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Mini-Review

Mushrooms' Natural Arsenal: Ultimate Weapons for Obesity Combat, Allergy Relief and Future Horizons

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ABSTRACT: Obesity is a global health condition associated with metabolic disorders, chronic inflammation and increased risk of diabetes and cardiovascular diseases. Scientific research is now focusing on strategies that rely on natural sources with minimal side effects. On the other hand, allergy is an immune-mediated disorder that affects quality of life. Mushrooms are prolific producers of bioactive compounds with many medical applications and untapped potential. Moreover, mushrooms can act as functional foods and nutraceuticals, helping prevent, manage, and heal various health conditions and boosting immunity. In this review, the contributions of mushroom-originated bioactive compounds, whether as extracts or pure compounds, to the field of fighting obesity and relieving allergies were highlighted. Understanding the importance of mushrooms as natural healing sources encourages further clinical trials to clarify their efficacy and confirm their safety for use in humans.

Keywords: Anti-allergy, Anti-obesity, Biological Activities, Mushrooms.
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1. INTRODUCTION

Mushrooms, a highly nutritious food, contain large amounts of bioactive compounds, including polysaccharides, fibers, terpenes, polyphenols, sterols, flavonoids, and alkaloids. These compounds may be rich in antioxidants and affect a variety of cardiac biomarkers, which can be used to treat cardiovascular diseases associated with obesity. Regular mushroom eating dramatically lowers hypertension, atherosclerosis, dyslipidemia, inflammation, and obesity, according to numerous animal studies (Ganesan, 2018; Daba et al., 2020). Mushrooms are full of secondary chemicals that haven't been used much yet. To figure out what medical and biological effects these mushrooms have, we would have to look at the chemicals that make them up. Some mushrooms play a vital role in different diseases due to the metabolic components (Chopra et al., 2021; Bhambri et al., 2022; Łysakowska et al., 2023). However, macrofungi, including mushrooms (Elkhateeb et al., 2019) and truffles such as *Tirmania nivea*, *Tirmania pinoyi*, and *Tuber indicum*, contain bioactive compounds (Elkhateeb et al., 2020; Elkhateeb et al., 2024) with diverse biological activities.

Mushrooms are fungi classified among the superior phyla Ascomycota and Basidiomycota, characterized by a stem (stipe), a cap (pileus), and gills (lamellae, singular lamella) located beneath the cap. Fungi have historically been valued for their taste, consistency, and nutritional benefits as culinary ingredients, as well as for their therapeutic and restorative properties as medicinal fungi (Chang and Miles, 2003). The shape of medicinal mushrooms can be distinguished by their size, color (white, black, yellow, brown, cream, pink, purple-brown, and others), and shape (Gebreyohannes and Sbhatu, 2023). There are more than 2,000 kinds of mushrooms in the world, but only a few can be eaten or used as medicine. *Agaricus bisporus* is the most widely grown mushroom, followed by *Lentinus edodes* and

Flammulina velutipes (Elkhateeb & Daba,2021; Bhambri et al., 2022). Mushrooms contain various metabolites, such as steroids, terpenes, anthraquinones, benzoic acid, phenolic acids, and different vitamins, while primary metabolites contain oxalic acid, proteins, and peptides. Nutritionally, mushrooms are rich in amino acids and proteins but lack fatty acid content (Elkhateeb and Daba, 2022).

So, mushrooms are a great way to get the nutrients you need and improve your health because they contain bioactive chemicals that work together. Many studies have shown that mushrooms are good for your health. For example, they can help with weight loss and allergies. These benefits have prompted people to learn more about mushrooms in both the food and medicine industries, where they could be used to treat or prevent life-threatening diseases (Ogidi & Oguoma, 2025).

Because of bad eating habits, obesity has become a worldwide health problem. It appears that mushroom polysaccharides (MPs) may help combat obesity (Ma et al., 2021). Allergies are becoming a bigger problem worldwide, and we need new ways to prevent and treat them promptly. This is possible with medicinal mushrooms. Antiallergic activities have been found for *Agaricus subrufescens*, *Pleurotus ostreatus, Pleurotus pulmonarius, Flammulina velutipes*, *Ganoderma tsugae*, *Ganoderma lucidum*, *Tricholoma populinum, Phellinus linteus*, *Inonotus obliquus*, *Armillaria ostoyae* and some other mushroom species. Still, most of the effects have been observed only in cell or animal tests, and the bioactive compounds that cause them have not yet been identified. Also, to date, only a few types of mushrooms have been tested for their potential to help with allergies (Merdivan & Lindequist, 2017).

