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Review Article

Bioavailability in edible mushroom *Pleurotus spp.*

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Abstract

Pleurotus has more than 200 species and is one of the edible mushrooms with great potential as a food source with various nutritional and biological benefits and its ability to synthesize essential amino acids. These mushroom species have been investigated for their antioxidant activity and their value ranges from 60 to 90% depending on the species, culture conditions, and extraction methods. These mushrooms have a wide variety of beneficial nutrients for health, whether as a functional food, nutraceutical or as a component for medicines, they have a high biological activity for the well-being of people. Bioavailability is the amount of a nutrient absorbed by the intestine and from that moment becomes available to carry out physiological functions and as storage. Methodologies for measuring nutrient bioavailability involve investigation in humans, mice, pigs, and other animals (*in vivo*) or simulation in laboratory assays (*in vitro*). This fungal resource is promising in improving the health conditions of the current population through the sale of products. On the other hand, understanding the term bioavailability can help to optimize diets and establish adequate nutrient recommendations. Therefore, this work explains the approach from botanical characteristics, nutritional content, and its health benefits, as well as processed foods that have been developed with fungi, analyzing the aspects of bioavailability.

1. Introduction

Edible mushrooms are a food of high nutritional quality. They represent an important source of protein, essential amino acids, dietary fiber, and low-fat content [1]. Its greatest contribution is carbohydrates, varying in amounts of up to 60%. Most of these carbohydrates are polysaccharides such as chitin and β-glucans (Fig. 1) [2]. Mushrooms contain 20–35% protein (dry weight), are low in lipids and contain all the nine essential amino acids [3]. Phenolic compounds found in mushrooms have gained importance due to their antioxidant properties in the body [4]. The mushrooms *P. floridanus, P. ostreatus, P. djamor and P. sajor caju* mainly contain the minerals manganese, copper, potassium, zinc, calcium, magnesium, sodium, and iron.

The genus *Pleurotus* includes around 40 species commonly known as "oyster mushrooms". Oyster mushrooms rank 3rd among the most cultivated mushrooms on an industrial scale globally. They are very efficient due to their ease of cultivation, high yield potential, and high medicinal and nutritional value [5].

Oyster mushrooms *ostreatus* contain different nutrients inside, such as glycans that help the immune

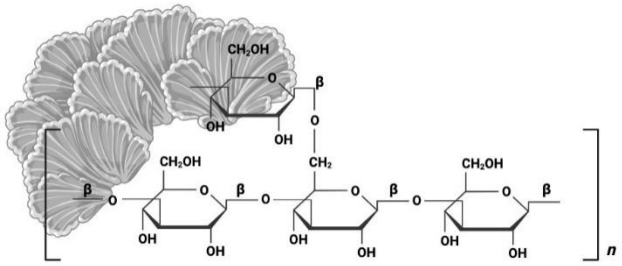

Figure 1. Carbohydrate structure in edible mushroom

system in several ways: they provide cytotoxicity in cancer cells, activate lymphocytes, NK cells, and macrophages, increase the development of cytokines and decrease cancer cells, promote apoptosis, and blocking blocking angiogenesis (Fig. 2).

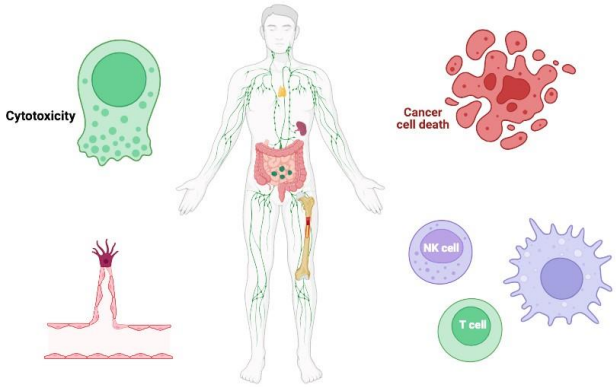

Figure 2. Benefits of *Pleurotus* nutrients on the immune system, a) cytotoxicity in cancer cells, b) activate lymphocytes, NK cells and macrophages, and c) blocking angiogenesis

