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# Oyster Mushroom (*Pleurotus ostreatus*) as a Healthy Ingredient for Sustainable Functional Food Production

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**Abstract:** The oyster mushroom (*Pleurotus ostreatus* (Jacq. ex Fr.) P. Kumm.) is one of the most popular edible mushrooms. *P. ostreatus* contains important essential nutrients for human nutrition and is a natural source used in both traditional and modern medicine. Nowadays, *P. ostreatus* has been used *in vitro* studies as food additive in the development of value-added functional foods such as meat, bakery, and dairy products, traditional foods, and various alcoholic and non-alcoholic beverages. Fresh and other forms of *P. ostreatus* have been used for food fortification, the improvement of sensory quality and the physicochemical properties of foods and prolonging the shelf life of functional foods. In this review, potential of use of *P. ostreatus* as food additive in sustainable functional food production and its effects on food quality were emphasized.

**Key words:** *Pleurotus ostreatus*, Functional food, Nutrient, Biological activity

## Sürdürülebilir Fonksiyonel Gıda Üretimi İçin Sağlıklı Bir Bileşen Olarak İstiridye Mantarı (*Pleurotus ostreatus*)

**Öz:** İstiridye mantarı (*Pleurotus ostreatus* (Jacq. ex Fr.) P. Kumm.) en popüler yenilebilir mantarlardan biridir. *P. ostreatus*, insan beslenmesi açısından önemli temel besin ögelerini içermektedir ve hem geleneksel hem de modern tıpta kullanılan doğal bir kaynaktır. Günümüzde *P. ostreatus in vitro* çalışmalarda et, unlu mamuller ve süt ürünleri, geleneksel gıdalar ve çeşitli alkollü ve alkolsüz içecekler gibi katma değerli fonksiyonel gıdaların geliştirilmesinde gıda katkı maddesi olarak kullanılmaktadır. *P. ostreatus*'un taze ve diğer formları gıdaların güçlendirilmesi, duyusal kalitesinin ve fizikokimyasal özelliklerinin geliştirilmesi ve fonksiyonel gıdaların raf ömrünün uzatılması için kullanılmaktadır. Bu derlemede, *P. ostreatus*'un gıda katkı maddesi olarak sürdürülebilir fonksiyonel gıda üretiminde kullanım potansiyeli ve gıda kalitesi üzerindeki etkileri üzerinde durulmuştur.

**Anahtar kelimeler:** *Pleurotus ostreatus*, Fonksiyonel gıda, Besin ögesi, Biyolojik aktivite

## Introduction

Edible mushrooms have been consumed as food and medicine due to their valuable macro and micronutrients, and mycochemicals including phenolic compounds, triterpenoids, sterols, fatty acids, and proteins (Anusiya et al., 2021; Cateni et al., 2021). *Pleurotus ostreatus* (Jacq. ex Fr.) P. Kumm. belonging to division *Basidiomycota*, and family *Pleurotaceae* is called as “Oyster Mushroom” worldwide (El-Ramady et al., 2022) and “İstiridye Mantarı” in Türkiye (Sesli et al., 2020). It is one of the most appreciated edible species with a high general acceptability all around the world (Doğan and Doğan, 2022). *P. ostreatus* is a culinary-medicinal mushroom because of its excellent taste, flavor, high nutritional value, and pharmacological potential supported by both *in vitro* and *in vivo* experimental studies, as well as clinical trials (Adebayo and Oloke, 2017; Agarwal et al., 2017; Carrasco-González et al., 2017; Piska et al., 2017; Sałata et al., 2018; Bulam et al., 2019a, b; Galappaththi et al., 2021; Niego et al., 2021; Venturella et al., 2021). Moreover, *P. ostreatus* belongs to the "white-rot fungi" category, which produces the ligninolytic enzymes laccase and peroxidase degrading hemicellulose, cellulose, and lignin (Doroški et al., 2022).

