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The Role of Mushrooms and Their Bioactive Compounds in Cancer Prevention and Treatment

Narrative Review

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ABSTRACT

Background: Cancer remains one of the most significant global health concerns, contributing to high morbidity and mortality rates. Conventional treatments such as chemotherapy, radiation therapy, and targeted therapies are widely used but often come with significant limitations, including severe side effects, resistance development, and compromised quality of life. The search for safer and more effective complementary therapies has led to growing interest in natural compounds with anticancer potential. Medicinal mushrooms have long been valued in traditional medicine for their nutritional and therapeutic properties, offering a promising alternative for cancer prevention and treatment.

Body: Mushrooms are a rich source of bioactive compounds, including polysaccharides, terpenoids, phenolic compounds, sterols, and lectins, which exhibit diverse pharmacological properties such as antioxidant, immunomodulatory, and tumor-suppressive effects. Notable species, including Shiitake (Lentinula edodes), Reishi (Ganoderma lucidum), Maitake (Grifola frondosa), and Turkey Tail (Trametes versicolor), have been extensively studied for their ability to enhance immune function, induce apoptosis, and inhibit angiogenesis and metastasis. Preclinical and clinical studies have demonstrated that mushroom-derived compounds can influence key cancer-related pathways, including immune regulation, oxidative stress reduction, and cell cycle arrest, suggesting their potential as adjunct therapies alongside conventional treatments.

Conclusion: The existing body of research provides compelling evidence supporting the anticancer potential of medicinal mushrooms. However, challenges such as standardization of bioactive compounds, dose optimization, and regulatory validation remain. Further large-scale clinical trials and mechanistic studies are essential to fully harness their therapeutic benefits and facilitate their integration into conventional cancer treatment strategies. Medicinal mushrooms hold promise as natural, well-tolerated agents that could complement existing therapies and improve patient outcomes in oncology.

Keywords: Anticancer, Bioactive compounds, Cancer prevention, Immune modulation, Medicinal mushrooms, Oncology, Therapeutic potential.

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INTRODUCTION

Cancer remains one of the most significant global health challenges, contributing to substantial morbidity and mortality. According to global health estimates, cancer accounted for approximately 10 million deaths in 2020, making it one of the leading causes of mortality worldwide(1, 2). Furthermore, projections suggest that cancer-related deaths will continue to rise, with an estimated increase to 18.5 million by 2050. Despite advancements in medical science, cancer remains a complex and multifactorial disease influenced by genetic, environmental, and lifestyle factors. Among the primary modifiable risk factors, tobacco use stands as the leading cause of lung cancer and contributes significantly to cancer-related deaths(3, 4). Additionally, dietary patterns, obesity, physical inactivity, alcohol consumption, infections, radiation exposure, environmental pollutants, and occupational hazards further exacerbate cancer incidence. Addressing these risk factors remains crucial in reducing the global burden of cancer(5, 6).

Conventional cancer treatments, such as chemotherapy, radiation therapy, and surgical interventions, have been instrumental in improving survival rates. However, these approaches come with inherent limitations(7, 8). Chemotherapy, although effective against various malignancies, often results in adverse effects due to its non-specific cytotoxicity, leading to damage in healthy cells. Moreover, cancer cells can develop resistance to chemotherapeutic agents, reducing treatment efficacy and necessitating alternative therapeutic strategies(9, 10). Another supportive approach in cancer management is nutritional therapy, which emphasizes the role of diet and specific nutrients in mitigating cancer progression. While dietary interventions have shown promise in cancer care, the lack of standardized guidelines and the need for more extensive research have limited their widespread clinical application. Given these challenges, there is an increasing need for novel and integrative approaches that can enhance treatment efficacy and minimize adverse effects(11, 12).

One emerging area of interest in cancer prevention and adjunctive therapy is the role of natural compounds with bioactive properties. Chemoprevention, a strategy aimed at using natural or synthetic compounds to prevent, reverse, or delay the progression of cancer, has gained substantial attention in recent years(13, 14). This approach has demonstrated promise in various clinical settings, such as the use of tamoxifen in reducing breast cancer risk. Among natural sources, mushrooms have garnered significant scientific interest due to their diverse array of bioactive compounds and potential therapeutic effects(15, 16). Historically, mushrooms have been integral to traditional medicine and dietary practices across different cultures. In recent decades, extensive research has uncovered their potential role in cancer prevention and treatment(17, 18).