Pleurotus mushrooms, either as a functional food, nutraceutical or as a component for medicines, have a high biological activity for the well-being of people, which makes them an important promising fungal resource in the sale of products that improve conditions of health of the current population and increase the quality and life expectancy [6]. In turn, they contain very important phenolic compounds such as phenolic acids and flavonoids [7] due to their antioxidant properties. These compounds combat the negative effects of free radicals in the body. Also, they help combat the signs of aging on the skin and, likewise, prevent chronic diseases [4] due to their biological effects (anticancer, antidiabetic, antiviral, antioxidant, hepato-protective, immune-potentiating, and hypo-cholesterolemic activities) [8].

To better understand nutrients, we approach the term bioavailability. Bioavailability is the amount of a nutrient absorbed by the intestine and from that moment becomes available to carry out physiological functions and also as storage. Different nutrients and the forms in which they exist in the ingested medium will react in different ways to inhibitors and enhancers and to the nutritional status of consumers, all of which contribute to the complex variability of nutrient bioavailability. Understanding this term can help optimize diets and establish proper nutrient recommendations.

According to the European Medicines Evaluation Agency (EMEA, guidelines for humans), it is the speed and degree to which the active ingredient is absorbed and becomes available at the site of action [9]. Bioavailability is the measurement of the relative amount of drug and the rate at which the drug reaches the systemic circulation from its dosage form and becomes available at the site of action [10]. The bioavailability (expressed as F%) quantifies the proportion of a drug that is absorbed and is available to produce systemic effects [9].

Bioavailability aims to explain the effect of a series of metabolic events, such as digestion, solubilization, organ absorption and release, enzymatic transformation, secretion, and excretion, on nutrient utilization. The bioavailability of macronutrients (carbohydrates, proteins, and fats) is usually high since more than 90% of the amount that is ingested is absorbed and used in the human body. As for micronutrients (vitamins and minerals), and bioactive phytochemicals (flavonoids and carotenoids), these can vary widely in the extent to which they are absorbed and utilized after ingestion [11].

The objective of this review is to analyze the bioavailability aspects of the *Pleurotus* mushroom as well as its botanical characteristics, nutritional content, health benefits, and the applications of the mushroom in food development due to its nutritional importance.

2. Materials and methods

The information was collected by searching for English keywords. Literature was taken from different sources such as Google Scholar, Wiley Online Library, Science Direct, and Springer Link databases. An updated bibliography was sought, trying to cover the last five years.

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3. Results and discussion

3.1. General botanical characteristics of Pleurotus

Global mushroom production is represented at about 85% by five main species or genera: *Agaricus bisporus* (estimated at 30% of global mushroom production), the genus *Pleurotus* (five to six species cultivated in approximately 27%), *Lentinula edodes* (17%), *Auricularia* (6%) and *Flammulina* (5%) [12].

Mushrooms are macroscopic fungi of great nutritional and therapeutic importance [13]. Structurally fungi are different from plants, animals, and bacteria. Fungi have a saprophytic diet, they obtain their food by absorption on organic substrates [14], they are capable of degrading organic substances such as agricultural waste, helping waste management [15]. They naturally grow in tropical climates on fallen branches, rotten trunks, dead and decaying trees, and various moist organic matter [16]. The cultivated edible mushrooms are fruiting bodies or basidiocarps that represent the reproductive stage of the basidiomycetes (Fig. 3), their production process consists of a solid-state fermentation, the mycelium of the fungus grows through the substrate which covers the nutritional requirements of the species, the lignocellulosic residues represent an important source of sustainable nutrients such as straw, sawdust, agave bagasse, sugarcane bagasse, coffee residues, rice husks, grape pomace, coconut shell, among others [5,17-19].

They include unisexual reproduction, that is, different forms of reproduction, for which their high reproduction is successful [20].