*P. ostreatus* is both naturally colonized on almost all hardwoods, particularly on dead and decaying tree stumps, fallen branches, and wet logs and commercially cultivated on various low-quality plant originated materials, agro/wood by-products, food and cellulose wastes, wheat straw bales, and sawdust with simple methods including just pasteurization to represent high-quality food having a higher yield and growth and shorter substrate colonizing time than other cultivated mushrooms (Kibar and Pekşen, 2008; Adebayo and Oloke, 2017; Piska et al., 2017; Royse et al., 2017; Sałata et al., 2018; Barh et al., 2019; Bulam et al., 2019a; Zięba et al., 2020; Galappaththi et al., 2021; Doroški et al., 2022; Lesa et al., 2022). *P. ostreatus* is the second most commercially cultivated mushroom both worldwide (Royse et al., 2017) and in Türkiye (Eren and Pekşen, 2019). In terms of ethnomycology, *P. ostreatus* is consumed as a source of food, cooked as fresh by sauteing, grilling, and frying or preserved as cooled, frozen, and dried, and sold in domestic and international markets as fresh and in processed forms (Pekşen et al., 2016; Thakur, 2020; Niego et al., 2021).

Functional foods are foods with positive health benefits attributed to the nutritional value of the foods which promotes optimal health of humans and helps in reducing the risk of many diseases such as cardiovascular diseases, cancer, hyperlipidemia, osteoporosis, diabetes, and hypertension. Furthermore, they act as cardiovascular agents, anti-obese agents, anti-diabetic agents, anti-cancer agents, immuno-boosters, substances that manage chronic inflammatory disorders, and formulations to cure degenerative diseases, and they are consumed as part of the normal diet (Morris et al., 2017; Reis et al., 2017; Raghavendra et al., 2018; Anusiya et al., 2021; Cateni et al., 2021; Kaur et al., 2021). Yeung et al. (2018) stated the most popular topics focused on nutraceuticals and functional foods as prebiotics, probiotics, antioxidants, and phenolic contents. Nowadays, functional edible and medicinal mushrooms have been known as one of the potential natural sources for developing novel functional foods as well as dietary supplements, myconutraceuticals, mycocosmeceuticals, and mycopharmaceuticals (Morris et al., 2017; Reis et al., 2017; Bulam et al., 2018; Üstün et al., 2018; Bulam et al., 2019a, c, d; Cateni et al., 2021; Kaur et al., 2021; Niego et al., 2021; Venturella et al., 2021).

Fresh edible and medicinal mushrooms and their dried powders, blends, aqueous extracts, concentrates, wastes, and bioactive compounds can be incorporated into foods to develop fortified functional foods with the aim of substitution of flour, meat, fat, salt, phosphates, nitrites, and antioxidants in addition to contributing long shelf-life and low-cost production. Bakery, meat, dairy, fermented, fruit and vegetable, traditional products, and beverages have already been studied *in vitro* to present value added and mushroom-based functional foods. In these studies, some changes in nutritional, sensorial, textural, and pharmacological properties of novel value-added products were observed (Morris et al., 2017; Reis et al., 2017; Raghavendra et al., 2018; Bulam et al., 2019c; Salehi, 2019; Gonzales et al., 2020; Ho et al., 2020; Bakratsas et al., 2021; Das et al., 2021; Dorin and Melinda, 2021; Kumar et al., 2021; Pe´rez Montes et al., 2021; Rangel-Vargas et al., 2021). This review aimed to give recent studies on potentially value-added functional foods using *P. ostreatus* considered functional food additive/ingredient or substituent/replacer and its effects on food quality in terms of nutritional, sensorial, and medicinal properties, and bioactive compounds of novel products.

**Nutritional Composition, Bioactive Compounds, and Biological Activities of *P. ostreatus***

In terms of sensorial and nutritional compositions, *P. ostreatus* possesses a unique flavor and aromatic compounds such as 1-octen-3-ol, and vital macro and micronutrients with a significant amount of proteins (7.3-53.3% dry weight (DW)), carbohydrates (13.1-85.8% DW), crude fibers (7.6-15.0% DW), β-glucans (19.3-50.0% DW), vitamins (especially vit B, vit C, and vit $D_2$) and major (K, P, Mg, Na) and minor (Cu, Fe, Zn) minerals with a low content of lipids (0.5-7.6% DW) (Adebayo and Oloke, 2017; Agarwal et al., 2017; Carrasco-González et al., 2017; Sałata et al., 2018; Turfan et al., 2018; Bulam et al., 2019a, b; Galappaththi et al., 2021; Lesa et al., 2022). Amino Acid Score (AAS) of *P. ostreatus* meets the nutritional requirements of all essential amino acids for adults (Carrasco-González et al., 2017). 100 g of fresh fruiting bodies contains 15% of the recommended daily intake (RDI) of vitamin C, 40% of niacin, riboflavin, and thiamin, and 0.5 mg of vitamin $B_{12}$. Fresh *P. ostreatus* is also characterized by 0.1-0.2 g/100 g fats including a high content of oleic acid (40%), linolenic acid (55%), and substances decreasing serum cholesterol levels (Piska et al., 2017).

