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Pharmacological Effects of *Sanghuangporus* spp. Extract and Its Application in the Prevention and Treatment of Chronic Diseases

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Abstract *Sanghuangporus* spp., a traditional medicinal fungus, has garnered significant scientific attention due to its diverse pharmacological properties. This study systematically explores the bioactive components of *Sanghuangporus* spp., such as polysaccharides, triterpenoids, and flavonoids, and their mechanisms of action in preventing and treating various chronic diseases. *Sanghuangporus* spp. exhibits potent antioxidant, anti-tumor, anti-inflammatory, immunomodulatory, hepatoprotective, anti-diabetic, and cardiovascular protective effects. These characteristics make it a promising natural remedy for managing chronic conditions such as cancer, diabetes, liver disease, and cardiovascular disorders. However, challenges remain in standardizing *Sanghuangporus* spp. extracts, ensuring quality consistency, and translating preclinical findings into clinical practice. Future research should focus on large-scale clinical trials to elucidate the molecular mechanisms of its bioactive compounds and overcome regulatory barriers to integrate *Sanghuangporus* spp. into modern therapeutic strategies. This study evaluates the safety and efficacy of *Sanghuangporus* spp. extract, providing theoretical and practical references for its development into functional foods and pharmaceuticals.

Keywords *Sanghuangporus* spp.; Pharmacological effects; Chronic diseases; Antioxidant; Anti-tumor

1 Introduction

Sanghuangporus spp., commonly known as Sanghuang, is a traditional medicinal fungus widely used in Chinese medicine for its therapeutic properties. Historically, *Sanghuangporus* has been utilized to treat various ailments, including gastrointestinal disorders, liver diseases, and cancer. Recent studies have revealed that *Sanghuangporus* contains multiple bioactive compounds such as polysaccharides, triterpenoids, phenolics, and flavonoids, which contribute to its pharmacological activities (Zhang et al., 2022). Research has shown that these compounds exhibit anti-tumor, anti-inflammatory, antioxidant, antiviral, hypoglycemic, immunomodulatory, and hepatoprotective effects (Dong et al., 2019; Yang et al., 2021). Due to its broad spectrum of bioactivities, *Sanghuangporus* has attracted interest as a potential natural remedy for managing chronic diseases, including cancer, diabetes, cardiovascular diseases, and liver disorders (Dong et al., 2020; Wang et al., 2023).

Chronic diseases, including cancer, diabetes, and cardiovascular disorders, are leading causes of morbidity and mortality worldwide (Shelton et al., 2022). Traditional therapeutic approaches often involve synthetic drugs, which may have significant side effects and limitations in long-term efficacy. In recent years, there has been a growing interest in natural products, including medicinal fungus like *Sanghuangporus*, due to their broad spectrum of biological activities and relatively low toxicity (Dong et al., 2024). Studies have shown that *Sanghuangporus* possesses various pharmacological properties, including antioxidant, anti-inflammatory, antiviral, antitumor, and immunomodulatory effects (Jiang et al., 2018). Pharmacological research on natural extracts like *Sanghuangporus* not only provides scientific validation for traditional medicine practices but also offers insights into developing novel therapeutic agents for chronic diseases with fewer adverse effects (Zhou et al., 2022b).

Moreover, exploring the complex interactions between bioactive compounds in natural extracts and biological systems can lead to discovering new pathways for disease prevention and treatment (Lv et al., 2023).

This study systematically examines the pharmacological effects of *Sanghuangporus* spp. extract and its potential applications in the prevention and treatment of chronic diseases. It details the primary bioactive components of *Sanghuangporus* spp., such as polysaccharides and triterpenoids, and their pharmacological activities, including antioxidant, anti-tumor, and immunomodulatory properties. The study explores the application of *Sanghuangporus* spp. in combating chronic diseases such as cancer, diabetes, liver diseases, and cardiovascular disorders. Additionally, it assesses the safety and efficacy of *Sanghuangporus* spp. extract, providing theoretical and practical references for its development into functional foods and pharmaceuticals.

2 Primary Active Components of *Sanghuangporus* spp.

2.1 Polysaccharides

Polysaccharides are one of the primary bioactive components of *Sanghuangporus*. They typically consist of a complex structure of glucose, galactose, mannose, xylose, and other monosaccharides. One study reported the isolation of a high-molecular-weight polysaccharide named PIP-1 from *Sanghuangporus* mycelia, which exhibited a linear repeating backbone composed of glucopyranose (Glcp), galactopyranose, and mannopyranose linked by α-(1→4), α-(1→3), and α-(1→6) glycosidic bonds, and contained single α-terminal-D-Glcp as side chains (Yuan et al., 2018). Extraction methods for *Sanghuangporus* polysaccharides include hot water extraction, ethanol precipitation, and chromatographic techniques for purification (Figure 1). Polysaccharides can be further modified to enhance their bioactivities, such as preparing selenium-enriched polysaccharides that have demonstrated antioxidant and anti-inflammatory effects (Luo et al., 2021).

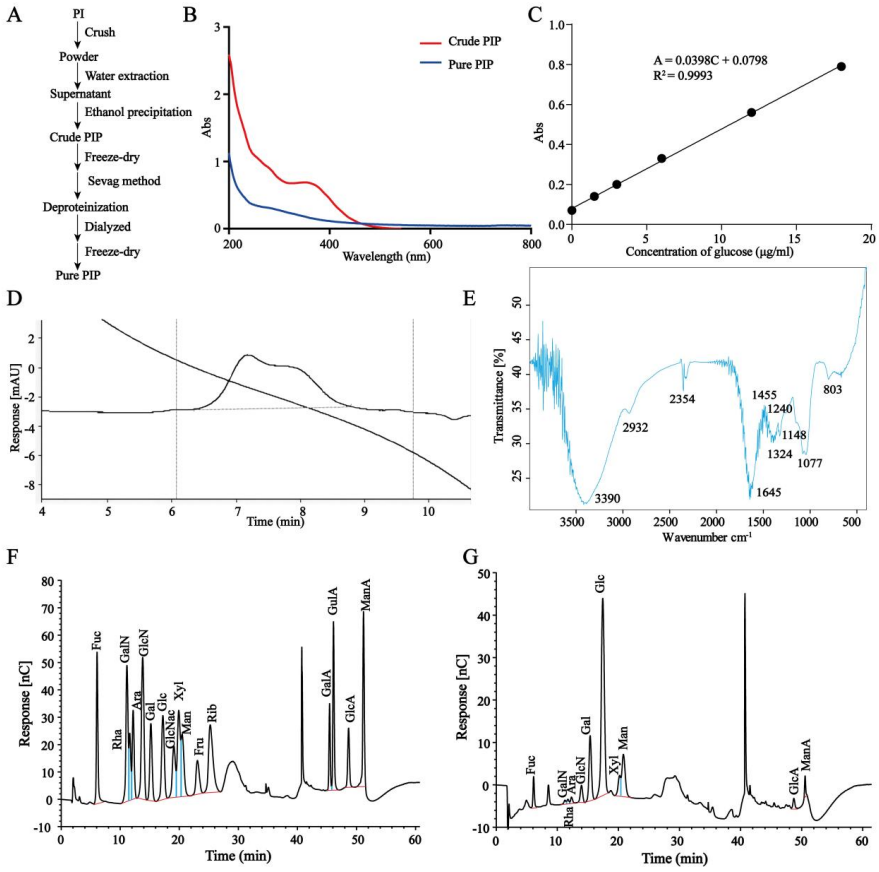

Figure 1 The characteristic of PIP (Adopted from Jin et al., 2023)