Mushrooms contain a rich repertoire of bioactive components, including polysaccharides (such as beta-glucans), terpenoids, flavonoids, phenolic compounds, and lectins. These compounds exhibit a wide range of pharmacological properties, including antioxidant, anti-inflammatory, immunomodulatory, and anticancer effects(19, 20). Studies suggest that certain mushroom-derived compounds can inhibit tumor growth, induce apoptosis in cancer cells, enhance immune response, and modulate key signaling pathways involved in carcinogenesis. Furthermore, the ability of mushrooms to mitigate oxidative stress and inflammation—two critical factors in cancer progression—further highlights their therapeutic potential(21, 22).

Given the increasing scientific and clinical interest in mushrooms as potential chemopreventive agents, it is imperative to systematically evaluate their efficacy, mechanisms of action, and clinical relevance(23, 24). This review aims to comprehensively analyze the current evidence surrounding the role of mushrooms and their bioactive compounds in cancer prevention and treatment. By synthesizing findings from preclinical, clinical, and epidemiological studies, this review seeks to provide a critical perspective on the potential of mushrooms in oncology. Ultimately, understanding the mechanisms through which mushrooms exert their anticancer effects may contribute to the development of novel integrative strategies in cancer prevention and therapy(25, 26).

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BODY

Overview of Mushrooms and Their Bioactive Compounds in Cancer Prevention and Treatment

Mushrooms, the spore-producing reproductive structures of fungi, have long been valued for their nutritional and medicinal properties. Historically, fungi were classified within the plant kingdom; however, modern taxonomy recognizes them as a distinct kingdom due to their unique biological characteristics. Mushrooms grow on various substrates and exist in diverse ecological settings. Out of approximately 14,000 known mushroom species, only a small proportion—around 2,000—are considered edible, while approximately 700 species exhibit medicinal properties. For centuries, different cultures have incorporated mushrooms into traditional medicine due to their diverse pharmacological benefits. Several well-documented medicinal mushrooms, such as Ganoderma lucidum (Reishi), Lentinus edodes (Shiitake), and Inonotus obliquus (Chaga), have been extensively used in Eastern and Western medical traditions to treat a variety of ailments, including cancer(27, 28).

Bioactive Compounds in Mushrooms and Their Therapeutic Potential

Mushrooms are rich in bioactive compounds that contribute to their pharmacological efficacy. These compounds include polysaccharides, terpenoids, phenolic compounds, sterols, and lectins, which exhibit antioxidant, immunomodulatory, and anticancer properties. Understanding the molecular mechanisms by which these compounds exert their effects is crucial for their integration into cancer prevention and therapy(29, 30).

Polysaccharides: Immunomodulatory and Anticancer Agents

Polysaccharides, particularly β-glucans, are among the most studied bioactive compounds in mushrooms. These structurally diverse macromolecules primarily exist in the fungal cell wall and play a crucial role in immunomodulation. β-glucans can be categorized into β-1,3-glucan and β-1,6-glucan, which interact with immune receptors in the gastrointestinal tract, stimulating the immune response. Studies indicate that β-glucans enhance macrophage activity, promote the maturation of dendritic cells, and activate natural killer (NK) cells, thereby contributing to an enhanced anti-tumor response. Additionally, fungal polysaccharides have demonstrated anti-inflammatory, antibacterial, antiviral, and antioxidant properties, which collectively contribute to cancer prevention and treatment(31, 32).

Terpenoids: Multifaceted Bioactive Metabolites

Terpenoids are another significant group of bioactive compounds found in mushrooms, characterized by their diverse chemical structures and biological functions. These secondary metabolites, composed of isoprene units, include monoterpenes, diterpenes, and sesquiterpenes, each displaying unique therapeutic properties. Terpenoids are potent antioxidants, reducing oxidative stress, which is a major contributing factor to carcinogenesis. Their anticancer effects are primarily mediated through apoptosis induction, inhibition of angiogenesis, and suppression of tumor proliferation. Several studies have highlighted the efficacy of terpenoids in targeting multiple cancer pathways, making them promising candidates for cancer therapeutics(33, 34).

