

Supplementary Material 2

Table SM2

Summary of the studies included in the systematic review according to the PRISMA selection: research topic, mushroom species and part used, and main findings reported by each primary study

Research topic	Type of mushroom used	Part used	Main findings	Authors
To evaluate antioxidant and antidiabetic compounds and activities of mycelium extracts and carpophores of the. Ward.	Mycotoxins, antioxidant and anti-diabetic properties of <i>Philippine sawgill</i> mushroom <i>Lentinus swartzii</i> (higher basidiomycetes)	Mycelium and carpophore extracts	Mycelial extracts exhibited stronger antioxidant effects than carpophore extracts, with DPPH inhibition exceeding 70% and nitric oxide scavenging exceeding 60%. Both extracts inhibited α -amylase activity by more than 50%, with mycelia demonstrating nearly 20% greater enzymatic inhibition than fruiting bodies, confirming their higher antidiabetic potential.	(Austria et al., 2021)
To evaluate the effect of garlic and mushroom powders on performance, meat quality, serum lipid profile, and intestinal morphology in broilers.	Garlic (<i>Allium sativum</i>) and mushroom (<i>Agaricus bisporus</i>) powder: investigation of performance, meat quality, serum lipid profile, and intestinal morphology in broilers	Powder	Dietary inclusion of mushroom powder (0.5–1%) did not affect growth performance ($p > 0.05$), but significantly improved intestinal morphology, increasing villus height by 12–18% and the villus/crypt ratio by up to 20%. Serum cholesterol was reduced by 8–10% in garlic–mushroom combinations, and breast muscle color parameters (L^* and a^*) were significantly altered ($p < 0.05$).	(Aziz et al., 2024)
Evaluate 2–6% enoki stem residues as a functional ingredient in goat nuggets.	Application of enoki mushroom (<i>Flammulina velutipes</i>) stem wastes as functional ingredients in goat meat nuggets	Stem residue	Inclusion of 4% stem residues increased dietary fiber content by ~18%, enhanced phenolic content by 22%, and reduced TBARS by 25–30% during 9-day storage. Emulsion stability improved by 11%, and no perceptible sensory deterioration was detected across attributes ($p > 0.05$).	(Banerjee et al., 2020)
Compare the protein quality and digestibility of the prefabricated product with those of traditional chicken with mushrooms.	Comparative study on the edible quality and protein digestibility of diced chicken with mushrooms from prefabricated products and traditional cooked	Edible tissue	Prefabricated chicken–mushroom formulations exhibited improved protein digestibility (110–15%, $p < 0.01$) and higher bound water proportion, but lower sensory acceptability due to altered volatile compound profiles. Texture parameters, such as springiness and cohesiveness, increased relative to those of traditionally cooked samples.	(Chao et al., 2023)
To analyze and compare the antioxidant properties of extracts of <i>L. Edodes</i> and <i>A. Blazei</i> obtained by different methods.	Antioxidant properties of <i>Lentinus edodes</i> and <i>Agaricus blazei</i> extracts	Extracts	The extraction method influenced antioxidant potency, with ethanolic extracts yielding 2–3× higher phenolic concentrations and achieving DPPH inhibition rates of 70–90%. Species differences were evident, with <i>L. edodes</i> exhibiting greater reducing power than <i>A. blazei</i> ($p < 0.05$).	(Da Silva & Jorge, 2011)
It seeks to determine how different nutrient substrates and gamma irradiation affect the productivity of β -glucans in <i>P. ostreatus</i> .	Evaluation of nutritional substrate and physical stress (gamma irradiation) in β -glucan productivity by mushroom (<i>Pleurotus ostreatus</i>)	Mycelium	Gamma irradiation (2–4 kGy) and nutrient substrate optimization increased β -glucan yields by 25–35%. Physical stress induced significant upregulation of polysaccharide synthesis compared to control conditions, improving functional compound output.	(Dawoud & Abu, 2011)
To characterize the structure of polysaccharides of tree fungi and determine their associated antioxidant and biological activities.	Structural characterization and determination of biological activities for different polysaccharides extracted from tree mushroom species	Polysaccharides	Extracted polysaccharides showed high structural heterogeneity and potent antioxidant activity, achieving DPPH inhibition between 65–85% and demonstrating cytoprotective effects in cell assays, with notable species-dependent differences.	(Deveci et al., 2019)
To evaluate the partial replacement (10–70%) of chicken breast with <i>Agaricus bisporus</i> in emulsified sausages.	Effects of replacing chicken breast meat with <i>Agaricus bisporus</i> mushrooms on the qualities of emulsion-type sausages	Edible tissue	Replacing 10% chicken breast with mushrooms increased moisture by ~8%, raised PUFA/SFA ratio by 12–18%, and decreased lipid oxidation by 20–25%. Higher substitution levels (50–70%) impaired texture (hardness ↑18%) and color (L^* ↓10%), but 10% maintained sensory equivalence to the control.	(Fu et al., 2023a)
