IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 17, Issue 4 Ser. 1 (April. 2024), PP 52-60
www.iosrjournals.org

The Research Progress Of Pleurotus Eryngii

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Abstract:
Pleurotus eryngii is a delicious edible mushroom that is widely cultivated in many parts of the world and is highly prized for its unique flavor and excellent medicinal properties. Its enzymes, phenolic compounds and reactive oxygen species are key to its browning and aging and can affect nutrition and flavor. Pleurotus eryngii also possesses antioxidant, anti-hyperlipidemic, anti-tumor, immunomodulatory and bacteriostatic properties. In this paper, the mechanism of functional properties and the current research status of Pleurotus eryngii in food are reviewed.
Keyword: *Pleurotus eryngii; Functional characteristics; research status*

Date of Submission: 19-04-2024 Date of Acceptance: 29-04-2024

I. Introduction

Edible mushrooms are a group of macrofungi with medicinal and food properties that are used as folk medicines and health foods. Edible mushrooms are rich in nutrient-active substances such as proteins, polysaccharides, terpenes and lipids, which have multiple effects, including anticancer, immune modulation, cholesterol lowering, anti-virus, diabetes symptomatic and anti-inflammatory effects (Mwangi, Macharia, Wagara, & Bence, 2022; Reis, Martins, Vasconcelos, Morales, & Ferreira, 2017; Y. Zhang et al., 2021). With the rapid development of the global economy and the deepening of the concept of green and healthy diet, edible mushrooms are welcomed by many consumers. Apricot mushroom (*Pleurotus eryngii*) belongs to the phylum of fungi, subphylum of stramenopiles, order Umbelliferae, family Pleurotaceae, genus Pleurotus. In the natural world, because of the Apricot Abalone mushroom usually grows on the dead wood of the Umbelliferae herbaceous plant Parsley, so it is also known as Parsley sidearm (X. Li et al., 2015). The cap of *Pleurotus eryngii* is round in the early stage of growth, and then gradually spreads out, with a diameter of about 3-15 cm, and a grayish-brown color with a slight yellowish-white tinge; the stalk of the mushroom is about 3-10 cm in length, with a rod or bulbous shape, and a rounded cut, with a firm white flesh (Mau, Lin, Chen, Wu, & Peng, 1998). In recent years, this rare new species of edible fungus has been successfully cultivated, not only with food value, but also with medicinal and therapeutic functions (Torun & Aracagök, 2023). *Pleurotus eryngii* is a typical wild fungus of subtropical grassland-arid desert area, widely distributed in Southern Europe, Northern Europe, Central Asia and North Africa, etc (Bellettini et al., 2019). Artificial production of *Pleurotus eryngii* was first realized in 1958, and by 1977, its commercial cultivation was also successfully realized (Akyüz & Kırbağ, 2022). Although China's cultivation of *Pleurotus eryngii* started relatively late, it has developed rapidly and has now jumped to the top of the world's production of the almond mushroom, and the annual production is still steadily increasing.

Pleurotus eryngii are rich in nutrients, including polysaccharides, proteins, minerals and vitamins, as well as antioxidant, antitumor and antiviral properties, making them a favorite among consumers (Yuan et al., 2017). The results of the study showed that the protein content of *Pleurotus eryngii* was 25.4%, the fat content was 1.88%, the ash content was 6.9%, the total sugar content was 36.78%, and the carbohydrate content was 58.1% (Guo et al., 2023). *Pleurotus eryngii* are rich in nutrients and contain a variety of vitamins and mineral elements, including vitamin C content of 7.6 mg/100 g, calcium, magnesium, iron, copper, zinc, manganese, potassium and phosphorus content of 142.4 μg/g, 1214.3 μg/g, 101.8 μg/g, 11.5 μg/g, 79.6 μg/g, 13.41 μg/g, 1.81% and 1.45% (Su, Lv, Wang, Li, & Wang, 2020; C. Zhang et al., 2016).

