Journal of Clinical and Nursing Research, 2026, Volume 10, Issue 6
http://ojs.bbwpublisher.com/index.php/JCNR
Online ISSN: 2208-3693
Print ISSN: 2208-3685

Effects of Different Extraction Processes on the Anti-Tumor Activity of *Phellinus linteus*

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Abstract: *Phellinus linteus* is a traditional medicinal fungus in China, mainly including four common species with a long medicinal history. Modern pharmacology has confirmed that *Phellinus linteus* exhibits significant anti-tumor activity, and its core active components include polysaccharides, polyphenols, and terpenoids. The extraction process of *Phellinus linteus* greatly affects the dissolution, structural integrity, and anti-tumor activity of its active components. Different processes may lead to significant differences in the activity of extracts due to variations in their principles and operations. In view of this, this paper analyzes the effects of different extraction processes on the anti-tumor activity of *Phellinus linteus*, and proposes some prospects for optimization directions and application prospects, so as to provide references for the extraction of active components from *Phellinus linteus*.

Keywords: *Phellinus linteus*; Extraction process; Anti-tumor activity; Influence

Online publication: Jun 30, 2026

1. Introduction

Malignant tumors are a major global public health issue. The incidence and mortality rates of liver cancer, lung cancer, and other tumors remain high. Traditional radiotherapy and chemotherapy have significant side effects, so there is an urgent need for natural and efficient anti-tumor drugs and adjuvant treatment methods. The anti-tumor activity of *Phellinus linteus* is closely related to the extraction efficiency and structural integrity of its active components. Different extraction processes (such as water extraction and alcohol precipitation, ultrasonic-assisted extraction, microwave-assisted extraction, and enzymatic hydrolysis) significantly affect the yield, purity, and biological activity of active components [1]. Current research on *Phellinus linteus* mainly focuses on the activity verification of single components, lacking a systematic comparison of the inhibitory effects of different processes on multiple tumors. As the core medicinal part, the process optimization and clinical transformation research of fruiting bodies still need to be deepened. Combined with the 2026 tumor intervention goals, this study takes malignant tumors such as liver cancer and lung cancer as research objects, conducts comparative research on different extraction processes of *Phellinus* *linteus* fruiting bodies, analyzes the effects of process parameters on the content of active components and anti-tumor activity, screens the optimal extraction scheme and optimizes the purification process, clarifies the inhibitory effect of *Phellinus linteus* on specific tumors, provides experimental basis for the development of anti-tumor preparations of *Phellinus linteus* and their application in clinical adjuvant therapy, and also lays a foundation for high-level academic research and achievement transformation [2].

2. Mechanism of anti-tumor activity of *Phellinus linteus*

The anti-tumor mechanism of Phellinus linteus is relatively complex, mainly achieved through inhibiting tumor cell growth, inducing apoptosis, and regulating the body's immunity. Different active components have different mechanisms of action, and there is a significant synergistic effect between them. Phellinus linteus polysaccharides are the core anti-tumor components, which can directly induce tumor cell apoptosis, arrest the cell cycle, and enhance immune surveillance function by regulating the body's immunity. Polysaccharides from different varieties of Phellinus linteus can basically exert good anti-tumor and immune regulatory effects[3]. Phellinus linteus polyphenols scavenge free radicals in the body through antioxidant activity, reduce DNA damage, and effectively inhibit the proliferation and differentiation of tumor cells. At the same time, polyphenols can regulate tumor signaling pathways, thereby greatly reducing the invasive and metastatic ability of tumors, making them extremely important anti-tumor substances in *Phellinus linteus*. *Phellinus linteus* terpenoids (mainly triterpenoids) can also significantly inhibit tumor cell proliferation, induce tumor cell apoptosis, and inhibit angiogenesis. Some active components have strong inhibitory effects on tumor cells with low toxicity to normal cells [4].

3. Effects of different extraction processes on the anti-tumor activity of *Phellinus linteus*

3.1. Traditional extraction processes

3.1.1. Hot water extraction method

The hot water extraction method is a traditional method for extracting active components from *Phellinus linteus*. It mainly uses water as a solvent and then breaks cell walls by heating to better promote the dissolution of water-soluble polysaccharides. It has the advantages of simple operation, low cost, and no residual organic solvents, making it very suitable for large-scale industrial production. It is currently widely used for the preliminary extraction of *Phellinus linteus* polysaccharides. In the hot water extraction method, parameters such as extraction temperature, time, and solid-liquid ratio greatly affect the dissolution amount and activity of polysaccharides. Excessively high temperature is likely to cause polysaccharide degradation, while excessively low temperature leads to insufficient dissolution. Only under appropriate conditions can the structure and activity of polysaccharides be well retained [5]. The shortcomings of this process are low extraction efficiency: hot water is difficult to penetrate cell walls, failing some active components to dissolve; there are many dissolved impurities; high temperature can also cause pyrolysis, leading to low polysaccharide yield, which is difficult to meet the demand for high-activity extracts.

