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Research on the Development of High-Value-Added Bioproducts Based on Cordyceps Residues

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Abstract This study focuses on the by-products remaining after the processing of *Cordyceps sinensis*, exploring their potential applications in pharmaceuticals and cosmetics. The residues contain biologically active compounds such as cordyceps polysaccharides, cordycepin, and other physiologically effective substances, which have demonstrated antioxidant, immunomodulatory, and anti-aging properties. The research further examines the use of cordyceps residues as additives in animal feed. Through techniques such as solid-state fermentation and microbial biotransformation, the structural composition of the residues can be modified to enhance nutrient bioavailability. Despite their potential, several challenges remain in the effective utilization of cordyceps residues. However, advances in biotechnology—including enzyme-assisted extraction and precision fermentation—are gradually addressing these limitations. Integrating modern technologies with traditional cordyceps cultivation practices may improve resource efficiency and promote the sustainable, circular development of the cordyceps industry.

Keywords Cordyceps residue; Bioactive compounds; Anti-aging; Fermentation technology; Functional food

1 Introduction

Cordyceps militaris is a medicinal fungus that has long been used in traditional Chinese medicine. It contains a variety of beneficial ingredients, such as cordycepin and polysaccharides, which have pharmacological effects such as regulating blood lipids, protecting the liver and anti-oxidation (Wang et al., 2015). In the past, after harvesting Cordyceps, people would treat the remaining culture medium and mycelium as waste, but in fact these residues are also rich in valuable ingredients and can be used in other industries, such as medicines and skin care products (Pintathong et al., 2021; Wu et al., 2021).

At present, many studies have begun to focus on how to make use of these "wastes". The polysaccharides in the residues of Cordyceps have antioxidant and immune-enhancing effects (Bi et al., 2018; Zhang et al., 2020). This type of ingredient is very promising in health foods. There are also studies that have developed new extraction technologies, such as using macroporous resins to decolorize and remove proteins to extract purer active polysaccharides (He et al., 2019; Wang, 2024).

In terms of the cultivation of Cordyceps, many improvements have also been made to increase the content of key ingredients such as cordycepin. This ingredient can inhibit skin aging and melanin production and is often used in functional skin care products (Kunhorm et al., 2019). The commercial value of Cordyceps is no longer limited to the main body, and its residues can also be developed into new uses.

This study focuses on the residues from Cordyceps cultivation, exploring methods to extract active components and analyze their structural and functional properties, particularly their potential applications in health and beauty products. It also aims to optimize cultivation and extraction processes to enhance both the yield and quality of active substances. These efforts will provide better raw material sources for functional foods, pharmaceuticals, and cosmetics while reducing waste and promoting resource recycling (Pintathong et al., 2021).

2 Chemical Composition and Biological Characteristics of Cordyceps Residues

2.1 Main chemical composition

There are many useful components in the residues left after the cultivation of *Cordyceps militaris*. These residues contain polysaccharides, nucleosides, amino acids, phenols, etc. The polysaccharides (RPS) from the SU-12 strain are mainly composed of glucose, arabinose and mannose, and have a wide molecular weight distribution, indicating that their structure is not simple (Wang et al., 2015). The crude products extracted from the solid fermentation residues (SBRs) of Cordyceps contain phenolic acids, flavonoids, nucleosides, as well as sugars and peptides (Pintathong et al., 2021).

The researchers analyzed the structures of these components and found that there are many types of polysaccharides in Cordyceps. The new polysaccharide CBP-1 is mainly composed of (1→4)-α-d-mannose units, with glucose and galactose as branches (Yu et al., 2009). Another polysaccharide called CMP Fr II contains glucose, galactose and mannose, and its structure is also complex (Lee et al., 2010).

2.2 Biological characteristics

These residues are not only rich in ingredients, but also have many biological activities. RPS polysaccharides can lower blood lipids, protect the liver, and also have antioxidant functions. In animal experiments, it can significantly reduce lipids in the blood and liver and increase antioxidant levels (Wang et al., 2015). In addition, the crude extract of Cordyceps residues showed a strong ability to scavenge free radicals in in vitro experiments and inhibit the activity of tyrosinase, which makes it also promising in cosmetics, such as skin care and anti-aging (Pintathong et al., 2021) (Figure 1).