II. Functional Properties Of Pleurotus Eryngii

Lowering blood lipids, lowering cholesterol, preventing cardiovascular diseases

The main component in *Pleurotus eryngii* that has the effect of eliminating fat and lowering blood pressure is polysaccharides. *Pleurotus eryngii* polysaccharide is one of the main chemical components and bioactive factors in *Pleurotus eryngii*. Z. Ren et al. (2017) isolated an alkaline polysaccharide (Al-MPS) with glucose as the main component from the mycelium of the *Pleurotus eryngii*, and treated hyperlipidemic mice with Al-MPS by gavage, which decreased the levels of low-density lipoproteins (LDL-C), very-low-density lipoproteins (VLDL-C), total cholesterol (TC), and triglycerides (TG), and increased the level of high-density lipoproteins (HDL-C), suggesting that Al-MPS has a role in lowering blood lipids. Chen, Zhang, Sha, Xu, and Wang (2016) through experiments, it was found that oral administration of *Pleurotus eryngii* polysaccharide (PEP) could inhibit the weight gain of mice and cause a decrease in plasma insulin levels, serum glycerol lipids, cholesterol, low-density lipoproteins, and the level of blasting blood glucose in mice, thereby controlling the lipid level of mice, and playing a role in preventing the occurrence of cardiovascular and cerebral vascular diseases, such as cerebral thrombosis and cerebral stroke. Zheng et al. (2014) demonstrated experimentally that both acidic and alkaline extracts of mycelial polysaccharides (AcMZPS, AlMZPS) from the mycelium of *Pleurotus eryngii* significantly increased HDL-C levels and lowered serum levels of LDL-C, VLDL-C, TC, and TG, thereby alleviating hyperlipidemia.

Improve immunity, anti-tumor

Sun, Hu, and Li (2017) extracted the polypeptide from the mycelium of *Pleurotus eryngii* (PEMP) Abelmoschus mycelium and used it to treat cancer cells and macrophages, and found that when the concentration of PMEP was 0.05-2 mg/mL, PMEP could promote the proliferation of macrophages and the secretion of TNF-α and IL-6, and at the same time, it could promote the release of NO and H_2O_2 to increase the phagocytosis capacity of macrophages. Therefore, PMEP has the effect of activating macrophage-mediated immune response.

Butanol extract of the by-products of *Pleurotus eryngii*, purified by Sun and Li (2017) using silica gel column chromatography, significantly enhanced macrophage proliferation, cytosolic drinking and increased the secretion of TNF-alpha, IL-6 to its highest level. Macrophages have a role in protecting organisms from infection and regulating the development of tissue inflammation. (Wynn, Chawla, & Pollard, 2013). Pinocytosis, one of the major processes of immune response and immunosurveillance, is carried out by macrophages derived from bone marrow stem cells (Pliyev, Dimitrieva, & Savchenko, 2014; Wong, Lai, & Cheung, 2011). Meanwhile, the expression of TNF-α, IL-6 has an important impact on immunity to various infectious agents and cancer.

D. Xu et al. (2016) successfully extracted the polysaccharide from *Pleurotus eryngii* (EPA-1) by ion exchange and gel filtration chromatography, and used EPA-1 to induce RAW 264.7 cells to secrete NO and other cytokines, and the expression of phosphorylation-promoting p38, ERK, JNK and NF-κB was significantly increased when the treatment dose of EPA-1 was increased, i.e., EPA-1 may release some factors related to the immunomodulation-related factors and can participate in the immune process through the channel of mitogen-activated protein kinase (MAPK), suggesting that EPA-1 has a good effect on immune stimulation.

In vitro, cell viability, cell proliferation and cell morphology of B16-F10 mouse melanoma cells treated by Biscaia et al. (2017) with *Pleurotus eryngii* polysaccharide (MG-Pe) were normal, confirming that MG-Pe is not cytotoxic and that MG-Pe also reduces the invasive ability of B16-F10 cells. In further in vivo experiments in mice, MG-Pe was shown to be a novel anticancer molecule, as the tumor volume of mice injected with 10 days of MG-Pe was 60% smaller than that of control mice, and no changes in physiological parameters were observed in the mice.