The goal of this mini-review is to highlight the wonderful benefits and varieties of mushrooms, as well as explain how they can be used in a wide range of therapeutic situations, such as helping people who are overweight or allergic.

2. OBESITY

Obesity is a feared condition that impacts a significant segment of the worldwide populace and leads to considerable illness and mortality. Weight control is a continuous journey, as sustaining weight loss can be somewhat challenging. The primary factor contributing to obesity is an imbalance between caloric intake and energy expenditure, driven by complex interactions between genetic and environmental factors. Timely weight management initiatives are essential to align caloric consumption with energy output. Nutritional intake and exercise often govern weight management (Ganesan, 2018). Obesity is defined by an overabundance or irregular accumulation of body fat that can result in significant health issues and concerns. Obesity significantly elevates the likelihood of metabolic disorders including fatty liver, hypertension, cardiovascular disease, diabetes mellitus, and various malignancies, all of which adversely affect both quality of life and longevity (Bhupathiraju & Hu, 2016). Historically, anti-obesity medications primarily function by restricting caloric consumption. Nonetheless, the therapy is expensive, and the negative side effects (such as depression and steatorrhea) sometimes arise with prolonged use of these medications, which further restrict patient adherence. Consequently, there is an immediate necessity to seek safer, more economical, and more efficacious treatments for obesity (Huang et al., 2020). Mammals primarily have two types of adipose tissue, white adipose tissue (WAT) and brown adipose tissue (BAT), distinguished by distinct morphological and physiological characteristics. Unlike the primary role of white adipose tissue in energy storage as triglyceride droplets, brown adipose tissue expends chemical energy as heat (Marlatt & Ravussin, 2017).

Obesity, characterized by a body mass index exceeding 30 kg/m^2, is a worldwide health concern. It results in persistent ailments, such as type II diabetes, hypertension, and cardiovascular disorders. Traditional interventions for obesity encompass exercise and sustaining a caloric deficit. Nonetheless, physical exercise alone cannot determine body weight, as numerous other factors contribute to the overall energy balance. Alternatively, weight reduction can be accomplished through pharmacological interventions and surgical procedures. Nonetheless, these alternatives may incur high costs or produce adverse effects. Consequently, nutritional interventions such as dietary modifications, nutraceutical formulations, and functional foods have been examined recently. For instance, edible fungi confer benefits to human well-being. Polysaccharides (primarily β-D-glucans), chitinous materials, proteoglycans, heteroglycans, alkaloids, peptidoglycans, lectins, lactones, steroids, flavonoids, terpenes, terpenoids, phenolic compounds, nucleotides, glycoproteins, proteins, amino acids, antimicrobials, and minerals constitute the principal bioactive constituents in these fungi. These bioactive substances exhibit chemopreventive, anti-diabetic, anti-obesity, cardioprotective, and neuroprotective characteristics. The intake of edible fungi diminishes plasma triglycerides, overall cholesterol, plasma glucose, and low-density lipoprotein concentrations. Polysaccharides derived from edible fungi inhibit mRNA expression in 3T3-L1 adipocytes, thereby contributing to their anti-obesity effects. Consequently, edible fungi or their bioactive compounds might help prevent obesity and several chronic diseases (Mustafa et al., 2022).