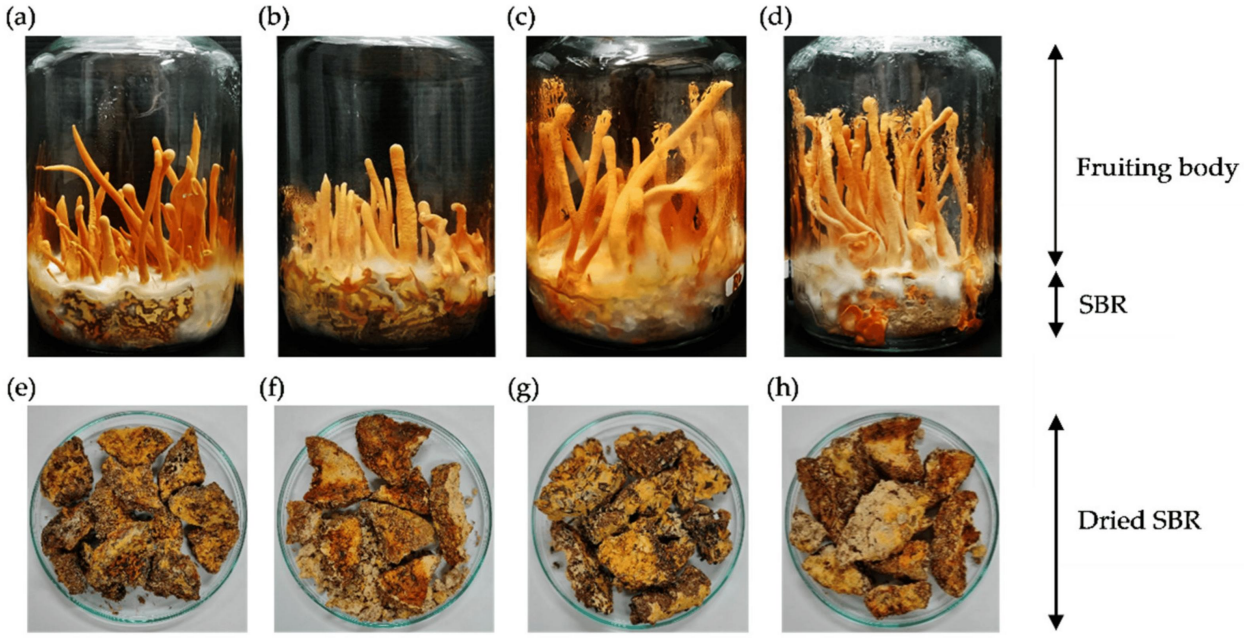

Figure 1 Morphology of C. militaris cultivated on solid media containing defatted rice bran and different types of cereals, and the appearance of dry solid-based residues (SBRs) prepared from different culture media: (a,e) barley, (b,f) white rice, (c,g) Riceberry rice, and (d,h) wheat (Adopted from Pintathong et al., 2021)

In addition to anti-oxidation, these residues also affect immune function. CMP Fr II polysaccharide can stimulate macrophages to release nitric oxide and various cytokines, which helps to improve immune response (Lee et al., 2010). Another polysaccharide, CMPB90-1, can promote the proliferation of spleen lymphocytes and increase the activity of NK cells (Bi et al., 2018).

2.3 Analysis techniques

In order to find out what exactly is in the Cordyceps residue, researchers have used a variety of analytical techniques. Gas chromatography-mass spectrometry (GC-MS) and nuclear magnetic resonance (NMR) are often

used to analyze the composition and connection of polysaccharides (Yu et al., 2009; Lee et al., 2010). These methods can help researchers understand how the polysaccharide chains are connected and whether there are branched structures.

Liquid chromatography-mass spectrometry (LC-MS/MS) can be used to detect and quantitatively analyze phenolic acids, flavonoids, and other components in residues (Pintathong et al., 2021). Common antioxidant assays such as DPPH, ABTS, and FRAP tests are also employed to evaluate the free radical scavenging capacity of cordyceps extracts.