Image caption: (A) PIP isolation and purification process; (B) Ultraviolet full wavelength scanning; (C) Standard curve of glucose by Sulfuric acid - phenol method; (D) GPC result of PIP; (E) FT-IR of PIP; Anion chromatograph result of control (F) and PIP (G) (Adopted from Jin et al., 2023)

Sanghuangporus polysaccharides have been shown to exhibit a variety of biological activities, including antioxidant, antitumor, immunomodulatory, hypoglycemic, and anti-inflammatory properties (Zhang et al., 2022). For instance, PIP-1 demonstrated potent antioxidant activities, effectively scavenging hydroxyl radicals and chelating ferrous metal ions. Furthermore, it exhibited inhibitory effects on the growth of cancer cells, including HT-29 and MCF-7 cells, indicating potential anticancer properties (Yuan et al., 2018). Another study found that polysaccharides from *Sanghuangporus* induced mitochondrial apoptosis in hepatic carcinoma cells by enhancing reactive oxygen species-mediated AKT/p53 signaling pathways, highlighting their potential in cancer therapy (Jin et al., 2023). *Sanghuangporus* polysaccharides also possess immune-enhancing activities by activating Toll-like receptor 4 (TLR4)-mediated signaling pathways in macrophages, thereby showing promise as an immune adjuvant (Wang et al., 2019). Additionally, polysaccharides from *Sanghuangporus* have been reported to modulate gut microbiota and alleviate hyperglycemia in diabetic mice, indicating potential benefits for metabolic health (Ni et al., 2023). Studies indicate that polysaccharide peptides from *Sanghuangporus* spp. exert anti-inflammatory effects through multiple mechanisms, including regulation of inflammatory cytokine expression, inhibition of oxidative stress, and improvement of colon tissue damage (Zuo et al., 2021).

2.2 Triterpenoids

Triterpenoids are another group of bioactive components found in *Sanghuangporus* spp. They are known for their complex chemical structures, often featuring various functional groups such as hydroxyl, carbonyl, and carboxyl groups (Table 1). Research has identified several 22-hydroxylanostane triterpenoids from the fruiting bodies of *Sanghuangporus* (Figure 2), which possess unique structures and potential biological activities (Li et al., 2021). Additionally, igniarine, a tirucallane-type triterpenoid, along with other known triterpenoids like meshimakobnol A and B, ergosterol, and ergosterol peroxide, have been isolated from *Sanghuangporus* spp. These compounds have demonstrated various biological activities, including cytotoxicity against certain tumor cell lines (Thanh et al., 2018).

Table 1 Triterpenes in Fa from *Sanghuangporus* sanghuang (Adopted from Liu et al., 2024)

No.	Compound	m/z	tR(s)	Accuracy (×10^6)	Lon mode
1	Glycyrrhetinic acid	453.320 4	768.7	2.51	$[M+H-H_2O]^+$
2	Obaku none	437.191 7	802.1	0.15	$[M+H-H_2O]^+$
3	Ursolic acid	439.342 3	809.2	4.05	$[M+H-H_2O]^+$
4	Euphorbol	427.353 8	918.1	2.70	$[M+H]^+$
5	4.25-Dihydroxylanosterol in Dianzhi Agraria	429.401 6	931.2	1.74	$[M+H]^+$
6	Soyasaponin	459.383 6	862.1	0.71	$[M+H]^+$
7	Lanosterol	425.267 2	806.5	2.79	$[M-H]^-$
8	Maslinic acid	471.346 9	941.0	1.97	$[M-H]^-$

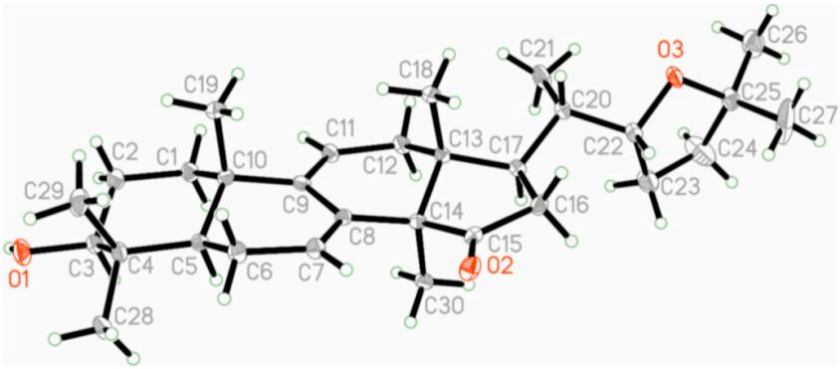

Figure 2 22-X-ray crystal structure of hydroxylanoane triterpenoids (Adapted from Li et al., 2021)

Triterpenoids from *Sanghuangporus* spp. have been shown to exhibit a range of pharmacological activities. Cardioprotective effects have been observed in some 22-hydroxylanostane triterpenoids, which were found to protect against oxygen-glucose deprivation/reoxygenation injury in H9c2 cells, suggesting potential benefits for cardiovascular health (Li et al., 2021).In addition, triterpenoids have been reported to exhibit anticancer, antioxidant, and anti-inflammatory activities. For example, *Sanghuangporus* triterpenoids have shown inhibitory

effects on human colon cancer cell line HT-29 and human prostate cancer cell line PC3 (Kim et al., 2020). They also possess antioxidant activity (Zhou et al., 2022a), enhancing the overall therapeutic potential of *Sanghuangporus* in various chronic diseases.

2.3 Other bioactive components

Sanghuangporus not only contains abundant polysaccharides and triterpenoids but also a variety of other bioactive components, such as phenolics, flavonoids, and sterols (Figure 3). In particular, flavonoids are widely recognized for their remarkable antioxidant properties and potential health benefits. Several phenolic compounds, including protocatechuic aldehyde, syringic acid, phelligridimer A, and inoscavin A, have been identified in *Sanghuangporus* (Li et al., 2022). These flavonoids and other polyphenols collectively contribute to the antioxidant, anti-inflammatory, and anticancer properties of *Sanghuangporus*.