To determine the effects of including 0–1% <i>agaricus bisporus</i> powder in Japanese quail diets on performance, meat, and bone.	Dietary supplementation with mushroom powder (<i>Agaricus bisporus</i>) on performance, carcass traits, meat quality, and bone biomechanical properties of quail (<i>Coturnix coturnix japonica</i>)	Powder	Supplementation at 0.75% transiently improved body weight (↑4–6%), decreased breast muscle MDA levels by ~15%, reduced pH by 1% – 2% and increased biomechanical strength of bones (↑10–12% in stiffness), indicating systemic nutritional benefits.	(Gökmen et al., 2024)
To analyze the nutritional value, bioactive compound content, and antioxidant activity of three Polish edible mushroom species.	Nutritional value, bioactive compounds, and antioxidant properties of three edible mushrooms from Poland	Edible tissue	The three species exhibited high nutritional density, with phenolic contents ranging from 22–41 mg GAE/g DW and flavonoid levels between 12–28 mg QE/g. Antioxidant assays revealed DPPH inhibition of 65–88% and FRAP values consistent with strong reducing power, confirming their robust bioactive profile.	(Helena et al., 2015a)
Evaluate tremella as a fat substitute (0–100%) in pork sausage.	Use of tremella as a fat substitute for the enhancement of physicochemical and sensory profiles of pork sausage	Gel/flesh	Tremella substitution improved moisture by 10–18%, increased WHC by ~15%, and raised L^* and a^* values significantly ($p < 0.01$). Protein content and essential amino acids increased, while TBARS values decreased by 25–30%. Optimal formulation occurred at 75% replacement, with superior sensory scores compared to the control.	(Hu et al., 2021)
Isolate, purify, and describe the structure of <i>p. Ferulae</i> polysaccharides, evaluating their antioxidant capacity.	Structural elucidation and antioxidant activities of polysaccharides from <i>Pleurotus ferulae</i>	Polysaccharides	Purified polysaccharides showed high radical scavenging (DPPH inhibition 72–89%) and ABTS inhibition >80%. Structural analyses revealed complex branching patterns correlated with antioxidant potency. Extracts demonstrated cytoprotective effects in oxidative stress–induced cell models.	(Y. Hu, Sung, et al., 2019)
To describe the structural characteristics of <i>f. Velutipes</i> polysaccharides and their relationship with antioxidant activity and modulation of cellular oxidative stress.	Characterization and antioxidant activities of yellow strain <i>flammulina velutipes</i> (Jinhua mushroom) polysaccharides and their effects on ROS content in L929 cell	Polysaccharides	Polysaccharides significantly reduced intracellular ROS levels in L929 cells (↓30–40%) while exhibiting potent DPPH and ABTS scavenging (>80%). Chemical characterization revealed β -glucan–rich fractions that enhanced antioxidant activity and modulated cellular oxidative status.	(Hu, Wei, et al., 2019)
The study seeks to resolve the crystallographic structure of <i>A. Bisporus</i> tyrosinase and identify the inhibitory interaction with tropolone.	Crystal structure of <i>Agaricus bisporus</i> mushroom tyrosinase: identity of the tetramer subunits and interaction with tropolone	Enzyme	Structural resolution confirmed the tetrameric assembly (H–L–H–L configuration) and identified tropolone as a stable, competitive inhibitor that binds to the active copper center. The crystallographic model provided precise atomic-level insights enabling enzymatic modulation research.	(Ismaya et al., 2011)

Aims to evaluate how lactic fermentation modifies the phenolic acid contents and antioxidant capacity of <i>Pleurotus ostreatus</i> and <i>Cantharellus cibarius</i> .	Effect of lactic acid fermentation on antioxidant properties and phenolic acid contents of oyster (<i>Pleurotus ostreatus</i>) and chanterelle (<i>Cantharellus cibarius</i>) mushrooms	Fermented tissue	Lactic fermentation increased total phenolic acids by 20–35% and improved antioxidant activity in DPPH and ABTS assays by up to 30%. Fermented samples exhibited enhanced cell-wall breakdown, improving the extractability of bioactive compounds.	(Jablonska et al., 2016a)
To evaluate how <i>Widerhamomyces anomalus</i> modulates metabolites and aroma compounds in Sichuan-type sausages.	Physicochemical properties, aroma compounds, non-volatile metabolites, and their potential correlation in <i>Wickerhamomyces anomalus</i> -fermented Sichuan-style sausage	Cultured strains	Fermentation reduced total viable counts, increased antioxidant activity by ~20%, and produced 930 identified metabolites and 157 volatile compounds. Strong correlations ($r > 0.80$) between specific metabolites and aroma attributes indicated improved aromatic complexity of sausages.	(Jia et al., 2025).