3 Drug Development Based on Cordyceps Residues

3.1 Application of polysaccharides in medicine

The residues after processing *Cordyceps militaris* also contain some useful polysaccharides. These polysaccharides have good medicinal effects. Studies have found that polysaccharides (RPS) extracted from these residues are helpful in lowering blood lipids and protecting the liver. It can reduce fat levels in the blood and liver, and improve antioxidant capacity, which has a certain effect on treating lipid metabolism disorders and oxidative damage (Wang et al., 2015). The main components of this polysaccharide include glucose, arabinose and mannose, and the structural characteristics of these sugars may be related to its medicinal effects.

These cordyceps polysaccharides can also regulate the immune system. They promote the production of cytokines and enhance immune responses, which may have therapeutic effects on some immune-related diseases. These polysaccharides can influence the activity of immune cells and regulate inflammatory responses, demonstrating certain medicinal value (Das et al., 2021).

3.2 Alkaloids and active ingredients drug development

There are also many alkaloids and other active ingredients in Cordyceps, which are also meaningful for the development of new drugs. Cordycepin is a nucleoside substance that has been shown to have anti-cancer, anti-inflammatory and immune-regulating effects (Qin et al., 2019; Sharma et al., 2022). Many studies are currently exploring how cordycepin binds to targets in the human body, and are also trying to increase its production through methods such as metabolic engineering (Sharma et al., 2022). In addition to cordycepin, researchers have also found that there are many other metabolites in Cordyceps, which also have medicinal potential, such as antibacterial, anti-apoptotic, and antioxidant effects (Table 1) (Krishna et al., 2023). If you want to use these ingredients in medicines, you need to further understand how they are synthesized and how they work specifically.

3.3 Innovative drug forms

To better utilize the active ingredients in cordyceps residues, researchers are developing new drug forms such as sustained-release and controlled-release preparations. The advantages of these preparations are that they allow the drug to be more stable, easier to absorb, have a longer duration of action, and have fewer side effects.

At the same time, new technologies such as CRISPR gene editing and ultraviolet mutagenesis are being used to modify cordyceps and increase the yield of important components such as cordycepin (Sharma et al., 2022). These methods can precisely adjust genes and change production environments.

4 Functional Foods and Health Products Based on Cordyceps Residues

4.1 Nutritional effects of polysaccharides and proteins

Polysaccharides from *Cordyceps sinensis* and *Cordyceps militaris* have been shown to be beneficial to the human body. These polysaccharides have antioxidant, immune-enhancing, and tumor cell-suppressing activities and are often used as raw materials for functional foods (Bi et al., 2018; Zhang et al., 2020; Shashidhar et al., 2021). Polysaccharides from *Cordyceps militaris* can activate macrophages and promote the secretion of cytokines (Zhang et al., 2020). They can also improve intestinal flora, lower blood sugar levels, and help maintain metabolic balance (Lee et al., 2021).

Table 1 Pharmacological and therapeutic properties of different polysaccharides derived from *Cordyceps* spp. (Adopted from Krishna et al., 2023)