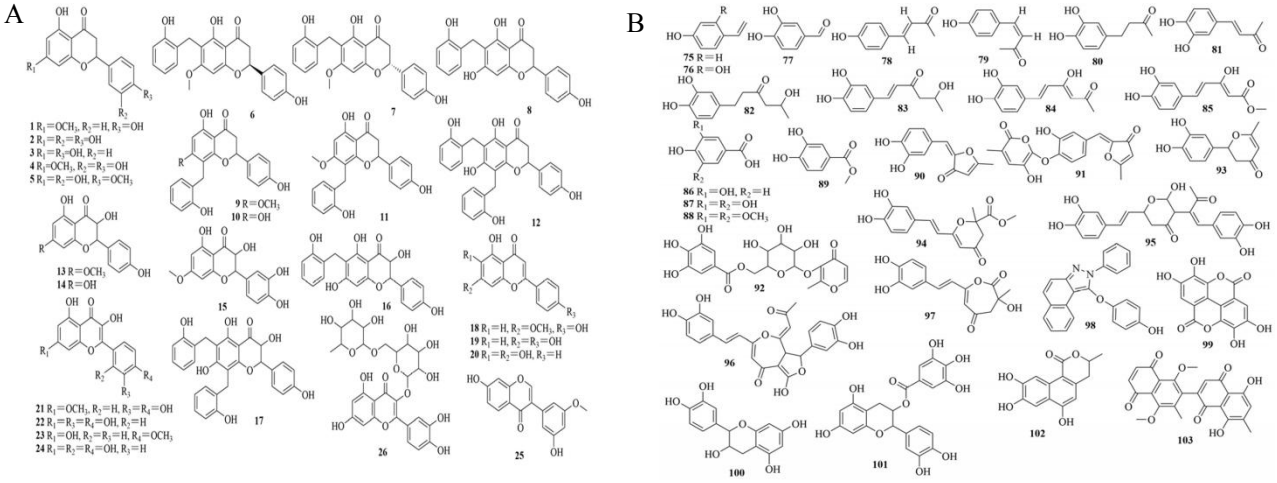

Figure 3 Chemical structures of flavonoids and other phenolic compounds in *Phellinus linteus* (Adopted from Peng et al., 2023)
Image caption: (A) Flavonoids; (B) Other phenolic compounds (Adopted from Peng et al., 2023)

The presence of phenols and flavonoids enhances the pharmacological profile of *Sanghuangporus* by providing additional mechanisms for disease prevention and treatment. These compounds have been shown to inhibit inflammatory responses and provide protective effects against oxidative stress (Dong, 2024). Flavonoids from *Sanghuangporus* have demonstrated immune-enhancing activities, stimulating the production of interleukin (IL)-2, IL-6, and interferon (IFN)-γ in immune cells while inhibiting tumor necrosis factor (TNF)-α expression (Zhu et al., 2023). These multifaceted actions of minor constituents, alongside the major components like polysaccharides and triterpenoids, make *Sanghuangporus* a promising candidate for managing various chronic diseases.

3 Pharmacological Effects of *Sanghuangporus* Extract

3.1 Antioxidant properties

Sanghuangporus exhibits potent antioxidant properties primarily through free radical scavenging activities (Krstanoski et al., 2023). Its antioxidant activity is attributed to the presence of bioactive components such as polysaccharides, flavonoids, and phenolic compounds (Mu et al., 2021). These components have been shown to neutralize free radicals, thus preventing oxidative damage to cells. In a study investigating the antioxidative effect of *Sanghuangporus* on RAW 264.7 macrophage cells, *Sanghuangporus* demonstrated a dose-dependent increase in DPPH radical scavenging activity, indicating its strong antioxidant capacity (Kim et al., 2019).

In vitro studies have shown that *Sanghuangporus* extracts possess significant antioxidant activity by inhibiting lipid peroxidation and enhancing cellular antioxidant enzyme activities. In a study involving fortified yogurt with *Sanghuangporus* extracts, *Sanghuangporus* demonstrated substantial antioxidant activity in vitro through its high DPPH inhibition rate. In an antioxidant study on nematodes, it was demonstrated that *Sanghuangporus* extract promotes antioxidant effects by reducing ROS accumulation, upregulating the expression of antioxidant-related genes, enhancing antioxidant capacity, and influencing metabolite levels (Dong et al., 2023).

Due to its antioxidative properties, *Sanghuangporus* has potential therapeutic implications for diseases associated with oxidative stress, such as cardiovascular diseases, cancer, and neurodegenerative disorders. By scavenging free radicals and reducing oxidative damage, *Sanghuangporus* may help in mitigating the progression of these conditions.

3.2 Anti-tumor and anti-cancer effects

Sanghuangporus exhibits anti-tumor and anti-cancer effects through multiple mechanisms, including the induction of apoptosis, inhibition of cell proliferation, and suppression of metastasis. For instance, *Sanghuangporus* polysaccharides have been shown to induce mitochondrial apoptosis in hepatic carcinoma cells by enhancing reactive oxygen species-mediated AKT/p53 signaling pathways (Jin et al., 2023). Another study found that the total ethanol extract of *Sanghuangporus* caused apoptosis in gastric cancer SGC-7901 cells through a mitochondria-dependent pathway, indicating its potential as a natural anti-cancer agent (Wang et al., 2018).

Research has demonstrated that *Sanghuangporus* exhibits cytotoxicity against various cancer cell lines, including hepatic carcinoma, gastric cancer, and colon cancer. A combined phytochemistry and network pharmacology approach revealed that *Sanghuangporus* possesses potential antitumor effective substances that induce apoptosis in colon cancer cells (Dong et al., 2019). Another study revealed that *Sanghuangporus* polysaccharides inhibit the growth and development of human SW480 colon cancer cells, leading to increased apoptosis in the sub-G1 and G2/M phases (Figure 4) (Li et al., 2004; Li et al., 2023). Polysaccharides isolated by Mei et al. (2015) (125-1,000 μg/mL) were found to significantly suppress SW480 cell proliferation, reduce the expression of β-catenin and cyclin D1 (downstream regulatory genes of the β-catenin signaling pathway), and inhibit the transcriptional activity of TCF and LEF, thereby suppressing tumor growth. Given its anti-tumor properties and low toxicity, *Sanghuangporus* may be considered as an adjunct therapy in combination with conventional cancer treatments to enhance efficacy and reduce side effects.