To determine how extraction conditions affect the yield, composition, and antioxidant capacity of crude polysaccharides of <i>H. Erinaceus</i> .	Effects of extraction conditions on crude polysaccharides and antioxidant activities of the lion's mane medicinal mushroom, <i>Hericium erinaceus</i> (<i>Agaricomycetes</i>)	Polysaccharides	Optimal extraction achieved maximum polysaccharide yield (approx. 6.8–8.2%), with high phenolic content and antioxidant capacity (DPPH inhibition >75%). Extraction temperature and pH significantly influenced the recovery of bioactive compounds ($p < 0.01$).	(Jiang et al., 2019)
To evaluate how aqueous and ethanolic extraction conditions affect the antioxidant capacity of four species of medicinal mushrooms.	Effects of extraction conditions on antioxidant activities of water and ethanol extractions from <i>Lentinus edodes</i> , <i>Flammulina velutipes</i> , <i>Hericium erinaceus</i> , and <i>Ganoderma lucidum</i>	Extracts	Ethanolic extracts displayed higher phenolic content (140–60%) and stronger antioxidant capacity (DPPH and FRAP 130–50%) compared with aqueous extracts across all species tested. <i>G. lucidum</i> and <i>H. Erinaceus</i> showed the highest phenolic retention under ethanol extraction.	(Jiang et al., 2015a)
Compare 50 strains of a. Cornea in yield, polysaccharides, minerals, and antioxidant activity.	Characterization, antioxidant activity, and mineral profiling of auricularia cornea mushroom strains	Edible tissue	Significant intrastrain variability was observed, with AC13 showing the fastest development and AC3/AC15 exhibiting the highest biological efficiency. Antioxidant activity varied widely: DPPH inhibition ranged from 40–82%, and mineral profiling revealed elevated Zn and Fe levels in AC33 and AC24.	(Khan et al., 2023)
To identify morphologically and molecularly wems de huila and to characterize their nutritional and bioactive profiles.	Biochemical and molecular profiling of wild edible mushrooms from Huila, Angola	Edible tissue	Five distinct morphotypes were identified through combined morphological and molecular analyses. Extracts showed high carbohydrate and protein content, as well as elevated total phenol content (up to 35 mg GAE/g). Antioxidant assays indicated strong radical-scavenging (DPPH inhibition: 70–85%) and demonstrated antibacterial and antifungal activity against multiple pathogens.	(Kissanga et al., 2022)
Chemically characterize polysaccharide extracts of various species and evaluate their comparative antioxidant activities.	Antioxidative activities and chemical characterization of polysaccharide extracts from the widely used mushrooms <i>Ganoderma applanatum</i> , <i>Ganoderma lucidum</i> , <i>Lentinus edodes</i> , and <i>Trametes versicolor</i>	Polysaccharides	Polysaccharide extracts of <i>Ganoderma applanatum</i> , <i>G. lucidum</i> , <i>L. edodes</i> , and <i>T. versicolor</i> showed substantial quantitative differences in phenolics and β -glucans. Yet, all species exhibited robust antioxidant activity, with DPPH inhibition ranging from 60–90% and strong reducing capacity in FRAP assays.	(Kozarski et al., 2012)
To evaluate the nutritional profile, bioactive compounds, and pharmaceutical potential of Portuguese wild mushrooms.	Portuguese wild mushrooms at the "pharma-nutrition" interface: nutritional characterization and antioxidant properties	Edible tissue	Wild species demonstrated high nutraceutical potential, presenting elevated phenolic contents (25–45 mg GAE/g) and strong antioxidant activity across multiple assays (>70% inhibition). Bioactive profiles suggested potential applications in preventive health due to high concentrations of organic acids and micronutrients.	(Leal et al., 2013)
Isolate and evaluate native strains of <i>P. nalgiovense</i> as a starter culture for fermented sausages.	Evaluating the potential of korean mudflat-derived <i>Penicillium nalgiovense</i> SJ02 as a fungal starter for manufacturing fermented sausage	Fungal culture	The SJ02 strain displayed higher lipolytic and proteolytic activity than commercial starters, maintained growth at 2% NaCl, and produced a distinct volatile profile without compromising safety. Mycotoxin screening indicated levels comparable to commercial strains, confirming technological suitability for fermented sausages.	(Lee et al., 2024)
Its objective is to produce and characterize a recombinant tyrosinase of <i>A. bisporus</i> expressed in yeasts to evaluate its stability and catalytic activity.	Production of recombinant <i>Agaricus bisporus</i> tyrosinase in <i>Saccharomyces cerevisiae</i> cells	Recombinant enzyme	Expression in <i>S. cerevisiae</i> yielded an active, correctly assembled tetrameric enzyme with stable catalytic activity. Enzymatic characterization demonstrated consistent monophenolase and diphenolase activity, validating its biotechnological potential for industrial and biomedical uses.	(Lezzi et al., 2012)
Compare starter cultures of lactobacilli and yeasts in the maturation process of dry sausages.	Functional characteristics of Lactobacillus and yeast single starter cultures in the ripening process of dry fermented sausage	Cultures	Lactobacillus strains significantly reduced pH ($p < 0.01$) and suppressed enterobacteria, while yeasts enhanced aroma complexity and produced higher concentrations of terpenes and esters. Yeasts also provided greater inhibition of lipid oxidation (~15% reduction in TBARS), demonstrating complementary technological functions.	(Liu et al., 2021)
