each ton of industrial bananas produced, about 4 tons of lignocellulosic waste are generated, including 3 tons of pseudostem, 160 kg of stem, 480 kg of leaf and 440 kg of peel. The pseudostem is considered to be the main waste generated in industrial banana production. In the case of onions, approximately 120 kg of waste is generated per ton produced, including the outer scales, skin, roots, bulb tops and damaged bulbs (Cebin et al., 2020). In general, the disposal of agroindustrial waste into the environment is inefficient. The practice of burning or burying such waste in soil is common, resulting in the pollution of the air, water, and global warming. Therefore, studies on the use of these kinds of wastes are of great importance for realizing economic and environmental benefits. As they can minimize negative environmental impacts and add value to them, they positively influence the local circular bioeconomy, which involves the reduction, reuse, and recycling of wastes to boost sustainable agriculture and minimize environmental pollution (Gupta et al., 2022; Koul et al., 2022).

In order to propose sustainable processes, many researchers have studied the use of these two types of agro-industrial wastes for the production of different value-added products such as organic acids, polyphenols, polysaccharides, enzymes, pigments, biofuels and biocomposites (Črnivec et al., 2021; Imeneo et al., 2022; Koul et al., 2022; Pereira et al., 2017; Rocha et al., 2020; Teodoro et al., 2018; Wisbeck et al., 2017).

Another possibility, which has also been extensively studied, is the use of this type of waste for food production, such as the production of edible mushrooms (Akcay et al., 2023; Akter et al., 2022; Albertia et al., 2021; El-Ramady et al., 2022; Islam et al., 2021; Moxley et al., 2022; Pereira et al., 2017; Vieira Júnior et al., 2023). The cultivation of mushrooms is increasing worldwide every year, driven by the search for a healthy diet. The global consumption of edible fungi (mushrooms) was 12.74 million tons in 2018 and is expected to reach 20.84 million tons in 2026. Among the most consumed are Paris mushrooms (*Agaricus bisporus*), shiitake mushrooms (*Lentinula edodes*), and oyster mushrooms (*Pleurotus* sp.) (Akcay et al., 2023; Moxley et al., 2022).

In particular, oyster mushrooms have a high nutritional quality, being a source of protein and fiber and having a low content of lipids, as well as being an excellent source of minerals (Akter et al., 2022; El-Ramady et al., 2022).They are a source of bioactive compounds that have been attributed with immunomodulatory, anticancer and anti-inflammatory activities, among others (Črnivec et al., 2021; Imeneo et al., 2022; Wisbeck et al., 2017; Zhao et al., 2024). Moreover, as a primary decomposer of organic matter, *Pleurotus* can grow on a wide range of substrates, including agro-industrial wastes such as banana leaves, rice husks, coffee waste, sugarcane bagasse, wheat straw, among others (Akcay et al., 2023; Albertia et al., 2021; Khatana et al., 2024). The use of agro-industrial wastes for mushroom production, in addition to providing a product with high nutritional and nutraceutical value through a simple, cheap and sustainable process, also provides data to support the global trend of recycling to avoid environmental pollution, i.e. the eco-friendly use of lignocellulosic wastes (Devi et al., 2023; Moxley et al., 2022; Vega et al., 2022).

Therefore, in order to minimize the negative impacts caused by the generation and disposal of these wastes and to contribute to the valorization of agro-industrial wastes and sustainable food systems, the aim of this study was to evaluate the production parameters of fungi of the genus *Pleurotus* cultivated on agro-industrial wastes derived from the abundant local banana and onion crops.

MATERIAL AND METHODS

Microorganism

Pleurotus sajor-caju CCB019 was provided by the Instituto de Botânica de São Paulo (São Paulo, Brazil); *Pleurotus djamor* UNIVILLE 001 was isolated at the Joinville campus of the University of the Region of Joinville (Univille) (Santa Catarina, Brazil), and registered at SisGen under accession number A87B3EE (08/14/2019); *Pleurotus ostreatus* DSM1833 was provided by the Deutsche Sammlung von Mikroorganismen und Zellkulturen (DSMZ, Germany). The strains were cultivated in Petri dishes containing WDA (wheat dextrose agar) (20 g glucose, 15 g agar, 1 L wheat extract) (Furlan et al., 1997).