Phenolic Compounds: Antioxidants with Chemopreventive Properties

Phenolic compounds in mushrooms are secondary metabolites with significant structural diversity, including flavonoids, tannins, and tocopherols. These compounds exert strong antioxidant activity by scavenging free radicals and reducing oxidative stress, thereby protecting cellular components from damage. The presence of hydroxyl groups in their structure enhances their ability to neutralize reactive oxygen species (ROS), which are implicated in DNA damage and tumor progression. Phenolic compounds also exhibit antiproliferative effects by modulating key signaling pathways involved in cancer cell growth and survival. Their role in modulating enzyme activity related to detoxification further underscores their potential as chemopreventive agents(35, 36).

Sterols: Potential Antitumor Agents

Mushroom sterols, particularly ergosterol, have garnered attention for their pharmacological effects. Ergosterol, a precursor to vitamin D2, exhibits antimicrobial, antioxidant, anti-inflammatory, and anticancer properties. One of its key attributes is its ability to modulate oxidative stress by neutralizing ROS, thereby preventing cellular damage. Studies suggest that ergosterol and its derivatives possess antitumor activity by inhibiting cancer cell proliferation while sparing normal cells. This selective cytotoxicity makes sterols promising candidates for targeted cancer therapies(37, 38).

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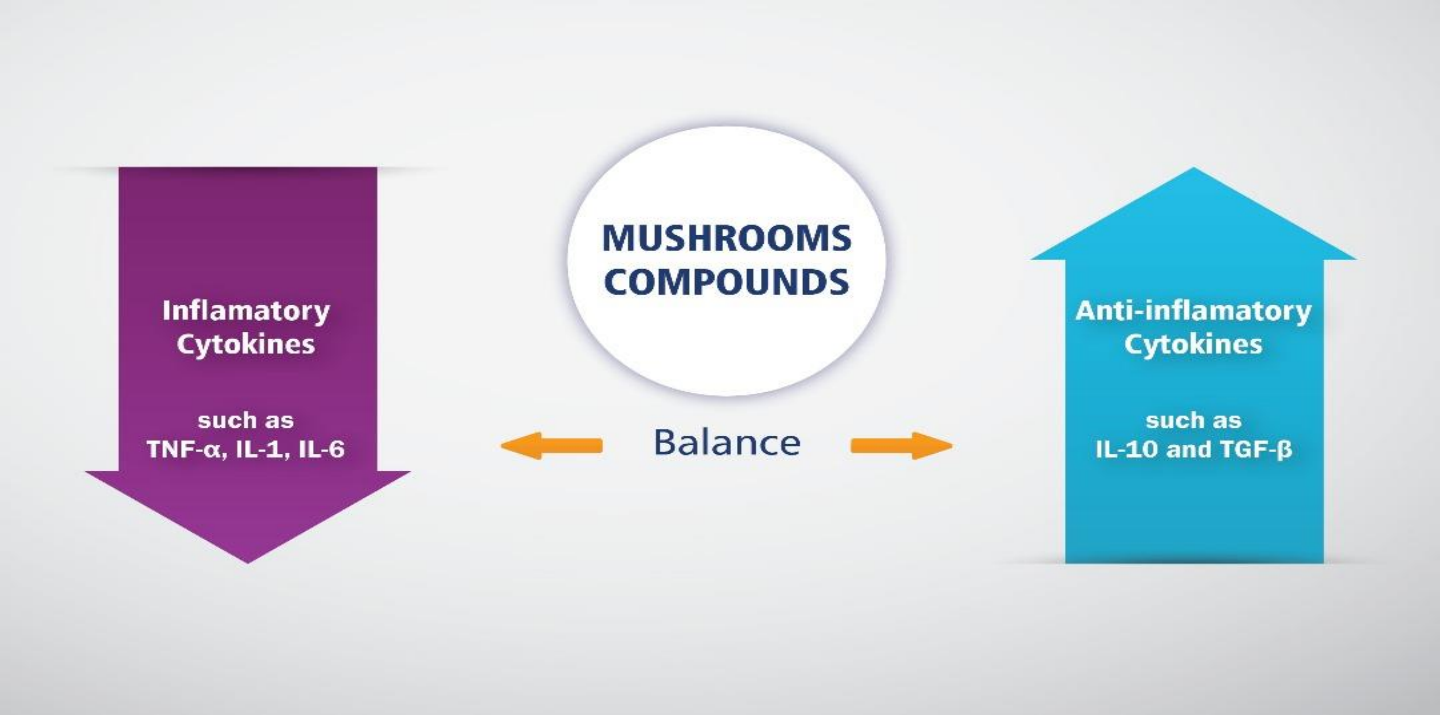
Lectins: Biological Mediators of Apoptosis