Macro fungi include more than 700 species and varieties of nutritional and/or medicinal importance and are widely distributed throughout the world. *Pleurotus* has more than 200 species and is one of the edible macro mushrooms with great potential as a food source with various nutritional and biological benefits and its ability to synthesize essential amino acids [14, 21, 22]. They grow at temperatures between 10 to 30 °C and pH 6 to 8, they secrete a wide range of enzymes to degrade the lignocellulosic biomass of the substrates [23]. Also commonly known as oyster mushrooms, they belong to the second most cultivated mushroom worldwide according to some authors [16]. However, other authors mention that oyster mushrooms occupy the 3rd place among the most industrially cultivated mushrooms. In addition, they are very efficient due to their ease of cultivation, high yield potential, and high medicinal and nutritional value [5].

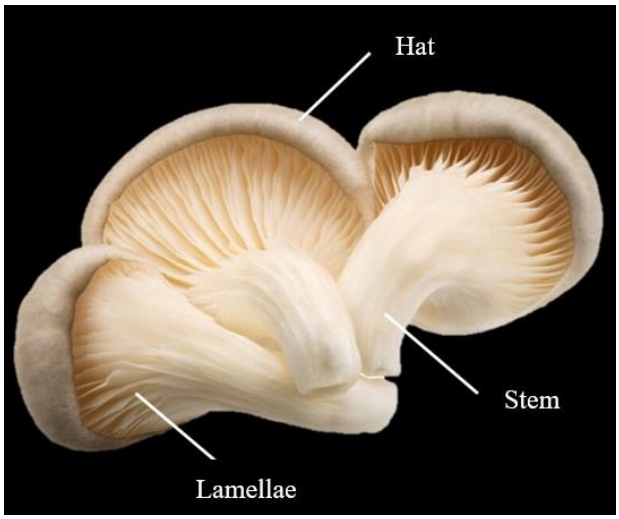

Figure 3. General scheme the edible mushrooms of *Pleurotus ostreatus*

The *Pleurotus* species belongs to the Kingdom of Fungi, Phylum of Basidiomyceta, Class of Agaricomycetes, Order of Agaricales, Family of Pleurotaceae, and Genus of *Pleurotus* [24].

The morphological characteristics of *Pleurotus* are determined by the culture climate, culture method, and substrate used, so they have a high phenotypic variability. *Pleurotus* species are identified using some unique characteristics, such as carpophore margin, stipe texture, basidiocarp color, spore-bearing surface, and any other fruiting body characteristics [19]. The word *Pleurotus* (from Latin = Displaced foot) refers to the lateral growth of the stem with the cap, while *ostreatus* refers to the oyster-like shape of the cap which ranges from 5 to 25 cm in length. The colors range from white to gray and in some brown tones [25].

3.2 Nutritional composition of Pleurotus

Oyster mushrooms have all nine essential amino acids, for this reason, they can be considered as a substitute for a meat diet. However, the amount of protein can be variable, due to factors such as stage of maturation, type of fungus, place of harvest, and availability of nitrogen content in the medium; therefore, if a nitrogen-rich substrate or supplemented with nitrogen sources is used in your grow, the protein content could be higher. *Pleurotus* spp. it has between