Spawn

Pre-washed wheat grains were boiled in water for 10min, in a ratio of 1:2 (grains:water, w/w). After cooling, the grains were filtered through gauze and mixed with 0.35% $CaCO_3$ and 1.3% $CaSO_4$ (dry weight). Then 250 g of the mixture was placed in polypropylene bags and sterilized at 121 °C and 1 atm, for 1h. After cooling, the grains were inoculated with three agar disks (12 mm diameter) containing the fungal mycelium, and incubated at 30 °C, in the absence of light, until their complete colonization (Bonatti et al., 2004), which occurred in approximately 20 days.

Culture conditions

The strains were grown on two types of waste, banana pseudostem and onion waste. The banana pseudostem waste was ground into 2-5 cm particles in a forage mill (Trapp) and dried at 55 °C to constant weight. The banana pseudostem waste (*Musa cavendishii*) was obtained from a cultivation at the Joinville campus of Univille. Onion waste (*Allium cepa*, unidentified varieties), including peel, sheaths and outer layer, was provided by restaurants in the city of Joinville. It was dried at 55 °C until constant weight.

Briefly, the substrates were soaked in water for 12 h and after that the excess of water was drained. 50 g (dry weight) of substrates, were placed in polypropylene bags (40x30 cm) and sterilized at 121 °C and 1 atm, for 1 h (Madan et al., 1987). Each bag contained equal volumes of the substrate in all treatments, maintaining similar conditions of gas exchange. The experiments were done in sextuplet replicates. After cooling, the substrates were inoculated with 10% (dry weight) of spawn (wheat grain colonized by mycelium) and homogenized. The bags were incubated at 30 °C, in the absence of light, until complete substrate colonization (visual analysis). The complete colonization of all substrates was observed approximately 10 to 20 days after inoculation. Next, the bags were perforated, for CO_2 liberation and transferred to a room with light control (12h/day), 90% RH and 28 °C ± 2, to promote primordia development (Bonatti et al., 2004).

Harvest

Fruiting bodies were harvested when the margin of the pileus was flat, in a stage that precedes the sporulation (Sturion & Ranzani, 2000) (Figure 1). They were weighed for wet weight determination, dried at 55 °C for 24h until constant weight, weighed again for dry weight determination, and stored. All the fruiting bodies of the first production flush were harvested when the first fruiting body reached the harvest point. The global process production is summarized in Figure 2.

Figure 1
Harvesting *Pleurotus* fruiting bodies

The yield (Y%), biological efficiency (BE%) and the productivity (Pr g/day) of the process were determined according to Eqs. (1), (2) and (3) (Bisaria et al., 1987; Chang et al., 1981).

$$Y\ (\%) = \frac{Wet\ fruiting\ body\ mass}{Dried\ substrate\ mass} x100 \qquad (1)$$

$$BE\ (\%) = \frac{Dry\ fruiting\ body\ mass}{Dried\ substrate\ mass} x100 \qquad (2)$$

$$Pr\ Pr\ \left(\frac{g}{day}\right) = \frac{Dry\ fruiting\ body\ mass}{Days\ of\ cultivation} \qquad (3)$$

