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Analysis of Health Value of Secondary Metabolites of Fungi Based on Microecological Regulation

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Abstract: *This article focuses on the potential value of fungal secondary metabolites in the health field, focusing on the impact of microecological regulation on their health value. In this study, the composition of fungal microecosystem and the characteristics of secondary metabolites were expounded, and the mechanism of microecological regulation affecting the synthesis of fungal secondary metabolites was deeply analyzed, including the regulation of environmental factors and the interaction between microorganisms. At the same time, the health regulation functions of fungal secondary metabolites on human immune system regulation, intestinal microecological balance maintenance, antioxidant and anti-inflammatory were studied. This article puts forward some strategies to improve its health value based on microecological regulation, such as optimizing culture conditions, using genetic engineering means and adopting microbial co-culture strategy. Microecological regulation is closely related to the synthesis and health function of fungal secondary metabolites. Rational use of relevant strategies can effectively enhance the health value of fungal secondary metabolites and provide theoretical basis and technical support for developing new health products.*

Keywords: *Microecological regulation; Secondary metabolites of fungi; Health value; Influence mechanism; Promotion strategy*

1. Introduction

In the field of life science, the close relationship between microorganisms and human health has always been a research hotspot. Among them, the secondary metabolites of fungi show great potential in maintaining human health because of their various biological activities, and the related research based on microecological regulation has also attracted increasing attention [1]. Fungi widely exist in various ecological environments and play a key role in the material circulation and energy flow of ecosystems [2]. In the complex microecological environment, fungi interact with the surrounding environment and other microorganisms through their own metabolic activities [3]. Secondary metabolites are a kind of small molecular compounds produced by fungi at a specific growth stage or under environmental conditions. Although they are not necessary for the growth and reproduction of fungi, they are of great significance in ecological competition and signal transmission.

With the continuous progress of modern medicine and biotechnology, scientists have gradually deepened their research on fungal secondary metabolites [4]. Many studies have found that these products have antibacterial, antiviral, antitumor, immunomodulatory and other biological activities, and have broad application prospects in medicine, food, health care products and other industries [5]. The influence of microecological regulation on secondary metabolites of fungi can not be ignored [6]. Factors such as temperature, humidity, pH value and nutrients in the microecological environment may change the metabolic pathway of fungi, and then affect the synthesis and accumulation of secondary metabolites [7]. The interaction between microorganisms, such as symbiosis, competition and antagonism, can also significantly regulate the species and yield of fungal secondary metabolites. By reasonably adjusting the microecological environment, it is expected to achieve accurate regulation of fungal secondary metabolites and improve the yield and activity of their beneficial products.

At present, the systematic research on the health value of fungal secondary metabolites based on microecological regulation is still insufficient. On the one hand, the molecular mechanism of microecological regulation affecting fungal secondary metabolism is still shallow, which limits the development of precise regulation strategies. On the other hand, how to effectively translate the laboratory research results into practical applications and realize the large-scale application of fungal secondary metabolites in the health field is also an urgent problem. In view of this, it is of great

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significance to deeply analyze the health value of fungal secondary metabolites based on microecological regulation. By revealing the internal relationship between microecological regulation and fungal secondary metabolites and exploring effective strategies to enhance their health value, we can enrich the theoretical knowledge of microbiology and biomedicine, and provide support for developing new health products and ensuring human health.

2. Overview of fungal microecology and secondary metabolites

Fungal microecosystem is composed of fungi and their living environment, which covers many niches. Fungi are active in soil, water and animals and plants [8]. In this system, fungi interact with other microorganisms, hosts and environmental factors, forming a complex and dynamically balanced whole.

The secondary metabolites of fungi are unique products in the process of fungal life activities. These products are rich in structural types, including alkaloids, terpenoids, steroids and so on. Although they are not necessary for the growth and reproduction of fungi, they play an important role in coping with environmental pressure, competing with other organisms or symbiosis. A clear understanding of fungal microecology and secondary metabolites is an important basis for further exploring how to improve its health value based on microecological regulation.

3. Mechanisms of microecological control over fungal metabolism

Many factors in microecological environment will affect the synthesis of secondary metabolites of fungi, including environmental factors and the interaction between microorganisms.