Compound	Property	Effect
EPSF	Immunomodulatory function and antitumour activity	↑Peritoneal macrophage Neutral Red adsorption capacities and spleen lymphocyte multiplication in B16-bearing mice
EPS	Immunomodulatory effect	↑Cytokine release,CD11b expression,and phagocytosis
Exopolysaccharide fraction (EPSF)	lmmunomodulatory effect	↑Expression of IFN and TNF mRNA in splenic lymphocytes ↑Immunocytes activity in H22 tumor bearing mice
Acid polysaccharide (APS)	Antioxidant effect	↑Antioxidant defense capability of the cell PC12 cells are shielded against oxidative damage
Acid polysaccharide fraction (APSF)	Anti-inflammatory effect	↑IL-12,TNF-a and iNOS production ↓I L-10 of Ana-1 cells production
PSCK2-2 and PSCK 2-3	Antioxidant effect	Scavenging abilitieson hydroxyl radicals.Strong capacity on protective effect of DNA damage
Polysaccharides (PS)	Immunomodulatory effect	↑Thymus and spleen indexes,proliferation of splenic cells, macrophage phagocytosis and levels of TNF-a and IFN- γ
CPS-1	Anti-inflammatory activity	↓Serum hemolysin formation of mice
CPS-2	Cure -Renal failure clinically	TGF1 and extracellular matrix(ECM)levels in patients have stabilized
	Immunomodulatory effect	↓Cell proliferation caused by PDGF-BB via the TGF-b1/Smad and PDGF/ERK pathways, and it potentially havetwo way regulatory impacts on the PDGF/ERK cellular signaling pathway
WIPS and AIPS	Antitumor and immuno-stimulatory effect	Animal studies on melanoma tumor-bearing mice revealed antitumor and immunostimulatory effects
Cordysinocan	Immunomodulatory effect	↑Effectiveness of phagocytosis and acid phosphatase enzymatic activity in macrophages
PS-A	Anti-hypercholesterolemia effect	Significant inhibition of cholesterol esterase was seen in an in-vitro enzyme test
EPS-II	Hypoglycemic effect	Inhibited a-glucosidase effectively alleviate weight loss, ↓plasma glucose concentrations,↑glucose tolerance
CBPS-II	Hypoglycemic effect	Controls the energy metabolism,intestinal flora,and amino acid metabolism disruption
CCP	Anti-inflammatory and Anti-fibrotic	Suppressed inflammation,renal pathological changes,and renal dysfunction, slowing the progression of renal interstitial fibrosis,modulated gut microbiota dysbiosis ↓LPS-induced inflammatory cytokine levels and TGF-1-induced fibroblast activation
CPS	Management of allergic asthma	Inhibited the expression of eotaxin,IL-4,IL-5,IL-13,and IFN- γ in the blood and bronchoalveolar lavage fluid (BALF),Lowered serum lgE levels in mice.
SDQCP-1	Natural antioxidant and immunomodulator	Activate macrophages to produce NO,TNF-a,IL-6,and IL-10,as well as promote M1 polarization
CSP (Cordyceps sinensis polysaccharide)	Anti-cancer	↓HCT116 cell growth by inducing apoptosis and blocking autophagy flux,via PI3K-AKT-mTOR and MPK-mTOR-ULK1 signaling
(Se) -rich C.militaris polysaccharides (SeCMP)	Anti-Hyperlipidemia	Promoted satiety and thermogenesis of obese mice ↓Gut bacteria,such as Lactobacillus,Dorea, Costridium,Ruminococcus ↑Mucosal beneficial bacteria Akkermansia

The proteins in Cordyceps are also very nutritious, especially the albumin, globulin and glutenin contained in *Cordyceps militaris*. These proteins provide the amino acids required by the human body and meet the recommended standards of FAO/WHO (Yu et al., 2021). They also help improve the processing properties of food, such as better foaming and emulsification effects.

4.2 Development space of health products

With the increasing preference for natural products, the production of health foods using cordyceps residue has become a new direction. Polysaccharides, which regulate immunity and improve metabolism, are being used as health supplements and nutritional supplements (Zhang et al., 2019; Yang et al., 2020).

Cordyceps polysaccharides exhibit complex structures, with diverse glycosidic bonds and molecular sizes enabling their potential for developing various products. These compounds can be utilized in anti-aging or immunity-enhancing formulations (Liu et al., 2016; Luo et al., 2017). As research progresses and deeper understanding of their components and mechanisms emerges, the market for such products is expected to continue expanding.

4.3 Functional validation study

The polysaccharides in *Cordyceps militaris* have been found to promote lymphocyte proliferation and enhance the killing effect of natural killer cells, showing its ability in immune activation (Bi et al., 2018). These effects are related to the activation of signaling pathways such as TLR2, MAPK and NF-κB.

Cordyceps polysaccharides also have strong antioxidant capacity and can effectively remove free radicals in the body and reduce oxidative stress. This is important for preventing chronic diseases (Zhang et al., 2019; 2020). They can also affect the structure of intestinal flora and help improve the digestive system (Lee et al., 2021).