Lectins, carbohydrate-binding proteins found in mushrooms, play a pivotal role in immune modulation and cellular signaling. These proteins have been identified as potent anti-cancer agents due to their ability to bind to specific sugar moieties on cancer cell surfaces, triggering apoptosis. Furthermore, lectins enhance immune responses by activating tumor necrosis factors and increasing the production of cytokines involved in immune surveillance. Their potential use as diagnostic reagents, owing to their carbohydrate-binding specificity, further extends their application in cancer detection and therapy(39, 40).

Antioxidant and Anti-Inflammatory Properties of Mushrooms

Mushrooms are abundant sources of bioactive compounds with potent antioxidant and anti-inflammatory properties. Oxidative stress, resulting from an imbalance between ROS production and antioxidant defenses, is a key contributor to cancer development. Mushroom-derived antioxidants, including phenolics, flavonoids, polysaccharides, and carotenoids, play a crucial role in scavenging free radicals, thereby mitigating cellular damage. In addition to their antioxidant potential, mushrooms exhibit strong anti-inflammatory effects by modulating the production of cytokines. They promote the secretion of anti-inflammatory cytokines, such as interleukin-10 (IL-10) and transforming growth factor-beta (TGF-β), while suppressing pro-inflammatory cytokines, including tumor necrosis factor-alpha (TNF-α), interleukin-1 (IL-1), and interleukin-6 (IL-6). This cytokine balance helps reduce chronic inflammation, which is a known risk factor for carcinogenesis(41, 42).



Immunomodulatory Effects and Cancer Prevention

The immunomodulatory properties of mushrooms contribute significantly to their anticancer potential. Mushrooms enhance the immune response by increasing the production of cytokines that stimulate NK cells, macrophages, and T lymphocytes. This immune activation plays a crucial role in identifying and eliminating cancer cells before they proliferate uncontrollably. Additionally, mushroom-derived polysaccharides have been shown to induce cell cycle arrest and inhibit tumor angiogenesis, thereby limiting tumor growth and metastasis(43, 44).

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Apoptosis Induction and Cancer Cell Suppression

One of the fundamental mechanisms by which mushrooms exert anticancer effects is through apoptosis induction. Apoptosis, or programmed cell death, is a tightly regulated process that eliminates damaged or cancerous cells. Several mushroom-derived bioactive compounds, including polyphenols and terpenoids, have been shown to modulate apoptotic pathways. These compounds enhance oxidative stress within cancer cells, leading to DNA damage and cell death. Furthermore, they influence mitochondrial pathways and activate caspases, key enzymes involved in apoptosis execution(45, 46).

Inhibition of Angiogenesis and Metastasis

Angiogenesis, the formation of new blood vessels, is critical for tumor growth and metastasis. Certain bioactive compounds in mushrooms have been identified as potent angiogenesis inhibitors. For example, terrein, a bioactive compound derived from fungi, has been shown to reduce vascular endothelial growth factor (VEGF) secretion, thereby limiting blood supply to tumors. Additionally, melatonin from mushrooms has demonstrated the ability to alter cell adhesion molecules, preventing cancer cell migration and metastasis. By inhibiting these critical pathways, mushrooms contribute to the suppression of tumor progression(47, 48).

