



Review Article

Exploration strategies for food and medicine homologous resources: future direction in food development

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Abstract: The theory of food and medicine homology emphasizes the integration of food and medicine functions to achieve health interventions through daily diet, becoming a significant development direction for the health industry. With the rapid advancement of modern disciplines such as mass spectrometry, omics technologies, artificial intelligence (AI), and bioinformatics, the scientific underpinnings of food and medicine homology are gradually being revealed. The in-depth exploration and development of food and medicine homology resources and their products are increasingly shaping the future of food innovation. This paper summarizes the application of classical herbal texts, folk practices, and cutting-edge technologies like AI and multimodal omics technology in mining food and medicine homologous resources. It also highlights the bidirectional value exploration, uncovering medicinal properties in edible resources and the edible potential in medicinal resources, to foster innovative scientific paradigms in this field. This approach accelerates the development of food and medicine homologous resources and paves new pathways for future food innovation.

Keywords: food and medicine homology; herbal classics; medicinal value; edible value; multimodal omics technology; artificial intelligence (AI) technology

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1 Introduction

With the rise of health consciousness, the traditional Chinese medicine principle that “medicine comes from food, food has the function of medicine, and medicine has the nature of food” is flourishing. The concept of food medicine homology (FMH), which highlights the interrelationship between food and medicine, is receiving increased attention. FMH posits that many foods also serve as medicines, emphasizing the scientific combination of their functions. This concept not only possesses nutritional value but also plays a crucial role in preventing and treating diseases, embodying the unique charm of Chinese medicine culture^[1-4]. The relationship between medicine and food seeks to regulate the human body long-term through diet, aiming for antioxidant effects, stress reduction, anti-aging benefits, improved immunity, as well as disease prevention and treatment. As drugs often have certain toxic side effects, people are increasingly recognizing that “food is better than medicine” and that “prevention is better than treatment.”

The homology of food and medicine traces back to ancient times. In the *Huainanzi Xiuwu Xun*, it is stated, “Shennong tasted a hundred herbs and encountered seventy poisons in one day.”

This can be considered the first practice of the homology of medicine and food, laying the foundation for later food therapy and drug therapy^[5]. Since then, the concept of food therapy and the relationship between medicine and food in Chinese medicine have been reflected in works such as the *Huangdi Neijing* (The Yellow Emperor's Classic of Internal Medicine), *Typhoid Miscellaneous Diseases* (Treatise on Typhoid Miscellaneous Diseases), *Jin Gui Yao Liao* (The Essentials of the Golden Chamber), *Classic of Materia Medica Annotated*, *Qimin Essentials*, *Elbow after the Preparation of the Emergency Prescription*, and *Dietary Preparation*^[6].

With the development of various instrumental analytical techniques and histological methods, the scientific understanding of “medicine and food” has gradually evolved, enriching and maturing the underlying theory. Techniques such as chromatography, spectroscopy, and mass spectrometry, alongside transcriptomics, metabolomics, and proteomics, have transcended the limitations of traditional single-molecule research. These advancements provide robust technical support for uncovering the medicinal value of food resources and edible value in medicinal resources. Active Components abundant in food resources including polysaccharides, flavonoids, quinones, terpenoids, and

alkaloids, exhibit a range of biological functions such as anti-inflammatory, antioxidant, anti-obesity, hypoglycemic, hepatoprotective, hypotensive, hypolipidemic, and gastrointestinal regulation^[7-12], which makes it to exhibit preventive and therapeutic effects on various diseases. For example, the flavonoids components presented in mulberry leaves could effectively inhibit the deposition of fat in blood vessels, promote the metabolism and excretion of lipids, thereby helping to lower indicators such as triglycerides and cholesterol in the blood, and play a role in regulating blood lipids^[13]. *Artemisia argyi* polysaccharides could regulate the balance of intestinal flora, enhance the intestinal mucosal barrier function, maintain the normal digestive absorption and immune regulatory capabilities of the intestine, and build a natural defense line for intestinal health^[14]. And by the year 2024, China's food-as-medicine market surpassed 265 billion CNY, with ready-to-eat products growing by 23.8% and average order value increasing by 40% year-on-year. The market is projected to exceed 400 billion CNY by 2025, where ready-to-eat products will account for over 60% of sales. Post-1990s generation has become the core consumer group, with 72% replacing traditional health supplements with functional snacks. For instance, Tongrentang's barberry wolfberry Ejiao Mooncakes saw a 40% annual sales surge, with 70% buyers being women aged 25–35.

Therefore, this paper summarizes the integration of multidisciplinary techniques for exploring medicinal and food resources to propose a strategy for the in-depth exploration of food and medicine homologous resources, including the exploration of herbs based on herbal classics and folk practices, the exploration of medicinal value in edible resources and the edible value in medicinal resources, as well as the application of artificial intelligence (AI) and future technologies in the excavation of medicinal foods and food resources. Through this, it aims to accelerate and innovate the development of food and medicine homologous resources, and provide ideas for their further development and utilization.