5 Development of Feed and Food Additives Based on Cordyceps Residues

5.1 Animal feed additives

Cordyceps residues are widely used to make animal feed additives, especially for poultry and livestock. It is usually processed by liquid or solid fermentation, which can better retain the active ingredients in cordyceps. Such additives can help animals grow faster, eat less, enhance resistance, and reduce the use of drugs (Chen et al., 2014; Zou et al., 2015).

When the residues of mushroom stems such as *Cordyceps militaris* are added to broiler feed, the chickens gain weight significantly and have healthier intestines. These residues contain ingredients such as polysaccharides and phenols, which can activate antioxidant reactions and are beneficial to the animal body (Hsieh et al., 2020). This way of using feed not only improves the efficiency of breeding, but also gives agricultural waste a new value, which is helpful for the sustainable development of the breeding industry.

5.2 Food additives

Cordyceps militaris residue contains numerous bioactive components, making it a promising candidate for food additive development. The remaining material exhibits lipid-lowering and hepatoprotective properties, effectively regulating lipid metabolism and reducing oxidative stress—a dual benefit with potential health benefits (Wang et al., 2015). These residues contain complex polysaccharide structures that serve as the primary source of antioxidant and immune-enhancing properties, making them ideal for functional food applications (Zhang et al., 2020).

Although Cordyceps residue has certain applications in food, its safety still needs attention due to the potential risk of mycotoxins, so further toxicological tests must be carried out. Cordycepin has certain antioxidant and immune-regulating effects, but its safe range after human intake still needs to be defined (Chen et al., 2020).

5.3 Security and regulations

Whether used in feed or food, the safety of cordyceps residues must be taken seriously. In particular, the mycotoxins and metabolites (such as adenosine analogs) that may be contained in them may have an impact on

humans or animals and need to be confirmed through rigorous experiments (Chen et al., 2020). At this stage, special safety standards and testing procedures should be formulated as soon as possible to clarify which ingredients are allowed to exist and which need to be controlled.

It is the responsibility of the government or regulatory agencies to issue relevant regulations to ensure that these products can be used within a safe range. The maximum content of polysaccharides, cordycepin and mycotoxins should be specified, while ensuring that the production process is not contaminated. As research continues to deepen, these regulations also need to be adjusted according to the latest data to ensure that products sold on the market do not cause harm to consumer health (Zou et al., 2015; Chen et al., 2020).

6 Development of Fermentation and Microbial Technology Based on Cordyceps Residues

6.1 Development of fermented products

The residues of *Cordyceps militaris* can be used as raw materials for fermentation to produce functional products. When used in solid-state fermentation (SSF), it can not only increase the total phenolic and flavonoid content in substrates such as beans, but also enhance the antioxidant activity, making it suitable for making healthy foods (Liu et al., 2022). There are also studies trying to use agricultural waste and Cordyceps residues to ferment together to produce bioactive ingredients (Wang et al., 2022).

Some fermentation processes include pretreatment steps, such as alkaline treatment, before operation. This practice can increase the yield of volatile fatty acids and recover cellulose from the screened residue (Duan et al., 2021).

6.2 Microbial transformation technology

Microorganisms can be used to transform Cordyceps residues into useful products. Researchers have modified microorganisms (including metabolic pathways and transcription factors) to improve the ability to decompose lignocellulose, which is particularly effective for Cordyceps residues, a carbon-rich raw material that can be used to produce biofuels and chemicals (Paula et al., 2019).

Scientists have also begun to use fungal cell factories, such as Saccharomyces cerevisiae, to produce cordycepin, a medicinal substance. This method has a short fermentation cycle and high yield, and is an alternative to traditional production methods, solving the problems of high cost and low yield (Li et al., 2024b).

6.3 Process innovation

To make more efficient use of cordyceps residue, some new processes are emerging. Some studies have tried to use Bacillus subtilis and cordyceps in stepwise culture. This serial fermentation method not only improves the production of cordycepin, but also reduces the use of solvent (Wu et al., 2013).

Solid-state fermentation (SSF) is also commonly used for the conversion of agricultural waste, and cordyceps residues are suitable for this process. SSF can produce a variety of useful enzymes and metabolites, and the process itself is in line with the concept of recycling (Chilakamarry et al., 2021).