Analysis

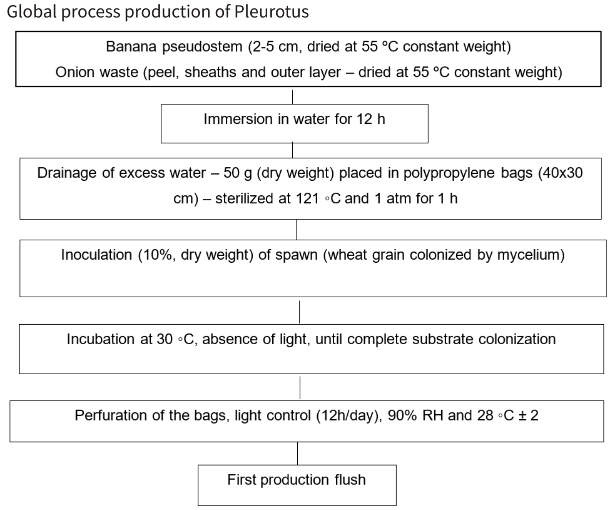
The analyses were carried out in triplicate and consisted of: moisture, ash, crude fiber, total carbohydrates, total protein, crude fat and energy value. The analyses were carried out according to the Association of Official Analytical Chemists (Association of Official Analytical Chemists, 1995). The total nitrogen content was determined by the Kjeldahl method. The total protein was determined from the total nitrogen content, using the correction factor 4.38 (Breene, 1990). The total energy value (kcal) was determined according to equation 5 (European Economic Community, 1990).

$$Energy\ (kcal) = 4\ x\ (g\ of\ protein + g\ of\ carbohydrate) + 9\ x\ g\ of\ lipids \qquad (5)$$

Statistical analyses

Data were analyzed by Dixon's Q-test for deviant values (Rorabacher, 1991). Statistical significant differences between the values ($p < 0.05$) were analyzed by Student´s t-test using Microsoft Office Excel (Microsoft, Redmond, WA, USA).

Figure 2
Global process production of Pleurotus



RESULTS AND DISCUSSION

According to Table 1, the results of the first production flush showed that the strains cultivated on onion waste performed better in terms of Y%, with a significant difference between *P. ostreatus* and *P. sajor-caju*, while the cultivation of *P. djamor* on onion waste did not show the formation of fruiting bodies. Considering the results of the first production flush and the total production, the best cultivation performance was shown by *P. ostreatus* on onion waste, with the highest Y% between species and cultivation substrate studied. The cultivations of *P. ostreatus* and *P. djamor* on banana pseudostem were found to be statistically equal, with a significant difference only for *P. sajor-caju*, whose Y% was lower.

Table 1
Yield (Y%) (mean ± standard deviation) for the first and second production flushes, and total production of P. sajor-caju, P. ostreatus and P. djamor cultivated in banana pseudostem and onion wastes

		Yield (%)		
		1st flush	2st flush	Total production
P. sajor-caju	Onion waste	79.14±41,2a	54.34±44.67a	110.2±39.33a
	Banana pseudostem	39.67±18.1b	-	39.67±18.1b
P. ostreatus	Onion waste	108.18±19.1c	26.32±20.91a	126.18±26.12c
	Banana pseudostem	70.4±21.18a	29.84±21.29a	100.25±15.93a
P. djamor	Onion waste	-	-	-
	Banana pseudostem	64.01±11.85a	33.58±15.74a	97.59±10.17a

Equal letters in a column do not differ statistically at the 5% significance level, according Tukey´s test ($p \leq 0.05$), n = 6.

According to the results shown in Table 2, it is possible to observe that *P. ostreatus* presented the highest BE%, both for the first production flush and the total production, when it was cultivated using onion waste instead of banana pseudostem. When cultivated in banana pseudostem, no significant difference was observed in the values of BE% for the three *Pleurotus* species studied. In agreement with the literature (Akter et al., 2022; El-Ramady et al., 2022), the second production flush showed lower results than the first production flush in all the cultivation methods studied.

Table 2
Biological efficiency (BE%) (mean ± standard deviation) for the first and second production flushes, and total production of *P. sajor-caju*, *P. ostreatus* and *P. djamor* cultivated in banana pseudostem and onion wastes

		Biological efficiency (%)		
		1st flush	2st flush	Total production
P. sajor-caju	Onion waste	6.8±3.61a	7.03±2.75a	10.81±4.29a
	Banana pseudostem	7.52±6.22a	-	7.52±6.22a
P. ostreatus	Onion waste	8.55±1.3b	2.27±1.75b	10.09±2.97b
	Banana pseudostem	5.67±1.18a	2.95±1.33b	8.62±1.65a
P. djamor	Onion waste	-	-	-
	Banana pseudostem	4.91±0.76a	2.7±1.15b	7.61±1.36a

Equal letters in a column do not differ statistically at the 5% significance level, according Tukey´s test ($p \leq 0.05$), n = 6.