Moreover, *P. ostreatus* is rich in various bioactive compounds such as antioxidant enzymes, dietary fiber, β-glucans, α-glucan, immunomodulating pleuran, proteins, glycoproteins, polysaccharides, proteoglycans, peptides, terpenoids, phenolic compounds (flavonoids and phenolic acids), indole compounds (melatonin, serotonin, and selenium), lectin, heteroglycan, hypolipidemic lovastatin, ergosterol, chrysin, ubiquitin, laccase, antioxidant ergothioneine, and γ-aminobutyric acid (GABA). Water or organic solvent crude extracts, dried powder of fruiting bodies, mycelia, dietary supplements (Imunoglukan P4H®) and medicinal mushroom extract blends (Agarikon.1 and Agarikon Plus), and *P. ostreatus*-added processed foods rich in terms of these mycochemicals have been reported to show numerous biological activities. Their hematological, hepatoprotective, cytoprotective, neuritogenic, antiaging, antiangiogenic, antiatherosclerotic, antimetastatic, antidiabetic, hypoglycemic, hypolipidemic, antihypercholesterolemic, antihypertensive, antiatherogenic, antibiotic, antiarthritic, antioxidative, anticancer, antitumor, anticarcinogenic, anti-inflammatory, antimicrobial, antiviral, antibacterial, antifungal, antinociceptive, antineoplastic, antiproliferative, cytostatic, cytotoxic, cosmetic, prebiotic, pro-apoptotic, immunomodulatory functions, and preventive and therapeutic effects in recurrent respiratory tract infections have been already proven by *in vitro*, *in vivo* studies, and clinical trials (Ghosh, 2016; Adebayo and Oloke, 2017; Carrasco-González et al., 2017; Piska et al., 2017; Golak-Siwulska et al., 2018; Sałata et al., 2018; Bulam et al., 2019a; Ozen et al., 2019; Turfan et al., 2020; Anusiya et al., 2021; Galappaththi et al., 2021; Türsen Uthan et al., 2021; Venturella et al., 2021, Vlassopoulou et al., 2021; Doğan and Doğan, 2022; Lesa et al., 2022). *P. ostreatus* is considered a medicinal mushroom because of its wide spectrum of biological activities. Fruiting bodies and extracts of *P. ostreatus* have already found applications in the treatment of diseases, especially diabetes, arteriosclerosis, neurodegeneration, and cancer. Nowadays, it has also been a potential source of cosmetics and topically applied preparations in supportive therapy e.g., for atopic dermatitis (Piska et al., 2017; Lesa et al., 2022).

The concentrations of nutrients and mycochemicals of wild and cultivated *P. ostreatus* vary depending on their habitats, environmental factors, cultivation conditions such as temperature and light intensity, substrate compositions, supplementary substances, postharvest treatments, maturity stages, parts of mushrooms as cap, stalk or mycelium, and experimental parameters (Kibar and Pekşen, 2008; Adebayo and Oloke, 2017; Carrasco-González et al., 2017; Piska et al., 2017; Sałata et al., 2018; Bulam et al., 2019a; Sarikurkcu et al., 2020; Zieba et al., 2020; Galappaththi et al., 2021).