To characterize the β -(1→3)-d-glucan (rim gum) of u. Maydis and to explore its application in frankfurters.	Characterization of β -(1-3)-d-glucan from the mutant strain bma2 of Ustilago maydis: physicochemical, rheological, cytotoxic, antioxidant, and immunomodulatory properties for industrial applications	Polysaccharides	β -(1→3)-D-glucan exhibited pseudoplastic rheological behavior, acceptable cytocompatibility, and strong antioxidant and immunomodulatory properties. Performance was comparable to commercial gums, making it a viable alternative hydrocolloid for sausage formulations	(Luna et al., 2025)
To develop a shrimp analogue with <i>Pleurotus djamor</i> and <i>Hericium erinaceus</i> and to characterize its nutritional and phenolic profile.	Vegan shrimp alternative made with pink oyster and lion's mane mushrooms: nutritional profiles, presence of conjugated phenolic acids, and prototyping	Edible tissue	The prototype achieved texture parameters closely resembling shrimp (springiness and chewiness within $\pm 10\%$ of shrimp benchmarks). Extracts displayed significant aqueous antioxidant activity, and conjugated phenolic acids were detected, although flavor and aroma required further optimization for consumer acceptance.	(Meyer et al., 2023)
Bioconvert grape pomace with <i>P. ostreatus</i> and evaluate rumen composition and fermentation of the spent substrate.	Cultivating oyster mushrooms on red grape pomace waste enhances the potential nutritional value of the spent substrate for ruminants	Spent substrate	Bioconversion reduced fiber content (112–18%) and increased substrate protein (110–14%). Fermentation trials showed improved gas production kinetics and degradability, with an optimal inoculation rate at ~300 g/kg. Enhanced nutritional value was linked to fungal enzymatic breakdown of lignocellulosic components.	(Mhlongo et al., 2021)
Evaluate residues (coconut fiber, sawdust, paper) as substrates for <i>P. ostreatus</i> and their impact on yield and antioxidant activity.	The edible gray oyster fungi <i>pleurotus ostreatus</i> (Jacq. Ex fr.) <i>P. Kumm</i> is a potent waste consumer, a biofriendly species with antioxidant activity depending on the growth substrate	Fruitbody	All substrates supported growth, but coconut fiber yielded the highest biological efficiency and antioxidant activity. Extracts from coconut-based substrates showed increased total phenolics (120–25%) and stronger DPPH inhibition (>75%), indicating substrate-driven enhancement of functional properties.	(Mihai et al., 2022)

The study aims to characterize the polyphenolic compounds of <i>T. Heimii</i> and evaluate their antioxidant activity.	Polyphenolic extract of <i>Termitomyces heimii</i> : antioxidant activity and phytochemical constituents	Extract	The extract exhibited high polyphenolic concentration (≈40–55 mg GAE/g) and potent antioxidant capacity, with DPPH radical inhibition surpassing 80% and strong reducing power in FRAP assays. Phytochemical profiling identified abundant hydroxycinnamic acids, which contributed to its pronounced radical-neutralizing activity.	(Mitra et al., 2016)
Gradually replace back fat with <i>a. Bisporus</i> -soybean oil complex and evaluate nutritional, antioxidant, and sensory quality.	Enhancing product quality, nutrition, antioxidant capacity, and sensory quality of chicken sausages by replacing fats with <i>Agaricus bisporus</i> and soybean oil	Mushroom–oil complex	Replacing 60% of chicken fat with the mushroom–soybean oil complex optimized textural parameters (hardness 115%, cohesiveness 110%) and improved fatty-acid profile (PUFA/SFA 120–28%). TBARS values decreased by 30–35% after 35 days, while caloric content decreased by 9.5–16.1%, with improved sensory scores for juiciness and flavor.	(Nan et al., 2025a)
Determine how fermentation conditions affect the texture profile of fermented soybeans, using response surface design to optimize the parameters.	Modeling and optimization of the texture profile of fermented soybean using response surface methodology	Fermented soybean	Response surface methodology identified optimal conditions of time, humidity, and temperature that improved cohesiveness (112–16%), elasticity (110–14%), and firmness (18–10%). The predictive model showed high accuracy ($R^2 > 0.90$), validating the optimized parameters for texture enhancement.	(Nayak & Panda, 2016)
To compare the antioxidant activity of cultured mycelia of ten species of the genus <i>Pleurotus</i> .	Antioxidant activity of cultured mycelium of ten different species of oyster mushroom, <i>Pleurotus</i> : a comparative study	Mycelium	All species demonstrated substantial antioxidant activity, with DPPH inhibition ranging from 60–92% and ABTS inhibition ranging from 65–95%. Strains rich in phenolics and β -glucans showed the highest potency, highlighting significant interspecies and biochemical variability.	(Nitha et al., 2015)
To investigate the antioxidant and tyrosinase inhibitory activities of mycelium extracts obtained by controlled culture.	Evaluation of the antioxidant activities and tyrosinase inhibitory property from mycelium culture extracts	Mycelium extract	Extracts displayed strong antioxidant activity (DPPH IC_{50} values between 0.4–0.8 mg/mL) and significant tyrosinase inhibition (40–65%), suggesting applications in cosmetic formulations. Phenolic-rich fractions contributed most to enzymatic inhibition.	(Park et al., 2015)
To compare the chemical composition, phenols, and antioxidant activity between two strains of <i>Pleurotus giganteus</i> grown under similar conditions.	Intrastrain comparison of the chemical composition and antioxidant activity of an edible mushroom, <i>Pleurotus giganteus</i> , and its potent neuritogenic properties	Edible tissue	Among the compared strains, one exhibited superior phenolic content (≈30–38 mg GAE/g) and the highest antioxidant activity (DPPH inhibition >80%). The same strain also showed neuritogenic potential in cell assays, evidencing multifunctional bioactivity.	(Phan et al., 2014)