2 Exploration of homology of food and medicine resources

The exploration of food and medicine homologous resources was summarized from multiple dimensions. On one hand, based on herbal classics and folk-used resources, modern technologies are employed to explore varieties not yet included in the catalog, providing a basis for the development of new raw materials and cultural inheritance, such as *Rehmannia glutinosa*, *Ophiopogon japonicus*, and other species have been successfully included in the catalog. On the other hand, in-depth exploration is conducted on the medicinal value of edible resources. The active polysaccharides, phenols and terpenoids contained in these resources have significant effects in immune regulation, anti-cancer, and other aspects, and some already used in the development of drugs or health products. Meanwhile, in response to health needs, the nutritional and health-preserving functions of medicinal resources are also explored. Health products are developed through processing or fabricate to reduce toxicity, enhance efficacy, and control quality. Cutting-edge technologies such as AI and omics have brought new opportunities to research, and will drive the development of medicinal and edible homologous resources towards precision, personalization, and scientization in the future.

2.1 Exploration of homology of medicine and food resources based on herbal classics and folk practices

From ancient times to the present, humans have accumulated a large amount of medicinal and food resources over thousands of years of production and practice. Gradually, these resources have been differentiated into food, medicine, and substances that serve both medicinal and dietary purposes. Ancient herbal literature such as Compendium of Materia Medica, Shennong's Classic of the Materia Medica, Collected Notes on the Classic of the Materia Medica, Xinxu Materia Medica, Zhenqi Materia Medica, Qianjin Yaofang, Food Therapy Materia Medica, Taiping Shenghuifang, Salvation Materia Medica, Wild Vegetable Bokoru, and Drinking Meals Just Now, etc., have recorded a large number of medicinal plants that are homologous with medicinal food in detail. At present, there are 106 kinds of Chinese herbs included in the Catalogue of Medicines and Foods with the Same Origin, but there are still many varieties of herbs that are not included in the Catalogue of Medicines and Foods with the Same Origin. For example, exterior-releasing herbs including *Saposhnikovia divaricata*, *Ephedra sinica*, and *Perilla frutescens*; heat-clearing herbs encompassing *Prunella vulgaris*, *Artemisia annua*, *Dictamnus dasycarpus*, *Hedyotis diffusa*, *Cynanchum nobile*, *Lysimachia christinae*, *Eupatorium adenophorum*, *Artemisia capillaris*, *Chrysanthemum sinicum*, and *Cynanchum japonicum*; purgative herbs including *Rheum palmatum*; qi-regulating herbs consisting of fennel, *Citrus reticulata* peel, and *Anethus amplex*; blood-activating and stasis-resolving herbs including *Dioscorea opposita* (Chinese yam), white peony root, *Polygonum multiflorum*, *Glycyrrhiza uralensis*, *Trichosanthes kirilowii*, *O. japonicus*, and *Cornus officinalis*; diuretic and dampness-draining herbs comprising *Poria cocos* and kelp; toxic/special herbs including *E. adenophorum*, *Viola tricolor*, and *A. annua*; other rare herbs including *Ulmus pumila*, *Bactropodium spiculatum*, *Euphorbia helioscopia*, *Pseudolarix albus*, *Taxillus chinensis*, *Chrysanthemum indicum*, *Quercus acutissima*, *Populus euphratica*, and *Myriocarpus punicatus*.

With the development of modern science and technology, the use of modern scientific theories and methods to explore herbal medicine and food homologous plants, as well as non-traditional medicinal parts and folk customs not included in the “medicinal food homologous directory,” provides a material basis for developing new food ingredients. This approach also facilitates the application of ancient medicinal food homologous plants, fosters the inheritance and innovation of traditional therapeutic culture, and enriches the resources of the same source of medicines and food, offering a scientific foundation for substances such as rhizomes, groundnuts, plants, and herbs, exemplified by Dihuang and Maitong.

Dihuang is the fresh or dried tuberous root of *R. glutinosa* Libosch. It has a long history of use as a food ingredient in regions such as Henan, Gansu, and Shandong, China, commonly prepared in the form of pickles, tea, wine, soups, and stews. Dihuang was first mentioned in the “Shennong Ben Cao Jing,” where it is noted for its therapeutic properties, including alleviating tendon injuries, expelling blood stagnation, filling the bone marrow, promoting muscle growth, and removing cold and heat accumulation. It is especially beneficial for those who are weak or recovering from illness, and prolonged consumption is believed to promote vitality and longevity^[15].

With the application of modern chromatographic methods and pharmacological research in-depth, to date, more than 200

compounds have been found from Dihuang, mainly cyclic enol ether terpenes and their glycosides^[16], phenylethan glycosides^[17], violet ketones^[18], triterpenoids^[19], flavonoids^[20], sugars^[21] amino acids^[22], etc., with a hypoglycemic, antiaging, immune enhancement, improve osteoporosis and other pharmacological effects^[23] (Fig. 1). Among these, cyclic enol ether terpenoids are the most abundant, with catalpol being the most significant and representative active ingredient. Catalpol is recognized as an index ingredient for identification and content determination in the 2020 edition of the Pharmacopoeia of the People's Republic of China, and it is an important indicator for the quality control of Dihuang.