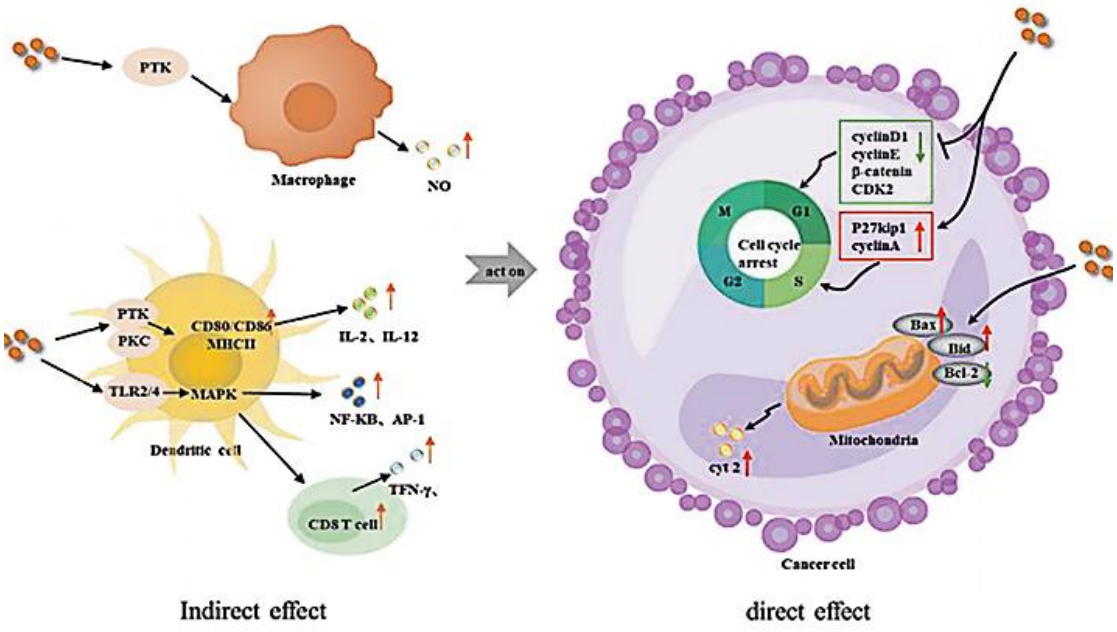

Figure 4 Potential Antitumor Mechanisms of *Phellinus linteus* (Adopted from Li et al., 2023)

3.3 Immunomodulatory effects

Sanghuangporus modulates the immune system by enhancing the activity of immune cells, such as macrophages, and regulating cytokine production. Polysaccharides and flavonoids from *Sanghuangporus* have been shown to stimulate the expression and secretion of interleukin (IL)-2, IL-6, and interferon (IFN)-γ in immune cells while inhibiting tumor necrosis factor (TNF)-α expression (Zhu et al., 2023).

Sanghuangporus extract has been found to enhance T- and B-lymphocyte proliferation and natural killer (NK) cell activity, improving immune response in immunosuppressed conditions (Figure 5). Additionally, *Sanghuangporus* has been observed to modulate cytokine levels, contributing to its role in immune enhancement. Due to its immunomodulatory properties, *Sanghuangporus* shows potential in the management of immune-related diseases, including autoimmune disorders and conditions that require immune system support.

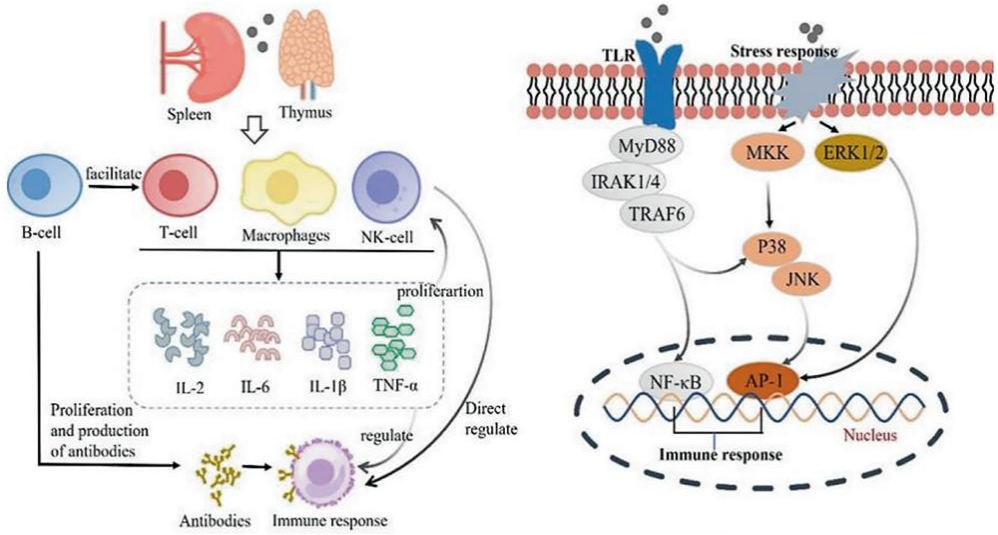

Figure 5 Potential immunomodulatory mechanisms of *Phellinus linteus* (Adopted from Li et al., 2023)

3.4 Anti-inflammatory effects

Sanghuangporus exerts anti-inflammatory effects by inhibiting the nuclear factor-kappa B (NF-κB) signaling pathway, thereby reducing the production of pro-inflammatory cytokines. A study investigating *Sanghuangporus*'s anti-inflammatory activity demonstrated that *Sanghuangporus* extract significantly decreased the expression of COX-2, iNOS, IL-1β, IL-6, and TNF-α in RAW 264.7 macrophage cells (Kim et al., 2019).

The anti-inflammatory properties of Sanghuangporus suggest its potential application in managing inflammatory diseases such as colitis, arthritis, and other inflammatory conditions. For instance, *Sanghuangporus* was shown to ameliorate dextran sodium sulfate-induced colitis in mice by reducing inflammatory markers (Sun et al., 2018).

3.5 Hepatoprotective effects

Sanghuangporus has demonstrated hepatoprotective effects by reducing liver enzymes and improving hepatic steatosis and inflammation. It modulates key metabolic pathways and targets such as the farnesol X receptor (FXR), providing a protective effect against chronic ethanol-induced liver injury (Dong et al., 2020). *Sanghuangporus* was found to significantly reduce serum biomarkers such as ALT, AST, triglycerides, and total bile acids, indicating its role in ameliorating liver damage and enhancing liver function.

3.6 Antidiabetic effects

Sanghuangporus possesses antidiabetic properties, as it has been shown to improve glucose tolerance, reduce hyperglycemia, and normalize insulin levels. Its effects are partly due to the activation of GLUT4 translocation via the modulation of the AMP-activated protein kinase (AMPK) pathway (Zheng et al., 2018). Studies involving KK-Ay mice with spontaneous type 2 diabetes mellitus showed that *Sanghuangporus* significantly lowered fasting blood glucose levels and improved lipid profiles, suggesting its potential in managing diabetes and related metabolic disorders.