Evaluation of Y% and BE% are important agronomic parameters to evaluate the efficiency of mushroom production. The first one represents the production efficiency of wet fruiting bodies, and the second one represents the production of dehydrated mushroom (Vieira Júnior et al., 2023). The productivity parameters (Pr) for the substrates and the three *Pleurotus* species are presented in Table 3. The highest productivity values, both for the first production flush and for the total production, were observed in the experiments with *P. sajor-caju* cultivated in onion waste. The lowest productivity value was observed for *P. djamor* cultivated in banana pseudostem. Regarding the time (days) for the first production flush, lower values were observed in the experiments using onion waste as substrate than banana pseudostem, justifying the higher values of productivity observed in the experiments using onion waste as substrate. The cultivation of *P. sajor-caju* in pseudostem showed the longest cultivation time (42 days), considering the total production.

Table 3
Productivity (Pr) (mean ± standard deviation) for the first production flush, and total production of P. sajor-caju, P. ostreatus and P. djamor cultivated in banana pseudostem and onion waste

		P. sajor-caju		P. ostreatus		P. djamor	
		Onion waste	Banana pseudostem	Onion waste	Banana pseudostem	Onion waste	Banana pseudostem
Pr (g/day)	1st flush	0.43±0.32a	0.21±0.2b	0.23±0.11c	0.13±0.06d	-	0.26±0.067e
	Total production	0.39±0.29a	0.21±0.2b	0.20±0.08b	0.15±0.04c	-	0.09±0.03d
t (day)	1st flush	10±4.76a	15.71±5.25b	21±6.66b	23.43±6.02c	-	16±7.94b
	Total production	19.29±11.88a	15.71±5.25a	25.43±4.47b	30.57±7.16b	-	42.14±4.74c

Equal letters in a line do not differ statistically at the 5% significance level, according Tukey´s test ($p \leq 0.05$), n = 6.

Different substrates for *Pleurotus* cultivation are being studied worldwide to optimize their production (Table 4). The yield obtained by the researchers ranged from 27.7 to 68.5% (Akcay et al., 2023; Akter et al., 2022; Khatana et al., 2024; Pereira et al., 2017; Vieira Júnior et al., 2023). These results are lower than those presented in Table 1, in which the best value is observed with the use of onion waste and the species *P. ostreatus*. The time (days) for the production of mushrooms observed in this work (Table 3) were lower than those reported in the literature (48 – 84 days) (Akcay et al., 2023; Albertia et al., 2021; Khatana et al., 2024), mainly for the cultivation of *P. sajor-caju* in onion waste. In a few manuscripts, the time (days) to obtain the first productive flush of mushrooms (8 – 14 days) is lower than those presented in Table 3 (Akter et al., 2022; Pereira et al., 2017).

Table 4
Types of substrates used for Pleurotus production

Substrate	Reference
Residues of the horticultural and agronomic crops (cotton, rice, wheat, mustard and water chestnut)	Khatana et al. (2024)
Hazelnut branches (Corylus avellana L.), hazelnut husk, wheat straw, rice husk and spent coffee grounds	Akcay et al. (2023)
Eucalyptus sawdust, wheat bran, cottonseed bran and soybean meal	Vieira Júnior et al. (2023)
Rice straw, wheat straw, corncobs, saw dust and rice husk, sugarcane bagasse	Akter et al. (2022)
Coffee pulp, rice straw, corncobs, and their mixtures	Vega et al. (2022)
Brachiaria dictyoneura mixed with sugarcane bagasse (bulk material)	Albertia et al. (2021)
Banana pseudostem	Islam et al. (2021)
Onion waste and, onion waste mixed with banana straw	Pereira et al. (2017)

According to Pereira et al. (2017), some substrate types can promote higher agronomic parameter values due to their suitable size for good microorganism development. Normally, larger particles promote larger interparticle spaces, as well as a higher area-to-volume ratio, promoting higher yields in mushroom cultivation, as the substrate molecules become more accessible to the hydrolytic enzymes responsible for the development of the fungal mycelium. The granulometric profile of the onion waste is reported as the majority of the particles (>57%) were between 2.36 and 4.75 mm, resulting in a high area-to-volume ratio.