Genomics techniques such as genomics, proteomics and metabolomics combined with molecular biology methods were utilized to reveal the diversity of the metabolism of Dihuang as well as the potential molecular mechanisms of the active components. Using LC-MS non-targeted metabolomics analysis, we revealed the differences in the accumulation of 434 metabolites of the traditional Chinese medicine Dihuang at different growth stages, and pointed out that the quality of Dihuang was closely related to the content of Mauritius glycosides^[24]. Bao *et al.*^[25] established a spontaneous diabetic *db/db* mouse model, and demonstrated that catalpol could significantly reduce the fasting

blood glucose (FBG), insulin (INS), triacylglycerol (TG), and adiponectin (APN) levels in diabetic mice, and has a certain effect on the disorders of lipoglycemic metabolism and INS resistance, and its mechanism may be related to the up-regulation of the expression of p-AMPK α 1/2. Yan *et al.*^[26] utilized the glucosamine to induce the INS resistance model of HepG2 cells *in vitro* and found that catalpol could reduce blood glucose level, increase serum INS level, and inhibit liver injury and steatosis in diabetic mice; it showed inhibition of hepatic gluconeogenesis and increase of hepatic glycogen synthesis in both *in vivo* and *in vitro* experiments, and it could improve type 2 diabetic hepatic INS resistance by acting on the AMPK/NOX4/PI3K/AKT pathway. Based on the above studies, along with traditional usage practices and no reported adverse effects, Dihuang was included in the 2024 catalog of substances recognized as both food and herbs.

O. japonicus (L. f) Ker-Gawl. is the dried tuberous root of *O. japonicus* (L. f) Ker-Gawl., which is one of the famous “eight flavors of Zhejiang”, and was first mentioned in Shennong’s Classic of the Materia Medica^[27]. Maitong has a long history of use as a food ingredient in regions such as Sichuan and Guangdong, China, commonly prepared as tea, porridge, or soup. The active ingredients include steroidal saponins and other saponins. The active ingredients include steroidal saponins, high isoflavones,