Lower blood sugar

Gong et al. (2022) divided thet polysaccharides of *Pleurotus eryngii* into two fractions (WPS and P-1).WPS was mainly β-glycosidic bonds with α-glycosidic bonds and P-1 contained only α-glycosidic bonds. The molecular weights of WPS and P-1 were 4.5 × 105 Da and 2.2 × 104 Da, respectively. The GC results showed that the 2 fractions consisted of rhamnose, arabinose, xylose, mannose, glucose, and galactose. The ratio of WPS was 0.35:0.24:0.45:0.24:28.78:1.10, and the ratio of P-1 was 0.95:0.64:0.66:1.84:60.69:0.67. Higher structural studies showed that both fractions did not have a triple-helical structure, with WPS having a dense structure and P-1 a loose structure. In addition, based on in vitro and cellular assays, the antioxidant activity of WPS exceeded that of P-1, and both fractions also exhibited high hypoglycemic activity by inhibiting α-glucosidase activity and promoting the expression of the PI3K-AKT signaling pathway.

Yudi Liu et al. (2022) prepared wheat bread enriched with different levels of *Pleurotus eryngii* powder and the results of the experiment indicated that the total phenolic content of wheat bread increased significantly with the addition of *Pleurotus eryngii* powder. Reduced sugar, hydrogenation index, and expected glycemic index gradually decreased with mushroom powder. *Pleurotus eryngii* powder can be used as a highly valuable ingredient to improve the nutritional profile of bread and to reduce the glycemic index of bread.

Protection of the liver

Cellulose and chitin play a role in protecting the liver in *Pleurotus eryngii*. Huang et al. (2016) explored the therapeutic effect of *Pleurotus eryngii* cellulose on rats with experimental fatty liver. The rats were fed with high-fat chow to establish a rat fatty liver model, and then fed with different concentrations of apricot mushroom cellulose for 6 weeks. *Pleurotus eryngii* abalone cellulose increased the antioxidant capacity of liver tissues, improved liver activity, and reduced hepatic fat deposition, thereby protecting and lowering the lipid level of the liver. N. Xu et al. (2017) has demonstrated experimentally that a novel enzymatic zinc polysaccharide (En-MZPS) with glucose as its main component can be isolated from the mycelium of *Pleurotus eryngii* variant, and that En-MZPS has the potential to prevent and treat HFHCE induced liver injury.

Antioxidant activity

Petraglia et al. (2023) evaluated the antioxidant and neuroprotective activities of an enriched polysaccharide fraction obtained from cultivated *Pleurotus eryngii* (EPF). Proximate composition (moisture, protein, fat, carbohydrate and ash) was determined using the AOAC procedure. EPF was extracted sequentially using hot water and alkaline extraction, followed by deproteinization and precipitation with cold ethanol. Total α and β-glucans were quantified using the Megazyme International Kit. The results showed that the process allowed high yields of polysaccharides, with a high content of (1-3;1-6)-β-D-glucan. The antioxidant activity of EPF was assayed from total reducing power, DPPH, superoxide, hydroxyl, and nitric oxide radical scavenging activities. EPF scavenges DPPH, superoxide, hydroxyl, and nitric oxide radicals with IC50 values of 0.52 ± 0.02, 1.15 ± 0.09, 0.89 ± 0.04, and 2.83 ± 0.16 mg/mL, respectively. By MTT assay EPF was assessed to be biocompatible with DI-TNC1 cells in the range of 0.006-1 mg/mL and significantly counteracted H_2O_2-induced reactive oxygen species production in the concentration range of 0.05-0.2 mg/mL. His study suggests that polysaccharides extracted from *Pleurotus eryngii* could be used as functional foods to enhance antioxidant defense and reduce oxidative stress.