The regulatory effect of environmental factors on secondary metabolic pathways is significant. Temperature is a key environmental factor, and different fungi require different suitable temperatures for synthesizing specific secondary metabolites [9]. For example, in filamentous fungi, when the temperature is between 25 ℃ and 30 ℃, the synthetic enzyme activity of certain terpenoid compounds is higher, which is conducive to the generation of terpenoid secondary metabolites (see Table 1). This data is based on in vitro enzyme activity determination: logarithmic growth stage mycelium was taken, and crude enzyme solution was obtained by liquid nitrogen grinding, phosphate buffer extraction, and centrifugation; The reaction system contains Tris HCl buffer, Mg^{2+}, and farnesyl pyrophosphate substrate. After incubation at 30 ℃, the products are quantified by GC-MS. Enzyme activity is expressed as the amount of product generated per unit time (U/mg protein). Humidity cannot be ignored either. Moderate humidity can maintain the normal physiological functions and metabolic activities of fungal cells, while high or low humidity may inhibit the synthesis of secondary metabolites. The pH value affects the activity of enzymes and membrane permeability in fungal cells, thereby altering secondary metabolic pathways. Under acidic conditions, some fungi have an enhanced ability to synthesize secondary metabolites of alkaloids.

Table 1 Impact of Temperature on the Activity of Terpene Synthase in Filamentous Fungi

Temperature (°C)	Synthase Activity (U/mg)	Enzyme Activity Change Rate (compared to 25°C)
20	25.5	-33.2%
22	30.1	-21.2%
25	38.2	0%
28	36.8	-3.66%
30	34.5	-9.69%
32	31.7	-16.9%
35	22.1	-42.1%

The interaction between microorganisms also mediates the changes in the synthesis of secondary metabolites. In the symbiotic relationship, fungi and other microorganisms can provide each other with substances needed for growth and stimulate the synthesis of secondary metabolites. When some endophytic fungi coexist with plants, the signal molecules secreted by plants can induce fungi to produce more bioactive secondary metabolites. Under the competitive relationship, in order to compete for resources, fungi will change their metabolic strategies, which may increase the synthesis of specific secondary metabolites. In the antagonistic relationship, the metabolites produced by one microorganism inhibit the growth of another microorganism, and the inhibited fungi may synthesize

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defensive secondary metabolites by changing the secondary metabolic pathway.

4. Health regulation function of fungal secondary metabolites

Fungal secondary metabolites play important roles in various aspects of human health regulation, including their effects on the immune system, gut microbiota, as well as antioxidant and anti-inflammatory properties. Fungal secondary metabolites exhibit unique efficacy in regulating the human immune system [10]. Some secondary metabolites can activate immune cells such as macrophages and T lymphocytes, enhancing the body's immune response ability. Taking Ganoderma lucidum polysaccharides as an example, it is an important secondary metabolite produced by Ganoderma lucidum. Research has found that it can promote the release of cytokines such as interleukin-1 (IL-1), tumor necrosis factor alpha (TNF - α), and interleukin-6 (IL-6) by macrophages, thereby enhancing the body's immune defense ability (see Table 2). This conclusion is based on in vitro experiments: using the mouse RAW264.7 macrophage line, after treatment with different concentrations of Ganoderma lucidum polysaccharides (0-30 μ g/mL) for 24 hours, the cytokine levels in the supernatant were detected by ELISA, and the results showed a dose-dependent increase in the release of each factor. These cytokines play a crucial role in resisting pathogen invasion and regulating immune balance.

Table 2 Impact of Ganoderma lucidum Polysaccharide on Cytokine Release from Macrophages

Ganoderma lucidum Polysaccharide Concentration (μg/mL)	IL-1 Release Amount (pg/mL)	TNF-α Release Amount (pg/mL)	IL-6 Release Amount (pg/mL)
0 (Control group)	25.6 ± 3.2	38.5 ± 4.1	18.3 ± 2.5
5	32.1±4.2	45.6±5.2	22.4±3.1
10	38.9±4.5	52.3±5.6	27.8±3.6
15	43.7±5.0	58.1±6.0	32.5±4.0
20	45.7±5.1	60.2±6.3	34.6±4.2
25	48.2±5.5	63.8±6.8	37.9±4.5
30	52.1±6.2	68.9±7.5	42.1±5.0

The secondary metabolites of fungi are also of positive significance for the maintenance and improvement of intestinal microecological balance. Some fungal secondary metabolites can be used as prebiotics to provide nutrition for intestinal beneficial bacteria and promote their growth and reproduction. Some secondary metabolites of oligosaccharides can selectively stimulate the proliferation of beneficial bacteria such as Bifidobacterium and Lactobacillus, and inhibit the growth of harmful bacteria, thus maintaining the balance of intestinal flora, enhancing the intestinal barrier function and reducing the occurrence of intestinal diseases.

The antioxidant and anti-inflammatory effects of fungal secondary metabolites have a positive impact on health. During normal physiological process and external stimulation, the human body will produce free radicals, and excessive free radicals will damage cells and tissues. Polyphenols, flavonoids and other substances in fungal secondary metabolites have antioxidant activity, which can scavenge free radicals and reduce oxidative stress damage. These secondary metabolites can also inhibit inflammation-related signal pathways, reduce the expression of inflammatory factors, play an anti-inflammatory role, and help prevent and alleviate a variety of chronic inflammation-related diseases.