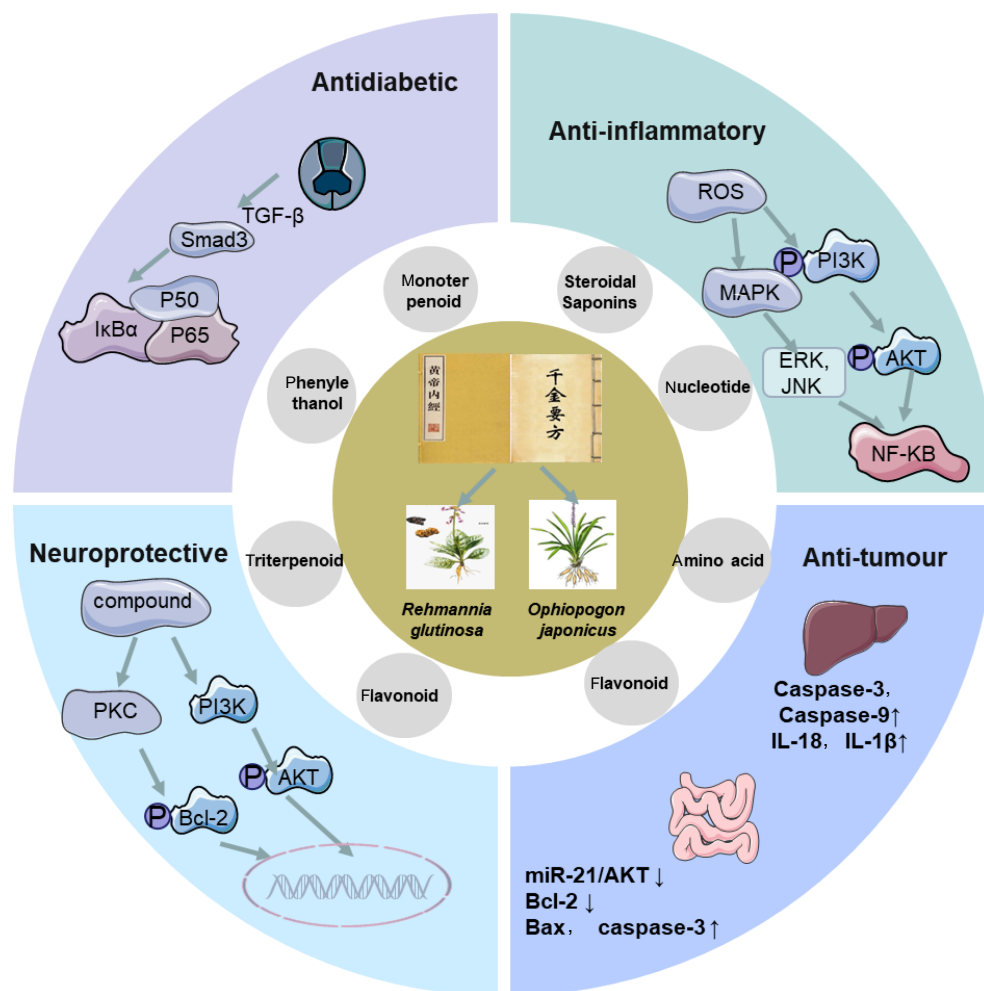


Figure 1 Exploration of homology of medicine and food resources based on herbal classics and folk practices. TGF- β (transforming growth factor- β), Smad3 (Sma- and Mad-related protein 3), P50 (P50 protein, NF- κ B1 subunit), P65 (p65 protein, RelA subunit), I κ B α (inhibitor of κ Ba protein), PKC (protein kinase C), PI3K (phosphoinositide 3-kinase), p-AKT (phosphorylated AKT), p-Bcl-2 (phosphorylated B-cell lymphoma/leukemia-2), MAPK (mitogen-activated protein kinase), p-PI3K (phosphorylated phosphoinositide 3-kinase), p-AKT (phosphorylated AKT), ERK (extracellular signal-regulated kinase), JNK (c-Jun N-terminal kinase), NF- κ B (nuclear factor- κ B), Caspase-3 (cysteine aspartyl-specific protease-3), Caspase-9 (cysteine aspartyl-specific protease-9), IL-18 (interleukin-18), IL-1 β (interleukin-1 β), miR-21/AKT (microRNA-21/protein kinase B), Bcl-2 (B-cell lymphoma/leukemia-2), Bax (Bcl-2-associated X protein).

terpenoids, polysaccharides and other components, of which steroidal saponins and high isoflavones are the characteristic components, and they are also the main active ingredients of maitake to play the role of hypoglycemia, anti-cardiovascular disease, anti-aging, anti-tumor and other effects^[28, 29].

Using metabolomic research methods, specifically ultra-performance liquid chromatography-tandem quadrupole time-of-flight mass spectrometry (UPLC-Q/TOF-MS), we investigated the effects of maitake extract on the metabolites in the serum of mice with type 2 diabetes mellitus (T2DM), and found that maitake extract exerts a therapeutic mechanism for the treatment of T2DM, which may be through the enhancement of the glyceric acid, malonate semialdehyde, and 4-hydroxy phenyl pyruvic acid, the three potential metabolites containing in ubiquinone and other terpenoid quinone biosynthesis metabolism to exert hypoglycemic effects^[30]. The application of network pharmacology method to explore the mechanism of action of XuanShen-Medicine pair in the treatment of anxiety disorders proved that XuanShen-Medicine pair may regulate the activity of neuronal cells through molecular targets such as 5-hydroxytryptophan (5-HT), γ -aminobutyric acid (GABA), dopamine (DA), and treat anxiety disorders through antioxidant, protection and promotion of neuronal cell regeneration and other mechanisms^[31]. Based on the above research and traditional consumption practices, no adverse effects have been reported. Maitake is also included in the catalog of substances recognized as both food and herbal medicines according to tradition.

2.2 Exploration of the medicinal value in edible resources

Traditional Chinese medicine emphasizes the treatment of diseases through dietary practices, adhering to the concepts of “food and medicine sharing the same origin” and “integrating medical treatment into dietary regimens”. The practice of food therapy (Shi Liao) has existed in China for thousands of years. With the characterization of bioactive components in edible resources and systematic research on their nutritional value, health-promoting properties, and pharmacological effects, the medicinal value of a growing number of edible resources has been uncovered. Currently, components abundant in edible resources such as polysaccharides, glycosides, phenolic compounds, and others are widely applied in the prevention and treatment of various diseases including diabetes, cardiovascular disorders, and other types of ailments. Therefore, by employing technologies such as chemistry and molecular biology to explore the medicinal components and mechanisms of action in edible resources, we can further elucidate their therapeutic potential, establish a scientific foundation for novel drug development, and advance progress in medical and biological sciences (Fig. 2).

Edible mushrooms have distinctive flavors, rich nutritional value, and polysaccharides with anti-tumor, immune-regulating, anti-aging, and antioxidant functions. In-depth studies on these components (e.g., lentinan) can reveal their medicinal mechanisms. Lentinan, a β -glucan-rich bioactive substance from