S. Li and Shah (2017) concluded from ABTS free radical assay that sulfonated *Pleurotus eryngii* polysaccharide (PEPS) scavenging capacity was higher, and both PEPS and S.PEPS significantly inhibited reactive oxygen species and malondialdehyde in H_2O_2-treated CCD and Caco-2 cells as compared to the control. In addition, SOD, catalase and glutathione peroxidase activities in H_2O_2-treated CCD and Caco-2 cells were significantly improved by S.PEPS compared to the control. Thus, sulfonation had an enhancing effect on the antioxidant activity of PEPS.

A. Zhang, Li, Xing, Yang, and Sun (2014) extracted crude polysaccharides from *Pleurotus eryngii* by ultrasonic extraction (PEPS30, PEPS60, and PEPS80). In vitro, the concentrations of these crude polysaccharides were positively correlated with DPPH radical scavenging rate and superoxide anion radical scavenging capacity, with PEPS80 exhibiting the best antioxidant activity.

III. Current Status Of Research On Pleurotus Eryngii In Foodstuffs

Drinks

Lin, Wu, Lo, and Mau (2018) analyzed the composition of centrifugal broths from different grades of substrates and further made instant beverages from centrifugal broths using the indigestible dextrin Fibersol-2 as a carrier. The recovered centrifugal broth represented 54.2-62.8% of the total weight of blanched mushrooms. The centrifugal broth solids contained free amino acids (15.20-34.23%), 5-nucleotides (7.44-9.71%), sugars and polyols (33.55-34.97%), and significant amounts of ergothioneine (5.49-9.90%) and γ-aminobutyric acid (1.23-6.90%). Instant beverages SD13-40 and SD15-40 were rated the highest using a 7-point hedonic scale for color (6.3), flavor (5.7), and overall preference (5.7-6.0). Overall, centrifugal broths of *Pleurotus eryngii* can be developed as functional foods in the form of beverages.

Fermented products

Song, Xu, and Chen (2022) investigated the improvement of the quality of sour soybean milk with the addition of *Pleurotus eryngii* polypeptides and evaluated the immunomodulatory effects of sour soybean milk fermented with apricot mushroom polypeptides in cyclophosphamide-induced immunosuppressed mice. The results showed that the physicochemical properties of fermented soymilk with small molecular peptides (<3 kDa) were superior to those of other products, including decreased pH, increased acidity, water holding capacity, and increased lactic acid bacteria population. Animal experiments showed that the peptide-containing tamarind pulp was effective in reversing the downward trend of thymus/spleen index and hematological parameters, enhancing immune function in mice, including serum hemolysin and splenic lymphocyte proliferation, and inhibiting oxidative stress. In addition, fermentation of tamarind pulp with peptides increased the diversity of the intestinal flora, increasing the abundance of Thick-walled Bacteria phylum, Bacteroidetes phylum, and Lactobacillus. In summary, this may provide a theoretical basis for the development of immunomodulators or functional food additives with antioxidant activity.

Food

Cirlincione et al. (2022) has developed a functional bread containing *Pleurotus eryngii* flour. The bread was produced using a traditional Italian style sourdough technique. *Pleurotus eryngii* flour is added to coarse flour of tender wheat varieties (Grano Dei Miracoli, Inalettabile, Mentana, Gentilrosso, a mixture of Ardito, Rieti, Verna and Mentana) or of durum wheat local varieties (Saragolla) and sourdough fermentation is carried out. The sourdough inoculum was produced with selected strains of lactic acid bacteria (LAB) belonging to Lactobacillus brevis, Lactobacillus weissei and Lactobacillus citriodora. The addition of *Pleurotus eryngii* powder (PP) (10% w/w) did not affect the fermentation process as LAB developed to 109 CFU / g after 8 h. The pH, TTA and organic acid values of PP doughs were higher than those of control fermented doughs. All breads differed in height, weight loss, hardness, color, and porosity. Sensory evaluation showed that the breads made with Mentana flour and PP were most appreciated by the judges. Therefore, only breads processed from this wheat variety were studied for vitamins and micronutrients, showing an increase in B_1, B_2, B_3 and D vitamins, total polyphenols and β-glucan. This work provides evidence for PP supplementation to increase the functional aspects of bread.