2.1. Obesity and Mushrooms

Many individuals from Asia, particularly Koreans, Japanese, and Chinese, are widely recognized for their nutritious dietary habits and for regularly incorporating various mushrooms. Numerous studies have documented the anti-obesity properties of mushrooms; however, less research has explored the impact of consuming diverse edible mushroom varieties in practical amounts. Japanese gastronomy generally encompasses a broader array of ingredients, including fish, soybeans, vegetables, and mushrooms, than European or American culinary traditions. Mushrooms are a prominent ingredient in Japanese cuisine. The use of mushrooms is on the rise in Asian nations, particularly in Japan, due to advancements in production methods that have ensured a steady supply, as well as several studies highlighting the health benefits of mushrooms. Recently, the production volume of Japanese mushrooms reached 440,000 tons per year, with Enokitake mushroom (*Flammulina velutipes*) produced in the largest quantities, followed by Bunashimeji (*Hypsizygus marmoreus*), Shiitake (*Lentinus edodes*), Maitake (*Grifola frondosa*) and King Oyster mushroom (*Pleurotus eryngii*) (Shimizu et al., 2018). These mushrooms contain various nutritional components like dietary fibers, folic acid, vitamins D, B_1, B_2, and B_6, and niacin (Valverde et al., 2015; Elkhateeb et al., 2023), and are reported to have immunomodulatory, antitumor, anti-atherosclerotic, anti-diabetic, and anti-obesity effects (Mizutani et al., 2010; Iuchi et al., 2015; Yeh et al., 2014).

Recently, natural substances derived from fruits and food byproducts have garnered significant attention for their safety and prolonged effectiveness in the formulation of nutraceutical and pharmaceutical treatments for obesity and associated disorders. (Rupasinghe et al., 2016). *Ganoderma* mushroom is a popular dietary supplement in the modern market. Contemporary pharmacology indicates that Ganoderma exhibits various bioactivities, including anti-inflammatory, antibacterial, antitumor, and antiviral activities (Baby et al., 2015). Current studies have also suggested that *Ganoderma* sp. may have anti-obesity effects. Nonetheless, earlier studies on the possible physiological effects of Ganoderma on adipogenesis and lipid metabolism have yielded conflicting findings. For instance, it has been documented that triterpenoids from G. lucidum have suppressive effects on adipogenesis, leading to reduced lipid production and storage (Thyagarajan-Sahu et al., 2011). Also, secondary metabolites of *Ganoderma applanatum* induced apoptosis through different pathways to prevent cancer (Elkhateeb et al., 2018).

2.2. Major Mushrooms Exhibiting Anti-Obesity Properties

Edible mushrooms exhibit considerable diversity, and investigations into their anti-obesity properties in species such as Ganoderma lucidum and Hericium erinaceus are widely conducted due to their abundance of bioactive compounds, including fungal polysaccharides and dietary fibers. Numerous studies have underscored their preventive and therapeutic attributes, indicating significant potential to enhance human health. It has the capacity to diminish the body's caloric consumption by curtailing appetite, enhancing feelings of fullness, decreasing fat production, and stimulating fat breakdown through modulation of lipase activity and the regulation of genes and pathways associated with lipid metabolism; ameliorate obesity-related inflammation by inhibiting pro-inflammatory agents; and modulate gut microbiota and its byproducts to avert and manage obesity and metabolic syndrome. Nonetheless, the methods by which edible fungi combat and manage obesity differ (Wang et al., 2023).

Agaricus bisporus, referred to as the white button mushroom, is a species of edible fungus that is extensively eaten globally. This fungus serves as an excellent source of nutrients, including protein, fiber, vitamins D and B, minerals, and bioactive compounds such as polyphenols and polysaccharides (Muszyńska et al., 2017). This mushroom has been studied for its potential health benefits, including anti-inflammatory, antimicrobial, antioxidant, anticarcinogenic, and immunomodulatory activities (Usman et al, 2021). This mushroom contains an array of bioactive substances, including β-glucan, glycoproteins, chitin, and its derivatives, within its cell walls. Various extraction techniques for *A. bisporus* may yield varying biological outcomes. Currently, findings from clinical trials indicate that *A. bisporus* extract, rich in polysaccharides, can produce an anti-obesity effect (Clemente-Ramos et al., 2020). Nevertheless, its precise mode of operation has yet to be elucidated. Numerous investigations have indicated that *A. bisporus* may demonstrate anti-obesity properties via autophagy and beta-oxidation, albeit these effects are contingent upon the content of the *A. bisporus* extract (Iñiguez et al., 2018; Kim et al., 2023).