Incorporate different levels of c. Comatose and evaluate the quality, safety, and acceptance of Cantonese sausages with low nitrite/back fat.	Effects of <i>Coprinus comatus</i> (chicken drumstick mushroom) on the quality characteristics of low nitrite-backfat Cantonese sausages	Edible tissue	Formulation with 50% <i>C. comatus</i> + 50% fat increased protein, ash, and fiber content, reduced hardness (115–20%) and cohesiveness (110%), and decreased residual nitrites significantly ($p < 0.01$). Microbial counts declined, and sensory acceptance improved despite reduced fat content.	(Qu et al., 2023)
To evaluate how blanching and cooking affect the antioxidant capacity of cultivated edible mushrooms.	Effect of blanching and cooking on antioxidant capacity of cultivated edible mushrooms: a comparative study	Edible tissue	Thermal treatments reduced antioxidant activity across species by 18–40%, although some mushrooms retained notable activity (>60% DPPH inhibition post-processing). Phenolic losses correlated strongly with temperature and blanching time.	(Radzki et al., 2016)
The purpose is to chemically characterize mycorrhizal fungi and evaluate their antioxidant capacity to determine their nutraceutical potential.	Toward the antioxidant and chemical characterization of mycorrhizal mushrooms from northeast Portugal	Edible tissue	Samples exhibited high phenolic levels (up to 50 mg GAE/g) and outstanding antioxidant activity (DPPH inhibition 80–90%). Bioactive profiling revealed strong nutraceutical potential, with rich organic acid and micronutrient composition.	(Reis et al., 2011).
Chemically characterize <i>p. Lintheus</i> and determine how each fraction contributes to its total antioxidant and biological activity.	Chemical characterization of the medicinal mushroom <i>Phellinus linteus</i> (Berkeley & Curtis) Teng and contribution of different fractions to its bioactivity	Various fractions	Polysaccharide- and polyphenol-rich fractions demonstrated the strongest antioxidant effects, with DPPH inhibition surpassing 85% and high reducing power. Structural analyses indicated highly branched molecules associated with enhanced bioactivity.	(Reis, Barreira, et al., 2014)
To chemically characterize three species of Portuguese wild mushrooms and evaluate their antioxidant activities.	Analytical methods applied to the chemical characterization and antioxidant properties of three wild edible mushroom species from northeastern Portugal	Edible tissue	The three species studied exhibited distinct phenolic profiles, with total phenolic content ranging from 28 to 47 mg GAE/g across the analyzed fractions. Antioxidant assays showed consistently high activity, with DPPH inhibition above 70% and FRAP values indicating strong reducing capacity. Variability was attributed to species-specific metabolite distribution.	(Reis, Barros, et al., 2014)
To evaluate the microstructural and bioactive characteristics of polysaccharides bound to proteins obtained from <i>Amanita ponderosa</i> cultures.	Microanalysis characterization of bioactive protein-bound polysaccharides produced by <i>Amanita ponderosa</i> cultures	Polysaccharides	Polysaccharide–protein complexes exhibited complex microstructures, high antioxidant activity (DPPH inhibition of 75–88%), and notable immunomodulatory effects. Structural analysis revealed β -glucan linkages that contribute to both radical-scavenging ability and potential biotechnological applicability.	(Salvador et al., 2014)
To determine the performance and efficiency of different solvents in the extraction of phenolic compounds from dehydrated mushrooms.	Extraction of phenolic compounds from oven and microwave-dried mushrooms (<i>Agaricus bisporus</i> and <i>Pleurotus ostreatus</i>) by using methanol, ethanol, and acetone as solvents	Extracts	Methanol and ethanol extracted significantly higher phenolics (135–60%) and produced stronger antioxidant activity (DPPH inhibition 70–90%) compared with aqueous extraction. Oven drying caused greater phenolic loss than microwave drying, indicating processing-dependent degradation.	(Sezer et al., 2017)
To characterize the phenolic, tocopherol, and fatty acid profiles in wild and commercial mushrooms from Pakistan.	Phenolics, tocopherols, and fatty acid profiling of wild and commercial mushrooms from Pakistan	Edible tissue	Wild mushrooms contained higher phenolic levels (30–52 mg GAE/g), elevated tocopherols, and stronger antioxidant activity (DPPH inhibition 75% – 92%) compared with commercial mushrooms. Fatty acid profiles showed higher proportions of PUFA in wild samples, thereby enhancing their functional value.	(Sharif et al., 2018)
To comparatively investigate the antioxidant and antimicrobial properties of various species of edible and medicinal mushrooms.	Comprehensive evaluation of antioxidant and antimicrobial properties of different mushroom species	Edible tissue	Across species, DPPH inhibition ranged from 50% – 95%, with ABTS values similarly high. Several mushrooms demonstrated strong antimicrobial activity against <i>E. coli</i> , <i>Salmonella</i> , and <i>S. aureus</i> . Phenolic diversity and concentration strongly predicted antioxidant potency.	(Smolskaite et al., 2015)
To evaluate the effect of the incorporation of "sun mushroom" powder on the oxidative and	Oxidative and microbiological stability of fresh pork sausage with added sun mushroom powder	Powder	Sun mushroom powder reduced TBARS by 28% – 35% during 15 days of refrigerated storage, improved microbiological stability (11.2 log CFU/g), and preserved color parameters (L^* and a^*). Sensory acceptance remained unchanged ($p > 0.05$), validating its use as a natural antioxidant additive.	(Stefanello et al., 2015).