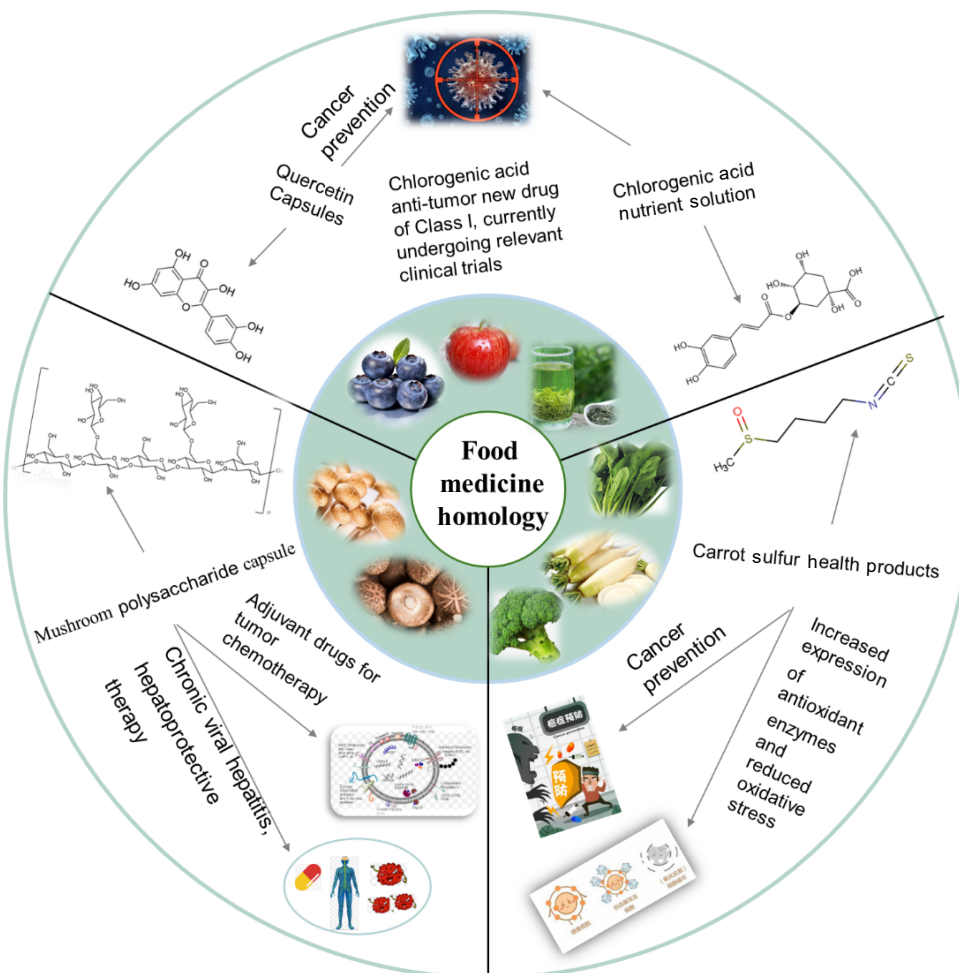


Figure 2 Exploration of the medicinal value in edible resources.

shiitake mushrooms, enhances non-specific immunity (promoting macrophage phagocytosis, NK cell cytotoxicity, and T-lymphocyte ratios^[32]), boosting disease resistance. It exerts anti-tumor effects by inhibiting tumor growth, inducing apoptosis, and suppressing angiogenesis^[33], and enhances chemo/radiotherapy efficacy while reducing side effects^[34]. Additionally, it shows potential in adjunctive therapy for chronic diseases like lipid metabolism disorders (upregulating acetyl-CoA acetyltransferase 2 (ACAT2) to alleviate abnormalities^[35]) and diabetes. Lentinan has been developed into drugs or health products such as tablets, injections, and capsules.

Cruciferous vegetables such as broccoli, cabbage, and radish have high medicinal value contain primary active components including phenolic compounds, glucosinolates, carotenoids, tocopherols, ascorbic acid, and flavonoids^[36]. Glucosinolates are distinctive components of cruciferous vegetables^[37-39]. Their metabolites, particularly isothiocyanates (e.g., sulforaphane), derive their bioactivity from key functional groups such as the isothiocyanate moiety and the 4-methylsulfinylbutyl side chain. These compounds exhibit significant effects in anticancer, antioxidant, and anti-inflammatory activities. Modern scientific studies indicate that sulforaphane exerts its anticancer effects by suppressing nicotine-induced matrix metalloproteinase-9 (MMP-9) through inhibition of reactive oxygen species (ROS)-mediated MAPK/AP-1 and NF- κ B signaling pathways, thereby inhibiting cell invasion in human gastric cancer AGS cells^[40,41]. Sulforaphane also protects RPE cells from LPS-induced damage by inhibiting the PWRN2/NF- κ B signaling pathway^[42]. Using qRT-PCR, Western blotting, and immunohistochemistry, it was found that sulforaphane can inhibit the metastasis of esophageal cancer cells by down-regulating the expression of stearoyl-CoA desaturase (SCD) and cadherin 3 (CDH3). It also inhibits cell metastasis by inactivating the Wnt pathway, and suppresses cell proliferation by activating the GADD45B-MAP2K3-p38-p53 positive feedback loop^[43-45]. Sulforaphane can also activate the Nrf2 signaling pathway to enhance the expression of antioxidant enzymes such as superoxide dismutase (SOD) and glutathione peroxidase (GPx), which scavenge free radicals, reduce oxidative stress, and protect cells from oxidative damage^[46]. Furthermore, by inhibiting the NF- κ B signaling pathway, sulforaphane reduces the expression of inflammatory cytokines (e.g., TNF- α , IL-1 β , IL-6), suppresses inflammatory responses, and decreases the production of inflammatory mediators^[47]. Although sulforaphane has not yet been directly developed into pharmaceutical drugs, it has been widely applied in dietary supplements and functional foods, such as broccoli sprout extracts and broccoli powder.

Phenolic compounds are natural organic substances with diverse bioactivities that exhibit significant effects in antioxidant, anti-inflammatory, anticancer, and antimicrobial activities. They are widespread in our daily foods, from fresh fruits and vegetables like apples, blueberries, and spinach, to popular drinks such as tea and coffee. In-depth research on phenolic compounds in edible resources can explore their medicinal value, like salicylic acid, chlorogenic acid, and quercetin in tea. Salicylic acid exerts its anti-inflammatory effects by inhibiting the activity of cyclooxygenase (COX), thereby reducing prostaglandin synthesis^[48]. Through structural modification of salicylic acid, aspirin is derived and has been widely used in the treatment of headaches, fever, arthritis, and related conditions.