3.7 Cardiovascular protective effects

Sanghuangporus has shown vasodilatory effects by influencing vascular smooth muscle cells and potassium channels. In studies using rat mesenteric arteries, *Sanghuangporus* extracts induced vasodilation in a dose-dependent manner, indicating their potential for managing hypertension and cardiovascular diseases (Kwon

et al., 2020). By improving blood pressure regulation and exerting antioxidant and anti-inflammatory effects, *Sanghuangporus* may contribute to the prevention of atherosclerosis and other cardiovascular conditions.

4 Application in the Prevention and Treatment of Chronic Diseases

4.1 Cancer prevention and therapy

Sanghuangporus has been traditionally used in East Asia as an adjuvant treatment for cancer due to its antitumor properties. Studies have demonstrated that *Sanghuangporus* extracts can induce apoptosis and inhibit the proliferation of various cancer cell lines. For example, the total ethanol extract of *Sanghuangporus* has been shown to induce apoptosis in gastric cancer cells (SGC-7901) through a mitochondria-dependent pathway (Wang et al., 2018). Similarly, *Sanghuangporus* polysaccharides have been found to induce mitochondrial apoptosis in hepatic carcinoma cells by enhancing reactive oxygen species-mediated AKT/p53 signaling pathways (Jin et al., 2023).

Sanghuangporus extracts have been proposed as potential adjuncts to conventional cancer therapies. Their ability to induce apoptosis and enhance immune responses suggests that they could be used to enhance the efficacy of chemotherapy and radiotherapy while potentially reducing side effects. A combined phytochemistry and network pharmacology approach revealed that *Sanghuangporus* contains active substances that may enhance the effects of conventional cancer treatments by inducing apoptosis through various pathways (Dong et al., 2019).

4.2 Diabetes management

Sanghuangporus exhibits antidiabetic properties by improving insulin sensitivity and glucose regulation. A polyphenol-rich extract from *Sanghuangporus* was shown to stimulate GLUT4 translocation and increase glucose uptake in vitro. This extract also lowered fasting blood glucose levels in KK-Ay mice, indicating its potential for managing type 2 diabetes (Figure 6). Mechanistic studies revealed that *Sanghuangporus* enhances the expression of p-AMPKα and GLUT4, suggesting that its antidiabetic effects are partly due to the activation of the AMPK pathway (Zheng et al., 2018).

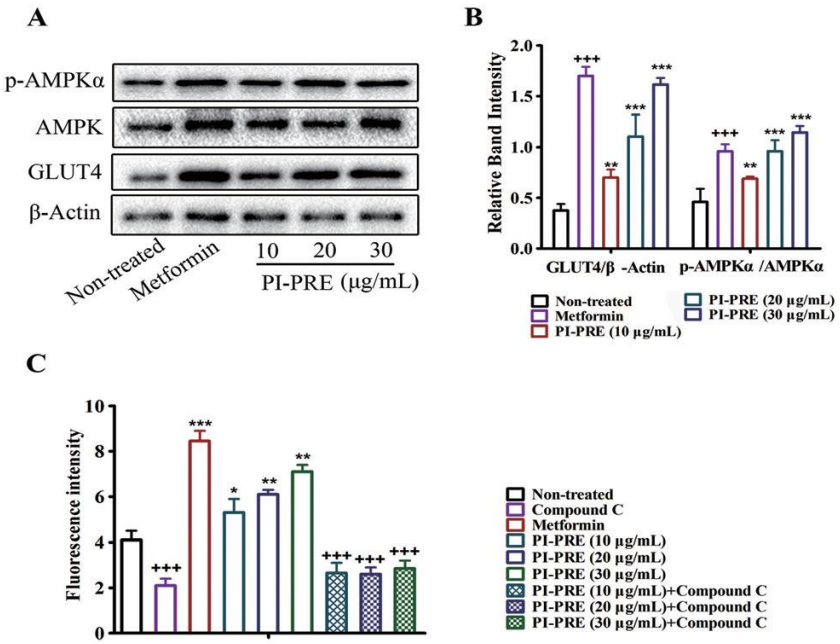

Figure 6 Anti-diabetic effects of *Phellinus igniarius* Polyphenol-Rich Extract (PI-PRE) in diabetic KK-Ay mice model (Adapted from Zheng et al., 2018)

Image caption: (A) Shows the effect of PI-PRE on reducing body weight in KK-Ay diabetic mice; (B) Illustrates the impact of PI-PRE on food intake, indicating no significant difference between the PI-PRE treated group and the control group; (C) Demonstrates the effectiveness of PI-PRE in lowering fasting blood glucose levels; (D) Depicts the results of the oral glucose tolerance test (OGTT), where both the PI-PRE and metformin-treated groups showed significant improvements in glucose levels during the test; These findings suggest that PI-PRE effectively alleviates diabetic symptoms, including reducing blood glucose levels and body weight, while improving glucose tolerance (Adapted from Zheng et al., 2018)

Sanghuangporus polysaccharides have been shown to modulate gut microbiota and ameliorate hyperglycemia in diabetic mice. By improving gut dysbiosis, *Sanghuangporus* may help prevent complications associated with diabetes, such as inflammation and tissue injuries. Supplementation with *Sanghuangporus* has been found to improve insulin sensitivity and antioxidative capacity in diabetic mice, suggesting its potential in preventing the progression of diabetes and its related complications (Ni et al., 2023).

4.3 Liver diseases

Sanghuangporus has shown hepatoprotective effects against liver injury. A study using a chronic ethanol-induced liver injury model in mice found that *Sanghuangporus* decoction significantly reduced the levels of serum biomarkers, such as ALT and AST, and improved hepatic steatosis and inflammation. *Sanghuangporus* was found to regulate key metabolic pathways, including biosynthesis of unsaturated fatty acids and primary bile acid biosynthesis, providing a protective effect against liver injury (Dong et al., 2020).

Sanghuangporus not only protects the liver from damage but also shows potential in preventing liver fibrosis. Its ability to modulate lipid metabolism and reduce inflammation suggests that *Sanghuangporus* could be an effective natural agent in improving liver function and preventing the progression of liver diseases.

4.4 Cardiovascular disorders

Sanghuangporus has demonstrated effects on cardiovascular health by influencing factors such as lipid metabolism, blood pressure, and endothelial function. *Sanghuangporus* extracts have shown vasodilatory effects in rat mesenteric arteries, indicating their potential role in managing hypertension. The extract induces vasodilation in a dose-dependent manner, which is associated with the activation of calcium-activated potassium channels in vascular smooth muscle cells (Kwon et al., 2020).

By promoting vasodilation and improving blood pressure regulation, *Sanghuangporus* may help in the prevention and management of cardiovascular diseases, such as hypertension and atherosclerosis. Its antioxidative and anti-inflammatory properties further contribute to its protective effects on the cardiovascular system.