7 Development of Cosmetics and Beauty Products Based on Cordyceps Residues

7.1 Anti-aging and antioxidant applications

The residues left after the extraction of *Cordyceps militaris* have good prospects for use in the development of skin care products. The Cordyceps residues treated with hot water can produce crude extracts with strong antioxidant capacity. This activity is important for skin cells because it can reduce damage caused by free radicals, which is a major cause of skin aging (Pintathong et al., 2021). These extracts can also promote the growth of fibroblasts.

In addition to ordinary extracts, the effect of encapsulating the active ingredients of Cordyceps through nanotechnology is more obvious. This form of Cordyceps ingredients can not only remove oxides, but also stimulate autophagy reactions, help increase collagen production, and accelerate the metabolism of skin cells (Upatcha et al., 2023).

The phenolic acids and flavonoids in Cordyceps are the main antioxidant ingredients, and they also have a certain sunscreen effect. These substances can absorb ultraviolet rays and reduce skin damage caused by sunlight, making them suitable for addition to sunscreen skin care products (Pintathong et al., 2021). Nanoemulsions made from Cordyceps extracts have good anti-inflammatory and antioxidant effects and can help maintain the youthful state of the skin (Rupa et al., 2020).

7.2 Repair functional products

Beyond its anti-aging properties, cordycepin residue from Cordyceps can be utilized in skin repair products. The compound's ability to reduce oxidative stress and promote skin tissue regeneration makes it particularly effective for addressing skin damage. Additionally, cordycepin enhances collagen and elastin synthesis, which helps improve skin elasticity and firmness (Upatcha et al., 2023).

Some small molecule peptides isolated from cordyceps also show antioxidant effects, which can protect cells from free radical damage and are suitable for adding into repair skin care products (Li et al., 2024a).

Cordyceps extract can also inhibit the production of melanin, which helps to reduce spots and brighten the skin. Cordycepin can inhibit a variety of enzymes and pathways involved in melanin production and is also widely used in whitening products (Jin et al., 2011). Combining the two effects of repair and whitening, cordyceps residues have high application value in the development of multifunctional skin care products.

7.3 Market trends

Nowadays, an increasing number of skincare brands are focusing on Cordyceps residues, particularly as they originate from natural and reusable resources that align with consumers 'demand for eco-friendly ingredients. The antioxidant, anti-inflammatory, and reparative properties of Cordyceps perfectly match the "multi-functional integration" concept emphasized in today's skincare market. Reusing these discarded Cordyceps residues not only conserves resources but also promotes sustainable development (Kunhorm et al., 2019; Pintathong et al., 2021).

Advancements in biotechnology have enabled more efficient extraction and higher purity of active ingredients like cordycepin. These technologies allow manufacturers to consistently produce high-quality raw materials that meet demands from skincare and cosmeceutical markets (Oh et al., 2018; Kunhorm et al., 2019). Several companies have already incorporated cordycepin-based components into various personal care products, including skincare and hair care formulations.

8 Difficulties in Using Cordyceps residues

8.1 Difficulty in extracting ingredients

The ingredients of Cordyceps residues are very complex, and it is not easy to extract useful substances from them. The ingredients of different batches of residues vary greatly, such as phenolic acids, flavonoids, polysaccharides and other bioactive ingredients. These ingredients are mixed with each other and easily affect each other during extraction, increasing the difficulty of separation. If the extraction method is not appropriate, it will not only be inefficient, but may also destroy the activity of the ingredients (Pintathong et al., 2021; Wu et al., 2021).

Different solvents also have a great impact on the extraction effect. Some solvents can extract more active substances, but they are expensive or not environmentally friendly, and are not suitable for large-scale use (Pintathong et al., 2021). There are also some improved methods, such as using macroporous resins to simultaneously decolorize and deproteinize, which can improve efficiency and retain the structure of polysaccharides (He et al., 2019). However, these technologies are not mature enough. If they are to be applied to industrial production, they need to be further optimized and reduced in cost (Ran et al., 2019).