Chlorogenic acid demonstrates antioxidant and anti-inflammatory properties through multiple mechanisms, including free radical scavenging, activation of the Nrf2 signaling pathway,

and suppression of the NF- κ B pathway^[49]. Meanwhile, chlorogenic acid also serves as an effective differentiation inducer for various solid tumor cells. Acetyl-CoA acetyltransferase 1 (mtACAT1) has been identified as its potential target, leading to the development of a Class 1 anti-tumor innovative drug-chlorogenic acid for injection, which has currently entered clinical trials. Quercetin exerts anticancer effects through multiple mechanisms including promoting ferroptosis, inducing apoptosis, and inhibiting the cell cycle^[50]. Additionally, it alleviates lipopolysaccharide-induced hepatic inflammation by downregulating mRNA expression of autophagy-related genes and necroptosis-related genes^[51]. Furthermore, quercetin demonstrates anti-allergic activity by suppressing histamine release^[52]. Therefore, quercetin is commonly incorporated into dietary supplements and functional foods for its anticancer, antioxidant, and anti-inflammatory properties, as well as cardiovascular health enhancement.

2.3 Exploration of nutritional and health-promoting functions in medicinal resources

With the transformation of modern lifestyles and heightened health consciousness, the pursuit of wellness has shifted from a paradigm of passive treatment to proactive prevention, driving in-depth investigations into the nutritional and health-promoting properties of medicinal resources. Against the backdrop of increasing chronic diseases among younger populations and the normalization of suboptimal health states, traditional Chinese medicinal herbs, natural plant extracts, and food-medicine homologous substances are undergoing value redefinition. For instance, modern scientific studies have validated the anti-aging mechanisms of *Cordyceps* polysaccharides, while the immunomodulatory effects of *Ganoderma* triterpenes have been enhanced through nano-encapsulation technologies to improve bioavailability (Fig. 3). These advancements reflect breakthroughs in biotechnology and nutriomics, as well as a creative integration of traditional wellness wisdom and evidence-based medicine.

Purified medicinal materials, such as *Cordyceps sinensis*, have increasingly entered daily life as dietary supplements. Analytical techniques including infrared spectroscopy^[53], gas chromatography-mass spectrometry (GC-MS)^[54,55], and high-performance liquid chromatography (HPLC)^[56-60] have identified key bioactive constituents in *C. sinensis*, such as cordycepin, cordycepic acid, polysaccharides, and nucleosides^[61]. Biological experiments demonstrate that these active compounds exhibit significant anti-inflammatory, antioxidant, and immunomodulatory effects^[62]. Transcriptomic and gut microbiota studies reveal that *Cordyceps* polysaccharides protect gastrointestinal mucosa^[63], reduce blood glucose levels, and suppress pathogenic gut bacteria^[64]. Cordycepin, a major bioactive component, inhibits ROS production and cellular migration. These diverse bioactivities have spurred the development of health products, including *Cordyceps* herbal teas, oral liquids, functional beers, and capsules.

Theoretical approaches to enhancing bioactivity through processing with auxiliary materials have expanded options for health product development. For example, raw *C. officinalis* (Shanzhuyu) becomes medicinally viable after drying over low heat or briefly scalding to remove kernels. Phytochemical analyses identify iridoid glycosides and flavonoids in raw *Cornus*^[65], which are traditionally used to tonify the liver and kidneys and to arrest sweating. Modern studies confirm its anti-inflammatory, gut microbiota-modulating, and hepatorenal-protective effects in

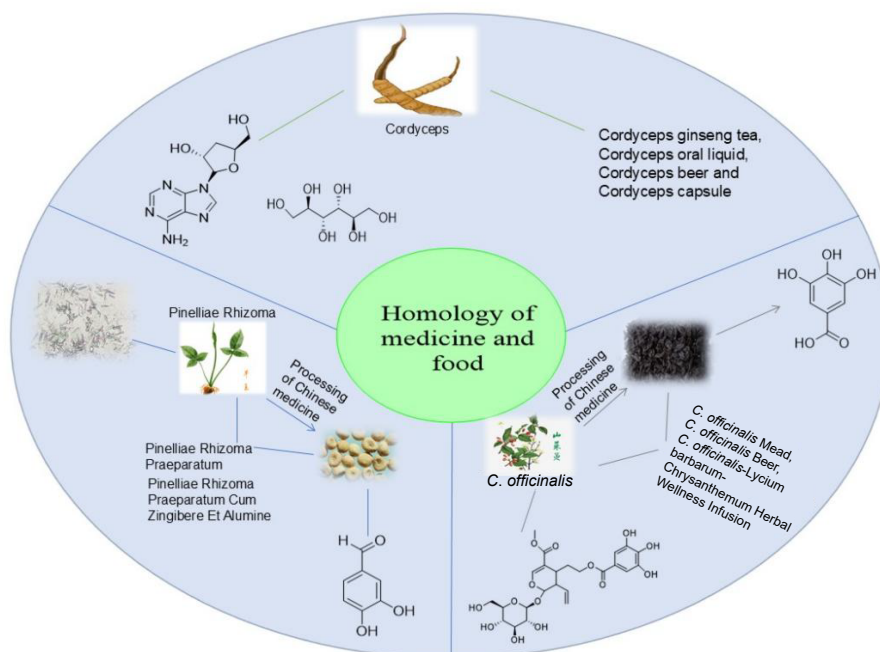


Figure 3 Exploration of nutritional and health-promoting functions in medicinal resources.