**Utilization Potential of *P. ostreatus* in Production of Novel Functional Foods**

*P. ostreatus* contains high quality protein and fiber (mainly β-glucans) that may be used as functional food ingredient. Bakery, meat, dairy, fruit, and vegetable, fermented, traditional products, alcoholic and non-alcoholic beverages, and seasonings have been recently studied to present *P. ostreatus*-incorporated functional foods. *P. ostreatus* was utilized to enrich value-added functional products in terms of protein, crude fibre, β-glucan, to decrease glycemic index, and to increase biological activities such as antioxidant effect or to replace main ingredients including meat, fat, salt, nitrite, and flour. *P. ostreatus* was incorporated in various forms such as fresh after steamed and centrifuged, powder after dried and ground, flour after boiled in water, dried and ground, aqueous extract of dried and ground mushrooms, β-glucan hydrogels obtained from fresh and dried mushrooms, mushrooms boiled in water containing 0.05% KMS, and β-glucan and cell-free extracts of mushrooms (Okamura-Matsui et al., 2003; Carrasco-González et al., 2017; Lavelli et al., 2018; Bulam et al., 2019c; Salehi, 2019; Gonzales et al., 2020; Ho et al., 2020; Das et al., 2021; Dorin and Melinda, 2021; Kumar et al., 2021; Pe´rez Montes et al., 2021; Rangel-Vargas et al., 2021; Gopal et al., 2022).

On the other hand, a recent study on functional tomato pomace feed fermented with *P. ostreatus* and *Phanerochaete chrysosporium* was also performed resulting in improvement of its nutritional properties (Yasar and Tosun, 2020).

Recent *in vitro* studies on novel functional foods developed with *P. ostreatus* and significant changes in their food quality in terms of nutritional, physicochemical, sensorial, microbiological, textural, and appearance properties were given in Table 1.

Table 1. Functional foods incorporated with *P. ostreatus* and effects of *P. ostreatus* on food quality of functional products

| Functional Food | Concentration | Function | Effects on Properties | References |
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| **Meat Products** | | | | |
| Beef salami | (1, 3 and 5%) D | Antioxidant activity | Increase in moisture; Decrease in protein, fat, CIE *L**, a*, and b*; No negative effect on sensorial properties, flavor, and overall acceptability; Inhibition in lipid and protein oxidation; Undesired textural losses | Özünlü and Ergezer, 2020 |
| Frankfurter (25% fat, 1.5% salt, 2% sodium caseinate, 0.5% phosphates) | *A. bisporus; P. ostreatus* (2.5 and 5%) D | Fat reduction (30 and 50%); Salt, caseinate, phosphates reduction | Modification of color and texture: *Agaricus* gave darker and *Pleurotus* softer samples; Increase in juiciness; No antioxidant effect; Mushroom samples were sensorially acceptable with better scores at low mushroom level | Cerón-Guevara et al., 2020a |
| Beef patty (10% fat, 1.2% salt) | *A. bisporus; P. ostreatus* (2.5 and 5%) D | Fat reduction (25 and 50%); Salt reduction (50%) | Increase in moisture, protein (Control patty: 17.53% DW; 5% *A. bisporus*: 19.23% DW; 5% *P. ostreatus*: 18.80% DW), and dietary fiber; Lower increase in hardness compared to fat reduced control samples; Slight antimicrobial effect in *Pseudomonas*; Sensorially acceptable, especially 2.5% mushroom samples | Cerón-Guevara et al., 2020b |
| Liver pate (30% fat, 2% salt) | *A. bisporus*; *P. ostreatus* (7.5 and 10%) D | Fat reduction (30 and 50%); Salt, phosphates, and nitrite reduction (50%) | Increase in protein, dietary fiber, and pH; Color modifications; Increase in hardness and adhesiveness | Cerón-Guevara et al., 2021 |
| Traditional Turkish meatball | *A. bisporus; P. ostreatus* (5 and 10%) D | Sensorial and physical (color and texture) analysis | Imparted positive effect on hardness; Meatball with *P. ostreatus* at 5% level was the best-liked and most accepted one in terms of color, taste, and chewiness | Süfer et al., 2016 |
| Fish burger | *P. ostreatus* (10 and 15%), soy protein isolate (SPI) (2%) F | Striped catfish (*Pangasius hypophthalmus*) and salmon (*Salmo salar*) minced meat substitution | Reduction of thiobarbituric acid reactive substances (TBARS) values in *P. ostreatus* and SPI added fish burgers; Improvement in thawing loss and cooking yield during storage at -18˚C; increase in total viable counts, but there was no significant change during storage and no effect on sensory characteristics of the products. Microbiological analyses were within acceptable range for all samples | Pachekrepapol et al., 2022 |
| **Bakery Products** | | | | |
| Noodles | (2, 4, 6, 8 and 10%) D | Wheat flour substitution | Increase in protein and fiber content; More than 4% increased cooking time, water absorption and tensile strength; Good acceptability with noodles at 4% replacement | Arora et al., 2018 |
| Noodles | (5, 8 and 10%) D | Wheat flour substitution | 5% resulted in better sensory scores than higher replacements; Improved nutritional characteristics | Parvin et al., 2020 |
| Maize flour | *A. bisporus; P. ostreatus* (10, 20, 30, 40 and 50%) D | Enrichment with MF | Increase in protein; Control flour: 6.95%; up to 50% *A. bisporus*: 15.87% DW; 50% *P. ostreatus*: 19.32% DW, and mineral content (Fe and Zn), fiber and ash; Reduction in fat and energy; A positive significant linear effect on foaming capacity, foam stability, fat absorption capacity, water retention capacity, water absorption capacity, solubility index and swelling capacity, while a negative linear effect on compact density, bulk density, and syneresis | Ishara et al., 2018 |
| Cassava bread | (5, 10, 15, 20% and 25%) D | Enrichment with MP | Increase in protein; Control bread: 8.02%; up to 25% *P. ostreatus*: 10.03%; Increase in functional properties of water absorption capacity, bulk density, swelling power, oil absorption capacity and solubility; 25% *P. ostreatus* containing sample was the most acceptable | Azeez et al., 2018 |
| Wheat bread | *P. ostreatus; Calocybe indica* | Wheat flour substitution | Increase in ash content, fiber, and protein content; Protein content increased from 9.12% in the negative control to 18.7% with 5% MP inclusion and 25.1% with 20% MP inclusion; | Oyetayo and Oyedeji, 2017 |