5. Enhanced fungal metabolites via microecological strategies

In order to fully tap the health value of fungal secondary metabolites, a series of effective strategies can be adopted based on microecological regulation. Strategies mainly include optimizing culture conditions, using genetic engineering and co-culture of microorganisms.

Optimizing cultivation conditions is a fundamental strategy for enhancing the health value of fungal secondary metabolites. The cultivation conditions such as temperature, pH value, and nutrient composition have a significant impact on the synthesis and accumulation of secondary metabolites in fungi. For specific medicinal fungi, there are significant differences in the production of their active secondary metabolites at different temperatures (see Table 3). In this study, Ganoderma lucidum was cultured in PDB liquid medium at 24-34 ℃ for 14 days. Its active secondary metabolites were

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extracted with 70% ethanol and quantitatively analyzed using HPLC-DAD. The results showed that at 28 ℃, the yield of secondary metabolites with immune regulatory function synthesized by the fungus reached its peak (50.5 ± 3.0 mg/L), and the purity of the product was the highest (85.0%); If the temperature deviates from this range, the yield significantly decreases (see Table 3). Meanwhile, adjusting the ratio of carbon and nitrogen sources in the culture medium can also significantly affect the synthesis of secondary metabolites. Increasing the carbon to nitrogen ratio is beneficial for the accumulation of certain terpenoid secondary metabolites.

Table 3 Impact of Temperature on the Yield of Active Secondary Metabolites from Ganoderma lucidum

Temperature (°C)	Active Secondary Metabolite Yield (mg/L)	Product Purity (%)	Yield Change compared to 28°C (mg/L)
24	30.5±2.0	80.0	-20.0
26	38.2±2.5	83.0	-12.3
28	50.5±3.0	85.0	0
30	45.8±2.8	84.0	-4.7
32	40.2±2.6	82.0	-10.3
34	33.7±2.3	81.0	-16.8

Precise regulation of fungal secondary metabolism can be achieved by genetic engineering. By cloning and expressing key genes or modifying key enzyme genes in metabolic pathway, the synthesis direction and yield of secondary metabolites can be changed. For example, introducing a gene encoding a key synthetic enzyme into a specific fungus can enhance the activity of the enzyme, thus increasing the yield of secondary metabolites with anticancer activity. Using RNA interference technology to inhibit the gene expression of competitive pathway can also make metabolic flow flow more to the synthesis of target secondary metabolites.

The co-culture strategy of microorganisms opens up a new way to improve the health value of fungal secondary metabolites. The interaction between different microorganisms can induce fungi to produce new secondary metabolites or increase the yield of existing products. In the co-culture system, it is the key to improve the yield and activity of secondary metabolites by reasonably adjusting the inoculation ratio and culture time of microorganisms.

6. Conclusions

In this article, the health value of fungal secondary metabolites based on microecological regulation was comprehensively and deeply discussed. Fungal microecosystem is complex and dynamically balanced, which is closely related to the production of secondary metabolites. Microecological regulation has a significant effect on the synthesis of fungal secondary metabolites through the interaction between environmental factors and microorganisms. Among environmental factors, the changes of temperature, humidity, pH value and nutrients can change the secondary metabolic pathway and affect the types and output of products. Interactions such as symbiosis, competition and antagonism among microorganisms also play an important mediating role in the synthesis of secondary metabolites.

The secondary metabolites of fungi have shown remarkable functions in the field of human health regulation. It can regulate the human immune system, activate immune cells such as macrophages and T lymphocytes, and enhance the immune response ability of the body, thus improving the level of human immune defense. In the maintenance and improvement of intestinal microecological balance, some secondary metabolites are like "nourishing agents" of intestinal beneficial bacteria, which can promote the growth and reproduction of beneficial bacteria, inhibit the breeding of harmful bacteria, stabilize the balance of intestinal flora, enhance intestinal barrier function and reduce the incidence of intestinal diseases. Its antioxidant and anti-inflammatory properties can effectively eliminate excessive free radicals in the body, reduce the damage caused by oxidative stress to cells and tissues, inhibit inflammation-related signal pathways and reduce the expression of inflammatory factors, which is of positive significance for preventing and alleviating chronic inflammation-related diseases.

In order to further enhance the health value of fungal secondary metabolites, a series of strategies were put forward in this study. Optimizing culture conditions and accurately controlling factors such as temperature, pH value and nutritional components can create a suitable environment for the synthesis of fungal secondary metabolites. By means of genetic engineering, through the operation of key genes, the precise regulation of secondary metabolism process can be realized. The co-culture strategy of microorganisms can induce the production of new secondary metabolites or increase the output of existing products with the help of the interaction between different microorganisms. In the future, we

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should further study the relevant mechanisms and accelerate the transformation of results, so as to fully tap the great potential of fungal secondary metabolites in safeguarding human health and promote the innovative development of health industry.

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