3.1.2. Ethanol extraction method

The ethanol extraction method is mainly used for extracting fat-soluble components *from Phellinus linteus*. Workers can use the polarity of ethanol to destroy the lipid bilayer of cells, thereby promoting the dissolution of components such as polyphenols and terpenoids. At the same time, it can effectively inhibit the growth of microorganisms, with the advantages of simple operation and strong selectivity. In the ethanol extraction method, the concentration of ethanol is a crucial parameter. Excessively high concentration causes cell dehydration, which is not conducive to component dissolution; excessively low concentration easily leads to insufficient dissolution of fat-soluble components. Only under appropriate conditions can fat-soluble extracts with strong activity be obtained [6]. The advantages of the ethanol extraction method are high purity of extracts and easy recovery of ethanol. The disadvantages are that ethanol itself has certain toxicity, so the entire operation process needs strict control; this method has a poor extraction effect on some water-soluble components; prolonged high temperature can cause oxidative degradation of fat-soluble components, affecting extraction efficiency.

3.2. Novel assisted extraction processes

3.2.1. Ultrasonic-assisted extraction method

In the extraction of *Phellinus linteus*, the ultrasonic-assisted extraction method is a novel extraction technology that mainly uses the mechanical vibration and cavitation effect of ultrasonic waves to destroy cell structures, thereby realizing the dissolution of active components. As a new green process, it has the advantages of high extraction efficiency, short time, and good retention of active components, and has been widely used in the research on the extraction of active components from *Phellinus linteus*. In the ultrasonic-assisted extraction method, ultrasonic power and time are crucial parameters. Excessively low power makes it difficult to break cell walls, while excessively high-power causes component degradation. Only under appropriate conditions can efficiency be guaranteed [7]. The ultrasonic-assisted extraction method also has a significant extraction effect on fat-soluble components. The ultrasonic-assisted enzymatic method can achieve very good extraction efficiency, and the overall yield is much higher than other traditional auxiliary methods. The shortcomings of the ultrasonic-assisted extraction method are that excessively high power or prolonged time can degrade active components; during large-scale extraction, uneven extraction may occur; the overall equipment investment cost is relatively high [8].

3.2.2. Microwave-assisted extraction method

The microwave-assisted extraction method is an extraction technology that uses the thermal and non-thermal effects of microwaves to destroy cell structures, promote the dissolution of active components, and has the advantages of high extraction efficiency and low energy consumption. It has become an important research hotspot in recent years. In microwave-assisted extraction, microwave power and time are also important parameters. Excessively low microwave power is likely to cause uneven heating and insufficient dissolution; excessively high microwave power leads to local high temperatures that damage components. Only under appropriate conditions can the extraction time be greatly shortened, the dissolution amount of polysaccharides be increased, and the active components extracted by this method are better than those by traditional methods [9]. The advantages of the microwave-assisted extraction method are high efficiency, energy saving, and good retention of active components, making it very suitable for industrial production. The disadvantages are that uneven microwave heating may cause damage to some components; special equipment is required, which invisibly increases investment; the extraction effect on some high-viscosity systems is not ideal.

3.2.3. Enzymatic hydrolysis-assisted extraction method

The enzymatic hydrolysis-assisted extraction method mainly uses biological enzymes such as cellulase and pectinase to decompose cell wall components, thereby destroying cell structures and enabling the dissolution of active components. This method can greatly improve extraction efficiency, has excellent retention of active components, and causes little environmental damage. In the enzymatic hydrolysis-assisted extraction method, the type of enzyme and the enzymatic hydrolysis conditions are crucial. Cellulase and pectinase can effectively destroy cell walls, while protease can reduce the dissolution of impurities. Under appropriate conditions, the dissolution amount of polysaccharides is higher than that of the traditional hot water extraction method, and the overall structure and activity are better. The advantages of the enzymatic hydrolysis-assisted extraction method are high purity of extracts and environmental friendliness. The disadvantages are high enzyme cost, strict control of enzymatic hydrolysis conditions, high overall operation difficulty, and long enzymatic hydrolysis time, which makes it difficult to be widely applied in industrial production at present [10].