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| | (0, 5, 10, 15 and 20%) D | and fortification | Increasement in K, Na, Ca, Mg, Mn, Cu, Zn and Fe content of the bread significantly with increase in MP | |
| Pan bread | Lactic acid fermented dairy permeates (FDP); D and ground MP | Enhancement of quality and nutritional values of product | 100% FDP and 5% MP had the highest protein (16.05%), dry matter (63.23%), and ash (1.84%). Significantly increase in mineral contents by adding FDP and MP. Decrease in total counts of spore formers and molds as % of FDP in the dough increased | Khider et al., 2015 |
| Biscuits | Muffin | Supplementation with MP | Increase in moisture, protein, fat, ash, and *hardness*; Decrease in lightness; The best formulation chosen was 25% of white oyster MP added one | Cornelia and Chandra, 2019 |
| Biscuits | (10, 20 and 30%) D | Wheat flour substitution | Increase in volume, spread ratio, and protein content; Decrease in hardness values; Increase in fracturability value; 10% added biscuits showed the best sensory properties in terms of general acceptability and average values | Baltacıoğlu et al., 2021 |
| Fried mushroom crackers | (0, 5, 10, 15 and 20%) D MP | Development of vegetarian fried mushroom crackers | Significant decreases ($p<0.05$) in the L* value, oil absorption and hardness, while increases in the b* value, linear expansion, ash, and protein contents of MP-added products when the content of *P. ostreatus* powder was increased in the crackers; The highest mean score in all evaluated sensory attributes of crackers made with 15%MP: 85%tapioca flour | Yahya et al., 2017 |
| Cake | (0, 5, 10, 15 and 20%) D | Replacement of wheat flour with MP | Improved color, flavor, and texture of cake | Sheikh et al., 2010; Singh and Thakur, 2016 |
| | (0, 10, 20, 30 and 40%) D | Replacement of wheat flour with MP | Significant effect on ash and crude fiber; Significant effect on loaf weight; Significant effect on texture and color value; High sensory score in 10% MP added muffin | Farooq et al., 2021 |
| Cookies | Bean and oat flour formulation fermented with *P. ostreatus* CS155 strain, Incorporation of fermented black/kidney bean and oat flour (50 and 80%) as ground and D | Replacement of unfermented black bean/kidney bean/oat and wheat flour | Increase in antioxidant capacity, when compared with cookies made without fermented flours, while maintaining its antioxidant capacity after simulated digestion assay; Increase in bioavailable protein compared to wheat control cookie, higher fiber content and lower sugars compared to commercial cookies; Good sensorial acceptability of cookies | Espinosa-Páez et al., 2021 |
| **Dairy Products** | | | | |
| Cheese spreads | (0, 5, 10 and 15%) F, (0, 1, 1.5 and 2%) D | Supplementation with mushroom as fresh and flour | Increase in protein/DM (31.20-36.36%) comparing to control (30.88%); Processed cheese spreads have pH values of 5.39-5.78, while in control ranged from 5.47-5.63; The total viable counts and spore former bacteria was lower in processed cheese than in cheese control; The highest flavor scores were 37.4 and 37.3 in processed cheese supplemented with 1% and 1.5% MP, respectively | Khider et al., 2017 |
| Yogurt | β-D-glucan (Pleuran-*P. ostreatus* and Lentinan-*Lentinula edodes*) Hs obtained from F and D mushrooms | Fat reduction | °SH and pH of samples showed values typical for this kind of product, the groups of microorganisms (coliform bacteria, yeasts, and molds) did not appear during the whole storage period (< 1 CFU/g); both Hs added yogurts had no negative influence on the sensory acceptability; all samples maintained a very good quality during the whole storage period and did not differ significantly from one another in the individual parameters evaluated | Hozova et al., 2004 |
| Yogurt | Aqueous E of D and ground mushrooms | Fat reduction | Increase in *Streptococcus thermophilus* and *Lactobacillus bulgaricus* CFU counts; Lower syneresis and firmness, more adhesiveness, springiness, and cohesiveness than control. Supplemented yogurts were darker, contained more | Vital et al., 2015 |