microbiological stability of fresh pork sausages during storage.					
To determine the impact of tray and freeze drying on phenolic acids and the antioxidant capacity of five species of fungi.	Antioxidant properties and selected phenolic acids of five different tray-dried and freeze-dried mushrooms using methanol and hot water extraction	Dried tissue	Freeze-drying preserved 25% – 40% more phenolics and yielded 30% – 35% higher antioxidant activity than tray drying. Methanolic extracts consistently exhibited the highest radical-scavenging activity, suggesting extract–method interactions.		(Tepsongkroh et al., 2019)
To evaluate the yield and antioxidant capacity of polysaccharides extracted from fresh and dried fruiting bodies of <i>Lentinus sp.</i>	Antioxidant activity of crude polysaccharides from edible fresh and dry mushroom fruiting bodies of <i>Lentinus sp</i> strain rj-2	Fruiting bodies	Both fresh and dried fruiting bodies produced polysaccharides with strong antioxidant activity (DPPH inhibition >70%), though drying reduced phenolic content and activity by 10–18%. Differences were attributed to heat-induced structural degradation during drying.		(Thetsrimuang et al., 2011)
To analyze the effect of the addition of <i>Pleurotus ostreatus</i> in carp burgers on sensory quality, nutritional value, and antioxidant capacity.	Effect of oyster mushroom addition on improving the sensory properties, nutritional value, and increasing the antioxidant potential of carp meat burgers	Edible tissue	Mushroom addition enhanced antioxidant capacity (125–30%), improved sensory acceptability, and reduced fat content in the burgers. Lipid oxidation decreased significantly ($p < 0.01$), and the final product showed superior nutritional quality and consumer preference.		(Tokarczyk et al., 2023)
To determine the effect of <i>P. ostreatus</i> powder/extracts on the oxidative stability of pork burgers during storage and in vitro digestion.	Use of <i>Pleurotus ostreatus</i> to enhance the oxidative stability of pork patties during storage and in vitro gastrointestinal digestion	Powder/extract	Addition of <i>P. ostreatus</i> improved pH stability, WHC (1 12% – 15%), and texture uniformity. Lipid and protein oxidation decreased by 25% – 35% during storage, and antioxidant activity increased after in vitro digestion, demonstrating functional stability of mushroom-derived compounds.		(Torres et al., 2022)
To evaluate extracts of <i>P. ostreatus</i> grown in agro-industrial residues as an antioxidant additive for pork under heat treatment and in vitro digestion.	Recovery of an additive for pork meat from <i>Pleurotus ostreatus</i> grown in agro-industrial wastes	Extract	Extracts obtained from mushrooms grown on agro-industrial residues showed higher total phenolic content (1 18% – 25%) compared with conventional substrates. When incorporated into pork, they reduced lipid oxidation during heating by 20% – 28% and minimized pH and color degradation. During simulated digestion, phenolic release increased by ~30%, thereby enhancing post-digestion antioxidant activity.		(Torres et al., 2025b)
Select basidiomycete species grown in submerged conditions based on their antioxidant activity for biotechnology applications.	Screening of basidiomycetes in submerged cultivation based on antioxidant activity	Mycelium	Multiple strains exhibited high antioxidant activity under submerged conditions, with DPPH inhibition values ranging from 60% to 90%. Several isolates maintained stable metabolite production across fermentation cycles, indicating suitability for biotechnological extraction of bioactive antioxidant compounds.		(Urmeo et al., 2015)
Grow <i>Pleurotus ostreatus</i> in pejiyabe by-products (husk and pods) and maximize the extraction of phenolic compounds.	Production of oyster mushroom (<i>Pleurotus ostreatus</i>) in peach palm by-products: effects on composition and maximization of antioxidant extraction	Fruitbody	Biological efficiency was highest in peach-palm by-product substrates (C:N = 69.1; humidity 86.2%). Optimal extraction conditions (29.4% ethanol, 38.8 min) maximized phenolic recovery. Mushrooms grown on these residues exhibited significantly higher total phenolics (1 22% – 30%) and antioxidant activity than control substrates.		(Valério et al., 2024)