8.2 Product quality is difficult to guarantee

The quality of products processed from Cordyceps residues is not easy to be uniform. This is mainly because the residue raw materials themselves are unstable. For example, different substrates used in the cultivation process or different extraction methods will affect the active ingredient content of the final product (Pintathong et al., 2021).

This requires strict standards to be established throughout the entire processing process, such as uniform extraction processes and standardized testing steps (Wu et al., 2021).

Another problem is that residual impurities, such as solvents or proteins, will affect the purity and safety of the product. There are now some purification technologies, such as macroporous resins, which can effectively remove unwanted components without destroying useful substances (He et al., 2019). These technologies need further verification, especially to adapt to production conditions of different scales and establish a reliable quality control process (Sodhi et al., 2021; Zhou, 2024).

8.3 Limited industrial promotion

Although Cordyceps residues have utilization value, they still face many problems when they are actually used in industrial production. The first is high cost. Many extraction and processing equipment are very expensive and cannot be easily afforded by ordinary companies (Dessbesell et al., 2017; Bejenaru et al., 2024). Some technologies are effective in the laboratory, but it is much more difficult to operate them in large factories (Wang et al., 2022).

In addition to cost and technical issues, regulations are also an obstacle. Developing products with Cordyceps residues must meet safety standards for food, medicine, etc. These procedures are complicated and time-consuming (Bejenaru et al., 2024). A clear regulatory mechanism must be established to clarify the quality and safety requirements of Cordyceps products (Sodhi et al., 2021).

9 Sustainable Development and Economic Analysis of Cordyceps Residues

The reuse of cordyceps residues can not only reduce waste, but also bring economic benefits, such as the solid waste (SBRs) left after the cultivation of cordyceps (*Cordyceps militaris*). These residues contain active ingredients, and after simple treatment, substances with antioxidant and tyrosinase inhibition can be extracted, which have good effects in skin care products (Pintathong et al., 2021).

Other agricultural wastes can also be used in the process of cordyceps cultivation, such as biochar made from corn cobs. This material can not only be used as a culture medium, but also increase the yield and active ingredients of cordyceps (Phoungthong et al., 2022). This shows that cordyceps cultivation can form a virtuous cycle with agricultural by-products and reduce resource waste.

From an economic perspective, the collection of cordyceps, especially *Cordyceps sinensis*, is of great significance to some remote areas. In Karwal, India, the local residents earn their main income by collecting Cordyceps (Caplins and Halvorson, 2017; Caplins et al., 2018). Artificial cultivation of Cordyceps has also become a new way. Through large-scale cultivation, people can stabilize output, reduce dependence on wild resources, and expand market supply (Li et al., 2018). Taking Tibet as an example, the local government has set up protected areas, strengthened management, and regulated market transactions to ensure that Cordyceps resources are not over-exploited (Liu et al., 2010). In the Karwal region of India, there is also a community-led protection mechanism to ensure that local people can have fair access to Cordyceps resources (Caplins and Halvorson, 2017). The government encourages artificial cultivation policies, which not only reduces environmental pressure, but also helps the long-term development of the industry (Li et al., 2018).

10 Conclusions

After the cultivation of *Cordyceps militaris*, a lot of residues are left. These residues are usually treated as waste, but in fact they contain many useful ingredients and are worth further development and utilization. These residues are promising in both medicine and skin care. The polysaccharide components in Cordyceps residues have been found to have the effects of lowering blood lipids and protecting the liver, and are expected to be used as raw materials for health products. These solid residues have also been studied for use in cosmetics, showing antioxidant and anti-aging effects.

Converting these residues that were originally to be discarded into useful products can not only bring economic benefits, but also reduce pollution to the environment. Active substances such as cordycepin extracted from the residues can be applied to cosmeceuticals to increase product added value. This recycling of resources can also help the Cordyceps industry achieve a more environmentally friendly production method.

Future research directions may focus on technology improvement and industrial application, such as improving the recovery rate of active ingredients by improving extraction methods, such as using macroporous resins to efficiently extract polysaccharides. Policy support is also critical and will help promote the scale-up of these products. With the development of biotechnology, the combination of traditional planting methods and modern technology will help improve the utilization efficiency of active substances in Cordyceps residues and further promote the development of related bio-industries.

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Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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