animal and cellular models^[61,63-64]. Wine-processed *Cornus* (Jiuyurou), prepared by steaming raw *Cornus* with rice wine, shows elevated levels of 5-hydroxymethylfurfural and gallic acid^[66], enhancing its tonifying properties^[67]. Metabolomic and gut microbiota studies demonstrate that iridoid glycosides in *Cornu* increase Firmicutes abundance, supporting intestinal health^[68]. Jiuyurou also ameliorates linoleic acid, caffeine, and phenylalanine metabolism in diabetic nephropathy rats^[69]. To meet growing health demands, innovative products such as *Cornus*-honey wine, health-promoting rice wines, beers, herbal teas with chrysanthemum and wolfberry, and fruit jams have been commercialized^[70,71].

Certain medicinal resources with narrow therapeutic indices require detoxification processes to reduce toxicity while preserving efficacy^[72]. The 2020 *Chinese Pharmacopoeia* lists 83 toxic medicinal materials, including *Pinellia ternata* (Banxia). Both raw and processed *Pinellia* are used in traditional medicine for drying dampness, resolving phlegm, and suppressing nausea. Chemical analyses reveal that raw *Pinellia* contains alkaloids, flavonoids, nucleosides, sterols, proteins, and amino acids, with toxicity attributed to calcium oxalate crystal needles, alkaloids, and lectins^[73]. Processing methods significantly reduce toxic components: *Qing Banxia* (alum-processed) exhibits decreased calcium oxalate and alkaloid content, while *Fa Banxia* (licorice and lime-processed) reduces protochatechuic aldehyde levels, with glycyrrhizic acid neutralizing calcium oxalate toxicity^[74,75]. Adjuvants in processing enhance therapeutic effects: alum in *Qing Banxia* augments phlegm-resolving activity, ginger and alum in *Jiang Banxia* improve antiemetic effects, and licorice in *Fa Banxia* strengthens antitussive properties^[76]. Bioactive components in raw *Pinellia*, such as dihydroxyflavones, inhibit inflammatory factor release^[77], while its aqueous extract modulates MAPK signaling^[78]. *Jiang Banxia* extract suppresses cytochrome P450 3A (CYP3A) protein expression to mitigate drug adverse effects^[79], and *Fa Banxia* extract alleviates inflammation^[80]. Multi-omics studies indicate that polysaccharides in *Qing Banxia* promote *Bacteroides* proliferation in the gut^[81]. In the classic formula *Banxia Xiexin Tang*, *Pinellia* synergizes with other herbs to reduce hemolytic

phosphatidylcholine content while stimulating *Ferribacterium* and *Actinobacteria* growth and inhibiting *Helicobacter pylori*^[82]. *Pinellia*'s alkaloid-rich profile underpins its regulatory effects on endogenous proteins, with emerging research focusing on its α -glucosidase inhibitory potential for diabetes management^[83]. Despite toxicity concerns, controlled use in health products—such as *Pinellia*-Magnolia phlegm-resolving tea, hawthorn-Poria-*Pinellia* lipid-lowering tea, and functional snacks like antitussive ginger cookies or immune-boosting jellies—demonstrates its versatility^[84-86]. However, toxicological limitations (e.g., ginkgolic acids in fresh *Ginkgo* seeds) underscore the necessity of detoxification strategies and rigorous quality control in nutraceutical applications.

2.4 Application of AI and future technologies in the excavation of medicinal foods and food resources

The future direction of research on medicinal foodstuffs and homologous substances must clearly identify bioactive components, separate them precisely, clarify their targets and mechanisms of action, and promote their acceptance as functional foods and therapeutic drugs. Therefore, further exploration and a better understanding of these bioactive components will stimulate innovative ideas in the discovery of medicinal and food compounds. Conventional analytical methods are inadequate for directly and accurately determining the relationship between chemical structure and observed bioactivities, or for confirming the targets of active substances. To address these challenges, there is an urgent need for powerful tools and methods.

Emerging technologies such as AI and histological techniques have created new opportunities for the “precision conditioning” of medicinal substances (Fig. 4). For instance, Wang *et al.*^[87] combined experimental binding data with AI technology to explore the pharmacological targets directly related to Chinese medicine compounds, thereby studying the active ingredients and pharmacodynamic characteristics of chrysanthemum in depth. Song *et al.*^[88] developed a multi-omics database for burdock to integrate molecular and chemical data, facilitating further