Specific Mushrooms with Anticancer Properties

The potential of mushrooms as anticancer agents has gained significant scientific attention, primarily due to their rich composition of bioactive compounds. Certain mushroom species, particularly those long used in traditional medicine, have demonstrated potent immunomodulatory, antioxidant, and tumor-suppressive properties. Over the years, extensive research has validated their effectiveness in cancer prevention and therapy. This section explores some of the most well-documented medicinal mushrooms, highlighting their mechanisms of action and therapeutic relevance(49, 50).

Shiitake (Lentinula edodes)

Shiitake mushrooms have been a fundamental component of traditional medicine, particularly in East Asia, where they have been consumed for their immune-boosting and medicinal properties. Modern research has identified key bioactive compounds in *Lentinula edodes*, including polysaccharides, terpenoids (such as shiitakene), and various antioxidants. These compounds contribute to its significant anticancer activity by modulating immune responses, reducing oxidative stress, and inducing apoptosis in cancer cells(51, 52). One of the most notable mechanisms by which *Lentinula edodes* exerts its effects is through immune modulation. Studies have shown that shiitake mushroom extracts stimulate the production of key cytokines, such as interleukin-4 (IL-4), interleukin-10 (IL-10), tumor necrosis factor-alpha (TNF-α), and interleukin-1α (IL-1α). This immune activation plays a critical role in enhancing the body's ability to detect and eliminate cancer cells. Additionally, shiitake-derived polysaccharides, particularly lentinan, have been shown to support conventional chemotherapy by reducing immunosuppression and improving treatment outcomes(53, 54).

Reishi (*Ganoderma lucidum*)

Reishi mushrooms, also known as Lingzhi, have been used in traditional Chinese medicine for centuries due to their purported ability to promote longevity and enhance immune function. In recent years, extensive research has uncovered their strong anticancer properties, primarily attributed to their high concentration of polysaccharides and triterpenoids. More than 150 polysaccharides and 50 triterpenes have been isolated from *Ganoderma lucidum*, making it one of the most extensively studied medicinal mushrooms(55, 56). One of the key bioactive compounds in Reishi is ganoderic acid, which has demonstrated significant potential in inducing apoptosis and inhibiting cancer cell proliferation. Studies have shown that ganoderic acid affects critical cancer-related pathways, including the NF-κB, RAS-MAPK, and PI3K/Akt/mTOR signaling cascades. These pathways play essential roles in cell survival, metastasis, and resistance to chemotherapy, making them attractive targets for cancer treatment. The immunomodulatory effects of Reishi further enhance its therapeutic potential, as it has been found to stimulate T-cell activation and enhance the cytotoxicity of natural killer (NK) cells(57, 58).

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Maitake (Grifola frondosa)

Maitake mushrooms have been utilized in traditional Japanese medicine for centuries and have gained recognition for their potent anticancer properties. The primary bioactive components in Grifola frondosa include polysaccharides and triterpenoids, both of which contribute to its immunomodulatory and tumor-suppressive effects. One of the most extensively studied fractions of Maitake mushrooms is the D-Fraction, a polysaccharide extract known for its ability to stimulate immune cells and enhance their anticancer activity(59, 60). Research has demonstrated that the D-Fraction promotes immune function by activating macrophages, T cells, and NK cells, which play a vital role in detecting and destroying cancer cells. Additionally, Maitake extracts have shown potential in inhibiting tumor growth, preventing angiogenesis, and reducing inflammation, all of which are crucial in limiting cancer progression. The combination of these effects makes Maitake mushrooms a promising candidate for integrative cancer therapy(61, 62).

Turkey Tail (Trametes versicolor)

Turkey Tail mushrooms have a well-documented history of use in both conventional and traditional medicine. Rich in essential proteins, polysaccharides, sterols, and triterpenoids, Trametes versicolor exhibits a broad spectrum of pharmacological activities, including antioxidant, immune-modulating, and anticancer effects. Among its most studied components are polysaccharopeptides (PSP) and polysaccharide-K (PSK), both of which have been evaluated in clinical settings for their anticancer potential(63, 64). PSK, in particular, has been widely used as an adjunct therapy in cancer treatment, especially in Japan. It has been found to enhance the efficacy of chemotherapy and radiation therapy by modulating immune responses and reducing tumor-induced immunosuppression. Studies have shown that extracts from Trametes versicolor exhibit cytotoxic activity against various cancer cell lines and can induce apoptosis through the activation of caspase-dependent pathways. Additionally, these compounds contribute to reducing inflammation and oxidative stress, further highlighting their potential role in cancer prevention(65, 66).