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50-60% of the dry weight of carbohydrates; these consist mainly of sugars (oligosaccharides, monosaccharides, and disaccharides) that are correlated with the synthesis of polysaccharides. Generally, these are represented by fiber, as glycoproteins including chitin, α-β, glucans, cellulose, as well as other hemicelluloses, such as mannans, galactans, and xylans. Generally, *Pleurotus* species are an important source of minerals, containing a mixture of essential minerals, such as potassium (933–967 mg/100 g), phosphorus (212–224 mg/100 g), calcium (221–238 mg /100 g), magnesium (366–407 mg/100 g) and, to a lesser extent, sodium (40–46 mg/100 g), these account for the majority of fruiting bodies, other minerals include copper (465–46 mg /100g), zinc (113–131 mg/100 g), iron (105–112 μg/g) and cadmium (5–35 μg/g), which represent minor components. *Pleurotus* could be an important source of vitamins, such as niacin, riboflavin and folates, as good as vegetables, but the bioavailability of the latter is better for folic acid in contrast to peas or spinach. In addition, mushrooms contain a small amount of vitamin C (12–15 mg/100 g) and thiamine (B1) (0.2–0.4 mg/100 g), niacin (vitamin B 5) (6–9 mg/100 g), pyridoxine (vitamin B 6) (0.1 mg/100 g), retinol (vitamin A) (25–26 μg/100 g), riboflavin (B2) (0.5–0.7 mg/100 g) and ergocalciferol (D2) (0.8–0.9 μg/g) among others. This genre is characterized by its low-fat content, and, therefore, they are classified as low-calorie foods, with a small amount of cholesterol and fat, less than 4%. However, as mentioned above, this amount depends on the substrate used in the crop. The most dominant unsaturated fatty acid in mushrooms has been reported to be linolenic acid (C18:2), an essential fatty acid, which is essential for the production and conversion of flavor components in *Pleurotus*. In addition, other reported fatty acids are oleic (C18:1) and palmitic [26]. On the other hand, regarding the content of vitamin B_{12} specifically for the *P. ostreatus* fungus, it is 0.6 μg per 100 g where among 38 common edible mushrooms analyzed for the content of vitamin B_{12}, only found that 9 contained this vitamin, where *P. ostreatus* was one of the best producers. Therefore, this mushroom could be a good source of B_{12} for vegans, otherwise, it would normally enter the human food chain through incorporation into foods of animal origin [27]. Table 1 shows how there are nutritional differences and similarities between *Pleurotus* spp. species. from *P. floridanus, P. ostreatus, P. djamor* and *P. sajor caju*, respectively. It is observed that the nutrient content in *Pleurotus ostreatus* is similar to other research with 19.08%, 1.60%, 51.80%, and 5.49% in terms of protein, fat, carbohydrates, and ash, respectively [28]. *Pleurotus ostreatus* is an edible mushroom of high nutritional value that uses industrial and agricultural lignocellulosic waste as substrates for its growth and reproduction [29]. Changes in nutrient content and mineral composition are influenced by various factors and conditions such as substrate and growing supplements. Different growing substrates can be used such as rice straw, wheat straw, or mixtures between straws [30]. *Pleurotus* species can also utilize wood waste or unused wood residue to promote economic growth and rescue the forest ecosystem. The most used substrate for cultivation in Asia is rice straw and cotton waste [31]. Table 1 shows that protein content among mushrooms was higher in *Pleurotus ostreatus*, as well as fat and carbohydrates, however, this was not the fiber case. *P ostreatus* and *P. Floridanus* present the highest Potassium values. Among all, *P. sajor caju* has the least amount of zinc. *P. ostreatus* has the most iron, sodium, magnesium and calcium. For its part, in the comparison of vitamins b3 and b6 of *P. djamor* and *P. sajor caju*, *P. djamor* had a greater amount of both than *P. sajor caju*.

3.3 Health benefits of Pleurotus bioactive compounds.

Phenolic compounds have gained importance due to their antioxidant properties. In the body, these compounds combat the negative effects of free radicals and reactive oxygen species. Its presence helps reduce the signs of skin aging and, in turn, contributes to the prevention of chronic diseases [4].

Pleurotus has a wide content of metabolites such as vitamin D, beta-glucans, phenolic compounds, alkaloids, glycosides, proteins and amino acids, flavonoids, phytosterols, tannins, saponins, and polyunsaturated fatty acids (Table 2). These components have been associated with various therapeutic properties, such as antiviral, antibacterial, antifungal, antiparasitic, antihypertensive, anti-inflammatory, and antidiabetic [13, 35].

Pleurotus species have been investigated for their antioxidant activity, which is attributed to their beta-

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Table 1. Nutrients in *Pleurotus* species.