Amerikanou et al. (2023) developed a *Pleurotus eryngii* chip to chemically characterize and determine the nutritional value of an innovative UVB-irradiated and baked snack from *Pleurotus eryngii*. Proximate composition, amino acids, fatty acids, vitamins, and macro- and micronutrient analyses were applied. In addition, we calculated indices to assess the nutritional quality of the food and evaluated the sensory characteristics of *Pleurotus eryngii* snack. We found that this snack has a high nutritional, consumer and biological value. More specifically, it is low in calories, high in fiber and protein, low in lipids, has no added sugar, and is high in ergosterol and β-glucan. In addition, it contains high levels of vitamins and micronutrients. Its NRF score of 9.3 is quite high compared to most popular snacks, and the snack exhibits high hypocholesterolemic and low atherosclerotic and thrombotic potential, providing a "healthy snack" option.

A. Ren et al. (2022) investigated the effect of ultrasound-assisted pretreatment on the changes in pore structure of vacuum-fried *Pleurotus eryngii* with reduced oil absorption. The pore structure of blanched, bleached and infiltrated, bleached and ultrasonicated, and bleached and ultrasonically assisted infiltrated *Pleurotus eryngii* slices from four pretreatment methods were determined using mercury intrusion porosimetry (MIP) and scanning electron microscopy (SEM) methods. In addition, quality parameters such as hardness, rehydration ratio, reducing sugar, protein and oil content of vacuum fried *Pleurotus eryngii* slices were measured. The results showed that the oil absorption of vacuum fried *Pleurotus eryngii* slices was influenced by the porous structure. The oil content of vacuum-fried *Pleurotus eryngii* slices was significantly and positively correlated with the pores of the samples with diameters larger than 50, 5-50, and 0.5-5 μm, and negatively correlated with the pores with diameters smaller than 0.5 μm, both before and after vacuum deep-frying. The ultrasonic pretreatment changed the microporous structure of *Pleurotus eryngii* chips and effectively hindered the oil absorption of the samples. In particular, ultrasound-assisted osmotic pretreatment induced the formation of more micropores. The results suggest that blanching + ultrasound-assisted osmotic pretreatment is a promising method to reduce oil absorption and improve the quality of vacuum-fried foods.

Dry product

The fresh water content of *Pleurotus eryngii* is as high as 90%, and they still undergo respiration and metabolism after picking and storing, which makes them difficult to be preserved at room temperature, and prone to bacterial growth and spoilage(Su, Lv, Wang, Wang, & Li, 2020). Therefore, it has become a pressing issue to properly preserve food products such as *Pleurotus eryngii* to ensure that they remain in the best condition for a long period of time.

Drying is not only an ideal processing method, but also a crucial step to ensure the long-term preservation of the product (Ying Liu, Zheng, Ibrahim, Yang, & Huang, 2018). The drying process is widely used in several industries, and it extends the shelf life of products by reducing the moisture content of materials. For *Pleurotus eryngii*, when the moisture content is reduced to less than 13%, it can effectively inhibit the growth of microorganisms and protect the nutrients from loss. In addition, dried *Pleurotus eryngii* are more resistant to collision during transportation, and can better restore the original quality after rehydration(Xi et al., 2023).

X. Li et al. (2015) compared the effects of five drying methods, hot air drying (HA), microwave drying (MW), vacuum drying (VA), freeze drying (FZ), and natural air drying (NA), on the flavor compounds of *Pleurotus eryngii*, and finally concluded that the FZ and HA treatments preserved the flavor of *Pleurotus eryngii* better. Browning phenomenon occurs during the drying process of *Pleurotus eryngii*, so it is often treated with color protection.