Preclinical Evidence: In Vitro and In Vivo Studies

Preclinical research has provided compelling evidence supporting the anticancer potential of mushroom-derived bioactive compounds. A combination of in vitro and in vivo studies has elucidated their molecular mechanisms and demonstrated their effectiveness against various types of cancers(67, 68). One of the fundamental processes affected by these compounds is mitochondrial outer membrane permeability (MOMP), which is a crucial step in apoptosis regulation. Studies have shown that aqueous extracts of Cordyceps militaris and Tricholoma matsutake can induce conformational changes in pro-apoptotic proteins such as Bax and Bad, leading to mitochondrial membrane disruption and subsequent activation of caspases responsible for apoptosis. These effects have been confirmed in hepatocellular carcinoma and breast cancer models, both in cell cultures and animal xenograft studies(69, 70). Similarly, ethanol extracts of Phellinus ferulae and Phellinus igniarius have demonstrated the ability to modulate the Bax/Bcl-2 ratio, favoring pro-apoptotic signaling and inducing cell death in hepatocellular carcinoma, melanoma, and gastrointestinal cancer models. These findings highlight the importance of mitochondrial-mediated apoptosis as a key mechanism through which mushroom bioactive compounds exert their anticancer effects(71, 72).

Clinical Studies and Human Trials

The clinical relevance of medicinal mushrooms in oncology has been widely explored through observational studies and clinical trials. Over 600 clinical studies have been conducted worldwide, evaluating the efficacy of mushroom-derived compounds in cancer prevention and treatment. The primary focus has been on polysaccharides, protein-bound polysaccharides, and triterpenoids, many of which have shown promising results in clinical settings(73, 74). One of the most well-known clinical applications of medicinal mushrooms is the use of *Trametes versicolor*-derived polysaccharide-K (PSK) in cancer therapy. PSK has been approved in Japan as an adjunct treatment for various cancers, including gastric, breast, and colorectal malignancies. Clinical studies have demonstrated its ability to enhance the immune response, reduce chemotherapy-induced side effects, and improve overall survival rates in cancer patients(75, 76).

Similarly, *Lentinula edodes*-derived lentinan has been extensively studied for its immunomodulatory properties. Clinical trials have shown that combining lentinan with chemotherapy improves treatment outcomes in lung, gastric, and colorectal cancers by enhancing tumor response and reducing chemotherapy-related toxicity(77, 78). A growing body of evidence also supports the role of *Ganoderma lucidum* in cancer management. Randomized clinical trials have demonstrated its ability to enhance immune function, improve quality of life, and support conventional cancer therapies. Furthermore, meta-analyses of epidemiological studies suggest that habitual mushroom consumption is associated with a reduced risk of epithelial ovarian and breast cancers(79).

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Mushroom	Type of Study	No. of patients	Type of cancer	Extracts/compounds/ active principle	Findings	Ref
Agaricus bisporus	Observational study	500 participants	Ovarian	Polysaccharides	Moderate inverse association between habitual mushroom intake and epithelial ovarian cancer.	(78)
Agaricus bisporus/ Amauroderma rude	Meta-analyses, observational studies	6890 women	Breast	Daily intake −1g/d in pre/postmenopausal women	Mushroom consumption is associated to lower risk of breast cancer.	(77)
Ganoderma lucidum	Randomized, clinical trial	373 adults	Various types	Spore vs mycelium	Improve tumor response of lung cancer to conventional therapy. Enhance immunity. Promising adjunct treatment in immunosuppressive effects of chemotherapy. QoL relatively improved.	(79)
Lentinula edodes	Open pilot study	10 participants	Various types	L.edodes mycelia	Combine treatment of LEM and immunotherapy might improve QOL and immune function.	(74)
Pleurotus cornucopiae Oyster	Double-blind, placebo-controlled study	20 participants	Various types	Oyster extract	Potentiate immune system, may prevent cancer and other diseases.	(75)