Samples (Species)	Protein (%)	Fat (%)	Carbs (%)	Fiber (%)	Ashes (%)	Moisture (%)	Manganese (mg/kg)	Copper (mg/kg)	Ref.
P. Floridanus	2.413-19.074	-	4.979-39.359	4.223-33.386	1.032-8.16	87.35	9.89-16.43	9.43-13.49	[15, 19]
P. Ostreatus	7.3-53.3	0.5-7.6	13.1-85.8	4.2-31	4.1-15.9	85-89.69	16-23	9.10-11.69	[24, 31, 32]
P. Djamor	11.3-32.3	0.1-4.6	35.5-50.75	-	5.24-8.3	11.54-22.97	-	-	[31, 33]
P. Sajor caju	12.89-44.3	0.2-5.3	23.5-65.1	-	4.27-8.9	13.14-23.41	-	-	[31, 33]

Table 1. *(continued)*

Samples (Species)	Potassium (mg/kg)	Zinc (mg/kg)	Calcium (mg/kg)	Magnesium (mg/kg)	Sodium (mg/kg)	Iron (mg/kg)	Vitamin B3 (mg/kg)	Vitamin B6 (mg/kg)	Ref.
P. Floridanus	2056-30050	6.09-61.41	9.72-76.81	121-171.4	-	10.9-86.86	-	-	[15, 19]
P. Ostreatus	36830-42180	82-124	340-600	1570-2500	154-194.4	115.67-151	-	-	[24, 31, 32]
P. Djamor	241.2-558.25	38.6-45.08	9.04-18.26	118.73-134.27	10.1-16.38	4.73-5.04	1.142-2.521	0.261-1.136	[31, 33]
P. Sajor caju	398.8-550.60	0.72-13.33	3.35-36.24	63.26-90.24	7.23-14.33	1.65-4.81	0.777-2.196	0.175-0.252	[31, 33]

glucan and ergosterol (vitamin D) content. The antioxidant power of mushrooms can range between 60 and 90 % depending on the species, culture conditions, and extraction methods [4].

Unlike animal foods, mushrooms do not contain steroidal cholesterol, but vitamin D_2 can be converted to vitamin D by irradiation. Ergosterol has been associated with various biological activities and is considered a beneficial dietary supplement human [37].

Other compounds present in *Pleurotus* are vitamins that involve antioxidant activities, including [8] riboflavin, also known as vitamin B_2, which plays an important role in maintaining good eye health, helps convert food into energy, contributes to the production of red blood cells, fights aging and prevents heart disease. Niacin, or vitamin B3, has also been detected, a vitamin that contributes to the maintenance of a healthy digestive system, is also involved in the production of hormones, maintains a good function of the skin and nerves, and also helps in the conversion of food in energy [15]. In addition, the exopolysaccharides obtained from *Pleurotus* exhibit an antioxidant activity close to 100 %, similar to the activity of vitamin C. Studies on exopolysaccharides from *P. pulmonarius* present

Table 2. Bioactive compounds in *Pleurotus*.

Compounds	Biological function
Polysaccharides	Antioxidant, antiviral, anticancer, hypoglycemic, hypolipidemic, anti-inflammatory, immunomodulatory, antimicrobial, and cytoprotective.
Terpenoids	Antioxidant, anticancer, hypolipidemic, anti-inflammatory, and antimicrobial.
Phenolic compounds	Antioxidant, antiviral, antimicrobial, anticancer, and hypolipidemic.
Lectins	Antiviral, anticancer, and cytoprotective.
Peptides	Antiviral, antimicrobial, and antihypertensive.
Enzymes	Antiviral, antimicrobial, and anticancer.
Lovastatin	Antioxidant and hypolipidemic.
Glycoproteins	Anticancer and hypoglycemic.
Ergothioneine	Antioxidant
Pleuron	Antiaging

Adapted from Carrasco-González et al. [35].

functional groups such as -OH, $-CH_3$, -COOH and -C=O, with different monosaccharide units such as glucose, mannose, galactose, xylose, arabinose, fucose and rhamnose. The exopolysaccharides of *P.*

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pulmonarius have been shown to have a high antioxidant potential, becoming a natural option as preservatives in the development of foods and, in turn, allowing the development of functional foods [38].