4.5 Other chronic diseases

While research on *Sanghuangporus*'s role in neurodegenerative diseases is still emerging, its known antioxidant and anti-inflammatory properties suggest potential benefits in preventing or slowing the progression of conditions like Alzheimer's and Parkinson's disease. Additionally, *Sanghuangporus* has been reported to modulate the immune response and reduce inflammation in various chronic conditions. In a study on hyperuricemia and acute gouty arthritis, *Sanghuangporus* exhibited significant anti-inflammatory activity by down-regulating the secretions of IL-1β and IL-6, indicating its potential in managing inflammatory and autoimmune diseases (Li et al., 2022).

5 Clinical Research on Safety and Efficacy

5.1 Overview of clinical trials and human studies

Several clinical trials and pilot studies have investigated the safety and efficacy of *Sanghuangporus* species, in various health conditions. Most studies have focused on the related species *Sanghuangporus* due to its similar pharmacological profile. One clinical study evaluated the efficacy and safety of *Sanghuangporus* extract for treating knee osteoarthritis (KOA) in 24 patients. The study demonstrated that the extract significantly improved symptoms of KOA without any adverse events (Ryu et al., 2022). Another randomized, double-blind, placebo-controlled pilot trial assessed the efficacy of *Sanghuangporus* extract in enhancing immunity. It found that the extract improved natural killer cell activity and interleukin-6 levels, indicating an immune-enhancing effect (Ku and Kang, 2022).

5.2 Safety profile of *Sanghuangporus*

Toxicity studies on *Sanghuangporus* extracts have shown a favorable safety profile. In the study on KOA, no adverse events related to *Sanghuangporus* were reported, and there were no abnormal hematological or physical findings, suggesting the extract is safe for consumption at the administered doses (Ryu et al., 2022). Another

study evaluated the effects of *Sanghuangporus* ethanol extract on serum uric acid metabolism and the gut microbiome in rats, concluding that the extract did not cause toxicity in the studied dosages (Li et al., 2021). These findings suggest that *Sanghuangporus* and its related species are generally safe. However, further pharmacological and toxicological studies on *Sanghuangporus* and its extracts are necessary to provide a scientific basis for more effective research, development, and utilization of this functional mushroom as a food resource.

5.3 Efficacy in clinical settings

Clinical trials have demonstrated the efficacy of *Sanghuangporus* extracts in managing specific conditions. In the study on KOA, the group receiving 1,500 mg/day of *Sanghuangporus* extract showed significant improvement in symptoms compared to the placebo group (Ryu et al., 2022). Similarly, the randomized trial on immunity enhancement revealed that participants who received *Sanghuangporus* extract showed an increase in natural killer cell activity, indicating improved immune function (Ku and Kang, 2022).

5.4 Challenges and considerations for clinical application

While current research points to the therapeutic potential of *Sanghuangporus* extracts, challenges remain in their clinical application. First, the variability in bioactive compound content due to differences in extraction methods and sources can affect the consistency of clinical outcomes. Therefore, standardizing *Sanghuangporus* extracts is crucial for ensuring their safety and efficacy. Additionally, while existing studies on *Sanghuangporus* and related species indicate a favorable safety profile, larger-scale, long-term clinical trials are needed to establish safe dosage ranges, especially for chronic use. Another consideration is the potential for interactions with other medications, which warrants careful evaluation when *Sanghuangporus* is used as an adjunct therapy. Addressing these challenges is essential for the successful integration of *Sanghuangporus* extracts into modern therapeutic protocols.

6 Development into Functional Foods and Pharmaceuticals

6.1 Potential of *Sanghuangporus* as a dietary supplement or functional food

Sanghuangporus holds significant potential as a dietary supplement or functional food due to its diverse pharmacological properties, including antioxidant, anti-inflammatory, antitumor, immunomodulatory, and hepatoprotective effects. *Sanghuangporus*'s bioactive components, such as polysaccharides, triterpenoids, and flavonoids, can be incorporated into functional foods to promote health and prevent diseases. For instance, a recent study demonstrated the antioxidant properties of yogurt fortified with *Sanghuangporus* extracts, indicating that *Sanghuangporus* can be effectively incorporated into food products to enhance their nutritional value and health benefits. Moreover, *Sanghuangporus* can be used as a dietary supplement in the form of capsules, powders, or extracts to provide a convenient way for consumers to access its health-promoting properties. Its natural origin and long history of use in traditional medicine further support its potential acceptance as a functional food or dietary supplement.

6.2 Strategies for developing *Sanghuangporus*-based pharmaceuticals

Developing *Sanghuangporus*-based pharmaceuticals requires a multidisciplinary approach to harness its therapeutic potential effectively. The first step is to identify and isolate the bioactive compounds responsible for *Sanghuangporus*'s pharmacological activities. Advanced techniques such as high-performance liquid chromatography (HPLC), mass spectrometry, and nuclear magnetic resonance (NMR) spectroscopy can be employed to purify and characterize these compounds. For example, a study using ultrafiltration and liquid chromatography-mass spectrometry (LC-MS) identified several active compounds in *Sanghuangporus* with potential therapeutic effects (Wang et al., 2021). Following the identification of active constituents, in vitro and in vivo studies are crucial for understanding their mechanisms of action, pharmacokinetics, and pharmacodynamics.

To develop *Sanghuangporus*-based pharmaceuticals, formulating the extract into a suitable dosage form is essential, ensuring stability, bioavailability, and efficacy. Nanotechnology can be explored to enhance the bioavailability of poorly soluble *Sanghuangporus* compounds, while encapsulation techniques can protect the

bioactive compounds from degradation. Furthermore, clinical trials are necessary to evaluate the safety and efficacy of these pharmaceuticals in human populations. As seen in clinical trials involving *Sanghuangporus* extracts, standardized formulations can be tested in randomized, controlled studies to determine therapeutic dosages and effects (Ryu et al., 2022).

6.3 Regulatory and standardization challenges

One of the major challenges in developing *Sanghuangporus* into functional foods and pharmaceuticals is the lack of standardized extraction methods and quality control protocols. The bioactive compound content in *Sanghuangporus* extracts can vary significantly depending on factors such as the extraction method, solvent used, and source of the mushroom. Therefore, establishing standardized extraction and processing methods is crucial to ensure consistent quality, safety, and efficacy of *Sanghuangporus* products. Additionally, the regulatory requirements for dietary supplements and pharmaceuticals differ across countries, posing another challenge in bringing *Sanghuangporus*-based products to the market.