Obesity has emerged as a critical global health issue that needs immediate and effective management. *Pleurotus citrinopileatus*, an edible fungus rich in bioactive compounds, represents a possible avenue for attaining this objective. Sheng et al. (2019) assessed the anti-obesity and hypolipidemic properties of *P. citrinopileatus* water extract through various biochemical assays on randomized high-fat diet-induced obese (DIO) C57BL/6J mice, which received daily gavage of either low or high doses of the extract (400 or 800 mg/kg of body weight, respectively) alongside a high-fat diet for a duration of 12 weeks. The findings indicated that the aqueous extract of *P. citrinopileatus* markedly diminished weight increase, fat deposition, and food consumption in DIO mice over a period of 12 weeks. The aqueous extract of *P. citrinopileatus* also reduced serum cholesterol, triglycerides, low-density lipoprotein, aspartate transaminase, non-esterified fatty acid, and creatinine, while elevating high-density lipoprotein. Moreover, the aqueous extract of *P. citrinopileatus* enhanced glucose tolerance in the mouse subjected to a high-fat diet. From our analysis, we conclude that PWE shows significant promise as a functional food for the control of obesity and related metabolic conditions.

In recent years, the growing prevalence of obesity and overweight individuals has emerged as a global public health issue, given the absence of effective pharmacological interventions for obesity. *Auricularia heimuer* is abundant in bioactive compounds that may possess significant biological activities. The anti-obesity properties and mechanisms of *A. heimuer* fruiting body alcohol extract (AHA, 150–600 mg/kg·bw) were examined by Yang et al. (2022) in obese mice through the evaluation of alterations in endogenous liver metabolites utilizing a liquid chromatography-tandem mass spectrometry technique. The objective of this research was to determine a potent dietary intervention for managing human obesity. AHA at a dosage of 600 mg/kg·bw (HC) markedly reduced body weight and enhanced serum biochemical parameters. Sixty-eight liver metabolites were discerned and markedly differentiated across the normal, high-fat diet (HFD), and HC cohorts. Furthermore, the metabolic assessment indicated that HC markedly altered specific metabolites in mice, including amino acids, lipids, and carbohydrates. Eight weeks post-supplementation with HC, significant metabolites in associated pathways affected by a high-fat diet returned to baseline levels, indicating that HC exhibited anti-obesity properties.

3. ALLERGIC DISEASE

The issue of IgE-mediated hypersensitivity has been on the rise worldwide, with no established remedy to date (Okada et al., 2010). This category of hypersensitivity response is referred to as type 1 allergic illness, encompassing food allergies, allergic rhinitis, asthma, and atopic dermatitis. It is typically triggered by allergens such as food, dust, and pollen (Tanno et al., 2016). Type 1 allergy disorders pose a worldwide challenge, prompting the exploration of alternative treatments. Fungi have numerous therapeutic and physiological advantages.

Nevertheless, limited information is available regarding the anti-allergic characteristics of polysaccharides derived from mushroom fruiting bodies and mycelia. We employed an in vitro co-culture model consisting of Caco-2 cells (a colorectal cancer epithelial cell line) and RBL-2H3 cells (a rat basophilic leukemia cell line). Diminished mast cell degranulation suggested antihistaminic effects. The suppressive influence of crude polysaccharides derived from various mushroom fruit bodies and mycelia on the release of β-hexosaminidase from RBL-2H3 cells was assessed. Isikhuemhen et al. (2014) demonstrated that the crude polysaccharide from Inonotus obliquus has the potential to reduce β-hexosaminidase release by 16%. However, the polysaccharides of *Pleurotus ostreatus* and *Lentinus squarrosulus* didn't show a significant reduction in β-hexosaminidase (Isikhuemhen et al., 2024).

3.1. Allergy Disease and Mushrooms

Many mushrooms have the potential to reduce allergies. Moreover, different studies have reported that fungal mycelia could be promising sources of therapeutic products, thereby opening the door to further research into the potential of mycelia-based mushroom polysaccharides to manage allergic diseases and other health challenges (Isikhuemhen et al., 2024). The prevalence of allergies is rising globally, necessitating the urgent development of new preventive and therapeutic techniques. Therapeutic fungi provide a significant prospect. Antiallergic activities have been found for *Agaricus subrufescens*, *Flammulina velutipes*, *Pleurotus ostreatus*, *Pleurotus pulmonarius*, *Armillaria ostoyae*, *Ganoderma lucidum*, *Ganoderma tsugae*, *Phellinus linteus*, *Tricholoma populinum*, and *Inonotus obliquus*. The prevalence of allergies is rising globally, necessitating the urgent development of new preventive and therapeutic techniques. Moreover, to date, only a limited number of mushroom species have been examined for their antiallergic properties (Merdivan & Lindequist, 2017).