The beta-glucans of the *Pleurotus* edible mushroom are present between 48.1 and 68 %, in addition, they present a total phenol content of 62.41 to 66.47 µg EAG. *Pleurotus* beta-glucans when consumed also act as prebiotics, promoting the growth of beneficial bacteria present in the intestinal microbiota. Due to this, polysaccharides such as beta-glucans provide an important nutritional value that is complemented by their antioxidant and prebiotic power, so the development of functional foods, supplements, and nutraceuticals could enhance the beneficial effects of *Pleurotus* from the economic and nutritional aspect [39]. An anticancer effect has been demonstrated in a synergy between beta-glucans with chitin present in the *Pleurotus* cell wall. These compounds help regulate the immune system in various ways by showing cytotoxicity in cancer cells. *Pleurotus* edible mushrooms, whether as a functional food, nutraceutical, or in the form of a compound for medicines, have a powerful bioactivity to improve people's health, which makes them a promising fungal source for the commercialization of products that improve living conditions and health of the current population and increase the quality and life expectancy [6].

Due to all the benefits that this edible mushroom has, it has been determined through a study carried out in mice that the ideal daily intake of *Pleurotus* for a person weighing 80 kg is 217.75 g. This amount is considered adequate to be consumed daily as part of a healthy diet and to obtain the necessary amount of metabolites that allow the development of all the biological activities contained in *Pleurotus* spp [40].

3.4 Bioavailability

There are few studies about the bioavailability of nutrients because this is very diverse and can be modified by various factors, such as physicochemical properties such as the form of the chemical bond; the matrix or food in which the nutrient is found; the presence or absence of other compounds in foods that enhance or inhibit absorption; metabolization after absorption; host-related factors (health status, genetic factors, age and lifestyle); as well as other individual or own factors [41].

Among the main nutrients of *Pleurotus* is protein, however, other sources of protein are legumes in which some anti-nutritional compounds have been found to negatively influence the bioavailability and digestibility of proteins. However, various food processing methods (soaking, husking, cooking, extrusion, enzymatic hydrolysis, fermentation, and sprouting) improve protein quality and reduce levels of anti-nutritional factors, thereby increasing protein digestibility [42].

Methods for measuring the bioavailability and/or bioaccessibility of nutrients involve investigation in humans, mice, pigs, and other animals (*in vivo*) or simulation in laboratory tests (*in vitro*). *In vivo* methods provide direct bioavailability data and have been used for a wide variety of nutrients and foods. Typically, a response is measured after consumption of a pure nutrient (natural or synthetic) by a living being, whether human (most common) or animal, and compared to a nutrient equivalent found in a food source [43].

3.5 Product development

3.5.1 Edible paper

Paper foods have desirable properties, such as longer shelf life, good taste, and preservation of nutritional qualities. Generally, they are consumed as a garnish and snacks. These types of products also facilitate transport and storage. There are studies on the development of edible paper foods using dietary fiber from Chinese cabbage [44] where they indicate its use for food packaging and pharmaceutical products. In turn, there are studies on the development of potato chips [45], which used jackfruit bulbs, obtaining a product with acceptable color and texture, through freeze-drying and hot air drying, for the benefit of consumers. Likewise, more recent studies [46] presented a novel methodology for the development of paper-like foods with fruiting bodies and mycelium of the fungus *P. eryngii*, described below 4 g of the dry weight of mycelium, stem, cap, and whole fruiting body, with 1 liter of distilled water, respectively, which was dispersed in a fibrous form by a fluffer. It was then mixed with a blender and vacuum dried (110 °C for 5 min.), and then sheets were formed using a paper sheet. Finally, the leaves were removed from the filter cloth to obtain the *P. eryngii* paper food of

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mycelia, stems, caps, and entire fruiting bodies [47]. This is how they exploited the potential of the *P. eryngii* fungus in the production of edible paper, available for different uses.

3.5.2 Tortillas

The addition of *Pleurotus Sajor caju* powder improved the nutrient composition, sensory acceptability, and glycemic index (GI) of Tortillas according to a study [47], where they reported that the protein concentration in the tortilla increased by 8.26 % up to 10.60% when incorporated with 15% *Pleurotus Sajor caju* Powder (PSP). The β-glucan content was the highest in the tortilla with 15% PSP added (1.21%). Finally, in the sensory evaluation, the tortilla fortified with 15% PSP was well accepted by the panelists. On the other hand, the control tortilla had an intermediate GI value (value 58), while the 15% PSP tortilla had a low GI value (value 53). On the other hand, in a study with the edible mushroom *Pleurotus agaves* [4], appreciated in many regions of Mexico, the nutritional and sensory quality of blue corn tortillas improved when added to flours prepared by organic nixtamalization, the amount of *P. agaves* added to tortillas was equivalent to 3% enrichment with β-glucans.