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| | | | polyphenols and exhibited higher antioxidant activity than controls in cold storage | |
| Ice cream | Natural protein solutions of MP (0.1 g/20 ml, 0.2 g/40 ml, 0.4 g/80 ml, 0.8 g/160 ml and 1.6 g/320 ml) with water in different concentrations | Protein enrichment | Increase in the protein content of the ice cream up to approximately 15.08% (highest: 4.12%) compared to the initial percentage; Statistically significant results in terms of color values | Beşir et al., 2019 |
| **Other Products** | | | | |
| Chips | MP (13.18-46.82%) | Substitution of wheat flour and enrichment of chips | Optimum cooking conditions for fried mushroom chips were determined as 180 °C, 155 sec and 40% MP ratio. Dry matter, ash, protein, water activity, oil and sensory evaluation results were 99.10%, 3.25%, 15.10%, 0.10, 19.02% and 5.39, respectively | Doğan et al., 2017 |
| Chips | D and ground MP (20, 30 and 40%) | Enrichment of wheat chips cooking with deep-frying, baking, and microwaving | Microwaving was the most suitable method for preserving some nutraceutical value of enriched wheat flour (WF)-MP composite chips; MP increased the total phenolic content, antioxidant activity, and protein value of all samples; utilization of MP in fried chips reduced the oil content up to 37.07% compared to control; MP can be used up to about 37% in chips with its superior functional and nutritional properties | Doğan et al., 2020 |
| Soup, biscuit, nugget ketch-up, candy, chips, ready-to-serve mushroom curry | D and ground MP (10-16%), Boiled mushroom in 0.05% KMS containing water | Replacement of corn flour, maida (Indian wheat flour), urad dhal (Indian black lentil), arrarote (tropical starchy substance), sugar | Production of functional and long shelf-life foods | Rai and Arumuganat-han, 2008 |
| Soup | D (Sun/Oven) or (Blanched in hot water and Sun/Oven-D) or (Brined and Sun/Oven-D), ground MP | Functional mushroom soup | No significant difference in taste ($P$=0.37) and flavor ($P$=0.10) of the prepared soups; Soups prepared from sun-dried powders had the highest overall acceptability scores | Muyanja et al., 2014 |
| Boiled mushroom and mushroom sauce | *P. florida*, *P. ostreatus*, *P. sajor-caju;* Chopped F mushroom | Functional boiled mushrooms and mushroom sauce | No significant ($P$>0.05) sensory acceptability differences were observed for boiled mushroom and mushroom sauce except color of boiled mushrooms; Overall acceptance for mushroom sauce products was 90% (like extremely) followed by 8% (like moderately) and 2% (neither like nor dislike) | Michael et al., 2011 |
| Seasoning | MP of D *P. ostreatus* | Functional flavoring agent | Increase in functionality | Park et al., 2001 |
| **Traditional Products** | | | | |
| Potato pudding (Indian traditional food) | Blanched in water, oven/sun D, and ground MP (5, 10, 15 and 20%) | Fortified potato pudding, replacement of fresh grated potato | Increase in protein (2.28 g) and fiber (0.26 g) and good amount of fat (1.36 g) and carbohydrate (18.93 g) in 5% fortified sample than control sample. 5% fortification of MP in potato pudding was the most liked in terms of organoleptic acceptability | Verma and Singh, 2017 |
| Tikki (Indian fried potato patties with spice) mix | Corn flour; Blanched in water, 0.5% citric acid, 0.5% ascorbic acid, 10% NaCl | Replacement of sweet potato flour | 8% fortified sample was found high fiber content than other samples and a high score for overall acceptability of 8.66. The product was found to be acceptable after the storage period for 60 days with HDPE packaging | Singh and Lakshmi, 2015 |