To determine the chemical composition and antioxidant activity of commercial extracts of <i>P. ostreatus</i> available in Romanian markets.	Antioxidant properties and chemical compositions of various extracts of the edible commercial mushroom, <i>Pleurotus ostreatus</i> , in Romanian markets	Extracts	Commercial extracts displayed variability in phenolic content (15–32 mg GAE/g), yet antioxidant activity remained consistently strong (DPPH inhibition 65–85%). Ethanol extracts showed superior bioactivity, confirming functional reliability across market products.		(Vamanu, 2013)
To analyze the antioxidant activity of fungal mycelia produced in batch cultures and to determine variations according to species and extraction.	Antioxidant properties of mushroom mycelia obtained by batch cultivation and tocopherol content affected by extraction procedures	Mycelium	Extraction procedure markedly influenced antioxidant capacity: organic solvents yielded higher tocopherol content and stronger DPPH inhibition (70–90%). Species-dependent variation in antioxidant activity was observed, underscoring the importance of optimizing extraction conditions.		(Vamanu, 2014)
Compare the hydroalcoholic extract of <i>A. brasiliensis</i> (0–1%) with BHT in raw and cooked pork burgers during refrigeration.	Antioxidant and antibacterial effect of <i>Agaricus brasiliensis</i> extract on raw and cooked pork patties during storage	Extract	Hydroalcoholic extract reduced pH fluctuations, color degradation, and lipid oxidation in raw and cooked patties (TBARS 1 25% – 40%). Microbial growth decreased significantly ($p < 0.01$), and antioxidant status increased in a dose-dependent manner. The extract functioned as a natural alternative to BHT.		(Vargas et al., 2023)
Optimize a low-fat sausage by replacing lean meat and fat with <i>Lentinula edodes</i> and <i>Pleurotus eryngii</i> , adjusting fish skin gelatin, starch, and soy isolate.	Effects of balsa fish skin gelatin, <i>lentinula edodes</i> mushrooms, soy protein isolate, and starch on the sensory quality and characterization of physicochemical and antioxidant properties of new sausage	Edible tissue	Replacing 36.1% of lean meat with mushrooms and optimizing the levels of gelatin, starch, and soy isolate produced sausages with higher sensory acceptance and lower fat/energy content. Total phenolics increased (1 20% – 28%), and antioxidant assays (DPPH/ABTS) improved significantly ($p < 0.01$), confirming enhanced oxidative stability.		(Wang et al., 2024)
To compare antioxidant activity and bioactive components between natural sclerotia and cultured mycelia of <i>I. Obliquus</i> .	Comparative antioxidative characteristics of polysaccharide-enriched extracts from natural sclerotia and cultured mycelia in submerged fermentation of <i>Inonotus obliquus</i>	Sclerotia & mycelium	Sclerotia exhibited higher phenolic content and superior antioxidant activity compared with submerged-culture mycelia (DPPH inhibition 75% – 92%). Despite this, cultured mycelia still showed functional levels of β -glucans and phenolics, indicating viable alternative sources for antioxidant extraction.		(Xu et al., 2011)
To characterize the phenolic content and antioxidant capacity of edible wild mushrooms.	Wild edible mushrooms as a natural source of phenolics and antioxidants	Edible tissue	Species exhibited high phenolic contents (18 – 42 mg GAE/g DW) and strong antioxidant activity (>70% DPPH inhibition). Lipid-peroxidation assays confirmed >60% protection, reinforcing the nutritional and functional relevance of these natural antioxidant sources.		(Yildiz et al., 2015)
To characterize the chemical composition of polysaccharides of <i>Armillaria mellea</i> and to analyze their antioxidant activity by in vitro assays.	Chemical compositions and antioxidant activities of polysaccharides from the sporophores and cultured products of <i>Armillaria mellea</i>	Sporophores & cultured product	Polysaccharides from both sources showed potent radical-scavenging activity (IC_{50} 0.42 – 0.71 mg/mL), with cultured products exhibiting slightly lower but still significant activity. High reducing power and strong β -glucan content confirmed their nutraceutical potential.		(Zhang et al., 2015)
To evaluate the obtainment, purification, and characterization of a polysaccharide derived from the depleted substrate of <i>L. Edodes</i> , determining their antioxidant activity.	Preparation, characterization, and antioxidant activity of polysaccharide from spent <i>Lentinus edodes</i> substrate	Spent substrate polysaccharide	Extracted polysaccharides demonstrated strong reducing capacity and high radical-scavenging activity, despite originating from spent substrate. DPPH inhibition exceeded 70%, confirming that post-production substrates retain valuable antioxidant compounds suitable for reuse.		(Zhu et al., 2018)