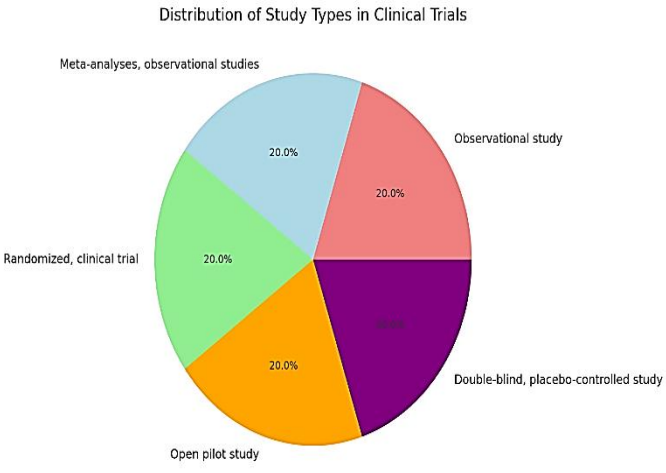

Figure 1 Distribution of Study Types in Clinical Trials

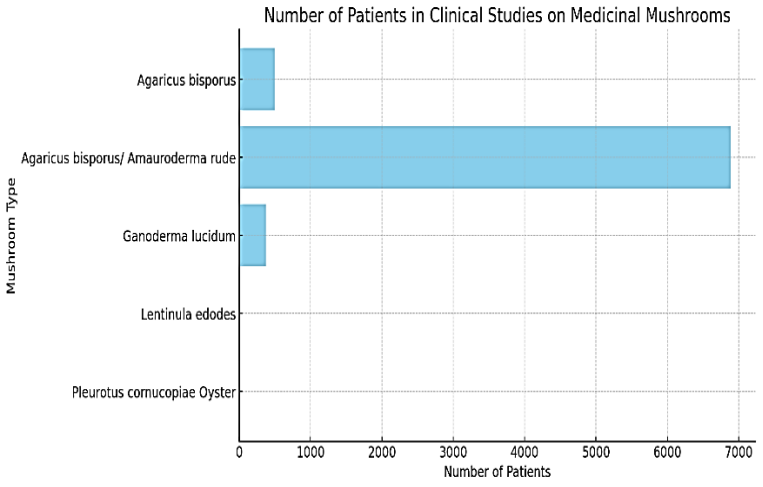

Figure 2 Number of Patients in Clinical Study on Medical Mushrooms

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DISCUSSION

The findings presented in this review highlight the significant potential of medicinal mushrooms and their bioactive compounds in cancer prevention and treatment. The diverse array of bioactive molecules, including polysaccharides, triterpenoids, phenolics, sterols, and lectins, has demonstrated promising anticancer properties through immunomodulation, oxidative stress reduction, apoptosis induction, and inhibition of tumor growth and metastasis. These mechanisms align with the increasing recognition of natural compounds as complementary or adjunct therapies in oncology, particularly in cases where conventional treatments may have limited efficacy or severe side effects. The evidence from preclinical studies, including in vitro and in vivo models, has reinforced the hypothesis that mushroom-derived compounds possess the ability to target multiple cancer-related pathways. Furthermore, clinical investigations have suggested improvements in immune function, tumor response, and quality of life in cancer patients receiving mushroom-based therapies alongside conventional treatment(80-82).

Despite these promising findings, several challenges remain in translating preclinical and clinical research into standardized therapeutic applications. One of the primary concerns is the lack of standardization in mushroom extracts, which leads to variability in bioactive compound concentrations across different formulations. The complexity of mushrooms as natural sources of therapeutic agents presents difficulties in isolating and characterizing individual active compounds with precise mechanisms of action. Most studies have evaluated whole extracts rather than individual constituents, which limits the ability to determine the specific molecular targets of each bioactive compound. Furthermore, many investigations have not reported IC50 values, making it difficult to ascertain the potency of mushroom-derived compounds in cancer treatment. Addressing these gaps would require further research into structure-activity relationships to optimize the therapeutic effects of bioactive components while minimizing non-specific toxicity(1, 2).