3.5.3 Bread

Studies have shown the fortification of wheat bread with *Agaricus Bisporus* [48]. The addition of mushrooms increased the content of bioactive compounds (total polyphenols, vitamin D_2) and the antioxidant properties of the bread. In addition, it caused a significant change in the basic technological quality of the loaves (color parameters, specific volume, hardness, cohesion, elasticity). On the other hand, in another study, functional bread was developed with powdered *Pleurotus eryngii* [49]. The breads were produced using traditional Italian-style sourdough technology. *P. eryngii* powder was added to flour of soft wheat varieties (Grano Dei Miracoli, Inalettabile, Mentana, Gentilrosso, Ardito, and a mixture of Rieti, Verna, and Mentana) or Creole durum wheat semolina (Saragolla) and subjected to fermentation with sourdough. The sourdough inoculum was prepared with selected strains of lactic acid bacteria (LAB) belonging to the species *Levilactobacillus brevis*, *Weissella cibaria*, and *Leuconostoc citreum*.

The supplementation did not cause alteration of the microbiological parameters, but it interfered with the chemical parameters acting as a pH buffer, increasing the TTA and consequently raising the amount of organic acids. *Pleurotus eryngii* powder could be used as a food ingredient in gastronomy for various applications, especially in cereal-based fermented products. Furthermore, they suggest that it could be marketed as a healthy alternative for consumers with special nutritional requirements, such as lactose intolerant people, or for ethical reasons, such as vegans. Irakiza PN, Chuma GB, Lyoba TZ, Mweze MA, Mondo JM, and Zihalirwa PK [50] conducted experiments substituting wheat flour for cassava flour in proportions of 10 to 25% to find the optimal combination. They also added oyster mushroom flour (2.5-10%) to the composite flour to compensate for nutrient deficiencies in cereals and tubers. With this, they demonstrated that 0-10% mushroom flour increased the bread protein from 19.63 to 22.66%. In addition, the 7.5% mushroom flour allowed raising the calories of the bread from 311.8 to 354.5 kcal, and the dry matter from 77.33 to 87.86%. Substituting wheat for cassava fortified with mushroom flour negatively affected bread volume, color, and flavor ($p<0.001$). The study recommended 5% to 15% to 80% and 10% to 10% to 80% flour composed of mushrooms, cassava, and wheat for better baking results, good consistency, and high protein content and energy. In more recent studies, a wheat bread with *P. ostreatus* powder was developed to increase its nutritional value and reduce its glycemic index. The nutritional value of the bread was enriched since the protein, fiber, and mineral content increased [51].

4. Conclusions

The content of nutrients present in edible mushrooms *Pleurotus spp* depends on the environment in which they grew, however, they have been little studied in terms of their bioavailability. Therefore, it is suggested that future studies focus on investigating the bioavailability of these nutrients, even though these already represent health benefits and therefore, in addition to their low cost, they are part of the most cultivated mushrooms globally. The high content of antioxidants present in mushrooms makes them beneficial to health and, in turn, antioxidants are

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considered functional ingredients, which makes them functional foods capable of minimizing and preventing diseases. Due to this, they are frequently used for consumption and are highly used in the production of food products and other purposes. The mineral content in *Pleurotus* species is low, however, one of the fungi that contains the most is *Pleurotus ostreatus*.

Authors' contributions

Conceptualization, B.G., M.C., I.M. and R.B.; Investigation, B.G., M.C., I.M. and R.B.; Writing-original draft preparation, B.G., M.C., I.M. and R.B.; and Writing-review and editing, B.G., M.C., I.M., R.R., A.L., J.M. and R.B; Supervision, B.G., M.C., I.M., R.R., A.L., J.M. and R.B.

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Availability of data and materials

All data will be made available on request according to the journal policy

Conflicts of interest

The authors declare that they have no conflict of interest.

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