Another important parameter for the adequate development of the genus *Pleurotus* is the carbon to nitrogen ratio (C:N). Wood is the natural habitat of the genus *Pleurotus* which is characterized as a low nitrogen source (C:N ranging from 350:1 to 500:1) (Pereira et al., 2017). According to the literature, the C:N of the onion waste was 266:1, mainly due to the compounds with lignin, hemicellulose and cellulose present in the composition of the onion peel that integrates the onion waste (Pereira et al., 2017). The onion waste has also been analyzed for some nutritional components. For example, the ash content varies from 1.4 to 4.6% depending on the onion variety, and the growing medium is given an acid pH, which favors the growth of fungi and minimizes bacterial contamination (Pereira et al., 2017). Onion waste is a rich source of nutrients and phytochemicals with bioactive properties that are beneficial to human health. The skins of onions are a valuable source of bioactives like flavonoids, phenolic acids, fructooligosaccharides, organosulfur compounds, and phenolic glycosides (Stoica et al., 2023).

Regarding the banana pseudostem waste, the nutritional composition of the banana pseudostem can vary depending on the soil, irrigation and fortification during cultivation. However, in terms of C:N ratio, the amount of carbon and nitrogen are about 30 to 35% and 0.5 to 0.8%, respectively, with the C:N ratio ranging from 38.82:1 to 73.20:1 (Islam et al., 2021). Banana peel is a compound rich in various fiber types including cellulose (38-39%), hemicellulose (28-29%), lignin (8-9%) and pectin, and contains approximately 11% protein (Sandrin, 2018).

The moisture and ash content of *P. sajor-caju*, *P. ostreatus* and *P. djamor* grown in the substrates studied in this manuscript are presented in Table 5. The average moisture content of the fruiting bodies ranged from 73.65 to 92.27%. These values were considered statistically equal ($p>0.05$) both between the fungal species and between the cultivation substrates. The percentage of ash in all samples was also considered equal. These values are consistent with those reported in the literature for *Pleurotus* genus grown in different types of substrates (Akter et al., 2022; Irshad et al., 2018; Khatana et al., 2024). The amount of ash refers to the inorganic or fixed mineral residue, and in fungal fruiting bodies it depends on the growing conditions and the type of substrates used for growing, as well as the fungal species. Normally, the mineral content of the mushrooms is influenced by the substrate, with their order of abundance in the mushrooms being similar to that of the substrates (Vega et al., 2022).

Table 5
Moisture and ash content of fruit bodies grown in onion waste and banana pseudostem waste

		Moisture (%)	Ash (%)
P. sajor-caju	Onion waste	90.04±1.78a	8.78±0.39b
	Banana pseudostem	73.65±2.93a	8.83±0.66b
P. ostreatus	Onion waste	92.27±1.63a	9.06±0.27b
	Banana pseudostem	91.28±1.95a	8.67±0.94b
P. djamor	Onion waste	-	-
	Banana pseudostem	92.19±1.24a	8.75±0.69b

Different letters determine values with statistically significant differences ($p<0.05$)

Table 6 shows the results of the nutritional analysis of the fruiting bodies of the fungal species that showed the highest Y% and BE% values among the experiments carried out, as these are important parameters for mushroom producers. Therefore, the analyses were carried out on fruiting bodies of *P. ostreatus* grown in onion waste and in banana pseudostem.

Table 6
Nutritional value of P. ostreatus grown in onion waste and banana pseudostem

	Onion waste	Banana pseudostem
Crude fiber (%)	12.0a	14.67b
Total carbohydrates (%)	63.74a	73.81b
Protein (%)	26.2a	10.10b
Crude fat (%)	1.0a	7.42b
Energy value (kcal/100 g)	368.76a	402.42b

Different letters determine values with statistically significant differences ($p<0.05$).