3.3. Other novel extraction processes

3.3.1. Fermentation extraction method

The fermentation extraction method is an extraction technology that uses microbial metabolic effects to convert macromolecular active components of *Phellinus linteus* into small molecules. At the same time, it can effectively destroy cell structures and better promote the dissolution of active substances. The fermentation extraction method has the advantages of high extraction efficiency, strong activity of active components, and low overall cost. In the fermentation extraction method, fermentation strains are the most important factor, and different strains have significant differences in transformation effects. Under appropriate conditions, the yield of fermented polysaccharides is significantly higher than that of the traditional hot water extraction method. At the same time, the polysaccharides obtained by the fermentation extraction method have stronger antioxidant and anti-tumor activities. The advantages of this process are that it can greatly improve the bioavailability of active components and produce some new active components, making it very suitable for industrial production [11]. The disadvantages of the fermentation extraction method are a complex fermentation process, high overall operation difficulty, certain difficulty in strain screening and optimization, and complex composition of fermentation products, which greatly increases the difficulty of separation and purification.

3.3.2. Supercritical carbon dioxide extraction method

The supercritical carbon dioxide extraction method is an extraction technology that uses the solubility and permeability of supercritical carbon dioxide to extract fat-soluble components from *Phellinus linteus* effectively. It has the advantages of high extraction efficiency, good retention of active components, and no residual organic solvents. As a high-end extraction process, it is mainly used for the extraction of high-purity active components. In the actual extraction process, extraction pressure and temperature are the most crucial parameters, which greatly affect the solubility of carbon dioxide and the dissolution of components. Under appropriate conditions, the supercritical carbon dioxide extraction method can greatly increase the dissolution amount of terpenoid components, with higher overall purity, and its anti-tumor activity is significantly better than that of the traditional ethanol extraction method. It is also an important research content for the extraction of triterpenoid components from *Phellinus linteus* [12].

4. Optimization directions and prospects of extraction processes

4.1. Optimization directions of extraction processes

At present, there are still some problems to be improved in the extraction process of *Phellinus linteus* in China, such as insufficient structural integrity of active components, high production cost, and great difficulty in subsequent separation and purification. For this reason, we can carry out the following process optimizations:

First, optimize the composite extraction process. We can combine two or more extraction processes to give play to their respective advantages, further improve extraction efficiency, and the retention rate of active components. For example, we can try to use the ultrasonic-enzymatic hydrolysis composite extraction method for extraction, which can greatly improve extraction efficiency and the anti-tumor activity of extracts.

Second, optimize extraction parameters. Researchers can use methods such as single-factor experiments, orthogonal experiments, and response surface methodology to optimize the key parameters of the extraction process, so as to find the optimal extraction conditions, thereby greatly improving extraction efficiency and the dissolution amount of active components, and helping to reduce the degradation of active components.

Third, optimize the research, development, and application of novel solvents. We can find some efficient and environmentally friendly extraction solvents to replace traditional water and ethanol, which can greatly improve extraction efficiency and the retention rate of active components. For example, we can introduce deep eutectic solvents (DES), a new type of green solvent, which can greatly improve the extraction efficiency of *Phellinus linteus* polyphenols. At the same time, this solvent is environmentally friendly and non-toxic, and can greatly reduce production costs [13].

4.2. Prospects

As a very precious medicinal fungus, the anti-tumor activity of *Phellinus linteus* has very broad research value and application prospects. With the continuous development of extraction technology, the extraction process of *Phellinus linteus* is gradually moving towards a more efficient, green, and environmentally friendly direction. In the future, we should further strengthen the research and development of composite extraction processes and better combine technologies such as ultrasound, microwave, and enzymatic hydrolysis to achieve a higher level of extraction of active components from *Phellinus linteus*. In addition, relevant personnel can further strengthen the research on the anti-tumor activity mechanism of *Phellinus linteus*, so as to clarify the effects of different extraction processes on the structure and mechanism of active components, thereby providing a more sufficient theoretical basis for the subsequent optimization of extraction processes [14].

Furthermore, we need to strengthen the industrial transformation of the *Phellinus linteus* extraction process, further optimize the production process, and reduce production costs, so as to better realize the large-scale production of *Phellinus linteus* anti-tumor products. In terms of quality control of *Phellinus linteus* products, we can try to establish a more scientific quality evaluation system to better ensure the safety and effectiveness of products. At present, the relevant departments have issued local standards for food safety related to *Phellinus linteus*, which clearly stipulate the minimum content requirements of main active components, providing an important basis for the quality control of *Phellinus linteus* products. By continuously improving the relevant industry standards, we can provide more key guarantees for the standardized production of *Phellinus linteus* raw materials [15]. With the continuous improvement of people's demand for natural anti-tumor drugs, the optimization of the extraction process and product research and development of *Phellinus linteus* will become a research hotspot in the future. Through the continuous efforts of researchers, the relevant extraction processes of *Phellinus linteus* will be continuously improved, and their anti-tumor activity will be more fully exerted, which invisibly provides a new idea and method for the treatment of tumors.

Disclosure statement

The authors declare no conflict of interest.

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