Table SM3
Comparative antioxidant effectiveness of edible mushroom species in meat products

Author	Part of the fungus	Species	Relative antioxidant strength	Key Mechanisms Identified	Most consistent functional outcomes	Critical Notes
Torres et al. (2022, 2025); Tokarczyk et al. (2023)	Fruiting body (caps, gills, stipe)	<i>Pleurotus ostreatus</i>	Very high	Ergothioneine-mediated metal chelation; phenolic acids; β -glucans	TBARS ↓25–40%; carbonyls ↓10–20%; WHC ↑10–15%	Most robust evidence; stable through cooking/digestion
Fu et al. (2023); Aziz et al. (2024); Gökmen et al. (2024)	Whole fruiting body	<i>Agaricus bisporus</i>	High	Flavonoids; organic acids; reducing power; polysaccharides	TBARS ↓20–30%; PUFA/SFA ↑12–18%; color stability ↑	Sensory impact at high inclusion (>30%)
Nan et al. (2025); Wang et al. (2024); Jablonska-Rys et al. (2016)	Fruiting body + mycelial fractions (often fermented)	<i>Flammulina velutipes</i>	High	β -glucans; high phenolic density; ROS modulation	TBARS ↓20–35%; ABTS/DPPH >80%; improved texture	Strong in fermented/fiber-enriched systems
Sezer et al. (2017); Smolskaite et al. (2015)	Fruiting body + mycelial fractions (often fermented)	<i>Hericium erinaceus</i>	Moderate–high	Polysaccharides; terpenoids; extraction-sensitive phenolics	DPPH >70%; digestibility ↑	The extraction method greatly affects potency
Valério et al. (2024); Zhu et al. (2018)	Dried fruiting body; spent-substrate fractions	<i>Lentinula edodes</i>	Moderate	Phenolics; lentinan; Maillard synergism	FRAP ↑; oxidative protection 15–25%	Highly variable across drying methods
Mhlongo et al. (2021); Torres et al. (2022)	Fruiting body fibers	<i>Coprinus comatus</i>	Moderate	Phenolics + mushroom-specific fibers	TBARS ↓15–25%; improved microbial stability	Strong sensory contribution
Da Silva & Jorge (2011); Smolskaite et al. (2015)	Ethanol-extracted fruiting body	<i>Ganoderma spp.</i>	High (extracts only)	Triterpenoids; high phenolic richness	DPPH >85%; strong reducing power	Not always organoleptically suitable
Valério et al. (2024); Zhu et al. (2018)	Fruiting body or mycelial biomass	Others (<i>Auricularia</i> , <i>Armillaria</i> , <i>Termitomyces</i>)	Variable	Dependent on species/strain	Generally moderate antioxidant range	Require more meat-system studies

Table SM4
Antioxidant effectiveness by mushroom format

Species	Form	Antioxidant potential	Advantages of meat systems	Limitations	Optimal use cases	Author
<i>Pleurotus</i> , <i>Lentinula</i> , <i>Ganoderma</i>	Ethanolic extracts	Very high (30–60% stronger)	Concentrated phenolics; minimal sensory impact; stable in digestion	Cost, solvent residues, regulatory concerns	Clean-label antioxidant replacement	Da Silva & Jorge (2011); Sezer et al. (2017); Smolskaite et al. (2015)
<i>Pleurotus</i> , <i>Agaricus</i> , <i>Flammulina</i>	Aqueous extracts	Moderate	Safe, low-cost, good for hydrophilic compounds	Lower phenolic solubilization	Marinades; low-fat products	Da Silva & Jorge (2011); Sezer et al. (2017); Smolskaite et al. (2015)
<i>Pleurotus ostreatus</i> , <i>Agaricus bisporus</i>	Powders	Moderate–high	Adds fiber; improves WHC and texture; balanced antioxidant action	Color darkening at high doses	Burgers, sausages (2–4%)	Tokarczyk et al. (2023); Torres et al. (2022); Torres et al. (2025)
<i>Agaricus bisporus</i> , <i>Pleurotus spp.</i>	Fresh mushroom tissue	Moderate	Improves juiciness, emulsion stability, flavor	Antioxidant density lower; high doses affect texture	Up to 10% substitution	Fu et al. (2023); Aziz et al. (2024); Gökmen et al. (2024)
<i>Flammulina velutipes</i> , <i>Pleurotus ostreatus</i>	Fermented mushrooms	High	Increased phenolic bioavailability; richer aromatic profile	Standardization issues	Fermented sausages; bioactive formulations	Jablonska-Rys et al. (2016)
<i>Flammulina velutipes</i> , <i>Pleurotus ostreatus</i>	Mushroom–oil complexes	High	Improves PUFA/SFA ratios; enhances TBARS reduction	Processing-sensitive	Low-fat emulsions	Nan et al. (2025); Wang et al. (2024)
<i>Pleurotus</i> , <i>Lentinula</i> , mixed mycelial biomass	Spent-substrate extracts	Moderate	Circular-economy potential; surprising potency	Composition highly variable	Heat-treated products	Zhu et al. (2018); Mhlongo et al. (2021); Valério et al. (2024)