Bai et al. (2023) explored the effects of different drying methods on the drying characteristics, three-dimensional appearance, color, total polysaccharide content (TPC), antioxidant activity, and microstructure of slices of *Pleurotus eryngii*. The drying methods included hot air drying (HAD), infrared drying (ID) and microwave drying (MD). The results showed that the drying methods and conditions had a significant effect on the drying time, in which MD had a significant advantage in reducing the drying time. Shrinkage and roughness were used as quantitative indicators to evaluate the three-dimensional appearance of Rhodococcus slices, and the best appearance was obtained by hot air drying at 55 and 65 ºC. HAD and ID gave better color, TPC and antioxidant activity at lower drying temperatures, but MD significantly impaired the color and nutritional quality of *Pleurotus eryngii*. Scanning electron microscopy was used to observe the microstructure of dried almond slices, and the results showed that the drying method and conditions had a significant effect on the microstructure of *Pleurotus eryngii* slices. Scattered mycelium was clearly observed in HAD and ID dried samples of *Pleurotus eryngii* filamentous fungi at lower drying temperatures, while higher drying temperatures resulted in cross-linking and aggregation of mycelium.

Su et al. (2022) used microwave hot air rolling drying (MHARD) combined with ultrasonic pretreatment time (0, 20, 40 and 60 min) The drying curves, thermal characteristics, moisture migration, microstructure and rehydration kinetics of *Pleurotus eryngii* were investigated by Differential Scanning Calorimetry (DSC), Low Field Nuclear Magnetic Resonance (LF-NMR) analysis and Scanning Electron Microscopy (SEM). Results The results showed that *Pleurotus eryngii* were dried for 80, 70, 60 and 50 min. the energy consumption of ultrasonic pretreatment was significantly reduced, and the effective diffusivity of moisture (Deff) increased with the increase of ultrasonic pretreatment time. the DSC curves indicated that ultrasonic pretreatment significantly accelerated the drying process through enhanced heat transfer. Meanwhile, SEM images showed cell rupture and many irregular holes in the ultrasonically pretreated samples. In terms of rehydration kinetics, the Page model can well simulate the rehydration kinetics of dried *Pleurotus eryngii* with $R^2 > 0.99$.

IV. Conclusions

In recent years, there has been a gradual increase in the number of research reports on *Pleurotus eryngii* polysaccharides, mainly focusing on the extraction, isolation and purification, structural analysis and pharmacological activity of *Pleurotus eryngii* polysaccharides. A large number of literatures have confirmed that the polysaccharides of *Pleurotus eryngii* have pharmacological activities such as antioxidant, antihyperlipidemia, antitumor, immunomodulation and hepatoprotection. *Pleurotus eryngii* polysaccharides can exert antitumor activity indirectly through the body's own immune system with little or no cytotoxicity, which makes them a potential new type of anticancer drug. However, most studies have only reported the in vitro pharmacological activities and in vivo studies of polysaccharides extracted from *Pleurotus eryngii*, while there are few reports on the development of *Pleurotus eryngii* polysaccharide products. In addition, the studies on the relationship between the structure and pharmacological activity of *Pleurotus eryngii* polysaccharides and their mechanism of action lacked depth. Therefore, it is necessary to further investigate the conformational relationship of the polysaccharides of *Pleurotus eryngii* to provide a greater scientific and theoretical basis for the extensive processing and product development of the polysaccharides of *Pleurotus eryngii*.

The functional properties of *Pleurotus eryngii* are abundant, and although the research on the functional properties of *Pleurotus eryngii* has achieved certain results, it needs to be further explored, for example, to study whether *Pleurotus eryngii* has other functional properties or to conduct a more in-depth and broader exploration of the known functional properties. In addition, there are not many kinds of modern products related to *Pleurotus eryngii*, and innovations can be made in the kinds of *Pleurotus eryngii* products, therefore, the factors affecting the processing technology of the *Pleurotus eryngii* need to be explored in depth, so as to provide a reference basis for the development of more kinds of *Pleurotus eryngii* products, and also to optimize the processing technology of the known *Pleurotus eryngii* products.

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