The nutritional analysis of *P. ostreatus* grown on onion waste and banana pseudostem showed some differences. Fruiting bodies grown in onion waste substrate had higher protein content and lower crude fat content than those grown on banana pseudostem waste. In general, mushrooms are known to be high in protein and low in fat, with crude fat content ranging from 1 to 10% depending on the species and cultivation method (Akter et al., 2022; Vega et al., 2022). In terms of fatty acid profile, mushrooms have higher proportions of linoleic acid (ranges from 0.0–81.1%), oleic acid (ranges from 1.0 and 60.3%), and linolenic acid (ranges from 0.0 to 28.8%). Linoleic acid is one of the precursors of the characteristic smell and taste of this food (Sande et al., 2019). According to the literature, the values observed for the protein content of mushrooms of the genus *Pleurotus* range from 15 to 30% (Akter et al., 2022; Vega et al., 2022). The values presented in Table 6 are in accordance with these values. Some authors relate protein content of fruit bodies to nitrogen content, and de C:N ratio, of substrate, with higher protein content of fruit bodies grown in high nitrogen substrates (Akcay et al., 2023; Akter et al., 2022; Albertia et al., 2021; Vega et al., 2022).

The total carbohydrate content of the fruiting bodies of the genus *Pleurotus* consists of fibers such as β-glucans, chitins, and hemicelluloses, and sugars such as fructose, mannitol, glucose, sucrose, trehalose, and inositol. These substances together constitute about 40.6 to 53.3% of the total mass of the fruiting body. Total carbohydrate values of *P. ostreatus* grown on banana pseudostems and onion waste were higher than some reported in literature (Tolera & Abera, 2017; Vega et al., 2022); and consistent with other studies reporting total carbohydrate content of *Pleurotus* genus fruiting bodies grown on different substrates, ranging from 60 to 80% (Irshad et al., 2018; Tolera & Abera, 2017). Among the total carbohydrate content of a fruiting body, fibers can be highlighted. Mushrooms in general are rich in polysaccharides, mainly β-glucans (Pérez-Bassart et al., 2023; Wisbeck et al., 2017), which contribute to the high fiber content ranging from 3 to 32% (Breene, 1990). According to the literature (Akter et al., 2022; El-Ramady et al., 2022; Irshad et al., 2018), different species of the genus *Pleurotus*, cultivated in the same substrate, can present different values of fiber content, therefore, it can be seen that the variation occurs not only according to the substrate used, but also according to the fungal species reported. The crude fiber content values obtained in this study are in accordance with those reported in the literature, which range from 10 to 50% (Irshad et al., 2018; Tolera & Abera, 2017; Vega et al., 2022). The concentrations and types of fibers found in the fruiting bodies are responsible for various medicinal effects on the human body, such as anti-oxidant, anti-hyperlipidemic, anti-tumor and immunoregulatory activities (Devi et al., 2023; El-Ramady et al., 2022; Pérez-Bassart et al., 2023; Vega et al., 2022; Wisbeck et al., 2017; Zhao et al., 2024).

From the data obtained from the nutritional analysis of the fruiting bodies, it is possible to determine their energy content (European Economic Community, 1990). In this study, a significant difference was observed in the energy value of the fruiting bodies of *P. ostreatus* grown in onion waste and banana pseudostems. The same was observed by other researchers using different growing substrates (Khatana et al., 2024). This significant difference in energy content can be explained by the different values of fat content found in fruiting bodies grown on banana pseudostems (7.42%) and fruiting bodies grown on onion waste (1%). As this macronutrient has a higher calorific value (9 kcal/g), it has a direct influence on the energy content of the fruiting body.

CONCLUSION

According to the results, it is possible to conclude that the cultivation of *P. ostreatus* and *P. sajor-caju* in onion waste is a viable option that achieves high yields. Similarly, the banana pseudostem was confirmed as a viable option for the cultivation of *P. ostreatus* and *P. djamor*. It was also observed that the type of substrate has an influence on the nutritional composition of the fruiting bodies. *P. ostreatus* cultivated in onion waste had higher carbohydrate and protein contents than those reported in the literature, while *P. ostreatus* cultivated in banana pseudostem had a high fat content.

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