In many regions, dietary supplements are regulated less stringently than pharmaceuticals. However, for *Sanghuangporus* to be marketed as a dietary supplement or functional food, manufacturers must comply with safety, labeling, and health claims regulations. For pharmaceuticals, *Sanghuangporus* products must undergo rigorous clinical trials to demonstrate their safety and efficacy, followed by approval from regulatory agencies such as the U.S. Food and Drug Administration (FDA) or the European Medicines Agency (EMA). These regulatory hurdles necessitate a comprehensive understanding of local and international regulations to navigate the path to market successfully.

6.4 Market potential and consumer acceptance

The market potential for *Sanghuangporus*-based products is promising, given the growing consumer interest in natural health products and the increasing prevalence of chronic diseases. The global market for functional foods and dietary supplements has been expanding, driven by the demand for natural and preventive healthcare solutions. *Sanghuangporus*, with its array of health benefits, is well-positioned to capture a share of this market. Consumer acceptance of *Sanghuangporus* products is likely to be favorable, especially among those seeking natural remedies for health maintenance and disease prevention. Its historical use in traditional medicine and emerging scientific evidence of its health benefits can enhance consumer trust and appeal.

Effective marketing strategies are vital for consumer acceptance and market penetration of *Sanghuangporus* products. Educating consumers about the health benefits, safety, and scientific backing of Sanghuangporus can help build confidence and encourage usage. Collaboration with healthcare professionals to recommend *Sanghuangporus*-based supplements as part of a holistic health regimen can further boost consumer acceptance. Additionally, positioning *Sanghuangporus* products as part of a healthy lifestyle, alongside other functional foods and supplements, can attract health-conscious consumers. In addition, attention should be given to the application for unique *Sanghuangporus* brand trademarks, aiming to establish a brand owned by the nation. This effort will further accelerate the industrialization of *Sanghuangporus*, with the expectation of the emergence of a dedicated and trustworthy brand for consumers in the near future.

In summary, the development of *Sanghuangporus* into functional foods and pharmaceuticals presents a multifaceted opportunity. By addressing standardization and regulatory challenges and leveraging its therapeutic potential, *Sanghuangporus*-based products can be successfully integrated into the health and wellness market, offering consumers natural options for disease prevention and health promotion.

7 Limitations and Challenges

7.1 Current gaps in research

Sanghuangporus spp. is categorized as a minor agricultural product, with its large-scale commercialization developing relatively late. Its rapid development is constrained by limited wild resources, immature artificial cultivation techniques, insufficient efforts in the development of value-added products, and inadequate research into its medicinal mechanisms. Despite the promising pharmacological properties of *Sanghuangporus*, several

gaps in the current research limit its widespread application. Most existing studies on *Sanghuangporus* have been conducted in vitro or in animal models, with only a limited number of human clinical trials available to substantiate its efficacy and safety in treating chronic diseases. While these preclinical studies have provided valuable insights into the potential therapeutic effects of *Sanghuangporus*, they do not fully account for the complexities of human physiology and disease. There is a need for more well-designed, large-scale clinical trials to determine the effective dosages, long-term safety, and therapeutic outcomes of *Sanghuangporus* in humans. Additionally, while some studies have investigated the mechanisms underlying *Sanghuangporus*'s pharmacological activities, a comprehensive understanding of how *Sanghuangporus* interacts with cellular and molecular pathways in various disease states is still lacking (Ryu et al., 2022). This knowledge gap limits the ability to fully harness *Sanghuangporus*'s therapeutic potential and identify specific conditions for which it may be most beneficial.

7.2 Variability in *Sanghuangporus* extract composition and quality control issues

One of the significant challenges in developing *Sanghuangporus*-based products is the variability in the composition of *Sanghuangporus* extracts. The pharmacological activity of *Sanghuangporus* is largely attributed to its bioactive compounds, such as polysaccharides, triterpenoids, and flavonoids. However, the concentration and composition of these compounds can vary widely depending on factors such as the geographical origin of the fungus, growing conditions, part of the fungus used (e.g., fruiting body vs. mycelium), and extraction methods employed (Gao et al., 2017). This variability can lead to inconsistencies in the efficacy and safety of *Sanghuangporus* products. For instance, different extraction solvents and techniques can result in varying concentrations of active components, thereby affecting the biological activity of the final extract.

Standardization of *Sanghuangporus* extracts is crucial for ensuring quality control and consistent therapeutic outcomes. However, the lack of standardized protocols for the extraction and quantification of bioactive compounds poses a significant hurdle. Establishing quality control measures, such as defining the minimum content of key bioactive compounds and setting specifications for contaminant levels, is essential for the safe and effective use of *Sanghuangporus*-based products. These measures would not only ensure product consistency but also facilitate regulatory approval for the use of *Sanghuangporus* in clinical settings.

7.3 Challenges in translating preclinical findings to clinical practice

While preclinical studies have demonstrated the potential therapeutic effects of *Sanghuangporus* in various chronic diseases, translating these findings into clinical practice presents several challenges. First, the doses of *Sanghuangporus* used in preclinical studies often differ significantly from those that are feasible or safe for human consumption. Determining the optimal dosage for humans that is both effective and safe requires careful dose-escalation studies and clinical trials. Additionally, the bioavailability and pharmacokinetics of *Sanghuangporus*'s bioactive compounds in humans need to be thoroughly investigated. The absorption, distribution, metabolism, and excretion of these compounds can vary between humans and animal models, potentially leading to different therapeutic outcomes.

Furthermore, the complexity of chronic diseases in humans, which often involve multifactorial and individualized pathologies, poses a challenge for translating preclinical success into clinical efficacy. *Sanghuangporus*'s effects observed in isolated cell cultures or animal models may not fully capture the interactions and responses in human disease contexts. For example, the immune-modulating effects of *Sanghuangporus* demonstrated in vitro may differ in human patients with varying immune system status and comorbidities (Ku and Kang, 2022). To address these challenges, it is necessary to conduct comprehensive clinical studies that account for patient heterogeneity and evaluate the efficacy of *Sanghuangporus* in real-world settings.

In summary, while the pharmacological effects of *Sanghuangporus* are promising, several limitations and challenges must be addressed to facilitate its development into reliable therapeutic agents. Bridging the gaps in research, standardizing extract quality, and overcoming the challenges of clinical translation are essential steps toward realizing the full potential of *Sanghuangporus* in the prevention and treatment of chronic diseases.

8 Future Perspectives

8.1 Recommendations for future research

To fully harness the therapeutic potential of *Sanghuangporus*, future research must address current gaps and challenges. First, there is a need for more comprehensive clinical trials to evaluate the safety, efficacy, and optimal dosage of *Sanghuangporus* in humans. These studies should involve large sample sizes and diverse populations to ensure that the findings are generalizable. Specifically, randomized, double-blind, placebo-controlled trials should be conducted to confirm the benefits of *Sanghuangporus* in preventing and treating various chronic diseases, such as cancer, diabetes, liver diseases, and cardiovascular disorders (Ryu et al., 2022).