Tamrakar et al. (2019) evaluated ethanol extracts from 90 wild mushroom specimens sourced from Nepal, together with the isolated chemical hispidin, for their capacity to suppress β-hexosaminidase release (BHR) from rat basophilic leukemia-2H3 cells. Concurrently, the cytotoxicity of the extracts was assessed utilizing the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay. Specimens from the Hymenochaetales and Polyporales orders exhibited encouraging anti-allergic properties, with Phellinus adamantinus and Ganoderma lingzhi demonstrating BHR of just 19.4% and 16.7%, respectively, and no cytotoxic effects on cells. Furthermore, the 50% inhibitory concentration (IC50) values for *Inonotus clemensiae* and *P. adamantinus* were 51.24 and 50.65 μg/mL, respectively; in contrast, hispidin, the principal bioactive ingredient in I. clemensiae, exhibited an IC50 of 82.47 μg/mL. These results are essential in emphasizing the therapeutic potential of wild mushrooms as a source of potent antiallergic compounds. (Tamrakar et al., 2019). Moreover, Thomas et al. (2020) reported that *Inonotus obliquus* had different medical effects.

3.2. Major Mushrooms Exhibiting Anti-Allergic Properties

Medicinal effects have been documented in many scientific works, including the Basidiomycota mushrooms Grifola frondosa, Hericium erinaceus, and Agaricus blazei, from different countries and Eastern traditional medicine. Particular attention has been paid to their anticancer effects; however, the mushrooms' anti-inflammatory and antiallergic properties have also been examined. The antiallergic process involved correcting an imbalanced Th1/Th2 ratio. A prevalent Th2 environment is observed in cancer, frequently resulting from localized chronic inflammation, suggesting a correlation among the three conditions: tumor, inflammation, and allergy. Further mechanisms of Hericium erinaceus include increased nerve growth, beneficial gut microbiota, and regulation of oxidative stress. The medicinal mushrooms *Agaricus blazei*, *Hericium erinaceus*, and Grifola frondosa appear to be safe and can, in fact, increase longevity in animal models, possibly by reducing tumorigenesis and oxidative stress (Hetland et al., 2020).

Finally, Nguyen et al. (2020) reported that inotodiol exhibits a distinctive immunoregulatory function, alleviating allergy symptoms in a murine model of food allergy for the first time. Although CCME led to a significant improvement in food allergy symptoms, the effects of CCME and inotodiol on the overall immunological profile appeared markedly distinct. Inotodiol is a lanostane triterpenoid only present in the Chaga mushroom (*Inonotus obliquus*). Numerous prior investigations on the anti-allergic properties of fractionated Chaga mushroom extracts have demonstrated that purified inotodiol possesses the capability to inhibit mast cell function in vivo.

4. CONCLUSION

The richness of mushrooms in bioactive compounds that are not fully discovered encourages ongoing investigations, which are critically needed to obtain optimal benefits from these marvellous mushrooms. To achieve this goal, mushroom cultivation techniques should be improved. Also, cultivation using agricultural wastes will definitely reduce costs and positively affect the price and availability of bioactive compounds. Focusing on efforts to bioengineer mushroom strains to produce climate-resilient hybrids and enhance metabolite production and concentrations will enable over production of desired bioactive compounds. On the other hand, improving delivery systems and employing nanoencapsulation, particularly liposomal encapsulation, can enhance the bioavailability of bioactive compounds and their stability. Another approach that may yield unlimited options is to explore synergistic effects between different compounds extracted from different mushrooms, or the combination of these compounds with probiotic bacteria or their bioactive metabolites. Finally, more in vivo investigations and clinical trials are needed to validate bioactivity and clarify the mechanisms of action of these bioactive compounds.

Ethical Statement

Not Applicable.

Conflicts of Interest

The authors declare no competing interests.

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