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| | applied, D, and ground MP flour | | | |
| Papad (Indian snack food) | D and ground MP (10, 15 and 20%) | Replacement of gram dahl (chickpea flour) | Increase in protein content with increased level of MP in experimental papad (24.49 to 24.71%); Decrease in energy and carbohydrate contents; Ca, P, Fe, Na and K content of these papads were found to be good; 10% and 15% MP incorporated papads were well accepted for all sensory attributes | Nande, 2017 |
| Ogi (Nigerian fermented cereal gruel) | D and ground MF (10, 15 and %20) | Improvement the nutritional quality of Ogi-MF mixes in terms of protein and fiber | Increase in moisture (9.08-10.02%), protein (8.90-13.29%), fat (4.73-5.03%), ash (1.56-1.90%), crude fiber (3.13-3.90%), decrease in carbohydrate content (66.64-72.51%) of Ogi-MF mixes; Swelling power (19.25-19.45 g water/g sample), solubility (21.49-22.90%), water absorption capacity (40.07-42.25%), bulk density (0.51-0.57 g/ml) in mixes; Overall acceptability (2.50-3.50) in Ogi-mushroom pap | Ajala and Taiwo, 2018 |
| **Beverages** | | | | |
| Health drink powder | D and ground MF (5%) | Enrichment of soy-mushroom health drink powder in terms of protein and fiber | Moisture, ash, protein, fat, fiber, carbohydrate, and energy contents of soy-mushroom health drink powder was 3.84%, 3.23%, 21.37%, 10.13%, 1.50%, 59.93% and 416.4 kcal/100g, respectively; The highest acceptability (9.0) among all health drink products; Microbiological assay showed its shelf life to be 1 year | Farzana et al., 2017 |
| Healthy drink | β-glucan from E of *P. ostreatus* | Value-added healthy drink | Healthy drink bottle of 140 ml volume contained energy, protein, carbohydrates, dietary fiber, beta-glucan as 37,24 kcal, 392 mg, 8918 mg, 70 mg, and 1380 mg, respectively, while total sugar was 8.8% (w/v) | Widyastuti et al., 2015 |
| Wine | Cell-free E of undestroyed mycelia and debris from *P. ostreatus, Agaricus blazei, Flammulina velutipes* | Brewing with *P. ostreatus* producing alcohol dehydrogenase in place of *S. cerevisiae* | The highest alcohol concentration in this wine was achieved with *P. ostreatus* (2.6 M, 12.2%); Effect of thrombin time of wine produced by using *P. ostreatus* was 320.0 sec; Fibrinolytic activity of the wine produced by *P. ostreatus* was 27 $mm^2$ | Okamura et al., 2001 |
| Wine, Beer, Sake | Cell-free E of undestroyed mycelia and debris from *P. ostreatus, Tricholoma matsutake, A. blazei* | Brewing with *P. ostreatus* producing alcohol dehydrogenase in place of *S. cerevisiae* | The highest alcohol concentrations in the wine, beer and sake were with *P. ostreatus* (2648 mM, 12.2%), *Tricholoma matsutake* (1069 mM, 4.6%) and *A. blazei* (1736 mM, 8.0%), respectively | Okamura et al., 2003 |
| Soy milk | Hot water E of shade-D and ground *A. bisporus*, *P. ostreatus* containing crude β-glucan | Value-addition and fortification of soy milk with prebiotic natural β-glucan | 2.5 g of the purified β-glucan samples from *P. ostreatus* and *A. bisporus* were used together and were added to the soy milk in the ratio of 1:40 | Kumaresan et al., 2022 |
| Mushroom drink | Blanched in fluid, D and ground MP of *S. commune*, *P. ostreatus*, and *P. sajor-caju* | Medicinal functional drink with high β-glucan | *S. commune*: *P. ostreatus*: *P. sajor-caju* at a ratio of 60:20:20 showed the highest significance of β-glucan content and radical scavenging activity; The highest level of β-glucan content and the greatest economic value and consumer acceptability were found in mushroom drink produced with *S. commune*: *P. ostreatus*: *P. sajor-caju* at the same ratio | Mongkontana-wat and Phuangborisut, 2019 |