Additionally, further investigation into the mechanisms of action of *Sanghuangporus*'s bioactive compounds is essential. Understanding how these compounds interact with cellular pathways, immune modulation, and metabolic processes can help identify new therapeutic targets and enhance the efficacy of *Sanghuangporus*-based treatments. Advanced techniques like metabolomics, proteomics, and systems biology should be employed to explore these mechanisms at the molecular level. Moreover, research should focus on standardizing extraction methods to ensure the consistent quality of *Sanghuangporus* products, including identifying the specific bioactive components responsible for its pharmacological effects.

8.2 Prospects for integrating *Sanghuangporus* into modern healthcare

Based on the irreplaceable and unique medicinal value of *Sanghuangporus*, integrating it into the modern healthcare system, coupled with strong policy support in recent years—particularly in the field of complementary and alternative medicine—the *Sanghuangporus* industry is expected to develop even more rapidly in the future (Zhou et al., 2023). As patients increasingly seek natural remedies with fewer side effects than conventional drugs, *Sanghuangporus* can be positioned as a safe and effective adjunct therapy for chronic diseases. To facilitate this integration, healthcare professionals need to be educated about *Sanghuangporus*'s pharmacological properties, potential benefits, and safe usage guidelines. Incorporating *Sanghuangporus* into evidence-based practice will require robust clinical evidence, standardized extracts, and clear dosing recommendations.

Sanghuangporus can also play a role in preventive healthcare. Its antioxidant, anti-inflammatory, and immunomodulatory properties suggest that *Sanghuangporus* could be used to support overall health and reduce the risk of developing chronic diseases. Functional foods and dietary supplements containing standardized *Sanghuangporus* extracts could be promoted as part of a healthy lifestyle regimen. Additionally, *Sanghuangporus* could be used in integrative oncology as a complementary treatment to support cancer patients, potentially improving their quality of life by enhancing immune function and mitigating the side effects of conventional therapies (Ku and Kang, 2022).

8.3 Opportunities for developing novel therapeutic agents from *Sanghuangporus*

The diverse bioactive compounds found in *Sanghuangporus* present opportunities for developing novel therapeutic agents. Polysaccharides, triterpenoids, and flavonoids isolated from *Sanghuangporus* have demonstrated significant pharmacological activities, including antitumor, antioxidant, and hepatoprotective effects. By isolating and modifying these compounds, researchers can develop new drugs with targeted mechanisms of action. For example, *Sanghuangporus*-derived compounds could be optimized for enhanced anticancer activity, offering a new class of chemotherapeutic agents with potentially fewer side effects than conventional chemotherapy.

Furthermore, *Sanghuangporus*'s potential in the field of immunotherapy is noteworthy. Its immunomodulatory effects, which include enhancing natural killer cell activity and modulating cytokine production, could be harnessed to develop immune-enhancing therapies, particularly for patients with weakened immune systems or those undergoing treatments that suppress immunity. There is also the potential to use *Sanghuangporus* extracts or isolated compounds as adjuvants in vaccine formulations to enhance immune responses.

In addition to pharmaceutical applications, *Sanghuangporus* can be explored in the development of functional foods aimed at specific health conditions. For example, *Sanghuangporus*-enriched foods could be developed for

individuals with metabolic disorders, leveraging its antidiabetic and lipid-regulating effects to manage blood sugar levels and improve metabolic health. The use of advanced delivery systems, such as nanoparticles and liposomes, can further enhance the bioavailability and targeted delivery of *Sanghuangporus* bioactives, increasing their therapeutic efficacy.

In summary, the future of *Sanghuangporus* research and application holds significant promise. Through continued scientific exploration and innovation, *Sanghuangporus* can be integrated into modern healthcare as a valuable resource for both preventive and therapeutic strategies, offering new avenues for managing chronic diseases and promoting overall health.

9 Concluding Remarks

Sanghuangporus is a medicinal mushroom with a rich history in traditional medicine and an expanding body of scientific evidence supporting its diverse pharmacological effects. This review has highlighted the multifaceted therapeutic properties of *Sanghuangporus*, including its antioxidant, anti-tumor, anti-inflammatory, immunomodulatory, hepatoprotective, antidiabetic, and cardiovascular protective effects. These effects are largely attributed to the bioactive compounds found in *Sanghuangporus*, such as polysaccharides, triterpenoids, and flavonoids. Preclinical studies have shown that these compounds can modulate cellular and molecular pathways involved in chronic disease progression, offering a promising natural approach to disease management. However, to fully understand the medicinal value of *Sanghuangporus*, future research needs to delve deeper into its chemical composition. This involves detailed botanical identification of *Sanghuangporus* and the use of modern extraction and separation techniques to identify and purify more bioactive compounds. This process requires not only interdisciplinary collaboration but also the application of advanced analytical technologies, such as high-performance liquid chromatography (HPLC), mass spectrometry (MS), and nuclear magnetic resonance (NMR), to ensure the accuracy and comprehensiveness of the research.

Sanghuangporus's potential in preventing and treating various chronic diseases is particularly noteworthy. Its antioxidant and anti-inflammatory properties make it a strong candidate for managing oxidative stress-related conditions, such as cardiovascular diseases and neurodegenerative disorders. The antitumor and immunomodulatory effects of *Sanghuangporus* suggest its possible use as an adjunct therapy in cancer treatment, either to enhance the efficacy of conventional treatments or to mitigate their side effects. Additionally, *Sanghuangporus*'s hepatoprotective and antidiabetic activities highlight its potential role in managing liver diseases and metabolic disorders, providing a natural means to improve liver function and regulate blood glucose levels.

Although these findings are encouraging, it remains necessary to develop new, feasible, cost-effective, and efficient strategies, along with establishing corresponding databases, to optimize the cultivation and preparation of each type of *Sanghuangporus*. This will facilitate standardization, industrialization, and commercialization. While preclinical studies have provided valuable insights into its mechanisms of action and potential therapeutic benefits, more extensive clinical trials are needed to establish its efficacy, safety, and optimal dosing in humans. Addressing the challenges related to standardization and quality control of *Sanghuangporus* extracts will be crucial for its development into reliable therapeutic agents.

In conclusion, *Sanghuangporus* offers a promising avenue for future therapeutic development. Its broad spectrum of pharmacological activities and low toxicity make it an attractive candidate for integration into modern healthcare as a natural treatment or preventive measure for various chronic diseases. However, there remains a significant amount of research to be conducted on *Sanghuangporus* and its key active component, polysaccharides. As research progresses, *Sanghuangporus* has the potential to be developed into functional foods, dietary supplements, and novel pharmaceuticals, contributing to a holistic approach to health and wellness. The journey from traditional use to modern therapeutic application underscores the importance of *Sanghuangporus* in the evolving landscape of natural medicine.

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