The use of medicinal mushrooms as adjuvants in conventional cancer therapy is gaining traction, particularly in cases of metastatic or chemoresistant malignancies where novel therapeutic strategies are urgently needed. The combination of mushroom-derived bioactive compounds with conventional chemotherapy and immunotherapy may enhance treatment efficacy by targeting additional oncogenic pathways and reducing drug resistance. Investigating the synergistic effects of these compounds with existing cancer treatments could lead to improved patient outcomes and potentially lower doses of cytotoxic drugs, thereby reducing adverse effects. Future studies should explore how mushroom-derived compounds interact with mitochondrial pathways, cellular metabolism, and immune function to refine their therapeutic applications(3, 4).

While the clinical evidence supporting the anticancer potential of medicinal mushrooms is growing, large-scale, well-designed clinical trials are needed to establish their safety, efficacy, and optimal dosages. Many studies conducted to date have been limited by small sample sizes, lack of placebo controls, or variability in extract formulations, which hinders the ability to draw definitive conclusions. The lack of rigorous toxicological evaluations also raises concerns regarding the long-term safety of these compounds, particularly when used in combination with other treatments. Before mushroom-derived compounds can be fully integrated into clinical oncology, extensive toxicological assessments and pharmacokinetic studies are necessary to determine their bioavailability, metabolism, and potential interactions with conventional cancer therapies(5, 6).

A major limitation of existing research is the predominant focus on general cytotoxic effects rather than selective modulation of oncogenic signaling pathways. While mushroom extracts have been shown to induce cancer cell death, further studies are needed to elucidate how these compounds influence key molecular targets involved in carcinogenesis. Identifying selective modulators of oncogenic pathways could provide more targeted therapeutic interventions and enhance the precision of mushroom-derived cancer treatments. In addition, research should expand beyond the most commonly studied mushroom species to explore the potential of lesser-known fungi that may contain unique bioactive compounds with anticancer properties(7, 8).

The transition of mushroom-derived compounds from bench to bedside requires a multidisciplinary approach that integrates natural product chemistry, molecular oncology, pharmacology, and clinical research. The physicochemical characteristics of mushroom bioactive compounds must be thoroughly characterized to optimize their formulation for clinical use. Advances in biotechnology and nanotechnology may facilitate the development of more effective delivery systems that improve the stability and bioavailability of these compounds. Moreover, the role of gut microbiota in mediating the bioactivity of mushroom-derived polysaccharides and other bioactive molecules should be further investigated, as this may influence their therapeutic efficacy in cancer patients(9, 10).

While the preliminary findings on medicinal mushrooms and their bioactive compounds in cancer therapy are encouraging, significant challenges remain in refining their clinical application. Standardization of extracts, identification of precise mechanisms of action, and

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rigorous evaluation through large-scale clinical trials are necessary to establish their role in evidence-based cancer treatment. As research continues to advance, medicinal mushrooms hold promise as a valuable addition to integrative oncology, offering a complementary approach that enhances the efficacy of conventional treatments while potentially improving patient outcomes and quality of life(11, 12).

CONCLUSION

Mushrooms have emerged as a valuable natural source of bioactive compounds with significant potential in cancer prevention and treatment. Their diverse pharmacological properties, including antioxidant activity, immune modulation, apoptosis induction, and inhibition of tumor progression, position them as promising therapeutic agents. Unlike conventional cancer treatments, mushroom-derived compounds offer a favorable safety profile with minimal adverse effects, making them attractive as both standalone and complementary therapies. The therapeutic potential of specific mushrooms, such as Shiitake, Reishi, Maitake, and Turkey Tail, has been well-documented in preclinical and clinical studies, demonstrating their ability to enhance immune function and suppress tumor growth. However, challenges remain in standardizing bioactive compounds, ensuring consistent efficacy, and obtaining regulatory approval for clinical use. Addressing these gaps through rigorous clinical trials and mechanistic studies will be essential in translating these natural compounds into mainstream oncology. With further research, mushrooms may play an increasingly significant role in integrative cancer treatment, offering safer and more effective therapeutic options for patients worldwide.

AUTHOR CONTRIBUTIONS

Author	Contribution
Muhammad Aftab Shafiq*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Hadj Henni Imene	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Hira Tasneem	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Sidra Tul Muntaha	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muhammad Abdullahi Almu	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Sana Nasir	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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