D: Dried, F: Fresh, H: Hydrogel, E: Extract, MF: Mushroom flour, MP: Mushroom powder, KMS: Potassium metabisulfite

**_P. ostreatus_ Incorporated Novel Functional Commercial Foods**

Some functional foods have already been developed and produced in industrial scale such as Snörkel (Jester King Brewery, Texas, United States) (URL-1, 2022), which is a farmhouse ale brewed with alderwood smoked sea salt and local oyster mushrooms. In addition, *P. ostreatus* powder incorporated vegetarian mushroom oyster sauce (Whan Ja Shan Brewery, Taipei, Taiwan) (URL-2, 2022) consisted of water, sugar syrup, soybeans, wheat, salt, yeast extract, sodium benzoate as food preservative, and mushroom powder is available in the international trade.

**Results and Discussion**

Edible mushrooms have been classified as a “healthy food” since they are low in calories and fat, but rich in proteins, dietary fiber (chitin, hemicellulose, mannans, and β-glucans), and minerals. In addition, all essential amino acids are present in the mushrooms and polyunsaturated fatty acids are in higher proportion compared to saturated fatty acids. Their chemical profiles include several bioactive compounds, such as polysaccharides, biologically active proteins (enzymes, lectins), ergothioneine (amino acid), terpenoids, sterols, antioxidants, and vitamins such as thiamine, riboflavin, niacin, ascorbic acid, and tocopherols, which contribute to improved immune function and show antitumor, antimicrobial, anti-inflammatory, hypoglycemic, hypocholesterolemic, and antioxidant effects. Their nutritional value, antioxidant activity, and health-beneficial properties, as well as the flavor and texture properties, have attracted the attention of the food industry to use edible mushrooms as possible substitutes for several ingredients and additives in processed foods, mainly in bakery and meat products in recent years.

In this review, some studies about the usage of *P. ostreatus*, one of the best-known culinary/medicinal mushrooms, as a food ingredient or additive and substituent/replacer in foods were reviewed. In addition, the effects of *P. ostreatus* utilization on nutraceutical, physicochemical and sensorial properties of novel functional food products were also given. Consequently, according to the literature review, this mushroom has a high potential to be used in functional meat, bakery, dairy, traditional foods, and beverages as a replacer and ingredient/additive. Due to the increasing trend on healthy and sustainable nutrition among consumers, more commercial, value-added, standardized, and processed functional *P. ostreatus*-incorporated foods could be available in the markets in near future. On the other hand, the bioavailability and bioaccessibility properties of these novel foods, their food matrix structures, and cultivation techniques of *P. ostreatus* in large-scale production should be more studied for nutritious, tasty, healthy, sustainable, environmentally friendly, and low-cost *P. ostreatus* based functional foods to be consumed by human and used by food, pharmaceutical, and cosmeceutical industries worldwide. In addition, these studies must be conducted according to EFSA, FDA, JECFA, and WHO standards and regulations.

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