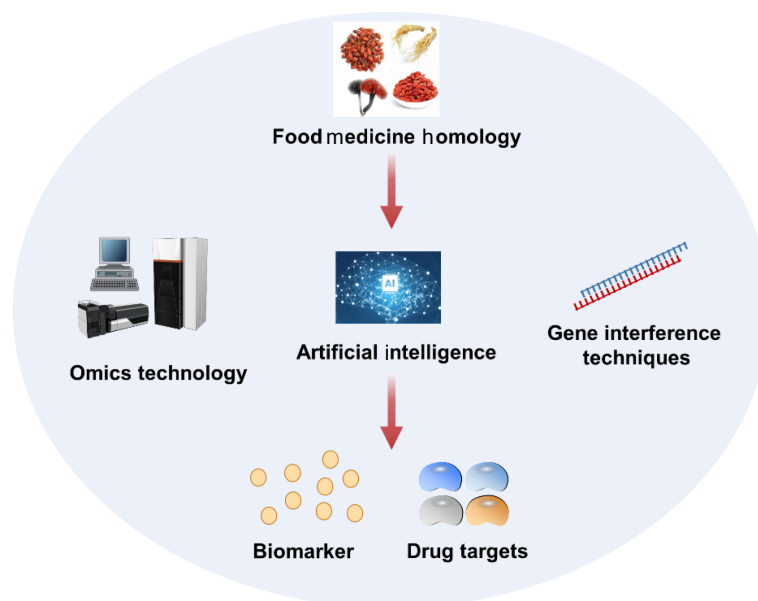


Figure 4 Application of AI and future technologies in the excavation of medicinal foods and food resources.

exploration of burdock biosynthesis pathways, breeding, and ecological research. This comprehensive information and analytical platform offer valuable support for researchers analyzing burdock data, aiding in cultivation, breeding, and molecular pharmacology research. Wu *et al.*^[89] conducted untargeted metabolomics to demonstrate that wine-processed schisandra polysaccharides alleviate Alzheimer's disease symptoms in mice by regulating the metabolism of glucose, proteins, lipids, and amino acids. Major *et al.*^[90] used gene editing to demonstrate that cruciferous vegetables, such as watercress, are more effective in alleviating the symptoms of Alzheimer's disease than other vegetables. They employed technology to identify molecules in cruciferous vegetables, such as broccoli and cauliflower, that induce protective AHR signaling in the pulmonary vasculature along the intestinal-lung axis. These molecules act as natural dietary AHR ligands that promote host defense against respiratory viral pathogens. *Gloeostereum incarnatum* (GI), a valuable fungus with medicinal and culinary applications, was identified by researchers through a protein histology study. They found that its purified polysaccharide could inhibit the growth of colon cancer in mice by targeting the Wnt/ β -catenin signaling pathway^[91].

While AI brings convenience, it also introduces numerous challenges, such as data quality and integration issues. For example, metabolomics and genomic data for food-medicine dual-purpose components are scattered across universities, pharmaceutical companies, and research institutions, with cross-institutional data sharing rates below 20%. When developing liver-protecting formulas, the model prediction errors exceeding 15% in AI companies due to the inability to obtain the data on the differences in polysaccharide content of wolfberries from different origins. Meanwhile, the synergistic mechanisms in traditional Chinese medicine formulas (e.g., "the principal herb dominates efficacy while auxiliary herbs support") are difficult to model using conventional algorithms. In addition, when optimizing the formula, the AI model can predict the efficacy of a single component, but it is unable to accurately simulate the metabolic interaction between the two components in the body, resulting in a low overall efficiency of the experiment. For example, the total effective rate of the "hawthorn-lotus leaf" lipid-lowering formula optimized by the AI model in animal experiments was only 62%,

which was lower than the 81% achieved through manual formulation.

In conclusion, future advancements in AI, omics technology, and other cutting-edge innovations will significantly enhance the development of medicinal and food resources. This will be achieved through the intelligent mining of ancient data, predicting active ingredients, and optimizing formulas with AI. By integrating multi-omics technology, we can create a dynamic network of "ingredient-target-host." Additionally, collaboration with synthetic biology, organoid chips, and other advanced methods will facilitate the precise synthesis and efficacy verification of functional ingredients. As a result, the accurate synthesis and verification of these ingredients will accelerate the development of traditional medicines and foodstuffs toward greater precision, personalization, and scientific advancement.

3 Summary

Diet and health are closely related, and enhancing the body's resistance and defense through dietary conditioning has become a common concern. After thousands of years of practice and verification, the concept of medicine and food—integrating the functions of food and medicine and emphasizing daily diet for health intervention—has emerged as an important direction for the health industry. Given the high incidence of chronic diseases and the increasing prevalence of sub-health issues among modern individuals, scientific and personalized dietary habits have taken center stage. Consequently, the demand for low-sugar, low-salt, high-fiber, and functional ingredients is driving food innovation.

The potential for discovering medicinal and food resources remains vast. On one hand, we should explore the undiscovered substances referenced in ancient literature; on the other hand, we need to investigate the medicinal properties of edible resources and the nutritional value of medicinal plants. More importantly, we should leverage modern science and technology to accurately interpret the scientific significance of these medicinal and food resources and expedite their development.

In the future, the development of medicinal and food ingredients will depend on new technologies such as biotechnology, precision nutrition, and AI. These innovations will lead to the creation of products that integrate disease prevention

and nutritional enhancement. This trend will not only reshape the traditional wisdom of “food as medicine” but also indicate a shift towards a lifestyle focused on active health management rather than passive treatment.

Conflicts of interest

The authors declare that there are no conflicts of interest in this work. Wenyi Kang is a Chief Editor of Food & Medicine Homology, Fatma M. El-Demerdash is an Editorial Board Member of Food & Medicine Homology, but they were not involved in the processing, peer review or decision making of this article.

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